Review Article *Journal of Multidisciplinary Research Advancements (JOMRA), Vol. 2, No. 2 (2024), 130 – 137*
e-ISSN 2990-7721 Available online at https://www.nepjol.info/index.php/jomra

Impact of Climate Change on Agriculture in Nepal and Strategies for Farmer Adaptation and Economic Resilience

Prabin Shrestha[1,6*], Anup KC[2], Dil Kumari Karki[3], Nishesh Shrestha[4], Aakriti Bharati[5], Suja Giri[6]

[1]Ace Institute of Management, Kathmandu, Nepal
[2]Kathmandu Forestry College, Nepal
[3]Tribhuvan University, Nepal
[4]Glasgow Caledonian University, UK
[5]National College, Nepal
[6]Global Research Institute and Training Center, Kathmandu, Nepal

*Corresponding author: prabinshrestha7314@gmail.com

Abstract: This document investigates the impacts of climate change on agriculture in Nepal, a country identified as highly vulnerable to climate-related losses. The study used desktop review to gather relevant literature and thematically present the obtained data. It highlights the crucial challenges farmers face, including decreasing crop yields, declining livestock health, and threats to food security due to rising temperatures, altered precipitation patterns, and extreme weather events such as floods and droughts. The study utilizes data from climate risk assessments, including the "Global Climate Risk Index 2021" and recent findings on glacial lake outburst floods (GLOFs), to underscore the urgency of adaptation strategies for agricultural resilience. The document emphasizes that even marginal changes in temperature and precipitation can significantly affect agricultural productivity, supported by analyses of historical data and regional studies on temperature trends. It shows the need for adaptation strategies that consider unique regional vulnerabilities and the socio-economic conditions of farmers in Nepal.

Keywords: *Adaptation Strategies, Agriculture, Climate Change, Extreme Weather Events, Food Security, Vulnerability*

Conflicts of interest: None
Supporting agencies: None

Received 13.9.2024 Revised 22.10.2024 Accepted 8.11.2024

Cite This Article: Shrestha, P., KC, A., Karki, D.K., Shrestha, N., Bharati, A., & Giri, S. (2024). Impact of Climate Change on Agriculture in Nepal and Strategies for Farmer Adaptation and Economic Resilience. *Journal of Multidisciplinary Research Advancements*, 2(2), 130-137.

1. Introduction

Climate change poses a significant challenge to global agriculture, affecting farmers, crop yields, livestock health, and food security. As global temperatures rise, it becomes increasingly vulnerable. This vulnerability leads to decreased production and poor livelihood outcomes for the global population (Wheeler, & Von, 2013). The impacts of high temperatures, altered precipitation patterns, increased water demand, and increased frequency of extreme events such as drought and floods, along with the elevated CO_2 on crops, will progressively depress crop yields and increase production risk in many regions in coming decades (Ainsworth & Long, 2005; Kimball et al., 2002). Therefore, studying the impact of climate change on agriculture is essential to develop strategies for food production, socio-economic sustainability, and adaptation measures for sustainable agricultural development (Keith, et al., 2015; Giri et al., 2023a).

Based on the "Global Climate Risk Index 2021" report, which investigated weather-related loss events from 2000 to 2019, Nepal ranked the 10th most affected country regarding climate-related losses (Eckstein et al., 2021). Nepal had a Climate Risk Index (CRI) of 31.33, signifying a high vulnerability to the impact of climate change, with 191 recorded events in the period. Rising temperatures, altered precipitation patterns, and an increased frequency of extreme weather events such as floods and landslides characterize these climate risks. An Asian Development Bank (ADB) report concluded that Nepal may observe a higher temperature increase by up to 4.2 degrees compared to the global average under the highest emission scenario (World Bank Group & Asian Development Bank, 2021). These findings draw a grim picture for Nepal in terms of climate risk.

One significant problem faced in Nepal is the increased risk of glacial lake outburst floods (GLOFs) due to climate change, which threatens communities, infrastructure, and agricultural lands (Bajracharya et al., 2018). A study in 2021 by Mohanty and Maiti (2021) considered 4198 glacial lakes to identify up to 224 lakes with a high probability of GLOF. These repeated studies conclude that there is a similar level of threat to Nepal's river basins from GLOF. Based on an analysis of the research by Bajracharya et al. (2018), the temperatures are expected to rise, resulting in a higher degree of snowmelt, contributing to river discharge during the pre-monsoon and monsoon periods. Furthermore, the projected precipitation patterns predict increased precipitation during monsoon and reduced precipitation during the dry season.

Various research indicates a change in the precipitation pattern in various parts of Nepal, with wet-get-wetter and dry-get-drier (Dahal et al., 2020; Chapagain et al., 2021). While these predictions may not strike as significant to observers, it is important to note that even the most minute change in weather patterns can impact crops significantly. An analysis of data from Nepal Living Standard Surveys (NLSSs) over an 8-year period (2003-2010) revealed that rice production decreases by 4183 kg for every 1°C rise in average summer temperature (Rayamajhee et al., 2021). The study concluded that extreme rainfall variations decreased agricultural productivity. Furthermore, precipitation patterns have become increasingly erratic, with some regions experiencing prolonged droughts while others face intense and unpredictable rainfall.

In Nepal, extreme weather events have increased frequency and intensity, such as heavy precipitation and prolonged dry spells (Giri et al., 2023b). A study into the 26 climate extremes recommended by the World Meteorological Organization (WMO) in 90 meteorological stations concluded that the frequency of high-intensity precipitation events (greater than 100mm in 24 hours) is increasing, impacting life and nature seriously in all regions and seasons (Awasthi & Owen, 2020). This extreme change in precipitation patterns has been observed more frequently in the mountain and Himalayan regions.

An early study showed that the average temperatures in Nepal have been rising at a rate of 0.06°C per year, with higher increases in the mountainous regions (Shrestha et al., 1999). More recent studies from 1976 to 2015 examining elevation-dependent warming (EDW) reinforced the previous studies while discovering that the maximum temperature increased more than the minimum temperature, showcasing a grimmer reality than an analysis of average change in temperature shows.

Despite the growing body of research on climate change and its impacts on agriculture, significant gaps remain in understanding the specific adaptation strategies applicable to Nepalese farmers, particularly in the context of distinct regional vulnerabilities and socio-economic conditions. Existing studies often focus broadly on climate change effects without delving into localized solutions that consider traditional farming practices, economic constraints, and community needs. This research aims to fill these gaps by exploring innovative and context-specific adaptation strategies that can bolster economic resilience among farmers in Nepal. The novelty of this study lies in its comprehensive examination of both the socio-economic dimensions and the climatic challenges faced by farmers, ultimately providing targeted recommendations for policymakers and practitioners to enhance sustainable agricultural development in the region.

2. Materials and methods

This study used a literature-based methodology, using desktop research, to investigate climate change adaptation strategies for farmers in Nepal. The study collected and analyzed existing academic publications, reports, and studies to examine climate change's impacts on agriculture and identify effective adaptation measures tailored to Nepalese farmers. A systematic search across multiple academic databases was undertaken to gather relevant resources. The selected databases include Springer, Elsevier, ResearchGate, and Google Scholar.

3. Results and discussion

3.1. Impact of Climate Change on Agriculture-Global Perspectives

Climate change is a critical global issue impacting various sectors, with agriculture being particularly vulnerable due to its dependence on climatic conditions and water availability (Shrestha et al., 2024a). Lehner & Stoker (2015) explored the relationship between local perception and global perspectives on weather variations due to climate change's impact on global agriculture. They noted that short-term weather fluctuation at specific locations can influence people's understanding of long-term global climate change. Therefore, it is necessary to emphasize the importance of long-term global perspectives when assessing climate change's impact patterns worldwide. This comprehensive approach ensures a more accurate understanding of climate change's effects on agriculture and aids in developing adaptation strategies for the effects (Lehner & Stoker, 2015).

Globally, the adverse effects of climate change on agriculture are seriously acknowledged. Extensive literature also indicates that climate change significantly impacts global agriculture through alterations in weather patterns, increased water stress, and reduced crop yields (Wheeler, & von Braun, 2013). The United Nations (2003) highlights that the global agricultural sector utilizes approximately 70% of freshwater. Consequently, changes in hydrological systems due to climate change are expected to affect water supply (Shrestha et al., 2024b) and demand for irrigation, directly influencing the socio-economic condition of poor, landless, and smallholder farmers. Therefore, potential climate-related impacts on future crop yield are a major societal concern (Jagermeyr et al., 2021).

Lehner & Stocker (2015) observed that individuals globally are experiencing prolonged periods of warmer-than-normal temperatures, with increased rainfall, greenhouse gas emissions, intense heat waves, droughts, and fire hazards significantly impacting the agricultural sector. Similarly, Malla (2008) highlights those rising global temperatures, the exponential growth of CO_2, and the increase in other greenhouse gasses substantially threaten water resources, agriculture, freshwater habitats, vegetation, forests, snow cover, and geological processes. These changes lead to landslides, desertification, and floods, with long-term effects on food security and humans, often affecting crops, livestock, soil water resources, and agricultural workers (Malla, 2008).

According to the Intergovernmental Panel on Climate Change (IPCC, 2021), alterations in temperature, precipitation patterns, and increased frequency of extreme weather events threaten global agricultural productivity and food security. Tubiello & Rosenzweig (2008) predict that the elevated temperatures, altered precipitation patterns, increased water demand, and more frequent extreme events such as droughts and floods will collectively reduce crop yields and heighten production risks in many regions over the coming decades. Consequently, climate change introduces new uncertainties in the global agricultural sector, as climate conditions are projected to become increasingly erratic, with a higher frequency of extreme events such as landslides, floods, hurricanes, heat waves, and severe droughts (Parry, 2000).

Despite these, overall global agricultural productivity is projected to decline between 3-16 % with developing countries facing a 10-25% reduction by 2080 (Mahato, 2014). Moreover, Calzadilla et al. (2013) jointly indicate that key climate variables will reduce global food production by approximately 0.5% in the 2020s and 2.3% in the 2050s, particularly in developing regions such as the Middle East, Southeast Asia, and North Africa. If the temperature rises to 4^0C it could severely impact Africa's agriculture and food security by 2030 (Ngaira, 2007). In Bhutan, the impact of climate change is already evident, posing significant challenges to agriculture production and food security being already felt and, agricultural production and food security, necessitating further research in mitigation strategies (Chogyal & Kumar, 2018). Additionally, climate change threatens the future of agriculture in Europe, affecting farmlands, industrial food production, and manufacturing (Lavalle et al., 2009).

Similarly, authors Anh & Chandio (2023) found that extreme weather conditions, such as heavy rainfall, adversely affect Vietnam's agricultural production and economic performance, with both short- and long-term impacts of climate change. Moreover, increasing drought and extreme rainfall have significantly threatened maize production in the United States (Li et al., 2019). The rising global temperatures will likely cause a food crisis and human migration. For instance, 96% of Egypt is desert, and 97% of its population is concentrated on just 4% of irrigated land where the drying up of Nile waters would halt food production, forcing people to migrate to more habitable (Ngaira, 2007).

3.2. Impact of Temperature on Agriculture

Agricultural productivity is highly dependent on climatic temperature. Mendelsohn and Dinar (2009) also found that crops are sensitive to climatic temperature changes. For example, an increase in 10c temperature can reduce wheat production by 4-5 %, and a 1.50C warming could decrease crop net revenue by 13%, equivalent to US$ 93 billion (Mendelsohn, 2014). Similarly, Swaminathan et al. (2010) demonstrated that a 100C increase in temperature reduces wheat production by 4-5% in Pakistan (Gupta et al., 2020). Therefore, changes in temperature and rainfall patterns directly impact agricultural productivity, where increased temperatures and erratic rainfall can reduce crop yield (Acharya and Bhatta, 2013).

Furthermore, extreme heat events significantly affect global food production systems, leading to crop failure, food insecurity, and displacement of people due to food shortages. Increasing air temperatures also considerably affect the growing season's duration in Europe and other regions (Lavallee et al., 2009). As climate change will likely impact global food production, disseminating new farming techniques directly is essential. For example, advanced irrigation methods, innovative crop farming practices, and added cropping patterns are necessary for the agricultural sector's paradigm shift in this new era. Farming techniques, including new irrigation methods, new methods of crop farming, and adapted cropping patterns, would be the appropriate derivatives for the agriculture sector (Sakoor et al., 2011).

3.3. Impact of Heavy Precipitation on Agriculture

It can significantly harm crops by eroding soil, depleting soil nutrients, increasing agricultural runoff into the oceans and lakes, and degrading water quality. This runoff can lead to a decrease in oxygen levels of ocean water, causing hypoxia, which can be fatal to marine life and disrupt coastal ecosystems (Lavalle et al., 2009). Shuai (2018) predicts that melting glaciers in the Himalayas, more significant monsoon precipitation, and increasingly intense cyclones may contribute to more extensive flooding. Moreover, the more monsoon precipitation and cyclones of increasing intensity, the greater the extent of flooding in the future. As NASA studies indicate, alterations in temperature and precipitations and the increasing frequency of extreme weather events pose extreme risks to food security that necessitate adopting resilient and sustainable agricultural practices to ensure future viability (Shuai, 2018).

3.4. Impact of Extreme Weather Events on Agriculture

Extreme weather events cause significant difficulties and challenges for agricultural workers and residents in vulnerable areas, often resulting in loss of life and severe crop damage. These challenges underscore the urgent need for increased attention to climate change context-based adaptation strategies and integrative policies (Shuai, 2018). Furthermore, the increased droughts and floods can severely disrupt the food supply chains, which may be more substantial than current projections. As Tubiello & Rosenzweig (2008) predict, climate change’s impact on irrigation needs could be more significant than currently modeled, particularly in North America and Southeast Asia.

3.5. Impact of Climate Change on Agriculture in Asia

Climate change can impact particularly developing, underdeveloped, and low-income countries of Asia, which are largely dependent on agriculture for subsistence but lack resources and strategies for adaptation compared to developed countries (Bushra & Sharma, 2019). Although Asians produce two-thirds of the world’s food, as Mendelsohn (2014) stresses, there is a huge gap in the literature concerning the impact of climate change on Asian agriculture. Therefore, it is critical to assess an accurate measure of climate change's impact on the whole Asian continent.

Higher temperatures, changing precipitation patterns, and increased carbon dioxide in the atmosphere are affecting crop productivity and increasing vulnerability to the poor communities in India (Kumar & Gautam, 2014). Agriculture must feed over 1.3 billion people in China and supply industrial inputs, but climate change threatens this prospect (Dong et al., 2024). The overall extent of the negative impact of temperature is greater than the positive effect of rainfall in the arid region in Pakistan, where Shakoor et al. (2011) revealed that a 1% increase in temperature would lead to a loss of Rs. 4180 to the net revenue per annum. Bello et al. (2012) revealed that decreased rainfall and increased temperature over the past century have led to soil degradation, reduced crop yields, and heightened food insecurity in Nigeria. Among all, developing countries are expected to bear the brunt of the negative effects, experiencing more severe impacts on agricultural productivity and economic stability (Boselo & Zhang, 2005; Antle, 1995).

3.6. Impact of Climate Change on Agriculture in Nepal

With drought and floods, Nepal has experienced increased temperatures and erratic rainfall patterns, affecting farming activities during growing seasons (Acharya & Bhatta, 2013). Due to these, significant crops such as rice, wheat, and maize are affected by these changing climate conditions, with a potential decline in yields due to heat stress, and water scarcity. Since agriculture is the only primary source of livelihood for most of the Nepali population and the cornerstone of Nepal’s economy, climate change poses a significant threat to food security and economic stability (Gautam & Pokhrel, 2010). In addition, Nepal is experiencing more frequent extreme weather events such as floods, droughts, and hailstorms, causing severe crop damage, soil erosion, and loss of arable land (FAO, 2020). Furthermore, Climate change is already affecting Nepal's GDP, with increased flooding and heat stress on crops and livestock posing continual challenges to growth (World Bank, 2022).

Acharya and Shrestha (2013) examined the impact of climate change on agriculture in Nepal and highlighted the increased temperatures and erratic rainfall patterns as significant challenges. The study emphasizes that these climatic changes lead to reduced crop yields, particularly for staple crops like rice, wheat, and maize, due to heat stress and water scarcity, therefore calling for urgent adaptation strategies to mitigate these impacts and ensure food security and economic stability in Nepal.

Smallholder farmers face significant challenges in adapting to climate change due to limited resources and technology. The shift in traditional rainfall patterns has negatively affected paddy production in Nepal. Evident can be witnessed from the Darchula district, which faced unusual snowfall affecting the collection of precious medicinal herbs like Yarsa Gumba. Similarly, the Cold Wave in Nepal in 1997/98 had negative impacts on agricultural productivity. It showed a reduction in the production of crops by 27.8, 36.5, 11.2, 30, 37.6 and 38 % in potato, *toria, sarson, rayo,* lentil, and chickpea respectively, and an adverse impact on staple crops (98.7%), on human health (97.9%), on vegetation (94.7%), and on livestock (88.3%) (Gautam & Pokhrel, 2010).

Malla (2008) used a crop simulation model to study the effects of CO_2, temperature, and rain, which showed a positive impact on the yield of rice and wheat in all regions of Nepal but a negative effect on maize, especially in Terai. However, Paudel et al. (2019), in a survey of “farmers’ understanding of climate change in Nepal Himalaya,” found that the farmers perceived adverse impacts on staple crops (98.7%), human health (97.9%), vegetation (94.7%), from disasters (90.4%), and on livestock production (88.3%). Such variations in the data could be due to the region-specific and contextual differences of the country. These data suggest that there is a need for the government, responsible organizations, and policymakers to introduce scientifically sound adaptation implementation strategies, for example, drought-tolerant crops, disease- and pest-resistant seeds, irrigation facilities, expanded hospitals, educational programs, and training that improve farmers' livelihoods thereby developing climate resilient communities in Nepal (Paudel et al., 2019, p15).

In Nepal, approximately 62% of the total population is engaged in agriculture in one way or another, with the sector contributing to approximately 1/3 of the gross domestic product (GDP) (Pradhan., 2023). Therefore, the impact of climate change on agricultural production in Nepal is significant. A study from 1975 to 2010 revealed a significant positive effect of rainfall on the agricultural gross domestic product (AGDP) in Nepal (Acharya and Bhatta., 2013). The same study found improved seeds and chemical fertilizers to have an insignificant impact on AGDP. These findings show the reliance of the Nepali agricultural sector on precipitation. Nepal's vulnerability to climate change is particularly high due to its reliance on agriculture and limited adaptive capacity (Karki & Gurung, 2012).

Rising temperatures and changing precipitation patterns alter growing conditions across Nepal's diverse agroecological zones (Shrestha & Gurung, 2018; Karki et al., 2020). While some crops like rice and wheat may benefit from increased CO_2 levels and temperature in certain regions, others, such as maize in the Terai, are negatively affected (Malla, 2008). The impact varies by crop, season, and region, with the Himalayas and hilly areas generally more affected than the Terai (Shrestha & Gurung, 2018; Thapa et al., 2014). These changes pose risks to food security, particularly for smallholder farmers in mountainous areas (Karki et al., 2020).

In addition to crops, climate change significantly impacts Nepal's livestock. A study of 240 households from 60 distinct agroecological zones found that farmers perceived a noticeable impact of climate change (Dhakal et al., 2013). Livestock production was affected by various incidences of diseases and external parasitic infestations, reduced forages and fodders availability, heat stress, water scarcity, infertility, and a decline in the milk yield and lactation period (Koirala & Shrestha, 2017; Dhakal et al., 2013). Consequently, livestock populations have decreased in some areas of Nepal, affecting farmers' incomes and productivity. The study by Dhakal et al. (2013) concluded that vulnerability to climate change varies across agroecological regions, with mountainous areas particularly susceptible due to limited adaptive capacity.

3.7. Current Climate Adaptation Strategies

To address the significant problems caused to farmers by the change in climate, coordination of action among various stakeholders and policies tailored to local conditions by combining scientific and local knowledge have been suggested by various researchers (Karki et al., 2020; Shrestha & Gurung, 2018). A regional variation impact of climate change exists, with mid-elevation areas experiencing increased crop production compared to low-elevation regions. In the Rasuwa District, for example, summer monsoon precipitation and maximum temperatures increase, while winter and minimum temperatures decrease (Dawadi et al., 2022). These changes have led to shifts in cropping patterns, with decreases in millet and wheat production but increases in potato cultivation.

While adapting to the challenges in Nepal, farmers are adopting various strategies, such as integrated farming, herd management, improved feeding practices, and water harvesting (Dhakal et al., 2013; Poudel, 2015). Nepali farmers' strategies include soil and water management, adjusting planting times, and crop diversification, which has been shown to increase food productivity (Khanal et al., 2018). Various community-based practices for protection, development, conservation, and sustainable use are widespread and successful (Karki & Adhikari., 2015). However, these efforts are often limited and lack scientific rigor (Poudel, 2015). Barriers to adaptation include insufficient climate information, labor shortages, financial constraints, and limited market access (Dhakal et al., 2013). A review of Nepali framers' adaptation strategy to climate change found that all strategies were short-term oriented, reactive, and autonomous (Rijal et al., 2021).

To enhance farmers' adaptive capacity and ensure food security, there is a need for improved communication about climate change impacts, multidisciplinary interventions, and stakeholder collaboration to develop targeted, locally appropriate adaptation solutions (Budhathoki & Zander, 2020; Karki, 2020).

A study by Gentle and Maraseni (2012) used climate vulnerability and capacity analysis (CVCA) to conclude that the adaptation techniques to climate change have been reactive and short-term (Gentle & Maraseni, 2012). Internationally, farmers in various regions adopt diverse strategies to adapt to climate change. Common approaches include crop diversification, changing planting dates, and shifting to more resilient crops (Balama et al., 2013; Chunera et al., 2019; Kattumuri et al., 2017). Other strategies involve soil and water conservation, fertilizer application, and livestock diversification (Destaw & Fenta, 2021). Non-farming adaptations such as forest product use, petty trade, and migration are also employed (Balama et al., 2013; Kattumuri et al., 2017).

Some challenges faced by farmers internationally are high adaptation costs, limited knowledge, and lack of improved technology (Chunera et al., 2019). In Pakistan, for example, a need for investments toward capacity-building to achieve benefits from adaptation in agriculture was identified (Saddique et al., 2022). Factors influencing adaptation choices include age, education, farm size, income, and access to climate information (Destaw & Fenta, 2021). Current adaptation measures may be inadequate for future climate risks, highlighting the need for enhanced resilience and structured adaptation strategies (Kattumuri et al., 2017). Recommendations from various researchers include improving access to climate information, providing suitable crop varieties, and strengthening income-generating activities (Chunera et al., 2019; Destaw & Fenta, 2021).

4. Conclusion

The impact of climate change on agriculture in Nepal poses serious challenges that threaten agricultural productivity, food security, and the livelihoods of millions of farmers. The rising temperatures altered precipitation patterns, and the increased frequency of extreme weather events led to significant vulnerabilities within the agricultural sector. Adaptation strategies are vital to address these challenges and ensure Nepal's food security and economic stability. Farmers have implemented measures such as adjusting planting times, diversifying crops, and adopting soil and water management practices. However, these strategies are often reactive, short-term, and constrained by limited resources, knowledge, and infrastructure. To build resilience, it is important to enhance access to climate information, develop drought-resistant crop varieties, promote sustainable farming practices, and improve market access and financial support for farmers.

References

Acharya, S. P., & Bhatta, G. R. (2013). *Impact of climate change on agricultural growth in Nepal*. NRB Economic Review.

Anh, D. L. T., Anh, N. T., & Chandio, A. A. (2023). Climate change and its impacts on Vietnam agriculture: A macroeconomic perspective. *Ecological Informatics*, 74, 101960.

Antle, J. M. (1995). Climate change and agriculture in developing countries. *American Journal of Agricultural Economics*, 77(3), 741–746.

Awasthi, R. P., & Owen, J. S. (2020). Observed climate extreme in Nepal. *The Geographic Base*, 7, 1-14.

Bajracharya, A. R., Bajracharya, S. R., Shrestha, A. B., & Maharjan, S. B. (2018). Climate change impact assessment on the hydrological regime of the Kaligandaki Basin, Nepal. *Science of the Total Environment*, 625, 837-848.

Balama, C., Augustino, S., Eriksen, S., Makonda, F. S. B., & Amanzi, N. (2013). Climate change adaptation strategies by local farmers in Kilombero District, Tanzania. *Ethiopian Journal of Environmental Studies and Management*, 6(6), 724-736.

Bello, O. B., Ganiyu, O. T., Wahab, M. K. A., Afolabi, M. S., Oluleye, F., Ig, S. A., & Abdulmaliq, S. Y. (2012). Evidence of climate change impacts on agriculture and food security in Nigeria. *International Journal of Agriculture and Forestry,* 2(2), 49-55.

Budhathoki, N. K., & Zander, K. K. (2020). Nepalese farmers' climate change perceptions, reality and farming strategies. *Climate and Development*, 12(3), 204-215.

Calzadilla, A., Rehdanz, K., Betts, R., Falloon, P., Wiltshire, A., & Tol, R. S. (2013). Climate change impacts on global agriculture. *Climatic Change*, 120, 357-374.

Chapagain, D., Dhaubanjar, S., & Bharati, L. (2021). Unpacking future climate extremes and their sectoral implications in western Nepal. *Climatic Change*, 168(1), 8.

Chogyal, N., & Kumar, L. (2018). Climate change and potential impacts on agriculture in Bhutan: A discussion of pertinent issues. *Agriculture & Food Security*, 7(1), 1-13. https://doi.org/10.1186/s40066-018-0229-6

Chunera, A., Dash, D., & Deep, A. (2019). Farm level adaptation strategies to climate change in India: An overview. *Journal of Pharmacognosy and Phytochemistry*, 8(4), 1685-1690.

Dahal, P., Shrestha, M. L., Panthi, J., & Pradhananga, D. (2020). Modeling the future impacts of climate change on water availability in the Karnali River Basin of Nepal Himalaya. *Environmental Research*, 185, 109430.

Dawadi, B., Shrestha, A., Acharya, R. H., Dhital, Y. P., & Devkota, R. (2022). Impact of climate change on agricultural production: A case of Rasuwa District, Nepal. *Regional Sustainability*, 3(2), 122-132.

Destaw, F., & Fenta, M. M. (2021). Climate change adaptation strategies and their predictors amongst rural farmers in Ambassel district, Northern Ethiopia. Jàmbá: *Journal of Disaster Risk Studies*, 13(1), 1-11.

Dhakal, C. K., Regmi, P. P., Dhakal, I. P., Khanal, B., Bhatta, U. K., Barsila, S. R., & Acharya, B. (2013). *Perception, impact and adaptation to climate change: An analysis of livestock system in Nepal*.

Dong, K., Prytherch, M., McElwee, L., Kim, P., Blanchette, J., & Hass, R. (2024). *China's food security: Key challenges and emerging policy responses*. Centre for Strategic and International Studies. https://www.csis.org

Eckstein, D., Künzel, V., & Schäfer, L. (2021). *The Global Climate Risk Index 2021*. Bonn: Germanwatch.

Food and Agriculture Organization of United Nations (FAO) (2020). *Building Climate Resilience in Nepal*. Sustainable food and agriculture. https://www.fao.org/sustainability/detail/en/c/

Gentle, P., & Maraseni, T.N. (2012). Climate change, poverty, and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental Science & Policy*, 21, 24–34.

Giri, S., Prabhakar, A., Malla, R. B., Oli, S., Poudel, S., & Khanal, A. (2023a). Climate change mitigation and adaptation in Nepal and South Asia: Challenges, progress, and recommendations. *Journal of Sustainability and Environmental Management*, 2(2), 133–140. https://doi.org/10.3126/josem.v2i2.55206

Giri, S., Prasai, A., Khanal, A., Khamcha, R., Tiwari, S., Khadka, S., Thapa, Y., Rai, N., & Pantha, M. (2023b). Assessing climate change challenges and adaptation strategies in South Asian countries: A review. *Journal of Sustainability and Environmental Management*, 2(2), 141–149. https://doi.org/10.3126/josem.v2i2.55207

Gautam, A. K., & Pokhrel, S. (2010). *Climate change effects on crops in Nepal and adaptation measures*. In Thematic Working Group (agriculture and food security) meeting.

Gupta, A. K., Yadav, D., Gupta, P., Gupta, V., Ranjan, S., & Badhai, S. (2020). *Effects of Climate Change on Agriculture. FASJO*.

Jagermeyr, J., Muller, C., et al. (2021). Climate change impact on global agriculture emerges earlier in a new generation of climate and crop models. *Nature Food*, 2(10), 873-885. doi.org/10.1038/s43016-021-00400-y

Joshi, G., & Joshi, B. (2019). Climate change impact on agriculture sector of Nepal: Implications for adaptation and resilience building. *Agricultural Transformation in Nepal*, 110-155. doi: 10.1007/978-981-32-9648-0-6

Karki, M., & Adhikari, J. R. (2015). *Integrating indigenous, local and modern knowledge for sustainable conservation and management of forest ecosystems in Nepal*. Forestry Nepal: Gateway to Forestry Information in Nepal.

Karki, R., & Gurung, A. (2012). An overview of climate change and its impact on agriculture: A review from least developing country, Nepal. *International Journal of Ecosystem*, 2(2), 19-24.

Karki, S., Burton, P., & Mackey, B. (2020). Climate change adaptation by subsistence and smallholder farmers: Insights from three agro-ecological regions of Nepal. *Cogent Social Sciences*, 6(1), 1720555.

Kattumuri, R., Ravindranath, D., & Esteves, T. (2017). Local adaptation strategies in semi-arid regions: study of two villages in Karnataka, India. *Climate and Development*, 9(1), 36-49.

Khanal, U., Wilson, C., Lee, B. L., & Hoang, V. N. (2018). Climate change adaptation strategies and food productivity in Nepal: A counterfactual analysis. *Climatic Change*, 148, 575-590.

Koirala, A., & Shrestha, K. B. (2017). Effects of climate change on the livestock population in Mustang District, Nepal. *Asian Journal of Agriculture and Development*, 14(1), 37-49.

Lavalle, C., Micale, F., Houston, T. D., Camia, A., Hiederer, R., Lazar, C., ... & Genovese, G. (2009). Climate change in Europe. 3. Impact on agriculture and forestry. A review. *Agronomy for Sustainable Development*, 29(3), 433-446. https://doi.org/10.105/agro/2008068

Lehner, F., & Stocker, T.F. (2015). From local perception to global perspective. *Nature Climate Change*, 5(8), 731-134. https://doi.org/10.1038/nclimate2660

Li, Y., Guan, K., Schnitkey, G. D., DeLucia, E., & Peng, B. (2019). Excessive rainfall leads to maize yield loss of a comparable magnitude to extreme drought in the United States. *Global Change Biology*, 25(7), 2325-2337.

Malla, G. (2008). Climate change and its impact on Nepalese agriculture. *Journal of Agriculture and Environment*, 9, 62-71.

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, 13(3), 1318.

Mendelsohn, R. (2014). The impact of climate change on agriculture in Asia. *Journal of Integrative Agriculture*, 13(4), 660-665.

Mizina, S. V., Smith, J. B., Gossen, E., Spiecker, K. F., & Witkowski, S. L. (1999). An evaluation of adaptation options for climate change impacts on agriculture in Kazakhstan. *Mitigation and Adaptation Strategies for Global Change*, 4, 25-41.

Mohanty, L., & Maiti, S. (2021). Probability of glacial lake outburst flooding in the Himalayas. *Resources, Environment and Sustainability*, 5, 100031.

Ngaira, J. K. W. (2007). Impact of climate change on agriculture in Africa. *Scientific Research and Essays*, 2(7), 238-243.

Paudel, B., Zhang, Y., Yan, J., Rai, R., Li, L., Wu, X., ... & Khanal, N. R. (2020). Farmers' understanding of climate change in Nepal Himalayas: Important determinants and implications for developing adaptation strategies. *Climatic Change*, 158, 485-502.

Pradhan, M. (2023). *Nepal's Agricultural Landscape: Assessing the Government's Stance.* Nepal Economic Forum.

Praveen, B., & Sharma, P. (2019). A review of literature on climate change and its impacts on agriculture productivity. *Journal of Public Affairs*, 19(4), e1960.

Rayamajhee, V., Guo, W., & Bohara, A. K. (2021). The impact of climate change on rice production in Nepal. *Economics of Disasters and Climate Change*, 5, 111-134.

Rijal, S., Gentle, P., Khanal, U., Wilson, C., & Rimal, B. (2021). A systematic review of Nepalese farmers' climate change adaptation strategies. *Climate Policy*, 22(1), 132-146.

Saddique, N., Jehanzaib, M., Sarwar, A., Ahmed, E., Muzammil, M., Khan, M. I., ... & Bernhofer, C. (2022). A systematic review on farmers' adaptation strategies in Pakistan toward climate change. *Atmosphere*, 13(8), 1280.

Shakoor, U., Saboor, A., Ali, I., & Mohsin, A. Q. (2011). Impact of climate change on agriculture: Empirical evidence from arid region. *Pakistani Journal of Agricultural Science*, 48(4), 327-333.

Shrestha, A.B., Wake, C.P., Mayewski, P.A., Dibb, J.E. (1999). *Maximum temperature trends in the Himalayas and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94.*

Shrestha, R. P. (2010). *Climate change and agriculture in Nepal: Impact, adaptation and policy*. In Thematic Working Group (agriculture and food security) meeting.

Sohail, A. (2020). Agriculture, climate change and adaptation: A review. *Journal of Agricultural Science*, 11(9), 196.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., ... & Miller, H. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.

Shrestha, R. P., & Dutt, N. (2020). *Agriculture, climate change, and adaptation: A case study of Nepal*. In I. M. Z. Yasser, M. Khattab (Eds.), Climate Change and Agriculture in Africa. https://doi.org/10.1007/978-3-030-12689-8_8

Ullah, A., & Jin, M. (2021). Effects of climate change on agriculture and food security in Pakistan. *Environmental Science and Pollution Research*, 28, 57250-57261.

Wang, F., Zhang, W., & Xie, H. (2021). Assessing the potential impacts of climate change on agriculture in China: A case study. *Climate and Development*, 13(1), 1-13.