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ASSESSMENT OF CLIMATE CHANGE VULNERABILITY AND ITS IMPACTS ON SUMMER VEGETABLE PRODUCTION IN TRISHULI-NARAYANI RIVER CORRIDOR, NEPAL

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ABSTRACT

Climate change poses a significant threat to communities reliant on natural resources, particularly those dependent on agriculture. Summer vegetables, a major crop in Nepal, are acutely affected by changing weather patterns, impacting food security, income stability, and overall livelihood sustainability. This study employed a participatory approach to assess climate vulnerabilities and impacts on summer vegetable farmers in the Trishuli-Narayani River corridor. Using techniques like climate hazard ranking, seasonal vulnerability calendars, and forced field analysis, the study engaged 71 farmers from six sites across Chitwan, Dhading, and Nuwakot districts. The study identified location-specific vulnerabilities. Heavy rainfall emerged as the most concerning climate hazard for farmers in lower altitude areas (e.g., Chitwan), while heat stress posed the greatest threat at higher elevations (e.g., Dhading and Nuwakot). Furthermore, the study revealed that specific summer vegetables were perceived as more vulnerable than others. For instance, tomatoes were ranked as the most affected crop in Chitwan, while cucumbers were seen as highly susceptible to climate risks in Dhading and Nuwakot. A forced field analysis identified various factors contributing to vulnerability, with social factors (SF), physical factors (PF), and natural factors (NF) being the most prominent across the region. The level of vulnerability varied by district, with Chitwan exhibiting moderate vulnerability (NF=2.09, PF=2.51, SF=2.71), Dhading experiencing higher vulnerability (NF=3.13, PF=3.34, SF=2.55), and Nuwakot facing challenges driven primarily by economic and human factors (NF=2.29, PF=2.29, SF=1.88). Farmers have adopted various adaptation strategies to cope with these vulnerabilities. These strategies include afforestation within farms (a prominent practice in Nuwakot) (AF=5.31) and canal reconstruction (frequently implemented in Chitwan) (CR=3.26). However, the study highlights a gap between vulnerability scores and mitigation measures, suggesting a need for more robust adaptation strategies. The participatory approach employed in this study yielded valuable insights into the specific climate challenges faced by local farmers. This underscores the importance of engaging communities in climate change assessments and tailoring adaptation plans to address their unique needs. These findings not only contribute to a deeper understanding of climate change impacts on summer vegetable production in Nepal but also hold significant global implications for vulnerable regions facing similar challenges. The study emphasizes the urgency of proactive measures to navigate a changing climate and ensure the sustainability of agricultural livelihoods.

Key words Adaptation strategies, climatic hazards, participatory tools, vulnerability assessment

INTRODUCTION

The reality of climate change pervades everywhere, transcending myth and manifesting in every corner of the globe. Communities reliant on natural resources stand particularly vulnerable to its impacts (Kaushik & Sharma, 2015). Previous studies have demonstrated the profound effects of climatic abnormalities on vegetable cultivation (Potop et al., 2014). Intensified extreme weather events such as variations in rainfall, rising temperatures, and prolonged droughts threaten crop yields, alter pest and disease dynamics, and disrupt traditional farming practices (Grigorieva et al., 2023). Vulnerability refers to the susceptibility of a system or community to climate change impacts, including variability and extremes. It's a function of exposure (the nature and extent of climate variations experienced), sensitivity (the degree to which the system is affected), and adaptive capacity (the ability to cope with impacts) (Boureima et al., 2013; Füssel, 2009). Climate-sensitive sectors like agriculture face risks of land loss, livelihood disruption, and even loss of life (Tiani et al., 2015; van Aalst et al., 2008; Fakhruddin et al., 2020).

Summer vegetable production is directly affected by variations in rainfall, rising temperatures, droughts, and extreme weather events (Kumari et al., 2018). In

Nepal, summer vegetables are cultivated during the pre-monsoon and monsoon seasons, which generally span April, May, June and July. Erratic rainfall disrupts irrigation schedules and leads to water stress, while rising temperatures exacerbate heat stress in vegetables, affecting flowering, fruit set, and yield (Bisbis et al., 2018). Drought limit water availability and stunt plant growth, while extreme weather events like storms, hail, and pest outbreaks can damage crops and reduce yields (Kumar & Reddy, 2021).

Vulnerability is not just about natural hazards like floods and droughts, but also social factors like poverty and discrimination. It depends on exposure, sensitivity, and adaptive capacity. Exposure refers to the degree a system experiences hazards based on location (Hutton et al., 2011). Sensitivity is the degree to which the system is affected, while adaptive capacity is the ability to cope with impacts using available resources (Locatelli et al., 2008). Climate vulnerability is a complex phenomenon influenced by various factors, particularly livelihood resources such as economic, social, demographic, and political factors. Exposure, sensitivity, and adaptive capacity depend on access to and control over these resources. For instance, communities dependent on environmental resources like water, forests, and land are highly vulnerable when these resources are depleted. Economically disadvantaged people have fewer resources and alternatives to address climate impacts, increasing their vulnerability (Kaushik & Sharma, 2015). Social and demographic factors like strong social networks can also influence how communities cope with impacts. Infrastructure, policies, and institutions also play a role. Thus, it is important to learn and understand the diverse set of influences such as social, cultural, economic, institutional, political and psychological factors that support and enhance people's livelihoods (Tiani et al., 2015). Participatory assessments offer a valuable approach for communities, practitioners, and policymakers to gain firsthand insights into local climate challenges. This empowers them to advocate for and develop effective solutions (Hinds, 2013). This paper details a participatory assessment using the Participatory Climate Vulnerability Assessment (PCVA) methodology, specifically designed to examine climate vulnerabilities (Ahmed et al., 2012). The PCVA approach helps us understand how susceptible summer vegetable production is to climate impacts within the Trishuli-Narayani River corridor. Our objective is to explore and comprehend climate-related vulnerabilities within the study area and generate transferable knowledge applicable to similar regions.

MATERIALS AND METHODS

The study was conducted within the Trishuli-Narayani river corridor, encompassing three districts in Nepal: Chitwan (27.61°N, 84.88°E) located in the lowlands, Dhading (27.90°N, 85.19°E) in the mid-hills, and Nuwakot (27.68°N, 85.42°E) in the high hills. This variation in elevation, ranging from roughly 27.61°N to 27.90°N latitude and 84.88°E to 85.42°E longitude, plays a role in the climatic vulnerabilities experienced by farmers. For instance, lowland areas like Chitwan might face more intense erratic rainfall compared to higher elevations in Nuwakot (Rai et al., 2022; Luitel et al., 2020; Dandekhya et al., 2017). Climatic data was outsourced from Department of Hydrology and Metrology, Babarmahal, Kathmandu.

Participatory Climate Vulnerability Assessment (PCVA)

To assess the vulnerability of summer vegetable production to climate change, the study employed a PCVA approach across the three districts. PCVA aims to identify the weaknesses of the agricultural system in the face of a changing climate. Recognizing the complexities of climate change adaptation and vulnerabilities, the study utilized a multifaceted approach integrating various participatory tools (Moret 2014). These tools were used to assess the vulnerability components (Table 1).

A total of 71 summer vegetable farmers participated in the study from Chitwan, Dhading and Nuwakot, with a composition of 69% male and 31% female respondents. FGDs were conducted across six distinct locations, with two sites selected from each of the three districts. This approach ensured active involvement from diverse demographics within the communities, including the elderly, youth, women, and local ethnic groups. Various participatory tools were used to gather data and insights from farmers (Table 2).

Table 1. Vulnerability components and assessment tools

Vulnerability components	**Assessment tool**
Exposure	Seasonal vulnerability calendar
Sensitivity	Hazard ranking, ranking vegetables on climate risk
Adaptive Capacity	Force field analysis (identifying driving and counteracting forces

Table 2. Description of the methodology of the study

Participatory tools	**Purpose**	**Method used**
Problem ranking of climatic hazards and other abnormalities	Identify prominent climatic hazards	Farmers listed various problems affecting vegetables (e.g., windstorms, heat stress, high rainfall) and pairwise ranking identified the most severe hazard.
Seasonal vulnerability calendar	Understand vulnerabilities and coping strategies	Discussed risks and effects for each summer month (April-July) and farmers' adaptation strategies documented.
Ranking summer vegetable on the basis of climatic risk	Assess perceived vulnerability of different vegetables	Farmers ranked seven summer vegetables (1-7) based on perceived climate risk (1 = most sensitive)
Forced field analysis	Understand driving forces and counteracting measures	Listed driving vulnerabilities and counteracting measures based on farmers' perception and farmers ranked each factor (0-4) based on influence (0 = least, 4 = most).

(Adapted based on (Pangali Sharma et al., 2022); (Poudel et al., 2020) and (Dazé, 2014))

RESULTS AND DISCUSSION

Climatic trends of Chitwan

Based on the provided climate data for Chitwan district from 1989 to 2021 the average yearly temperature in Chitwan fluctuates around 24°C with no clear increasing or decreasing trend over the years yet the warmest year on record was 2021 (25.2°C) and the coolest was 2012 (22.3°C). Rainfall shows significant variation across the years, ranging from a low of 1209.3 mm (47.6 in) in 2019 to a high of 2644.9 mm (104.1 in) in 1998. Interestingly, four out of the last five years (2017-2021) have rainfall below the overall average, hinting at a possible decrease in recent years.

Climatic trend of Dhading

Based on the climate data for Dhading district from 1989 to 2021, Dhading district has an average yearly temperature of around 21°C. The hottest year was 2021 (22.9°C) and the coldest was 1990 (19.9°C). Rainfall in Dhading district is also highly variable, ranging from 979 mm (38.5 in) in 2015 to 3025.2 mm (119.1 in) in 1999.

Climatic trend of Nuwakot

Based on the data provided from 1989 to 2021, Nuwakot appears to have a temperate highland tropical climate with an average yearly temperature of around 22°C. The warmest year was 2021 (23.2°C) and the coldest was 2004 (21°C). Nuwakot exhibits similar variations in rainfall, with the lowest amount recorded in 2009 (880.3 mm) and the highest in 2000 (2572.7 mm).

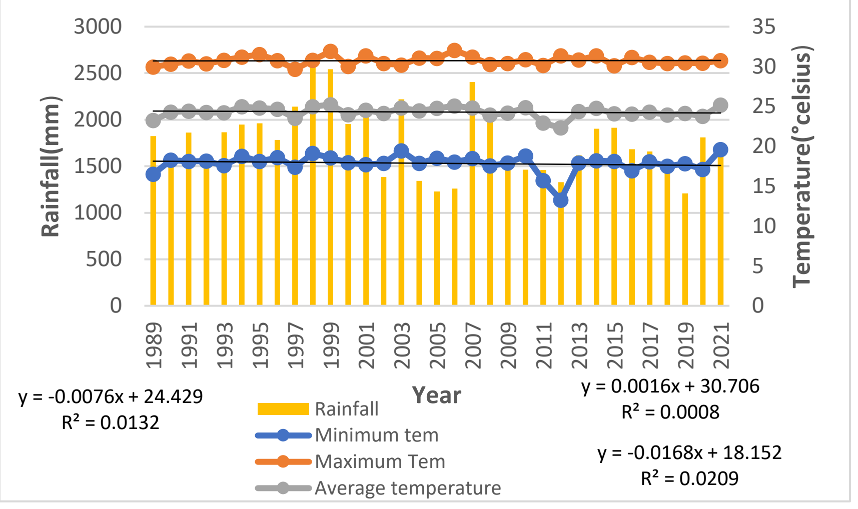


Figure 1. Annual temperature and rainfall of Chitwan (1989-2021)

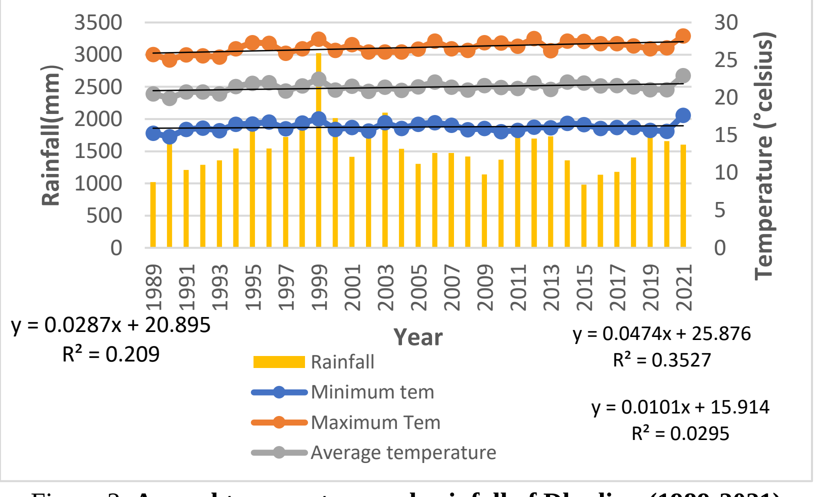


Figure 2. **Annual temperature and rainfall of Dhading (1989-2021)**

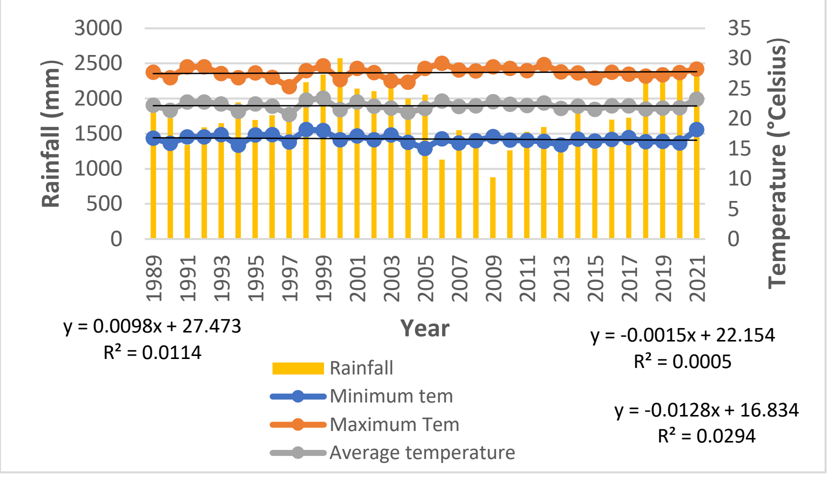


Figure 3. Annual temperature and rainfall of Nuwakot (1989-2021)

Problem ranking of climatic hazards and other abnormalities

The ranking of climatic hazards and other abnormalities varied across the three districts studied (Chitwan, Dhading, and Nuwakot) (Figure 4, Figure 5 and Figure 6), highlighting the location-specific nature of climate change impacts. In Chitwan, high rainfall emerged as the most concerning issue, followed by heat stress, windstorms, decreased pollination, soil erosion, new weed (e.g. *Mikania micrantha*) infestation, and finally insect and disease infestations. Dhading ranked heat stress as the most problematic, followed by high rainfall, soil erosion, windstorms, and then new weed infestation. Nuwakot identified heat stress as the most concerning climatic hazard, followed by soil erosion, insect and disease infestations, decreased pollination, new weed (e.g., *Parthenium hysterophorus*, etc.) occurrences, windstorms, and lastly high rainfall. In this study, high rainfall emerged as a major climatic hazard at lower altitudes, i.e., Chitwan, while heat stress due to climate change in summer vegetables was a major issue seen in higher altitudes, i.e., Dhading and Nuwakot.

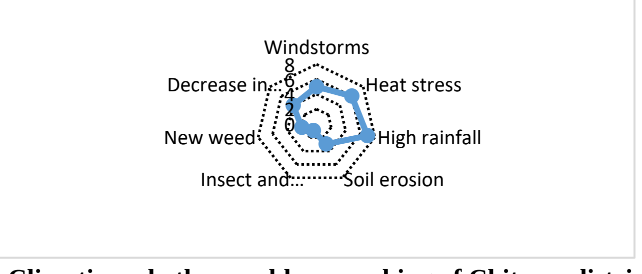


Figure 4. Climatic and other problems ranking of Chitwan district, Nepal

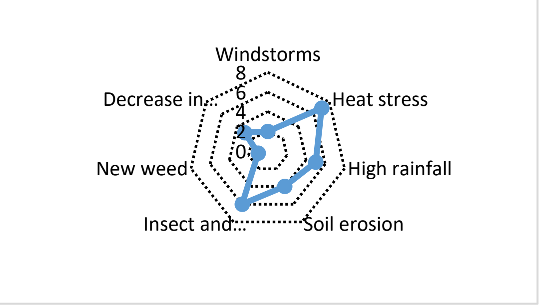


Figure 5. Climatic and other problems ranking of Dhading district, Nepal

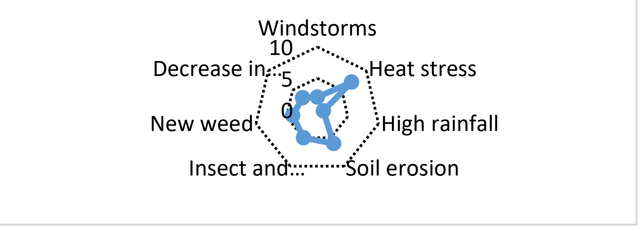


Figure 6. Climatic and other problems ranking of Nuwakot district, Nepal

Seasonal calendar

The seasonal calendars developed with farmers reveal the various challenges they encounter throughout the summer vegetable growing season, along with the coping strategies they employ (Table 3). In Chitwan, diverse insect infestations and adverse weather conditions necessitate interventions such as manual insect control, altering crop selection, and afforestation measures. Practices during dry periods include frequent irrigation, constructing boreholes, mulching, and implementing agroforestry and afforestation initiatives. During high rainfall periods, strategies include drainage, afforestation, riverbank embankments, and adjusting crop varieties. Farmers in Dhading address issues of drought and high temperatures accompanied by concerns about plant wilting and increased insect activity, through irrigation strategies, early harvesting, and cultivating resistant varieties. In Nuwakot, windstorms and drought in April and May necessitate increased irrigation and alternative water sources like boreholes and rainwater harvesting. By May to June, high temperatures become prominent, prompting measures like well construction and mulching. July brings waterlogging and insect infections, demanding drainage, pesticide use, and resistant crop varieties.

Farmers adjust their cropping calendars and interventions based on seasonal changes in response to climatic hazards.

Table 3. Seasonal calendar of climate hazards and adaptation measures in summer vegetable farmers in Chitwan, Dhading and Nuwakot districts of Nepal

District	Hazards and interventions	April	May	June	July
Chitwan	Hazards and impact	Painted Lady Butterfly caterpillar in bitter gourd, black cutworm in pumpkin, wind, hailstorm, risk of forest fire	Shield bug in sponge gourd, various insects in brinjal, dryness, low rainfall, hot winds on the farm	Black long worm affecting pumpkin roots, yellow worm in bitter gourd, dryness, wind, high temperatures	Flower wilting in bottle gourd, flood, landslide, high temperatures
	Adaptation interventions	Manual insect control, insecticide use, irrigation, weeding, fertilization, afforestation, forest fire awareness, crop variety adjustment	Manual insect control, crop variety adjustment, afforestation	Crop variety adjustment, proper irrigation, fertilization, afforestation	Crop change, afforestation, river management, riverside embankment
Dhading	Hazards and impact	Drought, high insect infection	Drought, high temperatures, plant wilting	High temperatures and plant wilting	Water logging, high insect infection
	Adaptation interventions	Increased irrigation frequency, pesticide usage or traps for insects	Irrigation, well construction, early harvesting, use resistant varieties	Early harvest, resistant varieties	Water drainage, pesticide usage, earthing up, resistant varieties
Nuwakot	Hazards and impact	Windstorms, drought	Drought, high temperatures	High temperatures	Waterlogging and high insect infection
	Adaptation interventions	Increased irrigation frequency, boring construction	Well construction, mulching	Irrigation	Water drainage, pesticide usage, insect-resistant varieties

These findings suggest that specific vegetables may require more targeted adaptation strategies in certain regions.

Ranking the effects of climate change in different summer vegetable

The pervasive negative impact of climate change is undeniable, exhibiting varied effects across different crops. The ranking of summer vegetables based on climate risk indicates the perceived vulnerability of different vegetables to climate change (Table 4). A within-study analysis showed that cucumber was perceived as the most severely impacted crop in Nuwakot and Dhading. Conversely, tomato was ranked as the most affected crop in Chitwan. Pumpkin, bottle gourd, and sponge gourd were seen as moderately affected by climate change. Interestingly, eggplant in Nuwakot, cucumber in Chitwan, and bitter gourd in Dhading appeared to be the least affected.

Table 4. Ranking of effects of climate change on different vegetables in Chitwan, Dhading and Nuwakot districts of Nepal

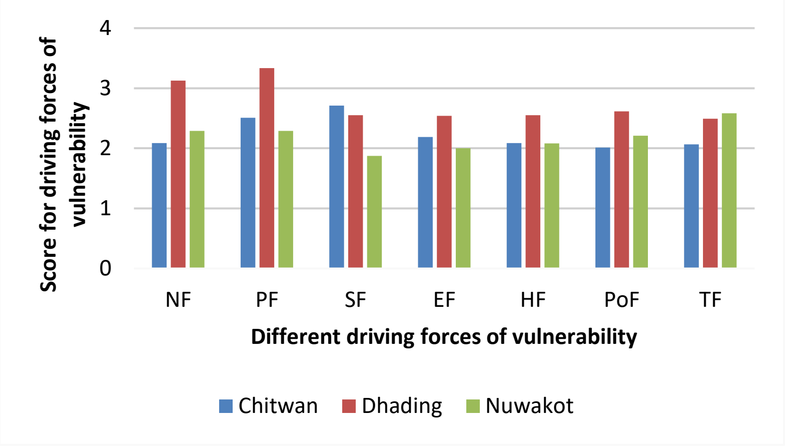
Study Area	Vegetables						
	Cucumber	Pumpkin	Bottle-gourd	Bitter-gourd	Sponge-gourd	Egg-plant	Tomato
Chitwan	7	3	4	5	5	2	1
Dhadhing	1	3	4	7	5	6	2
Nuwakot	1	3	2	6	4	7	5

Forced field analysis

The force field analysis identified various factors contributing to the vulnerability of summer vegetable farmers to climate change (Figure 6). Spanning Chitwan, Dhading, and Nuwakot districts, the study encapsulated seven distinct driving factors of climatic vulnerability. In Chitwan, a moderate level of vulnerability was identified, with social dynamics (high) and physical factors being the most prominent. The multifaceted nature of vulnerability in Chitwan is evident, with NF at 2.09, PF at 2.51, and SF at 2.71. This highlights the importance of strengthening community ties and infrastructure development in building resilience. Dhading exhibited higher vulnerability due to natural factors, physical factors, and social factors with NF at 3.13, PF at 3.34, and SF at 2.55. Technological factors and policy factors play a crucial role in enhancing resilience in this district with TF valued at 2.49 and PoF at 2.62. Vulnerability in Nuwakot stemmed from economic factors and human factors, along with moderate levels of natural and physical factors i.e. NF at 2.29, PF at 2.29, and SF at 1.88. Technological factors were identified as a key area for intervention. This analysis underscores the need for tailored adaptation strategies that address the specific vulnerabilities faced by farmers in each district, aligning with previous research on the intricate interplay of various factors shaping vulnerability.

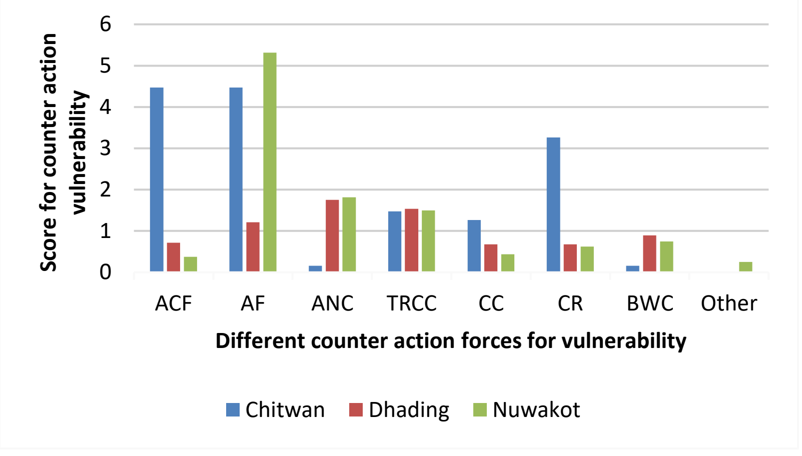
The study also explored the strategies employed by farmers to mitigate the vulnerabilities identified (Figure 8). In Chitwan, afforestation to control floods and canal reconstruction were the primary counteraction forces implemented to address social and physical factors with ACF recorded at 4.47 and CR at 3.26.

Dhading prioritized raising awareness of natural calamities and providing training related to climate change to counter the



Note: NF= Natural Factor, PF = Physical Factors, SF = Social Factors, EF = Economic Factors, HF = Human Factors, PoF = Policy Factors, TF= Technological Factors

Figure 7. Driving forces of vulnerability among summer vegetable farmers in Trishuli-Narayani River corridor, Nepal



Note: ACF= Afforestation to control flood, AF= Agroforestry in Farm, ANC= Awareness of natural calamities, TRCC= Training related to climate change, CC= Canal construction, CR= Canal reconstruction, BWC= Boring or well construction, Other = Other interventions

Figure 8. Counter action forces of vulnerabilities among summer vegetable farmers in Trishuli Narayani River corridor, Nepal

challenges posed by natural and economic factors. ANC is noted at 1.75 and TRCC at 1.54. Nuwakot's main strategies to address economic and human resource limitations were afforestation within farms and construction of boreholes or wells. AF stands at 5.31 and BWC at 0.75, highlighting the emphasis on environmental and infrastructural enhancements. These findings showcase the proactive efforts undertaken by farmers to build resilience against climate change.

DISCUSSION

This study provides a comprehensive understanding of the impacts on summer vegetable production in three different physiographic regions of Nepal. The participatory approach, involving 71 farmers, ensures the findings are grounded in the lived experiences of those directly affected by a changing climate.

Climatic trends and district variations

While all three districts face challenges, the specific climatic trends and their impacts vary. Chitwan exhibits a possible increase in temperature, potentially leading to heat stress for summer vegetables (Devkota et al., 2019). Declining rainfall patterns throughout the districts pose challenges for water availability (Rai et al., 2022). Nuwakot, being a highland district, might experience cooler temperatures compared to Chitwan, offering a potential advantage for heat-sensitive vegetables (Joshi and Joshi, 2017), however, the high variability in temperature and rainfall across all districts makes planning difficult for farmers, necessitating adaptation strategies.

Participatory tools and corroborating evidence

The study employed a range of valuable tools, including Climate Hazard Ranking, Seasonal Calendars, Vegetable Vulnerability Ranking, and Force Field Analysis. These tools facilitated the gathering of nuanced data and insights from the farmers themselves. For instance, the Climate Hazard Ranking identified drought, insect infestations, and heat stress as major concerns, which aligns with previous research (Pangali Sharma et al., 2022; Poudel et al., 2020). Similar studies documented these threats alongside soil erosion and hailstorms (Maharjan et al., 2017). Research by Malla (2008) further highlights the significant impact of humidity, rainfall, and temperature stress on pest and disease prevalence in Nepali agriculture.

Seasonal challenges and farmer adaptation

The Seasonal Calendars, co-created with farmers, reveal the diverse challenges encountered throughout the growing season and the coping strategies employed. This aligns with findings by Paudel et al. (2014), Dhanya & Ramachandran

(2015), and Launio et al. (2020), who documented farmers' adjustments to cropping calendars and interventions based on seasonal variations and vulnerability assessments. Notably, farmers themselves have observed significant changes in seasonal patterns over time, necessitating adjustments in management practices (Launio et al., 2020). Previous research supports this, highlighting how farmers adapt by modifying cropping calendars and interventions based on vulnerability assessments (Rahman et al., 2017) and employing diverse on-farm management practices (Pandey et al., 2015).

Vulnerability ranking and targeted interventions:

The ranking of summer vegetables based on climate risk emphasizes the perceived vulnerability of different vegetables. Similar findings from the Ganga River basin (Singh et al., 2021) indicate a spectrum of climate change impacts on various vegetables, underlining the need for specific adaptation strategies tailored to both crop and region. These findings underscore the urgent need for targeted interventions and policy measures to support vulnerable farming communities. Previous studies (Hoang et al., 2023; Darjee et al., 2023) emphasize the importance of strengthening community ties, infrastructure development, and raising awareness of climate threats. Additionally, providing training related to climate change adaptation strategies is crucial.

Force field analysis and tailored adaptation

The Force Field Analysis conducted in this study identifies various factors contributing to farmer vulnerability, including natural phenomena, social dynamics, physical limitations, and economic constraints. Similar to Luo et al. (2024), this study highlights the need for tailored adaptation strategies that address the specific vulnerabilities faced by farmers in each district. Parallel research by Luo et al. (2024) further corroborates these findings, highlighting natural phenomena like vegetation cover and humidity as significant drivers of vulnerability.

CONCLUSION

Recent warming trends, particularly in Chitwan, could lead to heat stress for summer vegetables, reducing yields and quality. Declining rainfall patterns throughout the district’s present challenges for water availability, potentially increasing irrigation needs and production costs. The significant variability in temperature and rainfall makes planning difficult for farmers. They need to adapt by using heat-resistant varieties, adjusting planting schedules, and employing water management practices like mulching or water harvesting. While Nuwakot's higher elevation might offer some advantage for heat-sensitive vegetables, targeted adaptation strategies are crucial considering the varying climate hazards across locations. The ranking of climate hazards varied across the three districts. Lower elevation areas like Chitwan faced more insect and disease issues, while higher elevations experienced greater heat stress. This emphasizes the need for geographically targeted adaptation strategies. Seasonal calendars revealed diverse challenges throughout the growing season, including water stress, pest infestations, and extreme weather events. Farmers adjust their cropping calendars and employ different interventions based on those changing vulnerabilities, demonstrating their capacity for adaptation. Ranking exercises showed that some summer vegetables were perceived as more vulnerable to climate change compared to others. For instance, cucumber was seen as highly vulnerable in Nuwakot disease and pest, while eggplant was considered less affected. This highlights the need for crop-specific adaptation strategies. The study also highlights the value of participatory tools in assessing climate change vulnerability. These tools facilitated a nuanced understanding of the challenges faced by farmers, enabling the development of tailored adaptation strategies. Overall, the study contributes to a deeper understanding of climate change impacts on summer vegetable production in Nepal and offers valuable insights for informing effective adaptation strategies at the local level.

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REFERENCES

Ahmed I., Fuenfgeld H. and McEvoy, D. (2012) *Integrated disaster risk reduction and climate change: Participatory capacity and vulnerability analysis (PCVA) toolkit*. Oxfam Australia.

Bisbis M. B., Gruda N. and Blanke M. (2018) Potential impacts of climate change on vegetable production and product quality–A review. *Journal of Cleaner Production,* 170, pp. 1602-1620. https://doi.org/10.1016/j.jclepro.2017.09.224

Boureima M., Abasse T. A., Sotelo Montes C., Weber J. C., Katkoré B., Mounkoro B., Dakouo J. M., Samaké O., Sigué H., Bationo B. A. and Diallo B. O. (2013) *Participatory analysis of vulnerability and adaptation to climate change: A methodological guide for working with rural communities,* World Agroforestry Centre, Nairobi, Occasional Paper 19 (In English). ISBN 978-92-9059-351-5.

Dandekhya S., England M., Ghate R. and Goodrich C. G.. (2017) The Gandaki Basin – Maintaining livelihoods in the face of landslides, floods, and drought. HI-AWARE Working Paper 9. HI-AWARE, Kathmandu.

Darjee K. B., Neupane P. R., and Köhl M. (2023) Proactive Adaptation Responses by Vulnerable Communities to Climate Change Impacts. *Sustainability,* 15(14), 10952. https://doi.org/10.3390/su151410952

Dazé A. (2014) *Using analysis of climate change vulnerability and adaptive capacity for program decision-making: Lessons from CARE Ethiopia's experience*. CARE Ethiopia.

Devkota, D., Dhakal, S., Khatri, S. K., and Devkota, N. R. (2019). FARMER’S PERCEPTION ON VULNERABILITY OF CROPPING PATTERN AND ADAPTIVE MECHANISM IN PANCHTHAR AND CHITWAN, NEPAL. Journal of Agriculture and Forestry University, 3, 11.

Dhanya P. and Ramachandran A. (2015) Farmers’ perceptions of climate change and the proposed agriculture adaptation strategies in a semi-arid region of south India. *Journal of Integrative Environmental Sciences,* 13(1), pp.1-18. https://doi.org/10.1080/1943815X.2015.1062031

Fakhruddin B. S., Boylan K., Wild A. and Robertson R. (2020) Assessing vulnerability and risk of climate change. In: Sillmann J, Sippel S, Russo S (eds.), Climate extremes and their implications for impact and risk assessment. *Elsevier* pp. 217-241. https://doi.org/10.1016/B978-0-12-814895-2.00012-4

Füssel H. M. (2009) *Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts*. World Development Report. Potsdam Institute for Climate Impact Research, Germany.

Grigorieva E., Livenets A. and Stelmakh, E. (2023) Adaptation of agriculture to climate change: A scoping review. *Climate,* 11(10), pp. 202. https://doi.org/10.3390/cli11100202

Hinds R. (2013) *Tools for participatory analysis of poverty, social exclusion and vulnerabilit*y. Helpdesk Research Report. Applied Knowledge Services. Available at: https://gsdrc.org. (Accessed: 15 January 2024).

Hoang D. H., Nguyen Q. T., Tran N. T., Hoang T. H. Q. and Truong V. T. (2023) Towards inclusive resilience: Understanding the intersectionality of gender, ethnicity, and livelihoods in climate-prone upland areas of Central Vietnam. *Environment and Ecology Research,* 11(4), pp. 630-646. https://doi.org/10.13189/eer.2023.110410

Hutton C. W., Kienberger S., Amoako Johnson F., Allan A., Giannini V. and Allen R. (2011) Vulnerability to climate change: people, place and exposure to hazard. *Advances in Science and Research,* 7(1), pp. 37-45. https://doi.org/10.5194/asr-7-37-2011

Joshi, L. R., and Joshi, K. R. (2017). Understanding the Climate Change Adaptation Needs of Communities: A Case Study from Nuwakot District, Central Nepal. *Journal of Environment Sciences*, 3.

Kaushik G. and Sharma K. C. (2015) Climate change and rural livelihoods-adaptation and vulnerability in Rajasthan. *Global NEST Journal,* 17(1), pp. 41-49. https://doi.org/10.30955/gnj.001376

Kumar R. and Reddy K. M. (2021) Impact of climate change on cucurbitaceous vegetables in relation to increasing temperature and drought. In: Solankey S. S., Kumari M. and Kumar M. (eds.), *Advances in Research on Vegetable Production under a Changing Climate*. Vol. No. 1, Springer, pp. 175-195.

Kumari M., Verma S. C. and Shweta S. (2018) Climate change and vegetable crops cultivation: A review. *The Indian Journal of Agricultural Sciences,* 88(2), pp. 167-174. https://doi.org/10.56093/ijas.v88i2.79158

Launio C. C., Batani R. S., Galagal C., Follosco R. and Labon K. O. (2020) Local knowledge on climate hazards, weather forecasts and adaptation strategies: Case of cool highlands in Benguet, Philippines. *The Philippine Agricultural Scientist,* 103(3), pp. 67-79. ISSN 0031-7454

Locatelli B., Herawati H., Brockhaus, M., Idinoba M. and Kanninen M. (2008) *Methods and tools for assessing the vulnerability of forests and people of climate change* (Working Paper) Center for International Forestry Research. Available at: http://www.cifor.cgiar.org (Accessed: 14 January 2024).

Luitel D. R., Jha P. K., Siwakoti M., Shrestha M. L. and Munniappan R. (2020) Climatic trends in different bioclimatic zones in the Chitwan Annapurna landscape, Nepal. *Climate.* 8(11), pp. 136. https://doi.org/10.3390/cli8110136

Luo M., Jia X., Zhao Y., Zhang P. and Zhao M. (2024) Ecological vulnerability assessment and its driving force based on ecological zoning in the Loess Plateau, China. *Ecological Indicators,* 159, 111658. https://doi.org/10.1016/j.ecolind.2024.111658

Maharjan S. K., Maharjan K. L., Tiwari U. & Sen N. P. (2017) Participatory vulnerability assessment of climate vulnerabilities and impacts in Madi Valley of Chitwan district, Nepal. *Cogent Food & Agriculture* 3(1), 1310078. https://doi.org/10.1080/23311932.2017.1310078

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

Moret W. (2014) *Vulnerability assessment methodologies: A review of the literature*. FHI 360.

Pandey R., Meena D., Aretano R., Satpathy S., Semeraro T., Gupta A. K., Rawat S. and Zurlini G. (2015) Socio-ecological vulnerability of smallholders due to climate change in mountains: Agroforestry as an adaptation measure. *Change and Adaptation in Socio-Ecological Systems* 2(1), pp. 26-41. https://doi.org/10.1515/cass-2015-0003

Paudel B., Acharya B. S., Ghimire R., Dahal K. R. and Bista P. (2014) Adapting agriculture to climate change and variability in Chitwan : Long-term trends and farmers' perceptions. *Agricultural Research,* 3, pp. 165-174. https://doi.org/10.1007/s40003-014-0103-0

Potop V., Zahradníček P., Türkott L., Štěpánek P. and Soukup J. (2014) Potential impacts of climate change on damaging frost during growing season of vegetables. *Scientia Agriculturae Bohemica,* 45(1), pp. 26-35. https://doi.org/10.7160/sab.2014.450104

Poudel S., Funakawa S., Shinjo H. and Mishra B. (2020) Understanding households' livelihood vulnerability to climate change in the Lamjung district of Nepal. *Environment, Development and Sustainability, 22*(8), pp. 8159-8182. https://doi.org/10.1007/s10668-019-00566-3

Rahman S., Touhiduzzaman M. and Hasan I. (2017) Coastal livelihood vulnerability to climate change: A case study of char montaz in Patuakhali district of Bangladesh. *Americal Journal of Modern Energy,* 3(4), pp. 58-64. https://doi.org/10.11648/j.ajme.20170304.11

Rai S., Dahal B. and Anup K. C. (2022) Climate change perceptions and adaptations by indigenous Chepang community of Dhading, Nepal. *GeoJournal*, 87(6), pp. 5327-5342. https://doi.org/10.1007/s10708-022-10577-9

Rai, S., Dahal, B., and K. C., A. (2022). Climate change perceptions and adaptations by indigenous Chepang community of Dhading, Nepal. GeoJournal, 87(6), 5327-5342. https://doi.org/10.1007/s10708-022-10577-9

Sharma T. P., Zhang J., Khanal N. R., Nepal P., Sharma B. P., Nanzad L. and Gautam Y. (2022) Household vulnerability to flood disasters among Tharu Community, Western Nepal. *Sustainability,* 14(19), 12386. https://doi.org/10.3390/su141912386

Singh R., Patel S. K., Tiwari A. K. and Singh G. S. (2021) Assessment of flood recession farming for livelihood provision, food security and environmental sustainability in the Ganga river basin. Current Research *in Environmental Sustainability* 3, 100038. https://doi.org/10.1016/j.crsust.2021.10003

Tiani A. M., Besa M. C., Devisscher T., Pavageau, C., Butterfield, R., Bharwani, S. and Bele, M. Y. (2015) *Assessing current social vulnerability to climate change: A participatory methodology*. CIFOR Working Paper No. 169. Center for International Forestry Research (CIFOR), Bogor, Indonesia. https://doi.org/10.17528/cifor/005463

van Aalst M. K., Cannon T. and Burton T. (2008). Community level adaptation to climate change: The potential role of participatory community risk assessment. *Global Environmental Change* 18(1), pp. 165–179. https://doi.org/doi:10.1016/jgloenvcha.2007.06.002