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Resilience Under Threat: Climate Change Impacts and Adaptive Responses of Nepalese MSMEs

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Abstract

Nepal hosts over 923,000 registered businesses, with approximately 90% classified as Micro, Small, and Medium Enterprises (MSMEs). These businesses contribute to 45% of national employment, making them vital to economy. However, MSMEs face a significant financing gap, and climate change poses severe risks, particularly in sectors such as Non-Timber Forest Products (NTFPs), tourism, and aquaculture. The National Economic Census (2018) reports that climate change contributes to 1.8% of businesses failing to meet market demand, while 1.5% operate below full capacity due to climate-related factors. This study assesses MSME awareness of climate change, challenges, and impacts on production, costs, and raw material supply. Data were collected from 482 respondents across 16 districts in September 2024, revealed that most MSMEs are aware of climate change, yet struggle to adapt due to financial and resource constraints. Although awareness did not significantly differ between genders, a statistically significant difference was observed across age-groups. Key challenges include unpredictable weather patterns, increased pests and diseases, and declining raw material availability. The findings underscore the urgent need for targeted support to help MSMEs adapt to climate change. Policy recommendations include expanding access to climate finance, implementing capacity-building initiatives, and promoting market diversification strategies to enhance MSME resilience.

Keywords: *Adaptation strategies, Climate change, MSMEs, Resilience, Sustainable practices*

Introduction

Micro, Small, and Medium Enterprises (MSMEs) are crucial to Nepal's economy, contributing significantly to employment, poverty alleviation, and local economic development. These enterprises represent approximately 90% of the nation's 923,000 registered businesses (National Economic Census, 2018) and account for 45% of all employment (Neupane, 2017; NRB, 2019). However, despite their economic importance, the long-term sustainability of MSMEs is increasingly threatened by climate change and its disruptive impacts on operations, supply chains, and business value chains. Given Nepal's vulnerability to climate-induced hazards such as floods, droughts, landslides and erratic weather patterns (Amadio et al., 2023; Nepal et al., 2021; Pathak et al., 2023, 2025). MSMEs, especially those in sectors like agriculture, Non-Timber Forest Products (NTFPs), tourism, and aquaculture are disproportionately affected. These enterprises often lack the financial and technical ability to effectively adapt and recover from climate-related disruptions, placing their survival at risk.

A major barrier to adaptation is the significant financing gap. The financing needs of MSMEs are projected at $3.6 billion, but only $731 million is currently accessible (UNESC, 2020). This funding shortfall restricts MSMEs' ability to invest in climate-resilient infrastructure and adaptation strategies, leaving them more exposed to climate risks. Furthermore, the country's diverse geography worsens the vulnerability of these businesses. For example, small enterprises found in the lowland districts face greater risks from flooding, while businesses in the mid-hill regions are more susceptible to droughts and landslides.

Globally, MSMEs are recognized as being particularly vulnerable to climate change due to

their small size, limited resources, and dependence on climate-sensitive sectors such as agriculture, fisheries, forestry, and tourism (Khan et al., 2020;). Numerous studies have shown that MSMEs in developing countries often face increased operational challenges from extreme weather events, shifting ecological conditions, and resource scarcity (CSR Asia, 2011; Gamage et al., 2020). For instance, in Bangladesh, MSMEs were found to be more exposed to climate-induced risks, but their limited access to finance and lack of adaptation knowledge prevented effective responses (Bank, 2020; Khatun et al., 2021).

While larger enterprises in Nepal have begun implementing climate adaptation strategies(PwC, 2023; UNDP, 2016), MSMEs face substantial challenges in this regard due to financial constraints and a lack of adequate knowledge (Neupane, 2017). The USAID Biodiversity (Jal Jangal) Business Perception Study (2021) reports that NTFPs and aquaculture sectors are particularly affected by climate change, with businesses in these industries struggling with pests, diseases, and the declining availability of raw materials. Despite increasing awareness about the need for adaptation, there is limited empirical research on how MSMEs perceive and respond to climate risks and the specific adaptation strategies they are employing. Existing studies tend to focus on larger enterprises or single sectors, creating a gap in understanding how climate change impacts MSMEs across different districts and sectors in Nepal (Bhattarai et al., 2023; Neupane, 2017).

This study aims to address this gap by providing a comprehensive assessment of MSMEs' awareness of climate change, the challenges they face, and the adaptation strategies they employ. Furthermore, it looks to explore how climate change impacts MSME operations, production, and raw material availability, while also examining the role of financial and policy support in enhancing their resilience. By focusing on a broad range of districts and sectors, this research offers crucial insights into the vulnerability of MSMEs to climate risks and provides evidence-based recommendations for policy interventions that can support their adaptation and long-term sustainability.

Materials and Methods

Study Area

The study was conducted across 16 districts of Nepal, selected to represent a diverse cross-section of the country's geographical, climatic, and economic zones (Figure 1). These districts spanned five provinces: Karnali, Lumbini, Bagmati, Gandaki, and Sudurpashchim Province, covering both hill and Terai (plains) regions. The districts were chosen based on their economic activity, vulnerability to climate change, and the presence of Micro, Small, and Medium Enterprises (MSMEs). The selected districts included a mix of urban centers, peri-urban, and rural areas, ensuring a broad representation of MSMEs in sectors such as agriculture, tourism, Non-Timber Forest Products (NTFPs), and aquaculture.

Survey Design

The survey design followed a structured format with objective questions aimed at gathering quantifiable data on MSME beliefs, climate change awareness, and adaptive strategies. The questionnaire was divided into three main sections: (1) Awareness of climate change, (2) Challenges faced by MSMEs due to climate change, and (3) Impacts on production, costs, and raw material supply. Closed-ended questions were used to measure the level of awareness and impact beliefs, while multiple-choice questions captured specific challenges and adaptation strategies. Open-ended questions were included to gather more insights into how MSMEs are adapting to climate change and what external support they need.

A total of 500 respondents were initially selected using a two-stage sampling approach. First, stratified random sampling was applied at the district level to ensure broad geographic representation across 16 districts. The number of businesses surveyed per district ranged from 15 to 30, depending on the relative size and economic importance of the MSME sector in each area. Within each selected district, convenience sampling was used to identify and survey MSMEs, based on accessibility and willingness to participate. This approach was adopted

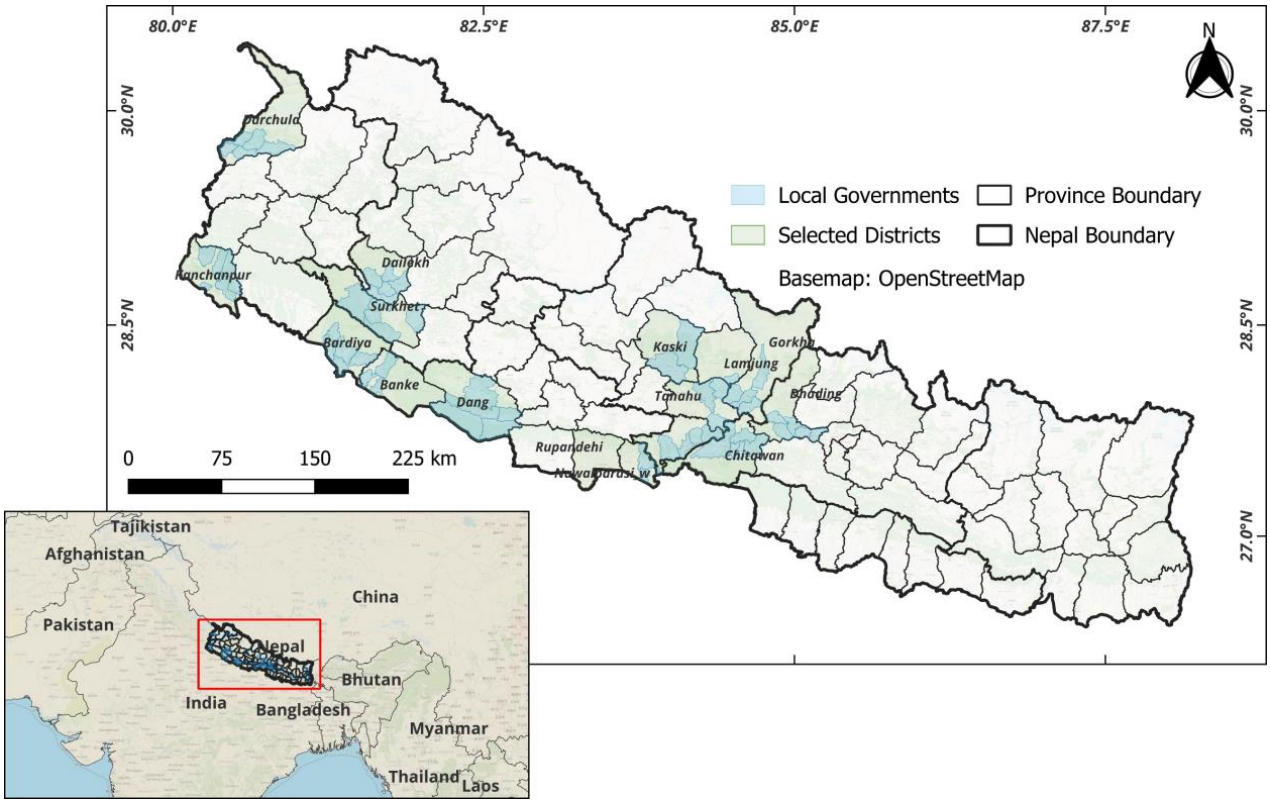

Figure 1: Map of the Study Area Depicting Districts and Local Governments Where Surveys have been Conducted

due to logistical and time constraints in the field. Out of 500 distributed questionnaires, only 482 fully completed responses were included in the final analysis, with incomplete or partially answered forms excluded. Gender representation was also considered; notably, 68% of respondents were women, reflecting the high level of female ownership and involvement in Nepal's MSME sector.

Data Collection and Analysis

Data collection was conducted in September 2024. The survey was conducted in-person with the help of trained enumerators. To ensure consistency and accuracy, enumerators were trained to explain the survey questions in Nepali or local dialects as needed, and respondents were assured of confidentiality. Indicators of impact included changes in productivity, supply chain disruptions, raw material availability, and income fluctuations. Adaptation indicators included practices such as adoption of the 3Rs, renewable energy use, and green certification. Vulnerability was inferred from factors such as business age, experience, resource dependence, and location-specific climate exposure.

The survey responses were processed using both quantitative and qualitative analysis methods. For closed-ended questions, statistical analysis was performed using Google Colab. Descriptive statistics, such as frequencies, means, and standard deviations, were used to summarize the data. Inferential statistics, including Chi-square tests were applied to examine the relationship between different. Open-ended questions were analyzed thematically, finding key patterns and themes related to adaptive strategies and climate change impacts. The results of the quantitative analysis were complemented by the qualitative insights to offer a comprehensive view of MSMEs' responses to climate change.

Results and Discussion

Descriptive Statistics

The survey captured 482 responses from MSMEs across 16 districts in Nepal, providing a comprehensive demographic and operational profile. Figure 2 illustrates the age distribution, gender representation, and business experience of

respondents. Age distribution among respondents shows that most (50%) were aged 30–40, followed by 27.39% aged 41 or older, and 22.61% under 30. The dominance of middle-aged entrepreneurs, coupled with the significant participation of women, underscores the sector's capacity for innovation and inclusive growth. However, the relative youth of many businesses also point to potential vulnerabilities, particularly in the face of external challenges such as climate change.

Women comprised 67.84% of respondents, emphasizing their significant contribution to the MSME sector, particularly in micro and small enterprises. Their participation underscores the role of women entrepreneurs in driving economic and social empowerment. Regarding business experience, 42.12% of respondents reported 5–10 years in business, while 37.14% had less than 5 years. Only 10% had over a decade of experience, indicating that most MSMEs in the survey are relatively young businesses. These findings highlight the potential challenges and opportunities for MSMEs in navigating growth and sustainability amidst the increasing impacts of climate change.

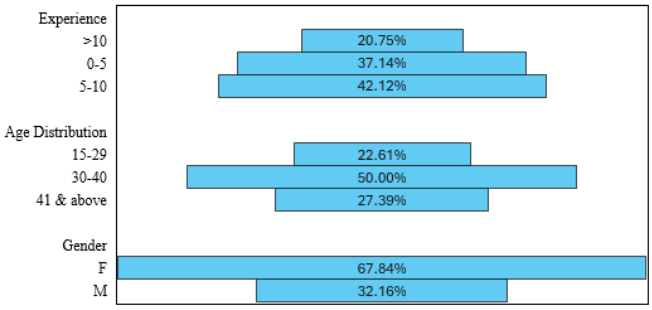

Figure 2*:* Descriptive Statistics of Respondents (482 MSMEs) Across 16 Districts in Nepal

The results underline the pressing vulnerabilities within the sector, particularly in terms of productivity losses and rising operational costs, aligning with findings from other developing regions where MSMEs are disproportionately affected by climate-induced risks (Ghimire, 2011; Nepal & Kadayat, 2024). Despite widespread awareness of climate change, the uptake of initiative-taking adaptation measures stays limited, highlighting a significant gap in preparedness and action. This discrepancy calls for targeted interventions to enhance the adaptive capacity of businesses, particularly in the face of resource scarcity, which was a predominant concern in this study, with 65% of businesses reporting decreased raw material availability. The significant association between age and climate change awareness among MSME owners, with younger entrepreneurs (15–29 age group) showing higher levels of awareness. This aligns with global observations that younger demographics tend to be more engaged with climate issues, possibly due to greater exposure to environmental education and media (Spence et al., 2011). However, the relatively low awareness among older entrepreneurs highlights the need for targeted interventions to bridge this gap and ensure inclusive climate adaptation efforts.

Awareness of Climate Change

The survey results revealed varied levels of awareness about climate change among MSMEs. A total of 14.32% of respondents reported being well-informed about climate change and its potential impact on their businesses. The majority, 65.56%, indicated having limited awareness, suggesting a basic understanding but insufficient knowledge for informed decision-making. Meanwhile, 20.12% of respondents admitted having no knowledge of climate change or its impacts, highlighting a significant gap in awareness within a substantial part of the MSME community.

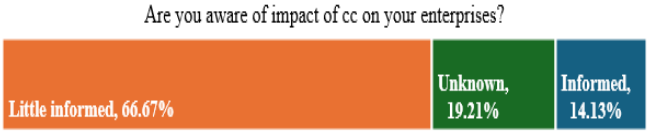

Figure 3: Response to the Question" Are you aware of impact of cc on your enterprises?"

Statistical analysis further examined the relationship between demographic factors and awareness levels. The p-value (0.1848) from the chi-square test for gender and awareness was greater than the 0.05 significance threshold, indicating no statistically significant association. This implies that differences in awareness levels between males and females are likely due to random variation rather than an underlying gender-based factor. Conversely, the chi-square test for age groups yielded a p-value of 0.0414, which is below the 0.05 threshold. This

result shows a statistically significant association between age group and climate change awareness, suggesting that awareness levels vary across different age categories, with some groups potentially being more informed than others. The 15-29 age group shows significant representation in both "Informed" and "Little Informed" categories. 41 & above age group has fewer "Informed" respondents compared to other age groups, suggesting a potential gap in awareness in this category.

The levels of adaptation to climate change within the MSME sector in Nepal vary significantly, with businesses largely falling into the "basic" and "managed/intermediary" levels of preparedness. At the basic level, many businesses show limited understanding of climate change and its potential impact, often lacking the knowledge required to mitigate risks (NRB, 2019). The fact that over 63% of businesses report being aware of climate change but do not take substantial action suggests

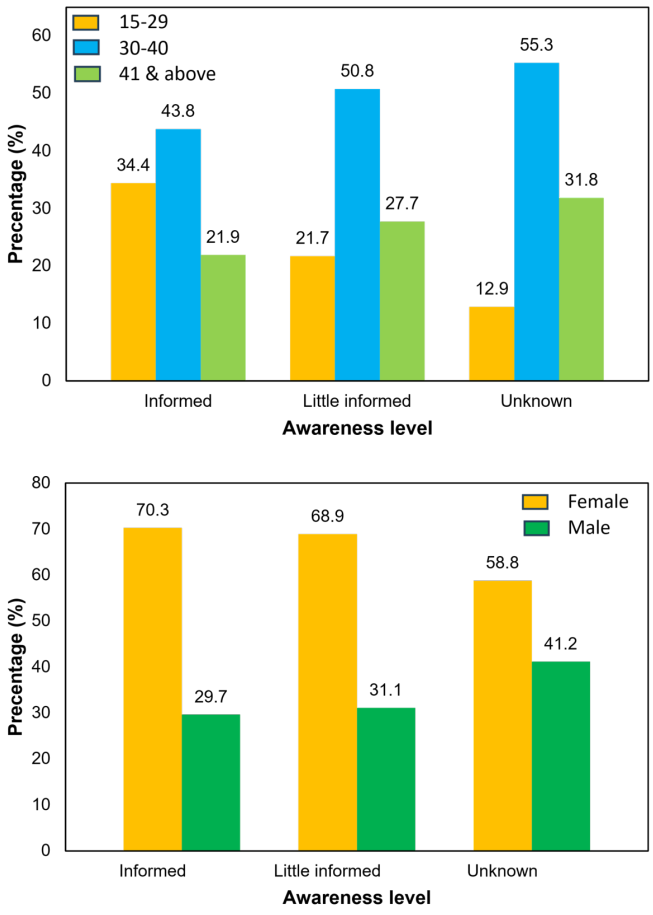

Figure 4: Distribution of MSMEs by Gender and Age Group Across Awareness Categories

that awareness alone is insufficient without access to the necessary resources and technical support. This finding resonates with literature from other regions, where smaller businesses often struggle with financial constraints and limited capacity for implementing adaptive technologies (Chhetri et al., 2012; Hokmabadi et al., 2024).

Common Challenges Faced

Nepalese businesses are becoming increasingly aware of the impacts of climate change on their operations. The majority of participants reported experiencing the effects of climate change, with changes in temperature and rainfall being identified as the key climate hazards affecting their businesses. In the past five years, businesses have met various climatic challenges, with the most prominent being extreme weather events. According to survey responses, the primary climatic extremes faced by businesses include floods (26.28%), droughts (10.36%), loss of natural resources (20.94%), diseases and insect infestations (16.36%), and other unclassified events (25.95%).

These climate-related challenges have had a significant impact on business operations. The most common effects reported include a decrease in production (28.57%), reduced access to raw materials (17.58%), an increase in production costs (13.49%), supply chain disruptions (21.88%), and difficulties in market access (16.38%). A small percentage of businesses (2.10%) reported no impact from these climatic challenges.

When asked about the aspect of their business most impacted by climate change, most businesses reported that the availability of raw materials was the most affected, with 35.24% of respondents showing it as a major concern. Another massive part of businesses (45.91%) noted that production quality was heavily affected by climate change. A smaller percentage of businesses pointed to market access (0.99%) and transportation and market access (6.65%) as being disrupted. Additionally, 8.93% of respondents showed that both availability of raw materials and production quality were jointly affected by climate-related changes.

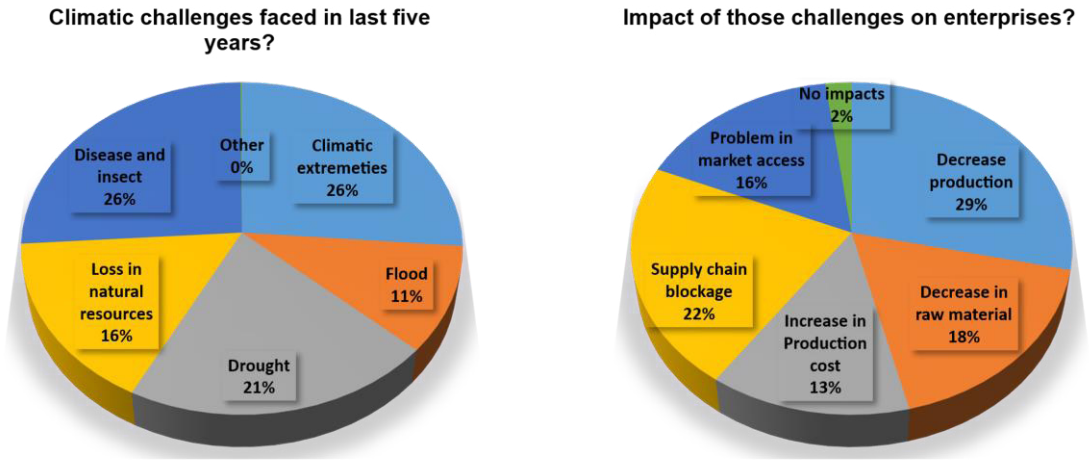

Figure 5: Impact of Climate Change on MSMEs

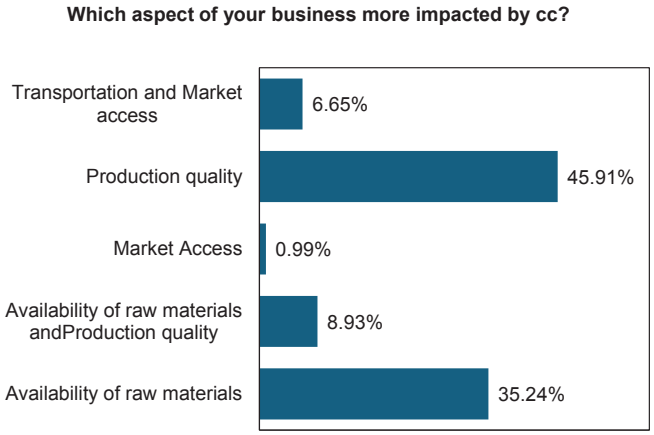

Figure 6: Primary Business Areas Affected by Climate Change

The significant impact of extreme weather events, such as floods and droughts, on MSME productivity is consistent with studies from Southeast Asia, where resource scarcity due to climate change is a primary concern (Gannon et al., 2018; Panda, 2021; Trabacchi & Stadelmann, 2013). The survey revealed that raw material availability and production quality were the most affected areas, with 35.24% of businesses showing raw material shortages as a major concern. This aligns with findings in other agrarian economies, where agricultural-dependent businesses are highly vulnerable to disruptions in natural resource availability (Khan et al., 2020; PwC, 2023). Nepal's vulnerability is further worsened by its socio-economic context, marked by high levels of poverty, a dependence on subsistence agriculture, and geographical challenges such as its fragile ecosystems and undulating topography (Government of Nepal, 2022). These factors make the country's MSMEs particularly susceptible to climate risks, highlighting the need for more tailored, region-specific adaptation strategies.

Business Responses and Financial Impacts of Climate Change

In response to questions about adopting new techniques to mitigate the impact of climate change, many businesses expressed interest in exploring and implementing new methods to better cope with climate change challenges. Specifically, 370 businesses said they would have a willingness to adopt new techniques to address climate change impacts.

When asked about the monetary impact, 306 businesses reported that climate change has increased their production costs. Additionally, 304 businesses acknowledged that climate change-related factors have influenced their income, underscoring the economic burden posed by climate change on business operations.

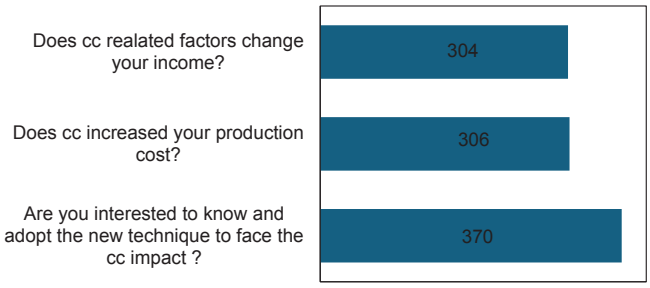

Figure 7: Respondents Responses on Financial Impacts of Climate Change

In response to climate change, businesses have implemented various strategies to mitigate its effects. Among the most common strategies, Sustainable Collection Technologies were adopted by 91 businesses, while Green Certification was pursued by 18 businesses as a way to demonstrate their commitment to sustainability. A substantial number of businesses (275) have embraced the 3R (Reduce, Reuse, Recycle) principle as part of their operations. Additionally, 130 businesses have turned to renewable energy solutions to reduce their carbon footprint. However, 17 businesses reported that they have not implemented any specific strategies to address climate change.

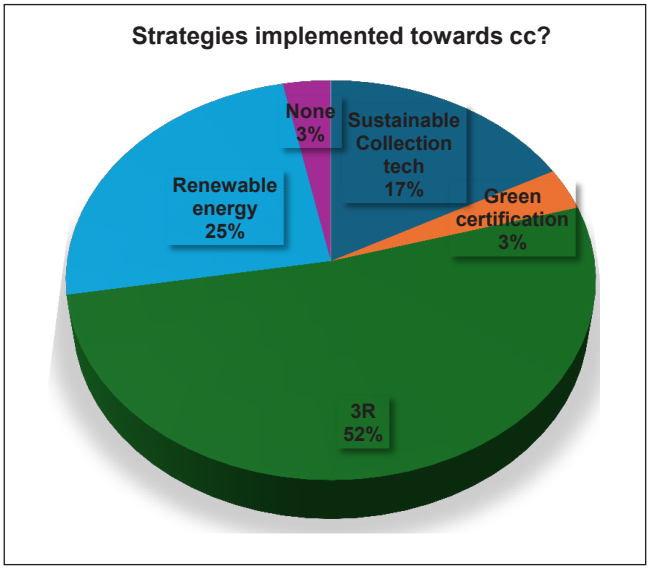

Figure 8: Strategies Implemented Towards Climate Change

The study also revealed notable regional disparities in the impact of climate change. Flooding, for example, was more prevalent in lowland districts (70%) than in mid-hill districts (40%). This geographic variation underscores the necessity of localizing adaptation measures to account for the distinct vulnerabilities of different regions within Nepal. Tailored policies and programs, informed by regional climate risks, are essential to ensuring that adaptation efforts are both effective and fair.

Although the adoption of adaptation strategies is still limited, the study found that many MSMEs are interested in exploring new methods to cope with climate challenges. This willingness to adapt, however, often faces barriers related to access to information, technical ability, and financial resources. The adoption of the 3R (Reduce, Reuse, Recycle) principle by a significant number of businesses reflects a preference for low-cost and readily implementable solutions. However, the more advanced adaptation strategies, such as the adoption of renewable energy and sustainable collection technologies, remain far less widespread. This pattern is consistent with findings from global studies that suggest smaller businesses often face difficulties in accessing the capital needed for transformative investments (Khan et al., 2020; Neupane, 2017; Thapa, 2015; UNDP, 2016).

Policy implications from this study are clear. To enhance the adaptive ability of MSMEs, policymakers must prioritize awareness programs that not only inform businesses about climate change but also equip them with the tools and knowledge necessary for effective adaptation. The Government of Nepal, along with development organizations, should focus on providing financial support and incentivizing the adoption of climate-resilient practices. The establishment of financial mechanisms, such as adaptation financing facilities, can help businesses overcome the upfront costs associated with adopting innovative technologies (NRB, 2019; PwC, 2023). Moreover, strengthening supply chain resilience should be a central focus, as climate-related disruptions in raw material availability and transportation are critical issues that threaten business continuity (Bhattarai et al., 2023).

The limitations of this study include the relatively small sample size in some districts and the short time frame for data collection, which may not fully capture the long-term impacts of climate change. Future research should explore longitudinal data to better understand the evolving climate risks faced by MSMEs and the long-term sustainability of their adaptation efforts. Additionally, further studies could investigate the specific barriers to the adoption of advanced adaptation strategies and the effectiveness of government support programs in fostering climate resilience.

Climate change poses a significant threat to MSMEs in Nepal, but it also presents opportunities for growth through effective adaptation. As the study

proves, businesses that are aware of the risks yet struggle with implementation need tailored interventions to overcome the barriers they face. Policymakers and development organizations must take a more proactive role in supporting these businesses through financial mechanisms, knowledge-sharing platforms, and community-based approaches. This collaborative effort, involving both public and private sectors, will be critical in building the resilience of Nepal's MSME sector and ensuring its long-term sustainability in the face of climate change. By fostering a collective approach to climate resilience, Nepal can better equip its MSMEs to navigate the challenges of a changing climate and contribute to national development goals.

Conclusion

This study highlights the significant vulnerabilities of Micro, Small, and Medium Enterprises (MSMEs) in Nepal to climate change, emphasizing the sector's limited adoption of proactive adaptation measures despite widespread awareness of climate-related risks. The findings reveal that climate change is already adversely affecting MSMEs through reduced productivity, increased operational costs, and disruptions in the supply of raw materials. While some businesses have initiated basic adaptation efforts, the overall level of preparedness remains inconsistent, underscoring the urgent need for targeted interventions to enhance resilience.

A key insight from this research is the geographical variation in climate impacts, with regions such as lowland districts facing heightened risks like flooding. This regional disparity underscores the importance of context-specific adaptation strategies tailored to the unique vulnerabilities of different areas. Furthermore, while MSMEs express a willingness to adopt advanced adaptation measures, significant barriers—such as limited access to financial resources, technical knowledge, and institutional support—hinder their ability to implement these strategies effectively.

The findings have critical implications for policymakers and stakeholders. First, there is a need to raise awareness about climate risks and adaptation strategies among MSMEs. Second, financial mechanisms, such as grants, low-interest loans, or climate risk insurance, should be established to support businesses in adopting resilient practices. Third, localized adaptation efforts must be prioritized, taking into account the distinct vulnerabilities of different regions. Finally, strengthening supply chain resilience and fostering collaboration between government agencies, development organizations, and the private sector will be essential for building a climate-resilient MSME sector.

To build on this study, future research should focus on longitudinal analyses to track the long-term impacts of climate change on MSMEs and evaluate the effectiveness of adaptation measures over time. Sector-specific studies, particularly in agriculture, tourism, and manufacturing, would provide deeper insights into the unique vulnerabilities and adaptation needs of different industries. Additionally, further exploration of the barriers to adopting advanced technologies and the role of institutional support mechanisms is crucial for designing targeted interventions. This study serves as a foundational contribution to understanding the climate adaptation challenges faced by Nepalese MSMEs. However, sustained research efforts and proactive policy measures will be essential to ensure the sector's long-term sustainability and growth in the face of a changing climate. By addressing these challenges, Nepal can unlock the potential of its MSME sector as a driver of economic resilience and inclusive development.

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Conflict of Interest

The authors declare that there are no conflicts of interest in the publication of this article.

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