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RESEARCH

Farmers' Perception and Adaptation Strategies on Climate Change and Variability in Rice Production in Sarlahi, Nepal

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Abstract

A study conducted in Sarlahi, Nepal, from February to July 2024 examined farmers' perceptions of climate change and their adaptive strategies to sustain rice yields. Among the 94 surveyed households, 96.8% reported rising temperatures, while 90.4% noted reduced rainfall frequency and intensity. Additionally, most respondents (70.2%) observed decreased flooding intensity, and 90.4% reported lower water availability in tube wells, ponds, and rivers. The study revealed limited climate knowledge among farmers, with only 2.1% being well-informed; personal experience was the primary source of information for 75.5% of respondents. Farmers employed various adaptation techniques, including improved rice varieties (66%), green manuring (34%), and alternate wetting and drying (24.5%), although only a small percentage (8.5%) utilized crop insurance. Key challenges included climate-induced disease outbreaks like blast and bacterial blight, along with pests such as the rice stem borer and leaf roller. The findings indicated that gender and landholding size significantly influenced the adoption of adaptation practices, with larger landholders more likely to adapt than smaller ones. This research contributes valuable insights into the adaptive capacities of farmers facing climate change, underscoring the need for targeted policy interventions to enhance resilience in rice cultivation through comprehensive education and resource support.

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Statement of Sustainability: The research highlights the sustainability of adapting rice farming practices to combat climate change in Nepal. By adopting improved rice varieties, alternate wetting and drying, and integrating green manuring, farmers contribute to maintaining productivity while promoting eco-friendly agricultural solutions tailored to local challenges.

1. Introduction

Rice (*Oryza sativa* L.) is a self-pollinated, semi-aquatic annual grass belonging to the family Poaceae and is one of the most crucial staple cereal crops globally. It sustains more than 50% of the world's population, making it vital for food security (Theivasigamani and Kootha, 2012). In Asia, rice is cultivated on approximately 140 million hectares, yielding a total production of 668 million tons; over 90% of the world's rice is grown and consumed in the Asia-Pacific region (Prasad, 2012). In Nepal, rice is integral to food security and is cultivated on 1,473,474 hectares, producing 5,621,710 metric tons with a productivity rate of 3.82 metric tons per hectare (MoALD, 2020). The cultivation occurs across three agroecological regions: Terai and Inner Terai (67 to 900 m asl), Mid Hills (1000 to 1500 masl), and High Hills (1500 to 3050 masl). Among these regions, Terai and Inner Terai account for 68% of total rice production in Nepal (Choudhary et al., 2022). Despite rising demand for rice, Nepal has struggled to enhance productivity to meet the needs of its growing population. Consequently, rice worth Rs 33.63 billion was imported between mid-July 2022 and mid-June

2023 during the current fiscal year (FY 2022/23). The agricultural sector in Nepal faces significant challenges due to climate change, which has been linked to rising temperatures and altered precipitation patterns. Maximum temperatures increase by 0.05°C per year while minimum temperatures rise by 0.03°C annually (Semenza et al., 2011). In the Terai region specifically, winter maximum temperatures are decreasing, leading to colder winters. However, in most parts of Nepal, except for a few districts such as Sankhuwasabha, Sunsari, Nawalparasi, Banke, and Bardia, the average maximum annual temperature continues to rise. The average maximum temperature recorded is 32°C while the minimum average temperature is 20°C (Ghimire, 2019).

Farmers predominantly grow main-season rice; however, many have shifted to spring rice cultivation due to climate change effects that have resulted in reduced rainfall and inadequate irrigation facilities (Khanal et al., 2024). In the year 2020/2021 alone, rice cultivation covered an area of 45,950 hectares with a production of 167,258 metric tons (MoALD, 2020). Approximately 80% of rainfall occurs during the monsoon season from June to September; any fluctuations in weather during this critical period can severely impact rice production (Pudasaini et al., 2012). Declining yields are attributed to insufficient irrigation resources and changes in temperature and rainfall patterns caused by climate change (Khanal et al., 2024). Issues such as dry fields damaging seedlings in nurseries and heavy rains destroying established crops have been reported (Regmi and Adhikari, 2007). Given these challenges, this study aims to investigate farmers' perceptions of climate change and their adaptive strategies for sustaining rice yields. The central research problem addressed by this paper is understanding how climate change impacts farmers' practices and their ability to adapt effectively. While existing literature highlights various aspects of climate change's impact on agriculture (Banjade et al., 2023), there remains a significant gap regarding specific adaptive strategies employed by farmers in Sarlahi District.

The central hypothesis of this research suggests that the adaptation strategies used by farmers are significantly influenced by their perceptions of climate change and its impacts on rice production. This study will aim to address several key objectives in exploring this relationship. First, it will examine how aware farmers are of climate change, including what they know about its causes and probable impacts on agricultural practice. The research will identify the specific adaptive strategies adopted by farmers in response to perceived climatic changes, which include changing planting schedules, crop selection, and adjustments of water management practices. Thirdly, the effectiveness of adaptation strategies will be assessed regarding how well they can mitigate the adverse effects of climate change on rice yields and the general productivity of the farms. The final result will be a set of policy recommendations actionable to strengthen farmers' resilience against the climatic changes being experienced. In addressing these objectives, this research aims to add important insights into how farmers can better adapt to climate change from a sustainable rice production perspective in Nepal.

A mixed-methods approach was made in order to achieve such objectives. Household surveys along with focus group discussions were performed on farmers in the Sarlahi District. Data gathered by this method were supplemented with relevant data collected from agricultural reports and climatic data obtained from the DHM and governmental publications. The SPSS software was employed to analyze statistical trends found among farmer perceptions and adaptation practices. Findings from this research will add to the understanding of how farmers perceive climate impacts and what adaptive measures they are implementing. Therefore, it will help in policy decision-making to make future policy decisions to enhance agricultural resilience in Sarlahi and other regions in Nepal.

2. Material and Methods

2.1. Description of Study Areas

The study was conducted in Haripurwa Municipality (wards 1, 5, 6, and 7) and Parsa Rural Municipality (wards 1 and 2) within the Sarlahi District of Nepal from February to July 2024. This research falls under the rice zone of the Prime Minister Agriculture Modernization Project (PMAMP), as illustrated in Figure 1. The selection of these specific wards was primarily guided by informal recommendations from Project Implementation Unit (PIU) officers, who anticipated minimal language barriers among the local population.

2.2. Sampling Techniques

As per the records of the PMAMP Rice Zone in Sarlahi, there were 3,400 rice farmers across various groups, organizations, farms, and individuals. However, due to constraints in time, effort, and resources, conducting a comprehensive survey of all farmers was not feasible. To overcome these challenges, a representative sample was selected to reflect the larger population. Using Raosoft's sample size formula, with a 10% margin of error and a 95% confidence level, a sample size of 94 respondents was determined for the survey.

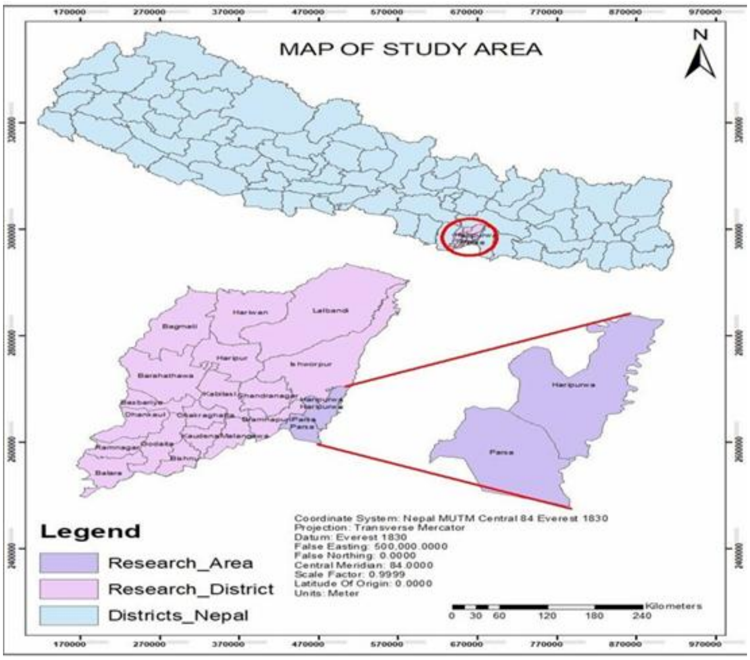

Figure 1. Map representing the study area.

2.3. Research Design

Preliminary field visits were conducted to gather information on the geographic, institutional, and socio-economic characteristics of the study area. Following the identification of key issues, the selection of the research area, and an in-depth review of relevant literature, appropriate methods and methodologies were designed in alignment with the study site and research objectives. Both primary and secondary data were collected for the study.

2.4. Data Collection and Analysis Techniques

The household survey questionnaire was pre-tested with 10 respondents from a nearby location to ensure its effectiveness. Primary data were gathered through field surveys and household questionnaire surveys, complemented by focus group discussions (FGDs). Secondary data were collected from various sources, including climatic trend analysis provided by the Department of Hydrology and Meteorology (DHM), reports published by the Ministry of Agriculture and Livestock Development (MoAD), the Sarlahi Rice Zone Profile, annual reports, newsletters, and brochures. Monthly climatic data related to rainfall and temperature were sourced from the DHM, with data specific to Sarlahi obtained from the Janakpur meteorological station. The collected data were coded, processed, and analyzed using Statistical Package for the Social Sciences (SPSS) and MS Excel. Various statistical tools, such as descriptive statistics, frequency distribution, trend analysis, and mean comparison, were applied for data analysis. Poisson regression was employed to identify factors influencing the adoption of climate change practices. Indexing and scaling techniques were used to rank farmers' perceptions regarding their preferences for various production problems and the severity of diseases and insect infestations they faced. A five-point scale was utilized for this ranking, where the most severe issue or pest was assigned a rank of 5, and the least severe a rank of 1, with intermediate rankings for moderately and less severe options. To derive valid conclusions, a priority index was calculated using the weighted average mean. This method provided a structured approach to determining the relative importance of different challenges and allowed for the identification of critical areas requiring attention.

3. Results and Discussion

3.1. Socio-economic and Demographic Information on Respondents

Out of 94 respondents surveyed in this study, the majority, 60 (63.8%), were aged between 35 and 60 years. This was followed by respondents over 60 years (19.1%) and those under 35 years (17%). The data also revealed a significant gender disparity, with 86.2% of respondents being male and only 13.8% female, indicating that males predominantly engage in rice agriculture and decision-making in the research area, while females primarily handle domestic responsibilities. These gender roles are prevalent in most farming communities, where men traditionally take a dominant role in farming responsibilities and economic decision-making (Agarwal, 2010). This highlights the need for inclusive approaches in agricultural practices that empower both men and women (Banstola et al., 2024). The households in the study were classified into two ethnic categories: Madhesi and Janajati. Particularly, all respondents (100%) identified as Madhesi, suggesting that this ethnic group dominates the study area. Education has a crucial role in societal transformation as reported by Karki and Gurung (2012). The educational status of respondents was categorized into four levels: no schooling, primary education, secondary education, and higher education. Most respondents (38.3%) had attained secondary education, followed by those with no formal schooling (28.7%), primary education (25.5%), and higher education (7.4%). Educated individuals are better equipped to adopt ideas from similar contexts and adapt them to their local climatic conditions (Ghini et al., 2019). The occupation of local community members reflects the nature of any locality's micro-economy, as well as the numerous commercial, business, and job opportunities in the area, and it also determines the well-being of the community. According to the research, agriculture was the predominant occupation (83.0%), followed by remittances (11.7%), business (3.2%), and service-related jobs (2.1%). The average total landholding in the study area was 49.53 hectares, ranging from 0 to 240 hectares. The average land size used for rice cultivation was 35.70 hectares, with a minimum of 5 hectares and a maximum of 100 hectares. The average size of irrigated land was 15.38 hectares, ranging from 0 to 100 hectares. Farming experience significantly influences farmers' perceptions of and responses to climate change (Li et al., 2009). Among respondents, 52.1% (n=49) had 15 to 25 years of farming experience, while 47.9% (n=45) had over 25 years of experience.

3.2. Perception of Climate Change, Changing Temperature, Rainfall and Water Table Recharge

According to the study, only 2.1% of respondents demonstrated a clear understanding of climate change, while 12.8% were moderately knowledgeable, and the majority, 85.1%, had no awareness of it. Farmers expressed their perceptions of climate change both directly and indirectly, often drawing comparisons to their past experiences, observations of changes in rainfall patterns, temperature fluctuations, and drought, as well as the influence of media (Pandey, 2012). The sources of climate change awareness among respondents varied, with most gaining knowledge through personal experience (75.5%), followed by group discussions (12.8%), neighbors (7.4%), and media outlets (4.3%). Local knowledge and experience have an important role in shaping farmers' understanding of the impacts of climate change (Mendelsohn, 2008). Consequently, effective communication and educational initiatives are essential for enhancing their awareness and comprehension of climate change (Nkoana, 2020). Most respondents (96.8%) reported experiencing an increase in temperature over the past 10 years (Table 1), and 93.6% observed an increase in the number of hotter days. Farmers in the study area also perceived a decrease in precipitation compared to the past 10 years. A majority (90.4%) noted a decline in rainfall frequency, while 88.3% observed shorter rainfall durations. However, 2.2% of respondents reported an increase in rainfall intensity, whereas a huge majority (90.4%) believed it had decreased. In similar studies by Bista et al. (2018), comparable patterns in rainfall and temperature fluctuations were observed impacting farmers. The study posits the pressing need for focused measures to enhance farmers' awareness of climate dynamics and to encourage adaptive strategies that can help reduce the adverse impacts of these climatic changes on rice production. Regarding flooding, 72.3% and 70.3% of respondents reported declines in flooding frequency and intensity, respectively, over the past 10 years. Also, 25% of respondents indicated that flooding was not a concern in their area due to the higher elevation of their locality. Additionally, 88.3% of respondents indicated that the drought period had lengthened over the years, leading to issues such as a declining water table. Despite having irrigation equipment, many farmers reported a lack of water for irrigation purposes. These findings suggest that most respondents have observed significant climatic changes, particularly an increase in temperature, droughts, and hotter days, alongside a decrease in rainfall-related variables. Regarding water resources, 85 respondents (90.4%) noted a decline in tube well/boring water sources, 6 (6.4%) observed no change, and 3 (3.2%) did not notice any difference. For ponds, 90.4% (n=85) reported a decrease in water levels, while 3.2% (n=3) observed no change, and 6.4% (n=6) were unaware of any changes. Similarly, 87.2% (n=82) reported declining water levels in rivers and streams, while 12.8% (n=12) noticed no change. Importantly, none of the respondents observed an increase in water resource levels. These findings are consistent with those reported by Malla (2008), who also noted similar trends in declining water resources and climatic changes.

Table 1. Change in microclimate as perceived by respondents.

Responses	Increased	Decreased	Not noticed
Temperature	91 (96.8%)	0	3 (3.2%)
Rainfall frequency	0	85 (90.4%)	8 (8.5%)
Rainfall duration	0	83 (88.3%)	11 (11.7%)
Rainfall intensity	2 (2.2%)	85 (90.4%)	7 (7.4%)
Flooding frequency	5 (5.3%)	68 (72.3%)	21 (22.3%)
Flooding intensity	4 (4.3%)	66 (70.2%)	24 (25.5%)
Drought	83 (88.3%)	0	11 (11.7%)
No hot days	88 (93.6%)	0	6 (6.4%)

3.3 Respondent's Experience on Impacts on Rice Cultivation Practices

Farmers' experiences with rice cultivation can be utilized to assess climatic and non-climatic factors influencing rice output and productivity (Mendelsohn, 2008). Their experiences with rice transplanting and harvesting time, rice output, weed infestation, and insect pest infestation have changed during the last ten years. Out of the total respondents, 82 (87.2%) reported transplanting rice 4–5 weeks later than usual due to insufficient irrigation facilities, water scarcity, and untimely rainfall in the study area. In contrast, 12 (12.8%) continued to transplant rice at the same time as before, relying on deep tube well irrigation, as shallow tube wells were ineffective due to the decreased water table. Additionally, 72 respondents (76.6%) agreed that the rice harvesting period had shifted to a later time compared to previous years. Wang et al. (2022) suggested that changes in climatic conditions, especially extended or unpredictable rainfall during crucial growth phases, are a key factor contributing to delays in the harvesting periods of rice and other crops. While 22 (23.4%) respondents stated that the harvesting period remains the same due to the substitution of early-maturing rice cultivars (Table 2). The substitution of traditional rice varieties with early maturing cultivars is a widely adopted strategy to adapt to shorter growing seasons and mitigate the risks associated with delayed harvesting periods (Jagadish et al., 2015).

Table 2. Experience of respondents on the impact on rice cultivation practices compared to before 10 years.

Rice Cultivation Practices as Compared to Before 10 Years	Respondent's Experience	Total
Transplanting time	Earlier	0
	Late	82 (87.2%)
	Same	12 (12.8%)
Harvesting time	Earlier	0
	Late	72 (76.6%)
	Same	22 (23.4%)
Rice yield	High	33 (35.1%)
	Low	50 (53.2%)
	Same	11 (11.7%)
Weed infestation	High	70 (74.5%)
	Low	11(11.7%)
	Same	13 (13.8%)
Pest infestation	High	82 (87.2%)
	Low	3 (3.2%)
	Same	(9.6%)

An extremely fascinating and contradicting outcome emerged from this study: despite all of the issues and current environmental conditions, 33(35.1%) respondents reported that the yield had increased during the previous ten years. This has been possible with ease of irrigation, fertilizers, quality seeds in their area, and also with the help of PMAMP. Meanwhile, the study revealed that 70 (74.5%) of the respondents found an increase in weed infestation and the resistance of weeds to herbicides. As a result, hand weeding has become necessary, replacing herbicide application.

Climate change exacerbates the challenge of herbicide-resistant weeds by boosting their detoxification, reducing the effectiveness of traditional herbicides, and requiring alternative management methods (Varanasi et al., 2016). Additionally, 82 respondents (87.2%) noted an increase in insect and pest infestations compared to previous years. In contrast, 11 respondents (11.7%) and 3 respondents (3.2%) reported a decrease in insect pest and weed infestations, respectively, due to appropriate herbicide recommendations and control measures provided by organizations and the PMAMP program.

3.4. Status of Adaptation Practices to Changing Climate on Rice Production

The majority of respondents (66%) used the improved rice variety Sona Mansuli. In addition, 8.5% of farmers adopted early-maturing varieties, while 23.5% used late-maturing varieties. The most common early-maturing varieties included Hardinath-1, Chaite, and Sukkah Dhaan, cultivated by 2.1%, 4.3%, and 2.1% of respondents, respectively. Farmers who grew early maturing varieties mentioned the benefit of harvesting a short-duration vegetable crop before the wheat season. This practice was reported to be financially beneficial. These varieties allow farmers to adjust their cropping schedules, ensuring the harvest occurs before critical water shortages become problematic (Dar et al., 2021). Most farmers chose late-maturing varieties to avoid heavy rains during the harvest season, which has been a significant problem in recent years. Katarni, Basmati, and Goraknath were the major late-maturing varieties cultivated by 16%, 4.3%, and 3.2% of farmers respectively. Katarni / Mohaniya (long-duration Indian varieties) was preferred over Nepalese long-duration varieties like Swarna Sab-1. The System of Rice Intensification (SRI) was adopted by a small number of farmers (1.1%), with only one farmer reported to have practiced this method, according to official PMAMP, and PIU reports from up to five years ago. No farmers were found using the Direct Seeding of Rice (DSR) technique, as they felt that DSR consumed more water for irrigation compared to puddle rice cultivation. Green manuring was practiced by 19.1% of respondents, with Dhaincha being the preferred green manure crop. Alternate Wetting and Drying (AWD) was adopted by 13.8% of respondents. Weed management was primarily done through herbicide application by 37.2% of farmers, while 51.1% reported the need for manual weeding due to the ineffectiveness of herbicides. Although 70.2% of respondents were aware of the crop insurance scheme, only 8 respondents (8.5%) had actually participated in it (Table 3).

Table 3. Status of adoption of climate change adaptation practices.

Adaptation Practices	Respondents Experience	Frequency (%)	Total
Cultivation of early maturing varieties	Hardinath-1	2 (2.1)	8 (8.5)
	Chaite	4 (4.3)	-
	Sukkah dhaan	2 (2.1)	-
Cultivation of late-maturing varieties	Katarni	15 (16.0)	22 (23.5)
	Basmati	4 (4.3)	-
	Goraknath	3 (3.2)	-
Cultivation varieties of improved	Sonamansuli	62 (66.0)	62 (66.0)
Weed management	Manually	11 (11.7)	94 (100.0)
	By using herbicide	35 (37.2)	-
	Need to use both	48 (51.1)	-
Diseases management and pest	Chemical pesticides	94 (100.0)	94 (100.0)
Use of green manuring	-	32 (34%)	18 (19.1)
Use of alternate wetting and drying	-	23 (24.5%)	13 (13.8)
Direct-seeded rice (DSR)	-	0	0
System of rice intensification (SRI)	-	1 (1.1)	1 (1.1)
Irrigation	Groundwater irrigation	85 (90.4)	94 (100.0)
	Canal irrigation	7 (7.4)	-
	Rainwater harvest	2 (2.2)	-
Crop insurance awareness	-	66 (70.2%)	-

3.5. Factors Affecting Adoption of Climate Change Adaptation Practices

Gender and total landholding were the only two factors found to have a statistically significant effect on the number of climate change adaptation practices adopted, both at the 5% level of significance. The effect of gender on adoption was negative, while total landholding had a positive effect. Males were more likely to adopt climate change adaptation practices compared to females. In the study area, females are primarily responsible for household tasks, while agricultural decisions and actions are largely dominated by males (Paudel, 2016). This aligns with the findings that males are more curious about new practices. Respondents with a higher area of land-holding were more likely to adopt a greater number of climate change adaptation practices. The possible reason is that farmers with more land and resources can take more risks when trying new methods and technologies than small farmers. Belief in climate change awareness appears to have no significant impact on farmers' adaptation practices. While awareness of climate change could play a role in their decisions to implement adaptation measures, this does not appear to be a decisive factor in this study. This could be due to the presence of assumptions that may not be fully justified, suggesting the need for more in-depth research. The overall model was significant at a 5% level of significance suggesting the reliability of the results. A log-likelihood of -131.90 was reported (Table 4).

Table 4. Factor affecting adoption of climate change adaptation practices.

Variables	Coefficients	Standard Error	P-value
Age	0.013	0.0143	0.369
Gender	-0.757**	0.3801	0.046
Education	0.101	0.3307	0.76
Farming experience	-0.019	0.0146	0.183
Climate change awareness	0.022	0.249	0.92
Agriculture insurance awareness	0.154	0.214	0.472
Mobile possession	-0.294	0.2072	0.154
Total land holding	0.007**	0.0143	0.027

Note: *, **, and *** represent statistically significant at 10%, 5%, and 1% level of probability.

4. Conclusion

The findings indicate that a majority of respondents possess limited knowledge about climate change, primarily relying on personal experience as their main source of information. Farmers have reported a noticeable increase in diseases and pest problems, which present significant challenges to their rice production. Additionally, changes in rainfall patterns have resulted in both floods and droughts during the rice growing season, leading to reduced yields. Despite some awareness of these issues, there exists a considerable gap in knowledge regarding climate change and its specific effects on rice cultivation. On average, farmers implemented 1.6 out of a possible seven adaptation practices. The study found that climate change awareness among farmers was relatively low. Factors such as gender and landholding size significantly influenced the adoption of adaptation practices; female farmers participated less due to traditional household roles, while those with larger land holdings were more likely to adopt these strategies compared to smaller landholders. To better prepare for the increasing challenges posed by climate change, further research is needed to explore future areas for crop cultivation and assess the potential demand and supply of agricultural products under changing climatic conditions.

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