

Determinants of Climate Change Adaptation Strategies Among Beef Cattle Farmers in East Java, Indonesia

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Abstract. Climate change poses a serious challenge to the livestock sector in Indonesia, particularly for beef cattle farmers in East Java who face declining productivity due to droughts, shifting rainfall patterns, and rising temperatures. Adaptation is therefore essential to sustain livestock production and maintain household economic stability. This study analyses the socioeconomic factors influencing the choice of adaptation strategies among beef cattle farmers in response to climate change. A total of 300 farmers were selected using a multistage sampling technique, and data were collected through structured interviews. The analysis employed a Multinomial Logit Model to examine the effects of socioeconomic characteristics on the choice between on-farm, off-farm, and combined strategies. The results show that 63 % of farmers adopted off-farm strategies such as enterprise diversification and secondary employment, while 11 % focused on on-farm strategies, and 26 % combined both approaches. Education, primary occupation, and access to agricultural residues significantly influenced the choice of adaptation strategy. Higher education and better access to agricultural residues increased the likelihood of adopting off-farm strategies, whereas having livestock farming as the primary occupation reduced the tendency toward diversification. These findings highlight the importance of human, natural, and financial capital in shaping farmers' adaptive capacity. Strengthening farmers' skills and optimizing local resource utilization are key to promoting sustainable and inclusive adaptation in the livestock sector.

Keywords: climate change, adaptation strategies, beef cattle farmers, east java, multinomial logit model (MNL)

1 Introduction

The existential threat of climate change has reached the forefront of beef cattle farming, manifesting through prolonged droughts, unpredictable seasonal shifts, and increased

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livestock vulnerability to diseases [1]. These conditions are no longer distant projections but operational challenges that directly reduce productivity, compromise animal welfare, and threaten the economic stability of farming households. In response, farmers across the world have initiated a range of adaptive measures, from feed resource diversification to the implementation of water conservation technologies and the utilization of agricultural waste [2]. However, the effectiveness and sustainability of these strategies largely depend on the complex set of factors underlying farmers' decision-making processes.

A review of the literature reveals that adaptation decisions are influenced by multiple determinants. Socio-demographic factors such as age, education, and farming experience are often associated with variations in adaptive capacity [3]. Access to climate information and training, whether through extension services or social networks, has also been identified as a crucial catalyst for innovation adoption [4]. From an economic perspective, capital ownership, credit accessibility, and enterprise scale determine farmers' ability to bear the initial investment costs of adaptation [5]. Internal farm characteristics, including production systems and infrastructure, further shape risk perception and strategic choices [2].

Empirical studies indicate that beef cattle farmers adopt a wide range of climate change adaptation strategies, including feed diversification, adjustments in livestock management systems, water resource management, and improvements in animal health practices [1]. The choice of these strategies is strongly shaped by farmers' socioeconomic and institutional characteristics, such as age, education level, farming experience, access to climate information, asset ownership, and enterprise scale, which collectively determine farmers' adaptive capacity in responding to climate-related risks [6]. However, most previous studies have examined adaptation strategies in an aggregated manner without clearly distinguishing the determinants influencing on-farm and off-farm adaptation strategies, thereby limiting a deeper understanding of farmers' decision-making processes under climate uncertainty [7]. Moreover, recent livelihood-based studies emphasize the need for more integrated and empirical approaches to explain how the configuration of human, natural, physical, financial, and social capital shapes household adaptation strategies to climate change [8].

Building upon this conceptual foundation, the present study focuses on a context-based understanding of adaptation strategy choices among beef cattle farmers in East Java, Indonesia, by analyzing the social, economic, and institutional factors influencing the adoption of climate change adaptation strategies. The findings are expected to contribute significantly to the development of appropriate adaptation strategies at the farm level and to inform effective policy formulation in the study area. This research is particularly relevant as the beef cattle sector remains both a key economic driver and one of the most vulnerable sectors to climate change impacts in the region. In addition, the study aims to support the achievement of sustainable development goals, particularly those related to food security, poverty reduction, and the improvement of farmers' livelihoods while maintaining ecosystem balance.

Accordingly, the objectives of this study are: (1) to identify on-farm and off-farm adaptation strategies adopted by beef cattle farmers in response to climate change, and (2) to analyse the determinant factors influencing farmers' choices between on-farm and off-farm adaptation strategies.

2 Research and Method

2.1 The Study Area

This research was conducted in East Java Province, Indonesia. As one of the country’s major livestock production centres, East Java contributes more than 20% of Indonesia’s total beef cattle population [9]. Agroecologically, the province is characterised by a tropical monsoon climate with an annual rainfall ranging from 1,500 to 2,500 mm and an average temperature of 22°C–34°C [10]. Rainfall is highly seasonal, with the wet season (November–April) marked by considerable temporal and spatial variability. Global climate change has led to shifting and increasingly uncertain rainfall patterns, directly affecting the availability of forage and feed resources for livestock.

2.2 Method of Data Analysis

Data were analysed using the Multinomial Logit Model (MNL) to identify factors influencing farmers’ choices of on-farm versus off-farm adaptation strategies at the household level. In this model, the dependent variable has three categories: 1 = On-farm, 2 = Off-farm, 3 = Combination, with the base outcome being the on-farm strategy. The independent variables (X) represent the farmers’ characteristics.

Table 1. Description of Explanatory Variables Used in the Multinomial Logit Model

Variable Name	Description / Measurement	Data Type	Expected Sign	Theoretical Basis / Reference
Farmer’s Age	1. Very young (<25 years) 2. Young (26–35 years) 3. Early middle-aged (36–45 years) 4. Late middle-aged (46–55 years) 5. Older (56–65 years) 6. Very old (>65 years)	Nominal	–	Older farmers tend to be less adaptive due to physical limitations and greater risk aversion [6]
Education Level	1. No formal education 2. Primary 3. Junior high 4. Senior high 5. Diploma/Bachelor’s degree 6. Postgraduate	Nominal	+	Higher education enhances the ability to understand climate information and adopt adaptive technologies [11]
Farming Experience	1. <1 year 2. 1–5 years 3. 6–10 years	Nominal	+	Longer experience improves the ability to recognize climate signals and appropriate responses [7]
Main Occupation	1. Livestock farming 2. Crop farming 3. Trader	Nominal	+	Full-time livestock farmers are more motivated to adapt

Variable Name	Description / Measurement	Data Type	Expected Sign	Theoretical Basis / Reference
	4. Entrepreneur 5. Government employee 6. Private sector employee 7. Student 8. Housewife 9. Retired 10. Job seeker 11. Others _____			in order to sustain their main source of income [12]
Access to Clean Water	1. Not available 2. Limited 3. Available 4. Highly available	Nominal	+	Access to clean water enables adaptive practices such as water storage and livestock maintenance during dry seasons [13]
Access to Agricultural Residues	1. Not available 2. Limited 3. Available 4. Highly available	Nominal	+	Agricultural residues can be utilised as alternative feed during drought periods [14]
Household Income (IDR)/month	1. < 50,000 2. 50,000–99,999 3. 100,000–199,999 4. 200,000–499,999 5. 500,000–999,999 6. 1,000,000–1,999,999 7. 2,000,000–4,999,999 8. 5,000,000–9,999,999 9. >10,000,000	Nominal	+	Rising temperatures, reduced rainfall, droughts, and livestock diseases lower productivity and meat/milk quality, thereby reducing household income [15]

Source : Primary data processed, 2025

Before running the Multinomial Logit (MNL) model, multicollinearity among independent variables was tested to ensure the absence of high intercorrelations that could affect the stability of parameter estimates.

Table 2. Results of Multicollinearity Diagnostics

Variable	VIF	1/VIF
Farmer’s Age	—	—
Education Level	1.12	0.894
Farming Experience	1.31	0.762
Main Occupation	1.41	0.712
Access to Clean Water	1.17	0.858
Access to Agricultural Residues	1.42	0.703
Household Income	1.43	0.700
Mean VIF	1.31	
Note: VIF values below 5 indicate the absence of serious multicollinearity.		

Source : Primary data processed, 2025

The diagnostic results (Table 2) show that all VIF values are well below the common threshold of 5, with an average of 1.31. This indicates that no serious multicollinearity issues exist, and therefore, all independent variables can be included simultaneously in the model estimation.

3 Result and Discussion

The analysis was conducted to examine how farmers’ socioeconomic characteristics influence their choice of adaptation strategies in response to climate change. Results are presented in two parts : (1) a descriptive account of adaptation strategies and (2) an econometric analysis of determinants using the Multinomial Logit Model (MNL).

3.1. Farmers' adaptation strategies to climate change

Beef cattle farmers in the study area have long adapted to changing biophysical conditions through a combination of locally developed practices and innovations introduced via extension services or peer learning. In this study, adaptation strategies are classified into two broad categories: on-farm strategies, which involve adjustments within the livestock production system, and off-farm strategies, which entail livelihood diversification beyond cattle farming.

Table 3. Types of adaptation strategies adopted by beef cattle farmers

Adaptation strategy		Have you practiced it? (%)	
		Yes	No
On-Farm			
1	Use of temperature-control technologies in barns	6.33	93.67
2	Change of feed type	6.67	93.33
3	Adoption of climate-tolerant cattle breeds	20.67	79.33
4	Water storage	25.33	74.67
5	Improved animal health management	22.00	78.00
6	Enhancement of livestock knowledge and skills	66.67	33.33
Off-Farm			
1	Business diversification	65.00	35.00
2	Seeking alternative employment outside livestock	64.00	36.00
3	Labour migration (sending family members abroad)	2.33	97.67

Source : Primary data processed, 2025

The results indicate that adoption levels vary considerably across adaptation options (Table 3). Among on-farm strategies, improvements in farmers’ knowledge and skills are the most widely adopted, highlighting the central role of human capital in adaptation. In contrast, technology-intensive measures such as temperature-control systems and changes in feed composition show very limited uptake. This pattern suggests that financial constraints, limited infrastructure, and restricted access to technological innovations remain major barriers to the adoption of capital-intensive on-farm adaptations.

Off-farm strategies are more prevalent than on-farm measures, with business diversification and engagement in alternative employment representing the dominant responses to climate-related risks. These strategies reflect household-level economic adjustments aimed at stabilizing income under increasing climatic uncertainty. By comparison, labour migration is rarely adopted, likely due to its higher financial, social, and institutional requirements.

Table 4. Distribution of dominant adaptation strategies

Dominant strategy	Frequency	Percentage (%)
On-Farm	33	11.00
Off-Farm	189	63.00
Combined	78	26.00
Total	300	100.00

Source : Primary data processed, 2025

The distribution of dominant adaptation strategies further confirms the predominance of off-farm responses (Table 4). Most farmers rely primarily on off-farm strategies, while a smaller proportion adopt exclusively on-farm measures. A notable share of farmers combines both approaches, indicating the capacity of some households to integrate production-level adjustments with income diversification. Overall, these patterns suggest that farmers tend to select adaptation strategies that are feasible within their socioeconomic constraints, with a strong emphasis on income stabilization rather than extensive transformation of livestock production systems.

While these descriptive results highlight clear differences between on-farm and off-farm responses, they do not explain why farmers choose particular strategies. Therefore, the following section employs a Multinomial Logit Model (MNL) to analyse the socioeconomic factors influencing farmers’ adaptation strategy choices.

3.2. Determinants of smallholder farmers' adaptation strategies to climate change

Model diagnostics:

Statistic	Value
Number of observations	300
Wald χ^2 (14)	116.65
Prob > χ^2	0.0000
Log pseudo-likelihood	-160.017
Pseudo R ² (McFadden)	0.3967

The MNL model is statistically significant ($p < 0.001$), indicating that the set of farmer characteristics jointly explains variation in adaptation choices. A McFadden pseudo-R² of

0.3967 is substantial for socioeconomic models, suggesting that roughly 39.7% of variation in strategy choice is explained by the included covariates.

Table 5. Multinomial Logit estimates (base outcome = On-farm)

Variable	β (Off-farm)	β Combined)
Farmer's Age	-0.2128	-0.4841**
Education Level	0.1036	-0.6595**
Farming Experience	-0.3243	-0.6277**
Main Occupation	-0.1773	-0.0035
Access to Clean Water	-0.0116	-0.5122
Access to Agricultural Residues	1.1197***	-0.4781
Household Income	0.6335	0.6280
Constant	-3.783	4.318
Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.		

Source : Primary data processed, 2025.

The Multinomial Logit estimation, with on-farm strategies as the base category, indicates that farmers' socioeconomic characteristics play an important role in shaping adaptation choices. Age and farming experience exhibit a negative and statistically significant influence on the adoption of combined adaptation strategies, suggesting that older and more experienced farmers tend to rely on a single adaptation approach rather than integrating on-farm and off-farm measures. This pattern implies a stronger attachment to established production practices among these groups.

In addition, having livestock farming as the main occupation shows a negative and significant effect on the likelihood of adopting off-farm strategies, indicating that full-time livestock farmers are less inclined to diversify their livelihoods outside the livestock sector and prefer to maintain their core farming activities.

Conversely, education level and household income display positive associations with economic diversification. Farmers with higher levels of education and income generally possess greater capacity and confidence to engage in off-farm activities beyond livestock production. However, the effect of education on the combined strategy category is negative and not statistically significant, suggesting that more educated farmers tend to specialize in economically efficient strategies rather than simultaneously adopting multiple adaptation options.

Environmental resource availability also contributes to adaptation decisions. Access to agricultural residues has a positive and statistically significant effect on off-farm strategies, implying that farmers who can utilize crop residues are more likely to diversify into related income-generating activities such as feed processing or organic fertilizer production. In contrast, access to clean water does not show a significant effect, indicating relatively

homogeneous water availability across the study area. Field observations confirm that most farmers rely on wells or simple irrigation systems, making water access a non-differentiating factor in strategy selection.

Overall, these findings highlight that economic capacity and access to physical resources are key determinants of adaptation patterns among beef cattle farmers in East Java. Farmers endowed with stronger financial and physical capital demonstrate greater flexibility in responding to climatic risks and market fluctuations through diversified adaptation strategies.

Table 6. Average Marginal Effects (AME) of the Multinomial Logit Model

Variable	AME	p-value
Outcome: Off-Farm vs On-Farm		
Farmer’s Age	+0.0118	0.489
Education Level	+0.0626	0.009
Farming Experience	+0.0096	0.647
Main Occupation	-0.0207	0.000
Access to Clean Water	+0.0378	0.467
Access to Agricultural Residues	+0.1689	0.000
Household Income	+0.0269	0.165
Outcome: Combined vs On-Farm		
Farmer’s Age	-0.0350	0.038
Education Level	-0.0778	0.000
Farming Experience	-0.0417	0.089
Main Occupation	+0.0132	0.005
Access to Clean Water	-0.0534	0.191
Access to Agricultural Residues	-0.1362	0.000
Household Income	+0.0181	0.409

Source : Primary data processed, 2025.

The Average Marginal Effects (AME) results indicate that off-farm adaptation choices are significantly influenced by education level, main occupation, and access to agricultural residues. Education shows a positive and significant effect (AME = 0.0626; p = 0.009), implying that higher educational attainment increases the probability of adopting off-farm

strategies. This suggests that better-educated farmers possess greater capacity to recognize and exploit alternative income opportunities beyond livestock farming.

Access to agricultural residues exhibits the strongest positive effect (AME = 0.1689; $p < 0.001$), highlighting the importance of natural resource availability in facilitating livelihood diversification. Crop residues provide opportunities for value-added activities such as feed processing and organic fertilizer production, thereby enhancing income stability under climate stress conditions.

In contrast, having livestock farming as the main occupation significantly reduces the likelihood of adopting off-farm strategies (AME = -0.0207 ; $p < 0.001$). This finding reflects an asset lock-in effect, where farmers with strong dependence on livestock production tend to remain within the sector and exhibit lower diversification incentives. Overall, these results reinforce the role of human and natural capital as key drivers of off-farm adaptation decisions, consistent with the Sustainable Livelihoods Framework.

4 Conclusion

The findings of this study show that beef cattle farmers in East Java have adopted diverse adaptation strategies to cope with the impacts of climate change, with off-farm strategies emerging as the most dominant response. The preference for livelihood diversification reflects farmers' efforts to stabilize household income under increasing climatic uncertainty, particularly in situations where technical and capital-intensive on-farm adaptations remain difficult to implement. In contrast, the adoption of on-farm strategies is relatively limited and tends to be associated with farmers who possess better access to knowledge, skills, and supporting resources.

The econometric results further confirm that farmers' adaptation choices are strongly shaped by their socioeconomic characteristics. Education level, main occupation, and access to agricultural residues play a central role in differentiating adaptation patterns. Higher education and better access to local resources are associated with a greater tendency toward economic diversification, while full dependence on livestock farming is linked to a lower inclination to adopt off-farm strategies. These findings indicate that farmers' adaptive behaviour is closely related to the configuration of human, natural, and financial capital available at the household level.

Overall, the results highlight that adaptation to climate change among beef cattle farmers is not solely a technical process but also a livelihood-based response influenced by broader socioeconomic conditions. Strengthening farmers' capacity to utilize local resources and enhance human capital emerges as a critical element in supporting adaptive processes that are both economically viable and socially inclusive. By providing empirical evidence on the determinants of adaptation strategy choices, this study contributes to a deeper understanding of climate change adaptation in the livestock sector and offers insights for the development of more context-sensitive and sustainable adaptation pathways.

References

1. Cheng, M., McCarl, B., & Fei, C. (2022). Climate change and livestock production: A literature review. *Atmosphere*, 13(1), 140.

- <https://doi.org/10.3390/atmos13010140>
2. Nwobodo, C. E., Nwokolo, B., Iwuchukwu, J. C., Ohagwu, V. A., & Ozioko, R. I. (2022). Determinants of Ruminant Farmers' Use of Sustainable Production Practices for Climate Change Adaptation and Mitigation in Enugu State, Nigeria. *Frontiers in Veterinary Science*, 9, 735139. <https://doi.org/https://doi.org/10.3389/fvets.2022.735139>
 3. Menghistu, H. T., Abraha, A. Z., Tesfay, G., & Mawcha, G. T. (2020). Determinant factors of climate change adaptation by pastoral/agro-pastoral communities and smallholder farmers in sub-Saharan Africa: A systematic review. *International Journal of Climate Change Strategies and Management*, 12(3), 305–321. <https://doi.org/10.1108/IJCCSM-07-2019-0049>
 4. Molla, E., Melka, Y., & Desta, G. (2023). Determinants of farmers' adaptation strategies to climate change impacts in northwestern Ethiopia. *Heliyon*, 9(8), e18514. <https://doi.org/https://doi.org/10.1016/j.heliyon.2023.e18514>
 5. Samiappan, S., Sarwary, M., Venkatachalam, S., Shinwari, E., Sembanan, K., Poornalingam, J., Natarajan, K., Muthusamy, N., Veeramuthu Murugiah, I., Natesan, S., Thiyagarajan, A., & Kathiravan, S. (2025). Determinants of Farmers' Strategies for Adaptation to Climate Change in Agricultural Production in Afghanistan. In *World*, 6(2), 59. <https://doi.org/10.3390/world6020059>
 6. Deressa, T. ., Hassan, R. ., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile Basin of Ethiopia. *Journal of Agricultural Science*, 149(1), 23–31. <https://doi.org/10.1017/S0021859610000687>
 7. Ricart, S., Gandolfi, C., & Castelletti, A. (2023). Climate change awareness, perceived impacts, and adaptation from farmers' experience and behavior: a triple-loop review. *Regional Environmental Change*, 23, 82. <https://doi.org/10.1007/s10113-023-02078-3>
 8. Quandt, A. (2018). Measuring livelihood resilience: The Household Livelihood Resilience Approach (HLRA). *World Development*, 107,253-263.
 9. Ministry of Agriculture. (2023). 2023 Livestock Sector Performance Report. Ministry of Agriculture, Republic of Indonesia.
 10. East Java Meteorology, Climatology, and Geophysics Agency (BMKG). (2022). East Java Climate Report.
 11. Belay, A., Oludhe, C., Mirzabaev, A., Recha, J. W., Berhane, Z., Osano, P. M., Demissie, T., Olaka, L. A., & Solomon, D. (2022). Knowledge of climate change and adaptation by smallholder farmers: evidence from southern Ethiopia. *Heliyon*, 8(12), e12089. <https://doi.org/https://doi.org/10.1016/j.heliyon.2022.e12089>
 12. Twumasi, M. A., Asante, I. O., Essilfie, G., Ntim-Amo, G., Modzi, S. K., & Jiang, Y. (2022). Household income improvement among Ghanaian livestock farmers: Does climate change adaptation strategies matter? *Environmental Development*, 44, 100737. <https://doi.org/https://doi.org/10.1016/j.envdev.2022.100737>
 13. Bahta, Y. T., & Myeki, V. A. (2021). Adaptation, coping strategies and resilience of agricultural drought in South Africa: implication for the sustainability of livestock sector. *Heliyon*, 7(11), e08280. <https://doi.org/https://doi.org/10.1016/j.heliyon.2021.e0828>
 14. Govoni, C., D'Odorico, P., Pinotti, L., & Rulli, M. C. (2023). Preserving global land and water resources through the replacement of livestock feed crops with agricultural by-products. *Nature Food*, 4(12), 1047–1057. <https://doi.org/10.1038/s43016-023-00884-w>

15. Feng, X., Qiu, H., Pan, J., & Tang, J. (2021). The impact of climate change on livestock production in pastoral areas of China. *Science of The Total Environment*, 770, 144838. <https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.144838>