



Impact of socio-economic determinants on goat farmers' adaptations to climate change: A multivariate probit approach

A K DIXIT^{1✉}, NARENDRA SINGH², A K SINHA², RAVINDRA KUMAR¹, M K SINGH¹ and K GURURAJ¹

ICAR-Central Institute for Research on Goats, Makhdoom, Farah, Mathura- 281 122 Uttar Pradesh, India

Received: 5 August 2025; Accepted: 28 January 2026

ABSTRACT

This study overviews at how goat farmers in the Bundelkhand region of Uttar Pradesh are adapting to the climate change and effects of these strategies on their socio-economic situation. The research used data from 300 households in the Banda and Mahoba districts. A multivariate probit econometric model was used to understand what factors influence farmers' choices when adapting to climate change. The results showed that factors like landholding size, farming experience, gender of the household head and especially access to credit institutions significantly influence farmers' adaptation strategies. Additionally, the study highlights the need for improved infrastructure and services particularly in areas like agricultural extension and market access—to support greater adoption of adaptation measures. These findings can help researchers, environmentalists, and policymakers create better strategies to support sustainable goat farming in the area.

Key words: Adaptation, Climate change, Goat farming, Probit Socio-economic

The livestock sector is a key source of income for people in rural areas, especially in developing countries. In a country like India, farming is highly vulnerable to challenges such as unpredictable weather, extreme weather events like droughts and floods and unstable markets, strategies to deal with climate change are especially important. Kumar *et al.* 2023 revealed that climate change has wide-ranging effects economic, environmental and social especially in rain-fed farming areas in developing countries like India, where agriculture is a key part of the economy.

Timely and reliable climate forecasts play a crucial role in improving the welfare of farm households, whereas inaccurate or unreliable forecast information can adversely affect poor farmers (Agarwal, 2008b; Agarwal and Perrin, 2008). Farmers' ability to effectively respond to climate forecasts and to derive benefits from their use largely depends on the prevailing policy and institutional environment, as well as the socio-economic characteristics of their households (Ziervogel *et al.* 2005; Vogel and O'Brien. 2006; Arimi. 2014).

Factors such as limited access to extension services, credit constraints, small landholdings and risk aversion often restrict the uptake of improved technologies and

management practices. Although a growing body of literature has examined farmers' adaptation to climate change, empirical evidence focusing specifically on adoption behavior of goat farmers and the socio-economic determinants of multiple adaptation strategies remains limited. This gap underscores the need for a comprehensive analysis of the factors influencing the adoption of climate change adaptation practices among goat farmers, which the present study seeks to address.

This study focuses on Uttar Pradesh's Bundelkhand region, which is located on the Indo-Gangetic Plains near the Vindhyan hills in central India comprises 7 districts of Uttar Pradesh. It contributes about 11 per cent to the state's total cropped area and 8.5 per cent to its livestock population. Interestingly, Bundelkhand is often referred to as the "goat country" of Uttar Pradesh, with nearly 10 percent of the state's total goat population, which is around 15.59 million (Weber *et al.* 2018). The region faces frequent droughts, irregular rain, dry periods, flash floods and sudden temperature changes, all leading to agrarian distress and seasonal migration. (Jain *et al.* 2020).

This study employs a multinomial probit model to analyse the determinants of climate change adaptation, following earlier empirical studies that have adopted similar methodological approaches (Hassan and Nhemachena. 2008; Deressa *et al.* 2008; Sofoluwe *et al.* 2011; Nzeadibe *et al.* 2011; Aemro *et al.* 2012; Nhemachena *et al.* 2014; Feleke and Berhe *et al.* 2016).

Adaptation to climate change is essential to mitigate its potentially adverse impacts (Kabubo-Mariara and Karanja (2007); Stern (2007); Hassan and Nhemachena (2008);

Present address: ¹ICAR-Central Institute for Research on Goats, Makhdoom, Farah, Mathura-281122, Uttar Pradesh. ²Professor and Head, Department of Agricultural Economics, N.M. College of Agriculture, NAU, Navsari-396450, Gujarat. ³PhD Research Scholar, Department of Agricultural Economics, N.M. College of Agriculture, NAU, Navsari-396450, Gujarat. [✉]Corresponding authors email: villinavi@gmail.com

Reidsma *et al.* 2009). When effectively implemented, adaptation measures can safeguard the livelihoods of resource-poor farmers and enhance food security by reducing negative impacts while strengthening potential benefits associated with climate variability and change (Bradshaw *et al.* 2004; IPCC. 2007; Reid *et al.* 2007; Bryan *et al.* 2009). In this context, goats are widely regarded as relatively resilient to climate change due to their ability to adapt to variable and uncertain climatic conditions (Tirivangasi, 2019).

Although some studies in India have explored farmers' perceptions of climate change and their corresponding adaptation choices, there remains a significant gap in understanding the socio-economic drivers behind goat farmers' adaptation strategies. Consequently, this research seeks to address this gap by investigating the socio-economic factors that affect the adoption of different adaptation strategies among goat farmers. Specifically, it investigates factors affecting the choice of strategies such as change in breed (Y_0), feed management (Y_1), land and water management (Y_2), access to veterinary services (Y_3), change in herd size (Y_4) and nature-based adaptation methods (Y_5).

MATERIALS AND METHODS

Analytical framework: The multinomial logit (MNL) and multinomial probit (MNP) models are widely used analytical tools in adoption-decision studies involving multiple choices. Both approaches allow for the examination of different combinations of adaptation strategies, including individual and multiple options, as highlighted by Hausman and Wise (1978) and Hassan (2008).

As noted by Nhemachena *et al.* (2014), multinomial discrete choice models provide an alternative framework for analysing complex multivariate decision-making processes by defining the choice set as all possible combinations of adaptation measures. However, the applicability of the multinomial logit (MNL) model is constrained by the IIA assumption. When this assumption is violated, estimation can instead be conducted using multinomial probit (MNP) models or models with mixed or random coefficients. While MNL models are often preferred due to their relative simplicity, both Bayesian and non-Bayesian simulation techniques can be employed to estimate large MNP and mixed logit models (Golob and Regan, 2002). A key limitation of this approach, however, is the difficulty in interpreting the marginal effects of explanatory variables on individual adaptation measures within a multinomial framework.

To address the limitations of univariate and multinomial discrete choice methods, this study employs a multivariate probit econometric tool to examine the factors influencing climate change. The multivariate probit econometric technique employed in this work, in accordance with Lin *et al.* (2005), is characterized as a collection of n binary dependent variables y_i (with observation subscripts omitted), such that:

$$Y_i = 1 \text{ if } x' \beta_i + \varepsilon_i > 0, \\ Y_i = 0 \text{ if } x' \beta_i + \varepsilon_i < 0, \quad i=1,2,\dots,n, \quad \dots(1)$$

Where, x is a vector of explanatory variables, b_1, b_2, \dots, b_n are the corresponding parameter vectors, and $\varepsilon_1, \varepsilon_2, \dots, \varepsilon_n$ are random error-terms distributed as multivariate normal distribution with zero means, unitary variance and an $n \times n$ contemporaneous correlation matrix $R = [rij]$, with density $\varphi(\varepsilon_1, \varepsilon_2, \dots, \varepsilon_n; R)$.

The n -variate standard normal probability is the likelihood contribution for an observation:

$$Pr(y_1, \dots, y_n | x) = \int_{-\infty}^{(2y_1-1)x' \beta_1} \int_{-\infty}^{(2y_2-1)x' \beta_2} \dots \times \\ \int_{-\infty}^{(2y_n-1)x' \beta_n} \varphi(\varepsilon_1, \varepsilon_2, \dots, \varepsilon_n; Z' R Z) \\ d\varepsilon_1 \dots d\varepsilon_2 d\varepsilon_1 \dots \quad (2)$$

Where, $Z = \text{diag}[2y_1-1, \dots, 2y_n-1]$. The maximum likelihood estimation maximizes the sample likelihood function, which is a product of probabilities (Eq. 2) across sample observations. The computation of maximum likelihood function using multivariate normal distribution requires multi-dimensional integration and a number of simulation methods have been put forward to approximate such a function with GHK simulator (Geweke 1996; Hajvassilion *et al.* 1996) being widely used (Belderbos *et al.* 2004). The marginal effects of explanatory variables on the propensity to adopt each of the different adaptation measures are calculated as:

$$\partial P_i / \partial x_i = \varphi(x' \beta)_i, \quad i = 1, 2, \dots, n \quad \dots(3)$$

Where, P_i is the probability (or likelihood) of event i (that is increased use of each adaptation measure), $\varphi(\cdot)$ is the standard univariate normal cumulative density distribution function, and x and β are the vectors of regressors and model parameters respectively (Hassan. 2010).

To assess potential multicollinearity in econometric analysis using cross-sectional data, the Variance Inflation Factor (VIF) for each explanatory variable was calculated. The VIF values ranged from 1.07 to 1.53, well below the conventional threshold of 10 typically used in regression diagnostics (Lin *et al.* 2005). Therefore, multicollinearity does not appear to be a concern in this analysis. A strong model was developed that employed a covariance matrix along with a series of equation-level scores to compute a reliable variance estimator, thereby addressing potential heteroscedasticity.

Description of data: A total of 300 goat-rearing households from the Banda and Mahoba districts participated in the survey. A cross-sectional household survey was conducted during from year 2022-25 the years 2022-23. The selection of respondents was based on specific inclusion criteria to ensure relevance to the study objectives. Only households that had been engaged in goat rearing for at least one year prior to the survey were included. The one-year minimum experience criterion was adopted to ensure that respondents had completed at least one full production and seasonal cycle, allowing them to

observe climate-related variations and to undertake basic adaptation responses such as changes in feeding, herd size adjustment, use of veterinary services or reliance on nature-based practices. This survey which included information on farmers’ perceptions of climate change, the adaptation strategies they have adopted and the challenges they had encountered in implementing these strategies. These include genetic improvement through suitable breed selection, improved feed and fodder management, land and water conservation measures and regular use of veterinary and animal health services. Nature-based adaptation practices such as the use of local and climate-resilient goat breeds, reliance on natural grazing resources, seasonal adjustment of grazing patterns and integration of goats with existing farming systems to enhance ecosystem resilience were also analysed. These recommended practices form the basis of the adaptation strategies analysed in the present study.

Dependent and independent variables: The dependent variables perceived for the model were six dummy variables: Change in breed (Y_0), Feed Management (Y_1), Land and Water Management (Y_2), Veterinary Services (Y_3), Change in Flock Size (Y_4) and Nature-Based Adaptation (Y_5). The variables include the age of the household head, their education level and farming experience. Veterinary costs, sex of the household head and the number of family labourers contributed to the understanding household dynamics. Summary statistics of the identified main adaptation measures are presented in Table 1.

The explanatory variables included in the model were derived from a review of adoption literature and our understanding of theoretical frameworks; however, this approach remained largely exploratory due to the limited availability of straightforward theoretical predictions. The selected independent variables represented some of the numerous factors influencing the adoption of adaptation options at the goat farm level. Although many factors might affect the farmers’ use of adaptation strategies, this study

has identified thirteen key variables, listed in Table 2, that were most relevant for explaining the adoption of different adaptation options by goat keepers. In the empirical analysis, each of these variables was incorporated into all the six equations to examine whether their impacts varied across different adaptation options.

RESULTS AND DISCUSSION

The research utilized a multivariate probit model and to make comparisons, univariate probit models were also calculated for each of the six adaptation choices. Descriptive statistics for these variables and the anticipated effects of adaptation options are also presented in Table 2. The findings presented in Table 2 indicate that the average flock size was 17 goats, average age of the household head was 46 years. Regarding access to public agricultural extension services, approximately 39 percent of respondents had contact with extension agents. Access to credit emerged as a key factor influencing the adoption of adaptation strategies, only 21 percent of the sampled households having access to credit. However, the average distance to input market was 26 km from the sampled households. Similar findings have been observed by (Dixit and Singh 2014).

The findings from the multivariate probit model, as shown in Table 3, revealed that the correlation coefficients of the error terms was significant (based on t-test statistics) across all pairs of equations, indicating that these are correlated. This suggested the presence of complementarities (positive correlations) among the different adaptation strategies adopted by farmers. The results affirmed the interdependence between various adaptation options, which might have arisen from complementarities among the strategies themselves, as well as unobserved household-specific and other factors influencing the adoption of multiple adaptation measures. Additionally, notable differences in the estimated coefficients across the different equations underscored the importance of treating each

Table 1. Definition of variables used in empirical analysis

Variable	Definition	Values/measure	Expected impact
X1	Age of household-head	Number of years	±
X2	Education of household-head	Number of literate members	+
X3	Flock size	Number of goats in a group	+
X4	Land holding	(Hectare)	+
X5	Area under green fodder	(Hectare)	+
X6	Veterinary cost	(Rs.)	+
X7	Sex of household head	Male =1 Female = 0	+
X8	Farming experience	Number of years	+
X9	Noticed climate change	1=yes and 0=no	±
X10	Family labours	Number of labourers	+
X11	Access to agricultural extension facility	1=yes and 0=no	+
X12	Access to credit	1=yes and 0=no	±
X13	Distance to input market	Distance in km	+

Table 2. Summary statistics of independent variables and their expected impacts on adaptation measures.

Variable	Variable	Mean	Maximum	Minimum	Standard deviation	Skewness	Kurtosis
X1	Age of household-head	45.687	75.000	22.000	9.682	0.157	-0.0013
X2	Education of household-head (Yrs.)	3.963	15.000	0.000	4.188	0.7145	-0.415
X3	Flock size (No.)	17.237	70.000	5.000	11.044	1.968	4.634
X4	Land holding (Ha)	1.380	10.125	0.203	1.487	2.664	8.636
X5	Area under green fodder (Ha)	0.124	0.810	0.010	0.132	2.378	6.461
X6	Veterinary cost (Rs.)	1086.4	3550	100.00	654.420	1.848	4.409
X7	Sex of household head	0.913	1.000	0.000	0.282	-2.513	4.404
X8	Goat Farming experience (Yrs)	3.24	12.000	1.000	1.714	1.848	4.409
X9	Noticed climate change	0.443	1.000	0.000	0.498	0.229	-1.961
X10	Family labours (No.)	6.013	18.000	1.000	2.904	0.797	1.245
X11	Access to agricultural extension facility	0.393	1.000	0.000	0.489	0.439	-1.819
X12	Access to credit	0.210	1.000	0.000	0.408	1.431	0.048
X13	Distance to input market (Km)	25.85	45.000	6.000	10.534	0.109	-0.648

adaptation option distinctly rather than aggregating them.

The univariate probit models represent a more restrictive form of the multivariate probit model, where all off-diagonal error correlations are assumed to be zero (i.e., that is, $P_{ij}=0$ for $i>j$) (Lin *et al.* 2005; Belderbos *et al.* 2004). A likelihood ratio test that evaluated the log-likelihood values of both the multivariate and univariate models indicated significant joint correlations. Separate univariate probit models were also estimated; however, the MVP model was preferred because the likelihood ratio test strongly rejected the null hypothesis of zero correlations among the error terms ($\chi^2(13) = 24.40$; $p = 0.0277$). This result justified the use of the multivariate probit model, which accounted for the interdependence among different adaptation options, rather than relying on separate univariate probit models. It also highlighted the inadequacy of combining adaptation choices into a single binary variable (adaptation vs. no adaptation), as done in some previous studies such as Maddison (2007).

The age of the household head (X_1) had negative coefficients for change in breed (-0.019), feed management (-0.003), land and water management (-0.018), and change in herd size (-0.188), but none of these effects were statistically significant. In contrast, age exerted a positive and statistically significant influence on nature-based adaptation strategies (0.022 , $p < 0.10$). This indicated that older farmers are neither significantly more nor less likely to adopt most adaptation measures, but they show a higher likelihood of relying on nature-based responses. The result suggested a selective preference rather than a generalized reluctance toward adaptation. The negative attitudes of elderly farmers toward novel technological options have been documented in prior studies on agricultural adaptation (Gould *et al.* 1989).

Education of the household head (X_2) exhibited mixed but statistically insignificant effects across all strategies.

Although education showed positive coefficients for feed management (0.243) and land and water management (0.032), these estimates were not statistically significant, indicating that formal education alone does not significantly influence the adoption of adaptation strategies among goat farmers in the study area. This echoes findings by Denkyira *et al.* (2017), who noted that while education can enable access to knowledge, it doesn't always translate into immediate adoption due to other constraints. Flock size (X_3) had small and statistically insignificant coefficients across all adaptation options, ranging from -0.021 for breed change to 0.011 for herd size adjustment. This implies that flock size by itself does not play a decisive role in influencing adaptation behavior. Larger landholdings may provide more capacity to undertake genetic improvement or expand herd size, consistent with findings in livestock adaptation literature (Deressa *et al.* 2009; Molla *et al.* 2023).

The area under green fodder (X_5) showed a negative association with breed change (-4.825) and herd size adjustment (-6.911), while positive coefficients were observed for feed management (0.462) and land and water management (2.287). However, none of these effects were statistically significant, indicating that fodder availability does not independently drive adaptation decisions, although it may complement feed-related practices. Veterinary cost (X_6) had a negative and statistically significant impact on the use of veterinary services (-0.001 , $p < 0.10$). This result indicates that higher animal health expenditures discourage farmers from utilizing formal veterinary care, highlighting financial constraints as a major barrier to the adoption of animal health-related adaptation measures. This indicates the critical role of financial constraints' in limiting access to key adaptive technologies, a constraint similarly noted by Kandlinkar and Risbey (2000) in crop adaptation contexts. The sex of the household head

Table 3. Results of multivariate probit analysis of adaptation measures

Variables		Change in breed (Y ₀)	Feed Management (Y ₁)	Land and water management (Y ₂)	Veterinary services (Y ₃)	Change in herd size (Y ₄)	Nature based adaptation (Y ₅)
C	Constant	2.160	-0.500	-0.583	-1.969	-1.162	-0.746*
X1	Age of household-head	-0.019	-0.003	-0.018	0.013	-0.188	0.022*
X2	Education of household-head	-0.012	0.243	0.032	-0.007	0.020	-0.061
X3	Flock size	-0.021	-0.009	-0.009	-0.016	0.011	0.004
X4	Land holding (Hectare)	0.365	-0.072	-0.282	0.133	0.503	0.049
X5	Area under green fodder	-4.825	0.462	2.287	0.491	-6.911	1.406
X6	Veterinary cost	-0.001	0.000	0.001	-0.001*	-0.000	0.000
X7	Sex of household head	-0.309	-0.032	0.576	0.827**	-0.305	-0.712
X8	Farming experience	0.022	-0.132	-0.127	0.150**	0.190**	0.001
X9	Noticed climate change	0.081	0.348	-0.106	-0.239	0.778	-0.247
X10	Family labours	0.002	-0.004	-0.011	0.003	-0.005	0.036
X11	Access to agricultural extension facility	-1.545**	0.139	0.143	0.189	0.461	0.061
X12	Access to credit	1.983**	0.005	0.142	0.274	-0.284	0.040
X13	Distance to input market	-0.021*	-0.001	0.000	0.013	-0.003	-0.007

* Significant at 10%, ** Significant at 5%

(X7) had a positive and statistically significant effect on veterinary service utilization (0.827, $p < 0.05$), suggesting that male-headed households are more likely to access veterinary services. For other adaptation strategies, the coefficients were statistically insignificant, indicating that gender effects are specific rather than universal across adaptation options. This may parallel observations by Ojo and Baiyegunhi (2018) who reported male dominance in accessing extension and veterinary support in rural settings. Farming experience (X8) positively and significantly influenced veterinary service adoption (0.150, $p < 0.05$) and change in herd size (0.190, $p < 0.05$). This suggests that experienced farmers are better equipped to respond to climatic stress through livestock health management and herd restructuring. For other strategies, farming experience did not exert a statistically significant effect. Surprisingly, awareness of climate change (X9) did not significantly affect the adoption of any adaptation strategy. Although the coefficient for herd size adjustment was positive (0.778), it was statistically insignificant, indicating that awareness alone is insufficient to translate into concrete adaptive action without supporting resources or institutional mechanisms. Access to agricultural extension services (X11) showed a negative and statistically significant effect on breed improvement (-1.545, $p < 0.05$), while its effects on other strategies were statistically insignificant. This suggests that existing extension services might not be effectively aligned with breed-related adaptation needs of goat farmers. Access to credit (X12) had a strong positive and statistically significant impact on the adoption of improved breeds (1.983, $p < 0.05$). These findings highlighted the capital-

intensive nature of breed improvement and underscores the critical role of financial institutions in enabling such adaptation strategies. Distance to input markets (X13) negatively and significantly influenced breed improvement (-0.021, $p < 0.10$), indicating that greater physical distance from markets constrains farmers' ability to access improved breeds and associated inputs.

The study employed a multivariate probit model, along with individual univariate probit models, to analyze the factors influencing the adoption of six distinct climate change adaptation strategies among goat farmers in the Bundelkhand region of Uttar Pradesh. The findings reveal that most farmers adopt multiple adaptive practices, with changes in herd size and utilization of veterinary services emerging as the most common strategies. In contrast, nature-based adaptations were less frequently implemented. Key socio-economic variables including the age and education level of the household head, landholding size, gender and farming experience were found to significantly influence the adoption of specific strategies. Farmers with larger landholdings and greater experience were more inclined to adopt breed improvements and herd management practices. Households headed by men made a greater use of veterinary services. Access to institutional support, particularly credit facilities, had a strong positive impact on the adoption of improved breeds, underscoring the vital role of financial resources in facilitating capital-intensive adaptation measures. On the other hand, access to agricultural extension services showed mixed effects, suggesting a need to better tailor these services to the specific needs of goat farmers. Additionally, greater

distance to input markets was found to negatively affect the adoption of breed improvement strategies, highlighting infrastructure-related barriers to accessing essential resources.

The present study is exploratory in nature and as such, has certain limitations that offer avenues for future research. First, the analysis is based on cross-sectional data, which captures adaptation behavior at a single point in time and does not allow assessment of dynamic or long-term adaptation pathways. Future studies could employ panel data to examine how adaptation strategies evolve over time. Second, the study focuses on observed adaptation measures and does not quantify the intensity or effectiveness of these strategies. Further research may assess the economic and welfare impacts of specific adaptation options. Third, while the multivariate probit framework captures interdependence among adaptation choices, qualitative factors such as farmers' risk preferences, social networks and institutional trust were not explicitly modelled. Incorporating these dimensions could provide deeper insights into adaptation decision-making. Finally, comparative studies across regions and livestock systems could help to generalize the findings and refine the policy recommendations.

ACKNOWLEDGEMENTS

This research is a part of the National Livestock Mission project: Development of Goat Value Chain in Bundelkhand Region of Uttar Pradesh funded by the Department of Animal Husbandry & Dairying (Govt. of India). The authors are thankful to the National Livestock Mission. The guidance received from the Director, ICAR-Central Institute for Research on Goats (CIRG), Makhdoom, is gratefully acknowledged.

REFERENCES

- Aemro T K, Mengistu and T Beyene. 2012. Climate change adaptation strategies of smallholder farmers: The case of Babile District, East Hararge Zone of Oromiya Regional State of Ethiopia. *Journal of Economics and Sustainable Development* 3(14): 1–12.
- Agarwal A. 2008b. The role of local institutions in adaptation to climate change. Paper prepared for a workshop on social dimensions of climate change organized by the Social Development Department, The World Bank, Washington, DC, March 5–6: 2008. 15.
- Agarwal A and N Perrin. 2008a: Climate adaptation, local institutions, and rural livelihoods. IFRI Working Paper, W081-6. International Forestry Resources and Institutions Program, University of Michigan.
- Arimi K. 2014. Determinants of climate change adaptation strategies used among fish farmers in Epe Local Government Areas of Lagos state, Nigeria. *Journal of the Science of Food and Agriculture* 94 (7): 1470–76.
- Belderbos R M, Carree B, Dieren B, Lokshin and R Veugelers. 2004. Heterogeneity in R and D cooperation strategies. *International Journal of Industrial Organization* 22: 1237–63. <http://dx.doi.org/10.1016/j.ijindorg.2004.08.001>.
- Bradshaw B. H. Dolan and B. Smit. 2004. Farm-level adaptation to climatic variability and change: Crop diversification in the Canadian prairies. *Climatic Change* 67(1): 119–41.
- Bryan E ,T T Deressa, G A Gbetibouo and C Ringler. 2009. Adaptation to climate change in Ethiopia and South Africa: Options and Constraints. *Environmental Science and Policy* 12(4): 413–26.
- Deressa T T, R M Hassan, C Ringler, T Alemu and M Yesuf. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 19 (2): 248–55.
- Deressa T T, R M Hassan, C Ringler, T Alemu and M. Yesuf. 2008. Analysing the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia. (IFPRI Discussion Paper 00798).
- Dixit A K and M K Singh. 2014. Economic analysis of goat rearing under field conditions of Bundelkhand region, *The Indian Journal of Small Ruminants* 20(2): 165–8.
- Feleke F B, Berhe M, Gebru G and Hoag D. 2016. Determinants of adaptation choices to climate change by sheep and goat farmers in Northern Ethiopia: The case of Southern and Central Tigray, Ethiopia. *Springer Plus* 5: 1–15.
- Geweke J. 1996. Variable selection and model comparison in regression in *Bayesian Statistics*, eds. J. M. Bernardo, J. O. Berger, A. P. Dawid, and A. F. M. Smith, London: Oxford Press, Vol 5, pp. 609–20.
- Golob T F and A C Regan. 2002. Trucking industry adoption of information technology: A multivariate discrete choice model. *Transportation Research Part C* 10(3): 205–228. Retrieved from <https://www.researchgate.net/publication/222701744>.
- Gould B W, W E Saupe and R M Klemme. 1989. Conservation tillage: The role of farm and operator characteristics and the perception of soil erosion. *Land Economics* 65: 167–82.
- Hassan R and C Nhemachena. 2008. Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. Retrieved from <https://www.researchgate.net>.
- Hassan R. 2010. Implications of climate change for agricultural sector performance in Africa: Policy challenges and research agenda. *Journal of African Economies* 19, S2: 77–105.
- Hausman J and D Wise. 1978. A conditional probit model for qualitative choice: Discrete decisions recognizing interdependence and heterogeneous preferences. *Econometrica* 46: 403–26.
- IPCC Report. 2007. https://www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_full_report.pdf.
- Jain R, P S Chand, S Rao and S Agarwal. 2020. Crop and soil suitability analysis using multi-criteria decision making in drought-prone semi-arid tropics. *Indian Journal of Soil and Water Conservation* 19(3): 271–83.
- Kabubo – Mariara J and K Karanja. 2007. The economic impact of climate change on Kenyan crop agriculture: A Ricardian approach. World Bank Policy Res. Series Work. P. 4334.
- Kandlinkar, M. and J. Risbey. 2000. Agricultural impacts of climate change: If adaptation is the answer, what is the question? *Climatic Change* 45: 529–39.
- Kumar K N R, M J M Reddy, K V Reddy, V Paramesha, M Balasubramanian, TK Kumar, RM Kumar and DD Reddy. 2023. Determinants of climate change adaptation strategies in South India: Empirical evidence. *Front. Sustain. Food Systems* 7:1010527. doi: 10.3389/fsufs.2023.1010527Sec. Land, Livelihoods and Food Security
- Lin C T J, K L Jensen and S T Yen. 2005. Awareness of Food-Borne Pathogens among US consumers. *Food Quality and Preference* 16 (5): 401–12.
- Maddison D. 2007. The perception of and adaptation to climate

- change in Africa. In Policy Research Working Paper 4308. Washington DC: The World Bank.
- Molla E Y, Melka and G Desta. 2023. Determinants of farmers' adaptation strategies to climate change impacts in northwestern Ethiopia. *Heliyon* **9** (8): e18514: 1–11.
- Nhemachena C R, Hassan and J Chakwizira. 2014. Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa. *Journal of Development and Agricultural Economics* **6**(5): 232–41.
- Nzeadibe T C, C L Egbule, N Chukwuone and V Agu. 2011. Farmers' perceptions of climate change Governance and adaptation constraints in Niger delta region of Nigeria. African Technology Policy Network, Research Paper No. 7.
- Ojo T and L Baiyegunhi. 2018. Determinants of Adaptation Strategies to Climate Change among Rice Farmers in Southwestern Nigeria: A Multivariate Probit Approach, 2018 Conference, July 28-August 2, 2018, Vancouver, British Columbia 277011, International Association of Agricultural Economists.
- Reid S B, Smit W, Caldwell and S. Belliveau. 2007. Vulnerability and Adaptation to Climate Risks in Ontario Agriculture. Mitigation and Adaptation Strategies for Global Change **12**: 609–637. Online <https://doi.org/10.1007/s11027-006-9051-8>.
- Reidsma P F, Ewert A O, Lansink and R Leemans. 2009. Vulnerability and adaptation of European farmers: A multi-level analysis of yield and income responses to climate variability. *Regional Environmental Change* **9**(1): 25–40.
- Sofoluwe N A, A A Tijani and O I Baruwa. 2011. Farmers' perception and adaptation to climate change in Osun State, Nigeria. *African Journal of Agricultural Research* **6**(20): 4789–4794. Retrieved online at <http://www.academicjournals.org/AJAR>.
- Stern N. 2007. The economics of climate change: the Stern review, Cambridge University Press, Cambridge.
- Tirivangasi H M. 2019. Challenges faced by rural people in mitigating the effects of climate change in the Mazungunye communal lands, Zimbabwe. *Jamba, Journal of Disaster Risk Studies* **11**(1): 1–9.
- Vogel C. and K O'Brien. 2006. Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. *Climate Research* **33**: 111–22.
- Weber C, Dixit A K, Singh M K, Kumar V, Jha A K, Teufel N and Baltenweck, I. 2018. Development of goat milk and meat value chains in Bihar and Uttar Pradesh. ILRI Project Report. Nairobi, Kenya: ILRI.
- Ziervogel G, M Bithell, R Washington and T Downing: Agent-based social simulation: A method for assessing the impact of seasonal climate forecasts among smallholder farmers. *Agricultural Systems* **83**(1): 1–26.