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Perception of Climate Change and Adoption of Cottonseed Cake in Pastoral Systems in the Hauts-Bassins Region of Burkina Faso

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Abstract

In the Sahelian context characterized by the increasing scarcity of forage resources, this study investigated how climate change perceptions influence the adoption of cottonseed cake in pastoral and agro-pastoral systems in the Hauts-Bassins region of Burkina Faso. Drawing on the Subjective Expected Utility (SEU) theory and using a logit model estimated from survey data collected from 366 livestock farms, the analysis reveals that the perceived degradation of rangelands due to climate change is a key determinant of adoption. Over 40% of surveyed herders believed that climate change is negatively affecting the availability of natural forage. This heightened awareness is significantly associated with a greater likelihood of adopting cottonseed cake as a feed supplementation strategy. This study highlights the crucial role of cognitive factors in shaping adaptation decisions, beyond traditional economic and structural determinants. It underscores the importance of incorporating environmental perceptions into public policies supporting livestock systems and technological innovations in pastoral.

Keywords: adoption; cottonseed cake; climate change perception; pastoralism; Burkina Faso; logit model

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1. Introduction

Livestock production in western Burkina Faso faces major constraints, particularly related to feed availability. Animals primarily rely on natural pastures, which are abundant during the rainy season but become scarce and nutritionally insufficient during the dry season [1]. As noted by Koutou et al. [2], these feed shortages significantly hamper livestock productivity. The cultivation of improved forage remains very limited in the region [3], which aggravates seasonal imbalances in feed supply.

Feeding is not only the most critical determinant of zootechnical performance but also the main component of production costs. Recent estimates from Benamara and Chihaoui [4] suggest that feed expenses can represent up to 79.1% of total operating costs in ruminant production systems. Moreover, the combination of low-quality feed availability and high input prices severely limits both technical efficiency and profitability [5]. This constraint directly affects animal performance, including growth, reproduction, and milk yield [6].

Climate change further exacerbates the situation by accelerating the degradation of natural grazing lands and reducing forage availability, especially during the dry season [7]. These effects are particularly pronounced in pastoral and agro-pastoral systems, which hold

a substantial share of the national livestock herd and contribute significantly to domestic meat and milk supply, rural income generation, and food security [8,9]. In such systems, feed resources come mainly from natural grazing [8], agricultural by-products [1], native browse species, and cultivated forages [10]. However, all these resources are subject to seasonal variation and availability constraints [11]. Additionally, access to concentrated feed—especially essential for dairy cows—remains very limited in rural areas. The implications of these structural feed shortages are both economic and social. Conflicts frequently arise between herders and crop farmers due to competition over natural resources [9]. On the supply side, growing demand for milk has led to a surge in dairy imports. In 2020 alone, Burkina Faso imported milk powder and other dairy products equivalent to over 70 million L of liquid milk, valued at more than CFA 14 billion [12]. This increase is also reflected in the rise of imported dairy product volumes, which grew from 690 tons in 2018 to 936 tons in 2019 and 1932 tons in 2020 [13].

Amid this feed crisis, cotton by-products, especially cottonseed cake, have gained attention as a viable and cost-effective alternative to address seasonal feed shortages. Their nutritional profile and local availability make them particularly suitable for dry-season supplementation [14]. Montcho et al. [15] report that these by-products help stabilize feed supply chains, while Mullins et al. [16] highlight their affordability and accessibility. Cottonseed cake, in particular, is known to enhance carcass yield and meat quality [17,18] and to improve economic efficiency in livestock operations, especially during feed-deficit periods [19]. Recent experimental studies further support these findings. Belem et al. [20] showed that cottonseed cake provides a critical protein supplement to cereal residues in ruminant diets. Arcanjo et al. [21] observed significant improvements in both dry matter intake and animal weight gain, while Zeeshan et al. [22] reported higher milk yields. Mullenix and Stewart [23] demonstrated that cottonseed cake lowers feed costs without compromising performance.

Yet, despite its technical and economic benefits, the adoption of cottonseed cake remains limited among pastoralists and agro-pastoralists due to factors such as high market prices and poor distribution infrastructure [24]. Multiple studies have identified key determinants of agro-industrial by-product adoption: price sensitivity [24], herd size [25], proportion of sedentary animals [26], education and age of the farmer [27], experience, remoteness [28], and access to information and storage facilities [25]. In addition, climate change perception is now recognized as a major driver of adaptation behaviors in agriculture. According to Chen et al. [29], farmers with a high perception of climate risks are more likely to adopt climate-smart technologies. Kassa and Abdi [30] confirmed that climate perception, alongside land size, significantly influences adoption behavior. Oli et al. [31] demonstrated the role of education and social media in shaping learning and awareness, while Tiyo et al. [32] documented various adaptive practices triggered by climate-related concerns. Despite this growing literature, few studies have examined the link between climate change perception and the adoption of cottonseed cake.

This study aims to bridge a critical gap in the literature by exploring the role of climate change perception in shaping the adoption of cottonseed cake among pastoral and agro-pastoral herders. It investigates how herders in the study area interpret the impacts of climate change on their livelihoods—particularly in terms of feed availability—and whether this perception influences their willingness to adopt alternative feeding strategies such as cottonseed cake. The underlying hypothesis is that herders who view climate change as a serious threat are more likely to seek adaptive solutions to maintain livestock productivity, with cottonseed cake emerging as a key supplement during feed-scarce periods. This behavioral response is examined through the lens of Savage's Subjective Expected Utility (SEU) theory (1954), which provides a framework for understanding decision making under

uncertainty. In this context, adoption choices are guided by herders' subjective evaluation of the expected benefits of using cottonseed cake in response to climate-related risks.

To address these research questions, the paper begins by reviewing the existing literature on the determinants of feed innovation adoption in livestock systems (Section 2). It then outlines the methodological approach, including the study setting, conceptual framework, variable definitions, data sources, and econometric strategy (Section 3). Section 4 presents the empirical results derived from the logit model, while Section 5 discusses these findings in comparison with existing research. Finally, Section 6 concludes the paper by outlining key policy implications, acknowledging the study's limitations, and proposing avenues for future research.

2. Literature Review

Over the past decade, a growing body of empirical research has investigated the factors influencing the adoption of livestock feed innovations, particularly the use of agricultural and agro-industrial by-products (ABPs and AIBPs). These feed alternatives are widely recognized for their potential to improve productivity in extensive and semi-intensive livestock systems, especially in regions facing structural feed shortages. Across diverse contexts, studies consistently highlight a set of key determinants: education level, herd structure, production objectives, market orientation, infrastructure availability, and access to information and extension services.

For instance, in Algeria, Mamine et al. [28] showed that AIBP adoption was significantly shaped by socio-professional characteristics, herd composition, and production goals, with education and farm size playing a crucial role. Similarly, Deffo et al. [26] in Cameroon found that education, experience, herd size, and product price were positively associated with the adoption of cottonseed cake. In eastern DRC, Mutwedu et al. [33] emphasized the weight of logistical and informational constraints—namely, poor infrastructure, high transport costs, limited storage, and lack of technical information. Studies in Uganda by Swidiq et al. [34] and in other contexts by Baba et al. [25] further reinforced the importance of resource availability, institutional linkages, and consistent product quality as key factors in adoption.

Together, these findings underscore that the drivers of AIBP adoption are not merely context-specific but share a common structure across agro-ecological zones: access to resources (land, capital, infrastructure), exposure to information and training, and broader market and institutional conditions. However, despite this extensive literature, one critical dimension remains insufficiently explored—the influence of climate change perception on the adoption of feed innovations. In regions increasingly exposed to climatic uncertainty, such as the Sahel, herders are compelled to adjust their livestock and feed strategies to cope with recurring droughts and pasture degradation. Recent research suggests that climate change awareness significantly shapes technology uptake and behavioral adaptation. Chen et al. [29], for example, show that heightened risk perception fosters adoption of climate-smart practices, while Kassa and Abdi [30] demonstrate the statistical significance of climate perception in explaining technology adoption. Likewise, Oli et al. [31] and Tiyo et al. [32] point to education, media exposure, and behavioral changes—such as crop diversification or early planting—as manifestations of climate-aware decision making.

Yet, few studies have explicitly examined the relationship between climate change perception and the adoption of agro-industrial feed by-products—particularly cottonseed cake—in the pastoral and agro-pastoral systems of the Sahel. This gap is particularly striking given the centrality of feed management in building resilience against climatic stress. The present study seeks to fill this void by analyzing how perceptions of climate change influence herders' decisions to adopt cottonseed cake as a strategic response to

seasonal feed shortages. By integrating this psychological and behavioral dimension into the adoption framework, this study offers a more comprehensive understanding of livestock management decisions in a context of both environmental variability and economic constraints.

3. Methodology

This methodological section is structured around six key components: the description of the study area, the theoretical framework, the definition of variables, the specification of the empirical model, the estimation method, and the data sources used for the analysis. A notable strength of this study lies in the originality and specificity of its dataset. The data were collected through a tailor-made field survey explicitly designed to investigate the multiple dimensions of cottonseed cake adoption in pastoral and agro-pastoral systems. This primary data collection approach made it possible to incorporate context-specific variables—such as climate change perception and distance to supply points—that are rarely available in secondary sources. In addition, the methodological choice of a binary logit model is particularly well suited to the research objective, as it allows the analysis of a dichotomous adoption decision. This model is widely recognized in the literature on agricultural innovation and has been successfully applied in similar studies focused on feed technology and climate adaptation. Its use here enables a rigorous assessment of the marginal effects of each determinant and strengthens the explanatory power of the analysis.

3.1. Study Area

The study was conducted in the Hauts-Bassins region, located in western Burkina Faso. The region consists of three provinces: Houet (capital: Bobo-Dioulasso), Kénédougou (Orodara), and Tuy (Houndé). It includes 3 urban municipalities, 30 rural communes, 33 departments, 483 villages, and 45 urban sectors. The region covers an area of approximately 25,479 km^2—about 9.4% of the national territory—and is home to 2,239,840 inhabitants according to recent data from INSD [35].

The Hauts-Bassins region is characterized by a relatively diversified economy, with a notable presence of industrial and artisanal units, including SOFITEX and FILSAH. The topography alternates between peneplains, plateaus, hills, and small mountains, with altitudes ranging from 250 to 700 m [35]. The soils vary from sesquioxide-rich types—high in iron and manganese and derived from tropical ferruginous soils—to hydromorphic soils. In the Kénédougou province, soils are deep, well-drained, and mineral-rich but low in organic matter, making them suitable for cash crops like cotton, sesame, and peanuts. In the Tuy province, approximately 50% of the land area is dedicated to agriculture. In the Houet province, hydromorphic soils overlying ancient lateritic crusts are well-suited for farming [35]. The region has a north-Sudanian climate, marked by alternating dry and rainy seasons, with annual rainfall ranging between 800 and 1100 mm. However, the effects of climate change are increasingly evident, with rainfall patterns becoming more irregular in both spatial and temporal distribution across growing seasons [35].

Livestock production is a fundamental component of rural livelihoods in the region. It provides income, food, nutritional support, animal traction, and organic fertilizer and serves as a socioeconomic safety net. It also plays a stabilizing role for rural populations by reducing economically driven migration [36]. The growing importance of livestock in the region is reflected in herd sizes: the number of cattle rose from 1,633,924 in 2018 to 1,750,932 in 2021, while sheep numbers increased from 957,163 to 1,045,916 over the same period [35]. Despite this upward trend, local milk production remains inadequate. Dairies face irregular supply, characterized by low, seasonal, and highly fragmented milk production [37]. This low productivity is primarily attributed to major nutritional constraints. These include the

reduction in available pastures due to expanding agriculture [38], the rising cost of livestock feed [39], and the limited adoption of forage crops—even in areas with high agricultural potential [40].

Moreover, the Hauts-Bassins region, which accounts for 36% of the national cotton output [35], hosts eleven cottonseed processing facilities that produce, among other things, edible oil, household soap, livestock feed, and cottonseed cake. The region also ranks second nationally in cattle (16.6%) and sheep (9.2%) populations, after the Sahel region [41]. These features make the Hauts-Bassins region strategically important for livestock production and provide a relevant setting to investigate the adoption of cottonseed cake as a livestock feed in the context of climate change adaptation.

3.2. Theoretical Framework and Definition of Variables

This study is grounded in the theory of Subjective Expected Utility (SEU), initially developed by Savage [42] and further elaborated by Danilov and Lambert-Mogiliansky [43]. The SEU framework, widely used in decision theory, provides a robust basis for analyzing individual choices under uncertainty. Unlike models based on objective probability, SEU posits that individuals construct subjective probability distributions for the outcomes associated with each decision. In the specific context of this research, the pastoral or agro-pastoral livestock producer is faced with a range of acts whose outcomes are uncertain—particularly the decision to adopt or not cottonseed cake for animal feeding. Suppose the producer assigns a subjective probability μ to the expected utility of adopting cottonseed cake, denoted as f. The expected utility of the act f can then be expressed as follows:

$$U(f) = \sum \mu(a(i)f(i)) \quad (1)$$

where μ denotes the subjective probability assigned to act f, a represents the potential outcomes, and i indexes a specific farmer within the sample. This formulation allows us to model utility-maximizing behavior in an environment marked by uncertainty.

To empirically test this framework, a binary regression model is specified using one dependent variable and several explanatory variables. The dependent variable (*adoption_tc*) is a binary indicator that captures whether the farmer has adopted cottonseed cake as part of their livestock feeding strategy. Adoption is defined as having used cottonseed cake at least four times over the past five years (2019–2023). The variable takes the value 1 if this condition is met, and 0 otherwise.

The explanatory variables (Table 1) include a set of socioeconomic, institutional, technical, and perceptual characteristics likely to influence adoption decisions. Instruction level (*instruction*) is often a key determinant in technology adoption. Higher formal education may enhance understanding of technical recommendations and improve responsiveness to extension services [44]. Age (*age*) of the producer may also play a role. Older farmers may possess more experience, resources, or authority to experiment with innovations, though the relationship is not always linear [44]. Access to agricultural credit (*agricredi*) is crucial in contexts where high initial investments are required. Financial liquidity—whether through savings or credit—can facilitate adoption [45]. Membership in a livestock association (*association*) facilitates information dissemination, builds social capital, and promotes peer learning [46,47]. Farmers frequently rely on fellow producers for technical advice [44]. Distance to supply source (*dist_LA*) is also considered. Greater distance from distribution centers can represent a significant logistical barrier, increasing transaction costs and discouraging adoption [26]. The number of sedentary ruminants (*rumin_sedent*) reflects livestock management style. Farms with a higher number of sedentary animals are more likely to adopt agro-industrial byproducts, as such systems facilitate controlled feeding [26]. The pastoralist status (*pasteur*), distinguishing between pure pastoralists and agro-pastoralists,

captures structural differences in feeding practices. Agro-pastoralists typically have better access to crop residues for feed. Milk production (*productlait*) is a key variable, as improved feeding practices often enhance milk yields. Research has shown that dietary supplementation is vital for dairy productivity in Sahelian settings [48]. Technical support (*contact_tech*)—measured through regular contact with extension agents—is expected to positively influence adoption by enhancing information access, reducing uncertainty, and facilitating learning [49]. Off-farm income (*revenu_hf*) serves as an additional resource to overcome financial barriers. Such income provides liquidity for input purchases [50,51]. The perception of climate change impacts (*pecc_rpfn*)—especially the perceived decline in natural pasture availability—may encourage the adoption of alternative, more reliable feed sources such as cottonseed cake [52]. Lastly, the number of working-age household members (*actifs*) serves as a proxy for available labor. A large household workforce can ease herd management and facilitate the adoption of feed supplements [53].

Table 1. Summary of model variables and their descriptions.

Variable	Description	Measurement	Expected Sign
Dependent Variable			
adopt_tc	Adoption of cottonseed cake by the livestock producer	1 if the producer adopts cottonseed cake, 0 otherwise	
Independent Variables			
instruction	Education level of the household head	1 if literate (can read or write), 0 otherwise	+
age	Age of the household head	Age in years	+
pasteur	Pastoral status	1 if pastoralist, 0 if agro-pastoralist	−
productlait	Quantity of milk produced	Number of liters produced by the household	+
revenu_hf	Off-farm income	Amount of non-farm income	+
association	Membership in an organization or social group	1 if member of a livestock group, 0 otherwise	+
Dist_LA	Distance to the cottonseed cake supply point	Distance in kilometers	−
rumin_sedent	Size of sedentary herd	Number of sedentary animals in the household	+
pecc_rpfn	Perceived impact of climate change on natural pastures	1 if the producer perceives an impact, 0 otherwise	+
agricredi	Access to agricultural credit	1 if the producer received credit, 0 otherwise	+
actifs	Number of active household members	Number of individuals aged 15–65 in the household	+
contact_tech	Access to technical support by livestock extension agents	1 if the producer receives technical support, 0 otherwise	+

3.3. Model Selection and Specification

The adoption of agricultural innovations has been widely examined through econometric models aimed at formalizing farmers' decision-making behavior. Among the most commonly used approaches, qualitative response models are well-suited for analyzing discrete choices. However, traditional models may face limitations in capturing complex psychological or socio-demographic dimensions [54]. The logit model is particularly appropriate for studying binary or multinomial decision outcomes. As Riddington et al. [55] argue, discrete choice analysis seeks to model the probability of selection among a finite set of alternatives. This type of model has been applied in various related contexts, including climate change perception [56,57], the adoption of forage crops [53], and the use of agro-industrial by-products [28,33].

In this study, the logit model is employed to identify the factors influencing the decision of pastoral or agro-pastoral household heads to adopt cottonseed cake. The adoption of this model is consistent with the literature on technology adoption. Indeed, several authors, including Griliches [58] and Rogers et al. [59], describe the adoption process as exhibiting a logistic dynamic. This analysis specifically draws on the threshold decision theory proposed by Hill and Kau [60]. According to this approach, when agro-pastoralists face a binary decision—whether or not to adopt a given technology—a response threshold exists, which depends on a set of individual and contextual factors. Below this threshold, adoption does not occur; above it, a favorable decision is triggered. This behavior can be modeled as follows:

$$Y_i = \beta X_i + \mu_i \tag{2}$$

where $Y_i = 1$ if the farmer adopts cottonseed cake, and $Y_i = 0$ otherwise. More precisely,

$$Y_i = \begin{cases} 1, \ si \ X_i \geq X^* \\ x, \ si \ X_i < X^* \end{cases}$$

where X^* denotes the critical threshold, representing the combined effect of the explanatory variables that triggers the adoption decision. The model thus represents a binary choice framework in which the probability of adoption ($Y_i = 1$) is a function of individual characteristics X_i. This relationship can be expressed as

$$Pr(Y_i = 1) = F(\beta' X_i) \tag{3}$$

$$Pr(Y_i = 0) = 1 - F(\beta' X_i) \tag{4}$$

where F denotes a cumulative distribution function. In the case of the logit model, this is a logistic function. Therefore, the probability of adoption is given by

$$Pr(Y = 1) = \frac{e^{\beta' X}}{1 + e^{\beta' X}} \tag{5}$$

$$Pr(Y = 0) = \frac{1}{1 + e^{\beta' X}} \tag{6}$$

According to Greene [61], the conditional expectation of the model can be written as

$$E(Y/X) = F\left(e^{\beta' X}\right) \tag{7}$$

The estimations are conducted using STATA 18 software, employing the maximum likelihood estimation method, which is standard in the econometric analysis of nonlinear models. The estimated logit model is specified as follows:

$$logit(P_i) = ln\left(\frac{Pi}{1 - Pi}\right) = \alpha + \beta X_i + \epsilon_i \tag{8}$$

where P_i is the probability of adoption for individual i, α is the intercept, and ϵ_i is the error term. The empirical specification of the logit model is defined as

$$\begin{aligned} Y_i = \beta_0 + \beta_1 Dist_{LA} \quad & + \beta_2 age + \beta_3 instruction + \beta_4 actifs + \beta_5 association \\ & + \beta_6 contact_{tech} + \beta_7 rumin_{sedent} + \beta_8 agricredi \\ & + \beta_9 pasteur + \beta_{10} r_{elev} + \beta_{11} pecc_{rpfn} + \beta_{12} productlait + \mu_i \end{aligned} \tag{9}$$

where Y_i is a binary variable indicating whether the farmer adopt cottonseed cake, β_j are the parameters to be estimated, and μ_i is the error term.

3.4. Data and Descriptive Statistics

The data used in this study were collected through a field survey specifically designed for the purpose of this research. The selection of survey sites was guided by several criteria identified through a comprehensive literature review: (i) the importance of cotton production in the region, (ii) the presence of processing units that convert cottonseed into livestock feed—particularly cottonseed cake, and (iii) the high concentration of cattle and sheep farming in the Hauts-Bassins region of Burkina Faso. The sample size was determined using the standard formula for estimating a sample proportion:

$$n = \frac{t^2 p(1-p)}{e^2} \tag{10}$$

where:

n is the required sample size;

t = 1.96, corresponding to the value of the Student's t-distribution at the 95% confidence level;

p = 0.4, the estimated proportion of the target population;

e = 0.05, the tolerated margin of error.

Based on this formula, the final sample consists of 366 pastoral and agro-pastoral households. These were distributed across two provinces, Houet and Kénédougou, as detailed in Table 2 below:

Table 2. Sample distribution by province.

Province	Survey Locations	Number of Households Surveyed
Houet	Bama	89
	Farako-Bâ et Darsalamy	47
	Nasso	49
Total Houet		185
Kénédougou	Djigouera	56
	Kourouma	61
	Samorogouan	64
Total Kénédougou		181
Overall Total		366

Sources: Authors.

The questionnaire was developed and administered digitally using the KoboToolbox Collect application. This approach ensured a reliable and efficient data collection process, enabling immediate data validation and facilitating subsequent statistical analysis. The descriptive analysis of the survey data (Table 3) outlines the socio-economic characteristics of the surveyed livestock producers, explores their feeding practices, and highlights key factors likely to influence the adoption of cottonseed cake in pastoral and agro-pastoral systems in the Hauts-Bassins region.

The results show that the age of household heads ranges from 18 to 77 years, with an average age of 47. This relatively young average reflects a potentially dynamic and adaptable population, underscoring the importance of public policies that support agropastoral entrepreneurship and innovation. Milk production varies considerably across farms. While a few report annual outputs reaching up to 90,000 L, the average is approximately 925 L. These figures underscore the strategic role of the Hauts-Bassins region in national livestock production. According to the Ministry of Animal and Fisheries Resources [41], the region

accounts for 24% of Burkina Faso's total milk production and is home to around 20% of its dairy processing units. This strong performance is partly attributable to the availability of cottonseed cake, commonly used as a supplemental feed to enhance milk yields. Nonetheless, access to cottonseed cake remains uneven. On average, farms are located 46 km from supply points, with the farthest being 185 km away. Such logistical barriers can hinder adoption, particularly for producers in remote areas. As noted by Deffo et al. [26], longer supply chains are a major deterrent to the use of agro-industrial by-products. Annual non-livestock income shows significant variation among surveyed households, ranging from CFA 225,000 to 4,250,000, with a mean of CFA 1,561,925 and a standard deviation of 688,036. These disparities reflect substantial differences in the capacity of households to diversify income sources beyond livestock. Regarding herd structure, the number of sedentary ruminants varies greatly, averaging four animals per farm, with some producers managing up to seventy. Sedentarization often implies more intensive feeding strategies during the dry season, increasing reliance on agro-industrial supplements. From a human capital perspective, 68% of household heads have no formal education, only 8% have completed secondary education, and just 1% have attained post-secondary education. This low level of formal schooling may impede the uptake of new technologies, although extension services can play a compensatory role. In terms of collective organization, only 24% of livestock producers belong to a professional association. These associations are vital platforms for information exchange and training, particularly in the context of climate change adaptation. Notably, 73.5% of respondents reported experiencing negative impacts of climate change on the availability of natural grazing resources. This perception may serve as a driver for adopting complementary feed options such as cottonseed cake. Regarding occupational status, 20% of respondents are exclusively pastoralists, while the majority combine livestock rearing with crop farming. Agro-pastoralists, who have access to crop residues, may be more likely to integrate agro-industrial by-products into their feeding systems. Finally, although technical advisors are present in the region, access to their services is not yet universal. However, 89% of respondents reported having contact with at least one extension agent, suggesting strong potential for promoting the adoption of innovations. In contrast, only 10.4% of producers reported having access to agricultural credit, which limits their capacity to invest in improved feeding practices.

Table 3. Descriptive statistics of model variables.

Variable	Description	Mean	Std. Dev.	Min	Max
Adoption_tc	1 if the farmer adopts cottonseed cake; 0 otherwise.	0.39	0.49	0	1
Dist_LA	Distance to the supply point (km)	45.56	36.33	1	185
age	Age of the household head (in years)	47.41	11.13	18	77
instruction	Education level (0 = none, 4 = university)	0.67	1.07	0	4
actifs	Number of active household members (aged 15–65)	8.00	7.05	0	60
association	Member of a livestock producer association (1 = yes)	0.43	n/a	0	1
contact_tech	Contact with a livestock technician (1 = yes)	0.31	n/a	0	1
rumin_sedent	Number of sedentary ruminants on the farm	3.43	15.84	0	70
agricredi	Access to agricultural credit (1 = yes)	0.31	n/a	0	1
pasteur	Status as a pure pastoralist (1 = yes)	0.40	n/a	0	1
revenu	Annual non-livestock income (F CFA)	1,561,925	688,036	225,000	4,250,000
pecc_rpfn	Perception of climate change effects on pastures (1 = yes)	0.44	n/a	0	1
productlait	Annual milk production (liters)	925.55	4849.26	0	90,000

Source: Author's survey, June 2024.

4. Results

This study used a logit model to identify the determinants of cottonseed cake adoption among livestock producers in pastoral areas affected by climate change. Table 4 shows that the model shows a satisfactory fit, with a pseudo R^2 of 0.424, indicating that a substantial portion of the variance in adoption behavior is accounted for. The chi-square statistic was highly significant ($p < 0.001$), confirming the joint relevance of the explanatory variables. Results are reported as odds ratios: values above 1 indicate a positive effect on adoption, while values below 1 indicate a negative effect.

Table 4. Determinants of cottonseed cake adoption.

adopt_tc	Coef.	Robust St. Err.	t-Value	*p*-Value
pecc_rpfn	**5.747 *** **	**3.395**	**2.96**	**0.003**
pasteur	0.131 ***	0.086	−3.10	0.002
rumin_sedent	1.174 *	0.097	1.94	0.052
Dist_LA	0.976 ***	0.007	−3.66	0.000
instruction	2.415 *	1.241	1.72	0.086
age	1.006	0.022	0.26	0.796
actifs	0.992	0.039	−0.21	0.836
logrevenu	9.118 ***	4.803	4.20	0.000
agricredi	8.656 **	7.371	2.53	0.011
productlait	1.000	0.000	0.62	0.533
association	8.434 ***	4.672	3.85	0.000
contact_tech	5.368 *	5.27	1.71	0.087
Constant	0.00 ***	0.00	−4.30	0.000
Pseudo r-squared	*0.424*	*Number of obs*	*366*	
Chi-square	*41.809*	*Prob > chi2*	*0.000*	
Akaike crit. (AIC)	*134.099*	*Bayesian crit. (BIC)*	*184.834*	

Note: $p < 0.10$ (*), $p < 0.05$ (**), $p < 0.01$ (***). **Dependent variable:** adoption of cottonseed cake, defined as the use of the product at least four times over the past five years (2019–2023). Coded as: 1 = yes; 0 = no.

Among the variables considered, climate change perception appeared as a primary determinant. Producers who perceive a decline in natural pastures due to climate change were found to be almost six times more likely to adopt cottonseed cake (odds ratio = 5.747, $p < 0.01$). Economic characteristics also showed strong associations with adoption. The log-transformed household income variable had an odds ratio of 9.118, and access to agricultural credit showed an odds ratio of 8.656; both effects were statistically significant.

In terms of physical access, the distance to the point of purchase had a statistically significant negative effect (odds ratio = 0.976). Regarding individual and structural characteristics, being a pastoralist was found to be associated with a much lower likelihood of adoption (odds ratio = 0.131), while the number of sedentary ruminants had a marginally significant positive effect (odds ratio = 1.174). The education level of the household head was also positively associated with adoption (odds ratio = 2.415; $p = 0.086$). Institutional variables also displayed strong associations. Membership in a professional association corresponded to an odds ratio of 8.434, and contact with agricultural extension agents to an odds ratio of 5.368.

5. Discussion

The empirical findings reinforce existing literature while also shedding light on context-specific dynamics in the Sahel. The strong influence of climate change perception supports the argument made by Aliyar et al. [62], Teklay et al. [63], and Cai et al. [64], who emphasize that perception is a key lever for behavioral change in response to environmental threats. The magnitude of this effect highlights the importance of cognitive and psychological

dimensions in shaping adaptation strategies. However, awareness alone is not sufficient. The role of economic resources, as underscored by Olutumise [65], demonstrates that financial constraints remain a major barrier to adopting agricultural innovations. Even with high awareness, limited purchasing power can inhibit action, indicating that efforts to promote adoption must be coupled with access to credit and income support.

Physical constraints also emerge as significant barriers. Our results align with Tede et al. [66] and Mutwedu et al. [33] who found that distance to markets and inadequate infrastructure hinder the adoption of feed technologies. These findings call for enhanced supply chain logistics and improved local availability of inputs. In line with this, lower adoption rates among pastoralists—confirmed by Deffo et al. [26] and Cisse [67]—highlight the structural limitations of more mobile systems, which often lack the logistical capacity to incorporate commercial feeds. Conversely, the increase in sedentary livestock suggests a shift toward more integrated production systems, likely as an adaptation strategy to declining access to pasture and water resources.

Furthermore, education plays a decisive role. As shown in the studies by Asfaw et al. [68] and Oli et al. [31], education enhances awareness and openness to new technologies, thereby facilitating adoption. Finally, the critical importance of social and institutional structures is reaffirmed. Our findings echo those of Wang and Xu [69], Iyabano et al. [70], and Baba et al. [25], who stress the role of farmer associations and extension services in disseminating knowledge, reducing uncertainty, and fostering trust in innovative practices.

6. Conclusions and Policy Implications

This study contributes to a deeper understanding of the factors driving the adoption of agro-industrial by-products in livestock systems in Sub-Saharan Africa, with a particular focus on the role of climate change perception. Using a binary logit model applied to original survey data collected from pastoral and agro-pastoral producers in the Hauts-Bassins region of Burkina Faso, the analysis reveals that adoption decisions are shaped not only by structural determinants—such as education, market access, and financial capacity—but also by producers' subjective interpretations of environmental changes.

The findings underscore that herders who perceive climate change as a direct threat to the availability of natural feed resources are significantly more likely to adopt adaptive practices, notably the use of cottonseed cake as a supplemental feeding strategy. This suggests that perception is a powerful cognitive lever in guiding behavioral responses to climatic stress, thereby enriching conventional models of technology adoption that tend to emphasize technical or economic constraints alone.

Beyond the perceptual dimension, this study also identifies several complementary drivers of adoption, including household income, access to credit, membership in producer organizations, level of education, and contact with extension agents. These findings point to the need for integrated policy responses that address both tangible constraints (e.g., access to inputs and financial services) and intangible drivers such as awareness, perception, and social support networks.

However, this study is not without limitations. First, the cross-sectional nature of the data limits the ability to establish causal relationships or track changes in adoption behavior over time. Longitudinal or panel data would allow for a more robust assessment of dynamic adaptation pathways. Second, while the binary logit model provides clear insights into the likelihood of adoption, it does not capture variations in the intensity or frequency of cottonseed cake use, which could be explored using count models or continuous adoption indices. Third, this study focuses on a single region, which may limit the generalizability of the findings to other agro-ecological zones or countries with different institutional and market contexts.

Future research could address these limitations by incorporating time-series or panel data, extending the analysis to other regions within the Sahel, and exploring complementary qualitative methods to gain deeper insights into behavioral drivers. It would also be valuable to assess the long-term effects of cottonseed cake adoption on livestock productivity, household income, and resilience outcomes, especially under scenarios of increasing climate variability.

From a policy standpoint, the results call for more perception-sensitive extension strategies. Recognizing that behavioral responses are shaped not only by economic incentives but also by how herders perceive and interpret environmental risks can help design more effective outreach, training, and communication tools. Policymakers and development partners should also invest in strengthening input supply chains, improving rural infrastructure, and expanding access to credit—particularly for mobile pastoralist groups, who face greater adoption constraints. Supporting producer organizations and enhancing extension coverage can also serve as critical levers for accelerating the uptake of resilient feeding practices across livestock systems in the region.

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References

1. Beigh, Y.A.; Ganai, A.M.; Rather, M.A.; Athar, H.; Hamdani, S.A. Livestock feed resources availability, feeding practices, and nutrient balances in high Himalaya (Gurez) valley of Kashmir. *Trop. Anim. Health Prod.* **2020**, *52*, 2469–2480. [CrossRef] [PubMed]
2. Koutou, M.; Sangaré, M.; Havard, M.; Vall, E.; Sanogo, L.; Thombiano, T.; Vodouhe, D. Adaptation des prati ques d'élevage des producteurs de l'Ouest du Burkina Faso face aux contraintes foncières et sanitaires. *Agron. Afr.* **2016**, *28*, 13–24.
3. Duguma, B.; Janssens, G.P.J. Assessment of Livestock Feed Resources and Coping Strategies with Dry Season Feed Scarcity in Mixed Crop–Livestock Farming Systems around the Gilgel Gibe Catchment, Southwest Ethiopia. *Sustainability* **2021**, *13*, 10713. [CrossRef]
4. Benamara, M.; Chihaoui, A. *Estimation du Coût de Production du Lait de Vache Dans les Élevages de la Région de Tizi-Ouzou*; Université Mouloud Mammeri: Tizi Ouzou, Algérie, 2023.
5. Sodre, E.; Moulin, C.-H.; Ouedraogo, S.; Gnanda, I.B.; Vall, E. Improving dairy cows feeding practices in the dry season: A strategy to increase the income of smallholder dairy farmers in Burkina Faso. *Cah. Agric.* **2022**, *31*, 12.
6. Kubkomawa, H.; Olawuye, H.; Krumah, L.; Etuk, E.; Okoli, I. Nutrient requirements and feed resource availability for pastoral cattle in the tropical Africa: A review. *J. Agric. Crop Res.* **2015**, *3*, 100–116.
7. McGrath, J.; Duval, S.M.; Tamassia, L.F.M.; Kindermann, M.; Stemmler, R.T.; de Gouvea, V.N.; Acedo, T.S.; Immig, I.; Williams, S.N.; Celi, P. Nutritional strategies in ruminants: A lifetime approach. *Res. Vet. Sci.* **2018**, *116*, 28–39. [CrossRef] [PubMed]
8. Kiema, A.; Tontibomma, G.B.; Zampaligré, N. Transhumance et gestion des ressources naturelles au Sahel: Contraintes et perspectives face aux mutations des systèmes de productions pastorales. *VertigO-La* **2015**, *14*, 1–16. [CrossRef]
9. Bayala, E.R.C.; Ros-Tonen, M.; Sunderland, T.; Djoudi, H.; Reed, J. Farmer-Fulani pastoralist conflicts in Northern Ghana: Are integrated landscape approaches the way forward? *For. Trees Livelihoods* **2023**, *32*, 63–89. [CrossRef]
10. Bikila, N.G.; Tigist, S.B. Assessment of livestock feed resources and feeding systems in Haramaya district, Eastern Ethiopia. International Journal of Livestock Production. *Int. J. Livest. Prod.* **2016**, *7*, 106–112. [CrossRef]
11. Maman Lawal, A.A. *Aspects Socioéconomiques de l'utilisation des Résidus de Cultures et Sous-Produits Agro-Industriels dans l'alimentation des Ruminants Domestiques à Niamey (Niger)*; Ecole Inter-Etats des Sciences et Médecine Vétérinaires de Dakar: Dakar, Senegal, 2014.

12. Bambio, Z.F. Burkina Faso: Plus de 14 Milliards de F CFA Dépensés dans l'importation de Lait et de Produits Laitiers en 2020. Available online: https://www.investirauburkina.net/secteurs-et-marches/commerce/burkina-faso-plus-de-14-milliards-de-f-cfa-depenses-dans-limportation-de-lait-et-de-produits-laitiers-en-2020.html (accessed on 17 July 2025).
13. FAO. *FAOSTAT: Crops and Livestock Products*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2023.
14. Warner, A.L.; Beck, P.A.; Foote, A.P.; Pierce, K.N.; Robison, C.A.; Hubbell, D.S.; Wilson, B.K. Effects of utilizing cotton byproducts in a finishing diet on beef cattle performance, carcass traits, fecal characteristics, and plasma metabolites. *J. Anim. Sci.* **2020**, *98*, skaa038. [CrossRef] [PubMed]
15. Montcho, M.; Babatounde, S.; Aboh, B.A.; Bougouma-Yameogo, V.; Chrysostome, A.; Mensah, G.A. Utilisation des sous-produits agricoles et agro-industriels dans l'alimentation des ovins Djallonké au Bénin: Perception des éleveurs, préférences et performances de croissance. *Afr. Sci.* **2017**, *13*, 174–187.
16. Mullins, E.P.; Poore, M.H.; Shaeffer, A.; Harmon, D.D.; Pickworth, C.L. Availability and Management of Cotton Byproducts in North Carolina: A State Survey. *J. Anim. Sci.* **2021**, *99*, 7. [CrossRef]
17. Silva, R.V.M.M.; Carvalho, G.G.P.d.; Pires, A.J.V.; Pereira, M.L.A.; Pereira, L.; Campos, F.S.; Perazzo, A.F.; Araújo, M.L.G.M.L.d.; Nascimento, C.d.O.; Santos, S.A.; et al. Cottonseed cake in substitution of soybean meal in diets for finishing lambs. *Small Rumin. Res.* **2016**, *137*, 183–188. [CrossRef]
18. de Assis, D.Y.C.; de Oliveira, F.A.; Santos, E.M.; de Gouvêa, A.A.L.; de Carvalho, B.M.A.; Nascimento, C.D.O.; Cirne, L.G.A.; Pina, D.D.S.; Pires, A.J.V.; Alba, H.D.R.; et al. Carcass and meat traits of goats fed diets containing cottonseed cake. *Arch. Anim. Breed.* **2021**, *64*, 395–403. [CrossRef] [PubMed]
19. Arcanjo, A.H.M.; Ítavo, L.C.V.; Ítavo, C.C.B.F.; Franco, G.L.; Dias, A.M.; dos Santos Difante, G.; de Assis Lima, E.; Santana, J.C.S.; Gurgel, A.L.C. Cotton cake as an economically viable alternative fibre source of forage in a high-concentrate diet for finishing beef cattle in feedlots. *Trop. Anim. Health Prod.* **2022**, *54*, 112. [CrossRef] [PubMed]
20. Belem, A.; Ouédraogo-Koné, S.; Lankoandé, Y.; Koulibaly, B.; Sakandé, F.; Bamogo, A.; Traoré, M. Evaluation du potentiel fourrager des residus de recolte dans les exploitations cotonnieres a l'ouest du Burkina Faso. *Afr. J. Food Agric. Nutr. Dev.* **2024**, *24*, 26531–26553. [CrossRef]
21. Arcanjo, A.H.M.; Ítavo, L.C.V.; Ítavo, C.C.B.F.; Dias, A.M.; dos Santos Difante, G.; Franco, G.L.; Longhini, V.Z.; Gomes, F.d.K.; Ali, O.; Santana, J.C.S.; et al. Effectiveness of cottonseed cake fibre included in the diet of Nellore steers finished in confinement. *N. Z. J. Agric. Res.* **2024**, *67*, 268–282. [CrossRef]
22. Zeeshan, M.; Fatima, S.A.; Ullah, S.; Farooq, U.; Ali, S. 17. Effect of supplementing various proteinaceous cakes on milk yield, milk composition and feed intake of lactating Damani goats. *Pure Appl. Biol. (PAB)* **2021**, *11*, 169–174.
23. Mullenix, K.K.; Stewart, L. Cotton Byproduct Use in Southeastern Beef Cattle Diets: Quality, Intake, and Changes in Feed Characteristics. *J. Anim. Sci.* **2021**, *99*, 18–19. [CrossRef]
24. Idrissou, Y.; Worogo, H.S.S.; Assani, A.S.; Ayena, J.A.; Assogba, B.G.C.; Traoré, I.A. Cottonseed cake replacement by soybean pulp in the diet of West African Dwarf lambs in Benin: Zootechnical and economic performances. *Rev. D'élevage Médecine Vétérinaire Pays Trop.* **2020**, *73*, 107–111. [CrossRef]
25. Baba, S.; Dagong, M.I.A.; Sohrah, S.; Utamy, R.F. Factors Affecting the Adoption of Agricultural By-Products as Feed by Beef Cattle Farmers in Maros Regency of South Sulawesi, Indonesia. *Trop. Anim. Sci. J.* **2019**, *42*, 76–80. [CrossRef]
26. Deffo, V.; Ottou, J.F.B.; Messiné, O.; Achundoh, L.E.; Djoumessi, M. Facteurs socio-économiques affectant l'utilisation des sous-produits agro-industriels pour l'embouche bovine à contre-saison dans l'Adamaoua, Cameroun. *BASE* **2009**, *13*, 357–365.
27. Alkhtib, A.; Wamatu, J.; Kassie, G.T.; Rischkowsky, B. Analysis of crop residue use in small holder mixed farms in Ethiopia. *Renew. Agric. Food Syst.* **2017**, *32*, 454–462. [CrossRef]
28. Mamine, F.; Boumali, N.E.I.; Montaigne, E.; Arbouche, F. Why Farmers Adopt Agro-Industrial By-Products in Animal Feed? Lesson Learned in Algerian Case. *Ann. Soc. Sci. Manag. Stud.* **2020**, *5*, 107–113. [CrossRef]
29. Chen, R.; Su, Y.; Tran, L. Small Farmer's Perceptions of Climate Change and Adoption of Climate-Smart Practices: Evidence from Missouri, USA. *Sustainability* **2024**, *16*, 9525. [CrossRef]
30. Kassa, B.A.; Abdi, A.T. Factors Influencing the Adoption of Climate-Smart Agricultural Practice by Small-Scale Farming Households in Wondo Genet, Southern Ethiopia. *SAGE Open* **2022**, *12*, 21582440221121604. [CrossRef]
31. Oli, D.; Gyawali, B.; Acharya, S.; Oshikoya, S. Factors influencing learning attitude of farmers regarding adoption of farming technologies in farms of Kentucky, USA. *Smart Agric. Technol.* **2025**, *10*, 100801. [CrossRef]
32. Tiyo, C.E.; Orach-Meza, F.; Edroma, E.L. Understanding small-scale farmers' perception and adaption strategies to climate change impacts: Evidence from two agro-ecological zones bordering national parks of Uganda. *J. Agric. Sci.* **2015**, *7*, 253. [CrossRef]
33. Mutwedu, V.B.; Bacigale, S.B.; Mugumaarhahama, Y.; Muhimuzi, F.L.; Munganga, B.; Ayagirwe, R.B.B.; Dontsop Nguezet, P.M.; Manyawu, G. Smallholder farmers' perception and challenges toward the use of crop residues and agro-industrial byproducts in livestock feeding systems in Eastern DR Congo. *Sci. Afr.* **2022**, *16*, e01239. [CrossRef]
34. Swidiq, M.; Jolly, K.; Emmanuel, Z.; George, L. Utilization of crop residues and agro-industrial by-products in livestock feeds and feeding systems of Uganda. *Int. J. Biosci.* **2012**, *2*, 82–89.

35. INSD (Institut National de la Statistique et de la Démographie). *Annuaire Statistique 2022 de la Région des Hauts Bassins*; Institut National de la Statistique et de la démographie (INSD): Ouagadougou, Burkina Faso, 2023; p. 325.
36. Les 10 Éléments de l'agroécologie. *Guider la Transition vers des Systèmes Alimentaires et Agricoles Durables*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2018.
37. Sib, O.; Bougouma-Yameogo, V.M.C.; Blanchard, M.; Gonzalez-Garcia, E.; Vall, E. Production laitière à l'ouest du Burkina Faso dans un contexte d'émergence de laiteries: Diversité des pratiques d'élevage et propositions d'amélioration. *Rev. D'elevage Médecine Vétérinaire Pays Trop.* **2017**, *70*, 81–91. [CrossRef]
38. Liehoun, E.B.; Daget, P.; César, J. Activités de pâturage, biodiversité et végétation pastorale dans la zone Ouest du Burkina Faso. *Rev. D'élevage Médecine Vétérinaire Pays Trop.* **2006**, *59*, 31–38. [CrossRef]
39. FAO. *Résidus Agricoles et Sous-Produits Agro-Industriels en Afrique de l'ouest*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2014; p. 73.
40. Tensaba, R.S.; Kiema, A.; Zongo, M.; Gnanda, B.I.; Tiema, A.K.P. Ressources alimentaires et stratégies d'alimentation des petits ruminants en Région Centre-Nord du Burkina Faso. *J. Appl. Biosci.* **2023**, *182*, 19007–19017. [CrossRef]
41. MRAH (Ministère des Ressources Animales et Halieutiques). *Annuaire Statistique de l'élevage*; Ministère des ressources animales et halieutiques: Abidjan, Côte d'Ivoire, 2019; p. 35.
42. Savage, L.J. *The Foundations of Statistics*; John Wiley & Sons Ltd.: Hoboken, NJ, USA, 1954; Volume 1.
43. Danilov, V.I.; Lambert-Mogiliansky, A. Expected utility theory under non-classical uncertainty. *Theory Decis.* **2010**, *68*, 25–47. [CrossRef]
44. CIMMYT. *The Adoption of Agricultural Technology: A Guide for Survey Design*; CIMMYT: Texcoco, Mexico, 1993.
45. Feder, G.; Just, R.E.; Zilberman, D. Adoption of agricultural innovation in developing countries: A survey. *Econ. Dev. Cult. Change* **1985**, *33*, 255–298. [CrossRef]
46. Mignouna, D.B.; Manyong, V.M.; Rusike, J.; Mutabazi, K.D.S.; Senkondo, E.M. Determinants of Adopting Imazapyr-Resistant Maize Technologies and its Impact on Household Income in Western Kenya. *AgBioForum* **2011**, *14*, 158–163.
47. Uaiene, R.N. Determinants of agricultural technical efficiency and technology adoption in Mozambique. Ph.D. Thesis, Purdue University, West Lafayette, Indiana, 2008.
48. Amadou, H.; Magnani, S.D. Améliorer l'accès des Éleveurs à une Alimentation du Bétail de Qualité Pour Augmenter la Production Laitière dans les Pays Sahéliens d'Afrique de l'Ouest. Ph.D. Thesis, OXFAM, Oxford, UK, 2020.
49. Adéoti, R.; Coulibaly, O.; Tamo, M. Facteurs affectant l'adoption des nouvelles technologies du niébé Vi-gna unguiculata en Afrique de l'Ouest. *Bull. Rech. Agron. Bénin* **2007**, *36*, 19–32.
50. Diiro, G.M. *Impact of Off-Farm Income on Agricultural Technology Adoption Intensity and Productivity: Evidence from Rural Maize Farmers in Uganda*; International Food Policy Research Institute: Washington DC, USA, 2013.
51. Reardon, T.; Stamoulis, K.; Pingali, P. Rural nonfarm employment in developing countries in an era of globalization. *Agric. Econ.* **2007**, *37*, 173–183. [CrossRef]
52. Foster, A.D.; Rosenzweig, M.R. Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. *J. Political Econ.* **1995**, *103*, 1176–1209. [CrossRef]
53. Hamadou, S.; Kamuanga, M.; Abdoulaye, A.; Lowenberg-Deboer, J. Facteurs affectant l'adoption des cultures fourragères dans les élevages laitiers périurbains de Bobo-Dioulasso (Burkina Faso). *Tropicultura* **2005**, *23*, 29–35.
54. Kini, J. *Analyse des Déterminants de L'adoption des Technologies de Conservation des Eaux et des Sols au Burkina Faso. Mémoire de Master*; Université de Ouagadougou: Ouagadougou, Burkina Faso, 2007. Available online: https://www.memoireonline.com/09/11/4812/Analyse-des-determinants-de-ladoption-des-technologies-de-conservation-des-eaux-et-des-sols-au-B.html (accessed on 18 July 2025).
55. Riddington, G.; Sinclair, C.; Milne, N. Modelling choice and switching behaviour between Scottish ski centres. *Appl. Econ.* **2000**, *32*, 1011–1018. [CrossRef]
56. Habtemariam, L.T.; Gandorfer, M.; Kassa, G.A.; Heissenhuber, A. Factors Influencing Smallholder Farmers' Climate Change Perceptions: A Study from Farmers in Ethiopia. *Environ. Manag.* **2016**, *58*, 343–358. [CrossRef] [PubMed]
57. Kabore, P.; Barbier, B.; Ouoba, P.; Kiema, A.; Some, L.; Ouedraogo, A. Perceptions du changement climatique, impacts environnementaux et stratégies endogènes d'adaptation par les producteurs du Centre-nord du Burkina Faso. *VertigO* **2019**, *19*, 1–29.
58. Griliches, Z. Hybrid Corn: An Exploration in the Economics of Technological Change. *Econometrica* **1957**, *25*, 501–522. [CrossRef]
59. Rogers, E.M.; Singhal, A.; Quinlan, M.M. Diffusion of innovations. In *An Integrated Approach to Communication Theory and Research*; Stacks, D.W., Salwen, M.B., Eichhorn, K.C., Eds.; Routledge: New York, NY, USA, 2014; pp. 432–448.
60. Hill, L.; Kau, P. Application of Multivariate Probit to a Threshold Model of Grain Dryer Purchasing Decisions. *Am. J. Agric. Econ.* **1973**, *55*, 19–27. [CrossRef]
61. Greene, W.H. *Econometric Analysis*; Pearson Education India: Upper Saddle River, NJ, USA, 2003; p. 827.

62. Aliyar, Q.; Keshavarz, M.; Salari, M.W.; Haro-Monteagudo, D.; Esmaelnejad, M.; Collins, N. Perceptions of and adaptation to climate change in mountainous agro-pastoral communities: The case of the Afghan central highlands. *Clim. Risk Manag.* **2024**, *45*, 100639. [CrossRef]
63. Teklay, A.; Ayalew, A.; Abate, A.; Ashenafi, M.; Marye, A.T.; Tilahun, A.; Bayabil, H.K.; Kassa, A.; Birara, H.; Gurebiyaw, K.; et al. Climate change perceptions and adaptation responses among smallholder farmers across three locations in Megech Watershed, Ethiopia. *Clim. Serv.* **2025**, *38*, 100566. [CrossRef]
64. Cai, Y.; Khan, A.; Zhao, M. Understanding herders' risk perceptions and preferences for climate change adaptations: An empirical study of pre and post disaster. *Int. J. Agric. Sustain.* **2025**, *23*, 2493400. [CrossRef]
65. Olutumise, A.I. Impact of credit on the climate adaptation utilization among food crop farmers in Southwest, Nigeria: Application of endogenous treatment Poisson regression model. *Agric. Food Econ.* **2023**, *11*, 7. [CrossRef]
66. Tede, S.; Sodjinou, E.; Hinnou, L.C. Déterminants de l'adoption des technologies de sédentarisation de la production d'igname au Centre-Bénin: Une analyse basée sur la régression probit. *Ann. L'université Parakou-Série Sci. Nat. Agron.* **2023**, *13*, 85–100. [CrossRef]
67. Cisse, P. Comportements des éleveurs sahéliens maliens face à la variabilité climatique. *Rev. Géographie Trop. D'environnement* **2014**, *1*, 107–121.
68. Asfaw, S.; Shiferaw, B.; Simtowe, F.; Lipper, L. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy* **2012**, *37*, 283–295. [CrossRef]
69. Wang, G.; Xu, M. Effect of cooperative membership on farmers' technology adoption based on the mediating effects of technology cognition. *Heliyon* **2025**, *11*, e42130. [CrossRef] [PubMed]
70. Iyabano, A.; Klerkx, L.; Faure, G.; Toillier, A. Farmers' Organizations as innovation intermediaries for agroecological innovations in Burkina Faso. *Int. J. Agric. Sustain.* **2022**, *20*, 857–873. [CrossRef]

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