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Modeling Agro-pastoralists' Preferences for endogenous and exogenous climate change adaptation strategies in Ibecetan Ranch, Niger Republic

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Abstract
A smart crop-livestock production system is becoming increasingly proposed and promoted as a mean to help agro-pastoralists in resilience building capacity. In addition, climate change adaptation packages have also been disseminated amongst agro-pastoralists. However, little is relatively known about the optimal combination of climate change adaptation strategies capable of enhancing agro-pastoralists' welfare. Based on synthesis of previous studies and survey with agro-pastoralists, thirteen endogenous and thirteen exogenous climate change strategies were identified and included in this study. We use best worst scaling approach (BWS) to design questionnaire served to collect data from 271 agro-pastoralists assigned to endogenous strategies and 281 randomly assigned to exogenous ones. For each question, respondents were asked to choose his most important and his least important climate change adaptation strategies. While these repeated choice series are consistent with random utility theory, the mixed logit model was employed to analyze data. Results reveal that settlement, emergency destocking, prolific animal selection, water and soil conservation activities, strategic mobility, transhumance and mutual assistance are the most important climate change adaptation strategies for agro-pastoralists. Results also suggest that multi-nutritional block, straw treatment, corridors marking up and assisted natural regeneration are the most important exogenous climate change adaptation strategies for agro-pastoralists. These findings may be used to address future challenges related to climate change and thereby ensuring sustainable development in the study area and beyond.

Keywords: *Agro-pastoralists, climate change adaptation, strategies, best worst scaling*

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I. Introduction

Climate change has been considered as one of the biggest challenges to international peace and security. Sub-Saharan Africa is one of the most affected continents in the world, while countries in the Sahel are the most vulnerable in terms of capacity to adapt and build resilience to the negative externalities of climate change. Furthermore, smallholder farmers in Niger are the most vulnerable to the changing climate negative effects because their adaptation measures are not properly coordinated and organized. The Intergovernmental Panel on Climate Change (IPCC, 2012) concluded that African countries relying heavily on rainfed-agriculture and livestock production will experience drought and water shortage, reduction in crop yields, increase in food insecurity, malnutrition and health related issues due to the changing climate. Significant relationship between climate change and some key socioeconomic variables such as food and nutritional security, migration, social stability and public health has been well-established and documented in climate change literature. However, smallholder farmers and agro-pastoralists' coping and resilience building capacity are poorly researched and documented.

Firstly, several studies have indicated that the relationship between the climate change and food and nutritional security is well established. Therefore, climate change is considered as a real challenge and threat to food and nutrition security, thereby increasing the rate of famine in the last three years in the world. In addition, the number of people who are hungry has increased, in 2016, 38 million compared to 2015. This number of people has continued to increase in 2017 and 2018. This means that climate change can compromise one of the major objectives of the sustainable development goals relative to zero hunger in the world by 2030. Livelihood diversification is now an important aspect that minimizes the effects of climate change on food security and becoming an important adaptation strategy. Furthermore, climate change is projected to affect all four dimensions of food security such food availability, food accessibility, food utilization and food system stabilization, which are impacting human health, livelihood asset, food production and marketing as well as purchasing power and market flows (FAO, 2008). Finally, high priority should be given to the most vulnerable and food insecure such as agriculture-based livelihood systems and low-income people and pastoralists.

Secondly, studies conducted in the Sahel also showed that the correlation of climate change on security and social and political stability is well-documented. For example, the birth and development of Boko Haram is in partly linked to the impoverishment of the population due to the withdrawal of water from the Chad Lake, which has had an impact on agricultural, pastoral and fisheries resources at the level of the whole of the country and beyond. Consequently, the established link between climate change and terrorism is now established. Climate change is one of the pressing issues capable of threatening the lives and livelihoods of billion of people. The impact of climate change on national security, military and energy security is real and adaptation measures should be developed and disseminated. The impacts of a warming world will also increase the risk of state fragility and instability (IPCC, 2018). While ecosystem, dry land regions, small-island developing states, and least developed countries are disproportionately vulnerable to climate change, higher negative externality are placed on disadvantaged and vulnerable populations such as some indigenous peoples, and local communities because they dependent on agricultural or coastal livelihoods (IPCC, 2018).

Thirdly, previous studies have also indicated that the relationship between the climate change and public health in African countries has been widely searched and documented. Human health has been increasingly affected by the changing climate. Thus, studies have reported that extreme temperatures and cold not only result in deaths, but also lead to changing habitat favoring the breeding of vectors by causing the spread of diseases such as malaria, cholera and typhus. They also concluded that appropriate adaptation measures such as weather-based forecasting and early warning systems, public education and awareness, putting in place appropriate policies, surveillance, research and monitoring as well as improving public health infrastructure and technology are key to make African nation's public health sector more resilient (Nhamo and Muchuru, 2019). The climate change is also causing environmental pollution, which negatively affects human health. Depledge et al. (2013) also reported that human health is increasingly become exposed and contaminated by accumulated chemicals mostly found in air, water and food, thereby leading to diseases such as cardiovascular diseases, cancers and diabetes. Finally, the climate change might generally jeopardize the achievement of sustainable development goals and those related to health (Nhamo, 2017).

Fourthly, others studies related to the situation in the Sahel suggest that there is strong link between climate change and migration. Many migrants leaving the Sahel are considered as climate migrants in the Western nations. This migration is likely to increase because the global warming will be more marked at the end of the century in the Sahel as compared to the rest of the world. It will record temperature increases exceeding +4°C in the western part, while on the coast and near the southern limit the rise will be less marked, but will reach a peak of +3°C. Therefore, the Sahel will probably be one of the main regions of origin of the 250 million migrants expected in 2050 in the world. By way of comparison, this figure is three times higher than migrants caused by the Second World War (Climate Commission for the Sahel Region, 2019). Also, the International Panel on Climate Change fifth assessment report indicates that countries have the potential of reducing the impacts of climate change through effective adaptation measures (IPCC, 2012). The seasonal migration of pastoralists has been negatively affected by climate change, thereby reducing the availability and accessibility water and forage resources and resulting in increased conflict amongst pastoralists, between pastoralists and sedentary farmers (UN, 2009). Additionally, the change in feed quality, spread of diseases and water availability will adversely affect the livestock sector, thereby reducing pastoralists' livelihoods.

Fifthly, to reduce greenhouse gas emissions, Niger as an active member of the United Nations Framework Convention on Climate Change, has prepared and submitted its contribution drafting attenuation and adaptation measures. This commitment primarily focused on the issue of Sustainable Land Management, the question related to smart agriculture, the limited access to sustainable energy and income and food diversification strategies, should ultimately lead Niger to establish a sustainable economy, low carbon and which ensures greater food and nutritional security. These strategies and policies take into account the challenges such as the interactions between climate change, demographic dynamics and migration. The places that we have visited, the people that we have met and histories that we have heard have significantly shaped our understanding and views about climate change. However, little is relatively known how agro-pastoralists develop resilience building capacity and there is also scanty information how they value exogenous climate change adaptation strategies.

Finally, studies have recently reported that the pastoral system in semi-arid is becoming increasingly affected by the changing climate. Fema et al. (2018) stated that agro-pastoralists are practicing various climate change adaptation strategies, while pastoralists are relying on livestock rearing as source of income. Therefore, agro-pastoralists had better adaptive capacity and are less vulnerable to climate change than pastoralists, implying that pastoral system is increasingly become a risky enterprise. Climate change adaptation strategies based on agro-pastoralists' endogenous strategies as well as exogenous levels should be considered as a better candidate for effective resilience capacity building. Sharing experiences at local, regional, national and global levels are also necessary to build resilience capacity amongst counties, regions, countries and continents. A number of both exogenous, endogenous and hybrid climate change adaptation strategies have been proposed to reduce negative externalities in developing countries.

Previous studies have indicated that exogenous and agro-pastoralists' strategies have been well documented, but relatively few studies have focused on determining the optimal combination capable of enhancing agro-pastoralists' climate change adaptation strategies. This would greatly enhance agro-pastoralists' resilience building capacity in the study area and beyond. This study addresses the question how to determine the optimal combination of endogenous and exogenous climate change adaptation strategies capable of enhancing agro pastoralists' welfare.

II. METHODOLOGY

This section presents how questionnaire was designed and how data were collected and analyzed. Agro-pastoralists living in Ibecetan's ranch are consistently facing challenges and urgent actions should be undertaken to help agro-pastoralists in the resilience building capacity process.

2.1 Conceptual framework

The authors assume that agro-pastoralists maximize their welfare when they are asked to make repeated choices about their best and their worst climate change adaptation strategies. The development agencies, the government should develop plan action based on agro pastoralists' choices and aspirations. The bottom up approach which emphasizing on agro-pastoralists participation and view regarding their life improvement should be targeted as a ways forward. The authors assumed that the difference between the best and worst endogenous and exogenous strategies is consistent with random utility theory, which is well rooted in microeconomic theory. This underlying behavior process can be mathematically represented as follows:

$$U_{njt} = \delta_{jt} - \delta_{kt} + \varepsilon_{njt} \qquad (1)$$

Where δ is the vector of estimated importance parameters of the best and worst climate change policies (j and k respectively) relative to some policy normalized to zero for identification reasons. The probability that respondents select item j as best and k as worst out of J items in BWS question t is the probability that the difference in utility of the chosen items (δ_{njt} and δ_{nkt}) is greater than all other J(J-1)-1 possible differences within each BWS question (Lusk and Briggeman, 2009).

2.2 Data collection

Data were collected in the Ibecetan Ranch, which is located at 100 km from Tahoua State. Established in 1975 and with an area of 420.000 ha, the objective of this ranch is to rebuild the cattle herd seriously decimated by 1974 drought. It also involves in multiplying and selecting the Azawak species. Finally, the center is also engaged in milk and cheese production and marketing.

The best worst scaling (BWS) is increasingly used in various fields of study. In various fields, BWS was used to collect data as choice experiment. In the field of agricultural economics, the use of BWS is still in its infancy and there is need to investigate the merit of several experimental design techniques. The balanced incomplete block design (BIBD) was used to design questionnaire served in the data collection. Respondents were randomly selected and interviewed. To increase diversity in our sample, a specific gender is targeted within a given household, thereby creating opportunity for rural women to get their voices heard. In total, 271 and 281 respondents were respectively selected for exogenous and endogenous strategies and interviewed. As shown in Figure 1 and Figure 2, are example of a question related to endogenous and exogenous strategies are presented.

Figure 1. Please select your best and worst endogenous strategies

Best	Endogenous Strategies	Worst
	Strategic mobility	
	Transhumance	
	Settlement	
	Human capacity building	

Sample of best worst scaling format used for exogenous strategies

Figure 2. Please select your best and worst exogenous strategies

Best	Exogenous Strategies	Worst
	Multi-nutritional block	
	Assisted natural Regeneration	
	Strategic feed storage	
	Mutual assistance	

Sample of best worst scaling format used for exogenous strategies

2.2 Data analysis

Agro-pastoralists are asked to make repeated choices about their best and worst strategies to build resilience capacity. This process is consistent with random utility function (Lusk and Rock, 2017). The algorithm thinking approach constructed with SAS was used to determine the weight of each strategy. For each question, respondents are facing J(J-1) possible combinations, indicating that each strategy has equal chance of being selected as the most and the worst strategy. The authors have followed the methods developed by Lusk and Briggeman (2009) stating that in a set of J elements, there are J(J-1) possible combinations. They have further highlighted that the choice of a pair of strategies in the J(J−1) combinations corresponds to a maximum allocation of the choice difference. Thus, this probability that a given person n selects j as best and k as worst can be mathematically represented as follows:

$$P_{nj} = \int \delta \prod_{t=1}^{T} \frac{e^{[\delta_{njt}-\delta_{nkt}]}}{\sum_{l=1}^{J}\sum_{m=1}^{J} e^{[\delta_{nlt}-\delta_{nmt}]-J}} f(\delta_n) d\delta_n \qquad (2)$$

Where $f(\delta_n)$ is the density of the importance parameters δ_n.

Thirdly, shares of preferences for each climate change adaptation adaptation can be expressed as follows:

$$\varphi_j = \frac{e^{\delta_j}}{\sum_{k=1}^{J} e^{\delta_k}} \qquad (3)$$

Where φ_j is the share of preference for a given climate change adaptation strategies.

The best and worst scaling method is increasingly used as data collection as well as choice experiment framework. The authors have used BWS to evaluate 13 strategies. These strategies were randomly assigned in 13 blocks each having four strategies. This implies that each strategy occurred four times through the entire block, indicating that the equal probability principle is held. For each question, respondents were asked to choose his best and worst strategies. The authors assumed that these repeated choices amongst best and worst items are consistent with utility theory, which is well-rooted in the microeconomics theory.

Finally, the mean and standard deviation obtained from the estimation the mixed logit model was used to calculate the probability above and below zero for each strategy. The authors assume that the ratio between the mean and standard deviation follows the standard normal distribution.

III. Results And Discussion

This section summarizes key results from the analysis. From Table 2 to Table 5 report the main results. Table 2 presents socioeconomic characteristics of agro pastoralists. Results show that most of agro pastoralists have an average of 40 years, implying that they have accumulated experience in agro pastoral production systems. Results also indicate that most of the agro pastoralists are married men with no formal education, implying that uneducated married men should be identified for sustainable production. Results also reveal that family size, large animal size and small animal size are respectively 8,16 and 24 on average, indicating that most household have accumulated human and animal capital. Finally, results show that most of agro pastoralists have indicated that climate change would have an impact on their immediate environment.

Table 2. Characteristics of surveyed respondents

Variable	Definition	Mean	Standard Deviation(SD)
Age	Age in number	40	12
Genre	1 if male, 0 female	0.76	0.42
Marital Status	2 if married, 0 otherwise	0.84	0.51
Education	1 uneducated, 0 other	0.25	0.22
Base: Income3	Above 180000 FCFA	0.00	1
Income1	Below 90000 FCFA	0.52	0.27
Income2	90000-180000 FCFA	0.27	0.52
Family size	Size in numbers	8	5
Large animal size	Size in numbers	16	18
Small animal size	Size in numbers	24	25
Climate and environment	1 if yes	0.87	0.49

SD stands for standard deviation. FCFA denotes local currency ($1=500FCFA)

Table 3 reports results from mixed logit model for adaptation package offered by exogenous and agro pastoralists' adaptation strategies. Coefficients with positive sign are preferred, while coefficients with negative sign are least important. Results show that multi-nutritional block, straw treatment, corridors marking up and assisted natural regeneration are positive and significant, implying that these strategies are the most important for agro pastoralists. However, fire band, vaccination and capacity building are negative and significant, indicating these strategies are the least important for agro pastoralists. Table 3 also presents standard deviations for each adaptation package. Thus, standard deviations for multi-nutritional block, straw treatment, corridors marking up, strategic feed storage, animal feed store, improved varieties, vaccination and capacity building are highly significant, indicating that coefficients of these strategies do indeed vary in the population. Table 3 also depicts climate change adaptation strategies developed by agro pastoralists. Results reveal that settlement, emergency destocking, prolific animal selection, water and soil conservation activities, strategic mobility, transhumance and mutual assistance are positive and highly significant, showing that these strategies are the most important for agro-pastoralists to enhance resilience building capacity in the ranch. In contrast, coefficients for strategic destocking and changing herd composition are negative and highly significant, revealing that these strategies are the least preferred among agro pastoralists. Furthermore, standard deviations of agro-pastoralists' climate change adaptation strategies are also reported in Table 2. Results indicate that standard deviations for settlement, emergency destocking, prolific animal selection, strategic mobility, transhumance, mutual assistance, sheep and goat fattening and changing herd composition are highly significant, signifying that coefficients for these strategies do indeed vary in the population. The most important climate change adaptation packages (multi-nutritional block, straw treatment, corridors marking up and assisted natural regeneration) and the most important climate change adaptation for agro-pastoralists(settlement, emergency destocking, prolific animal selection, water and soil conservation activities, strategic mobility, transhumance and mutual assistance) are the optimal combination strategies that should be implemented in the study area in order to build strong resilience capacity. These findings are consistent with a study by Tabbo and Amadou (2017) stating that combining endogenous and exogenous climate change adaptation strategies is capital to build strong resilience against negative externality induced by climate change. They have concluded that herd rebuilding by selecting the most prolific and environmentally friendly animals (goats and camels), human building capacity by training farmers how to use technology, introduction of aquaculture by improving food security and income, water and soil conservation by boosting food production and forage seed marketing by improving goat and sheep fattening are the most important climate change adaptation strategies, which are keeping producing successful stories. Furthermore, in planning adaptation process, it is important that local knowledge and belief should be acknowledged and that cultural identity should be safeguarded (Adger et al., 2009). Also, the degree and forms of vulnerability as well as the ways and manner different values will affect adaptation outcomes should be analyzed (Eriksen et al., 2011)

Table 3. Mixed logit model estimates based on agro pastoralists' and government climate change adaptation strategies

Exogenous strategies geared towards agro-pastoralists				Agro-pastoralists' climate change adaptation strategies			
Parameter	Estimate	SE	Probability	Parameter	Estimate	SE	Probability
Base: Grazing land seeding	0.000	0.000	0.000	Base: Forage cultivation	0.000	0.000	0.000
Multi-nutritional block	1.495	0.397	0.0002	Settlement	0.571	0.080	0.0001
Straw treatment	0.721	0.331	0.0296	Emergency destocking	0.369	0.075	0.0001
Corridors marking up	0.630	0.297	0.0341	Prolific animal selection	0.347	0.085	0.0001
Assisted natural Regeneration	0.608	0.297	0.0405	Water and soil conservation activities	0.299	0.068	0.0001
Strategic storage	0.601	0.416	0.1484	Strategic mobility	0.264	0.067	0.0001
River exploitation planning	-0.017	0.276	0.9524	Transhumance	0.214	0.069	0.002
Zootechnic and veterinary inputs	-0.067	0.166	0.6855	Mutual assistance	0.172	0.073	0.018
Animal feed store	-0.279	0.268	0.2983	Sheep and cattle fattening	0.080	0.074	0.280
Improved varieties	-0.318	0.189	0.0921	Income generating income	0.052	0.066	0.434
Fire band	-0.580	0.133	0.0001	Vaccination	-0.059	0.066	0.371
Vaccination	-0.635	0.314	0.043	Strategic destocking	-0.142	0.066	0.030
Human capacity building	-1.347	0.339	0.0001	Changing herd composition	-0.583	0.079	0.0001
Standard deviation estimates (sd)				Standard deviation estimates			
sd.(Multi-nutritional block)	2.377	0.463	0.0001	sd.(Settlement)	1.068	0.153	0.0001
sd.(straw treatment)	1.835	0.411	0.0001	sd.(Emergency destocking)	1.106	0.148	0.0001
sd.(Corridors marking up)	0.964	0.409	0.0184	sd.(Prolific animal selection)	1.430	0.152	0.0001
sd.(Assisted natural Regeneration)	0.630	0.356	0.0768	sd.(Water and soil conservation activities)	0.330	0.251	0.190
sd.(Strategic feed storage)	3.659	0.659	0.0001	sd.(Strategic mobility)	0.513	0.201	0.011
sd.(River exploitation planning)	0.091	0.851	0.9151	sd.(Transhumance)	0.549	0.178	0.002
sd.(Zootechnic and veterinary inputs)	0.446	0.557	0.4232	sd.(Mutual assistance)	0.935	0.151	0.0001
sd.(Animal feed store)	1.460	0.388	0.0002	sd.(Sheep and cattle fattening)	1.069	0.148	0.0002
sd.(Improved varieties)	1.808	0.280	0.0001	sd.(Income generating activities)	0.044	0.440	0.920
sd.(Fire band)	0.720	0.396	0.0693	sd.(Vaccination)	0.338	0.247	0.171
sd.(Vaccination)	2.469	0.529	0.0001	sd.(Strategic destocking)	0.223	0.374	0.551
sd.(Human capacity building)	2.875	0.575	0.0001	sd.(Changing herd composition)	0.974	0.149	0.0001
Sample size	276				281		
Log-likelihood	-2591				-8845		

Sd and SE stands for standard deviation and standard error respectively

Table 4 presents the preference shares above and below the mean of each strategy. The mean and standard deviation presented in Table 2 have been employed to determine the preference share. The authors assume that the ratio of the mean by the standard deviation follows the normal standard distribution. As shown in Figure 3 and Figure 4, the probability distribution for endogenous and exogenous strategies was reported in appendix for easy interpretation. Results show that assisted natural regeneration as exogenous adaptation package is preferred by 83% of agro-pastoralists, against 74% for multi-nutritional block and corridor marking up, against 65% for straw treatment (65%) and against 57% for strategic storage. However, fire band such as exogenous adaptation package is avoided by 79% of agro-pastoralists, against 68% for capacity building, against 60% for vaccination, against 58% for animal feed store, against 57% for improved seeds and river exploitation planning and against 56% for zootechnic and veterinary inputs. Results also indicate that income generating activities are 88% preferred by agro-pastoralists, against 82% for water and soil conservation, against 70% for settlement and strategic mobility, against 65% for transhumance, against 63% for emergency destocking, against 60% for prolific animal selection, against 57% for mutual assistance and against 53% for cattle and sheep fattening. However, strategic destocking such as agro-pastoralists climate change adaptation strategies is discarded 74%, against 73% for changing herd composition and against 57% for vaccination. These results suggest that assisted natural regeneration, followed by multi-nutritional block, corridor marking up, straw treatment and strategic storage are the most preferred exogenous adaptation packages; while income generating activities, followed by water and soil conservation activities, strategic mobility, transhumance, emergency destocking, prolific animal selection, mutual assistance and sheep and cattle fattening are the most important agro pastoralists climate change adaptation strategies. These results are similar to those documented by Tabbo et al. (2016) reporting that fire band as exogenous strategies is discarded by 16% of farmers and by 79% of agro-pastoralists. Water and soil conservation activities considered as exogenous strategy is preferred by 58% farmers, while it is preferred by 82% of agro-pastoralists once considered as endogenous strategy. Income generating activities as exogenous strategy is discarded by 95% of farmers, while income generating activities such as endogenous strategy is preferred by 88% of agro-pastoralists. Human capacity building as exogenous strategy is preferred by 68% of farmers, while it is avoided by 68% of agro-pastoralists. Improved seed as exogenous strategy is avoided by 57% of agro-pastoralists and by 58% of farmers. Sheep and cattle fattening as endogenous strategy is avoided 73%, while it is preferred by 53% of agro-pastoralists. Transhumance as endogenous strategy is preferred by 76% of farmers and by 65% of agro-pastoralists. River exploitation as endogenous strategy is preferred by 61% of farmers, while it is avoided as exogenous strategy by 57% of agro-pastoralists. The findings show that the probability generally varies amongst endogenous and exogenous climate change strategies, as well as between farmers and agro-pastoralists.

Table 4. Agro-pastoral's Vote for climate change adaptation policy implementation

Exogenous strategies	Mean	SD	Vote for	Vote against	Agro pastoralist or endogenous strategies	Mean	SD	Vote for	Vote against
Base: Grazing land seeding	0.00	1.00	50%	50%	Base: Forage cultivation	0.000	1.00	50%	50%
Multi-nutritional block	1.495	2.377	74%	26%	Settlement	0.571	1.068	70%	30%
Straw treatment	0.721	1.835	65%	35%	Emergency destocking	0.369	1.106	63%	37%
Corridors marking up	0.630	0.964	74%	26%	Prolific animal selection	0.347	1.430	60%	40%
Assisted natural Regeneration	0.608	0.630	83%	17%	Water and soil conservation activities	0.299	0.330	82%	18%
Strategic feed storage	0.601	3.659	57%	43%	Strategic mobility	0.264	0.513	70%	30%
River exploitation planning	-0.017	0.091	43%	57%	Transhumance	0.214	0.549	65%	35%
Zootechnic and veterinary inputs	-0.067	0.446	44%	56%	Mutual assistance	0.172	0.935	57%	43%
Animal feed store	-0.279	1.460	42%	58%	Sheep and cattle fattening	0.080	1.069	53%	47%
Improved varieties	-0.318	1.808	43%	57%	Income generating income	0.052	0.044	88%	12%
Fire band	-0.580	0.720	21%	79%	Vaccination	-0.059	0.338	43%	57%
Vaccination	-0.635	2.469	40%	60%	Strategic destocking	-0.142	0.223	26%	74%
Human capacity building	-1.347	2.875	32%	68%	Changing herd composition	-0.583	0.974	27%	73%

SD stands for standard deviation

Table 5 highlights results of the relative importance of exogenous (NGO and Government) adaptation packages and agro-pastoralists' climate change adaptation strategies. While grazing land seeding was used as base for NGO and Government adaptation packages, forage cultivation was retained as the base for agro pastoralists' climate change adaptation strategies. Results show that multi-nutritional block, straw treatment, corridor marking up, assisted natural regeneration and strategic storage are respectively 3.46, 1.06, 0.88 and 0.84 times more important than grazing land seeding, whereas human capacity building, vaccination and fire band are respectively 0.74, 0.47 and 0.44 times least important than grazing land seeding. Table 5 also indicates that multi-nutritional block (25.04%), followed by straw treatment (11.55%), corridor marking up (10.54%), assisted natural regeneration (10.32%) and strategic storage are the most valuable strategies. However, human capacity building (1.46%) followed by vaccination (2.98%), fire band (3.14%), improved varieties (4.09%) and animal feed store (4.25%) are the least preferred strategies.

Similarly, Table 5 also reports relative importance of agro pastoralists' climate change adaptation strategies relative to forage cultivation. Results suggest that settlement, emergency destocking, prolific animal selection and water and soil conservation activities are respectively 0.77, 0.45, 0.41 and 0.35 times more preferred than forage cultivation; while changing herd composition, strategic destocking and vaccination are respectively 0.44, 0.13 and 0.06 times least preferred than forage cultivation. Results also reveal that settlement (11.63%), followed by emergency destocking (9.51%), prolific animal selection (9.30%), water and soil conservation activities (8.86%), strategic mobility (8.56%) and transhumance (8.14%) are the most important preferred climate change adaptation strategies for agro-pastoralists. In contrast, changing herd composition (3.67%), strategic destocking (5.70%) and vaccination (6.20%) are the least preferred strategies among agro-pastoralists. These findings are online with studies reported by Tabbo and Amadou (2016) and Tabbo et al.(2017). Their results indicate that the preference share or the relative importance for transhumance as endogenous strategy is respectively 19.79% and 8.14% for farmers and agro-pastoralists, implying that farmers have a higher preference for transhumance. The relative importance of water and soil conservation activities as an exogenous strategy is 10.44% for farmers, while it is 8.86% for agro-pastoralists once considered as an endogenous strategy, revealing that farmers have higher relative importance for water and soil conservation activities as exogenous strategy than agro-pastoralists considered as an endogenous strategy because the former have been motivated by food or cash for work. The relative importance of sheep and goat fattening as an endogenous strategy is 2.69% and 7.12% for farmers and agro-pastoralists respectively, indicating that agro-pastoralists are more engaged in these activities than farmers. The preference share for income generating activities as an exogenous strategy is 3.40% for farmers, while it is 6.92% for agro-pastoralists once considered as an endogenous strategy. The relative importance of river exploitation as endogenous strategy is 10.69% for farmers, while it is 4.09% for agro-pastoralists as exogenous strategy. The relative importance of human capacity building as an exogenous strategy is respectively 13.48% and 1.46% for farmers and agro-pastoralists. The relative importance of herd rebuilding as exogenous strategy is 14.55% for farmers, while mutual assistance as an endogenous strategy is 7.81% for agro-pastoralists, showing that herd rebuilding as exogenous strategy for farmers is higher when it is considered as an endogenous strategy for agro-pastoralists. These results suggest that the relative important is influenced by exogenous and endogenous strategies as well as farmers and agro-pastoralists.

Table 5. Relative importance of exogenous Packages and endogenous climate change adaptation strategies

Exogenous packages	Mean	Relative to the base	PS	Agro pastoralists strategies	Mean	Relative to base	PS
Multi-nutritional block	1.495	3.46	25.04%	Settlement	0.571	0.77	11.63%
Straw treatment	0.721	1.06	11.55%	Emergency destocking	0.369	0.45	9.51%
Corridors marking up	0.630	0.88	10.54%	Prolific animal selection	0.347	0.41	9.30%
Assisted natural Regeneration	0.608	0.84	10.32%	Water and soil conservation activities	0.299	0.35	8.86%
Strategic feed storage	0.601	0.82	10.24%	Strategic mobility	0.264	0.30	8.56%
River exploitation planning	-0.017	-0.02	5.52%	Transhumance	0.214	0.24	8.14%
Zootechnic and veterinary inputs	-0.067	-0.06	5.25%	Mutual assistance	0.172	0.19	7.81%
Animal feed store	-0.279	-0.24	4.25%	Sheep and cattle fattening	0.08	0.08	7.12%
Improved varieties	-0.318	-0.27	4.09%	Income generating income	0.052	0.05	6.92%
Fire band	-0.580	-0.44	3.14%	Vaccination	-0.059	-0.06	6.20%
Vaccination	-0.635	-0.47	2.98%	Strategic destocking	-0.142	-0.13	5.70%
Human capacity building	-1.347	-0.74	1.46%	Changing herd composition	-0.583	-0.44	3.67%
Base: Grazing land seeding	0.000	0.00	5.62%	Base: Forage cultivation	0.000	0.000	6.57%

PS stands for preference share

IV. Conclusion And Recommendations

Several mitigation and adaptation strategies have been developed and introduced to assist agro-pastoralists to build resilience capacity against the negative effects associated with climate change. However, the preference and the relative importance for exogenous, endogenous and hybrid actions aimed at reinforcing agro-pastoralists' resilience building capacity are not properly documented and evaluated. The adaptation should normally be guided by external and internal governing agencies capable of combining their efforts for better and harmonized adaptation within a given community. The objective of this research is to determine the optimal climate change adaptation strategies for agro-pastoralists. Specific objectives include to determine preferences, the relative importance and as well as the probability distribution of each strategy. The balanced incomplete block design was used to design the questionnaire employed in data collection. Based on previous studies and interview with resource-persons, twenty six strategies respectively for thirteen exogenous and thirteen endogenous strategies were selected and included in this study. In total, thirteen blocks, having each four strategies randomly assigned are constructed. For each block or question, respondents were asked to select their best and worst strategies.

Results reveal that settlement, emergency destocking, prolific animal selection, water and soil conservation activities, strategic mobility, transhumance and mutual assistance are positive and highly significant, showing that these strategies are the most important for agro-pastoralists to enhance resilience building capacity in the ranch. Results also show that multi-nutritional block, straw treatment, corridors marking up and assisted natural regeneration are positive and significant, implying that these strategies are the most important for agro-pastoralists.

In addition, results show that assisted natural regeneration as an exogenous adaptation package is preferred by 83% of agro-pastoralists, against 74% for multi-nutritional block and corridor marking up, against 65% for straw treatment (65%) and against 57% for strategic storage. Similarly, results also indicate that income generating activities as endogenous strategies are 88% preferred by Agro-pastoralists, against 82% for water and soil conservation, against 70% for settlement and strategic mobility, against 65% for transhumance, against 63% for emergency destocking, against 60% for prolific animal selection, against 57% for mutual assistance and against 53% for cattle and sheep fattening.

Results suggest that endogenous adaptation as such settlement, emergency destocking, prolific animal selection, water and soil conservation activities, strategic mobility, transhumance and mutual assistance as well as the exogenous adaptation strategies such as emergency destocking, prolific animal selection, water and soil conservation activities, strategic mobility, transhumance and mutual assistance are the optimal combination capable of enhancing agro-pastoralists' resilience building. Limitations of this research include considering only one ranch, one county and one State. Future direction for research is to track a panel of agro-pastoralists to study the stability of these identified strategies and to develop demand indices for climate change adaptations. Additionally, machine learning between exogenous and endogenous adaptation strategies is worth investigating. These findings are important to implement smart climate change adaptation strategies amongst agro-pastoralists, thereby ensuring sustainable development in the study area and beyond.

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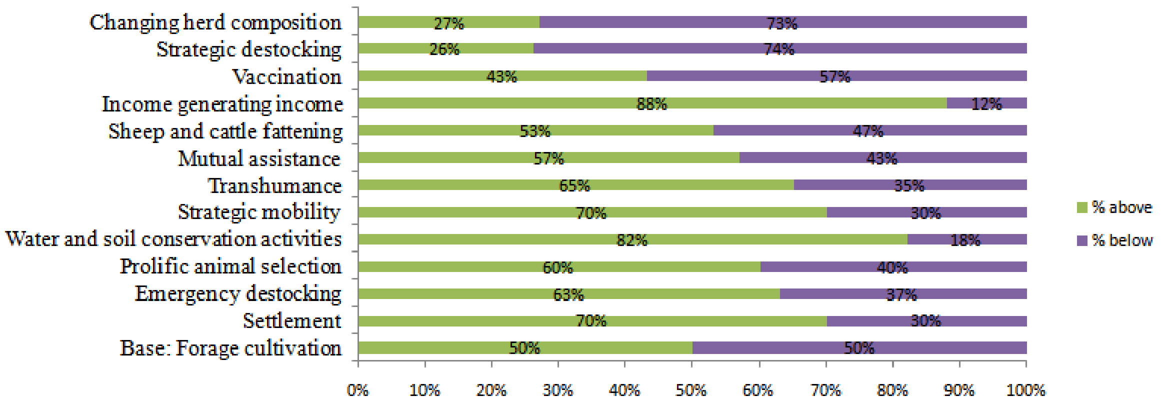

Figure 3. The probability above and below the mean for each endogenous strategy

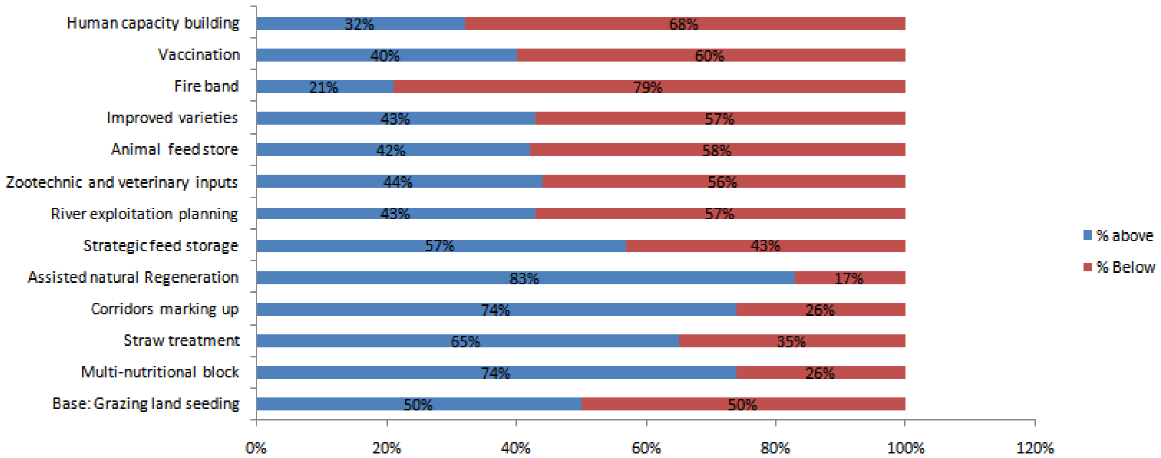

Figure 4. The Probability above and below the mean for each exogenous strategy

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