Impact of Climate Change Adaptation on Food Security: Evidence from Semi-Arid Lands, Kenya

S. Wagura Ndiritu (sndiritu@strathmore.edu)
Strathmore University https://orcid.org/0000-0002-8463-3758
Geoffrey Muricho
ICRISAT: International Crops Research Institute for the Semi-Arid Tropics

Research Article

Keywords: Climate change adaptation, endogenous switching regression, food security, Semi-Arid Lands, Kenya

Posted Date: February 10th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-174615/v1

Version of Record: A version of this preprint was published at Climatic Change on July 28th, 2021. See the published version at https://doi.org/10.1007/s10584-021-03180-3.

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Corresponding author
Given name(s): S. Wagura
Family name: Ndiritu
Strathmore University Business School, Kenya
Ole Sangale Road, Madaraka Estate
P.O. Box 59857- 00200 Nairobi, Kenya
Email: sndiritu@strathmore.edu

Given name: Geoffrey
Family name: Muricho
International Crops Research Institute for the Semi Arid Tropics (ICRISAT)
P.O. Box 39063
00623 – Nairobi
Email: g.muricho@cgiar.org

Acknowledgements

This data used in this study was supported by the Department for International Development (DFID) and Canadian International Development Research Centre (IDRC) through the Pathways to Resilience in Semi-arid Economies (PRISE) project led by Overseas Development Institute (ODI). The views expressed here are those of the authors and do not necessarily reflect the views of the donor or the authors' institution. The usual disclaimer applies.

Abstract

The paper investigates the impact of climate change adaptation on food security in the Semi-Arid parts of Kenya. Our research used a sample of 440 households, and an endogenous Switching regression is estimated to account for the heterogeneity in the decision to adapt or not, and for unobservable characteristics of pastoralists. We examined how pastoralists' decision to adapt, that is to implement a set of strategies; storage/purchase of fodder, change in water management, partial shift to other livelihoods, banking livestock assets and herd management. The results demonstrate that climate change adaptation increases food security among pastoralists significantly. Pastoralists who have not adapted are seven percentage points more likely to be food secure if they had adapted to climate change while adopters are 27 percentage points likely to be food insecure if they had not adapted. The paper recommends the strengthening of policies on adaptation to climate change in the Semi-Arid lands where pastoralism is the primary means of livelihood. Although pastoralists have information on the effect of climate change on their livestock, incomplete information on the mechanism of adaptation remains a hurdle. Consistent climate change monitoring, timely warning systems and communication of pertinent information to pastoralists is fundamental.

Key Words: Climate change adaptation; endogenous switching regression; food security; Semi-Arid Lands; Kenya

JEL Classification: Q18, Q54

1. Introduction

Climate change is profoundly affecting pastoralist activities which are conducted in extremely challenging conditions of the Semi-Arid economies. Some of the critical features of semi-Arid lands are climate variability and extremes, which are likely to increase in the coming decades (IPCC, 2014). Climate risk such as drought lead to higher livestock death in a pastoral system, while the surviving livestocks are weak due to poor growth and live weight losses (emaciated livestock) leading to declining in milk yield and meat production, hence food insecurity in the Semi-Arid economies. The intergovernmental panel of climate change, in its fourth assessment, notes that climate change and variability poses critical food security risk to the African continent (IPCC, 2007). It is expected that the increase in the frequency of climate fluctuations and increase in temperatures by the year 2030 will result in more food insecurity in Kenya. Changes in weather patterns have adverse effects on many sectors including food security and pasture, as well as adverse effects on those aspects which are dependent on rainfall (Kabubo-Mariara and Kabara 2015; GoK 2018). In this light, it is vital to adapt effective strategies to address climate change if food security was to be attained in Sub-Saharan Africa (Lobell et al., 2011).

It has been established that pastoral communities utilise the natural resources in arid areas where other land use systems cannot be sustained. In this light, water and pasture are commonly used by these communities and whose availability is dependent on time and space. To withstand and cope with adverse climate conditions that characterise arid and semi arid areas, the Kenyan pastoralists have used several approaches such as water and pasture management, reduced size of the herd, use of areas which are not prone to diseases, along with a precise selection of the settlement area. It is argued by Martin et al., (2014) that pastoralism economics put a context of proper risk management and addition of financial assets to address changes in climatic conditions, such as decreased amounts of rainfall. In the same respect, the main challenge in this dimension has been how to plan for herd size, fodder and water management, and support of the traditional family institutions characteristic among pastoral communities which have been sedentary and and that tendency of growing into a more subsistence form of organization and production (Catley et al., 2016).

The effects of climate change are worsened by overstocking of group ranches due to high population resulting in soil deterioration and environmental degradation. This makes the range lands vulnerable to even a normal dry spell which is characteristic of dry lands. Low quality and availability of pasture have acutely affected the pastoral communties in Kenya. Besides, recent IPCC special report on 1.5 degrees, which imply that the current efforts are not sufficiently enough to address and adapt to climate change associated with 1.5 degrees, despite that its contribution to reducing the adverse effects of climate change is significant (IPCC, 2018).

The government of Kenya responded to climate risks by developing the National Adaptation Plan (NAP) 2015-2030 that aims “to consolidate the country’s vision on adaptation supported by macro-level adaptation actions that relate with the economic sectors and county level vulnerabilities in order to enhance long term resilience and adaptive capacity.” The NAP is the principal guiding planning document for adaptation actions that mainstream climate change adaptation in Vision 2030. From the thematic perspective, Kenya's National Climate Change Action Plan (NCCAP 2018-2022) has prioritised in sustainability by offering measures and approaches aimed at achieving a low carbon, and climatic change resilience which solely focuses on adaptation and food security, and the fact that it aligns with the governmental big four agenda and Sustainable development goals. These initiatives have potential to increase food security in the harsh environment of the Semi-Arid economies. Although many efforts have been carried out, the process of adaptation practices to climatic change remains low and uneven in the dry area of the country, and their achievements in terms of food security in Kenya are mostly unknown.

Although there is considerable literature on the impact of climate change adaptation on agricultural production (increased productivity implies food security) in SSA, gaps in the impact of climate change adaptation on specific food security have not been widely discussed. In such a light, this paper adds to the existing academic literature in several perspectives. To begin with, the paper takes into an account how household perceives food security, thereby giving an overview of the overall state of food security in Kenya, unlike previous studies which focused on crop productivity as a measure of food security. Second, Unlike earlier researches whose studies focus on the impact of climate change adaptation on agricultural productivity (Di Falco et al., 2011; Kabubo-Mariara and Mulwa 2019) or farm net revenues (Di Falco & Veronesi 2013; Teklewold et al., 2017), this study is on pastoralism in the semi-Arid areas in Kenya, which allows us to examine the impact of climate change adaptation on food security of the less privileged in Kenya given the marginalization of Semi- Arid economies. As Di Falco *et al*., (2011) pointed out; it appears that adaptation is significant by the virtue that the current debacle on climate change in agriculture has focused on the effects rather than adaptation strategies towards food security. We, therefore, contribute to the literature by focusing on the neglected livestock sector by examining the impact of climate change adaptation by pastoralists to full assessment measure of food security. Lastly, the study aims at identifying the mechanisms which can be put in place to encourage pastoralists adopt sustainable climate change adaptation strategies.

In this paper, therefore, we explore the impact of climate change adaptation on food security using extensive household data collected in the Semi-Arid parts of Laikipia County, Kenya. Precisely, we seek to respond to the questions: Are climate change adapters more likely than non-adapters to be food-secure? If so, by how much are non-adapters going to be food secure if they had adapted? What are the mechanisms that could encourage pastoralists to accept and implement successful and sustainable adaptation strategies? Using a subjective food security measures and switching regression technique than previously applied to the pastoralist, we examine how pastoralists' decision to adapt, that is to implement a set of strategies (storage/purchase of fodder, change in water management, partial shift to other livelihoods, banking livestock assets and herd management) in response to long run changes in critical climatic variables like temperature and rainfall, affects the full assessment of their household's food security in the Semi-Arid Kenya.

Iram and Butt (2004) describe food security as a comprehensive construct including concepts related to ecosystem, on food accessibility, food safety, and food supply. The 1996 World Food Summit in Rome stated that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996). Hence, there exists no single proxy for food security. FAO (2008) and Schmidhuber and Tubiello (2007) identify four indicators of food security which include; food availability, food accessibility, food utilisation and food system stability which are affected by climate change either directly or indirectly.

The literature on food security in developing countries is attracting increasing research interest. One strand of literature probe the determinants of food security, for instance, Feleke *et al.* (2005) and Kidane *et al*., (2005) explored the household food security in rural Ethiopia. On the other hand, there is a rich literature on the impact /effect of climate change on agriculture production (proxy for food security) (McCarthy et al. 2001; Kurukulasuriya & Rosenthal 2003; Parry et al., 2004; Seo & Mendelsohn 2008; Deressa & Hassan 2010; Di Falco et al., 2012; Kabubo-Mariara & Kabara 2015). These agronomic models attempt to estimate directly, through crop models, the impacts of climate change on crop yields. More recently, limited literature has started to study impact of climate change adaptation strategies on food productivity such as Di Falco *et al.,* (2011). Dry land interventions such as the Makueni District Agricultural Project, Kenya demonstrates that irrigated agriculture improves household food security (Lemba, 2009).

The existent empirical studies use objective food security measures at household levels. Such proxies include food output by farmers, food expenditure data and caloric consumption. Pinstrup-Andersen (2009) postulates that several conditional assumptions of households and consumer behavior, the total income of the household, as well as the prices of food are the key determinants of household food security. Pinstrup-Andersen (2009) further critique is on consumption-based estimates as insufficient in assessing the measure of food security since such a measure does not account for food security vulnerability and sustainability.

Subjective food security measures have been identified to address the shortcomings of the consumption-based estimates (Mallick & Rafi; 2010; Kassie et al., 2014). Adapting the subjective food security measures by Mallick and Rafi (2010) and Kassie *et al*., (2014), the research participants were interrogated on assessment of status of food security in their households in the preceding year along with categorizing it into these categories: food shortage all through the year (chronic), occasional food insecurity, beak-even (food shortage non-existent but there is no surplus), or food surplus(implying food security). In such a perspective, the current study follows the very approach.

The next section discusses Pastoralists' Livelihoods, food security and their climate change adaptation strategies. Section 3 describes an exogenous switching regression (ESR) treatment effects approach to evaluate the impact of climate change on food security. Section 4 covers the data, the variables, and descriptive statistics. Section 5 entails results and discussion components of the study. Section 6 concludes the study and proposes several policy implications.

2. Pastoralists' Livelihoods, their climate change adaptation strategies and food security

Pastoralists rely on livestock directly for their survival and income generation (Jenet et al. 2016). Nevertheless, the sustainability of their livelihoods is endangered by climate change, especially droughts. Droughts have both short and long-term impacts on the pastoralist's livelihoods. In the short run, droughts cause the unprecedented decline of resources for grazing and consequent substantial losses of animals and expose pastoralists to severe food insecurity (Cossins & Upton 1988). In response to droughts, mobility typifies arid zone pastoralism being the hub of open transhumance routes and drought retreats that allow access to pasture in different areas depending on their climatic conditions (African Union 2010, IUCN 2010, Martin et al. 2014).

Most pastoralist systems have a tradition of communal pasture set aside as a drought reserve and also crucial for pasture rehabilitation objectives. Some also provide for household pasture reserves for feeding lactating and immature stock. While the household reserve system is expanding in some pastoral areas (Coppock 1994), population pressure and the weakening of tribal reciprocity agreements and traditional law in many pastoral communities has eliminated pasture set aside practices. However, fodder conservation does not often extend beyond family initiatives and is unlikely to return to pastoralist's communal resource management systems until governments improve pastoralist's land rights and strengthen capacity for participatory natural resource management in pastoral areas.

Supplementary feeding had no place in traditional pastoralism. However, the availability of industrial by-products such as oil-seed cakes and molasses has begun to change this situation, and wealthier owners of more massive herds are gradually taking advantage of the flexibility they offer (Blench & Marriage 1998). Activities include supplements, provision of hay, and some pasture related interventions. With reduced livestock mobility and higher population in ASALs, likely, hay made from selected quality grasses, supplemented by protein rich acacia products and combined with better water supply will be increasingly adopted as an adaptation to climate change amongst pastoralists (IIRR 2002). However, fewer pastoralists grow fodder plants for animal feed or drought proofing, and there is little positive evidence to date in Africa to support such action, with low incentives for commonly owned rangeland, inferior grass species, and general rangeland management constraints contributing to food insecurity.

For the pastoralists, to survive the harsh drylands when the grazing land is commonly owned, their livelihood strategy includes keeping a mixture of species and various traditional breeds, and the accumulation of animals as a significant store of wealth (Coppock 1994, Jenet et al. 2016). Pastoralist communities in Africa earn their income from livestock products such as milk rather than in cash from the selling livestock (Bailey et al., 1999). As such, these folks will hold onto their livestock until their salvage value is higher than their income generating value, which is usually well past the market prime of the livestock (Bailey et al., 1999). Pastoralist, nonetheless, regularly trade livestock and livestock product. Given the diversity of pastoral systems, it is challenging to characterise pastoralist livestock marketing strategies; however, it is a relative truism that in normal years, marketed livestock are overwhelmingly very old male animals. Pastoralist sales also typically show high seasonal and annual fluctuations and are often made to address specific cash requirements. During drought spells, market terms of trade for pastoralists can suddenly deteriorate, especially in situations where drought coping strategies are limited and infrastructure for the supply of grain and off-taking of livestock is weak. However, this is not a universal response.

The most critical longer term adaptation strategy is herd management through mainly commercial de-stocking which builds on existing marketing structures and improves access to markets (McDougald et al. 2001, Aklilu &Wekesa 2002, Silvestri et al. 2012). The aims of destocking include allowing pastoral households to sell some of their livestock before losing them thus building their purchasing power of or saving the money for buying food. Destocking or herd size reduction also serves to shed off weaker animals from the herd resulting in keeping stronger animals to preserve capital assets to suit the household and enable recovery after drought and continue with production of milk (major source of food security in pastoral areas).

Access to water is critical for efficient tracking of feed resources. In areas with permanent water supply, over-utilization and environmental damage are likely to take place. Coppock (1994) argues that water management is essential as a determinant of social relations. The study cites examples where improved access to water favored wealthy pastoralists and not weaker community members who provided the labour for lifting the water. Aklilu and Wekesa (2002) argue that strengthening community-based management of water supply system, especially the rehabilitation of water resources, is essential than carrying out new water developments. Providing water for livestock includes drilling and maintaining emergency and contingency boreholes. Within areas where the provision of water facilitated drought-time grazing, the boreholes should be closed during periods of average rainfall to discourage environmental degradation (Mati et al. 2005).

3 Conceptual Framework and Econometric Specification

Food security of the pastoralists depends on the sustenance of their herd which is driven by inputs improvement that leads to better herds. Key inputs in livestock productions system are pasture and water, which are at the threat of climate change and increased droughts. Therefore, with proper climate change adaptation, good markets and better herds, pastoralist can earn higher income to buy food. In addition, with healthy herds, the pastoralist have a consistent supply of milk which improve their nutritional security. High income leads to access to food and hence food security.

Impact assessment using non-experimental data is very challenging due to the problem of self-selection and lack of counterfactual against which impact can be evaluated. In experimental studies, these problems are ably addressed by assigning the treatment randomly to the target study population. However, in this current study, adaptation to climate change among the studied population of pastoralists is not randomly assigned, but instead, households self-select themselves into adaptation (treated) and non-adaptation (untreated) regimes. This self-selection into the two treatment groups means that there could be systematic differences between the treated and the untreated groups. Therefore, evaluating the impact of the treatment on food security of the sample by estimating a single outcome equation with a dummy adaptation variable as one of the explanatory variables will yield biased estimates.

Various econometric approaches have been developed to handle these problems of self-selection and lack of proper counterfactual to evaluate impact (De Janvry et al., 2011). These methods include propensity score matching methods (PSM) in a binary treatment framework, generalised propensity score matching methods (GPS) in a continuous treatment framework, the instrumental variable (IV) approach and the switching regression framework. One of the outstanding shortcomings of PSM and GPS methods is that they only control for observable/measured differences/heterogeneity in the treated and untreated groups. On the other hand, though IV approach controls for both observable and unobservable differences, its estimation of one outcome variable with the binary treatment being included as one of the explanatory variables assumes that the treatment has only an intercept shift effect. This assumption might not hold in most cases when the treatment variable is also correlated with other explanatory variables in the model. However, switching regression models relaxes this stringent IV assumption by estimating two outcome equations (one for each treatment regime) alongside the selection model. This latter approach significantly reduces the selection bias by controlling for both observed and unobserved differences among the treatment groups despite its distributional (tri-variate normal distribution) and exclusion restrictions (Kassie et al., 2014). We adopt this latter method (switching regression) to estimate the impact of climate change adaptation on food security among the sampled pastoralist households.

Since climate change adaptation is also potentially endogenous, we adopt endogenous switching regression (ESR) following Di-Falco *et al.*, (2011), Asfaw *et al.*, (2012), and Khonje *et al.*, (2015). ESR is a two-step procedure that involves first modelling the household decision to adapt to climate change following the random utility formulation of the non-separable household model approach. In this first step, a household is assumed to adapt to climate change if its utility from adaptation (U_{i1}) is higher than the utility from non-adaptation (U_{i0}), i.e. the utility derived from adoption (U^*) is greater than zero: -

$$U^* = U_{i1} - U_{i0} > 0 \qquad \text{Eqn. (1)}$$

Since this utility is unobservable, then the adoption decision can be represented as a function of observable characteristics (X_i) and the error term (ϵ_i) in the following latent variable model:-

$$T_i^* = \varphi_i X_i + \epsilon_i; with\ T_i = \begin{cases} 1\ if\ T_i^* > 0 \\ 0\ Otherwise \end{cases} \qquad \text{Eqn. (2)}$$

Where T_i^* is the unobserved binary variable indicator of climate change adaptation; T_i is the observed binary indicator variable of climate change adaptation and it is equal to 1 if the household adapted to climate and 0 if it does not adapt; φ_i is a vector of parameters to be estimated; X_i is a vector of variables that determines climate change adaptation and ϵ_i is the error term normally distributed with zero mean and constant standard variance.

Based on the past empirical studies, we hypothesise that adaptation to climate change has a positive and significant impact on the food security of the sampled households. In this study, we adopt the qualitative self-assessment of food security in the last 12 months (1 year) at the time of the interview. Respondents in the survey were asked to make self-assessment of household food security in the last 12 months preceding the survey considering all sources of foods. They were given four mutually exclusive options including food shortage all through the year (acute food insecurity), food shortage occasionally in the year (transitory food insecurity), no food shortage and no food surplus (breakeven), and food surplus throughout the year (food secure). Due to relatively small observations in some categories like acute food insecurity, we merged acute food insecurity and transitory food insecurity into one group called food insecure while breakeven and food secure categories were put together to form food secure group. Therefore, the dependent (outcome variable) was binary defined as one if a household was food secure and 0 if it was food insecure.

We, therefore, applied the two-stage endogenous switching regression by estimating equation (2) as the selection model, generated the inverse mills ratio (IMR) from this equation. The IMR was used as an additional explanatory variable in the two outcome models to correct for the selection bias following Heckman (1979). These two outcome functions were as follows: -

Regime 1: $Y_{i1} = \beta_1 X_{i1} + \alpha IMR_i + \omega_{i1}$ (if T=1) Eqn. (3)

Regime 2: $Y_{i0} = \beta_0 X_{i0} + \alpha IMR_i + \omega_{i0}$ (if T=0) Eqn. (4)

Where Y_{i1} is the food security probability of households that have adapted to climate change while Y_{i0} is the food security probability of households that have not adapted to climate change. In this ESR model, the error terms in Eqn. (2), Eqn. (3) and Eqn. (4) are assumed to have a trivariate normal distribution, with Zero mean and non-singular covariance matrix expressed as: -

$$\mathrm{Cov}(\omega_{i1}, \omega_{i0}, \varphi_i) = \begin{bmatrix} \delta^2_{\omega_{i0}} & . & \delta_{\omega_{0\varphi i}} \\ . & \delta^2_{\omega_{i1}} & \delta_{\omega_{1\varphi i}} \\ . & . & \delta^2_{\varphi i} \end{bmatrix} ------------\mathrm{Eqn.}\,(5)$$

Where:

$\delta^2_{\varphi i}$ = Variance of the error term in the selection Eqn. 2, (which can be assumed to be equal to 1 since the coefficients are estimable only up to a scale factor)

$\delta^2_{\varphi_{1i}}$ and $\delta^2_{\omega_{0i}}$ = Variances of the error terms in the welfare outcome functions, i.e. Eqn. (3) and Eqn. (4)

$\delta_{\omega_{1\varphi i}}$ and $\delta_{\omega_{0\varphi i}}$= Covariance of φ_i , ω_{1i} and ω_{0i}

Since Y_{i1} and Y_{i0} cannot be observed simultaneously, the covariance between ω_{i1} and ω_{i0} is not defined (Madala 1983; Lokshin & Sajaia 2014). The implication for this type of error structure is that because the error term of the selection model (Eqn. 2) is correlated with the error terms of the outcome models (Eqn. 3 and Eqn. 4), the expected values of ω_{i1} and ω_{i0} conditional on sample selection are non-zero, i.e.: -

$$E[\omega_{i1} \backslash T_i = 1] = \delta_{\omega 1_{\varepsilon i}} \frac{\phi(\beta X_i)}{\Phi(\beta X_i)} = \delta_{\omega 1_{\varepsilon i}} \lambda_{i1} --------Eqn.(6)$$

and:-

$$E[\omega_{i0} \backslash T_i = 0] = -\delta_{\omega_{1\varepsilon i}} \frac{\phi(\beta X_i)}{1 - \Phi(\beta X_i)} = \delta_{\omega_{0\varepsilon i}} \lambda_{i0} --------Eqn.(7)$$

Where:

$\phi\,(.)$ = Standard normal probability density function

$\Phi\,(.)$ = Standard cumulative density function

$\lambda_{i1} = \frac{\phi(\beta X_i)}{\Phi(\beta X_i)}$

$\lambda_{i0} = -\frac{\phi(\beta X_i)}{1-\Phi(\beta X_i)}$

λ_{i1} and λ_{i0} are the IMR computed from the selection equation

Therefore, we use Eqn. (3) to estimate the actual food security probability among climate change adapters and we use the coefficients from this equation to compute the average counterfactual food security probability of non-adapters to climate change households. Similarly, we use Eqn. (4) to estimate the actual food security probability of non-adapters to climate change and coefficients derived therein are used to compute the counterfactual food security probability of the adapters. The actual and counterfactual food security probabilities among adapting and non-adapting households are computed as follows in an endogenous switching regression framework: -

Actual scenarios: -

Adapting households: $E\,(Y_{i1} \backslash T=1;\,X) = \beta_1 X_{i1} + \alpha IMR_i + \varphi_{i1}$ Eqn. (8)

Non-adapting households: $E\,(Y_{i0} \backslash T=0;\,X) = \beta_0 X_{i0} + \alpha IMR_0 + \varphi_{i0}$ Eqn. (9)

Counterfactual scenarios: -

Adapting households had they not adapted: $E(Y_{i0} \backslash T=1;\,X) = \beta_0 X_{i1} + \alpha IMR_i + \varphi_{i0}$ Eqn. (10)

Non-adapting households had they adapted: $E(Y_{i1} \backslash T=0;\,X) = \beta_1 X_{i0} + \alpha IMR_i + \varphi_{i1}$ Eqn. (11)

We apply these conditional expectations and use climate change adaptation as a treatment (T) to compute the treatment effects among the sampled households as shown in Table 1 below

Table 1: Treatment effects

Adaptation regime	Adapters characteristics	Non-adapters characteristics	Treatment effects
Adapters	Eqn. (8): $E(Y_{1i} \backslash T = 1; X)$	Eqn. (10): $E(Y_{0i} \backslash T = 1; X)$	Eqn. (8) – Eqn. (10)
Non-adapters	Eqn. (11): $E(Y_{1i} \backslash T = 0; X)$	Eqn. (9): $E(Y_{0i} \backslash T = 0; X)$	Eqn. (11) – Eqn. (9)
Heterogeneity effects	Eqn. (8) – Eqn. (11)	Eqn. (10) – Eqn. (9)	-

Following Kassie *et al*., (2014) and Di Falco *et al*., (2011), for the ESR model to be identified, then the X_i variables in Eqn. (2) should contain at least a selection instrument, that is, variable(s) that significantly affect the selection model (adaptation to climate change) but not the outcome variable (food security). In this study, we follow past empirical studies (Di Falco et al., 2011; Di Falco & Veronesi 2013) and hypothesise that average rainfall, average temperature and early warning systems are the variables that affect climate change adaptation decisions directly but not household food security. We therefore use these three variables as part of the explanatory variables in the selection model (Eqn. 2) but exclude them in the subsequent outcome models (Eqn. 8 – Eqn. 11). Average rainfall and temperature drives households to adopt to climate change and this has a indirect effect on meat and milk production. Households who have better herds due to adaptation are likely to report that they are food secure. The idea is that rainfall affects directly the inputs for livestock production which can be reduced by approprite adaptation startegies. Access to information (early warning systems), directly affects the decision to adopt to climate change and the resultant outcome will affect the household food security outcome (i.e., the mere access to weather information without adaptation to climate change does not affect the food security of the pastoralist). We establish the admissibility of these instruments by performing a simple falsification test: if a variable is a valid selection instrument, it will affect the adaptation decision, but it will not affect the food security status (Di Falco et al., 2011). Table 5 shows that the average rainfall, average temperature and early warning systems can be considered as valid selection instruments: they are all statistically significant drivers of the decision to adapt or not to climate change but not of the food security status.

4 Data and description of variables

The data used in this study is part of the Pathways to resilience in semi-Arid Economies (PRISE) project. The project targets residents in the Semi-Arid parts of Laikipia (North). The target sites are taken to posses a prospective for animal keeping activities and livestock production. The climate in this area is mainly semi-arid with an average range of 400mm and 750mm rainfall annually. Further, the region has been experiencing cycles of dry spells with most recent ones recorded in 2000, 2009, 2011, 2014 and 2017. Laikipia County is one of the food deficient and food insecure Counties in Kenya during dry spells or droughts. The increasingly arid conditions in the county are generally viewed as impact of climate variability. The location of this county is such that it experiences variations in weather conditions such as dry spells and very little rainfall along with famine.

The researchers first conducted a previsit to the study areas before the actual survey, where secondary data was collected. The county government employees in the country department of livestock and fisheries were the critical research participants from whom data was collected from, where data on comprehensive livestock production, the basic socio-economic profiles of the hiuseholds, as well as the marketing information was then used to develop the research sample stategy.

To ensure a suffiecient understanding of adaptations to climate change and their food security status, households′ interview was conducted using a pretested structured questionnaire with 440 respondents from 8 group ranches in July 2016. Equal sample sizes of 55 herders from 8 group ranches (Il'Ngwesi, Ilpolei, Koija, Kuri Kuri, Makurian, Murupusi, Munichoi, and Tiamamut ranch) were sampled giving a total of 440 herders. The distribution of population within the group ranch was considered in order to stratify the group ranch and have a distribution of the sample. Three insecure ranches were excluded due to difficulties of access. Ranches without adequate security and the ranch used for pre-testing the questionnaire were excluded. Enumerators who had good knowledge of their respective sampling areas were selected from their own group ranches. The sampling strategy accounted for the vast distribution of settlements and terrain in the group ranches..

Long term mean rainfall and temperature from 1950-2014 are obtained from the Kenya Meteorological Department. Using GeoCLIM, we can derive the household specific temperature and rainfall values using the GPS longitude and latitude of each household. The GeoCLIM is designed for climatological analysis of historical rainfall and temperature data. It was developed by Tamuka Magadzire of USGS fews net in support of the USAID prepared and Global Climate Change activities.

Descriptive statistics

In this study, the following climate change adaptation strategies are applied by pastoralists: Purchase of fodder (Usually hay), water management, herd management and shift to other livelihoods (Table 2). About 19% of our survey respondents reportedly store and purchases fodder as their adaptation strategy to climate change. Some of the ranches (e.g. Il'Ngwesi Ranch) grow hay and sell to their members at a low, usually at discounted market rates. Water management involves maintaining existing boreholes, drilling of new boreholes, construction of water pans and dams. About 29% of the households reported a change in water management as a strategy adopted by their group ranch to manage climate risk. This low response was contributed by households who felt that the available boreholes and water pans were very far away from their residence. The study uncovers that 74% of households have changed their herd management including reducing herd size, selling and banking cash from livestock assets in response to dry spell and droughts. Changing from pastoralism is usually partially practiced since about 37% of the households reported to have partially shifted to other livelihoods such as crop cultivation, small businesses and seeking employment usually in the group ranch tourism activities.

Table 2 Climate change adaptation strategies (N=440)

Variable name	Variable definition	% response
Purchase fodder	Purchase and storage of fodder	19.3
Water management	Change in water management	28.9
Shift livelihoods	The partial shift to other livelihoods	36.6
Herd management	Overall herd management (reducing herd size, selling and banking livestock assets).	74.3

Source: Study data

To examine the contribution of climate change adaptation on the household food security status, the study disaggregated adapters and non-adapters of climate change adaptation measures. The general observation from the results presented in Table 3 is that adapters are more food secure (85.9%) compared to non- adapters (68.3%). Therefore, non-adapters are more food insecure (31.7%) compared to adapters (14.1%). The differences are statistically significant (Chi-Square 18.052, P-Value 0.000). These results support the hypothesis that households which takes adaptation measures are likely to be more resilient to the harsh conditions of semi-arid lands and more importantly to the changing climate. We will rigorously test these descriptive results in the econometric analysis.

Table 3: Household food security by climate adaptation status % households)

Food security status	Adapters (N=333)	Non-adapters (N=101)	Total (N=434)
Chronic food insecure	0.6	0.0	0.5
Transitory food insecure	13.5	31.7	17.7
Break-even	73.6	57.4	69.8
Food surplus	12.3	10.9	12.0

Table 4 provides descriptive statistics of the climate variables and the socio-economic characteristics for adapters and non-adapters. The mean annual temperature for the whole sample is 28.8ºC, with the value ranging from 25ºC in some areas to 29ºC in others. The average rainfall is 650mm, varying from 523mm to 1,001mm. From the findings of this research study, it is confirmed that there is significant variance across households in distinct ranches, along with the fact that there variables have a potential to explain disparities in adopting climate change adaptation strategies.

Out of 440 households, majorities (92%) are male headed and pastoralism the key economic activity. This is expected given the climatic condition of Semi-Arid lands where well managed rangelands can offer good livestock ranching. The data display somewhat higher average levels of education: the average highest level of education in the household is 9.5 years. However, this is higher than the level of education of the household head which is a low primary level (5.5years). Only 41 percent and 8 percent of the households received early warning messages after the devolved government for adapters and non-adapters, respectively. As expected there was more reported dry spell than number of droughts in the last 15 years affected the pastoralists' livestock. On average, two droughts affected livestock while four dry spells affected the livestock with a high variation of 5 dry spells.

Table 4: Descriptive statistics

Variable definition	All Pastoralists		Adapters		Non-Adapters	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**
Adapt (Yes/No)	O.78		1		0	
Average annual rainfall	649.584	80.240	658.011	81.710	619.874	67.194
Average annual Temperature	28.009	0.633	27.948	0.677	28.223	0.377
Number of times Delay in rainy season affected livestock since 2000	4.388	5.163	4.478	5.164	4.072	5.171
Number of times drought affected livestock since 2000	2.214	0.995	2.278	1.065	1.990	0.653
Access to early warning information (yes=1)	0.334		0.405		0.082	
Wealth index	0.000	1.627	0.163	1.657	-0.576	1.373
Livestock size in a standardized unit (TLU)	19.463	21.048	20.467	21.575	15.911	18.742
Age of the household head (years)	44.186	12.974	44.418	13.491	43.365	10.972
Male dummy Male=1 female=0	0.923		0.927		0.907	
Highest level of education in the household (years of schooling)	9.566	3.822	9.921	3.427	8.309	4.788
Household size	6.423	2.575	6.472	2.651	6.247	2.291
Distance to the main market (km)	7.956	5.213	7.741	4.599	8.717	6.941
Access to credit after devolution (yes=1)	0.189		0.224		0.062	

Pastoralism the main activity of this household (yes=1)	0.816	0.810	0.835

Source: Authors computation

5. Results and discussion

5.1 Determinants of climate change adaptation and household food security

From the econometric estimation (selection model, table 5), we identify credit access and information access supports household adaptation to climate change. This research establishes that pastoralists who were made aware of changes in weather conditions through early warning system are more likely to adapt. Increased access to credit facilities and information implies that they may need both information on the findings demonstrates the need for financial resources and information in climate change adaption. The findings of this paper on the role of information and credit access conform with the current literature (Di Falco et al., 2011; Di Falco & Veronesi 2013; Getachew et al., 2014)

We also found that pastoralists who live far away from the markets probably could not adapt some drought management approaches. We also found that the increase in rainfall leads to climate change adaptation. We suspect that these results uncover that we do find increase in rainfall in Semi-Arid but the distribution throughout the year is very poor leading to need for adapting to climate change. Similar results were found by Berhanu and Beyene (2015) in Ethiopia's pastoral areas.

As expected, wealthier households and those who were more endowed with livestock happen to be more food secure. This is expected given that livestock production is the main livelihood activity in the Semi-Arid economies. Delay in rainy season is likely to reduce food security status. Household food security was also found to be enhanced by access to credit. Also, the study uncovered that a high prevalence of food security among educated households. A comparison shows that households headed by men are more food secure compared to their female counterparts. The findings of this research study conform to those of Ahmad et al., (2016).

Table 5: Determinants of climate change adaptation and household food security

	Endogenous Switching Regression

Model	Probit (1)	Selection Equation (2)	Adaptation=1 (Pastoralists who adapted to climate change) (3)	Adaptation=0 (Pastoralists who did not adapt to climate change) (4)
Dependent Variable	**Food security**	**Adaptation (1/0)**	**Food Security**	**Food Security**
Avg_rainfall	-0.000	0.004***		
	(0.002)	(0.001)		
Avg_temp	-0.369	-0.892***		
	(0.284)	(0.235)		
Raindelayno	-0.020	0.004	-0.045*	0.082
	(0.023)	(0.023)	(0.027)	(0.063)
Droughtno	0.286**	0.167*	0.120	0.467
	(0.127)	(0.102)	(0.131)	(0.314)
Earlywarning	0.687	1.040***		
	(0.423)	(0.247)		
Wealthscore	0.190**	0.071	0.242**	0.160
	(0.080)	(0.070)	(0.098)	(0.168)
Lvstksize	0.022***	0.006	0.022***	0.021**
	(0.006)	(0.005)	(0.008)	(0.011)
Age	-0.012	0.008	-0.018*	-0.022
	(0.008)	(0.008)	(0.010)	(0.020)
Male	0.913***	-0.113	0.977***	0.844
	(0.291)	(0.293)	(0.346)	(0.580)
Higheduc	0.073***	0.026	0.025	0.110**
	(0.027)	(0.022)	(0.032)	(0.046)
Hhsize	-0.049	-0.021	0.008	-0.148
	(0.048)	(0.044)	(0.061)	(0.095)
dist2manmkt	0.033	-0.036*	0.042	0.017
	(0.026)	(0.019)	(0.030)	(0.037)
Credit	1.607***	0.843***	0.955**	dropped
	(0.470)	(0.309)	(0.449)	
Pastoralist	-0.039	0.075	-0.060	-0.242
	(0.271)	(0.242)	(0.323)	(0.528)
Inverse mills ratio (IMR)	-1.215		1.138	-3.771**
	(1.225)		(0.820)	(1.548)
Constant	10.498	21.623***	-0.489	0.989
	(8.028)	(6.499)	(0.744)	(1.319)
Observations	431	431	335	90
Model chi-square	115.3	118.1	75.60	34.30
Pseudo R2	0.277	0.258	0.275	0.290

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2 Impact of climate change adaptation on household food security

The switching regression results were used to estimate the expected conditional probability of food security and to estimate the impact of climate change adaptation. The results show that the probability of food security among adapters is likely to significantly drop from about 82% to about 55% had they not adapted to climate change (Table 6). On the other hand, the probability of being food secure among the non-adapters could significantly increase from about 64% to almost 70% had they adapted to climate change. These results show that climate change adaptation among the sampled pastoralists' households is crucial in ensuring household food security. We also find these findings to be consistent with past studies that have evaluated the impact of climate change on household welfare (Di-Falco et al., 2011). Further scrutiny of the results presented in Table 6 shows the heterogeneity effect of adaptations to climate changes on food security. We found that had the adapters not adapted; their food security probability could have dropped to the level that it could have been significantly lower than that of non-adapters in their current state of having not adapted. However, on the other hand, even if the non-adapters were to adapt, their food security probability would still be significantly lower than that of adapters given their current state of having adopted. These later findings on heterogeneity show that some unobserved characteristics make adapters to have significantly higher food security probability than their non-adapting counterparts.

To tease/entangle out some these differences that cause the significant food security gap between adapters and non-adapters, we decompose the observed differences in food security probability following Oaxaca (1973) decomposition procedure. The observed food security probability (column (a) less column (b)) 0.186 can be decomposed into that portion attributed to the differences in resource base and that one that is due to differences in efficiency in the use of resources held between the two groups of households (adapters and non-adapters). We found that if non-adapters were to keep their current resource use efficiency but given the same resources like the ones held currently by adapters, their food security probability would increase by about 0.119, which is just 64 percentage points of the existing food security gap (0.186). Only that, improving the resource base of the non-adapters would not close the food security gap as almost 36 percentage points of the gap would not be bridged. To bridge this 36-percentage point gap, the efficiency in the use of resources by non-adapters needs to be improved too. Therefore, to close the food security gap that exists between adapters and non-adapters, the resource base and efficiency in use of the resources by the non-adapters needs to be improved.

Table 6. Impact of climate change adaptation on food security

Household type	To adapt	Not to adapt	Treatment effect
Households that adapted	(a) 0.822 (0.011)	(c) 0.552 (0.017)	0.270*** (0.015)
Households that did not adapt	(d) 0.703 (0.023)	(b) 0.636 (0.029)	0.067*** (0.021)
Heterogeneity effects	0.119*** (0.021)	-0.084** (0.034)	0.186

Standard errors in parenthesis *** p<0.01, ** p<0.05, * p<0.1

Cells (c) and (d) and (a) and (b) denote the counterfactual outcome and actual outcomes, respectively.

6. Conclusions and policy implications

The study used data regarding pastoralist from the Semi-Arid Economies of Laikipia (North), Kenya. This study assessed the role of adaptation strategies adopted by Semi-Arid pastoralist to respond to changes in climatic conditions; discussed the critical determinants of adaptation decisions, and explained as to whether these strategies offer support towards realisation of food security among pastoralists, and determined whether these strategies support realising food security for pastoralists. This study used endogenous switching regression model to investigate the effect of climate change adaptations on household food security.

Both the descriptive and econometric findings put forward that pastoralist's who adapted to changes in climatic conditions are better off concerning food security relative to those who did not. In particular the results show that the probability of food security among adapters is likely to significantly drop from about 82% to about 55% had they not adapted to climate change. On the other hand, the probability of being food secure among the non-adapters could significantly increase from about 64% to almost 70% had they adapted to climate change. These results support the hypothesis that households which take climate change adaptation measures are likely to be more resilient to the harsh conditions of semi-arid lands and more importantly to the changing climate.

Following the above results, we recommend that for the pastoralist to be encouraged to adopt climate change adaptation strategies, the government could come up with programs in the ASALs to promote sustainable adaptation options such as herd size management through proper markets for pastoralists livestock combined with banking livestock assets for their insurance cover. Besides, there is need to invest in pasture and water management in the ASALs. For example, water harvesting during rainy seasons can increase availability of water during the dry spells. Partnerships with county governments and local communities to implement alongside expanding irrigation pasture production areas and identify high capacity pasture varieties and seeds for use in ASALs is one of the mechanisms to encourage sustainable adaptation options. Also, pasture rehabilitation campaigns in partnership with county governments on reseeding high yield grass that is adaptable to dry lands and rehabilitating the degraded rangelands can increase availability of pasture for dry season grazing. The use of purchased fodder such as hay and growing storage of fodder are some of the adaptive strategies which have gained importance in the Semi-Arid regions of Laikipia. Production of hay is a suitable activity in pasture lands in large farms and ranches. Therefore, the county government of Laikipia is committed to supporting and promoting hay production.

As expected the higher the distance from the market, the less likely to adapt to changes in climate. Given that livestock production is the main economic activity in the Semi-Arid economies, we found those households with more livestock to be more food secure. But one of the adaptation strategies is to have optimal herd size, therefore, there is need for efforts to encourage herders to reduce their herd size for more stability in the face of climate change - the lower the herd number, potentially the more savings and ability to get out of a drought or long dry spell for example. If drought hits and a household has invested a lot into developing a large herd and put little aside, this can cripple household food security and development. There is also need for pastoralist to combine herd size with the keeping of livestock as a business which enables them to have a plan on how to sell when animal gains the right live weight and consequently reduce the herd size to the optimal level.

Access to credit makes a household to be more food secure. These findings are consistent with the results of Ahmad et al., (2016). Access to credit may make a household food secure in the short-term, but in the long-term, if households do not plan well repayments of loans, there could be negatives effects of debt, reducing food security. Therefore, we recommend that pastoralist should be advised on responsible borrowing behavior.

These results have fundamental policy implication. First, it is essential to invest in the development of adaptation strategies that address issues of climate change relevant to the Semi-Arid economies. Second, facilitating and enabling credit facilities with responsible borrowing and disseminating information on climate change are vital facets that determine to implement the adaptation strategies, which could result in more food security. There is also need to enhance the current early warning system in the Semi-Arid with a component on the role of adapting to climate change on the food security of the pastoralists. Other interventions to climate change adaptations and private sector investments opportunities include: promoting livelihood diversification through conservancy/ tourism where the income is used for rangeland conservation and rehabilitation; restoring degraded grazing lands e.g. through adoption of silvo pastoral systems; enhancing selection, management of animal breeds; increasing people awareness of the effects of climate change on food security and livestock, strengthening land use management problems, fodder banks and strategic reserves capacity building in indigenous knowledge, introduction of livestock insurance schemes, making use of early signs, taking actions early in advance, as well as managing and breeding livestock (GoK 2013; 2016; 2018).

Lastly, Policy gap analysis on pastoralist focused climate change adaptation ought to be made as people deem them necessary, along with incorporating them in the national development planning, county governments planning and policies. Further support may be provided to the counties through research to identify their comparative advantage in pasture production in line with NCCAP priority adaptation of proper management of pasture lands /controlled grazing /fodder banks. For example, semi-arid and high potential counties present a better environment for fodder production while the arid counties present as users of the fodder and livestock markets.

Declarations

Funding : This data used in this study was supported by the Department for International Development (DFID) and Canadian International Development Research Centre (IDRC) through the Pathways to Resilience in Semi-arid Economies (PRISE) project led by Overseas Development Institute (ODI).

Ethical Approval- Not applicable

-Consent to Participate- Consent was sort from the respondent to participate in the survey. The following was read to the participant:

Hello,

Thank you for agreeing to speak with me. My name is [ENUMERATOR NAME]. I am here on behalf of [Institute name].

We are conducting a survey in the context of *Pathways to Resilience In Semi-arid Economies* (PRISE). This interview is not mandatory but your answers to these questions are what will make our study successful. Your views are important and will help us to generate research findings and learn lessons about the climate shocks in the sector of livestock. This information would help inform the investments and policies in the livestock sector.

We selected the producers randomly for the survey and would like to talk to you for about one and a half hours to collect information that is set out in this questionnaire.

We will be conducting the same survey in other communities in this group ranch and throughout Laikipia County as well as in other countries.

We value confidentiality and we will ensure that all the answers you provide will be kept confidential. We will not be using any device to record this interview and we will not share this information with anyone outside PRISE researchers.

-**Consent to Publish -** Not applicable

-**Authors Contributions:**

S. Wagura Ndiritu: Conceptualization, Methodology, Formal analysis, Writing - original draft.

Geoffrey Muricho: Methodology, Formal analysis

Availability of data and material- Provided upon request

Conflict of Interest statement

The authors declared that they have no conflict of interest.

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