



# Propensity to adapt to climate change: insights from pastoralist and agro-pastoralist households of Laikipia County, Kenya

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## Abstract

Climate change is a reality in Africa's drylands. Pastoralists are engaging and embracing a range of adaptive strategies to adjust to these changes. The socioeconomic factors driving them to engage in a portfolio of multiple adaptation strategies have not been adequately addressed in the existing literature. A multivariate probit model was used to analyze them as determinants of adaptive capacity that promotes or hinders adaptation to climate change. Adaptation is represented by uptake of multiple strategies (irrigation, livestock migration, fodder production, and improved livestock breeds) by households, a demonstration of a household's ability to diversify and adapt to the effects of climate change. The household asset base, particularly social capital represented by government assistance, stands out as it positively influenced by the uptake of four out of five adaptation strategies; that is, irrigation, livestock manure, fodder production, and improved breeds. Information heavily supports the adaptation process as it influenced all the five adaptation strategies analyzed but has a heterogeneous effect, supporting households to either adopt or reject a strategy. Crop-based information positively determines uptake of yield-enhancing strategies while relevant information for livestock activities contributes to the uptake of livestock-based strategies. These findings suggest that mainstreaming agricultural innovations, building a household asset base, and facilitating access to agronomic and climatic information will enable dryland communities to better adapt to climate change.

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## 1 Introduction

Climate change is real in the drylands of Eastern Africa (EA), which stands out as the worst hit region in the world due to its susceptibility, high levels of vulnerability, and low adaptive capacity (Hope 2009; Reid and Vogel 2006; Rosenzweig et al. 2008). In Kenya, this is more critical because nearly 89% of the landmass is arid and semi-arid lands (ASAL) (Government of Kenya 2012). These are homes to 38% of the Kenyan population, who are predominantly pastoralists and agro-pastoralists, communities that heavily depend on climate-sensitive natural assets and ecosystem resources for their livelihood and food security, thus exacerbating the already dire situation (Government of Kenya 2012). The negative impact of climate change and variability such as prolonged drought, delayed onset of rains, and extreme floods leads to economic losses, food insecurity, and conflict over scarce resources (Government of Kenya 2013). This comes amidst other complex stressors such as rapid demographic growth, chronic poverty, land fragmentation and degradation, depletion of natural resources, insecurity and conflict (Government of Kenya 2015; Headey and Kennedy 2011).

The uptake of adaptation strategies in the ASAL is reported to be low compared to other ecological zones, such as the humid and temperate zones (Bryan et al. 2013). This low adaptation situation is associated with greater constraints in the drylands, such as chronic poverty, insecure and ill-defined property rights, population pressure, the HIV/AIDS pandemic, insecurity and armed conflicts, land fragmentation and degradation (Bryan et al. 2013; Nassef et al. 2009; Silvestri et al. 2012). This notwithstanding, the dryland communities are learning, nurturing, and adopting multiple strategies such as livestock migration, irrigation, destocking, changing livestock breeds and diversifying animal feed to mitigate climatic and non-climatic shocks that threaten their livelihoods (Bryan et al. 2013; Silvestri et al. 2012). Adaptation to climate change is a demonstration of adaptive capacity (Smit and Wandel 2006), defined as as a reflection of the potential of a system to adapt to the effects or impacts of climate change (Downing 1991). It involves changes to better deal with problematic exposures and sensitivities (Smit and Wandel 2006) and the factors that drive this adaptive capacity or the determinants have been categorized as context-specific (Smit and Wandel 2006).

The objective of this paper is to analyze the socio-economic factors at play in encouraging or hindering pastoralist and agro-pastoralist households to engage simultaneously in multiple adaptation strategies. It focuses specifically on household assets, governance of land tenure, and climatic and agronomic information among the Maasai community of Laikipia County Kenya.

## 2 Background information

### 2.1 Pastoralism and agro-pastoralism in the drylands of Kenya

The Kenyan drylands, synonymous with arid and semi-arid lands (ASAL), occupy 89% of the country's total landmass (Government of Kenya 2012). The ASALs are climatically unstable with aridity as the dominant characteristic where low and erratic rainfall ranges from 150–550 mm per annum in arid areas and 550–850 mm per annum in the semi-arid areas (Fratkin

2001; Government of Kenya 2012). These drylands, are sparsely populated and host a numerically small percentage (38%) of the Kenyan population (Government of Kenya 2015). Pastoralism is the dominant social and economic activity in these risk-prone arid areas. It entails an extensive livestock production system in the rangelands where livestock mobility and communal natural resource as risk management strategies for water and pasture are the main defining features (Government of Kenya 2012). Pastoral mobility, is however not just about a coping strategy in the face of a problem, as commonly interpreted in literature, but also a strategy used by pastoralists to match the variable distribution of nutrients for livestock in the rangelands (Krätli 2015). It is a highly appropriate production strategy in environments characterized by high climate variability and unpredictability (Adriansen 2005).

In the literature from the 1990s, a gradual shift from nomadic pastoralism to agro-pastoralism was recommended, where fodder would be cultivated for livestock production (Steen 1994). In Ethiopia, this shift is observed (Lemenih and Kassa 2011), while in northern Tanzania pastoralists are modifying certain coping strategies such as mobility while taking up new adaptation practices such as purchasing rights to pasture and abandoning certain cultural coping practices such as reciprocity (Goldman and Riosmena 2013). This notwithstanding, changes in land use in ASAL has resulted in land fragmentation, intensification of agriculture demanding more farm inputs, overgrazing, conflict over scarce and diminishing resources, and water scarcity, among other issues (Maitima and Gumbo 2007). The Maasai community of Laikipia County, Kenya, is selected for this study for three reasons: First, as a pastoralist community whose main source of livelihood is domestic livestock (cattle, goats, sheep, camel, and donkeys). Second, as a community that is responding to political, environmental, social and economic changes by diversifying into agro-pastoralism, sedentary lifestyle and more individualized adaptation actions (Government of Kenya 2012). Finally, as a community whose footsteps other pastoralists in the drylands are following (Fratkin 2001).

Agro-pastoralism, is defined as a livelihood system where households obtain more than 50% of their domestic revenue from crop production and 10–49% from livestock and related products (Morton and Meadows 2000). Individualization of land use and ownership that promotes agro-pastoralism is a primary policy challenge as it undermines pastoral livestock mobility systems and collective customary institutions needed as adaptation strategies in ASAL regions (Mwangi 2006). Individualized actions result in socially differentiated vulnerability of the community to impacts of climate change (Adger Neil 2003) where households endowed with sufficient assets attain better adaptive capacity (Mude et al. 2007). This transformation among the Maasai community dates back to the infamous 1904/1911 Maasai agreement, a historical colonial regime which saw massive appropriation of Maasai land to foreigners (Koissaba 2016). Subsequently post-independence laws that promoted economic policies and measures advocating for land privatization and subdivision of communal lands into private group ranches and trust lands (Koissaba 2016). This was done through registration of private rights of pastoral groups and incorporating commercial livestock production systems into the market (Fumagalli 1978). Most ranch owners were able to make a reasonable living until the late 1980s, when the input costs became so high that ranchers began de-stocking. The collapse of the Kenya Meat Commission (KMC) and unpredictable beef prices made ranching even more economically unviable. Introduction of group ranches in Maasai land, ushered a process of individualization of land use and ownership in the early 1980s (BurnSilver 2016; Mwangi 2006; Rutten 1992). The subdivision of land hindered pastoral mobility, a production system viable in the ASAL region as well as other economic activities that benefited from collective action (Mwangi 2006). These land use changes followed by the drought of 2001 saw

an increase in sheep and goat farming, cultivation, and habitation in the transitioning ranches (Georgiadis et al. 2007). The need for alternative income in the late 1980s together with government policies suppressed pastoral communities in favor of eco-tourism and wildlife conservation while maintaining low livestock commercial ranching (Unks et al. 2019). These changes have had a bearing on the propensity of pastoral communities to adapt to climate change, and this explains the underlying reasons as to why some are shifting to more sedentary lifestyles. Whether or not these changes are in response to opportunity (positive) or constraints (negative), the root of this in Laikipia County lies in the historical contingencies of the past, exacerbated by climate change.

## 2.2 Conceptualizing the propensity to adapt

The climatic conditions, ecological landscapes, and institutional frameworks of the drylands have experienced drastic changes over the past century (Agrawal 2010; Wangui et al. 2012). Changes such as onset of rains, its cessation, duration, and intensity have adversely affected pastoral coping mechanisms to climate variability (Nassef et al. 2009; Wangui et al. 2012). Climate change adaptation rhetoric around pastoralists in the drylands of Kenya has featured more on institutional frameworks, while we explore the question of household adaptive capacity, based on the roles of assets, governance, and climatic and agronomic information in addressing climate change impacts (ACCRA 2010; Berkes 2002).

Adaptive capacity reflects the propensity of households and community systems to prepare, adjust or adapt to the effects or impacts of climate change (Downing 1991; Engle 2011; Smit and Wandel 2006). It is reflected through adaptation as a socio-technical process performed individually or as a collective action by actors in response to socio-ecological change (Crane et al. 2011; Eriksen et al. 2015). The forces of adaptive capacity, referred to as determinants, describe the characteristics of a system or society to adapt to the changing external conditions (Fussler and Klein 2006; Smit and Wandel 2006). These characteristics are based on the “Local Adaptive Capacity framework (LAC)” (Jones et al. 2010), which has five components. First, the household asset base that includes the five capitals in literature: human, financial, social, physical, and natural capitals. Second, institutions and entitlements that ensure impartial distribution of key resources. Third, knowledge and information considered important for adaptation to take place. Fourth, innovation where the systems’ ability to support innovation is examined. Finally, governance and informed decision-making, where issues of participatory, transparency, and community prioritization are considered.

Uptake of adaptation strategies is a manifestation of adaptive capacity (Smit and Wandel 2006). We build on this argument to conceptualize that the adaptive capacity of the pastoral community is demonstrated by the adaptation strategies they are engaging in. We therefore critically identify those factors that either encourage or hinder the uptake of the identified adaptation strategies. These factors are identified through the LAC framework; asset base, information, and governance (Jones et al. 2010). The asset base is observed through the Sustainable Livelihoods Framework (SLF), which identifies the five capitals owned and/or accessible by households. Information looks at agronomic and climatic information available and accessed by households on pasture, water, and farm technologies. Governance is observed through land tenure regimes that examines the state of land the households own or access, which determines their adaptation decisions. We connect these determinants of uptake of adaptation strategies as indicators of propensity or adaptive capacity of the pastoralists and agro-pastoralists communities.

## 2.3 Propensity to adapt among pastoralists and agro-pastoralists

The pastoral households are diversifying, taking up multiple strategies such as livestock migration, irrigation, and non-climate dependent livelihoods such as petty trade (Bryan et al. 2013). There is no coherent information on how these households adopt multiple strategies and the factors that drive their decisions. Opiyo et al. (2016) identified household capital such as human, financial, and physical as factors that determined the ability of pastoral communities to adapt using Heckman probit model. This, however, did not consider their ability to adopt multiple adaptation strategies similar to what is practically happening on the ground. In the Eastern drylands of Kenya, the Heckman model was equally used to identify farmers' adaptation strategies and the assets that influenced their likelihood of adaptation (Ndambiri et al. 2013). This study did not statistically relate the assets as determinants of any specific adaptation strategy. In Malawi, Multivariate Probit (MVP) was employed to model household selection of climate-smart agricultural practices (Asfaw et al. 2014). That study identified the distinct nature of climate change adaptation decisions made by individual farmers in employing different climate-smart farm practices (Asfaw et al. 2014). This is fundamental information in the adaptation process as it facilitates the understanding of community interaction with specific practices, the promoters and barriers. This information, although relevant for policy, research, and development among the pastoral community in the drylands of Kenya, is missing, and a key motivation for this work is to identify socio-economic factors that hinder or encourage adoption of multiple adaptation strategies and to empirically characterize adaptive capacity of a transitioning pastoral community. This knowledge provides important insights for policy makers, researchers, and development practitioners designing interventions to support the climate change adaptation process in the drylands.

## 3 Methodology

### 3.1 Description of the study area and community under study

Laikipia County, located in the drylands of Kenya, is home to the “Laikipiak” Maasai, of Il Ngwesi Group Ranch. This dryland community practices a mix of pastoralism and agro-pastoralism livelihood systems. While we recognize that there is a fluid gradient between these two categories of livelihood rather than a hard boundary (Krätli and Swift 2016), we use these labels as a heuristic to discuss the transitional trajectories toward crop based livelihood systems observed in some sub-populations of this community. Although this distinction has been critiqued (Krätli et al. 2015), the two terms are used as analytical categories rather than an indication of cultural self-identification. For the purposes of this study, pastoralists are therefore viewed as households with a high, over 50% (Morton and Meadows 2000), level of dependency on the livestock production system in the drylands with mobility as the main defining characteristic. Agro-pastoralists are viewed as households with some level of livestock mobility and have shifted to high levels of dependency on crop-based systems, such as taking up rain-fed and irrigated agriculture. This changing dynamic is related to the fragmentation of the “Laikipiak” Maasai who originally lived in the community-owned Il Ngwesi Group Ranch. The majority (>75%) of these ranch members have migrated from the semi-arid or arid savannah land to settle in neighboring semi-arid parts of Laikipia, Meru, and Isiolo. These are regions with climatic opportunities for crop production and therefore the transition

observed. The array of livelihood diversification strategies that accompany the Il Ngwesi diaspora provides a fertile ground for analyzing factors that contribute to adaptive capacity.

The transition of the ranch members became more prominent due to increased rainfall variability and consequently high (>75%) livestock mortality (Little et al. 2016; Unks et al. 2019). Equally, of importance was the critical decision made by the community leadership to convert the ranch into a conservancy and eco-tourism facility. According to the group ranch constitution, the villages where members have settled are aggregated and referred to as the seven neighborhoods. These are Chumvi, Ethi, Ngare-Ndare/Manyangalo, Lukusero/Nandugoro, Leparua, and Lower and Upper Il Ngwesi (Fig. 1). The community's main source of livelihood is pastoralism and agro-pastoralism.

### 3.2 Data collection procedures

#### 3.2.1 Quantitative procedures

A total of 12 villages (Fig. 1) were purposively selected and treated as separate units during data collection and only aggregated during data analysis to represent the seven neighborhoods of the group ranch. The unit of analysis was household level where a minimum sample size of 385 households was calculated using McClave et al. (2008) formula ( $n = \frac{Z_{\alpha/2}^2(pq)}{(SE)^2}$ ). This number was rounded upward to 500 to increase statistical power and to take care of errors. Six questionnaires were dropped due to incompleteness and the remaining 494 were analyzed. The household sampling frame was developed by the main researcher facilitated by the local field assistant, respective village chief, and village elders. This sampling frame was used to

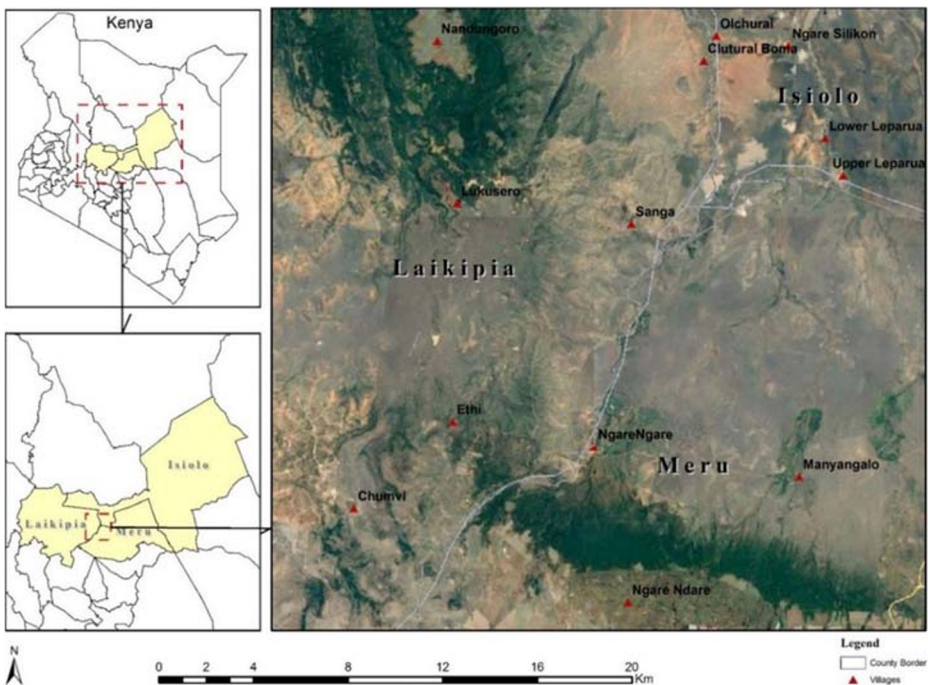


Fig. 1 Map of the study sites (neighborhoods) in the three counties

proportionally calculate sample size and randomly select households based on village population statistics (Fig. 2). A structured questionnaire was administered using the Open Data Kit (ODK) system by a team of 12 well-trained enumerators, over a period of 15 days. Information on household socioeconomic data, their perception of climate change, adaptation strategies employed, household assets, climate and agronomic information accessed, as well as main land tenure regime owned or accessed, was elicited.

### 3.2.2 Qualitative procedures

Qualitative data collection tools such as gender-disaggregated focus group discussions (FGDs), semi-structured and informal interviews and participatory observations were used to improve the questionnaire administered for quantitative data collection. This process identified adaptation strategies investigated in the questionnaire, triangulated the data, and supported interpretation of the survey results. The data collection process took place in the months of May through to August 2016 before the household survey was conducted. A total of 24 FGDs and 17 key informant interviews were conducted. A general interview guide was used for the FGDs and semi-structured interview guide for formal interviews.

### 3.3 Selection of the dependent variables

An exhaustive list of adaptation strategies (Fig. 3) generated from FGDs and literature was incorporated into the household questionnaire. The five adaptation strategies selected according to descriptive statistics are pro-active and not reactive to climate stress. They contribute to enhanced crop yields and improved livestock productivity and management and include: livestock manure, seasonal livestock migration, crop residue as fodder, irrigation, and improved livestock breeds. These five strategies were used as dependent variables and subjected to econometric model analysis.

Livestock manure is a dominant strategy among the agro-pastoralists (88%) (Fig. 3). Manure is used in crop production as well as a source of income in the livestock manure trade (Kigiria et al. 2013). Although livestock manure is documented as a contributor to global climate

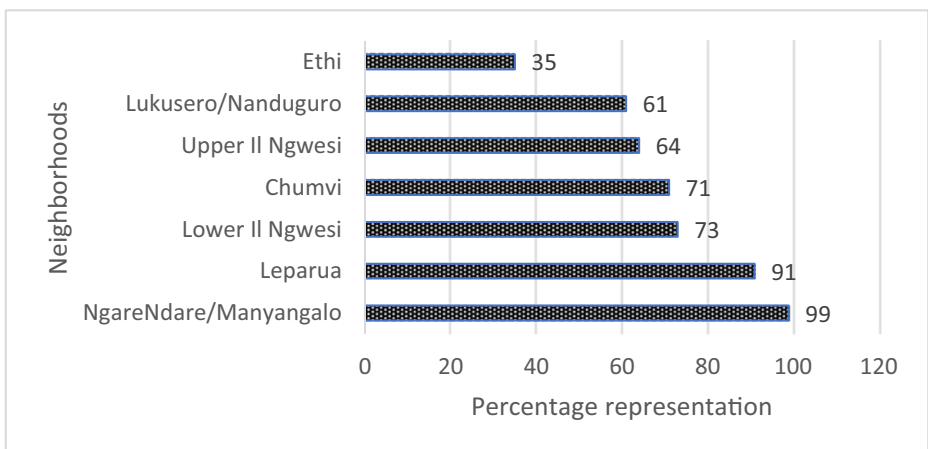
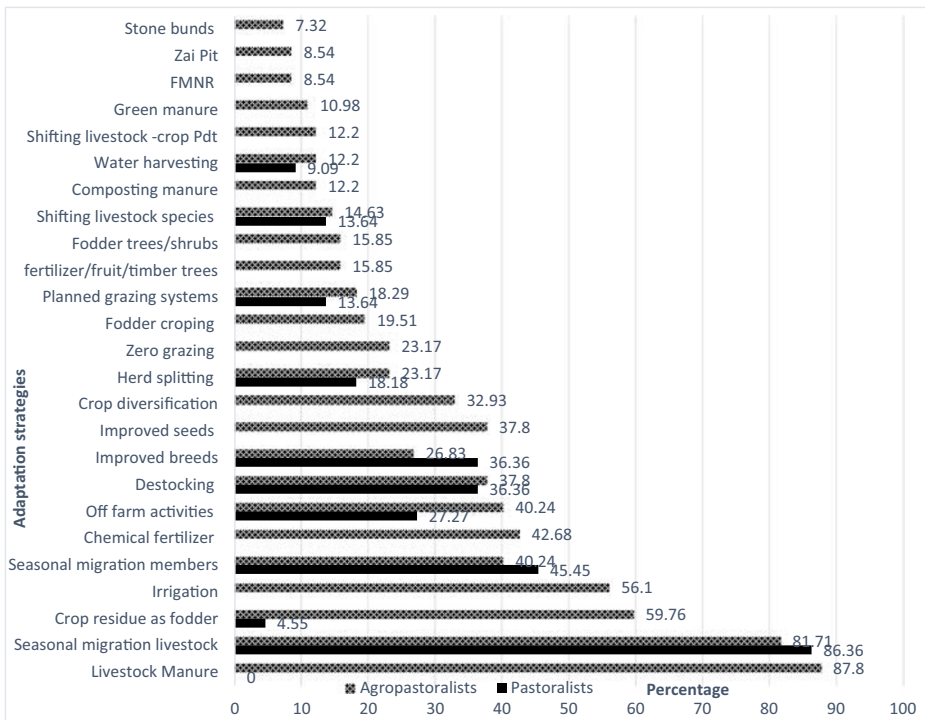


Fig. 2 Percentage representation of members in the various neighborhoods



**Fig. 3** Adaptation strategies embraced by the pastoralists and agro-pastoralists

change through greenhouse gas (GHG) emission (World Bank and CIAT 2015), with proper management, it is taken as an adaptation strategy among smallholder farmers in a mixed farming system (Roncoli et al. 2010). This is due to its low cost of fertility restoration in comparison to inorganic fertilizer and for improving soil water-holding capacity (Amole and Ayantunde 2016; EIP-AGRI Focus Group 2016; Roncoli et al. 2010).

Historically, pastoralists used seasonal migration of livestock as a way of life to overcome climate variability (Gautier et al. 2016) as well as to take advantage of variable distribution of resources in the rangelands (Krätli 2015). With the fundamental transitional changes taking place, the dryland community is adapting a modified pastoral mobility livestock strategy (86% pastoralist, 82% agro-pastoralist) (Fig. 3) to respond to heightened variability and unpredictability as a result of climate change. Livestock mobility is now more strategic with less involvement of family members such as the case of “Laikipiak” Maasai who let their livestock migrate with herders and/or with a family member and the rest of the household members are left in the established homesteads.

Irrigation is an investment among the agro-pastoralists (56%) (Fig. 3), a documented adaptation strategy at the farm level (Bryan et al. 2013). It facilitates the household to embrace production and marketing of high value crops, such as french beans, tomatoes, and onions, and reduces their dependence on the unpredictable rainy seasons, improving household food security and income (UNDP 2009). The capacity of households to engage in irrigation depends on multiple household capitals (social, financial, and physical) (King et al. 2018).



The utilization of crop residues as livestock feed is a dominant practice among the agro-pastoralists (60%) (Fig. 3), a community that practices crop production, and therefore an expected assumption. Additionally, a strategy documented as a fundamental practice of feeding livestock among pastoralists (Little et al. 2016). Crop residues as fodder was equally prioritized at the FGDs as participants discussed cultivation of fodder as hay, a practice that is on the rise in the drylands of Kenya.

Improving livestock breeds was identified as an adaptation strategy during FGDs. Its uptake in the region is on the rise. A strategy documented among the well-off Maasai of Tanzania who target livestock markets (Goldman and Riosmena 2013). It involves introducing a superior male breed to a herd of indigenous female livestock to produce improved offsprings.

### 3.4 Description and selection of the independent variables

Table 1 presents the independent variables (household assets, information, and governance) selected based on climate change adaptation literature.

Household assets entails analyzing the five sustainable livelihood assets: human, natural, social, financial, and physical capitals. Human capital as a determinant of adaptation is grounded in household structures and composition (Dulal et al. 2010; White 2009). The variables selected to represent it include: age and education of household head, family size, and female literacy. Female literacy was of particular interest because it was observed and indicated to be low (33%) by descriptive statistics (Table 2) in the pastoral community as confirmed by Mude et al. (2007). This is a hindrance to some decision making processes inclusive of adaptation. Natural capital defined as “world’s stock of

**Table 1** Independent/indicators variables identified for MVP model

Independent variables	Indicators identified for the analyses
Households assets/capital	
Human	<ul style="list-style-type: none"> <li>- Age of the household head</li> <li>- Education level of the household head</li> <li>- Female literacy</li> <li>- Family size</li> </ul>
Natural	<ul style="list-style-type: none"> <li>- Land quality for crop production</li> <li>- Land quality for fodder production</li> </ul>
Social	<ul style="list-style-type: none"> <li>- Membership in farmers’ group or association</li> <li>- Assistance from friends, relatives, and government</li> </ul>
Financial	<ul style="list-style-type: none"> <li>- Access to micro-credit institutions (formal, informal, community or NGO lending institutions)</li> <li>- Ownership of livestock (cattle, goats and sheep)</li> </ul>
Physical	<ul style="list-style-type: none"> <li>- Aggregate index encompasses household equipment such as radio, TV, cell phone, bicycle, motorbike, as well as farm equipment such as cart, water pump, ox plough, and access to road infrastructure</li> </ul>
Governance	<ul style="list-style-type: none"> <li>- Public Land Tenure</li> <li>- Community Land Tenure</li> <li>- Private Land Tenure</li> </ul>
Information	<ul style="list-style-type: none"> <li>- Climate information for grazing purposes</li> <li>- Information on pasture availability</li> <li>- Information on water point availability</li> <li>- Climate information for agronomic technology</li> <li>- Agronomic information for farm technology</li> </ul>

**Table 2** Definition of explanatory variables and their mean

Variable code	Variables	Description	Mean	Standard deviation
Human capital				
hhage	Age	Continuous (years)	45	13.2
hheduc	Education level of the household head	Continuous (years)	3.50	4.73
hhnot	Family size	Continuous (number)	7.00	3.16
flit	Female literacy	dummy: 1 if can read otherwise 0	0.33	0.48
Natural capital				
landfood1	Quality of land used for food production	Dummy: 1 if a yes high overall quality otherwise 0	0.32	0.47
landfood2	Quality of land used for fodder production	Dummy: 1 if a yes high overall quality otherwise 0	0.21	0.41
Social capital				
members	Membership to any association, cooperative, community	dummy: 1 if a member otherwise 0	0.33	0.47
assfriend	Assistance received from a friend	dummy: 1 if a yes otherwise 0	0.54	0.50
assrel	Assistance received from a relative	dummy: 1 if a yes otherwise 0	0.57	0.50
assgov	Assistance received from government	dummy: 1 if a yes otherwise 0	0.21	0.41
Financial capital				
smallivest	Small numbers of livestock	dummy: 1 if a yes otherwise 0	0.78	0.42
medivest	Medium numbers of livestock	dummy: 1 if a yes otherwise 0	0.15	0.36
credacc	Access to credit	dummy: 1 if a yes otherwise 0	0.26	0.44
Physical capital				
assetindx	Physical asset index*	Continuous	3.78E-09	2.44
Governance				
gov_own	Government land tenure	dummy: 1 if a yes otherwise 0	0.31	0.46
priv_own	Private land tenure	dummy: 1 if a yes otherwise 0	0.32	0.47
comm_own	Community land tenure	dummy: 1 if a yes otherwise 0	0.28	0.45
Information				
infilmwng	Seasonal climate forecast to decide where to graze	dummy: 1 if a yes otherwise 0	0.44	0.5
infpast	Information on pasture availability to decide where to graze	dummy: 1 if a yes otherwise 0	0.71	0.45
infwatpt	Information on water point availability to decide where to graze	dummy: 1 if a yes otherwise 1	0.64	0.48
infclimft	Climate information to decide which farm technology to use in the face of CC	dummy: 1 if a yes otherwise 2	0.11	0.31
infagriof	Agonomic information to decide which farm technology/adaptation option to use in the face of CC	dummy: 1 if a yes otherwise 0	0.50	0.22
	Constant	Number of observations (N)		

A comprehensive household asset index was constructed following the methodology developed by Gbetibou (2009) to aggregate the different indicators (household assets, household dwelling, and physical infrastructure) of physical capital

natural resources” (Morton and Meadows 2000) was represented by quality of land for crop and fodder production. Social capital that defines the way social relations develop between individuals and households in the society (Kgathi et al. 2007) was represented by assistance from a friend, relative or the government and membership to any association. The type of assistance elicited in this research was in the form of money or food the household received in the previous 12 months to the survey. Financial capital entails resources and assets, available to the household to provide goods and services (Morton and Meadows 2000). To model financial assets, livestock herd size, and access to credit were selected as representative variables. Although household livestock units has often been used as a proxy for analyzing household wealth, it failed to account for other household financial sources (King et al. 2018) such as access to credit and saving (Pettengell 2010). Taking note of this, access to micro-credit institutions was therefore included as a representative of financial asset variable. Physical capital was viewed as household infrastructure inclusive of household dwelling and physical infrastructures (roads and market) (Headey and Kennedy 2011). To aggregate these different indicators of physical capital, a comprehensive asset index was constructed following the methodology developed by Gbetibouo (2009).

Information as a public good provided by the government to enhance adaptation (Collier et al. 2008) and its accessibility improves the likelihood of households to adapt (Belay et al. 2017), while lack of it hinders adaptation (Gbetibouo 2009). To analyze climatic and agronomic-related knowhow of the households, the following variables were considered: climate information for grazing purposes, information on pasture availability, information on water point availability, climate information to decide about agronomic technology, and agronomic information on farm technology.

Governance of land tenure regime was defined as institutional arrangements that set up rules and govern the relationship people have with land (Damonte and Rodríguez 2016). Three such land regimes available in the dryland were identified and considered as variables in the model: 1. Public land, defined as land owned by the government and dedicated to a specified public use or made available for private use at the discretion of the government (Ministry of Lands 2007). 2. Private land which is land held by an individual or other entity under freehold or leasehold tenure (Ministry of Lands 2007). 3. Community land, defined as lawfully held, managed, and used by a specific community and aimed at ensuring preservation of the asset base for current and future generations (Ministry of Lands 2007).

### 3.5 Analytical methods

Descriptive statistics such as means and frequencies are used to first give an overall picture of the socioeconomic characteristics of the households (Table 2), and secondly, to determine the land tenure regime, which was constructed based on the respondents’ locations and their reported conditions of land ownership. Thirdly, the average values of the dependent and explanatory variables guided formulation of the econometric model, which was found suitable due to its ability to model the influence of a set of predictor variables on each of the adaptation options while allowing error terms between the unobserved and unmeasured disturbance to freely correlate jointly (Lin et al. 2005). This

would occur due to possible complementarity (positive correlation) or substitutability (negative correlation) between the different adaptation strategies (Asfaw et al. 2014; Ashraf et al. 2014). The Multivariate Probit (MVP) model used draws from the statistical literature of Asfaw et al. (2014), Ashraf et al. (2014), and Lin et al. (2005). It models the relationship between explanatory variables (household assets, governance, and information) and the five adaptation strategies identified.

The MVP model is characterized by a set of five ( $n$ ) binary-dependent variables (seasonal livestock migration, livestock manure, irrigation, crop residue as fodder, and improved livestock breeds), such that:

$$\begin{aligned} Y_{in} &= 1 \text{ if } X'_{in}\beta_n + u_{in} > 0 \\ Y_{in} &= 0 \text{ if } X'_{in}\beta_n + u_{in} \leq 0 \text{ Where } i = 1, 2, \dots, N. \quad n = 1, \dots, 5 \end{aligned} \quad (1)$$

In Eq. 1, the assumption is that a rational  $i$ th household has a latent variable  $Y^*_{in}$  that captures the unobserved preferences or demand associated with the  $n$ th option of adaptation strategy.  $X'_{in}$  is a vector of explanatory variables,  $\beta_1, \beta_2, \dots, \beta_n$  denotes the conformable vector of parameters to be estimated, and  $u_{in}$  are the random error terms distributed as multivariate normal distribution with zero mean and unitary variance.

## 4 Results and discussions

### 4.1 Social-economic determinants that promote or hinder adaptation strategies

The correlation matrix (Table 3) indicates interdependence between multiple adaptation strategies engaged by pastoralists and agro-pastoralists as either complementing or substituting each other. The MVP model (Table 4) shows statistically significant coefficients, indicating the notion of possible complementarity (positive correlation) or substitutability (negative correlation) across the different adaptation strategies (Asfaw et al. 2014; Ashraf et al. 2014). This supported the use of the MVP model that allowed potential correlation between the unobserved disturbances and interrelationship between the adaptation options (Kassie et al. 2013). This indicates critical points that require consideration during policy and development interventions.

To give insights on socio-economic and institutional factors that drive the adaptation process in the drylands, Table 4 outlines the household determinants that facilitate the pastoral community to adapt to climate change by engaging or disengaging in multiple portfolios of adaptation strategies. Female literacy as an indicator of human capital, has a negative influence

**Table 3** Estimated correlation matrix of MVP analysis

Dependant variables	Irrigation	Livestock migration	Fodder production	Livestock manure	Improved livestock breeds
Irrigation	1				
Livestock migration	-0.0383	1			
Fodder production	0.3401***	0.042	1		
Livestock manure	0.6158***	0.0567	0.2894***	1	
Improved livestock breeds	0.0879*	0.1591***	0.0844*	0.1638***	1

Significance levels: \*, \*\*, \*\*\* Significance at 10, 5, and 1%, respectively

**Table 4** Household determinants of propensity to adapt to climate change

Variables	Irrigation Coef (SE)	Livestock migration Coef(SE)	Fodder production Coef(SE)	Livestock manure Coef(SE)	Improved livestock breeds Coef(SE)
Human capital					
Age	-0.010 (E0.012)	-0.007 (0.01)	-0.014 (0.02)	-0.006 (0.01)	0.009 (0.01)
Education level of the household head	0.023 (0.03)	0.030 (0.04)	<b>0.082*(0.04)</b>	9 (0.04)	0.049 (0.03)
Family size	-0.023 (0.04)	0.043 (0.04)	-0.130 (0.09)	0.007 (0.05)	0.031 (0.06)
Female literacy	<b>-0.537*(0.29)</b>	0.041 (0.32)	<b>-0.614*(0.36)</b>	<b>-0.839***(0.39)</b>	-0.365 (0.38)
Natural capital					
Quality of land used for food production	0.656 (0.57)	-0.838 (0.53)	<b>4.228****(0.87)</b>	0.940 (0.59)	-0.453 (0.48)
Quality of land used for fodder production	0.033 (0.312)	-0.485 (0.39)	<b>3.131****(0.75)</b>	<b>1.507****(0.50)</b>	<b>-1.099****(0.40)</b>
Social capital					
Membership to any association, cooperative, community	-0.079 (0.29)	0.235 (0.27)	<b>-0.808***(0.35)</b>	0.525 (0.40)	-0.039 (0.41)
Assistance received from a friend	0.042 (0.34)	0.509 (0.37)	<b>0.877***(0.38)</b>	0.594 (0.43)	0.002 (0.47)
Assistance received from a relative	-0.226 (0.33)	0.013 (0.37)	-0.567 (0.41)	<b>-0.922***(0.43)</b>	-0.341 (0.35)
Assistance received from government	<b>0.918****(0.35)</b>	0.720 (0.44)	<b>1.487****(0.45)</b>	<b>0.976*(0.57)</b>	<b>1.044***(0.48)</b>
Financial capital					
Small numbers of livestock	-0.388 (0.29)	<b>-0.649***(0.29)</b>	0.322 (0.40)	0.197 (0.34)	-0.060 (0.47)
Medium numbers of livestock	-0.308 (0.47)	<b>4.925****(0.49)</b>	0.413 (0.59)	-0.519 (0.35)	-0.661 (0.45)
Access to credit	0.356 (0.34)	0.489 (0.39)	0.234 (0.52)		
Physical capital					
Physical asset index	0.017 (0.08)	-0.047 (0.11)	0.180 (0.13)	<b>0.219***(0.11)</b>	<b>0.191*(0.11)</b>
Information					
Climate information for grazing purposes	<b>1.077****(0.34)</b>	-0.358 (0.35)	<b>0.783***(0.39)</b>	0.224 (0.50)	<b>-0.759*(0.40)</b>
Information on pasture availability	-0.644 (0.60)	0.761 (0.54)	1.084 (0.79)	<b>2.134****(0.77)</b>	<b>2.530****(0.83)</b>
Information on water point availability	0.154 (0.53)	<b>0.813*(0.47)</b>	-0.539 (0.77)	0.101 (0.56)	<b>-2.586****(0.76)</b>
Climate information to decide about agronomic technology	<b>0.749*(0.42)</b>	<b>-1.081***(0.47)</b>	<b>1.047*(0.55)</b>	0.394 (0.78)	-1.020 (1.0)
Agronomic information on farm technology	0.436 (0.73)	-0.586 (0.55)	<b>-2.854****(1.03)</b>	<b>-2.150****(0.88)</b>	0.238 (1.16)
Governance					
Government land tenure	-0.697 (0.50)	0.992 (0.66)	<b>6.135****(0.84)</b>	<b>-1.531***(0.68)</b>	-0.708 (0.88)
Private land tenure	-0.289 (0.48)	<b>0.655***(0.50)</b>	<b>5.944****(0.80)</b>	0.004 (0.57)	1.161 (0.79)
Community land tenure	0.410 (0.65)	0.978 (0.74)	<b>5.367****(1.09)</b>	0.438 (0.76)	-0.859 (1.23)
Constant	1.337 (0.82)	-0.790 (0.96)	-9.763 (1.50)	-0.247 (0.943)	-1.258 (1.18)
Number of Observations (N)	149				

\*, \*\*, \*\*\* Significance at 10, 5, and 1%, respectively

in the uptake of three adaptation strategies; irrigation, fodder production and livestock manure. This is an unexpected scenario implying that an increase in the literacy levels of women in pastoral systems reduces household propensity to adopt proactive adaptation strategies in line with pastoralism and agropastoralism. We observe that the quality of land accessed or available to the households for either fodder or food production has a very high positive coefficient of correlation with production of fodder for livestock and utilization of livestock manure and an equally high but negative correlation with improved livestock breed, an indication that good quality of land reduces the likelihood to adopt improved livestock breeds.

Government assistance to the pastoral community was observed to significantly promote four technically demanding adaptation strategies (irrigation, fodder production, use of livestock manure, and adoption of improved livestock breeds). However, it is interesting to note how livestock migration as an adaptation strategy has been left out of government assistance, implying that the government does not facilitate pastoral livestock mobility as an adaptation strategy despite its effectiveness and strong historical track record. This could be explained by the stated government response to climate change on livestock and pastoralism that includes livestock breed improvement, livestock insurance, and fodder production (Government of Kenya 2013) but omits the creation of an enabling environment for pastoral mobility. Membership to associations, cooperatives or community groups had a negative influence on fodder production, a scenario attributed to Hardin's argument on the "Tragedy of the Commons", the common pool resources (Ostrom et al. 2002). This is explained by how fodder production as an increasing trend in the ASAL region is emerging as a private collective practice (Ng'ang'a and Crane 2020) where households are either individually or together as a group "privatizing" public good for fodder production, limiting its accessibility by others. This causes conflict and insecurity especially during periods of drought watering down efforts done in fodder production as "others" try to get access to graze their livestock. Additionally, a negative correlation coefficient between assistance received from relatives and livestock manure is observed. This is explained by the fact that during periods of drought, relatives in areas with pasture and water, host family members' livestock and the manure generated belongs to the host.

Two scenarios were observed in relation to the size of livestock herd, first a positive correlation between medium size of livestock herd (51–149) and livestock migration and secondly, a negative correlation with small herd (<50) of livestock. This ideally implies that households with large herds of livestock above 51 have a higher probability of migrating their livestock for pasture and water. A larger herd of livestock is considered not only as a livelihood strategy but also as an enterprise that can either engage the owner fully as a herder or can pay for the services of a contracted herder.

The overall household index (3.78E-09) constructed to represent the physical asset positively influences uptake of two adaptation strategies: livestock manure and improved livestock breeds. This indicates the usefulness of livestock manure in households with higher household index, ideally because they have the capacity to transport the manure to their farms, for example, by use of a cart or have mobile phones that they can use to contact potential buyers. Additionally, in regard to improved livestock breeds, these households can engage in livestock breed improvement programs because they can financially afford the higher quality male bulls or buck often purchased from neighboring private ranches. They can equally engage and participate in markets because they have access to the communication assets needed for such activities. Climatic and agronomic information as a component of adaptive capacity has direct influence on all the five adaptation strategies in either or both direction. Climate information for grazing purposes positively influences uptake of irrigation and fodder production strategies but hinders improved livestock breeds. This scenario is related to governance of land tenure as

households in private lands practicing irrigation can send their livestock to regions with pasture or fence off their land to produce fodder as a reserve during prolonged drought. Tradeoff between utilization of land for irrigation or for improved livestock breeds such as dairy goats and cows was observed to be in favor of the former, high value crop production.

Information on pasture availability promotes utilization of livestock manure and livestock breed improvement. Households use this information to plan the trade of livestock manure with potential buyers as they communicate their migration and grazing plans. They are equally able to invest in a livestock breed improvement program based on the information available on pasture availability. Information on water point availability promotes uptake of livestock migration strategy, this is expected because water points are often a center of influence in relation to livestock migration and grazing decisions in the pastoral systems. It however hinders improved livestock breeds whose labor demands are often localized. Climate information on agronomic technology promotes irrigation and fodder production but reduces the likelihood of livestock migration as families move toward sedentarization and crop production. Agronomic information on farm technology reduces the uptake of fodder production and utilization of livestock manure as a lot of information accessed is on horticulture production with recommended fertilisers and pesticides.

Fodder production is a near universal practice in the three land tenure regimes (government, private, and community land tenure systems) as shown by the very high and statistically significant positive correlation. It is however, implemented differently in each of these land tenure categories. Households with access to government land tenure in the Nandugoro neighborhood collectively engage in fodder production as a community project. In the private land tenure regime, individualized fodder production is practiced by the households to feed the weak or lactating animals that are left behind after others have migrated. At the community land tenure regime, rotational (holistic) grass management and conservation efforts is embraced to ensure grass regeneration for utilization during periods of prolonged drought. Interesting to observe is the positive influence private land tenure has on migration of livestock, a scenario that implies that the more the household settles into private land tenure the more the need for livestock migration and mobility in search of pasture and water. This is explained by the fact that households living in private land tenure embrace agro-pastoralism, growing crops and keeping livestock. However, due to limited land spaces in the private schemes, they graze their livestock in the community and government land tenure regimes.

## 4.2 Characterization of adaptive capacity

The second part of this paper aims at empirically characterizing the adaptive capacity of a transitioning pastoral community, ideally their propensity to adapt to climate change. This was assessed based on three components of the LAC framework: asset base, climatic and agronomic information, and governance of land tenure (Jones et al. 2010).

Social capital as a component of household asset base was represented by assistance received from the government, which promoted four out of the five adaptation strategies (irrigation, fodder production, livestock manure, and improved livestock breeds). This heavy government support can be explained by the role of the government in building the social safety net of vulnerable pastoral communities (Kgathi et al. 2007). In Kenya, the government, at the national and county levels, has been at the frontline supporting innovative and new practices among the dryland communities through water provision for irrigation, allocation of land and seeds for fodder production, livestock manure through extension services, and

improved livestock breeds through livestock breed improvement programs. An interesting insight though is how government is absent in livestock migration and mobility as an adaptation strategy. This is likely because it is the government policies that have continuously promoted the sedentary lifestyle of pastoralists, and therefore has not invested in landscape level strategies to facilitate livestock mobility.

Natural capital, as represented by quality of land for both crop and fodder production, was observed to highly promote fodder and livestock manure production. These high coefficients indicate the importance of good quality land as a determinant of strategies targeting crop yields enhancement and livestock improvement. Fodder production, although a new concept within the pastoral community, contributes toward the success of agro-pastoralism, which demands the availability of fertile lands for households to engage in both crop and livestock production (Little et al. 2016). Additionally, crop production and livestock keeping have mutual connection since livestock manure is a cheaper and more easily available means of improving soil fertility, while crop residues are consumed by the livestock (Maitima and Gumbo 2007). Quality of land, however, hinders uptake of improved livestock breeds that are associated with technically high and demanding labor due to their sensitivity to risks and diseases in comparison to the traditional breeds. It is argued that although improved breeds would pay households more, they have their own challenges such as diseases if not well taken care of (Abiodun 2014).

Human capital as represented by female literacy is surprisingly weak and hinders the uptake of three adaptation strategies (irrigation, fodder production, and livestock manure). The low female literacy level implies that the few educated women make decisions contrary to the two main systems of livelihood, pastoralism and agro-pastoralism. They are in favor of the limited emerging livelihood alternative that are non-climate sensitive such as petty trade, development work and leadership positions. This is an indication that education as a determinant of adaptive capacity is context specific. In western Kenya, although education promotes uptake of climate-smart agriculture, post-secondary education reduces its adoption because those who are more educated opt for urban “white collar” jobs over agriculture (Mungai et al. 2017).

Financial capital, represented by size of the livestock herd, portrays two scenarios. First, small livestock herd size (<50) correlates with lower livestock mobility, while medium (51–150) and large (>151) herd sizes correlate with higher livestock mobility. This is expected because large herd sizes enable flexibility of pastoral households (Nassef et al. 2009) with less diversification portfolio (Fratkin 2001; Mburu et al. 2017); furthermore, effectively maintaining larger herd sizes is not tenable without mobility. A small herd of livestock indicates a financial constraint in meeting the cost of migration. What is surprising, however, is the low influence financial capital has on other adaptation strategies. This could be due to the lower likelihood of pastoralist selling their livestock to engage in agricultural practices, implying a weakness on how financial resources are positioned through livestock sizes. Challenging the idea that financial assets are a pillar of adaptive capacity in the drylands. A similar scenario is reported with physical assets, where household index only influences the uptake of two out of the five adaptation practices examined. These are livestock manure and improved breeds. Households with no infrastructure do not engage in the vibrant livestock manure trade in the drylands (Kigiria et al. 2013).

Availability and accessibility of climatic and agronomic information influence uptake of three adaptation strategies that accommodate agro-pastoralism, irrigation, fodder production, livestock manure, and two that promote pastoralism, improved livestock breeds and livestock migration. Surprisingly, however, climate information for grazing purposes has a negative



influence on improved livestock breeds and is silent on livestock migration, implying that migratory households are not interested in this kind of information. This is explained by the inbuilt and historical mechanism of communicating pasture availability. These results show that climate change and agronomic information as components of adaptive capacity influence uptake of all five adaptation strategies analyzed in either or both direction. A heterogeneous relationship is implied, supporting household choices in taking up or rejecting adaptation strategies (Kgosikoma et al. 2018; Nassef et al. 2009; Ndambiri et al. 2013). In autonomous adaptation, households and communities at large need appropriate information about potential threats and impacts of future climate change (Jones et al. 2010).

As a component of adaptive capacity, governance is viewed as a facilitator of flexible decision-making, where issues of participation, transparency, and community prioritization are considered (Jones et al. 2010). All three types of land governance and property rights (government, private, and community) are observed to promote fodder production as an adaptation strategy. This introduces the idea of addressing fodder as a near universal practice through a multilevel system: individual household level, community, and the larger landscape level. On private land tenure regime, decision-making is within the limited land boundaries. Community land tenure facilitates community participation and commitment to reserve pasture for the tough periods of drought. Government land supports implementation of collective actions as community members can collectively benefit from the natural landscape. However, fodder production in government land is challenged by insecurity from other neighboring communities in need of pasture for their livestock. There is therefore need for community participation and consultation to be all inclusive to avoid discrimination that would result in internal and external conflict because of the “public good” perception.

The positive influence private land tenure has on fodder production and livestock migration implies that the land can be left free for engagement in other agricultural technologies that would support alternative adaptation strategies. Secure land tenure equally promotes investment and rapid uptake of adaptation strategies due to their individualized nature and localized decision-making. Fodder production in community land tenure introduces the boundary and property rights that can be enforced.

## 5 Conclusion and policy implication

Identification and analysis of socio-economic factors that hinder or promote the uptake of specific adaptation strategies and characterization of the adaptive capacity generates three fundamental findings relevant to the growing literature on adaptive capacity. (1) The household asset base is an important component in influencing adaptation process; however, it has a heterogeneous effect across the adaptation strategies because of the various capitals and the differentiated variables that compose it. This makes it necessary to identify the variables that specifically influence an adaptation strategy. For example, social capital is represented by a suite of variables that affect adaptation strategy differently: Assistance received from the government positively influences four (irrigation, livestock manure, fodder production, and improved breeds) out of the five adaptation strategies, while membership in any association, cooperative or community negatively influences one (fodder production) of the strategies. (2) Relevant climatic and agronomic information heavily shapes adaptation processes. The influence, however, can take either direction in relation to building adaptive capacity of the target community. Information can support households in taking up or rejecting adaptation strategies

implying a heterogeneous nature and therefore needs to be context-specific. (3) The multi-level governance of land tenure in the drylands opens fodder production as a universal practice in the ASAL; ideally because it can be practiced at different levels to meet differentiated household objectives. This demands a deliberate national and county policy attention and focus on community-driven adaptation and localized development. A cognizance that adaptation is multi-leveled, taking place at individual, household, community, and even at the larger landscape level as witnessed by the increasing privatization of fodder production. The security and clarity of the different tenure regimes however is significant for the success of this process.

Natural capital, although an important determinant of adaptive capacity, is very sensitive and vulnerable to natural shocks, political good will, climate change, and insecurity. As a key determinant of sustainably achieving the country's long-term development plan, Kenya Vision 2030, the overall governance of land tenure in the drylands, needs a detailed policy clarification and development strategies that propels the community toward a vibrant dryland economy. This entails embracing the stipulated National Climate Change Action plan, supporting the low carbon climate resilient pathways, and embracing the principles of a resilient landscape inclusive of water harvesting strategies, agroforestry, and capacity building.

Although discussed in literature as important household assets that facilitate adaptation, human, physical, and financial capital are in this study deemed to have little influence in facilitating adaptation. The intention is not to undermine their significance but to identify them as sectors that require development, research, and policy focus. Equally, both financial and physical capital influence very few adaptation strategies. A general observation is inducted: that the three—human, financial, and physical capital—are the weak points in relation to categories of assets that contribute to the adaptive capacity of households. The seemingly minor role they play in the uptake of proactive adaptation strategies ideally implies that households are deficient in them, contributing to their low utilization. They stand as assets that need to be improved to build the adaptive capacity of households in dryland areas.

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