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Adaptive pastoralists—Insights into local and regional patterns in livelihood adaptation choices among pastoralists in Kenya

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Abstract

Pastoralist adaptation strategies have to address multiple, overlapping, and often inter-related processes of socio-ecological change. The present study addresses the need for inter-regional comparative studies that account for different geographic, climate, and socio-economic contexts in order to understand how pastoralists adapt to changes in livelihood conditions. The paper uses data from a unique survey study of pastoralist households in four neighbouring counties in dryland Kenya. Taking our point of departure from an empirically based classification of the livelihood strategies available to pastoralists in the Horn of Africa, the survey offers novel insights into adaptation and fodder management strategies of pastoralist individuals and households. The results show that the use of migration as a strategy is more dependent on the *ability* to migrate than climate conditions. This is the case in localities where a substantial part of the land is subdivided, the population density is high, and where opportunities for migration are subsequently restricted. Diversification of livelihoods as a strategy is largely defined by opportunity. Intensification through active fodder management is mainly common in areas where there has been a proliferation of managed enclosures. Climate change will test the adaptive capacity of pastoralists in the studied region, and diversification and intensification strategies of both herd composition and livelihoods can be seen as strategies for increased climate resilience.

Keywords Pastoralist, Kenya, Coping strategy, Adaptation strategy, Fodder management

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Introduction

The future of pastoralist livelihood systems in East Africa is increasingly gaining traction in research and policy (Lind et al. 2020; Lind 2021; Scoones 2020; Aalders et al. 2021; Catley et al. 2013). Currently, more than 265 million people across the Horn of Africa (pastoralists and agro-pastoralists) depend on livestock as their main mode of livelihood. However, they are increasingly challenged by a combination of loss of land (in favour of agricultural expansion, infrastructure, nature conservation, and land investments), frequent and enduring conflicts and violence, population increase, accelerating economic inequality, and climate change (Knutsson et al. 2021; McPeak et al. 2011; Galaty 2013).

Pastoralist communities' vulnerability and adaptation capacity in relation to changing economic, political,

and environmental conditions have been an object of study for many years. Overall, this literature presents a contrasting picture of historically resilient livelihood strategies alongside persistent as well as emergent vulnerabilities. On one hand, numerous studies emphasize that pastoralism as a livelihood strategy constitutes a successful, long-term response to high levels of rainfall and temperature variability and that a precondition for its resilience is the flexible and mobile nature of pastoralist land use (Opyio et al. 2015; Lind et al. 2020). On the other hand, it is precisely these historically enduring adaptive strategies of customary pastoralist systems that are increasingly threatened by emerging global, regional, and national forces of trade, investment, insecurity, increasing land use pressure, and environmental change (Lind et al. 2020; Knutsson et al. 2021; Notenbaert et al. 2013; López-Carr et al. 2014; Ngángá et al. 2020).

Pastoralist adaptation strategies have to address multiple, overlapping, and often interrelated processes of socio-ecological change (O'Brien et al. 2009; Scoones 2021). Catley et al. (2013) have identified broad and alternative livelihood pathways for pastoralists in the Horn of Africa that are dependent on the level of resource—as well as market access in a specific geographical context.

Within and across such general pathway directions, previous research points at a diversity of more specific adaptation strategies that are commonly adopted by pastoralist households and communities. For example, Herrero et al. (2016) provide an extensive list of examples of climate-related adaptation strategies that range from customary (mobility, diversification of livestock composition, restocking/destocking, opportunistic crop cultivation, and sharing, loaning, and gifting of livestock) to newer strategies (development of groundwater resources, saving/credit schemes, supplementation of fodder, early warning systems, intensification, off-farm income, taking advantage of new market opportunities, education, and cash transfers and remittances). However, the availability and effectiveness of these strategies are heavily dependent on unequally distributed resources across dryland locations and contexts. This is showcased in a comparative study of pathways of change in pastoralism systems, which points at differentiated responses to and outcomes of similar dynamics of change across different pastoral systems in East Africa (Catley et al. 2016).

Existing studies highlight the challenges to sustainable development that pastoralist households in the East African drylands face from population growth, socio-economic change, and climate change, and subsequently the need for accessible and effective coping/adaptation strategies. To ensure an effective response to these challenges, it is essential to gain a better understanding of how different households respond to changes in their socio-ecological environment. This requires a more granular approach than broad-scale analysis, as there can be considerable heterogeneity among households, and their ability to cope with changing circumstances. However, with few exceptions, existing studies on pastoralist adaptation strategies to multiple processes of change in the East African drylands are either very general in scope (broad literature-based or quantitative studies at the national or inter-national level) or qualitative in-depth case studies of specific and localized pastoralist systems, which cannot be systematically compared (e.g. Bekele et al. 2018; Lugusa et al. 2016; Cormack and Kurewa 2018; Walker et al. 2022). There is therefore a need for comparative studies that cut across this divide and make both general patterns across localized contexts visible, as well as identify important localized conditions and factors. The present study addresses this gap by focusing on an interconnected region in the Kenyan rangelands, consisting of four neighbouring counties—West Pokot, Baringo, Laikipia, and Isiolo. Our analysis was guided by the following main research question: What are the similarities and differences in patterns of adaptation strategies within and across these counties, and how can they be interpreted and understood? Through a quantitative study of strategies employed by pastoralists in 12 local areas (wards) in these four counties, the aim is to enable an analysis that identifies both similarities and differences in terms of general and specific adaptation strategies. The analysis covers three geographical scales: (1) a wider region from western to eastern Kenya, dominated by semi-arid land where pastoralism and/or agro-pastoralism is the dominating mode of livelihood; (2) four counties characterized by different conditions in terms of climate, ethnic belonging, land tenure and land use, economic trajectories, and human and livestock population pressure; and (3) 12 wards that represent locally specific contexts and conditions within each of the counties.

The approach used in this paper, a systematic and uniform questionnaire and statistical analysis, fills a gap in the literature on pastoralist coping and adaptation strategies by focusing on the relative importance of a set of key factors within a delimited and specific dryland region to explain what makes particular adaptation strategies accessible and feasible. These include household demographics, climate effects, land tenure arrangements, fodder management techniques, and the interaction between the choice of livestock and the choice of adaptation strategies. We have not found a comparative study of this scope, focusing on the East African region, in the literature.

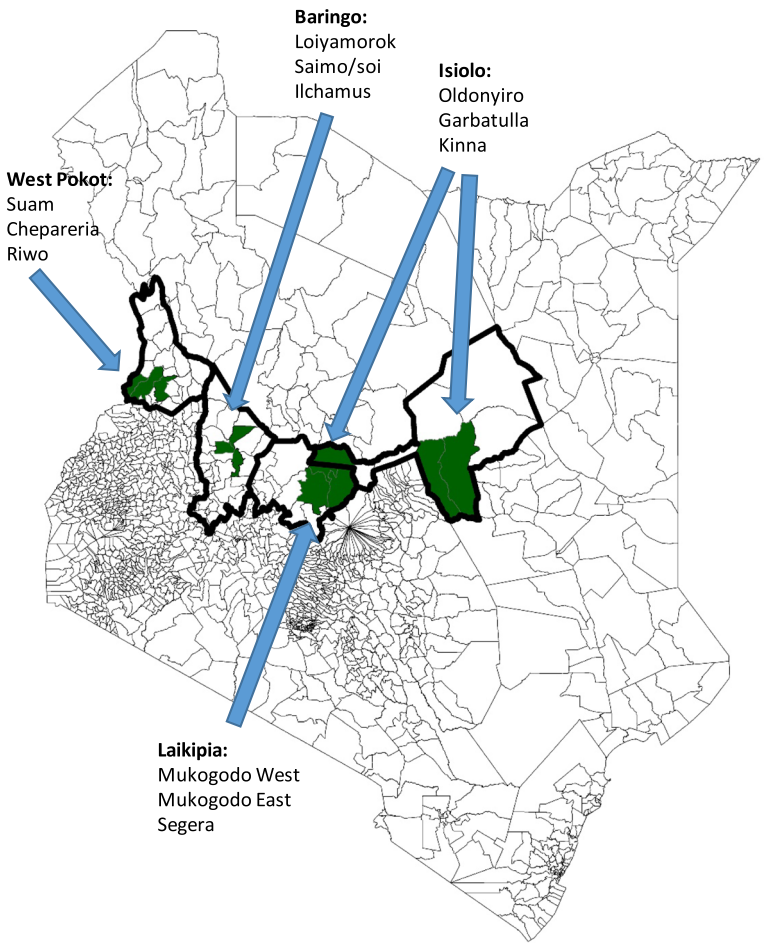

Fig. 1 Locations of counties (in bold) and wards in the study

The analysis is performed in two steps: First, we establish the prevalence of different adaptation strategies at county and ward levels. In the second step, causal factors that explain this prevalence are identified, estimated, and interpreted in relation to relevant existing studies on pastoralist adaptation strategies.

Background

The paper uses data from a unique survey study of pastoralist households in the above-mentioned counties. The wards in the studied counties were purposively selected to achieve a variation in pastoralist livelihoods (see Fig. 1).

While the landscape in parts of West Pokot County is dominated by enclosures that are individually managed for fodder and crop production, other parts of the county are dominated by open-access grazing (Nyberg et al. 2015). West Pokot is ethnically homogenous with a vast majority of the population identifying themselves as Pokot. On the contrary, Baringo County is relatively diverse in terms of ethnicity, including Tugen, Pokot, Ilchamus, and Kikuyu. In parts of Baringo County, there is a continually increasing number of both communal and individual enclosures managed for increased fodder production (Mureithi et al. 2016). In Laikipia County, areas under permanent crop agriculture and both private and communal wildlife sanctuaries are expanding, restricting the possibilities for traditional pastoralism (Boles et al. 2019; Huho et al. 2010). There are also considerable parts of this county that are occupied with enclosed, large-scale commercial ranches (Lengoiboni et al. 2010). Laikipia is furthermore ethnically diverse and home to groups such as Kikuyu, Maasai, Kalenjin, Turkana, Samburu, and Pokot. Isiolo County on the other hand is, in comparison with the three other counties, still dominated by more traditional pastoralism (ibid.), but is faced with changing conditions due to the development of a large-scale infrastructure development project (Lesutis 2020). While the majority of the population in Isiolo County identifies themselves as Borana, it is also ethnically diverse with

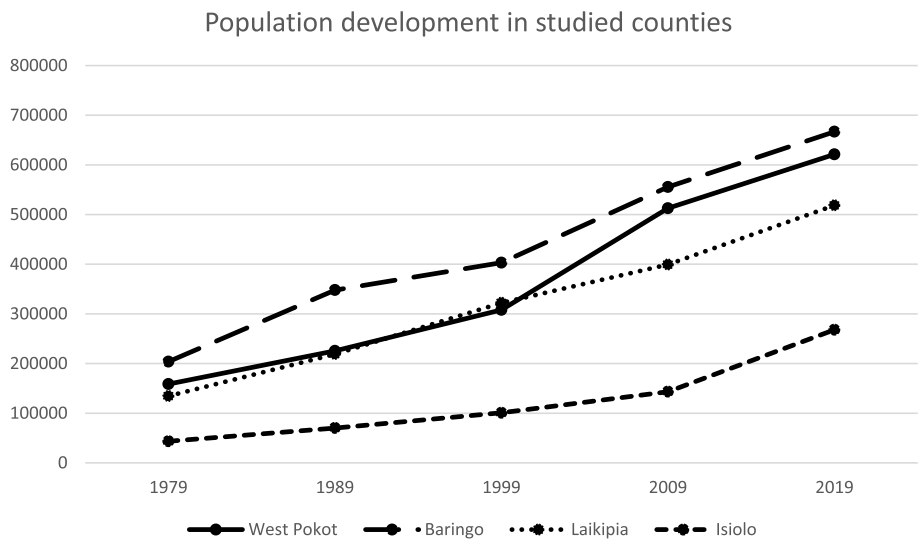

Fig. 2 Population growth in studied counties

minority groups including Somali, Turkana, Samburu, and Meru.

With an increasing population (see Fig. 2), and especially an increasing, relatively resourceful local/regional middle class (in actual numbers, even though not as a proportion of the population), there is an increased demand for livestock products (Kiambi et al. 2018; Mutsami et al. 2019). Population growth is generally high in drylands. For example, in West Pokot and Isiolo, the population has more than doubled during the last 20 years, which is faster than for Kenya as a country. All counties with a population doubling (or more) in the last 20 years, except Nairobi, are dryland counties dominated by pastoralism (KNBS 2019).

As elsewhere in Kenya, the studied counties have a bimodal type of rainfall. The long rains fall between April and August while the short rains fall between October and February. Data on annual average rainfall and temperature can be found in Table 1. While the different counties face different climate change trajectories, all counties are expected to face increased average temperatures. West Pokot and Laikipia are predicted to receive higher annual precipitation, while annual precipitation is projected to decline in Isiolo and Baringo (MoALF 2016 and 2017a, 2017b, and 2017c). However, climate variability will increase in all counties, meaning that dry spells and rainstorms will be more unpredictable and dry seasons-rain seasons more unreliable. This is a change already experienced in all counties, and its effects are expected to worsen as evidenced by the increasing frequency of protracted dry seasons and drought. The weather forecast for most dryland counties in northern Kenya has repeatedly shown below-normal rainfall (ICPAC 2023; Opiyo et al. 2012). As rain failure is becoming more common, it amplifies the already considerable challenge of pasture scarcity and crop failure in arid and semi-arid areas (Opiyo et al. 2016). Pastoralists and agro-pastoralists are engaging and embracing a range of adaptive strategies such as livestock migration, fodder production, and irrigation of crops where possible, to adjust to these changes (Ngángá et al. 2020).

Focusing on the studied wards, they can roughly be divided into four groups (see Fig. 3): the hot and dry group, consisting of neighbouring Garbatulla and Kinna in Isiolo County; the hot and wet group, consisting of neighbouring Ilchamus and Loiyamorok in Baringo County; the mild and dry group, consisting of all included wards in Laikipia County and neighbouring Oldonyiro in western Isiolo; finally, the mild and humid group, consisting of all included West Pokot wards, plus SaimoSoi in Baringo. Note here that hot/mild and humid/dry are very much relative terms, meant to be understood in the span

Table 1 Climate data for the studied counties. Source: for rainfall—Kenya National Drought Management Authority, average 1960–1999; for temperature—NASA, GES-DISC Interactive Online Visualization And Analysis Infrastructure (GIOVANNI)

	West Pokot	Baringo	Laikipia	Isiolo
Annual average rainfall (mm/year)	1025–1039	729–921	647–797	453–587
Average air temperature (°C)	~21	23–26	18–19	22–26

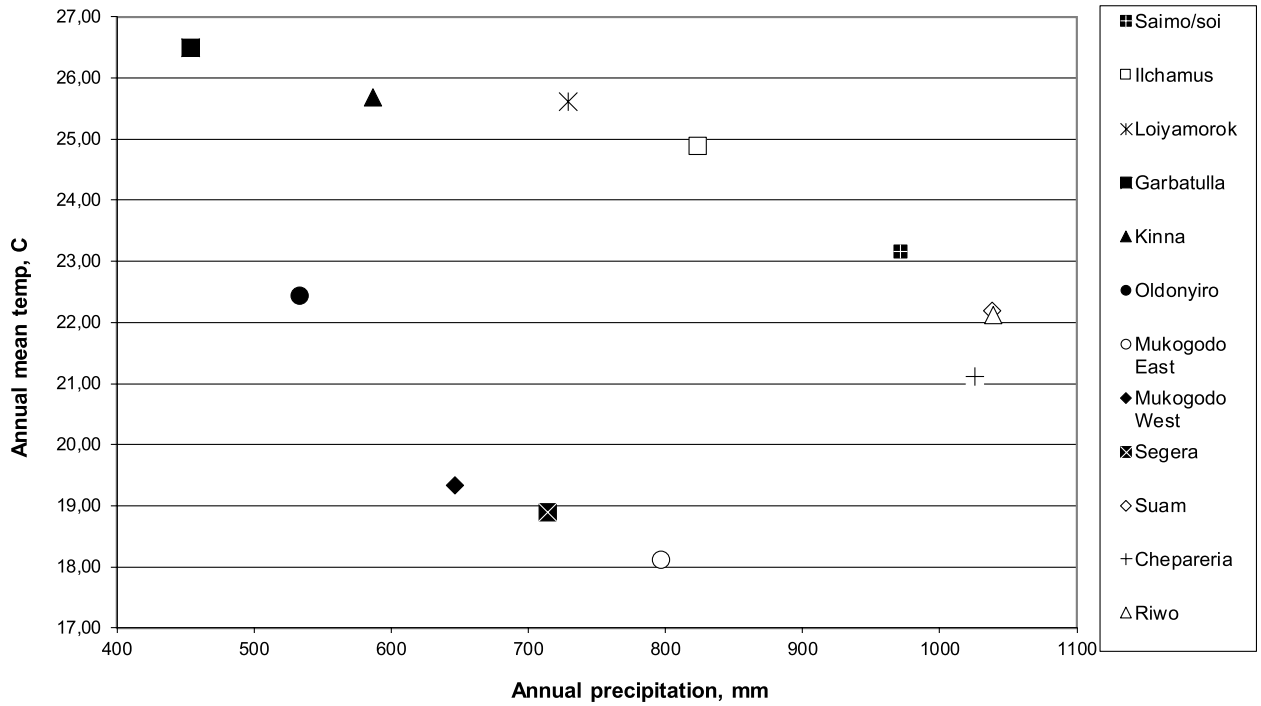

Fig. 3 Annual average mean temperature and precipitation in the studied wards. Source: for rainfall—Kenya National Drought Management Authority, average 1960–1999; for temperature—NASA, GES-DISC Interactive Online Visualization And Analysis Infrastructure (GIOVANNI)

of a temperature average of between 18 and 27 °C and a precipitation of between 400 and 1000 mm/year.

In terms of land use and production systems, Garbatulla and Kinna in Isiolo County, Ilchamus in Baringo County, and Chepareria in West Pokot are under agro-pastoralism, dominated by livestock keeping in combination with some crop farming, especially along the river basins. All the other counties fall under the semi-arid ecological zone and are dominated by a pastoralist livestock-keeping production system. Wards where rangeland enclosures for fodder production are practised include Ilchamus in Baringo County, all wards in Isiolo County, and Chepareria in West Pokot County.

Method

The final questionnaire and its administration were preceded by focus group meetings in all four counties in November 2018 and a pilot survey in May 2019. In the pilot survey, a total of 122 respondents were interviewed across the four counties. The survey instrument was revised following both the focus group meeting and the pilot study. Furthermore, the results from the final survey were presented to representatives of the county and ward administrations and the communities included in the survey, through interactive workshops in each of the four counties. The workshops provided important feedback, including potential interpretations and explanations in relation to key survey results.

The execution of the final survey took place in February/March 2020 and was conducted in two stages. In the first stage, sampling was equally proportioned between the four counties, West Pokot, Baringo, Laikipia, and Isiolo, because of the different land use changes occurring in the four counties. A multi-stage sampling approach was used in the second stage. Three wards per county were purposively selected considering the different land uses within the counties, conditional on whether a largely pastoralist or agro-pastoralist community was living in the ward. These were the primary 12 sampling units for the survey.

Systematic random sampling was used to select the individual household respondents. This was achieved by selecting every fourth household (*manyatta*) on either side of the road or path (Kothari 2010; Mugenda and Mugenda 2003). Data was collected at the household level using a semi-structured questionnaire that was administered through a face-to-face interview by trained local enumerators and encoded on tablets. The recruited enumerators—four per county—were

Table 2 Descriptive statistics—some demographic variables. Means and 95% confidence intervals within parenthesis

Variable	West Pokot	Baringo	Laikipia	Isiolo
Household head—share male	0.82 [0.75 to 0.89]	0.80 [0.73 to 0.87]	0.53 [0.44 to 0.62]	0.59 [0.50 to 0.68]
Household head—mean age (years)	44.4 [43.0 to 45.9]	52.5 [50.4 to 54.8]	39.4 [36.7 to 42.2]	39.9 [37.3 to 42.6]
Schooling of household head (years)	6.8 [5.8 to 7.8]	6.5 [5.8 to 7.3]	7.5 [6.5 to 8.5]	8.4 [7.3 to 9.5]
Mean no. of household members	8.2 [7.4 to 8.9]	8.9 [8.0 to 9.9]	6.1 [5.6 to 6.6]	6.09 [5.5 to 6.7]
Number of observations[a]	125	123	122	121

[a] Disregarding item non-response

university students from the University of Nairobi who spoke the relevant local languages fluently. Of the 520 respondents that were interviewed across the four counties, 491 were usable[1] responses. The distribution across the counties was fairly even with 125 respondents from West Pokot, 123 from Baringo, 122 from Laikipia, and 121 from Isiolo. Table 2 shows the key descriptive statistics on the county level for the sample.

Notable is that West Pokot and Baringo counties have a significantly higher share of male-headed households in the sample, compared to Laikipia and Isiolo. Baringo also has significantly older-aged household heads than the other three counties. Household heads in Isiolo County have somewhat more years of schooling than the other counties, but the differences are small. Furthermore, the mean number of household members is significantly higher in West Pokot and Baringo compared with Laikipia and Isiolo.

The survey consisted of 70 questions, including different sub-sections for many of the questions. However, in this paper, the particular focus is on adaptation choices. One of the questions in the survey reads: "What is your strategy to cope with changes in livelihood conditions? More than one alternative is possible", cf. Figure 4, below. The respondents were given eight pre-set alternatives:

- Reduce herds
- Increase herds
- Change composition of the herd
- Migrate further distances
- Diversifying livelihoods, e.g. taking up other activities/jobs
- Active management of fodder resources
- No change
- Other, please define

In the last alternative, the respondent gave an open-ended answer, which was noted by the enumerator. These alternatives were developed by the research group, based on the previously mentioned pastoralist livelihood pathways outlined in Catley et al. (2013) and the climate-related adaptation strategies presented in Herrero et al. (2016). The alternatives were then tested and revised through the above-mentioned focus group meetings and in the 2019 pilot survey.

Note that this question reflects our interest in broad categories of choices, very similar to other studies of household choices (for example, mode of transportation to work for an urban household), and there might be different underlying motives behind every choice. Note also that since few respondents chose the alternatives "increase herds", "no change", and "other", these responses are excluded in the following analysis.

The above-mentioned question was succeeded by the follow-up question: "If you answered "active management" in the previous question—how? More than one alternative is possible". In previous research by the authors, we have seen that active fodder management is emerging as a common strategy (Mureithi et al. 2016; Nyberg et al. 2015; Sala et al. 2020; Wairore et al. 2015), which has also been shown by others (Behnke 1986; Hailu 2016; Woodhouse 2003), as well as indicated by our pre-study. Here, the respondents were given five pre-set alternatives:

- Grass seeding
- Seasonal grass protection (by fence or agreement)
- Bush and/or tree management
- Management of invasive species
- Other, please define

Again, in the last alternative, the respondent gave an open-ended answer, which was noted by the enumerator. These alternatives were also tested in the four focus group meetings and in the 2019 pilot survey.

Following Cannon and Müller-Mahn (2010), we see adaptation strategies as including responses to change within a broad spectrum ranging from more spontaneous reactions to an acute situation to more anticipatory or planned strategies to meet prevailing conditions of an

[1] Usable in the sense that the questions focused in this paper were answered.

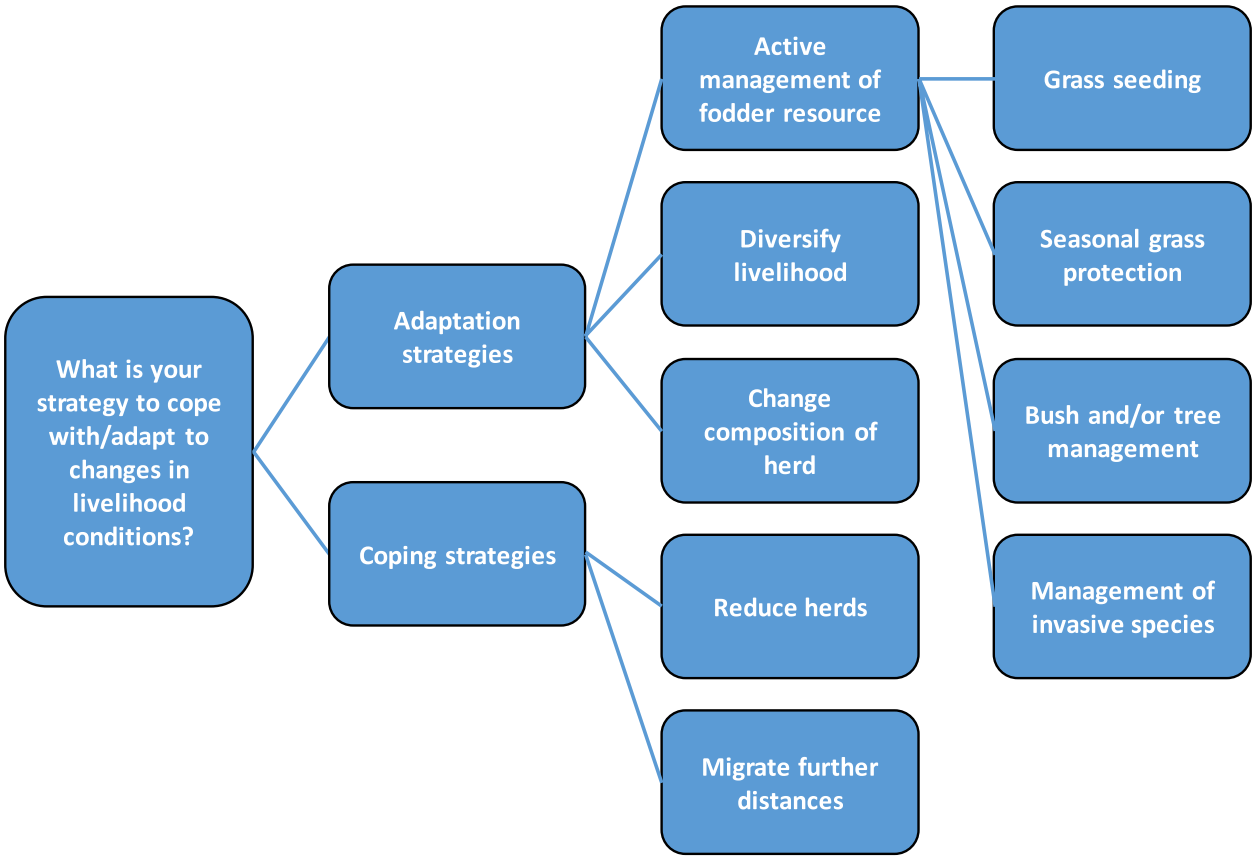

Fig. 4 Coping/adaptation grouping of choices the respondents could select

expected future. The pastoralist strategy to reduce herds is an illustrating and interesting example of the need for such a broad definition of adaptation strategies. In some cases, this strategy constitutes a reactive response to an acute crisis, such as drought. However, between 21 and 41% of the respondents (depending on livestock type) who stated they would use the strategy "reduce herd" had actually increased their herd of a particular livestock type in the last 5 years, signifying more of preparedness to reduce herds than completed actions during this time period.

Another example is the strategy "migrating further", which could be interpreted as reactive and short-term in the sense that during particular bad years, herders and livestock are forced to migrate further than during "normal" years. However, bad years are becoming more common with climate change, and subsequently, the strategy to change migration routes can also constitute a more long-term, anticipatory response to a "new normal".

"Changing the composition of the herd" is an adaptation strategy that is often a planned response to changes in environmental circumstances but can also be a reactive response to take advantage of short-term market changes. "Diversifying livelihood" includes both anticipatory, planned actions that aim at diversifying existing agricultural activities and more reactive actions in terms of periodically seeking livelihood opportunities outside the livestock/agricultural sector. Examples of the latter, mentioned by the respondents, include charcoal burning and sand harvesting.

"Active fodder management" is also mainly an anticipatory, planned adaptation strategy, although aspects of it can have formed part of customary management that is not necessarily a response to changing livelihood conditions. The four most common forms of active fodder management among the respondents were grass seeding, seasonal grass protection, bush and/or tree management, and management of invasive species. Grass seeding involves the collection/buying of grass seeds, land preparation, and seeding. Seasonal grass protection can be either in enclosures where grazers are seasonally excluded or it can be in the form of more customary practices where parts of the grassland are seasonally protected from grazing. In some places, such areas are today eroded or disrespected, while being the dominating mode of operation in

others (Tyrell et al. 2017; Boles et al. 2019). Bush and/or tree management involves lopping some trees for fodder and the clearing of unwanted bushes (i.e. not good for fodder), while favouring others, as well as some restrictions on charcoal burning and fuelwood harvesting. Management of invasive species is crucial in areas facing such infestations, e.g. around the southern shores of Lake Baringo (Bekele et al. 2018; Mwangi and Swallow 2008) and parts of Laikipia County (Strum et al. 2015).

To gain further insights into the coping/adaptation and fodder management strategies, probit models have been used. A similar approach was used productively by Ngángá et al. (2020) to analyse adaptation strategies in Laikipia. One set of probit models was used for the adaptation strategies. A probit model is a popular specification for a binary response model and is a type of regression where the dependent variable can take only two values, for instance, whether or not the respondent had used a specific adaptation strategy. Note that when interpreting the results of a probit model regression, the coefficients of the independent variables are valid while holding all other variables constant. Note also that the strategy "increase herds" could not be analysed, since the maximum likelihood estimates then failed to converge due to the limited number of observations on these choices.

The independent variables used in the county-level models were first a set of climate/geographic variables, which included annual average precipitation and temperature on the ward level, as well as average population density. For rainfall, the data comes from the Kenya National Drought Management Authority, while for temperature, the source is NASA's GES-DISC Interactive Online Visualization And Analysis Infrastructure (GIOVANNI). The population density figures are derived from the Kenya national census in 2019.

The second group of independent variables was dummies for whether the respondent had a communal or private title deed. A group of livestock ownership dummies was also included. The title deed and livestock dummies were selected to investigate whether ownership security and/or type of livestock made it more or less likely to choose a certain adaptation strategy.

To these independent variables, we added a group of key socio-economic variables, including gender of the household head, age, years of schooling of the household head, and household size. Household income was also included as one of the socio-economic variables. However, due to extensive item non-response, we were unable to use this question in the probit models. Descriptive statistics on this variable are however presented. In the second stage, the fodder management alternatives were analysed using probit analysis, with the same explanatory variables.

Results

Distribution of responses on county and ward levels

We performed an analysis in two steps: in step 1, we investigated how the responses to the adaptation strategy and fodder management questions were distributed at county and ward levels. The second step consisted of ordinary probit regressions of the five adaptation strategies *reduce herds*, *change herd composition*, *migrate further*, *diversify livelihoods*, and *active fodder management*. The result of step 1 is presented in Fig. 5.

In Isiolo County, the most common strategies include herd reduction and to migrate further, while in Laikipia County, the most common coping/adaptation strategies included herd reduction, diversification of livelihoods, and changing herd composition. In Baringo County, "diversify livelihood" and "reduce herds" are the most common strategies, while for West Pokot County, the main strategies are active fodder management and diversification of livelihoods. This pattern confirms results from recent livelihood studies (e.g. Achiba 2018), which suggest that in pastoralist as well as agro-pastoralist locations in Kenya, livelihood security is increasingly attained by both actively managing recurrent risks associated with livestock production and seeking diversification opportunities in non-livestock sectors.

As the county-level descriptive statistics may hide important geographical variation, we illustrate the differences within each county and show ward-level means for the adaptation strategies. Note that the ward level is the lowest geographical resolution that can be used statistically in a meaningful way. However, due to the small sample sizes (the number of observations on the ward level varies between 30 and 65 with a median of 42 observations/ward), the margin of error almost doubles. Figure 6a–d illustrate responses to the adaptation strategy on the ward level in the form of polar graphs.

The polar graphs confirm the importance of combinations of adaptation strategies but also interesting similarities and differences within and between counties. Going from east to west in the studied counties, herd reduction is evidently a key coping strategy mainly in Garbatulla and Kinna wards, while pastoralists in all three wards of Isiolo County are often forced to migrate further than "normal" in search of pasture and water. In Laikipia County, livelihood diversification is a key strategy, especially among pastoralists in Segera ward. The strategy of herd reduction is common in all three Laikipia wards. For the three wards in Baringo, the choice of strategy differs radically. For Saimo Soi ward—west

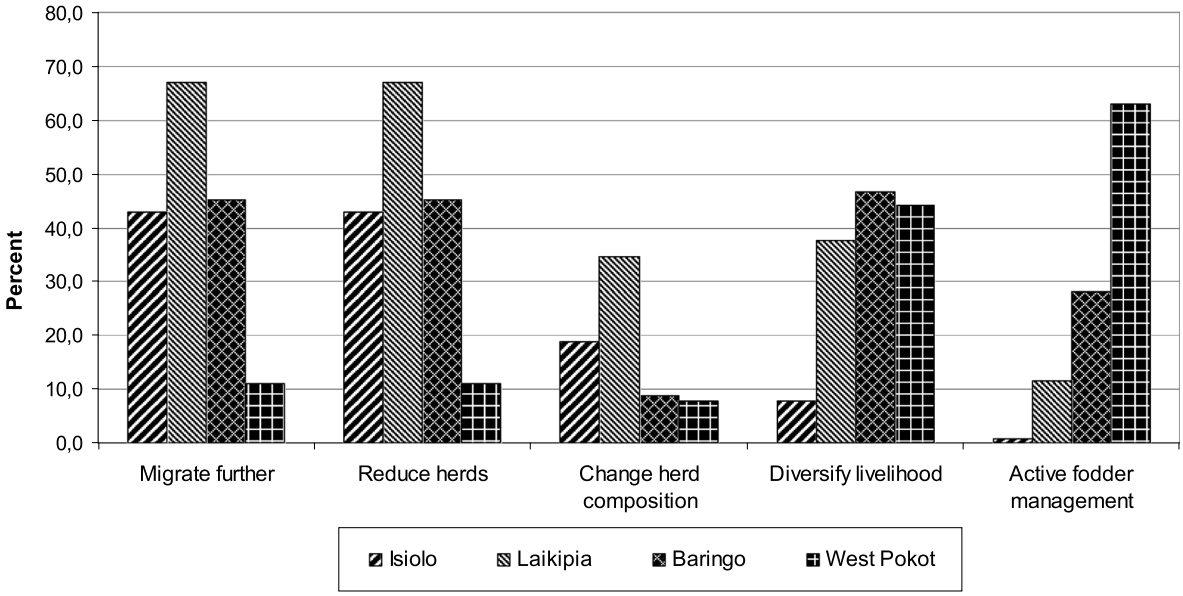

Fig. 5 Responses to the question: "What is your strategy to cope with/adapt to changes in livelihood conditions?" on the county level

of Lake Baringo—the most common strategy is "reduce herds". This strategy is also common in Ilchamus ward, which is south of and adjacent to Lake Baringo, but here, "diversify livelihood" and "active fodder management" are also important strategies. In Loiyamorok—north of Lake Baringo—"diversify livelihood" is the most common strategy. For West Pokot County, it is striking how popular the strategy "active fodder management" is in all three wards, but especially in Suam ward. Here, "migrate further" is also important—mainly to Amudat District in Uganda (Domokwang 2022), while in Chepareria and Riwo wards, "diversify livelihood" is evidently important.

A reasonable overall interpretation is that migrating further as a strategy is common in the wards and counties where this option is still practically possible and, in some cases, the only way to access grazing resources during the dry season (for example, in Isiolo and West Pokot). The strategy to reduce herds is a common strategy across wards and counties, except in West Pokot. A possible explanation is that, here, herds have often already been reduced due to privatization and intensification of land (Knutsson et al. 2021). Furthermore, active fodder management seems to be a common strategy in wards where land is used more intensively (for example, parts of West Pokot and Baringo). In wards where diversification of livelihoods is common, it can be interpreted as either a pull or a push strategy (Catley et al. 2016). For some individuals and households, diversification is a response to decreasing livestock production in others because of the increasing availability of diversification options.

Since the respondents could check more than one alternative, further insights can be gained from a correlation matrix (Table 3). Most correlations are rather weak, and with the exception of a positive correlation between "reduce herds" and "change herd composition", all significant correlations are negative. As previous research suggests (e.g. Lenaiyasa et al. 2020), this indicates that existing adaptation strategies are mainly substitutes for one another. The interpretation of Table 3, together with Figs. 5 and 6, is subsequently that pastoralists and agro-pastoralists tend to focus on a few adaptation strategies, rather than combining several. Several explanations for this are possible (for example, level of sedentarization, access to natural resources such as land and water, access to human capital, access to financial capital) but require qualitative, context-sensitive studies to be identified and confirmed.

By analysing the question: "If you answered "active management" in the previous question—how?", on the ward level, the pattern illustrated in the polar graphs in Fig. 7a–d emerges.

In the wards in Isiolo County, some grass seeding is performed, but the activity level when it comes to active fodder management is very low in both Isiolo and Laikipia counties. In Isiolo, there is a tradition of seasonal grazing areas, i.e. seasonal protection of some areas (Ontiri and Robinson 2015). This was also observed during field visits. However, respondents evidently do not perceive customary seasonal protection of some grazing areas as a form of active fodder management, as it was

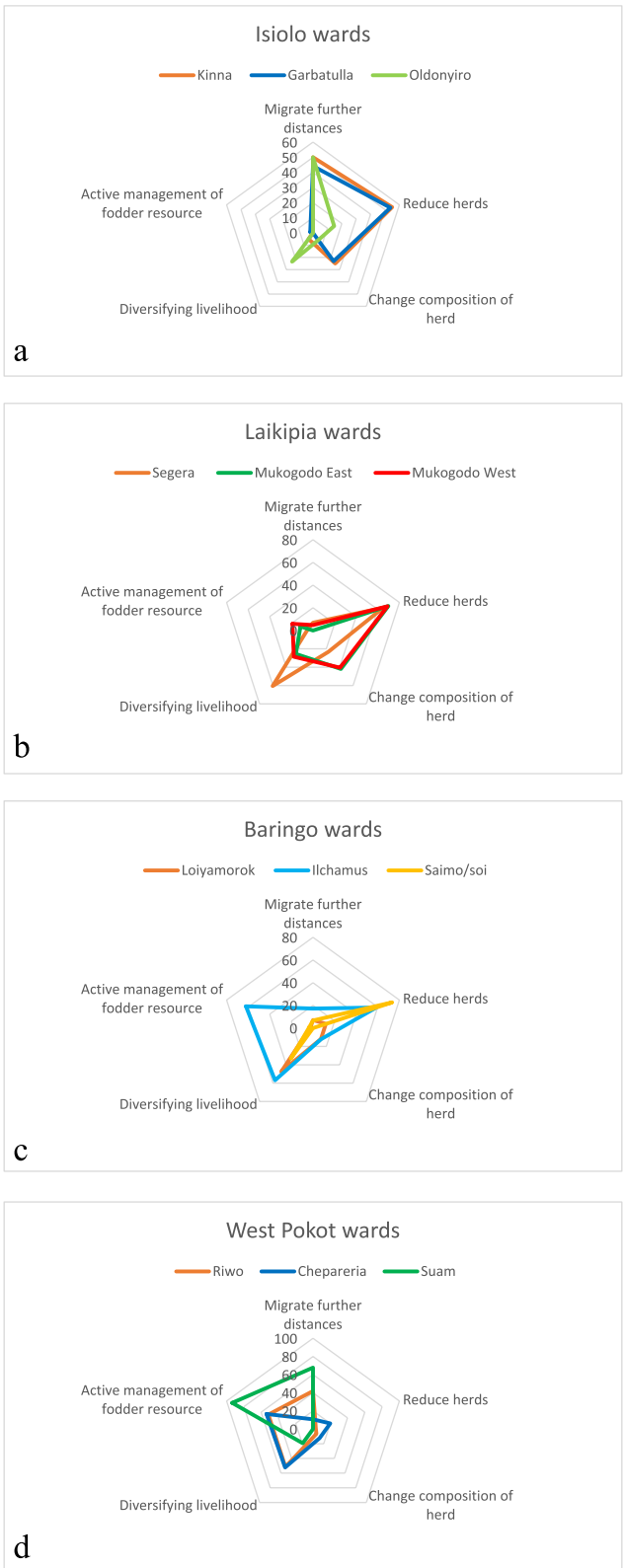

Fig. 6 **a**–**d** Responses to the question: "What is your strategy to cope with/adapt to changes in livelihood conditions?" on the ward level. Percentages do not sum to 100 for each ward, since respondents could check more than one option

Table 3 Correlation matrix for the coping/adaptation strategies[a]

	Reduce herds	Change herd composition	Migrate further	Diversify livelihood	Active fodder management
Reduce herds	1				
Change herd composition	.138[c]	1			
Migrate further	−.255[c]	−.019	1		
Diversify livelihood	−.196[c]	−.179[c]	−.214[c]	1	
Active fodder management	−.090[b]	−.195[c]	.021	.068	1

[a] Disregarding the alternatives "increase herd", "no change", and "others"

[b] Correlation is significant at the 0.05 level (2-tailed)

[c] Correlation is significant at the 0.01 level (2-tailed)

not included in the respondents' answers to the survey question on "seasonal grass protection".

In Baringo County, it is mainly in Ilchamus ward close to Lake Baringo where active fodder management techniques are applied. A variety of techniques are used, but note the low level of bush and/or tree management. This technique is instead very common in all studied West Pokot wards, in combination with seasonal grass protection and management of invasive species. We interpret these results as an indication that active fodder management is not a uniform or general adaptation strategy across the Kenyan drylands, but rather that specific management techniques (both customary and novel) are used in specific locations. Regarding the prevalence of more novel fodder management strategies, our results point at a present situation where the adoption of a variety of fodder production techniques promoted by the Kenyan government as well as NGOs is taking place gradually and differentially across counties, wards, and localities (Sala et al. 2020).

Since the respondent could check more than one fodder management alternative, further insights can again be gained from a correlation matrix (see Table 4). Unlike in Table 3, all significant correlations are positive, suggesting that the fodder management strategies are mainly complements of one another. This means that in contrast to the broader adaptation strategies, which tend to be pursued as substitutes to one another, fodder management techniques should be understood as a set of complementary options that often are adopted in combination.

Probit analyses

In the second step of the analysis, ordinary probit regressions of the five coping/adaptation strategies *reduce herds*, *change herd composition*, *migrate further*, *diversify livelihoods*, and *active fodder management* were conducted (Table 5). This was done to establish causal relationships between different key factors and the prevalent adaptation strategies identified in step 1. While some general patterns emerge from our data in our studied counties, one should however be careful not to make far-reaching general causal claims regarding which variables might determine which strategies.

The original estimated parameter values are not very interesting in themselves, since they depend on the unit of measurement of the respective independent variables. For this reason, we have chosen to present elasticities, i.e. the percentage change in the likelihood of choosing a particular strategy from a 1% in the independent variable, i.e. for a certain independent variable x_k, the elasticity is: $\left[x_k \cdot \partial E\left(y|x\right)/\partial x_k\right]/E\left(y|x\right)$. For any dummy variable, z, the marginal effects are computed as: $\partial E\left(y|x\right)/\partial x_k = \text{Prob}\left(y=1|z=1\right) - \text{Prob}\left(y=1|z=0\right)$. Note however that the t-values refer to the original estimated parameters.[2]

Precipitation and temperature present some interesting variations on the ward level. As illustrated in Fig. 3, and as Table 5 shows, an increase in precipitation has a significant negative effect on "change herd composition" and a positive effect on "active fodder management". Given that rainfall is generally the strongest determinant of forage production in dryland areas (Espeland et al. 2020), our interpretation is that more rainfall increases the returns from active fodder management. However, in areas with higher precipitation, the willingness to change herd composition reduces. A possible explanation for this may be that in many dryland areas, this strategy is interpreted as diversification of livestock species in response to the risk of drought and disease (Espeland et al. 2020). In areas with higher temperatures, the strategies "migrate further" and "active fodder management" are significantly more likely, while the strategies "reduce herds" and

[2] A multivariate model was also attempted, but the t-values of the estimated correlation coefficients were only significant in three out of ten possible correlations, so not much gain in statistical efficiency was achieved based on this approach.

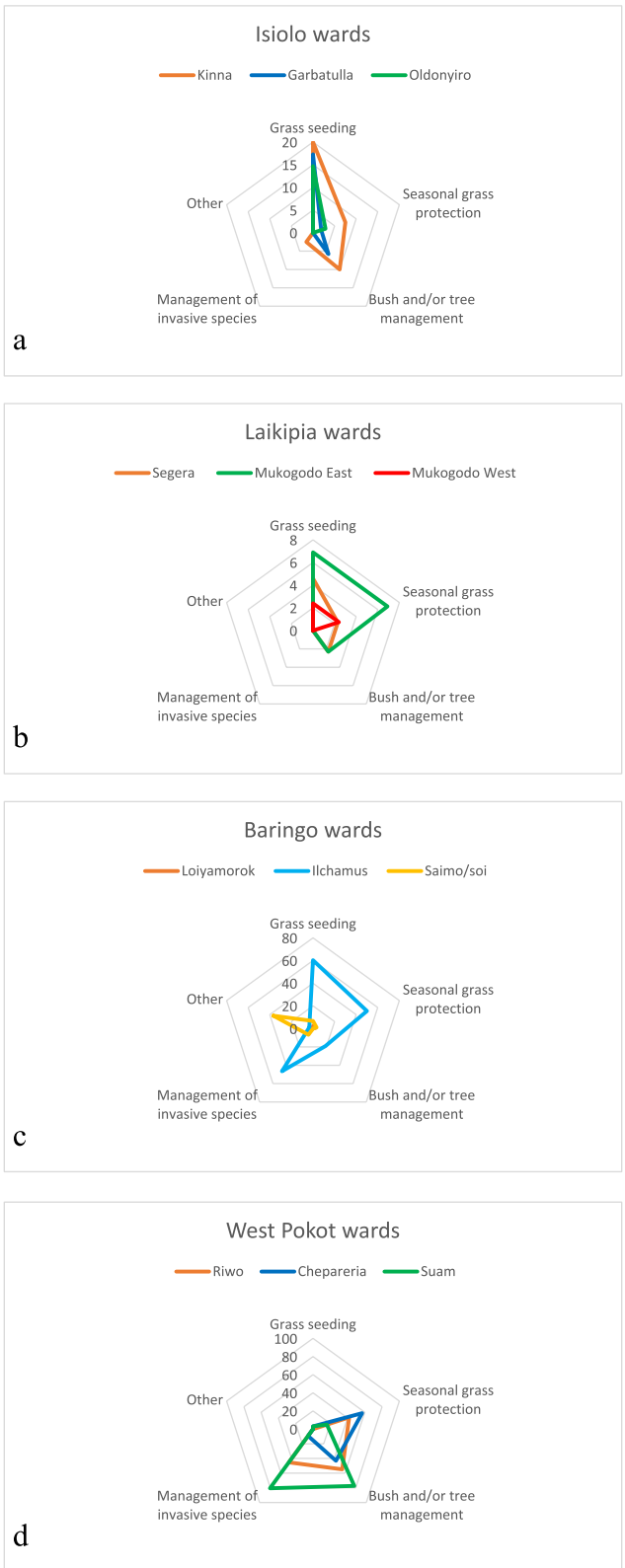

Fig. 7 **a**, **b** Fodder management strategies (responses to the question: "If you answered 'active management' in the previous question—how?") on the ward level

Table 4 Correlation matrix for the fodder management strategies[a]

	Grass seeding	Seasonal grass protection	Bush/tree management	Management of invasive species
Grass seeding	1			
Seasonal grass protection	.279[b]	1		
Bush/tree management	.045	.440[b]	1	
Management of invasive species	.289[b]	.282[b]	.436[b]	1

[a] Disregarding the alternatives "no fodder management" and "others"

[b] Correlation is significant at the 0.01 level (2-tailed)

Table 5 Ordinary probit regression of the four coping strategies. *Note*: Parameter estimates are elasticities

Variable	Reduce herds	Change herd composition	Migrate further	Diversify livelihood	Active fodder management
Climate/geographic variables					
Precipitation	−.912 (−2.23)[b]	−2.759 (−2.91)[b]	2.362 (3.37)[c]	−.005 (−.01)	2.305 (4.36)[c]
Temperature	−1.262 (−2.11)[b]	.387 (−.31)	6.156 (5.25)[c]	−3.579 (−4.40)[c]	3.499 (4.04)[c]
Population density	−.267 (−2.78)[c]	−.045 (−.22)	−.268 (−151)	.333 (2.91)[c]	.216 (1.79)[a]
Tenure dummies (baseline: no deed)					
Community title deed	.116 (2.36)[b]	.520 (4.17)[c]	−.151 (−1.77)	−.165 (−2.94)[b]	−.100 (−1.54)
Private title deed	.019 (1.35)	.048 (1.30)	−.033 (−1.31)	−.028 (−1.73)	−.022 (−1.20)
Livestock ownership dummies					
Owns cattle	−.055 (−.40)	.364 (1.24)	1.084 (5.05)[c]	−.419 (−2.28)[b]	.525 (3.26)[c]
Owns goats	.317 (1.28)	.219 (.36)	.364 (.69)	.662 (2.42)[b]	−.040 (−.12)
Owns sheep	−.068 (−.50)	.463 (1.63)	.153 (.60)	−.204 (−1.15)	−.059 (−.33)
Owns camels	−.019 (−.56)	−.0003 (−.004)	.159 (2.42)[b]	−.132 (−2.92)[c]	−.172 (−3.87)[c]
Demographic variables					
Male hh head	−.034 (−.40)	−.282 (−1.59)	−.305 (−1.87)[a]	.311 (2.89)[c]	.048 (.41)
Age of hh head	.582 (2.93)[c]	−.654 (−1.67)	−1.280 (−3.40)[c]	.607 (2.29)[b]	−.526 (−1.83)[a]
School years hh head	.084 (1.12)	−.153 (−.89)	−.162 (−1.11)	.176 (1.84)[a]	.078 (.80)
Hh size	.000 (.004)	.350 (1.65)	.216 (1.15)	.111 (.77)	.181 (1.24)
McFadden pseudo *R*-squared	.102	.144	.204	.144	.251
No. of obs	485				

T-values are within parenthesis

[a] Significant at the 10% level

[b] Significant at the 5% level

[c] Significant at the 1% level

"diversify livelihood" are less likely. A possible interpretation of this is that in areas with higher temperatures (and therefore dryer conditions), pastoralists are forced to migrate further and/or find ways to manage their fodder to last during the dry season. However, as shown by Turner and Schlecht (2019), the complexity of livestock mobility choices and patterns remains understudied. In addition, the areas in the study region with high temperatures are also the most remote, which may often explain the low likelihood of livelihood diversification.

In areas with higher population density on the ward level, the probability to choose "reduce herds" significantly reduces, but the probability to choose "diversify livelihood" increases. As stressed earlier, this illustrates the fact that diversification tends to be either associated by decreasing livestock production or the availability of diversification options. Having a communal title deed significantly increases the probability of choosing the strategies "reduce herds" and "change herd composition" and reduces the probability of choosing the strategy "diversify livelihood". This result may very well testify to the importance of secure, formal land rights for viable livestock-based pastoralist and agro-pastoralist livelihoods (Greiner 2016).

Cattle ownership significantly increases the probability of choosing the strategies "migrate further" and "active

Table 6 Ordinary probit regressions of the four active fodder management choices, with ward level precipitation and temperature variables, county dummies, and tenure dummies. *Note*: Parameter estimates are elasticities

Variable	Grass seeding	Grass protection	Bush/tree management	Management of invasive species
Climate/geographical variables				
Precipitation	−7.211 (−5.45)[c]	−1.842 (−2.81)[b]	2.405 (3.33)[c]	25.097 (4.07)[c]
Temperature	2.198 (.97)	.968 (.79)	1.341 (.91)	42.076 (3.33)[c]
Population density	.570 (1.42)	.939 (4.15)[c]	.088 (.43)	.264 (.44)
Tenure dummies (baseline: no deed)				
Community title deed	.035 (−.21)	.263 (3.47)[c]	.088 (.97)	−.141 (−.70)
Private title deed	−.035 (−.94)	.042 (1.92)[a]	.0289 (1.12)	−.047 (−1.06)
Livestock ownership dummies				
Owns cattle	.362 (.85)	.164 (.58)	.414 (1.43)	1.058 (2.18)[b]
Owns goats	.764 (1.40)	.752 (1.85)[a]	−.300 (−.71)	−.268 (−.22)
Owns sheep	.160 (.36)	.446 (2.03)[a]	.106 (.44)	.192 (.34)
Owns camels	.013 (.33)	−.029 (−1.24)	.011 (.45)	−.076 (−1.79)[b]
Demographic variables				
Male hh head	−.386 (−1.10)	−.039 (−.22)	−.371 (−1.78)[a]	−3.370 (−2.95)[c]
Age of hh head	−.426 (−.55)	.373 (.84)	−.641 (−1.37)	.354 (.26)
School years hh head	−.150 (−.60)	−.106 (−.78)	−.350 (−1.90)[a]	−.0123 (−.03)
Hh size	1.076 (2.00)[a]	.068 (.29)	−.141 (−.52)	1.276 (1.75)[a]
McFadden pseudo *R*-squared	.498	.334	.195	.418
No. of obs	176			

T-values are within parenthesis

[a] Significant at the 10% level

[b] Significant at the 5% level

[c] Significant at the 1% level

fodder management". This is reasonable, since active fodder management pays off better for cattle owners, and the fodder that cattle needs is more climate-sensitive, driving migration for cattle owners (McCabe 2010). Goat ownership increases the probability of choosing "diversify livelihood", while camel owners are significantly less likely to choose the strategy "diversify livelihood". This correlation is likely explained by a pattern observed in previous research. The relatively low-value goats tend to form part of livelihood diversification strategies more often than high-value camels and cattle (Bollig 2017).

Male household heads are more likely to choose "diversify livelihood" as an adaptation strategy, a result that is consistent with a wide range of previous studies of pastoralist communities, where male-headed households have been found to diversify more than female-headed households. There are furthermore often significant differences between the livelihood diversification activities performed by men and women (e.g. Watete et al. 2016). Also consistent with previous research is that more educated household heads are more likely to choose "diversify livelihood", as the opportunities for livelihood diversification tend to be correlated with the level of education (Ibid).

Results from ordinary probit regressions of the four fodder management strategies *grass seeding*, *grass protection*, *bush/tree management*, and *management of invasive species* can be found in Table 6. Since we are interested in explaining the choice of fodder management technique, the sample is here limited to the respondents who had indicated *active fodder management* as an adaptation choice. However, this precluded the use of the multivariate probit approach, since the number of observations was too few. Again, we have chosen to present elasticities, i.e. the percentage change in the likelihood of choosing a particular strategy from a 1% increase in the independent variable. Note again that the *t*-values refer to the original estimated parameters.

The results show that respondents in wards with higher precipitation and/or high temperature are more likely to use "management of invasive species". This might be due to invasive species being a bigger problem in higher precipitation wards, but there is on the other hand evidence that suggest that the relationship between precipitation and impacts of invasive species in drylands is highly complex and context-specific (Garbowski et al. 2021). The very high elasticities for the climate variables on this fodder management choice are likely due to the

high ward-level variation for this choice. For three wards, Ilchamus in Baringo and Suam and Riwo in West Pokot, more than 40% of all respondents do invasive species management, while in the remaining wards, no, or very few, do it. This can create a strong marginal effect in the probit regression.

Wards with higher population density are more likely to choose "grass protection", which is probably associated with the fact that with high levels of population density and/or sedentarization, land use needs to be intensified (Nyberg et al. 2015). Both group and private title deed increases the likelihood of choosing "grass protection", constituting yet another indication for the importance of secure land tenure for particular land investments and livelihood strategies.

Respondents with cattle are significantly more likely to use "management of invasive species" as a fodder management choice, which is reasonable since tend to be more affected by invasive species than other non-cultivated fodder sources. The same line of interpretation explains why camel owners are less likely to choose "management of invasive species".

Of the demographic variables, male household heads are less likely to choose "bush/tree management" and "management of invasive species", and more educated household heads are also less likely to choose "bush/tree management".

Discussion

The four counties we have investigated are characterized by differentiated conditions in terms of climate, ethnic belonging, land tenure and land use, economic trajectories, and human and livestock population pressure, and the 12 wards represent locally specific contexts and conditions within each of the counties. Moreover, by applying a uniform questionnaire and a uniform statistical analysis, it is possible to take one needed step towards identifying the underlying factors that correlate with pastoralist coping/adaptation strategies, under different societal and climatic conditions. While existing quantitative and some qualitative studies provide detailed knowledge about strategies at different places, national and international quantitative studies offer a general albeit simplified understanding. The approach this paper has taken offers a novel contribution to this gap through its general, regional scope combined with detailed information about both inter-regional and inter-county differences. Based on the outcome of this attempt, we propose that this can be a path towards both a more specific and general understanding of why pastoralists at different places choose different strategies.

Illustrating this argument, herd reduction is most common in eastern Isiolo, Laikipia, and in Ilchamus and SaimoSoi wards in Baringo, while it is notably absent in West Pokot. Changing herd composition on the other hand is a more common response to combined biophysical and economic changes in drier wards in general, and in in Isiolo in particular, where it includes the shifting to/complementation of camels in the herd. In Laikipia on the other hand, changing herd composition tends to mean an increase of goats and sheep. To migrate further is more common in the western- and easternmost edges of the wards under analysis, in Suam and Riwo in the west of West Pokot and in the Isiolo County wards. This signals that the use of more long-distance migration as a strategy is more about the *ability* to migrate than about climatic conditions. In areas where dry season grazing land is subdivided and the population density is higher, the opportunities for migration are fewer. However, when considering wet season grazing land, subdivision may be a factor behind decreasing migration if combined with land management that enables pastoralists to access fodder without migration. It is for example striking how the popularity of the strategy "migrate further" is low in Chepareria, where the implementation of rangeland enclosures and more intensive land management techniques has been extensive. Although this change has meant subdivision, it has facilitated land rehabilitation among agro-pastoralists in Chepareria and hence reduced the need to use migrating further as a coping strategy over the last three decades. This is however not the case in neighbouring wards in West Pokot, where land intensification and rehabilitation have not been extensively implemented (Nyberg et al. 2015; Knutsson et al. 2021). "Migrate further" is also a less common strategy in Laikipia, where competition for land has been high for decades and where the majority of the pastoralists are confined to group ranches, surrounded by large privately owned game reserves.

Diversification of livelihoods as a strategy is common in nearly all counties and wards, except for Isiolo County. This could be a reflection of the relative remoteness of the Isiolo wards included in the study, combined with low population densities and harsh climate conditions. Or to put it in other words, opportunities for livelihood diversification are few here. In contrast, in Segera, Laikipia County, livelihood diversification is perhaps the most prominent adaptation strategy. Here, Yurco (2017) and Unks et al. (2019) have shown that pastoralists are increasingly drawn into professional jobs as herders, security personnel, and tour guides with powerful landowners involved in joint commercial ranching and wildlife conservation activities. However, adopting livelihood diversification may

not only be defined as an indication of opportunity, but could also be an outcome of decreasing land and livestock productivity, pushing households to identify alternative means of livelihood.

Finally, active fodder management is mainly common in the West Pokot wards and in the Ilchamus ward in Baringo County. This is likely a reflection of the occurrence of managed private or group enclosures (private or group). In Baringo County, it is mainly in Ilchamus ward, close to Lake Baringo on Njemps Flats, where active fodder management techniques are applied, mainly through grass seeding, seasonal grass protection, and management of invasive (in this case *Prosopis*) species, but notably not bush and/or tree management. This technique is contrast very common in all West Pokot wards due to the tradition to lopp trees for fodder—in combination with seasonal grass protection and management of invasive species. The presence of organizations supporting communities in land rehabilitation is an important explanation as to why we find the adoption of active fodder management strategies in parts of Baringo and West Pokot. In Baringo, Rehabilitation of Arid Environments (RAE) Trust has been training agro-pastoral communities to rehabilitate severely degraded areas for fodder production around Lake Baringo and on the surrounding hills as a response to the heavy grazing pressure (Mureithi et al. 2016). In West Pokot, Vi Agroforestry led the adoption of silvi-pastoral practices of growing fodder and tending to multi-purpose trees from 1985 to 2001 (Makokha et al. 1999), practices that since then began to be adopted in neighbouring wards (Nyberg et al. 2015). Active fodder management strategy is notably absent in Isiolo, Laikipia, and northern Baringo, with the exception of some grass seeding being performed in the Isiolo wards.

Concluding remarks

With climate change, demographic changes, economic developments, and land reform as examples of important processes of change, we can use the results of this study to try to make sense of how particular strategies might correlate with these forces. In the future, migrating further as a strategy might become more needed as temperatures increase, but at the same time more difficult to perform and more prone to conflicts. This is as the population increases and the dryland commons are reformed and fragmented into community and private titles, which in turn provoke more intensive management of land. Such a trajectory seriously limits the "flexibility" of pastoralism, as land previously accessible for dry season grazing is increasingly and formally owned by others. One alternative then becomes to "opt out" of pastoralism through diversification, which tends to be a common strategy as population density increases. Furthermore, there is a trend towards changing herd composition in the region, for example, through more camels, which is most likely driven by a combination of climate change and increased market opportunities, as camel milk is attracting a growing market in Kenya. In sum, active fodder management and diversification of both herd composition and livelihoods may be the most effective strategies for increased pastoralist resilience to combined biophysical and socio-economic change.

It is important to understand that there is a multitude of strategies applied to meet impacts of climate change and to adopt to a continuously changing world. Different local contexts and conditions gives rise to differentiated adaptation strategies. It is equally important to understand general patterns in strategies to cope with shocks and to adopt to changing socio-ecological conditions. Within the climate change complex, increased climate variation is undeniably affecting pastoralists now, and will continue to do so in the future. However, climate variability is not the only challenge facing pastoralists; population increase leading to increased pressure on land, land tenure change, increased commercialization, urbanization and infrastructure development are other factors effecting the fate of pastoralist land use. For example, pastoralists have to find alternative pastures for their livestock when droughts become worse and more frequent and when traditional dry season grazing areas become occupied by other activities. The option to use migration as a coping/adaptation strategy depends on the *ability* to migrate, which is curtailed by increased land fragmentation. Diversification of both livelihoods and herd composition seems to be the most common strategy for many pastoralists. However, this strategy may not be applicable, available, or appropriate to all pastoralists in all contexts. It is important to acknowledge that the plethora of challenges facing pastoralists and pastoralism needs to be met by a plethora of context-specific adaptation strategies.

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Authors' contributions

GB: conception and design of the work; acquisition, analysis, and interpretation of the data; and drafted the manuscript. PK: conception and design of the work; acquisition and interpretation of the data; and drafted the manuscript. DM: conception and design of the work and acquisition and interpretation of the data. SM: conception and design of the work; acquisition and interpretation of the data; and drafted the manuscript. EW: conception and design of the work; acquisition and interpretation of the data; and drafted the manuscript. GN: conception and design of the work; acquisition, analysis, and interpretation of the data; and drafted the manuscript.

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Availability of data and materials
The datasets used during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
All survey participants have given their informed consent to participate in the survey.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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