Pastoral livelihood pathways transitions in northern Kenya: The process and impact of drought

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Abstract

Recurrent droughts and long-term changes to climate, social structures, and the economy in the world's arid and semi-arid lands have impacted pastoralists' livelihood activities over time, resulting in different livelihood pathways. Some pastoralists continue to follow more traditional strategies of herd accumulation, while others frequently engage in livestock markets and value addition activities, and others still are dropping out of pastoralism. Using data collected over 6 years from 924 households in northern Kenya and applying a generalized structural dynamic multinomial logit model, this study quantitatively determined the dynamic transitions between livelihood categories conditional on drought incidences. From the results, there were considerable and frequent transitions between livelihood pathways within the panel period (2009–2015). Notably, many households that started in the low-cash income, larger herd size category denoted as hanging in, were transitioning to lower cash income with small herds (dropping out). At the same time, there was a great deal of back and forth between the category with low-cash income and small herd size (dropping out) and the category with higher cash income and small herd size (moving out), indicating that moving out was the only way out of poverty. Also, an increase in vegetation index from a drought season where the index was at a 10% level to a good season where the level was 90% decreased the likelihood of households dropping out from a predicted probability of 37.9 to 28.7% and increased the likelihood of moving up and moving out from 22.2 to 25.0% and 22.6 to 34.3%, respectively, unconditionally. The study findings imply that any livelihood interventions aimed at reducing the impact of drought and alleviating poverty among pastoral households should support the transition to market-oriented, relatively successful pathways and also protect households from falling back into the ranks of poverty by dropping out.

Keywords: Trends, Poverty, vegetation index, cash incomes, herd size

Introduction

The sustainability of pastoralists' ability to generate income and earn a livelihood through extensive livestock grazing in drylands has been a subject of a global debate among development agencies, policymakers, and governments due to the challenges it faces (McPeak et al. 2012). Over time, long-term climatic, social, land-use, and economic changes have posed dynamic implications

on the livelihoods of pastoralists. While dependence on livestock prevails, these disruptions have led to transitions into livelihood options with varying degrees of reliance on livestock. For instance, poor households pursue low-return marginal activities such as charcoal burning and firewood sales, among others (Ellis 2000; Little et al. 2001). This happens when herds are no longer via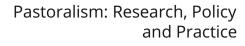ble to support their livelihoods (Lind et al. 2016). On the other hand, herd-sufficient households diversify to lucrative livestock business activities (Little et al. 2001). These tangents from traditional pastoralism pursued by the

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poor and wealthy households represent pastoralist livelihood pathways. In fragile production systems like pastoralism, expanded knowledge of these dynamics provides the foundation necessary to develop impactful context-specific interventions.

Pastoralists build their herds over the years through breeding from their stock, purchases from markets, and other socially instituted intake mechanisms (Hauck and Rubenstein 2017). It is a wealth-building process preferred by most pastoralists as the benefits through births and milk are perceived to outweigh returns from live animals sold (Lind et al. 2020). However, covariate and idiosyncratic shocks inhibit growth by causing adverse impacts, whose outcomes systematically vary across households and regions. These outcomes have long-run implications that are difficult to capture using cross-sectional surveys or even short-period longitudinal surveys accurately. Also, these disruptions and subsequent recovery dynamics imply that pastoralists would systematically oscillate across the income and herd size thresholds over time resulting in a change in livelihood pathways pursued. However, there is little understanding of the transition process between the various pastoral livelihood pathways. This study, therefore, sought to fill in the existing knowledge gaps with respect to how different groups of pastoralists transition between livelihood pathways over time and the impact of drought.

Earlier studies on pastoralist livelihoods have used different approaches while providing contextual dynamics in response to notable economic and environmental shocks. This includes pastoral risk management and social change (McPeak et al. 2012), pastoral resilience in a time characterized by drought and recovery phases (McPeak and Little 2017), policy-driven sedentarization initiatives like irrigation agriculture and growth of industries (Dai et al. 2020), options outside the livestock economy (Watete et al. 2016), and diversification to crop income-based livelihoods (Rufino et al. 2013). These studies used frameworks developed using household socio-economic indicators to generate insights on livelihood changes as occasioned by these shocks. For instance, and the most relevant to this study, McPeak et al. (2012) and McPeak and Little (2017) clustered 190 households in northern Kenya and 153 households in southern Ethiopia into four livelihood groups based on whether households were below or above the median thresholds of livestock assets from the baseline survey in March 2000 and cash income values in a repeat June 2000 survey. The four clusters were named 'staying with' referring to those maintaining traditional pastoralism, 'combining' and 'moving from', implying households deviating on opposite sides of the median herd size and 'left out' group referring to cases pushed out of pastoralism into other low-income livelihood options. These livelihood groups were used to demonstrate how households in the four identified livelihood clusters strive to achieve economic security and differ in exposure, sensitivity, and ability to cope with shocks. Similarly, using household-level data, the groups can be created and used to map pastoralist livelihood trajectories over time (Lind et al. 2020).
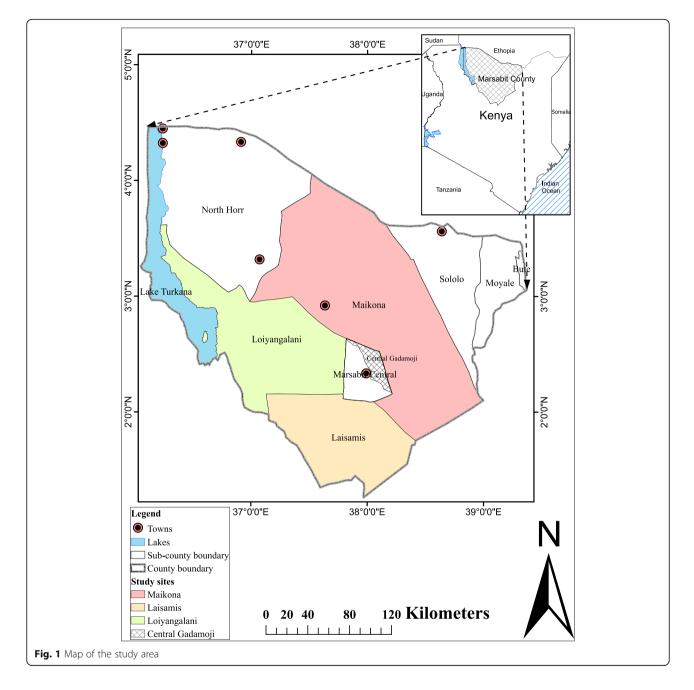
This study further advances the above literature by using a 6-year annual household-level panel data to map pastoralist livelihood pathways trends, transitions, and the impact of drought over time and space. The relatively more extended period allowed the analyses of transitions between categories in a way that other works have not. Accordingly, households were stratified based on relative thresholds of per capita cash income per day from all sources and livestock holdings per capita, calculated once over the panel period (2009–2015), but allowed to vary from one insurable unit to another. Insurable/index units are areas created for selling insurance to herders. The thresholds were allowed to vary by index units to focus on the changes in livelihood groups over time within units rather than using a single shared threshold which would have focused the study on more stationary differences between index units. By looking at livelihood dynamics among pastoralists and the impact of drought, this study provides a basis for the implementation of policy interventions for transitioning households into sustainable livelihoods. This is important considering the number of investments focusing on drought mitigation and the sustenance of the pastoralist way of life.

Study area
The study was conducted in Marsabit County in northern Kenya (Fig. 1). The county covers 70,944 km^2 representing 12% of the national territory. It borders Samburu County to the south, Isiolo and Wajir to the east, and Turkana County to the west. Ethiopia also borders the county to the north. It is divided into four sub-counties (North Horr, Saku, Moyale, and Laisamis), sub-divided into 20 electoral wards (KNBS 2019a).

The county receives an annual rainfall of between 200 and 1000 mm with an average precipitation of 254 mm, making it one of Kenya's driest counties (NDMA 2019). The area is also characterized by poor infrastructure, frequent droughts, low market access, and remote settlements. To cope with these harsh conditions, the communities in this area primarily practice semi-nomadic pastoralism, where livestock are moved during the dry season searching for pastures and water (McPeak et al. 2012).

Marsabit has 447,150 people and 77,495 households with an average household size of about 5.8 (Kenya National Bureau of Statistics 2019a). The county is home to several pastoral communities, including Borana, Somali, Samburu, Rendile, and Gabra. These communities rely on livestock as their primary livelihood source. The residents

Fig. 1 Map of the study area

depend on milk from livestock, most commonly from cattle and camels, for consumption, and they also trade in animals to buy other foods and meet their different daily needs (Mahmoud 2013). Other livelihood activities include casual labour, wage employment, petty trading, charcoal burning, and small agro-pastoralism.

Methods
Sampling and data collection
This study used six rounds of household panel data collected by the International Livestock Research Institute (ILRI) between 2009 and 2015 to track the impacts of the

Index-Based Livestock Insurance (IBLI) intervention. Briefly, IBLI was formulated as an innovation that seeks to bring the benefits of formal insurance to help pastoralists of Northern Kenya manage drought-induced livestock losses (Mude et al. 2010). The IBLI project initially started in 2010 as a strategy to help herders quickly recover from losses caused by frequent catastrophic droughts (Mude et al. 2010). As of writing, IBLI is commercially sold across the drylands of Kenya and in southern Ethiopia. In 2015, Kenya's government started using it as the first government livestock insurance scheme in Africa under the Kenya Livestock Insurance Program (KLIP).

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During the survey period, information was collected from 16 sub-locations from a proportionately stratified sample based on the 2009 census with a minimum sample size of 30 households and a maximum of 100 per sub-location. Households were placed in three wealth categories based on their livestock holdings in tropical livestock units (TLUs): 1 TLU = 250 kg of animal's live weight, equal to 0.7 of a camel, 1 head of cattle, and 10 shoats (Schwartz et al. 1991). The wealth groups were low (< 10 TLU), medium (≥ 10 ≤ 20), and high (> 20 TLU). In each of the 16 sub-locations, one-third of the location-specific sample was selected randomly from each of the three wealth groups, and the samples were then used to generate a list of 924 households.

To address attrition across the survey rounds, missing households were replaced from the same TLU class in the same sub-location. In the first four survey rounds, the replacement strategy yielded a consistent sample of 924. In round 5, the sample reduced to 923, and in the sixth and final round in 2015, the sample reduced to 919 households. A total of 770 respondents were consistently interviewed during the survey period in the six survey rounds conducted from 2009 to 2015.

The IBLI data is one of the most recent datasets in Kenya, with relevant variables needed to perform analyses on pastoralist livelihoods and change over time. According to Lind et al. (2016), empirical studies on pastoralists' livelihoods and changes over time should capture key variables on actual access and use of resources and markets. As of 2021, the only publicly available/accessible datasets in Kenya that had such variables were IBLI 2009–2015; Hunger Safety Net Program (HSNP) data; Pastoral Risk Management (PARIMA) 2000–2002 data; the Maasai South Rift's Homewood, Kristjanson, and Trench, Staying Maasai 1998–2004; and Grandin Maasai Systems Study 1981–1985. Therefore, this study used the relatively most recent primary data to contribute to the existing knowledge on pastoralist livelihoods and changes over time. Most importantly, it incorporated livelihood transition conditional on previous household and local circumstances to pastoral livelihood analyses.

In the analyses, Normalized Difference Vegetation Index (NDVI) data were used to measure drought. NDVI is a satellite-generated indicator of the amount and vigour of vegetation cover based on the observed level of photosynthetic activity (Tucker et al. 2005). Lower values of NDVI indicate forage scarcity, while higher ones reflect better vegetative greenness. NDVI image data are computed at high spatial resolution and consistent quality from advanced very high-resolution radiometer (AVHRR) onboard the US National Oceanic and Atmospheric Administration (NOAA) satellite (Chantarat et al. 2013).

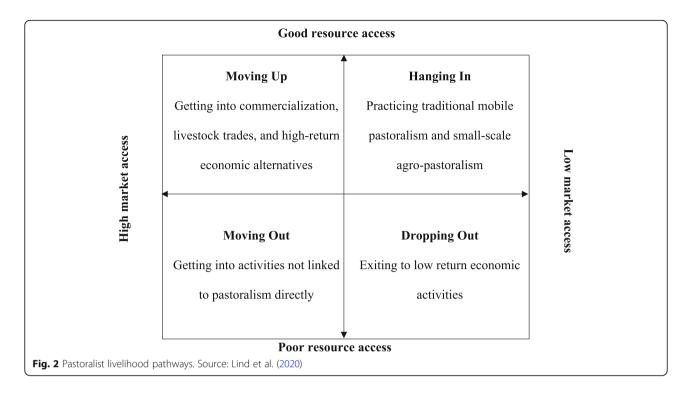The NDVI data are commonly used to compare the current vegetation state against long-term average conditions to detect any anomalies and anticipate drought (Bayarjargal et al. 2006). Due to their reliability in ASALs, NDVI data are widely used in studies that use remote sensing data for drought management. IBLI also uses the data. To account for differences in regions, agro-ecological conditions, climatic patterns, and herd composition, NDVI values specific for different index areas were extracted, namely Central and Gadamoji, Maikona, Laisamis, and Loiyangalani in each survey year. The Cumulative *z*-values of Normalized Difference Vegetation Index (CZNDVI) for these regions are provided in Table 1.

Livelihood classification

Studies on livelihoods often use different approaches based on various theoretical foundations to derive livelihood categories for insightful analyses. One method gaining popularity, especially in studies on changes in pastoralist livelihoods over time, is an approach used in McPeak et al. (2012), which was further improved in McPeak and Little (2017). In this approach, households are categorized into four livelihood groups distinguished by their access to markets and resources. The variable or proxy for market access is household cash income, and the proxy for access to key resources (mainly pastures and water) is livestock ownership. The four livelihood categories (hanging in, dropping out, moving up, and moving out), also termed the long-term pastoralism pathways, represent a simple schema for thinking broadly about change in pastoral areas over time (Lind et al. 2020). This study used this schema as illustrated in Fig. 2 to study the transition processes over time and the effects of drought on pastoral livelihood pathways.

In this study, livelihood pathways' relative terms were defined using area-specific thresholds. Accordingly, the sampled households from Marsabit County in northern Kenya were classified into the four livelihood groups using herd size in TLUs per capita (all adults) and cash income per capita (all adults) per day. More specifically, the means of household TLUs per capita and income per capita per day specific to five insurable units were calculated once over the 6 years and used as thresholds for categorizing households into the four livelihood pathways. Insurable units are geographical areas created to sell index insurance to herders. The use of these units

Table 1 Standardized normalized difference vegetation indices during survey rounds

Index area	Survey rounds					
	2009	2010	2011	2012	2013	2015
Central and Gadamoji	− 19.60	− 1.12	− 33.69	25.03	18.12	1.46
Laisamis	− 23.44	− 2.37	− 27.87	9.85	− 0.85	1.83
Loiyangalani	− 12.74	7.53	− 22.70	22.25	2.61	− 7.72
Maikona	− 12.00	− 0.46	− 24.13	19.16	9.85	− 10.82

Fig. 2 Pastoralist livelihood pathways. Source: Lind et al. (2020)

as opposed to administrative units such as sub-locations is that these units reflect socio-ecological patterns including rainfall patterns, agro-ecological factors, and herding/migration patterns among pastoralists in the area (Chelanga et al. 2017).

The rationale behind this study's classification approach is that pastoral areas are characterized by a high degree of spatial heterogeneity of land use. Therefore, insurable units better reflect socio-ecological patterns in the drylands compared to the standard administrative units. Indeed, household herd size and cash income thresholds that were derived showed a striking difference from one insurable unit to another, key factors in establishing a projection of likely individual household's livelihood pathways in the face of drought and drought-related stresses.

Modelling strategy

Given the response variable (livelihood pathways) is a discrete variable that assumes four unordered outcomes, this study applied a generalized structural dynamic multinomial logit model to determine the effect of drought on pastoralist livelihood pathways.

The generalized structural dynamic multinomial logit model follows the traditional multinomial logit (MNL) model but incorporates change over time (dynamism) by using covariates in period $t-1$ to predict livelihood outcomes in period t. This approach reduces reverse causality and allows these covariates to infer and predict future pastoralist livelihood outcomes. In this model, the

probability that a household i is following the jth livelihood pathway in the current period (t) as a function of drought among a set of other factors as measured in the previous period ($t-1$) is given as follows:

$$\Pr\left(y_{ij} = j | x_{it-1}, y_{it-1}\right) = \frac{\exp\left(x'_{it-1}\beta_j + y_{it-1}\right)}{1 + \sum_{r=1}^{3} \exp\left(x'_{it-1}\beta_r + y_{it-1}\right)} \forall j = 1, 2, 3, 4$$

where $j = 1$ is hanging in; $j = 2$ is dropping out; $j = 3$ is moving up; $j = 4$ is moving out, x_{it-1} and y_{it-1} are explanatory variables and livelihood pathways in the previous period ($t-1$), respectively; and β_j are parameters to be estimated. The major interest in the analysis was the effect of drought on livelihood pathways transitions. So, margins were calculated and reported which were interpreted as the effect of a unit change in vegetation index (drought indicator) in the previous period ($t-1$), on the probability of a household remaining or transitioning to another livelihood category in the current period (t) relative to the likelihood of hanging-in (the reference group).

Results

Thresholds for livelihood classification

Households were classified into the four livelihood categories based on relative thresholds of cash income per capita per day controlled for consumer price indices (CPI) and livestock holdings per capita in tropical livestock units. The thresholds (pooled means) varied between insurable units but were fixed over the 6 years. CPI for the periods 2009, 2010, 2011, 2012, 2013, and

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2015 were 96, 100, 114, 125, 132, and 150, respectively (Kenya National Bureau of Statistics 2019b). The base period chosen for the adjustment of cash income for inflation for this study was 2010 (CPI of 100). Accordingly, incomes were adjusted based on CPI ratios derived. Table 2 provides the thresholds used for the classification of households in the five insurable units.

As shown in Table 2, the highest TLU per capita threshold was 3.16, while the lowest was 0.71. On the other hand, the highest income per capita per day threshold was KES 47.44 (0.47 USD), while the lowest was KES 25.62 (0.25 USD). The disparity between these thresholds demonstrates the rationale for using relative thresholds rather than general ones. For instance, a household in Gadamoji with 1 TLU per capita and KES 30 (0.3 USD) cash income per capita per day would have been categorized as dropping out in Central when, in fact, they are moving up relative to other households in Gadamoji.

Proportions and trends of pastoralist livelihood pathways over time

The proportions of the four pathways had patterns of increase and decrease over the panel period. The proportion of households in the hanging in pathway generally decreased over time from 28% in 2009 to 12% in 2015. The proportion of households dropping out increased over time from 28% in 2009 to 32% in 2015. Moving up was a little bit stable, but it slightly decreased in proportion from 29% in 2009 to 24% in 2015. Finally, the trend displayed by households in the moving out group was a general growth from 16% in 2009 to 32% in 2015. Figure 3 provides the respective distribution and proportions of pastoralist livelihood pathways from 2009 to 2015.

Socio-economic characteristics by livelihood pathways

Various socio-economic characteristics were compared across the four livelihood pathways. Heads of households pursuing moving up strategies were relatively younger compared to their counterparts in the hanging in, dropping out, and moving out pathways. They also had more years of education and more savings (Table 3). Household settlement status, access to credit, livestock insurance, and land ownership showed significant variation

across the four pathways (Table 4). The highest percentage of settled households were those in the moving out pathway, while the least were those in the hanging in group. More households in the moving up group had access to credit, while those in the dropping out pathway had the least access. Most households that practised moving out activities privately owned land compared to their counterparts in the other groups.

Proportionate transitions between pathways

The transition of households from one pathway to another was very dynamic over the panel period. There were no clear pathways or sets of transitions that seemed much more common than others. The proportionate transitions also indicated that dropping out, moving up, and moving out pathways were very resilient. That is, each year, more than 50% of households categorized into these three livelihood pathways in the previous year remained in the same category in the current year (Table 5).

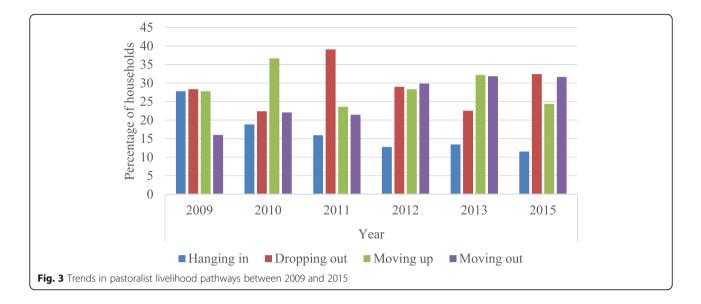### Effects of drought on pastoralist livelihood pathways

The effect of drought as indicated by CZNDVI was significant across all the four pastoralist livelihood pathways, unconditionally, controlling for the previous pathway and controlling for other covariates. Generally, an increase in CZNDVI from a drought season where the vegetation index was at 10% level to a good season where the index was at 90% level reduced the likelihood of households dropping out, increased the likelihood of moving up, and also increased the likelihood of households moving out (Table 6).

Discussion

Households in the hanging in livelihood pathway earn a living from traditional pastoralism and small agro-pastoralism. The highest percentage of their earnings comes from livestock, making other sources negligible. A striking trend of this group was their continued decrease in numbers over time. In 2009, 27.81% of households were categorized as hanging in. By 2015, that figure had fallen to 11.53%. According to Lind et al. (2020), this group of pastoralists is common in areas where there is good access to rangeland and water

Table 2 Thresholds (pooled means 2009–2015) for livelihood classification

Insurable units	Observations	Herd size in TLUs per capita	Cash income per capita per day (KES)
Central	563	1.42	47.44
Gadamoji	762	0.71	28.18
Laisamis	929	2.02	27.18
Loiyangalani	1659	2.36	25.62
Maikona	1625	3.16	41.58
Total	**5538**		

Fig. 3 Trends in pastoralist livelihood pathways between 2009 and 2015

sources, but market access is limited. People in such areas are hanging in customary pastoralism, and their incomes drive demand for other non-pastoral products or services such as crop produce, natural products, constructions services, and others (Headey et al. 2012).

The dropping out pathway represents households with the lowest herd size and cash incomes. It was the largest livelihood group that cumulatively represented 28.96% of the panel respondents. In the base year, 28.35% of households were categorized into this group. The proportion of households grew over the years, implying that relatively more households became dropouts over time. This group's striking feature was its drastic rise from 22.40% in 2010 to 39.07% in 2011, a trend attributable to the devastating 2010/2011 drought that began in late 2010 and peaked in 2011. Drought not only deteriorates livestock health or results in high mortality, but it also pushes pastoralists out of their production system, forcing them to seek alternative sources of livelihood. Therefore, the increasing number of

households dropping out depicts the increasing frequency and the severity of the drought. For instance, the 2010/2011 drought was thought to be the worst in the last 60 years, but the subsequent ones were even more severe, with 2017 having been the worst of all. Such a trend threatens pastoralism as a livelihood. As evidenced by the results of this study, the increasing number of households dropping out and decreasing number of households hanging in on pastoralism is an indication of a general exit from pastoralism over time.

Households in the moving up group represent the wealthiest in terms of both herd size and cash income. Also, from the income profiles of these households, much of their income comes from the sale of livestock and livestock products. Over time, the number of households categorized as being in this pathway decreased to 24.37% of households from the initial proportion of 27.81%. However, the rate of decrease over time is slower with patterns of increase, followed by a decrease, for instance, from 36.69% in 2010 to 23.59% in 2011 and

Table 3 Descriptive summary statistics of continuous variables by livelihood pathways

Variable	Livelihood pathways								F-statistic
	Hanging in		Dropping out		Moving up		Moving out		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Age of household head (in years)	48.14	17.42	52.78	16.83	47.60	17.12	48.58	15.83	32.51***
Household size (adult equivalent)	4.697	2.026	5.426	2.149	4.752	2.043	5.317	2.276	40.30***
IHS of household head's education	2.785	0.526	2.723	0.459	2.839	0.555	2.800	0.479	14.73***
IHS of household education stock	2.343	0.832	2.596	0.965	2.615	0.984	2.884	1.019	57.20***
IHS of amount of savings	1.539	2.992	1.031	2.478	2.635	4.031	2.785	3.997	96.42***
IHS of remittances	4.199	3.678	4.189	3.629	4.270	3.727	4.319	3.731	0.420
IHS of size of land irrigated	0.023	0.319	0.037	0.334	0.056	0.466	1.427	0.550	3.110**

Note: IHS stands for inverse hyperbolic sine transformation. Significance level: ***$p < 0.01$, **$p < 0.05$. The *F*-statistic is the ANOVA test that indicates if there is a significant difference in the means of the selected variables among the four livelihood pathways. The adult equivalents for household size were computed using the World Health Organization (WHO) adult equivalent conversion factors

Table 4 Summary statistics (percentages) for discrete and dummy variables by livelihood pathways

Variable	Hanging in	Dropping out	Moving up	Moving out	χ^2
Head change (1 = household head changed)	2.48	3.20	1.98	2.60	4.60
Gender of household head (1 = male)	57.62	57.98	66.29	68.25	54.48***
Household settlement status					
1 = fully settled	18.09	41.01	24.90	51.34	367.57***
2 = partially settled	77.94	56.98	71.82	47.65	
3 = nomadic	3.97	2.01	3.27	1.02	
Credit access (1 = accessed credit)	26.28	20.92	31.70	22.65	49.39***
Livestock insurance (1 = bought insurance)	11.15	9.88	13.09	14.22	17.13***
Land ownership (1 = yes)	13.38	20.58	17.05	32.00	147.95***

Note: Significance level: ***$p < 0.01$. χ^2 is the chi-square test that indicates if there is a significant difference in the percentages of the selected variables by livelihood pathways

then up to 28.35% in 2012. In northern Kenya, moving up activities are evident in Moyale where pastoralists are engaging in cross-border trade and other high-value livestock marketing activities with their counterparts from Ethiopia's eastern lowlands (Mahmoud 2013).

Moving out is the second largest group among the four livelihood pathways. Furthermore, it is also the second group (after dropping out) that depicts a trend of growth in numbers over time. At the starting period (2009), 16.02% of the sampled households were categorized into this group. Although there were instances of a slight decrease in some periods, the group generally registered an upward trend reaching 31.66% in the final year. Also, households in this group had high incomes with most of it coming from sources not directly linked to pastoralism such as salaried employment, sale of crops, business, and petty trading. Improved connections with large centres, small-town expansion, and acceptance of non-traditional livelihoods by the younger generation are some of the factors that promote household engagement in moving-out activities (Lind et al. 2020). The general trends observed from the proportions of these four livelihood pathways are illustrated in Fig. 3.

Socio-economic characteristics of pastoralist households by livelihood pathways

A number of socio-economic characteristics were associated with the four pastoralist livelihood pathways. Table 3 provides the descriptive summary statistics for

continuous household characteristics by livelihood pathways. The *F*-statistic values included in the table are the analysis of variance (ANOVA) tests for significant differences in the means of selected variables between the four livelihood pathways. As a precaution against extreme values including many zero-valued observations in some variables such as household head's education years, household education stock, amount of savings, remittances, and size of land irrigated, the study used inverse hyperbolic sine transformation (IHS) as used by Bellemare and Wichman (2020). This procedure, to some extent, is the same as taking the log of the variable, but it allows the retention of observations with zero values.

As provided in the summary statistics in Table 3, the mean age of household heads varied significantly across the four livelihood pathways. The dropping out group had the highest mean age while moving up had the lowest, reflecting participation in market-oriented keeping and moving of large herds among young pastoralists. Dropping out had the highest mean of household size, while hanging in had the smallest. These results indicate that a relatively older head leads an average drop-out household with many household members who increase pressure on an already small income and fewer animals due to severe droughts and other factors.

Schooling years of household head and household education stock (sum of schooling years over all household members) showed a significant difference between the four livelihood pathways. Moving up had the highest

Table 5 Proportionate transitions between livelihood pathways

Livelihood pathway ($t-1$)	Livelihood pathway (t)				Total
	Hanging in	Dropping out	Moving up	Moving out	
Hanging in	31.16	15.02	42.80	11.01	100
Dropping out	8.78	55.06	6.20	29.96	100
Moving up	17.73	7.99	59.13	15.14	100
Moving out	5.34	33.79	10.13	50.74	100
Mean sum	14.57	28.92	29.24	27.27	100

Table 6 The impact of CZNDVI on livelihood pathways

Variable	Dropping out		Moving up		Moving out	
	Coef.	SE	Coef.	SE	Coef.	SE
Unconditional						
CZNDVI = 10%	0.379***	0.011	0.222***	0.009	0.226***	0.009
CZNDVI = 90%	0.287***	0.010	0.250***	0.009	0.343***	0.010
Controlling for previous pathway (y_{it-1})						
CZNDVI = 10%	0.470***	0.015	0.117***	0.009	0.307***	0.014
CZNDVI = 90%	0.256***	0.011	0.254***	0.012	0.355***	0.012
Controlling for previous pathway and other variables in Tables 3 and 4						
CZNDVI = 10%	0.472***	0.017	0.113***	0.010	0.315***	0.015
CZNDVI = 90%	0.242***	0.012	0.272***	0.014	0.349***	0.014

Note: Significance level: ***$p < 0.01$

mean of schooling years of the household head while dropping out had the lowest average years of schooling. On the other hand, moving out had the highest average household education stock, while hanging in had the lowest average. This highlights a vulnerability among drop-outs concerning access to or their search for education. According to Teshome and Bayissa (2014), dropping out of pastoralism is mainly due to unexpected events such as drought, conflict, and chronic poverty, and households that drop out often end up in old peri-urban impoverished areas where access to education and other services is a challenge. Such households' activities are generally inferior survival strategies that yield low income that might not be sufficient for them to seek a better social status and education (Little et al. 2010). On the other hand, higher education years in the moving up and out pathways imply more cash income opportunities and greater access to education among those groups. Generally, moving up and out livelihood activities are common in urban areas where better living conditions, job opportunities, and access to education are among the pull factors that attract households to such areas (Lind et al. 2016).

The amount of savings significantly differed across the four livelihood pathways. The moving up group had the highest mean of household savings, while the dropping out group had the lowest mean. This finding highlights the vulnerability faced by households in the dropping out group. Should they face an income shortfall, these households have fewer resources to fall back on. Few savings are likely a result, in part, of their low income and could also be a signal of less access to savings institutions.

Moving out had the highest mean of irrigated land while hanging in had the lowest mean. Moving out involves participation in value-added activities such as micro-dairying, small-holder crop farming, and other activities; hence, irrigation projects play a very vital role

for households in this category, especially when it comes to the growing of fodder, watering crops, and other high income-generating activities that may not do well in some of the world's harshest lands that hardly receive adequate rainfall throughout the year.

To further show the difference in socio-economic characteristics by livelihood pathways, Table 4 provides the summary statistics for discrete and dummy variables.

The hanging in group had the highest percentage of households headed by females while moving out had the lowest. The highest percentage of female-headed households among traditional mobile pastoralists reflects a common practice of sending male heads to satellite camps while females take care of the basecamp (Jensen et al. 2017).

Settlement status varied significantly across the four livelihood pathways. Households practising traditional pastoralism (hanging in) had the highest mobility, while those in the moving out group had the least. These results affirm that the traditional adaptability and risk management strategy of mobility still plays a significant role among households that depend on livestock as their primary livelihood. This finding is consistent with the observation of McPeak et al. (2012) regarding livestock mobility among pastoralists that it must be supported and not hindered by policy or other changes.

Access to credit provides financial capital to venture into both livestock-based livelihood activities and those that are non-livestock-based. The majority of households that accessed credit were in the moving up group, with those dropping out having the lowest access rate to credit. Arguably, credit provides financial capital that increases the likelihood of household engagement in highly remunerative strategies such as moving up livelihood activities. Indeed, as Umeta and Temesgen (2013) note, helping pastoralists get credit enables them to participate in lucrative livestock and even non-livestock livelihood ventures.

Index-based livestock insurance is an intervention that aims to help pastoralists manage drought-related shocks. Moving out and up livelihood pathways had the highest insurance uptake, while the hanging in and dropping out groups had the lowest. This illustrates the idea that buying insurance enables pastoralists to build herds for trade, and any losses likely to be incurred in the event of drought will be catered for by indemnity received once the index reaches strike points set for payments to be released to all insured clients. Matsuda et al. (2019) also observed that insurance could increase herd size.

Land ownership varied significantly across the livelihood pathways. The findings of this study indicate that the moving out group had the highest percentage of land ownership while the hanging in group had the lowest. Ideally, traditional mobile pastoralism (hanging in)

requires extensive and free access to commonly managed pastures. Individual land ownership is thus not expected in such groups. On the other hand, having higher productive physical assets holdings is necessary for households transitioning into or engaging in more remunerative market-oriented livelihood activities such as moving out.

Pastoralist livelihood pathway transitions
In the context of change over time, it is possible to estimate the probability that a household categorized under a given livelihood pathway in the previous period (t–1) is likely to remain in the same group or transition to another category in the current period (t). Table 5 presents the computed proportionate transitions between the four livelihood pathways. Rows show the initial values at t–1, while the columns show the final values at time t.

The proportionate transitions between pastoralist livelihood pathways results showed that the transitioning of households from one pathway to another was very dynamic. This is interesting because targeting households in one pathway does not make sense since they would transition anyway. Furthermore, apart from the clear exit trend from pastoralism (hanging in) over time, no clear pathways or sets of transitions seem much more common than others.

Three main trends were observed from these livelihood transitions. First, dropping out, moving up, and moving out are all very resilient in that once a household falls into one, it is unlikely to leave. For moving up and moving out, this is great, but for dropping out, the stability indicates something like a poverty trap, which once a household is in it, it is difficult to exit. Secondly, it is tough/uncommon to transition into the hanging in group, as shown by the very low values in the 2–4 rows of the first column. This could reflect that it requires a great deal of capital or maybe because people do not want to, but still interesting that this is the least likely livelihood category to transition into. Thirdly, it seems there was a lot of back and forth between dropping out and moving out and that moving out is the only way out of dropping out (poverty). Perhaps, this suggests that livelihood interventions aimed at alleviating poverty among pastoral households should support activities that are important to helping people move from dropping out to moving out and infrastructure that allows those moving out to avoid falling into the poverty trap by dropping out.

Effects of drought on pastoralist livelihood pathways
Exposure to covariate drought shock has an impact on livelihood activities among pastoralists. The vegetation index best captures the severity of drought. Table 6 provides the effect of drought on pastoralist livelihood pathways unconditionally, controlling for previous livelihood pathways and controlling for other variables in Tables 3

and 4. The interest in the analysis was to determine the predicted change in the likelihood of each outcome (livelihood pathways) as CZNDVI changed from bad (drought) to good (rainy) season. Estimates of each outcome were computed with CZNDVI at 10% and 90% levels, holding other covariates at their means, the idea being that, keeping everything else at the mean, the difference between 10 and 90% is the estimated impact of CZNDVI alone.

As CZNDVI increased from a drought season where CZNDVI was at a 10% level to a good season where CZNDVI was at 90% level, the probability of households dropping out decreased from a predicted probability of 37.9% to a probability of 28.7% and the likelihood of moving up and moving out increased from 22.2 to 25.0% and 22.6 to 34.3%, respectively. When controlled for the previous pathway, an increase in CZNDVI decreased the probability of dropping out from 47.0% to a probability of 25.6% and increased the likelihood of moving up and moving out from 11.7 to 25.4% and 30.7 to 35.5%, respectively. Controlling for other covariates in Tables 3 and 4, an increase in CZNDVI reduced the probability of dropping out from 47.2 to 24.2%, increased the likelihood of moving up from 11.3 to 27.2%, and increased the likelihood of moving out from 31.5 to 34.9% relative to the likelihood of hanging in (the reference group) holding other factors constant.

Overall, the results revealed that forage scarcity or availability, as indicated by the changes in CZNDVI, is a key driver of pastoralist livelihood pathways. These results imply that frequent droughts leading to a devastating loss of herds drive households into being stockless; hence, they drop out and cannot participate in livestock-based lucrative ventures such as the sale of animals and even value-added livelihood diversification activities. The impact of drought is significant across all pastoralist livelihood pathways; hence, all households are vulnerable to drought over time, including those that have moved up and out of traditional pastoralism. Drought still pushes them into a destitute outcome (dropping out). This suggests that while helping households transition into market-oriented and relatively successful groups such as moving out reduces the impact of drought to some extent, there might be a need to support households in those groups as well to protect them from falling back to poverty by dropping out. Different measures that help build resilience and reduce vulnerability to drought or other shocks might be helpful to non-herders too.

Conclusions and policy implications
The pastoral livelihood transition process provides a long-term perspective on the change over time in pastoral areas. Based on relative thresholds of two key empirical indicators (cash income and herd size) and the

four long-term livelihood pathways, namely, hanging in, dropping out, moving up, and moving out, there is evidence that these pastoralist livelihood pathways show a changing trend over time. The analyses indicated that there is a great deal of transitioning between livelihood categories. Traditional pastoralism (hanging in) seems to be losing people to other livelihoods at the greatest rate. A majority of those exiting pastoralism pursue low-income activities, with a few others successfully moving up or out. This means that a household's income status defines the pathway trajectory that it (the household) follows and that a household's identified pathway characterizes its current livelihood status. Moreover, the transition from pastoralism to other modes of livelihood is mainly due to drought. This study's findings are meaningful in several ways. First, the results establish the possible livelihood pathways within the pastoral setting under drought threat and establish how pastoral households respond to droughts when the primary source of their livelihoods, namely cattle, is threatened. This is particularly important considering the number of investments focusing on drought mitigation and the sustenance of the pastoralist way of life. The second use for these results is to identify the possible livelihood interventions to reduce the impact of drought and transition households from dropping out (poverty) to less impacted pathways such as moving out. Finally, these findings underscore that any effective policy interventions in pastoral areas that are geared towards transitioning pastoral households towards more drought climatic variation contingent sustainable livelihoods ought to be based on contextualized analysis of the transition process and the critical factors such as drought associated with livelihood pathways that pastoralists pursue both livestock and non-livestock based over time.

Abbreviations
ANOVA: Analysis of variance; ASALs: Arid and semi-arid lands; CZNDVI: Cumulative *z*-scores of Normalized Difference Vegetation Index; CPI: Consumer Price Index; HSNP: Hunger Safety Net Program; IBLI: Index-Based Livestock Insurance; IHS: Inverse hyperbolic sine transformation; ILRI: International Livestock Research Institute; KES: Kenya shillings; KLIP: Kenya Livestock Insurance Program; KNBS: Kenya National Bureau of Statistics; MNL: Multinomial logit model; NDMA: National Drought Management Authority; NDVI: Normalized Difference Vegetation Index; TLUs: Tropical livestock units; WHO: World Health Organization

Authors' contributions
All authors made substantial contributions to the conception, design, and drafting of the paper. LK led the writing. GO and IK provided technical support, commented, and added to the draft. NJ, PC, and MI were part of the IBLI team that collected data from Marsabit. They also provided technical support, commented, and added to the draft. All authors approved the final draft for publication.

Availability of data and materials
The datasets that were analysed during the current study are available in the ILRI repository, https://data.ilri.org/portal/dataset/ibli-marsabit-r1.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

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

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References
Bayarjargal, Y., A. Karnieli, M. Bayasgalan, S. Khudulmur, C. Gandush, and C.J. Tucker. 2006. A comparative study of NOAA–AVHRR derived drought indices using change vector analysis. *Remote Sensing of Environment* 105 (1): 9–22. https://doi.org/10.1016/j.rse.2006.06.003.

Bellemare, M.F., and C.J. Wichman. 2020. Elasticities and the inverse hyperbolic sine transformation. *Oxford Bulletin of Economics and Statistics* 82 (1): 50–61. https://doi.org/10.1111/obes.12325.

Chantarat, S., A.G. Mude, C.B. Barrett, and M.R. Carter. 2013. Designing index-based livestock insurance for managing asset risk in northern Kenya. *Journal of Risk and Insurance* 80 (1): 205–237. https://doi.org/10.1111/j.1539-6975.2012.01463.x.

Chelanga, P., D.C. Khalai, F. Fava, and A. Mude. 2017. *Determining insurable units for index-based livestock insurance in northern Kenya and southern Ethiopia.* Nairobi: ILRI (aka ILCA and ILRAD).

Dai, X., B. Li, Z. Wu, B. Nan, Z. Ren, Y. Fan, and X. Zhang. 2020. Pastoral livelihood transition via divergent pathways: A case study in northern Xinjiang, China. *Journal of Arid Environments* 174: 104083. https://doi.org/10.1016/j.jaridenv.2019.104083.

Ellis, F. 2000. *Rural livelihoods and diversity in developing countries.* UK: University Press Oxford.

Hauck, S., and D.I. Rubenstein. 2017. Pastoralist societies in flux: A conceptual framework analysis of herding and land use among the Mukugodo Maasai of Kenya. *Pastoralism* 7 (1): 1–30. https://doi.org/10.1186/s13570-017-0090-4.

Headey, D., A.S. Taffesse, and L. You. 2012. *Enhancing resilience in the Horn of Africa: An exploration into alternative investment options (No. 1176).* Nairobi: International Food Policy Research Institute (IFPRI).

Jensen, N.D., C.B. Barrett, and A. Mude. 2017. Cash transfers and index insurance: A comparative impact analysis from northern Kenya. *Journal of Development Economics* 129: 14–28. https://doi.org/10.1016/j.jdeveco.2017.08.002.

Kenya National Bureau of Statistics. 2019a. *The 2019 Kenya Population and Housing Census: Population by county and sub-county*. Nairobi: Kenya National Bureau of Statistics.

Kenya National Bureau of Statistics. 2019b. *Consumer price indices and inflation rates*. Nairobi: Kenya National Bureau of Statistics. Available at: https://www.knbs.or.ke/consumer-price-indice/. Accessed 13 Aug 2019.

Lind, J., R. Sabates-Wheeler, M. Caravani, L.B.D. Kuol, and D.M. Nightingale. 2020. Newly evolving pastoral and post-pastoral rangelands of Eastern Africa. *Pastoralism* 10 (1): 1–14. https://doi.org/10.1186/s13570-020-00179-w.

Lind, J., R. Sabates-Wheeler, S. Kohnstamm, M. Caravani, A. Eid, D.M. Nightingale, and C. Oringa. 2016. *Changes in the drylands of eastern Africa: Case studies of pastoralist systems in the region*. Nairobi: DFID East Africa Research Hub.

Little, P.D., K. Smith, B.A. Cellarius, D.L. Coppock, and C. Barrett. 2001. Avoiding disaster: Diversification and risk management among East African herders. *Development and Change* 32 (3): 401–433. https://doi.org/10.1111/1467-7660.00211.

Little, P.D., R. Behnke, J. McPeak, and G. Gebru. 2010. *Future scenarios for pastoral development in Ethiopia, 2010-2025*. Ethiopia: Report Number 2, Pastoral Economic Growth and Development Policy Assessment.

Mahmoud, H.A. 2013. Pastoralists' innovative responses to new camel export market opportunities on the Kenya/Ethiopia borderlands. In *Pastoralism and Development in Africa*, ed. A. Catley, J. Lind, and I. Scoones, 121–130. London: Routledge.

Matsuda, A., K. Takahashi, and M. Ikegami. 2019. Direct and indirect impact of index-based livestock insurance in Southern Ethiopia. *The Geneva Papers on Risk and Insurance-Issues and Practice* 44 (3): 481–502. https://doi.org/10.1057/s41288-019-00132-y.

McPeak, J.G., and P.D. Little. 2017. Applying the concept of resilience to pastoralist household data. *Pastoralism* 7 (1): 1–18. https://doi.org/10.1186/s13570-017-0082-4.

McPeak, J.G., P.D. Little, and C.R. Doss. 2012. *Risk and change in an African rural economy*. London: Routledge.

Mude, A., S. Chantarat, C.B. Barrett, M.R. Carter, M. Ikegami, and J.G. McPeak. 2010. *Insuring against drought-related livestock mortality: Piloting index-based livestock insurance in northern Kenya*. Nairobi: AGRA and ILRI.

NDMA. 2019. *Marsabit*. Available at: http://www.ndma.go.ke/index.php/resource-center/send/54-2017/4497-marsabit. Accessed 27 Mar 2019.

Rufino, M.C., P.K. Thornton, I. Mutie, P.G. Jones, M.T. Van Wijk, and M. Herrero. 2013. Transitions in agro-pastoralist systems of East Africa: Impacts on food security and poverty. *Agriculture, Ecosystems & Environment* 179: 215–230. https://doi.org/10.1016/j.agee.2013.08.019.

Schwartz, H., S. Shaabani, and D. Walther. 1991. *Range management handbook of Kenya*. Nairobi: Ministry of Livestock Development.

Teshome, J., and Z. Bayissa. 2014. *A literature review report on understanding the context of people transitioning out of pastoralism (TOPs) in Ethiopia*. Addis Ababa: Haramaya University.

Tucker, C.J., J.E. Pinzon, M.E. Brown, D.A. Slayback, E.W. Pak, R. Mahoney, and N. El Saleous. 2005. An extended AVHRR 8-km NDVI dataset compatible with MODIS and SPOT vegetation NDVI data. *International journal of remote sensing 26* (20): 4485–4498. https://doi.org/10.1080/01431160500168686.

Umeta, G., and D. Temesgen. 2013. Determinations of agro-pastoralists participation in cattle attending package at FentaleWoreda, the case of East Showa Zone, Ethiopia. *American Journal of Research Communication* 1 (8): 205–226.

Watete, P.W., W. Makau, J.T. Njoka, L.A. MacOpiyo, and S.M. Mureithi. 2016. Are there options outside livestock economy? Diversification among households of northern Kenya. *Pastoralism* 6 (1): 1–13. https://doi.org/10.1186/s13570-016-0050-4.

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