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Assessing Interactions between Agriculture, Livestock Grazing and Wildlife Conservation Land Uses: A Historical Example from East Africa

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Abstract: Despite mobile livestock grazing being widely recognized as one of the most viable and sustainable land uses for semi-arid savanna, which can deliver clear wildlife conservation benefits, the levels of pastoral sedentarization and transitions to agricultural livelihoods continue to rise in many pastoral communities across the world. Using questionnaire interviews with community elders, our study assessed changing trends in livestock grazing, wildlife conservation, and sedentarization levels from the 1960s to the present day across three savannas in southern Kenya. Our study identified the drivers of land uses and land subdivision and the implications of land use change on savanna ecology. Over the last half century, there has been a 30% decline in livestock grazing land in southern Kenya due to the expansion of land for agriculture and wildlife conservation. Despite the decline, livestock grazing remains the preferred land use in subdivided and privatized lands. Pastoralist land used for wildlife conservation was perceived to be higher (30%) in southwestern Kenya compared to southeastern Kenya (16%), despite their geographical proximity. These historical insights provide useful lessons for maintaining space for wildlife, diversifying livelihoods, and increasing the resilience of pastoralists in the process of transitioning from traditional subsistence to market economies and the threats of social and ecological dislocation.

Keywords: Amboseli; climate; community perspective; Loita; Mara; sedentarization; savanna

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1. Introduction

Although rangelands cover 45% of the Earth's land surface and have primarily been used for livestock production and wildlife conservation, the relationships between pastoralists, other livelihoods, and wildlife conservation across the rangelands remains complex due to highly variable climates and rapidly changing socioeconomic and political factors [1–3]. Livestock grazing in mobile pastoral areas can be compatible with wildlife conservation [4], however the future of pastoralism is threatened by land subdivision, sedentarization and changing land uses [3,5]. In Kenya, 70% of livestock production and 75% of wildlife areas are located in the rangelands, however pastoral communities in the rangelands remain politically and economically marginalized and have poor access to social services and infrastructure [6,7]. The marginalization of pastoralist communities has been driven by government policies that have favored sedentary farming communities over pastoralist communities in the provision of infrastructure, support services and markets due to the political power of numbers [8]. The viability of pastoral economies across Africa in general is crucial to maintaining the open nature of savanna landscapes

and ecological resilience to droughts—essential for not only sustaining the health of the rangelands [5], but also the coexistence of livestock and wildlife pivotal to emerging mixed use economies [3]. In Kenya, where two-thirds of wildlife are found outside protected areas, understanding the interlinkages between pastoralism, land health, natural capital, and wildlife is crucial to sustaining the future of large migratory populations of herbivores and carnivores in and beyond protected areas [9].

The transition from seasonally mobile livestock husbandry practices to more sedentary lifestyles occurring across eastern Africa, China, India, and the Middle East [5,10–12] has been encouraged by policies to settle, govern, and commercialize nomadic societies [11,13,14]. Pastoralism first emerged in East Africa approximately 4500–4000 years ago, when it was characterized by shifting livelihood patterns [15,16]. Through livestock grazing and fire, pastoral activities shaped savanna ecology for millennia, and determined the structure, composition and nutrient levels of plants, and, consequently, of wildlife [17]. Historical wildlife numbers were also influenced by human activities, such as subsistence hunting and the global ivory trade, linked to the slave trade, which massively depleted elephant numbers across East and Central Africa in the late 19th century [18]. Since the mid-twentieth century, the coexistence between pastoralism and wildlife in East African savannas was uncoupled by the alienation of pastoralists' land for the formation of protected areas, settlements, farming, and commercial ranches by colonial and post-colonial legislation [8,17]. This period, beginning in the 1940s, saw governments and conservation organizations in East Africa evicting pastoralists from the wet areas and relocating them to drier and smaller areas, which limited pastoral mobility and access to late dry season grazing areas [19–21].

In eastern Africa, sedentarization has accelerated the breakdown of subsistence pastoral societies, tolerance of wildlife, and land degradation [22]. Sedentarization in key resource areas [23] creates a three-way conflict between farmers, pastoralists, and wildlife conservationists due to competing land uses [23,24]. Where protected areas are surrounded by community land meant to act as buffer zones for maintaining wildlife dispersion, a growing human population and land use intensification in the buffer zones challenges wildlife conservation [25]. These community lands, however, remain largely under pastoralism [14,20] and enable the continuance of wildlife migrations to the surrounding lands through pooling substantial portions of land owned by private landowners and setting it aside as wildlife conservancies [26].

Despite the long-term impact of pastoralism on the ecology of East African savannas [2,27] and the significant contribution of pastoralism to the economies of developing countries [28,29], the human contribution into savanna dynamics is poorly understood [30]. Most pastoralists are excluded from making decisions on the management of pastoral and wildlife conservation areas [31], despite their extensive knowledge in managing grazing resources under changing climates and their future dependence on the land. Pastoral practices on adaptation to climate change are frequently ignored or transformed to develop narratives suited for scientific audiences [32]. Moreover, studies that compare changes over time in pastoralists' perspectives on land uses, drivers of land uses, and land management approaches at a local scale in East African ecosystems are rare. The future of pastoralism as an economic mode of production and the sustainability of the rangelands depends on drawing on the views and skills of herding societies and devolving governance practices to local communities [31,33]. Using a comparative study to tap into pastoralist knowledge is also central to wildlife conservation, rangeland health, ecosystem services, and planning for land use and development [34].

In this study, we solicited the views from Maasai community elders to understand the drivers of land use changes in southern Kenya from the 1960s to the present day. The region spans a range of rainfall regimes, elevations, habitats, and land uses which are often overlapping, ranging from livestock raising in the dry and sub-arable areas, to agropastoralism and agriculture in the wetter region. Our study aimed to assess the variation in land uses across southern Kenya using three objectives: (1) to quantify changes in land use

types from 1960 to the present using the perceptions of local community elders in three different study areas; (2) to establish the drivers of land use changes and group ranch land subdivision in each area; and (3) to compare community perceptions of land subdivision in relation to land use patterns across the three study areas. The study hypothesizes that: (1) livestock grazing and wildlife conservation land in southern Kenya has reduced over the half-century, whilst agricultural land has increased due to sedentarization and changing socioeconomic factors; and (2) the pattern of land use change in southwestern Kenya will be different from southeastern Kenya due to differences in rainfall, population density and biodiversity.

2. Study Areas

The three areas we focused on were Amboseli, Mara, and the Loita Plains (Figure 1). The Amboseli ecosystem includes the Amboseli National Park (392 km^2) and the surrounding group ranches. The mean annual rainfall in Amboseli is 350 mm yr^{-1} and falls in two seasons: the short rains (November to January) and the long rains (March to May). Vegetation is characterized by sparse bushed grassland that is dominated by *Acacia* and *Commiphora* species [35]. Over the last fifty years, woodland species in the Amboseli basin have declined and halophytic species and wetlands have increased [36].

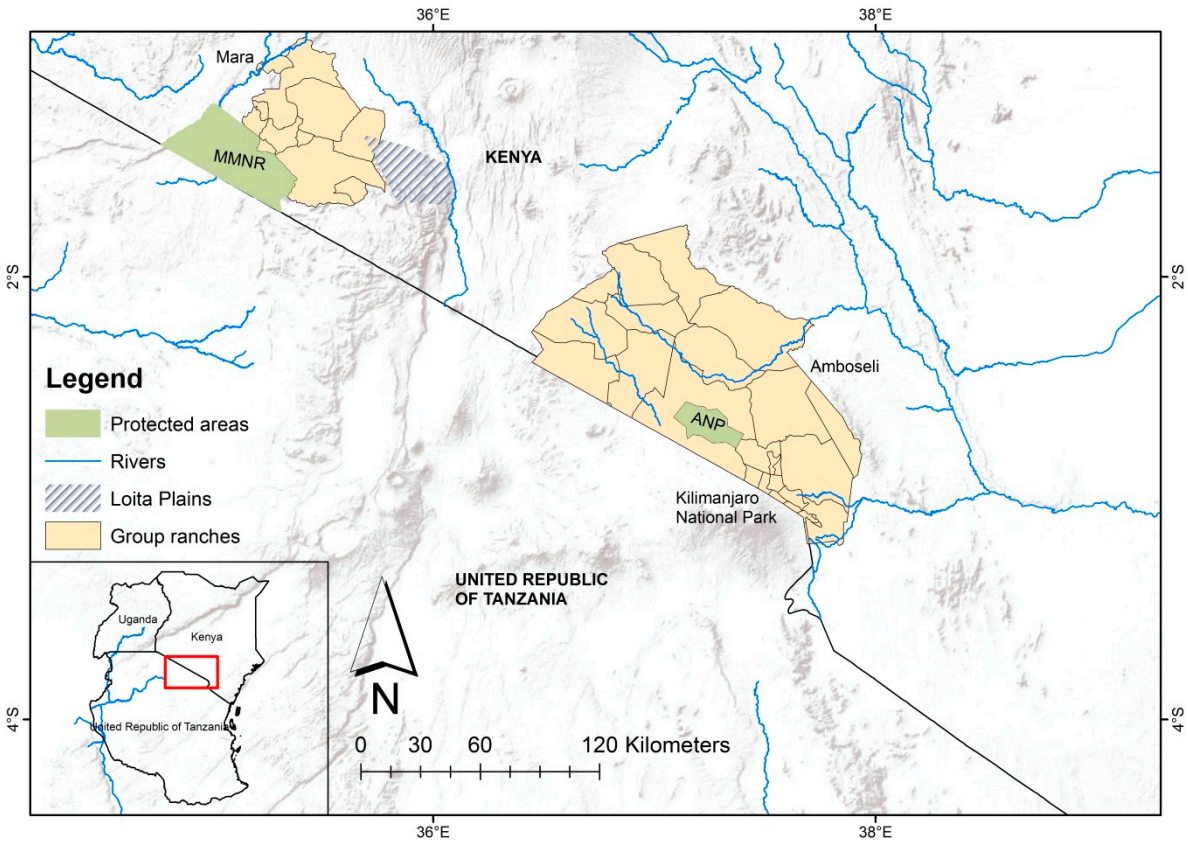

Figure 1. Location of the study areas and the surrounding ecosystems in southern Kenya. Protected areas labelled ANP and MMNR are Amboseli National Park and Maasai Mara National Reserve, respectively. Base Layer Source: Esri.

The Mara ecosystem encompasses the Maasai Mara National Reserve (1510 km^2) and the surrounding pastoral lands which act as wildlife buffer zones between the National Reserve and the highly fertile agricultural lands in northern Narok County [24,25]. Rainfall is bimodal (October–December and March–May), and highly variable with an average of 600 mm yr^{-1} in the eastern area and 1000 mm yr^{-1} in the western area [37]. Mara is characterized by grasslands with scattered woodlands, although over the last 100 years the grassland woodland cover has been quite changeable due to climate and land use change,

tsetse-fly and tick infections, and elephant activities [34,38]. The Maasai Mara National Reserve supports approximately 25% of Kenya's wildlife [39] and is greatly regarded due to the high wildlife density, stunning landscapes and its annual wildebeest migration between the Serengeti and Mara ecosystems [40].

The Loita Plains are approximately 30 km east of the Mara ecosystem (Figure 1), at an elevation of 1800 m, and receive a mean annual rainfall of 400 mm yr^{-1} over two rainfall seasons [24]. The plains are covered by a dwarf shrubland and an *Acacia drepanolobium*/grassland mosaic [41]. The Loita Plains are surrounded by woodlands on the slopes of the Mau ranges at the northern part, an evergreen scrubland to the east, the Siria escarpment to the west, and the Loita Hills to the south [42]. The low-rainfall nutrient-rich Loita Plains provide wet season grazing, and are the main breeding zone for the Kenyan wildebeest population [25].

3. Methods

3.1. Ethics Statement

This study was approved by the National Commission for Science, Technology and Innovation in Kenya under permit number NACOSTI/P/16/3779/9340 and the Ethics Review Committee at the Environment and Geography Department, University of York, U.K. When introducing our research to the participants, we asked them if they were willing to participate in the questionnaire, and we only worked with the participants who responded in the affirmative.

3.2. Data Collection

To understand continuous long-term changes in land uses, drivers of land uses, land tenure and livelihood strategies, insights from community elders were collected in January and February 2016 using 83 questionnaires: 29 in Amboseli, 26 in Mara and 28 in the Loita Plains. The questionnaire targeted community elders, because capturing the long-term (approximately five to six decades) perspectives of land use change was of interest; it was desirable to explore the living memory of community elders who had lived in the study areas for at least five decades and had witnessed the environmental change during that time. The questionnaire was collectively developed by all the authors in this study and tested on a target group of elders after it was designed. The elders interviewed were all those available and willing to partake in the study, and included 69 men and 14 women, aged between 50 and 90 years, with either primary education or no formal education, and livelihoods which included farming, pastoralism, agropastoralism and pastoralism combined with wildlife conservation. The questionnaire was written in English and communicated to the elders by research assistants in Maa as needed. Each questionnaire took an average of one-and-a-half to two hours to conduct.

The research assistants were native Maa speakers who lived in the study areas and had a tertiary level of education. Before conducting the interviews, the research assistants from each study area received training on the objectives and the content of the questionnaire, and the modalities of executing the questionnaire. Following the training, the questionnaire was tested by conducting it with a few community elders.

The elders had lived in the study areas for at least five decades and had land tenures that varied between communal land and private land. Communal land still prevailed in group ranches, yet to be subdivided and held in common title by all registered members. Private land tenures replaced communal ownership in subdivided group ranches where members held individual land parcels and title deeds. Due to variations in land uses, land tenure types, permanent water resources and wildlife conservation initiatives in the study areas, the elders were selected to represent different community group ranches which had varying land uses and were either near (1.7–5 kilometers (km)) or far (>5 km) from protected areas (Table 1). Elders were selected based on the proximity of their land to the protected areas in Amboseli and Mara, but not in the Loita Plains because there were no national parks/reserves in the area. Only willing resident landowners were

interviewed, and their selection depended on the research assistants' knowledge of where various elders lived and owned land. During the interviews, the spatial boundary for the views collected from each elder was based on the boundary of the group ranch. To ensure common understanding of the area of interest and the land uses, the researchers and the elders used printed maps showing the administrative boundaries of southern Kenya, roads, rivers, protected areas, forests, and water bodies to categorize the current local land uses into five broad categories. Livestock grazing land was defined as land used for pastoralism alone; agricultural land was defined by areas used for small-holder rain-fed and irrigated agriculture; conservation land was defined by pastoral land used for wildlife conservation, including subdivided and privatized lands used for wildlife conservation; and settlements and built-up areas defined as areas used for homesteads and social facilities such as churches, health centers, and schools. The elders and the researchers identified which areas on the reference map were currently used for livestock grazing, agriculture, livestock grazing with conservation, settlements, and were built-up.

Table 1. Sampled locations in the study areas and livelihoods supported.

Study Area	Number of Interviewees	Sampled Locations	Main Livelihoods
Amboseli	29 (four females and twenty-five males)	Olgulului/Ololorashi	Pastoralism
		Kuku	Pastoralism
		Namelok	Pastoralism, agropastoralism, agriculture
		Kimana	Pastoralism, agropastoralism, agriculture
Mara	26 (two females and twenty-four males)	Enonkishu	Community conservancy, limited pastoralism
		Mara North	Community conservancy, limited pastoralism
		Maji Moto	Pastoralism
		Naboisho	Community conservancy, limited pastoralism
		Talek	Pastoralism, conservation
		Motorogi	Community conservancy, limited pastoralism
Loita Plains	28 (three females and twenty-five males)	Narosura	Pastoralism, agropastoralism, agriculture
		Elangata	Pastoralism
		Kanukha	Agropastoralism, agriculture
		Osupuko	Pastoralism, agropastoralism

To capture the changing perceptions of land use, the respondents were asked to state how the percentage coverage of each land use in their area had changed over six decades. Decades were selected to represent the temporal unit of change because most elders associated major events that impacted their environment and livelihoods in terms of decades and not annually. In addition, to help the elders recall events that had happened in previous decades, major events, such as drought years or periods of national elections in Kenya, which are easily remembered, were discussed during the interviews. Using the same printed map which the elders had been provided, they were asked to identify and draw on which areas were used for different land uses from the 1960s to the present day. For each decade, the elders drew the distribution of the land uses on a map and identified the percentage coverage of each land use in each decade. Drawing on the map was mainly done to help the elders estimate the percentage coverage of different land uses. The information collected provided land use change insights spanning from the 1960s (when Kenya gained its independence from the British government) to the present. The allocation of percentage coverage for each land use across the three study areas depended on the elders' views. Most respondents could recall land use changes within the time frame of this study; although not to the same degree, therefore the only land uses perceptions that were recorded were those that were remembered by the elders. Land use change that the elders were uncertain about, such as the beginning of subdivision of their group ranch or policies that drove their land use options were not recorded. In the three study areas, there were no underlying reasons that could influence the allocation of percentage cover to different

land uses by the elders. Thus, we believe the insights we obtained from the elders were based purely on their views of land use change in their area.

Data analysis was performed in R [43], and the level of significance was set to $p < 0.05$ throughout. Analyses of variance (ANOVA) tests and subsequent Tukey post-hoc tests were used to assess differences in the percentage cover of land uses in different decades, study areas and land tenure types. To assess the relationship between land uses and land tenure, we used a Chi-squared test of association (χ^2). Published remote sensing results do not cover the same areas as our study areas, therefore it was difficult to compare the views of temporal land use change from the elders with published remote sensing results. Thus, we include the standard error of the mean to the percentage land use changes estimated by the elders as an estimate of uncertainty. In the discussion, we evaluate actual land use change in southern Kenya from the published literature and compare it with the elders' perspectives.

4. Results

4.1. Changes in Livestock Grazing, Agriculture, and Wildlife Conservation over Time

When combining all three areas the elders' responses showed the amount of land used for livestock grazing declining from 80% (±2.0) in the 1960s to 51% (±2.4) in 2016 (Table 2). A significant difference was found in the amount of land perceived to be used for livestock grazing across the decades ($F_{5,480} = 33.68$, $p < 0.001$) and the study areas ($F_{2,483} = 28.04$, $p < 0.001$). Subsequent post-hoc tests showed no difference ($p > 0.05$) in the amount of land used for livestock grazing between the 1960s, 1970s and 1980s, and between the 1980s and 1990s (Table 2). In contrast, the amount of land used for livestock grazing in the 2000s and 2010s was significantly different from the earlier decades. Among the study areas, the amount of land used for livestock grazing in Amboseli (79% ± 1.4) was different ($p < 0.05$) from Mara (65.3%± 2.0) and the Loita Plains (65.4% ± 1.3), which showed no significant difference ($p > 0.05$). A two-way ANOVA showed no significant interaction between the effect of time in decades (1960s to 2010s) and study areas (Amboseli, Mara and the Loita Plains) on the amount of land used for livestock grazing ($F_{10,468} = 0.74$, $p = 0.69$).

Land perceived to be used for agriculture was significantly different ($F_{5,465} = 32.25$, $p < 0.001$) across the decades. Elders perceived the 1960s to have the lowest (0.5% ± 0.4) coverage of agricultural land and the 2010s to have the highest (21% ± 2.5) coverage. The differences in size of agricultural land among the decades were classified into three different groups by a post-hoc test: (1) 1960s–1990s; (2) 1990s–2000s; and (3) 2010–2016 (Table 2). Amongst the study areas, land used for agriculture was significantly different ($F_{2,468} = 22.55$, $p < 0.001$), with the Loita Plains (10.8% ± 1.4) and Amboseli (9% ± 1.2) perceived to have higher proportions of agricultural land than Mara (1.0% ± 0.4). To assess whether the amount of agricultural land was affected by the interaction between the effects of time (decades) and the study area, a two-way ANOVA established a significant interaction ($F_{10,454} = 6.25$, $p < 0.001$).

The amount of land under communal and private ownership used for wildlife conservation activities was significantly different among the decades ($F_{5,217} = 2.25$, $p < 0.001$) and the study areas ($F_{2,220} = 10.34$, $p < 0.001$). Elders perceived that land used for wildlife conservation had increased from 3% (±1.4) in the 1960s to 19% (±2.7) in 2016 for all three study areas. Across the decades, the differences in land used for wildlife conservation was separated into three groups: 1960s–1990s; 1980s–2000s; and 2010–2016. Across the study areas, Amboseli was perceived to have an increased percentage of land allocated for wildlife conservation, from 1% (±0.7) in the 1960s to 16% (±3.1) in 2016. In Mara, land allocated for wildlife increased from 5% (±3.6) in the 1960s to 31% (±4.1) in 2016. In the Loita Plains, the land allocated for wildlife was perceived to have declined from 4% (±2.5) to 1% (±0.4) over the same period (Table 2). The interaction between the effects of time (decades) and the study area on land used for wildlife conservation was not significant.

Table 2. Percentage of land (and standard error) used for livestock grazing, agriculture, and private conservation areas/conservancies from 1960s to 2016, as estimated by community leaders in Amboseli, Mara and the Loita Plains. The level of significance comparing land use types across decades in each study area is also included. An asterisk (*) shows where there are significant differences in the land use among the decades, while the abbreviation NS shows where the difference is not significant.

	Year Survey Was Conducted—2016								
	Livestock Grazing (Percentage Cover and Standard Error)								
	1960s	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**	**Significance Level among Decades (*p*)**	**Number of Observations**	**Significance Level between Study Areas (*p*)**
Amboseli	91 (1.25)	90 (1.4)	87 (1.4)	81 (2.2)	73 (2.7)	55 (4.3)	<0.001 *	171	
Mara	72 (4.8)	74 (4.0)	69 (4.7)	68 (4.2)	59 (4.6)	50 (5.2)	0.002 *	150	<0.001 *
Loita Plains	77 (2.5)	76 (2.5)	72 (2.0)	65 (2.0)	57 (2.4)	47 (2.7)	<0.001 *	165	
	Agriculture (Percentage Cover and Standard Error)								
	1960s	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**			
Amboseli	0.3 (0.2)	1 (0.7)	3 (1.1)	6 (1.7)	13 (2.4)	29 (4.0)	<0.001 *	166	
Mara	0 (0)	0 (0)	0 (0)	1 (0.6)	1 (0.4)	3 (2.2)	0.151 NS	143	<0.001 *
Loita Plains	1.3 (1.2)	2 (1.5)	5 (1.8)	9 (2.4)	17 (3.3)	30 (4.4)	<0.001 *	163	
	Private Conservation Areas/Conservancies (Percentage Cover and Standard Error)								
	1960s	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**			
Amboseli	1 (0.7)	2 (0.9)	3 (1.5)	5 (1.4)	8 (1.7)	16 (2.7)	<0.001 *	95	
Mara	5 (3.6)	5 (3.6)	8 (3.7)	10 (3.9)	20 (4.3)	31 (4.1)	<0.001 *	102	<0.001 *
Loita Plains	4 (2.5)	3 (1.8)	2 (1.1)	1.2 (0.8)	1 (0.7)	1 (0.4)	0.72 NS	90	

4.2. Drivers of Land Use Change

Overall, the main drivers of land use change in all the three study areas, as reported by the respondents, were increased rainfall variability (23%), increases in education levels (15%), the need for financial stability (13%), land subdivision (12%), socioeconomic development (10%), and population growth (8%). The number of mentions for various land use change drivers varied across the study areas, with increase in rainfall variability perceived as the leading cause of change from pastoralism to other land uses by most (19%) of the respondents in Amboseli and the Loita Plains (24%), while in Mara, land subdivision (21%) and the increase in education levels (15%) were the leading land use change causes. Monetary benefit (or lack of monetary benefit) from conservation was mentioned as a driver of land use for wildlife conservation in Amboseli and Mara, but not in the Loita Plains (Table 3). Rainfall variability was associated with reduced livestock production, food insecurity, loss of livestock, and livelihood diversification to agriculture. Land subdivision was associated with the loss of livestock grazing areas and reduced income from pastoralism. Influence from non-pastoral immigrant communities was viewed as important because the foreign communities were seen to have stable agriculture livelihoods that had higher income compared to pastoralism.

Table 3. Drivers of land use change as perceived by pastoralists from Amboseli, Mara and the Loita Plains in southern Kenyan savannas.

Study Area	Drivers of Land Use Change	Mentions by Elders (%)
Amboseli	High rainfall variability	19%
	Population growth	19%
	Socioeconomic development	18%
	High education level (up to tertiary level)	11%
	Land subdivision	11%
	Animal diseases	7%
	Conservation has more monetary benefit	5%
	Agriculture expansion	4%
	Little monetary benefit from conservation	3%
	To secure financially stability	2%
	Land use change influence from non-pastoral immigrant communities	1%
Mara	Land subdivision	21%
	High education level (up to tertiary level)	15%
	To secure a financially stable land use	15%
	Conservation has more monetary benefits	12%
	Population growth	12%
	High rainfall variability	11%
	Socioeconomic development	10%
	Animal diseases	2%
	Little monetary benefit from conservation	1%
Loita Plains	High rainfall variability	24%
	High education level (up to tertiary level)	18%
	Land subdivision	16%
	Population growth	15%
	To secure a financially stable land use	13%
	Socioeconomic development	10%
	Increase in agriculture	3%
	Land use change influence from non-pastoral immigrant communities	1%

4.3. Drivers of Land Subdivision

Land subdivision as a factor of land use change was mentioned by 11%, 21% and 16% of pastoralists in Amboseli, Mara and the Loita Plains, respectively. The reasons for land subdivision varied with the desire to have personal ownership of land being common (Figure 2). Having individual land parcels was desired because the provision of

individual title deeds for the land parcels could be used as security for bank loans. People also associated private land ownership with independence in making investment decisions regarding their land and the freedom to sell their land in case they need money. Fear of losing land was mentioned by 18% of respondents in Mara compared to 9% in Amboseli and 10% in the Loita Plains. The fear of losing land was associated with corruption of group ranch leaders, unequal distribution of group ranch resources to all members, and the lack of clear policies regarding the management of group ranches. Agricultural expansion was mentioned only in Amboseli. The perception that pastoral communities from sub-divided group ranches were better off financially than non-sub-divided group ranches was mentioned by 19% of respondents in the Loita Plains, 6% in Mara, and 2% in Amboseli. Increasing human population growth as a key driver of land subdivision was mentioned by 17% of the respondents in the Loita Plains, 10% in Mara, and 9% in Amboseli (Figure 2). Distribution of benefits from wildlife conservation to the community was perceived to lower the rate of land subdivision while lack of benefits from wildlife conservation was perceived to enhance wildlife conservation.

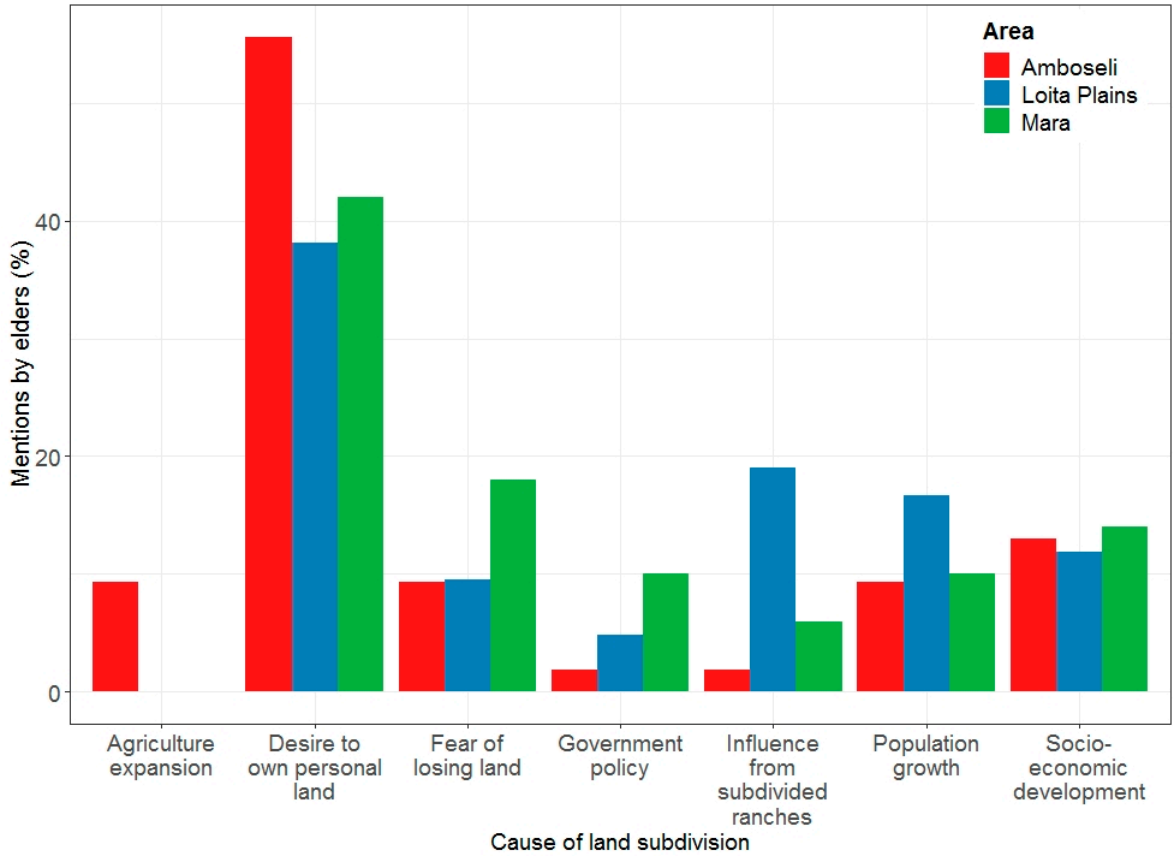

Figure 2. Causes of land subdivision, in percentage, as mentioned by community elders in Amboseli, the Loita Plains, and Mara in southern Kenyan savannas.

4.4. Changes in Land Use Types in Relation to Land Tenure Type

Across the three study areas and across all years, land under communal ownership was perceived to be useful mainly for extensive livestock grazing, while land under private ownership was perceived to be useful for both agriculture and livestock grazing. Land under communal and private land tenure was used for settlements and social facilities, where the latter had a designated area for development (Figure 3). In Amboseli, livestock grazing and agriculture were perceived to be dominant on privatized land. In Mara, elders noted the absence of agriculture and low levels of wildlife conservation on communal lands,

but privatized land had low levels of agriculture and high levels of wildlife conservation. In the Loita Plains, respondents noted high agriculture and low wildlife conservation activities in both communal and privatized land. The relationship between land use type and land tenure was significant (χ^2 = 18.67, df = 4, n = 362, $p < 0.001$; Table S1) as well as that between land use types and study areas (χ^2 = 27.43, df = 8, n = 295, $p < 0.001$; Table S2). Assessment of the frequency distribution tables showed communal land to be dominated by livestock grazing (38%), followed by social facilities (22%) and agriculture (19%). On the other hand, private land tenure was also dominated by livestock grazing (32%), agriculture (25%) and settlements (22%). Across the study areas, the dominant land uses were livestock grazing (35%), agriculture (25%) and settlements (16%). In Mara, livestock grazing (35%), social facilities (23%) and settlements (21%) land uses were dominant, whereas in the Loita Plains, livestock grazing (36%), agriculture (31%) and settlements (15%) were dominant.

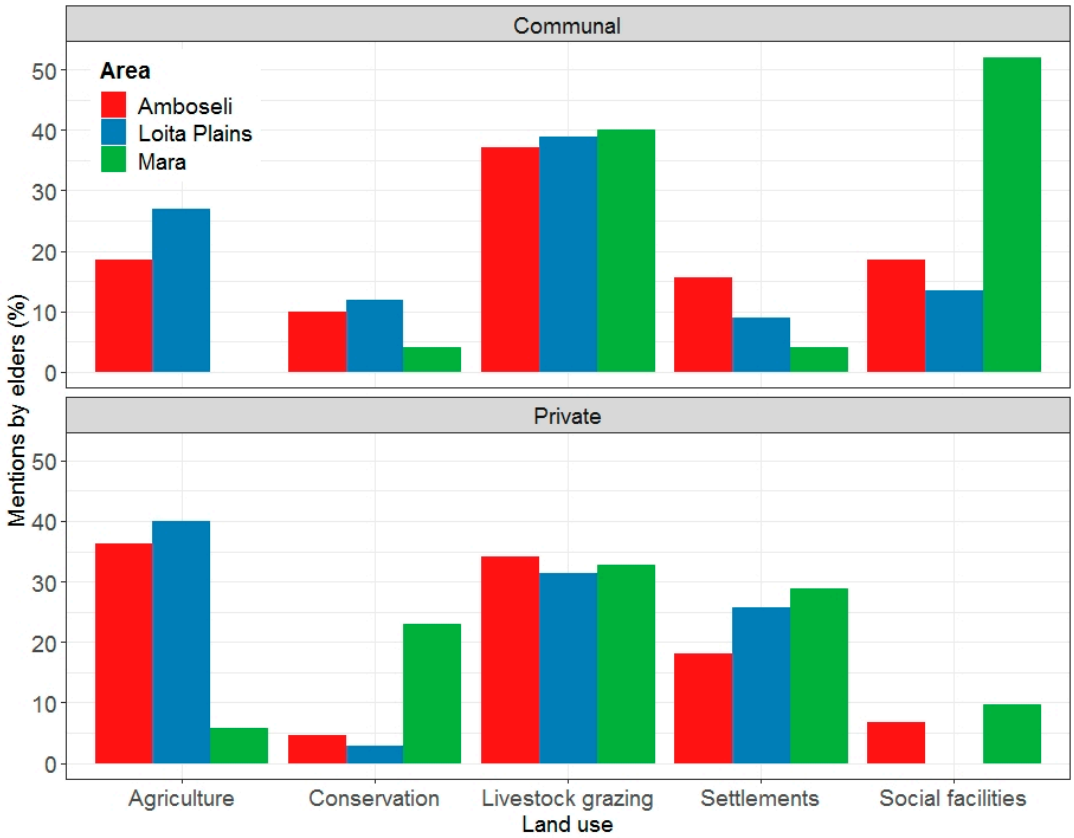

Figure 3. Land uses in communal and private across land tenure types as mentioned by community elders in Amboseli, the Loita Plains, and Mara ecosystems in southern Kenya.

4.5. Allocation of Private Land to Livestock Grazing and Agricultural Land Uses

There was a significant difference ($F_{2,237}$ = 75.67, $p < 0.001$) in the amount of land under private ownership that was allocated by pastoralists to livestock grazing (mean ± standard error (SE); 61.38% ± 3.6), subsistence agriculture (21.5% ± 3.4), and subsistence agriculture combined with commercial agriculture (20.04% ± 2.0). Of the three land uses, livestock grazing on privatized land was perceived to be more widespread in Mara than in Amboseli and the Loita Plains, where both subsistence and commercial agriculture were higher (Figure 4).

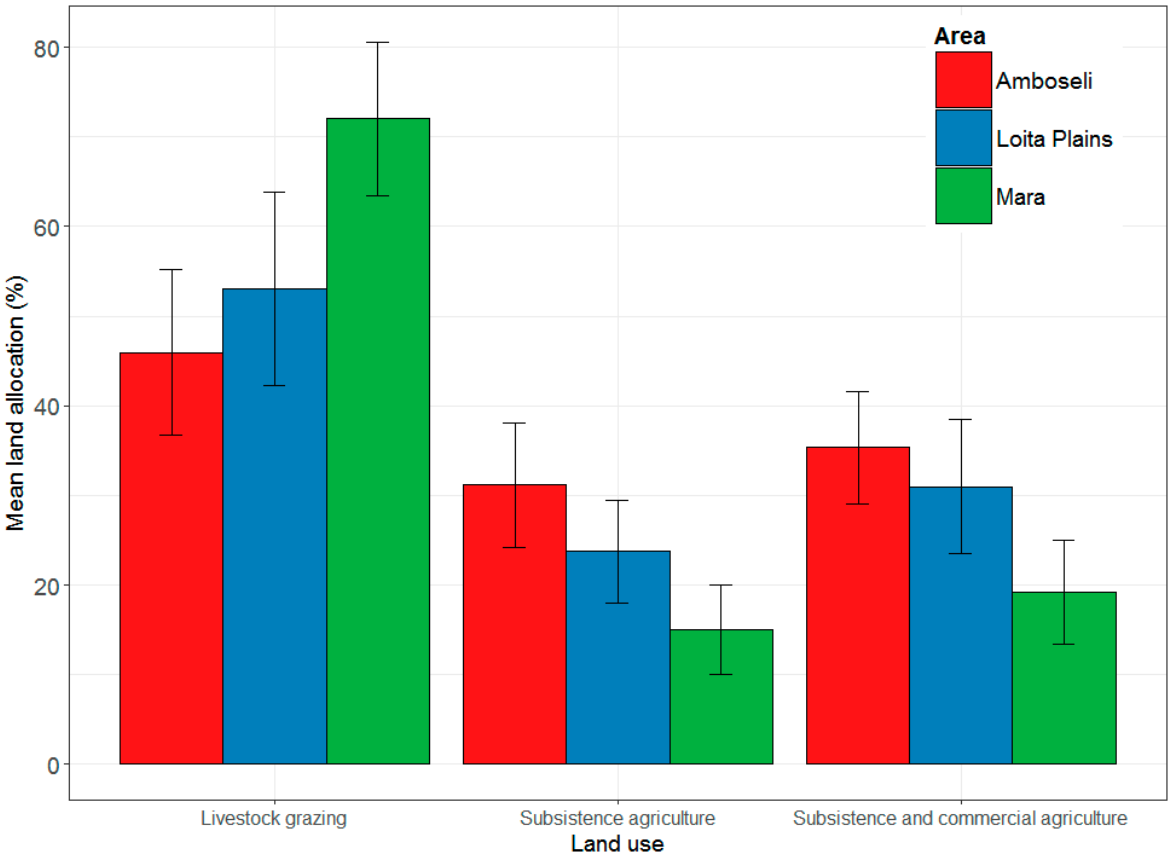

Figure 4. Proportion of livestock grazing and agricultural land uses on private land in Amboseli, the Loita Plains, and Mara. The error bars represent the standard error of the mean. Maize and beans are mainly grown for subsistence use, while fruits and vegetables such as tomatoes, cucumbers, onions, and green peppers are grown for sale.

5. Discussion

The interaction between pastoralism, wildlife conservation and agriculture in East African savannas is complex, and varies geographically and through time [30]. Here, we discuss these interactions.

5.1. Pastoralism, Wildlife Conservation and Agriculture

Across Kenyan rangelands, livestock numbers were documented to increase from the 1970s to 2016 [44]; however, elders in southern Kenya perceived that the amount of land used for livestock grazing had declined from the 1960s to present. Since the 1970s, cattle numbers have declined, and sheep and goat numbers have increased in southern Kenya rangelands [27]. A number of reasons, ranging from climate variability leading to livelihood diversification from livestock herding [14,20], land alienation for conservation [28,45], human population growth [37,46], land privatization and sedentarization [47], agriculture expansion [12,33] and limited access to markets for livestock products [48] could explain why pastoralists perceived a reduction in grazing land over the decades. These factors have constrained livestock production and may have led to land use change from livestock grazing. Competition between livestock grazing, agriculture, wildlife conservation and national development not only reduces livestock grazing land but also hinders livestock access to water resources and salt licks, increases grazing pressure, reduces the quality and quantity of pastures, and exposes livestock to diseases. Reductions in livestock herds following the 2006 and 2009 droughts led to the loss of 90% of cattle and 70% of sheep and goats in southern Kenya [49], and consequently drove land use transition from livestock grazing to other land-based livelihoods. The elders associated droughts in the early 1960s,

1984, and 2009 with intensifying the transitions from pastoralism to agropastoralism and smallholder farming that occurred after the droughts. In Amboseli, the wetter areas used by pastoralists for late dry season grazing have been converted to farming [27], while permanent swamps used by pastoralists were set aside for wildlife conservation, and thus livestock grazing was banned [50]. Consequently, livestock grazing is now prevalent in very dry areas such as Kuku ranch, whereas wetter areas with better road access such as Kimana group ranch have high agropastoralism and agriculture levels. In Mara, livestock estimates have followed rainfall and vegetation patterns, but generally there was no significant increase or decrease in livestock numbers from the late 1970s to the 1990s, although per capita livestock numbers have declined and consequently affected livestock income for most households [37]. Areas close to protected areas in Mara were predominantly used for livestock grazing which was intertwined with wildlife conservation. In the Loita Plains, livestock grazing was prevalent in dry areas, showing that livestock grazing has been pushed to marginal areas or areas with wildlife. In less marginal areas, change from cattle-dominated herds to goat and sheep dominated herds has enabled livestock grazing to continue in the face of increased frequencies of droughts, reduced grazing land, and changing socioeconomic factors.

The perception that land used for wildlife conservation had increased over time may be associated with the formation of wildlife conservancies from the 1970s to the present [26]. The greater portion of land perceived by the elders to be formally allocated to wildlife conservation and tourism in Mara compared to Amboseli and the Loita Plains is primarily due to its far-higher wildlife densities and tourism revenues [39]. The wildlife conservancies were established primarily to attract tourism and generate a cash income through land leases. The conservancies discourage the fragmentation of wildlife habitats and increase the prospects for compatible and sustainable wildlife and livestock uses at the landscape level. In Mara, formal conservancies grew from two in 2006, covering a total area of 14,576 ha, to 14 in 2017, covering 147,000 ha, supporting 6000 landowners, and employing 1500 people and 45 tourism partners [51]. In Amboseli wildlife sanctuaries in the process of registering as conservancies grew from one in 1997, to 17 in 2016 under the Amboseli Ecosystem Trust (AET) covering 79,562 ha and employing 476 people as rangers [26]. In contrast, elders at the Loita Plains perceived that land used for wildlife conservation had declined from the 1960s to the present, possibly because tourism enterprises have shrunk sharply over the same period. The Loita Plains also did not have any formal conservancies by 2017, perhaps due to land conversion to agriculture, resulting in a 70% to 80% decline in wildlife numbers [25]. Conservancies have been associated with promoting tolerance of wildlife by distributing benefits from wildlife to pastoral households [52], reducing poaching [2], opening up wildlife migration corridors [53], and providing an additional source of income to pastoral households during droughts when livestock income declines [54]. Regular income from conservancies to landowners was perceived to be more reliable than livestock grazing income, which is easily affected by changing rainfall patterns and other socioeconomic factors. The formation of conservancies has, however, been contentious. Moving pastoralists from their land to create space for wildlife conservancies is controversial, while restricting or denying pastoralists access to previous livestock grazing areas, which are set aside for wildlife, has increased human–wildlife conflict in Mara [55]. Wildlife in Kenya has also declined by 50–80% since the mid-1970s [54], despite investment in conservation initiatives and the creation of environmental conservation awareness by governmental and nongovernmental bodies suggesting the need for innovative approaches that will stop loss of biodiversity.

In agreement with the elders' perceptions that agricultural land had expanded in southern Kenya, various studies have documented agricultural expansion over the years [3,12,14]. In wet years, pastoralists turn to agriculture as a means of supplementing their income from livestock grazing [14]. Increases in rain-fed agriculture towards the end of the twentieth century may have been a result of the 1997/1998 El Niño rains. In Amboseli, both highland rain-fed agriculture and irrigated agriculture expanded from the 1970s [56]. By the late

1980s, most fertile areas in Amboseli had already been settled, with most Maasai pastoralists' actively practicing agriculture on their own farms from the 1980s and 1990s [27]. Amboseli elders identified the 2000s as a decade of high agriculture expansion, probably because during this decade agricultural expansion in Amboseli was driven by economic growth and improved market access in Kenya and overseas [23]. Presently, agriculture continues to be enhanced by local pastoralists who rent out large portions of their land to non-pastoral farming communities who mainly produce horticultural crops that are sold in larger towns in Kenya. Natural vegetation from some areas in Amboseli, such as in Kimana, have also been cleared for maize and legume production. Irrigated agriculture in Amboseli is driven by the many large swamps which have been tapped for irrigation and have attracted a large immigrant population of farmers as well as local Maasai. Income from irrigated agriculture is used to supplement and offset the shortfall in the pastoral economy. However, with swamp basins, from where most irrigation in Amboseli is procured, being predominantly saline [12] and highly susceptible to erosion [45]; irrigation agriculture is not sustainable. Furthermore, irrigated agriculture in the swamps reduces water access to people, livestock, and wildlife, and is a cause of human–wildlife conflict.

From remote sensing analysis, mechanized agriculture in areas surrounding the Maasai Mara National Reserve expanded by 42,725 ha between 1975 and 1995 [57]. A loss of 374,400 ha of woodlands, savannas, and grasslands between 1973 and 2000 has been associated with an expansion of 167,800 ha of agriculture, timber harvesting, and charcoal burning in the Mara Basin [58]. Smallholder agriculture in Mara expanded in the wetter subdivided areas and the wetlands, including the Mara River Basin, from 1995–2003 [37] but has since slowed probably because of the growth of local conservation initiatives from the 2000s. In the northern Loita Plains, lower wildlife populations, higher farming potential and better access to roads and markets compared to Mara has led pastoral families to lease their lands for large scale wheat farming [25,37]. The elders identified the late 1960s and early 1970s as periods when natural vegetation in the Loita Plains was removed to make room for wheat production. Expansion of large-scale agriculture in Mara and the Loita Plains has been driven by land suitability, accessibility to markets, and lower production costs, while the expansion of smallholder agriculture is driven by demographic and socioeconomic changes, land subdivision, and pro-sedentarization government policies [25]. Elders perceived agriculture expansion to be lower in Mara compared to the Loita Plains, because the areas we sampled in Mara were close to the Maasai Mara National Reserve and tend to have very low agriculture levels. Additionally, as a result of failed agricultural harvests every year in Mara, subsistence rain-fed agriculture tends to be restricted to poorer households who have no other livelihood opportunities [14]. By contrast, smallholder agriculture has been documented to expand on the northern Loita Plains since the 1970s [37]. Smallholder agriculture is also common along rivers in the Loita Plains, and is sometimes practiced together with dairy farming, especially among landowners whose land is close to roads and markets.

5.2. Drivers of Land Use Change and Land Subdivision

Rainfall variability and the differential economic potential of pastoralism, agriculture, and wildlife tourism are the main drivers of land uses in Amboseli, Mara and the Loita Plains, and largely explain the changes over the last few decades. Pastoralists in the wetter areas of all three locations have transitioned from pastoralism to agriculture, with the decline of subsistence herding and entry into the market economy, national education system, and increasing reliance of social services [25,27,37]. Rainfall variability was only mentioned as a key determinant of land use transformation by elders in Amboseli and the Loita Plains, probably because the two savannas are dry and lie on the leeward sides of Mt. Kilimanjaro and Mau uplands, respectively. Mara, on the other hand, is a wetter savanna, and elders did not associate rainfall variability with land use change. Rather, land subdivision and socioeconomic factors were perceived to be the most important factors driving land use transition in Mara, suggesting that both environmental and socioeconomic differences

between southern Kenyan ecosystems determine key land use change drivers. Maasai pastoralists do not view the impact of climate change on their livelihoods independently of other socioeconomic changes [59]. For instance, agricultural expansion has been associated with the growing human population. In Amboseli, the human population around the national park has tripled since 2000, rain-fed agriculture has increased 3.5-fold, and irrigated agriculture has increased 18-fold [60]. Some elders in Amboseli mentioned agriculture expansion and the influence from immigrant farming communities as factors that drove their land use change decisions. In Amboseli, irrigated agriculture along swamp edges is seen as a favorable land use to adapt to, because of the availability of water from swamps and pastoralists willing to lease their land to immigrant agricultural communities [45]. Additionally, agriculture is perceived to be beneficial because it provides subsistence foods and higher individual returns compared to wildlife [45,60]. In Mara, although the demand for leasing land for agriculture is still high, agriculture is declining in some areas partly because of local conservation initiatives [14]. Generally, agriculture expansion in Kenyan rangelands has also been promoted by pro-sedentarization government policies that promote food security agendas by providing the infrastructure and markets for agricultural products [8]. Similar patterns of agricultural expansion in rangelands promoted by government policies have occurred in Ethiopia [61], Brazil [62] and Sudan [63], and are forecasted to increase globally in the future as most countries intensify rangeland use to meet growing food demands and agricultural exports.

The leading causes of land subdivision identified by the elders within our three study areas (in order of impact) were: the need for individual land ownership rights, population growth, socioeconomic development, influence from subdivided group ranches and government policy. Policies that supported group ranch subdivision were a potential tipping point, because they commenced a positive feedback cycle resulting in further subdivision. That is to say that the failure of group ranches to manage livestock grazing, to provide security in land rights, and to provide better economic options for pastoralists amidst changing climates, rising human population and national development further enhanced the desire by pastoralists to subdivide the group ranches [25,54]. Agricultural expansion and the lack of benefit from conservation were perceived to cause land subdivision, probably because when land is subdivided, pastoralists, particularly those in wetter areas, turn to agriculture [37]. This is highlighted by the responses from elders in Amboseli and the Loita Plains, who perceived agriculture levels to be higher in private lands near bodies of water. In Mara, subdivided and private lands were perceived to have higher wildlife conservation levels compared to Amboseli and Mara, because individual landowners merged their land parcels and rented them for wildlife conservation. Wildlife-based income, however, is low, and is affected by external forces such as the terrorism attacks in Kenya in 1998, the post-election violence in 2007–2008 [14], and the coronavirus disease 2019 (COVID-19) pandemic in 2020. Interestingly, livestock grazing across the three areas was perceived to be practiced at almost similar levels in both communal and private lands. In addition, in all the three areas, the area allocated for livestock grazing on subdivided and privatized lands was perceived to be higher than that allocated for subsistence or commercial farming. This implies that Maasai in the rangelands continue to practice pastoralism despite its challenges, because it is equated with the pastoral identity and standing in society [20].

5.3. Implications of Sedentarization on Livestock Grazing and Wildlife Conservation

Although the adaptation of pastoralist strategies to climate and environmental stressors have been widely studied in the Andes [64], sub-Saharan Africa [2], Australia [65], and Asia [66], the interactions between pastoralism, the environment, socioeconomic and land tenure changes are controversial [67]. The number of pastoral households in southern Kenya that can survive on pastoralism alone continues to decline with growing population, land transformations, land subdivision and sedentarization. Pastoral sedentarization in southern Kenya has adversely impacted rangeland productivity, diversity, and resilience [5]. The environment trends in southern Kenya reflect similar changes in other pastoral range-

lands globally. In Gökdepe, Turkmenistan, for example, a loss of primary productivity was observed in extensive settlements [68], whereas in China, two decades of forced settlements by the government created short-term prosperity at the expense of rangeland productivity and resilience to droughts [69]. In the Great Plains of North America, extensive crop irrigation has replaced pastoral lands, causing a decline in forage quality [66].

Following environmental dislocations facing pastoralists, the reintegration of livestock mobility and wildlife conservation in the rangelands has been suggested as a solution for diversifying livelihoods and restoring rangeland health [70]. To community elders in all the three study areas, livestock grazing was the preferred land use on both community land and privatized land, suggesting the need for sustainable solutions to maintain livestock grazing in southern Kenyan rangelands. Communities reliant on land-based livelihoods manage land resources better than non-indigenous communities, pointing to the need to maintain and develop traditional livelihoods [21,71]. A pastoralist-centered approach that upholds the environmental integrity of the rangelands using local knowledge and informal governance has been proposed as a potential solution for maintaining the coexistence between livestock and wildlife [3]. To that end, government policies and legislation in a number of African countries now recognize the importance of mobile pastoralism as an efficient and productive use of the rangelands [72]. The declining traditional values of wildlife and wildlife-related costs incurred by pastoralists point to the need to ensure that economic cost–benefit analysis does not foreclose the ability and willingness for pastoralists to coexist with wildlife [31]. In cases such as in Mara, where wildlife populations are considered to be a national asset but impose a high local cost, the opportunity costs should be offset through compensation or other funding mechanisms [37].

6. Conclusions

Our study documents views from pastoral communities' elders and shows how these can be used to understand land use transformations and their drivers in East African savannas. We compared perspectives from community elders on land uses and drivers of land use change in three study areas in southern Kenya over six decades. Across southern Kenya, the major changes have been the decline in livestock production, land tenure changes, sedentarization, and the expansion of agriculture. Decline in livestock grazing land was mainly due to the expansion of agricultural land and wildlife conservation land. However, livestock grazing remains the dominant land use under communal and private land tenures across southern Kenya, suggesting the need for sustainable approaches that prevent the fragmentation of grazing land and that integrate livestock grazing and wildlife conservation. Higher agricultural expansion in Amboseli and the Loita Plains was linked to the availability of water for irrigation, improved market access, and higher individual income from farming compared to wildlife. The key land use change negatively affecting savannas is agricultural encroachment, particularly in sub-arable areas; therefore, science-based solutions should explore how to sustain their productivity and resilience. This can be addressed by answering important questions such as: how can continued mobility and the maintenance of wet and dry season grazing reserves be promoted in the savannas in the face of the rising human population and socioeconomic development? The case of Mara, where the increase in wildlife conservation land was attributed to higher wildlife numbers and local conservation initiatives, suggests that wildlife-related benefits can encourage the coexistence between livestock and wildlife. Where a location is important to wildlife conservation, and the costs of wildlife conservation to landowners are high, the opportunity costs to landowners can be offset by leases and payments for ecological services. In addition, stratifying wildlife areas relative to their importance and focusing on those with the greatest potential and least alternative demand would address rangeland sustainability issues. Findings from our study emphasize the global importance of pastoralism as a productive form of land use, however also to the need to incorporate new economic opportunities, including farming and wildlife enterprises, and collective governance arrangements, into pastoral societies.

Supplementary Materials: The following information is available online at https://www.mdpi.com/2073-445X/10/1/46/s1: Appendix S1.

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