Review Paper

Maasai Livelihoods, Terrestrial Wild Megafauna, and Ecosystem Services Synergies and Tradeoffs in the Semiarids of Kenya: Scenarios and Implications of Climate Change in DPSIR Model

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Abstract

Impaired sustainability of livelihoods, threatened survival of wildlife, and altered integrity of environments and ecosystems are the persistent critical challenges plaguing the Maasai-inhabited savanna rangelands of Kenya. This study engages the *Drivers-Pressures-States-Impacts-Responses* (DPSIR) model to integratively and simultaneously examine those challenges. Causal social-biophysical components and links driving shifts in the interactions of Maasai's livelihood strategies/diversifications and terrestrial wild megafaunas via ecological services (ecoservices) are explored; plausible scenarios under changing social-biophysical conditions explicated; and practical interventions illuminated. The study reveals that Maasai's traditional and emerging livelihoods contextually interact with diverse social-biophysical conditions, particularly those related to land-use/resource-extraction and recurrent/extreme droughts, to occasion diverse and shifting ecoservice-interactions. Sharing of provisioning ecoservices predominate Maasai's traditional strategies; emergence of heretofore rarely-extracted ecosystem goods become evident as livelihoods increasingly diversify. The study indicates that under recurrent and/or prolonged droughts occasioned by the changing climate, the existing ecoservice-tradeoffs between water needs for arable-farming and livestock, and amongst water-dependent ungulates will, *ceteris paribus*, intensify. Intensified ecoservice-tradeoffs among wild and domestic faunas under similar ecological-gild and/or trophic-level will plausibly unfold under that scenario. Under the same scenario, lion (*Panthera leo*) predation on Maasai's livestock will intensify, and *ceteris paribus*, increased retaliatory killings of such nuisance terrestrial wild faunas will ensue. Apropos these rangelands, the existence of nuisance lions is revealed as a human generated reality. Collectively, persistent shifts in cross-scale social-biophysical conditions will alter and are altering, in ways yet unknown, the existing ecoservice-tradeoffs/-synergies, and therefore the very sustainability of the Maasai's livelihoods and the survival of terrestrial wild faunas. Therefore, interventions toward ensuring sustainability of ecoservices and of linked livelihoods and terrestrial wild faunas should simultaneously be adaptive to shifts in those interactions and in the changing geography of the various social-biophysical landscapes. The DPSIR model suffices as a practical tool to guide and support such interventions. The need for practical interventions entailing paradigm shift from the existing relevant policies/practices to incorporate the causal-links of disharmonious human-wildlife interactions, in the context of various dynamic socio-ecological systems, cannot be overemphasized. Collectively, the current study reveals that it is through simultaneous assessment and systematization of the causal and proximate social-biophysical conditions linked to the presently pressing ecoservice-interactions that informed goals can be set, critical indicators defined, and evaluation and prioritization of plausible interventions made.

Ecosystem services interactions, tradeoff, synergy, sustainability, Maasai, livelihood strategies and diversifications, terrestrial wild megafaunas, megacarnivores, mesocarnivores, wildlife, DPSIR model, predation, rangelands, Kenya, Maasai-carnivores conflicts, shared ecoservices, poisoning

wildlife, retaliatory killings, socio-ecological systems, land-use, resource-extraction, droughts, climate change, causal and proximate drivers

1. INTRODUCTION

Impaired sustainability of livelihoods, threatened survival of wildlife, and altered integrity of environments and ecosystems are the persistent critical challenges plaguing Africa's arid and semiarid lands (ASALs): the Maasai-inhabited savanna rangelands of Kenya are not exceptional (e.g., Maingi, Mukeka, Kyale, & Muasya, 2012; M. Mwangi, 2012; Nyamasyo & Kihima, 2014; Okello, 2005; Nyariki, Mwang'ombe, & Thompson, 2009; Western, Russell, & Cuthill, 2009). Within these savannas, Maasai pastoralists have since time immemorial harmoniously shared land-space and the resources therein with the wild faunas and other land-/resource-users. However, that harmonious sharing has gradually eroded due to unremitting permeation of various social-biophysical conditions. For example, diverse modes of livelihood strategies and land-use/resource-extraction have encroached on vast areas of the savannas within where traditional Maasai-pastoralism was practiced (GoK, 2002; Maitima & Olson, 2006; M. Mwangi, 2012, 2017) often triggering competition for space and resources therein. Consequently, a situation of discordant sharing of land-space and impaired integrity of ecological services (ecoservices) is created. Apropos these last points, the increased competition for critical rangeland resources (CRR), particularly forage and water, among Maasai's livestock, terrestrial wild vertebrate herbivores, and arable-farmers commonly observed during periods of drought (M. Mwangi, 2012, 2018) exemplify discordant sharing of the same. It must be pointed out that the recurrent and prolonged droughts that characterize the region (e.g., M. Mwangi, 2016a) constitute an additional challenge confronting the proper operation of Maasai's livelihoods and indeed other resource-users across these rangelands.

Traditional users of these rangelands, mainly Maasai pastoralists and the diverse terrestrial wild faunas, have high level of socioeconomic and ecological risks due to frequent occurrences of drought, increased rainfall variability, and encroachments of various competing land-use types (E. Mwangi, 2007; GoK, 2002, 1997; Grandin, 1986; Jaetzold & Schmidt, 1983; Kimani & Pickard, 1998; Kituyi, 1990). Those risks will plausibly intensify under conditions of changed climate (Intergovernmental Panel on Climate Change [IPCC], 2001, 2007, 2014). In fact, a long-term and on-going project on livelihoods, environments, and development (LEDP) reveals that in 2005 alone, over 50% of Maasai households across these savannas suffered severe food-shortage and malnutrition following an extreme drought that plagued the region during that time (LEDP, *op. cit*; M. Mwangi, 2016a, 2018). Among the Maasai people, the emerging agropastoralists were the most affected: an interview conducted with these pastoralists revealed that over 90% have adopted diverse intensive arable-farming strategies (M. Mwangi, 2012, 2017). Therefore, a concern arise *vis-à-vis* the sustainability of Maasai's livelihood strategies and/or their various diversifications (hereafter strategies/diversifications, and collectively livelihoods) and survival of wild faunas, particularly as the challenges of the changing climate persist.

It must be pointed out that, apropos pastoral rangelands across Africa, concerns such as degradation of land, reduced wildlife biodiversity and abundance, persistent food-/nutrition-insecurity, and unsustainable livelihood production practices are well documented (e.g., Blaikie & Brookfield, 1987; Dahl & Hjort, 1976; Ellis, 1995; Ellis, Coughenour, & Swift, 1993; Kameri-Mbote, 2002; Little, 2003; M. Mwangi, 2007; Niamir-Fuller, 1999; Smith, Barrett, & Box, 2000) particularly for the broader-scales. However, the generation and/or interactions of those challenges through the buttressing ecosystem service tradeoffs/synergies[1] need an in-depth understanding and systematic documentation. Apropos the changing climate, and as regards the Maasai-inhabited savannas of Kenya, the nexus of livelihood strategies/diversifications and terrestrial wild megafauna biodiversity

[1] hereafter, ecoservice-synergy/-tradeoff, and collectively ecoservice-interactions

via linked ecoservices-interactions, in the context of sustainability/vulnerability dichotomy, remain unexplored. Likewise, the cross-scale social-biophysical conditions within which that nexus is entrenched remain poorly understood.

In addition to recurrent droughts and the aforementioned encroachments, Maasai pastoralists have had to contend with increased predation of their livestock by various terrestrial wild carnivores, particularly lion (*Panthera leo*, the Maasai lion), leopard (*Panthera pardus*), hyena (predominantly *Crocuta crocuta*, the Spotted/Laughing hyena) (e.g., Daily Nation, 2012; LEDP, *op*. *cit*; M. Mwangi, 2012). In fact, empirical evidence reveals that terrestrial wild fauna-occasioned intensified livestock-predations and heightened competitions for CRR with livestock affects over 50% of Maasai's households during periods of drought (M. Mwangi, 2012, 2018). As regards livelihoods interactions with wild faunas across these rangelands, presently, plausibly of greatest public concern is Maasai's killing of lions (*P. leo)* (e.g., Daily Nation, 2012), which killings are retaliatory. In an effort to stop such predations, meat laced with poison is sometimes used as *pesticide* to eradicate such nuisance wild fauna: as a rule, predators that prey on corralled livestock are counted as malicious, even cowards, and are always decimated (LEDP, *op*. *cit*). Maasais-carnivores conflicts of this nature will plausibly intensify under conditions of recurrent and/or prolonged droughts (e.g. M. Mwangi 2016a) and other deleterious effects of the changing climate (e.g., IPCC 2001, 2007, 2014; McSweeney, New, & Lizcano, 2007) and amidst the rapid encroachments of competing land-use types (e.g., Nyamasyo & Kihima, 2014; Okello, 2005; Nyariki *et al.*, 2009; Woodroffe, Thirgood, & Rabinowitz, 2005) across these savannas. Suffice that, the interactions of those encroachments with the Maasai's livelihoods and wild faunas' habitat/resource needs, amidst frequent occurrences of droughts, define the prevailing states of the socioeconomic development of the Maasai people, the survival of wild faunas, and the ethical sharing and sustainability of land/land-resources across these rangelands.

Therefore, a critical concern arises of achieving sustainability of ecoservices and of the linked livelihoods and wildlife biodiversity across these rangelands. Logically, there is no simple solution to this concern, and indeed regarding the various complex socio-ecological systems that define these savannas. However, by unraveling the types and dynamics of cross-scale social-biophysical drivers and pressures linked to the disharmonious relations among land-/resource-users, both man and fauna, and/or of impaired integrity of ecoservices, the actual location and causal-links of the existing discordant emanations can be unveiled and, therefore, feasible answer(s) to that concern be deciphered. In the context of the aforementioned nexus and dichotomy, the current study engages the *Drivers-Pressures-States-Impacts-Responses* (DPSIR) model as an approach to examine and unveil the interplay of the various cross-scale proximate and causal social-biophysical drivers and their links, and the outcome thereof. More specifically, scalar ecoservice-interactions through the lens of local livelihood strategies/diversifications and terrestrial wild vertebrate megafaunas across the Maasai-inhabited savanna rangelands of Kenya under various scenarios of the changing social-biophysical conditions are explored. In addition to encapsulating the relevant factors and processes across various scales, this study's approach permits the inclusion of diverse cross-scale sectors and stakeholders; and the integration of interdisciplinary views, and therefore provides a theoretically grounded means of testing hypotheses about dynamics in ecoservice-interactions, and the implications of shifts in social-biophysical conditions on the same.

2. STUDY AREA AND METHODOLOGY

The various data that inform this study captures the greater Maasai-inhabited savanna rangelands of Kenya, *viz*., Kajiado, Laikipia, and Narok. The participatory data concerning Maasai's livelihood strategies/diversifications draws from long-term studies covering Kajiado County (see Figure 1 for the geographic location of this county). Spanning *ca.* 21903 km^2, much of this county's area occurs at *ca*. 1000 meters above sea level (m a.s.l), but generally from 500–2500 m a.s.l (Georgiadis, 1989; GoK, 2002, 1994; Katampoi *et al.*, 1990). The county is characterized by several

agroecological spaces, but most area is predominantly semiarid; various land-use types under diverse holding are present (GoK, 2002, 1997; Grandin, 1986; Jaetzold & Schmidt, 1983; Kimani & Pickard, 1998; Kituyi, 1990; M. Mwangi, 2007).

Review of literature, participatory surveys with the Maasai people of Kenya, and field observations provided data and information for the current study regarding livelihoods, terrestrial wild faunas, and ecoservices across the Maasai-inhabited rangelands. The term *megafauna*, as employed for the purpose of this study include the economically important large/medium herbivores (both mega- and meso-ungulates) and carnivores (mega- and meso-carnivores (also megacarnivores and mesocarnivores) inhabiting the Maasai rangelands of Kenya. As regards this latter group, the study focuses on the nuisance carnivores (mainly megacarnivores). The use of the concept '*ecosystem services'* (hereafter ecoservices) is understood as, *"[t]he benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on earth. The concept 'ecosystem goods and services' is synonymous with ecosystem services* (Millennium Ecosystem Assessment [MEA], 2005, p895)." The study conceptualizes the various outcomes of ecoservice-interactions under plausible scenarios of the changing social-biophysical conditions using existing ecoservice tradeoffs/synergies among Maasai livelihoods and megafauna as the baseline.

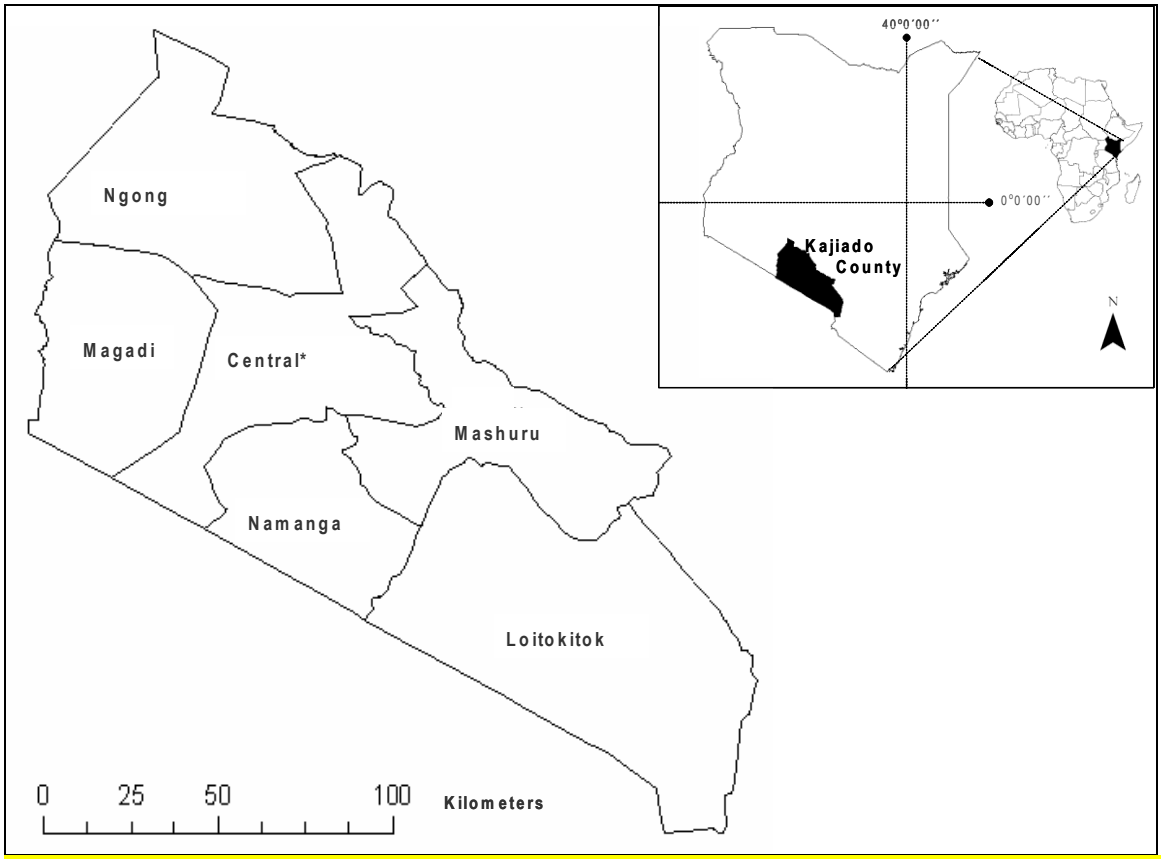

Figure 1: The geographic location of Kajiado County, Kenya. Names within the county's boundaries indicate political administrative units.* Central is presently sub-divided to include Isinya. Inset is included to situate Kajiado County in the broader geographic location, Kenya and Africa. Source: M. Mwangi, 2016a

The methodology for this study is based on integrated and simultaneous assessment and systematization of the causal and proximate social-biophysical factors/processes (drivers) and links occasioning shifts in the interactions of livelihoods and terrestrial wild faunas via ecoservices, *viz*.,

cross-scale climatic, ecological, and socioeconomic/sociopolitical factors and processes and their various interactions, in the *Drivers-Pressures-States-Impacts-Responses* (DPSIR) model (see Figure 2).

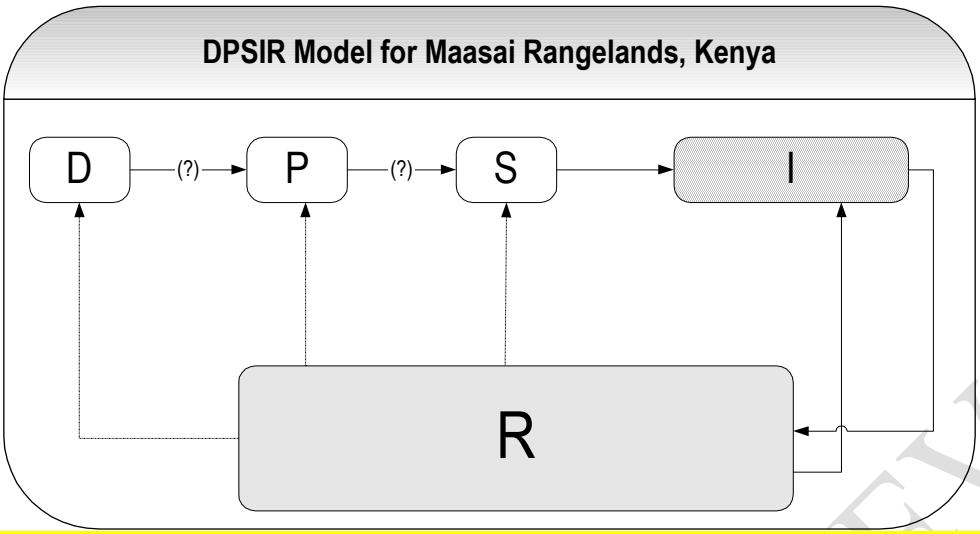

Figure 2: Schema of the *Drivers-Pressures-States-Impacts-Responses* (DPSIR) model depicting components and links for simultaneous assessment and systematization of information. D = anthropogenic factors/activities/processes; P & S = stresses/disturbances and status/condition/quality of the ecoservice; I = outcomes/consequences of ecoservice modification (locale of the pressing concerns). R = interventions that address pressing concerns. Parenthesized question marks (?) denote locale of causal-links for both increased megacarnivores/mesocarnivores predations on Maasai's livestock and consequent retaliatory killings of such nuisance wild faunas. The broken-line represents practical paths of response toward generation of feasible interventions

The advantage of DPSIR model lies in its capacity to assess and systemize the current states and changes across scales (e.g., spatiotemporal), and to explore the interconnectedness, and outcomes thereof, of social-biophysical happenings thereby revealing the specifics of proximate and causal factors/processes (drivers) and links. Innately progressive, the capacity of the DPSIR diverse components to allow for simultaneous assessment and systematization of the available information is already documented (e.g., EEA, 1999; Spangenberg, Martinez-Alier, Omann, Monterroso & Binimelis, 2009). The use of factors/processes via DPSIR is widely engaged in the assessment of environmental issues as well as human-environment interactions (e.g., *ibid*.), and therefore the application of this model in the current work is well informed. Worth pointing out, although the *Response(R)* component in the DPSIR typically focuses on social facet (e.g., conservation, ASALs, and/or natural resources policies and Maasai's drought-adaptations), for the purpose of the current work, responses from specific characteristics of ecosystems are highlighted whenever applicable.

As regards the ASALs of Africa, the scarcity and/or inaccessibility of data is plausibly one of the most limiting factors toward informative understanding of the effects of specific socioeconomic or environmental management policies/practices on the coupled socio-ecological systems that characterize these ecoclimatic regions. Thus, another advantage of the DPSIR model is that it serves to remedy such data limitation. In fact, elsewhere, studies on coupled socio-ecological systems have used the DPSIR model to provide practical alternative for data-limited conditions. For example, the recent study by Martin, Piscopo, Chintala, Gleason, and Berry (2018) exemplifies utilization of the DPSIR to remedy a data-limited condition. In their study, Martin *et al*. (2018) informatively explicates relations of ecoservice and environmental resource management decisions using the case of water quality management on Cape Cod, Massachusetts in the USA. It must be pointed out that the DPSIR model is both extensively documented and applied as an approach for guiding research and supporting

decision-making (e.g., Carr *et al*., 2007; Gari, Newton, & Icely, 2014; Kazuva, Zhang, Tong, Si, & Na, 2018; Lewison *et al*., 2016; Mangi, Roberts & Rodwell, 2007; Martin *et al*., 2018; Maxim, Spangenberg & O'Connor, 2009; Odermatt, 2004; Omann, Stocker, & Jager, 2009; Spangenberg *et al*., 2009; Tscherning, Helming, Krippner, Sieber, & Paloma, 2012). Thus it should be clear: the application of the DPSIR model is not entirety unique for the current study.

3. RESULTS AND DISCUSSIONS

3.1 Terrestrial Wild Megafauna and Challenges across the Maasai-inhabited Rangelands of Kenya

Various types of terrestrial wild megafauna disperse across the Maasai-inhabited savanna rangelands of Kenya (Table 1). The most common among these faunas include the African savanna/bush elephant (*Loxodonta africana*), Maasai giraffe (*Giraffa camelopardalis tippelskirchi*), African/Cape buffalo (*Syncerus caffer*), and common eland (*Tragelaphus oryx*). Some of these faunas, mainly ungulates, are water-dependent, for example elephant (*L. africana*), wildebeest (*Connochaetes taurinus*), zebra (*Equus burchelli*), and buffalo (*S. caffer*): they inhabit spaces near reliable watering-points, and often move with seasonal availability of water. Diverse megacarnivores/mesocarnivores (Table 1) such as the Maasai lion (*Panthera leo*), leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), Spotted/Laughing hyena (*Crocuta crocuta*), Striped hyena (*Hyaena hyaena*), Golden jackal (*Canis aureus*), and African hunting/wild dog (*Lycaon pictus*) are also to be found in these savannas. The most dominant among the carnivores include the Maasai lion (*P. leo*), Spotted/Laughing hyena (*C. crocuta*), leopard (*P. pardus*), and cheetah (*A. jubatus*); excepting the last one, these carnivores comprise the leading nuisance predators preying on Maasai's livestock.

Table 1: Terrestrial wild megafaunas of the Maasai-inhabited savanna rangelands of Kenya

Terrestrial Wild megafauna of Maasai-inhabited savanna rangelands of Kajiado County, Kenya[¥]			
Large/medium herbivores (mega-/meso-ungulates)			
Family	Scientific Name	Common Name	Remarks
Elephantidae	*Loxodonta africana*	African savanna/bush elephant	£, 1, 2
Giraffidae	*Giraffa camelopardalis tippelskirchi*	Maasai giraffe	#, 2
Equidae	*Equus quagga burchellii*	Plains/Common zebra	#, 1
Bovidae	*Connochaetes taurinus*	Wildebeest/Blue wildebeest	#, 1
	Synerus caffer	African/Cape buffalo	£, 1, 2
	Taurotragus oryx/pattersonianus	Common eland	#, 2
	Nanger/Gazella granti	Grants gazelle	#
	Alcelaphus buselaphus cokii	Hartebeest/Kongoni	
	Aepyceros melaphus	Impala	
	Gazella thompsonii	Thompsons gazelle	
	Oryx beisa callotis	Oryx	
	Kobus ellipsiprymnus	Common waterbuck	
	Tragelaphus scriptus massaicus	Bushbuck/East African bushbuck	
	Tragelaphus imberbis	Lesser kudu	
	Madoqua kirkii	Kirks dik-dik	
	Damaliscus lunatus jimela	Topi	
	Litocranius walleri	Gerenuk	
	Sylvicapra grimmia	Common duiker	
Large/medium carnivores (mega-/meso-carnivores)			
Family	Scientific Name	Common Name	Remarks
Felidae	*Panthera leo*	Maasai lion	3, §
	Panthera pardus	Leopard	3, §
	Acinonyx jubatus	Cheetah	3
Hyaenidae	*Crocuta crocuta*	Spotted/Laughing hyena	3, §
	Hyaena hyaena	Striped hyena	
Canidae	*Canis mesomelas*	Black-backed jackal	
	Canis adustus	Side-striped jackal	
	Canis aureus	Golden jackal	
	Lycaon pictus	African hunting/wild dog	

Legend: [¥]N=1563 (multiple sources); large/medium wild animals also found in other Maasai-inhabited rangelands of Laikipia & Narok, Kenya; the term megafauna, as used for the purpose of this study include the economically important large/medium ungulates (mega-/meso-ungulates) and carnivores (mega-/meso-carnivores). [£]Most dangerous to human. [#]Abundant. [3]Dominant carnivores. [§]Most nuisance predators. 1=water-dependent, 2=common ungulate. Examples of other wild faunas (large/medium/small): African civet; African wild cat; Bat-eared fox; Marsh mongoose, Slender mongoose, Dwarf mongoose, Grey mongoose; Honey badger; Large-spotted genet, Small-spotted genet; Olive baboon; Warthog; Hippopotamus; Ostrich.

From the studies with the Maasai people of Kenya, some of the problems occasioned by wild faunas include predation on livestock, direct attack/injury to man (sometimes fatal), cause road accidents, competition with livestock for the critical rangeland resource (CRR), and spreading of

diseases and pests to man and domestic animals (Table 2). Other problems caused by wild faunas include damage to beehives and stealing honey from the same, damaging crops, attacking/killing domestic dogs (without consuming their kill), predation on poultry. As regards wild faunas' spread of pests and transmission of diseases to livestock, most Maasai households are forced to herd their stock in disease-contaminated or pest-infested spaces because of shortage of pasturelands and lack of alternative sources of forage/pasturelands.

Table 2: Signatures of unfavorable human-wildlife interactions across the Maasai-inhabited savanna rangelands of Kenya

Signatures of unfavorable human-wildlife interactions across the Maasai-inhabited rangelands of Kenya[§]
Challenges enfeebling population of wild fauna
Encroachment of arable-farming
Increase in human-settlements, roads, & other build-infrastructures
Proliferation of unpalatable & invasive plants
Intensified habitat loss/fragmentation/modification/destruction
Environmental pollution
Uninformed/illegal extraction of wildlife
Poisoning of wildlife
Increase in disease incidences & pest infestations
Competition with livestock for critical rangeland resources (CRR)
Increased deleterious impacts of climate change/variability
Problems occasioned by wild fauna on human/livestock
Frequent predation on livestock
Increased crop damage
Increased attacks/injuries to man
Cause road accidents
Competition for critical rangeland resources (CRR)
Spread/transmission of diseases & pests

Legend: [§]N=1563, multiple sources, Maasai-inhabited savanna rangelands of Kenya include Kajiado, Laikipia, & Narok; other challenges include nature of the animal (e.g., physiological or genetic), its sensitivity to environmental or climatic changes, and location/space inhabited (e.g., inside vs. outside protected wildlife sanctuaries).

3.2 Maasai Livelihood Strategies/Diversifications and Linked Ecoservice Synergies and Tradeoffs

Formerly subsisting predominantly on rainfall-dependent pastoralism across the savanna rangelands, the Maasai people of Kenya have gradually espoused diverse forms of livelihood strategies and diversifications (e.g., Table 3; Figure 3). For example, practiced by over 80% of Maasai households, the most common livelihood-diversification is individualized/private arable-farming (M. Mwangi, 2017; Figure 3(*ii*)). Other widespread livelihood-diversifications include tourism-based enterprises, for example operation of community-based conservancies and small-scale trade in curios; and extraction of woody plants (trees and shrubs) for sale as fuelwood, mainly charcoal and firewood (Table 3). Other undertakings include cultivation of eucalyptus for sales as teleposts (e.g., Figure 3(*iii*)); sale of medicinal concoctions that are extracted from certain plants; and operation of cultural

bomas, and educational/scout tours (LEDP, *op. cit*). Worth noting, these strategies/diversifications are mostly land-based and are, therefore closely linked to specific ecosystem services (ecoservices).

Table 3: Livelihood strategies and diversifications among the Maasai people of Kenya

Livelihood strategies and diversifications among the Maasai people of Kenya[§]		
Strategy/diversification	Examples	Remarks[#]
Livestock husbandry	Cattle; sheep & goats (shoats); poultry (mainly chicken); camels; bees; donkeys	cattle & shoats
Arable farming (irrigated/rainfed)	Maize, beans, potatoes, wheat, barley (mainly large-scale), horticultural crop (e.g., onions, collards, tomatoes, carrots)	rainfed, small-scale & individualized/private
Trade	Sale of livestock, milk, eggs, hides/skin, agricultural goods, herbal remedies, sand, bricks, manure (sun-dried livestock dung) firewood & charcoal, & general groceries	various combination
Wildlife/tourism enterprises	Community-based conservancies; trade in curios; operation of cultural bomas, & educational/scout tours.	small-scale
Employment (formal/informal)	Security guard, herding, sand-harvesting, driving livestock for sale; research-assistance, tour-guides, civil-service	low-skill/manual labor

[§]Selected livelihood strategies and diversifications: Source: Field Data (by M. Mwangi). [#]Predominant livelihood strategy and/or diversification type and/or example

Figure 3: Selected portraits of livelihood strategies and diversifications among the Maasai people of Kenya. (i). Emaciated herd of Maasai's cattle in a depleted water-pan, near Nairobi-Tanzania Highway in Central Division, Kajiado County. (ii). Rainfed maize (*Zea mays*) farm and grass-dominated pastures in Kajiado County. (iii). Eucalyptus woodlots and grass-dominated pastures in Kajiado County (Photo Credit: Figure 3*i* & *ii*: M. Mwangi; Figure 3*iii*: M. Mwangi, 2016b)

Being predominantly land-based, the practice of these diverse livelihoods strategies translates to, and reveals, the diversity of ecoservices upon which they are buttressed. For example, in traditional nomadic Maasai-pastoralism, CRR, particularly natural grass (the predominant pasture, see Figure 3), but also include browse forage as livestock types in this system are diversified, water, and salt-lick spaces (M. Mwangi, 2012) are the key ecoservices. In arable-farming, the predominant livelihood-

diversification among the Maasais of Kenya and indeed other non-Maasai people (M. Mwangi, 2017), water and soil resources are the ecoservices used. In the extraction and sale of fuelwood, woody-plants, often an entire tree/shrub is extracted. Here, overlapping of some of the extracted ecosystem resource is evident: water in the former two livelihood-diversifications; and wild plants in the first and last modes of diversification. An intense demand is, therefore, placed on the land-resources where such diversifications co-exist across spatial and/or temporal scales. Consequently, conflicts linked to the use of shared ecoservices is to be expected, and is often generated where such co-existence are present.

In order to clearly comprehend the extent of demand on, and extraction rate of, the ecoservices across these rangelands, the following points must be highlighted: Maasai's arable-farms are, on average, small-sized and geared for subsistence; high population of non-Maasai arable-farmers are to be found across these savannas; and irrigated arable-farming, particularly as commercialized horticultural and floricultural firms and high-input agricultural farms, have encroached on vast tracts of historically Maasai's territories (GoK 2002; LEDP, *op. cit*; Maitima and Olson 2006; M. Mwangi, 2012, 2017). Suffice that, extraction of water in arable-farming, and other undertakings, is widespread, and predominantly by non-Maasais. Nonetheless, arable-farming offers fallback for the Maasai's livestock when natural pastures are inadequate: for example, maize-stovers and diverse post-harvest stubbles are used as animal feed. What's more, manure (dry livestock dung) is used to improve soil fertility in Maasai's small-scale farms. Sometimes, those with large herds sell this resource (mostly to external non-Maasai farmers). Some households forego application of manure on their farms, opting to sell it in order to meet pressing financial needs. Worth noting here is that, in nomadic Maasai-pastoralism, the migrations of herds across the then freely accessible vast tracts of savannas translated to widespread dispersal of manure and, therefore, an inadvertent enhancement of soil fertility of the pasturelands spaces supporting livestock and indeed other life forms: a form of synergetic relationship is thus revealed. Logically the loss of large pasture-spaces to arable-farming translates to reduction of all the key ecoservices linked to livestock needs therein: this is more so if such spaces are lost to non-Maasais. This last point is correctly so because there is an unspoken norm of sharing resources among the Maasai. Similarly, the loss of forage in fuelwood extraction, since the entire tree/shrub is often chopped down, translates to loss of browse for browser livestock (e.g., goat) where such plant species are palatable, for example, the preferred tree for fuelwood, especially in charcoal-making, is *Acacia spp* (LEDP, *op. cit*; M. Mwangi, 2016b, 2017). This loss becomes profound as livestock-diversification to incorporate other browsers, such as camel in addition to goats, in Maasai-pastoralism (M. Mwangi, 2012) is taken into account.

Nonetheless, amidst this loss, a surprise manifestation of a new ecoservice in the charcoal-making spaces has been observed. The abandoned charcoal-kiln sites often transition to spaces upon where natural local palatable-to-man herbaceous plants grow (LEDP, *op. cit*). Maasai women often extract these herbaceous plants and use them as vegetables (often consumed with *ugali*, a popular Kenyan maize-flour meal or with other accompaniments). This *surprise new* ecoservice although seemingly insignificant, is noteworthy because it translates to improved household nutrition, and when sold, for some enterprising Maasai-women sells the same locally, additional income to the household. These last points indicate emergence of heretofore rarely-extracted ecosystem goods with espousal of that mode of livelihood diversification. Overall, across these rangelands, livelihood strategies/diversifications contextually interact with diverse social-biophysical conditions, particularly those related to land-use/resource-extraction, to occasion diverse and shifting ecoservice-interactions.

It must be pointed out that Maasai pastoralists are excellently knowledgeable in sustainably stewarding livestock-linked ecoservices across these savannas, which explains well why they have lived and thrived on pastoralism since time immemorial in these variable ecoclimatic zones (e.g., Fratkin, 2001; M. Mwangi, 2012; Spear & Waller, 1993). This last point raises a more important concern, *viz*: presently, are Maasai people equally knowledgeable in managing ecoservices that buttress the emerging livelihood strategies/diversifications, and particularly amidst the rapidly shifting cross-scale climatic, ecological, and socioeconomic landscapes. Worth pointing out, as

livelihood strategies among the Maasai are continuously and intensively diversified, the amount, the sophistication, and the fastness with which ecoservices are extracted are also being changed, mainly intensified, and more so as other land-use/resource-extraction types, non-Maasais undertakings, and expansion of broader-scale-catering agri-firms (e.g., floricultural/horticultural farms and eucalyptus woodlots), are also involved. Apropos this last point, widespread changes in land-use are to be observed across historically Maasai's territories. Some of the factors and processes associated with land-use change (LUC) include agriculture expansion, rapid human-population increases, changing land-use/-tenure policies, shifts in macroeconomic policies, politics, and sociocultural factors particularly poverty, unequal education-levels, breakdown of traditional values and norms (e.g., African Land Development Board [ALDEV], 1962; Kameri-Mbote, 2002; Kimani & Pickard 1998; Sindiga 1984; M. Mwangi, 2007, 2012, 2017).

Continuing with the explication regarding the emerging livelihood strategies/diversifications, it must be pointed out that except where the conservancies/sanctuaries are run by the Maasai people, most wild faunas, including the nuisance ones (e.g., lion and hyena), rarely, if at all, benefit these pastoralists, but the state and the few elite. Nonetheless, at the local scale, the rapidly emerging practice of community-based wildlife/tourism-based enterprises translates to a formal mode through which the Maasai people can sustainably derive additional benefits from ecoservices. Apropos this last point, the need for informed capacity building cannot be overemphasized.

3.3 Maasai Livelihoods and Megafauna Interactions: Ecoservice Synergies and Tradeoffs

Maasai pastoralists have harmoniously lived with the diverse wild faunas across the savanna rangelands of Kenya (and Tanzania[2]) since time immemorial; and, on rare occasions, they judiciously extracted the same for food or ritual purposes. In fact, Maasai pastoralists regarded most ungulates such as the kongoni (Hartebeest, *Alcelaphus buselaphus cokii*), the common eland (*Taurotragus oryx*), the lesser kudu (*Tragelaphus imberbis*) and similar bovids that inhabit these rangelands (see Table 1) as their second-cattle, and they extracted some for food, but on rare occasions such as in times of want (M. Mwangi, 2017). Apropos this last point, Maasai's extraction of such wild bovid as the lesser kudu (*T. imberbis*) and kongoni (*A. buselaphus*) to supplement food-shortages that prevailed under conditions of extreme droughts (*ibid*.) was common. It must be pointed out that such game-meat was shared among several households, and nearly all the parts of the extracted animal judiciously utilized. (Worth mentioning is that the same nature of sharing was practiced whenever a livestock was slaughtered (LEDP, *op. cit*.)) Evident in these last points is the innate sharing of provisioning ecoservices in the Maasai's traditional livelihood strategies. However, the emergence of individuated/private livelihoods alongside the widespread encroachments of competing land-use/resource-extraction types has gradually eroded at this sharing (e.g., M. Mwangi, 2012). Moreover, as CRR availability and land-space continuously diminish due to land-use/tenure changes occasioned by implementation of various cross-scale interventions (e.g., Kameri-Mbote, 2002; M. Mwangi, 2007), Maasais' harmonious interactions with terrestrial wild faunas have gradually been eroded. Thus, where certain wild ungulates traditionally grazed side-by-side with Maasai's cattle, the former are presently seen as CRR-competitors, even pests, and reservoirs for diseases/pests from the perspective of these pastoralists.

In order to comprehend the implication of the foregoing contextual ecoservice-tradeoffs and ecoservice-synergies evident in Maasais' traditional and emerging livelihood strategies on the shared ecoservice for the diverse wild faunas that inhabit these rangelands, it is instructive that the nature of the existing ecoservice-interactions among the same be unraveled. It must be pointed out that, as regards Maasai-run wildlife-based enterprises, the wild faunas in such places/spaces are already beneficial as ecoservice for the Maasai people. Therefore, an explication exploring the implications of specific existing ecoservice-interactions among the diverse wild faunas and Maasai

[2] Maasai people are to be found in both Kenya and Tanzania

livelihoods; and highlighting resource use type/space by the specific wild fauna and/or gild is warranted here. As regards the various interactions among the Maasais' livelihoods and the wild faunas across these savannas, and particularly through the lens of CRR, diverse and shifting ecoservice-interactions are to be expected: this is more so as emerging livelihood strategies and various diversifications are rapidly adopted and intensively used.

As aforementioned, although Maasai people predominately subsist on pastoralism; they also engage in other livelihood strategies/diversifications (e.g., M. Mwangi, 2017, 2019). A recent study reveals that over 80% of livelihood-diversifications, principally into arable-farming, tourism-based enterprises, and extraction and trade in fuelwood (mainly charcoal and firewood), among the Maasais are hinged on local utilization of natural resources (M. Mwangi, 2017), which entail the various shared key ecoservices supporting diverse wild faunas. Suffice that, the various ecoservices buttressing the proper operation of the Maasai's core livelihood strategies/diversifications, also buttress the very survival of wild faunas dispersed across these rangelands. Thus, it is imperative that the interaction of Maasai livelihoods and wild faunas at the confluence created via the shared key ecoservices is understood: this is the greater focus of this explication.

From the current evidence, a rich mix of wild herbivores including browsers, grazers, and mixed-foragers; and carnivores inhabit Maasai-inhabited rangelands of Kenya (Table 1, Figures 4 & 5). (As aforementioned, the current study focuses on the economically important terrestrial wild vertebrate faunas, mainly large/medium ungulates and nuisance carnivores for these are closely linked to the concerns of Maasai's livelihoods.) The most common wild ungulates observed in these savannas include the African savanna/bush elephant (*L. africana*), zebra (*E. burchelli*), African/Cape buffalo (*S. caffer*), Maasai giraffe (*G. camelopardalis*), and wildebeest (*C. taurinus*) (Table 1). The most nuisance carnivores preying on Maasai's livestock include lion (Maasai lion, *P. leo*), leopard (*P. pardus*), and hyena (mainly the Spotted/Laughing hyena, *C. crocuta*) (Table 1, Figure 4).

Figure 4: Portraits of megacarnivores found across the Maasai-inhabited savanna rangelands of Kenya. (i) Leopard (*Panthera pardus*), (ii) cheetah (*Acinonyx Jubatus*), (iii) Maasai lion (*Panthera leo*) in Maasai Mara Game Reserve, and (iv) Spotted/Laughing hyena (*Crocuta crocuta*) in Amboseli National Park, Kenya. (Credit: Photos adapted from Prokosch, 2015)

Figure 5: Portraits of terrestrial wild mega-herbivores found across the Maasai-inhabited savanna rangelands of Kenya. (*i*) African/Cape buffalo (*Syncerus caffer*) in Maasai Mara Game Reserve, and (*ii*) African savanna/bush elephants (*Loxodonta africana*) in Amboseli National Park, Kenya. (Credit: Photos adapted from Prokosch, 2015)

Apropos these three nuisance megacarnivores, Maasai pastoralists have had to contend with predation of livestock, with increased incidences during periods of drought (M. Mwangi, 2012, 2018). In fact, empirical evidence reveals that increased wild fauna predations on livestock, and heightened competition for CRR, affects over 50% of Maasai's households during periods of drought (*ibid*.). As regards livelihoods interactions with wild faunas across these rangelands, presently, plausibly of greatest public concern is Maasai's killing of lions (e.g., Daily Nation, 2012), which killings are retaliatory. The retaliatory killings reveals well, in part, the affected-locals' disdain toward these state's assets. The nuisance carnivore(s) is tracked and speared to death; other times predators are simply poisoned using acaricide or other locally available agri-pesticides (LEDP, *op. cit*). During periods of drought, predators, predominantly leopard (*P. pardus*) and hyenas (mainly *C. crocuta*) (Table 1 & Figure 4) prey on corralled livestock (mainly sheep and goats (shoats), calves, donkey-colts, and sometimes dogs) at night; for this reason, meat laced with poison is used as *pesticide* to eradicate such wild fauna: as a rule, predators that prey on corralled livestock are counted as malicious, even cowards, and are always decimated. Worth mentioning, lions (*P. leo*, Figure 4) prey on both corralled and grazing livestock (mainly mature cattle and shoats, and sometimes donkeys) at night and during the day respectively (LEDP, *op. cit*). Logically, corralled livestock are already vulnerable to such predators because the fenced corral prevents them from escaping, and moreover, the owners are already asleep. Knowing that predators often return to their kill, the livestock carcass or part of the same is sometimes laced with poison, and left for the unsuspecting nuisance predator(s) to consume (*ibid*.). In such a case, the nuisance predator(s) is decimated; and so are other carnivores, and indeed scavenging birds, that consume the poison-laced carrion: in fact, the manifestation of cascading deleterious effects from such poisoning is likely to ensue along and across the greater food-chain. The deleterious extent of the impacts of such deliberate initial poisonings, and indeed those emanating from inadvertent leaks from the normal and originally intended usage (i.e., as agricultural crop pesticides or herbicides) is plausibly widespread and long-term than yet understood. It must be pointed out that, traditionally, such retaliatory killings were rare, and the use of poison to eradicate wild fauna non-existent among the Maasai. As regards the nuisance wild fauna, these are killed only when critical, but as a rule, predators that prey on corralled livestock are always decimated.

Thus far it should be clear: frequent predation and retaliatory killings reveal the manifest disharmonious states of Maasai and wild carnivore interactions. Therefore, a crucial concern should be why and how did the traditionally harmonious co-existence erode into the present disharmonies. The DPSIR model avails a practical approach toward unveiling the conditions and pathways generating those disharmonies. The DPSIR model (e.g., Gari *et al*., 2014; Kazuva *et al*., 2018; Martin *et al*., 2018; Maxim *et al*., 2009; Omann *et al*., 2009; Tscherning *et al*., 2012) provides a practical framework by which to explore the interactions of traditional and emerging livelihood strategies/diversifications, economically important terrestrial wild vertebrate faunas, and shared ecosystem services across the

Maasai-inhabited rangelands; to unveil the cross-scale social-biophysical drivers and pressures, and the causal-links thereof, occasioning those disharmonious emanations and indeed other persistent critical challenges; and to devise informed interventions.

Worth mentioning, wild faunas are one of the main, if not the most important, component of Kenya's tourism sector, a key revenue/foreign-exchange earner, and are, therefore, economically valuable resources at scales beyond local; and so is livestock for the Maasai pastoralists at the household scale in particular, and county/national scale in general. Suffice that, the need for the state to recast these wild faunas as assets to the Maasais; and to disclaim them as pests (i.e., wild fauna not the state) cannot be overemphasized. This recasting becomes important because these wild faunas are also to be found in other rangelands outside of the Maasai-inhabited savannas, where pastoralism and other livelihood strategies are practiced.

3.4 The Changing Geography of Maasai and Wild Megafauna Interactions: Inconvenient Resources, Precious Resources

As aforementioned, lion (*Panthera leo*, Maasai lion) is one of most nuisance carnivores preying on Maasai's livestock. Although Maasai's killing of the nuisance predators serves to 'send a definite warning' to would-be livestock-predators, and indeed to the existing plausibly 'insensitive-to-Maasai-livelihood' policies and/or practices, the decimation of lion (*P. leo*), being an already vulnerable keystone species and a top-predator, has far-reaching implications on the nature, availability, and quality of key ecoservices across these savanna rangelands. Maasai lion is already classified as vulnerable (see IUCN), and therefore continued decimation of this megacarnivore, alongside the already persistent climatic and socioeconomically induced habitat loss (see Table 2), serve to further threaten it.

In addition to constantly contending with the nuisance carnivores, Maasais have had to deal with land and land-resource degradation and competition for CRR and space with other socioeconomically important wild ungulates (e.g., Tables 1 & 2) particularly those dispersed within Maasai rangelands outside the state protected game sanctuaries. For example, buffalo (*Syncerus caffer*, African/Cape buffalo, Figure 5), a wild bovid, has a diet mirroring that of cattle and is a major reservoir for and transmitter of several diseases and pests to livestock (e.g., Table 2; Michel & Bengis, 2012). Wherever possible, Maasais often avoid areas inhabited by buffaloes (*S. caffer*) for this latter reason; and also because they are dangerous human-attackers. Among the Maasai pastoralists, it is generally acknowledged that buffalo calving sites are spaces that harbor contagious diseases, and are thus to be avoided (LEDP, *op. cit*). Worth mentioning, most of the large ungulates across these savannas are associated with transmittance of various diseases (e.g., East Coats Fever (ECF), anthrax, foot-and-mouth disease, trypanosomiasis, brucellosis) to livestock; wildebeests (*Connochaetes taurinus*) are particularly known as ECF transmitters. Maasais also recognize the African hunting/wild dog (*Lycaon pictus*) as a transmitter of rabies; therefore, wherever spotted, it is shooed off; normally, herders kill this canid whenever encountered. As regards diet, a CRR competition is, *ceteris paribus*, to be expected between Maasai's cattle and the buffaloes, and indeed other ungulates, such as the large populations of wildebeest (*C. taurinus*) and zebra (*E. burchelli*), found in these rangelands (Table 1). Maasai's avoidance of potentially disease-contaminated or pest-infested buffalo spaces translate to denial of CRR located therein: a manifest type of an ecoservice-tradeoff. Worth mentioning, since Maasai practice disease/pest control measures on their livestock, then, an ecoservice-synergy is generated in the spaces shared with wildlife. For example, Maasai's pest-control on livestock (e.g., dipping or race-spraying with acaricide) eradicates ticks, and disinfects areas where the stocks are herded immediately after such measures, thereby indirectly benefiting the wild fauna (e.g., buffalo) inhabiting or utilizing such spaces. The deworming and vaccinating of Maasai's livestock also avails indirect benefit to such wild fauna: for example by reducing plausible hosting and/or transmission of parasites and/or diseases. It is thus clear: in social-ecological terms, wild and domestic fauna under similar ecological-gild and/or trophic-level generally portray variety of ecoservice-tradeoffs.

Considering this last point, the aforementioned retaliatory killings can, in part, be viewed as plausible signatures of upset in trophic-levels in the wild. For example, shortage of preys in wild for the lion and indeed other carnivores, especially during periods of drought when most wild terrestrial herbivores move to wherever pastures may be found: this leaves the local livestock as easy-to-find prey for the nuisance megacarnivores. However, it must be pointed out that some of these *nuisance* lions are sometimes accidental strays from the game sanctuaries (LEDP, *op. cit*; Daily Nation, 2012), which coupled with the continuous and rapid human-encroachments into much of the remaining wilderness (e.g., GoK, 2002; Maitima & Olson, 2006; M. Mwangi, 2012, 2017), inadvertently traps this megacarnivore in human settlements within where the easy preys (i.e., Maasai's livestock) are herded and/or corralled. Therefore *ceteris paribus*, it suffices that the existence of nuisance lions is a human generated reality: there are no nuisance lions per se. Similarly, there are no wanton killings per se: these killings are retaliatory and have been forced upon the Maasai pastoralists. Clearly, in equity terms *vis-à-vis* sharing of land-space and ecological resources therein, the very killing of lions constitutes decimation of the very victim of cross-scale human-induced shifts in the CRR and space. Likewise, the very condemnation of the Maasai pastoralists (if only in mass-media) for those retaliatory killings constitutes placement of blame on the very victim of cross-scale human-induced loss of land-space and the CRR therein and indeed their very livelihood.

Comparable to the preceding point is this: since water-dependant wild faunas, for example the African/Cape buffalo (*S. caffer*) and the African savanna/bush elephant (*L. africana*) (see Table 2 & Figure 5) logically inhabit spaces near water, the very practice of irrigated intensive arable-farming along the rivers, swamps and other wetland-spaces across these rangelands translates to displacement of and denial of use and access to this critical resource by those wild megafaunas. By extension, that displacement/denial indirectly forces these faunas to enter crop-fields and thereby inadvertently damages the crops therein as they attempt to access water-points presently blocked or taken up by arable-farms, or to forage on the *seemingly natural spots* of lush pastures (i.e., the crops). Regarding these last points, it should not be construed as a romanticized view of terrestrial wild vertebrate faunas that inhabit these savannas, or a skewed criticism toward the farmers deriving livelihoods from such spaces. Rather, it is to point out the urgent need for the engagement of ethically informed sharing of these natural and critical resources among all the land-/resource-users who hold legitimate claim to the same. This ethical sharing is achievable by first gaining an informed understanding of the specific triggers and causal-links occasioning the various persistent critical challenges.

Thus far, it should be evident that across these rangelands, various challenges characterize interactions of human and terrestrial wild faunas. In Table 2, the signatures of unfavorable interactions between human and terrestrial wild faunas across the Maasai-inhabited savanna rangelands of Kenya are shown. Some challenges such as the encroachment of arable-farming (rainfed and/or irrigated), environmental pollution (e.g., through unregulated use of agrochemicals), and habitat loss (e.g., reduction in forest-/wood-/wet-/grass-land spaces) are widespread. Illegal extraction of terrestrial wild faunas (e.g., trapping or poaching), poisoning of wild faunas (deliberate or accidental using readily available agrochemicals), and climate change/variability (e.g., recurrent/prolonged droughts and extreme droughts/rainfall events) are also common challenges across these savannas. Table 2 also shows examples of problems caused by wild faunas to human and livestock including predation, crop damage, and transmission/spread of diseases and pests. Occasioning habitat change, and in its various manifestations, LUC is a core anthropogenic driver of unfavorable interactions between human and wild faunas across these savannas.

The impacts of human vs. wild fauna conflicts, particularly due to LUC (e.g., Table 2; Nyariki *et al.*, 2009; Woodroffe, Thirgood, & Rabinowitz, 2005; Young, Palmer, Gadd, 2005); and wild and domestic ungulates' competitions and co-existence via the CRR (e.g., Odadi, Karachi, Abdulrazak, & Young, 2011; Sitters, Heitkönig, Holmgren, & Ojwang', 2009; Table 2) are well documented. As regards LUC, in addition to increased human-wildlife conflicts, other common effects on wild faunas include displacement by livestock, continuous decline in numbers of some, and destruction of habitats supporting the same (e.g., Nyamasyo & Kihima, 2014; Okello, 2005;

Nyariki *et al.*, 2009; Woodroffe *et al.*, 2005). Suffice that LUC is a dominant causal factor occasioning shifts in interactions of Maasai's livelihoods and these wild fauna. Therefore, it's by assessing the drivers of LUC and the associated pressures linked to Maasai-wildlife interactions that informed interventions can be made.

3.5 Changing Climate, Changing Ecoservice-Interactions: Ecoservice Tradeoffs and Synergies among Maasai Livelihoods and Terrestrial Wild Megafauna

Studies have documented existing and potential effects of the changing climate on ASALs, and on specific modes of livelihoods and types of environments/ecosystems for Africa (e.g., IPCC 2001, 2007, 2014; Kaser, Hardy, Mölg, Bradley, & Hyera, 2004; McSweeney *et al*., 2007). For example, increased rainfall-variability, evaporation, temperature changes, and occurrence of extreme droughts; heightened aridity, water-stress, and desertification; altered growing seasons and species range of both domesticated and wild plants (e.g., IPCC 2001, 2007, 2014; Kaser *et al*., 2004). The IPCC (*ibid*.) projections indicate manifestation of an admixture of increased variability and occurrence of extreme drier and wetter conditions, with consequent destabilization of ecosystems; intensified livelihood vulnerabilities and environmental degradation across the ASALs are projected. Worth noting, prevailing discourses (e.g., Brooks, Adger, & Kelly, 2005; IPCC 2001, 2007, 2014; McSweeney *et al*., 2007) are in accord *vis-à-vis* attributing the heightened manifestation of predominantly deleterious effects of climate change on societies to existing inadequate adaptive capacities. It must be pointed out that, most livelihood production systems practiced across the ASALs of Africa are coupled socio-ecological systems that predominantly operates under landscapes of frequent manifestation of unfavorable social-biophysical conditions such as famines, conflicts/wars, recurrent/prolonged droughts, degraded natural resource-base (e.g., Brooks *et al*., 2005; Eliza *et al*., 2015; IPCC 2001, 2007, 2014; M. Mwangi, 2012, 2016a, 2018; Scheffran *et al*., 2014; Schilling *et al*., 2012, 2014). These socio-ecological systems are frequently exposed, and are already highly sensitive and vulnerable to shifts in climatic conditions (IPCC 2001, 2007, 2014) particularly occurrences of recurrent and extreme droughts (M. Mwangi, 2016a, 2018).

Apropos the ASALs of Africa, Sivakumar, Das, and Brunini (2005) document that a slight change in the climate system is sufficient to occasion occurrences of intense and frequent extreme climatic events. In fact, as regards Maasai-inhabited savanna rangelands of Kenya, recent studies documents high rainfall-variability across spatiotemporal scales, and occurrence of widespread, recurrent, cyclic, occasionally clustered droughts (M. Mwangi, 2012, 2016a). Indeed, over the past 30 years, Kajiado County recorded over 85% major-droughts (M. Mwangi, 2016a; Figure 6). It must be pointed out that the increasing dryness over East Africa coupled with the persistently declining snow cover on Mount Kilimanjaro are plausible signatures of deleterious effect of climate change (see Kaser *et al*., 2004) within where Kajiado County, a Maasai-inhabited savanna rangeland, is located. For the broader region (i.e., GHA), and regarding the rainfall amount received, Nicholson (2014) documents a total decline of 50–75% below average within the last decade. In sum, the various effects of the changing climate projected for the ASALs across Africa already devastates much of the GHA, and indeed the Maasai-inhabited savanna rangelands of Kenya.

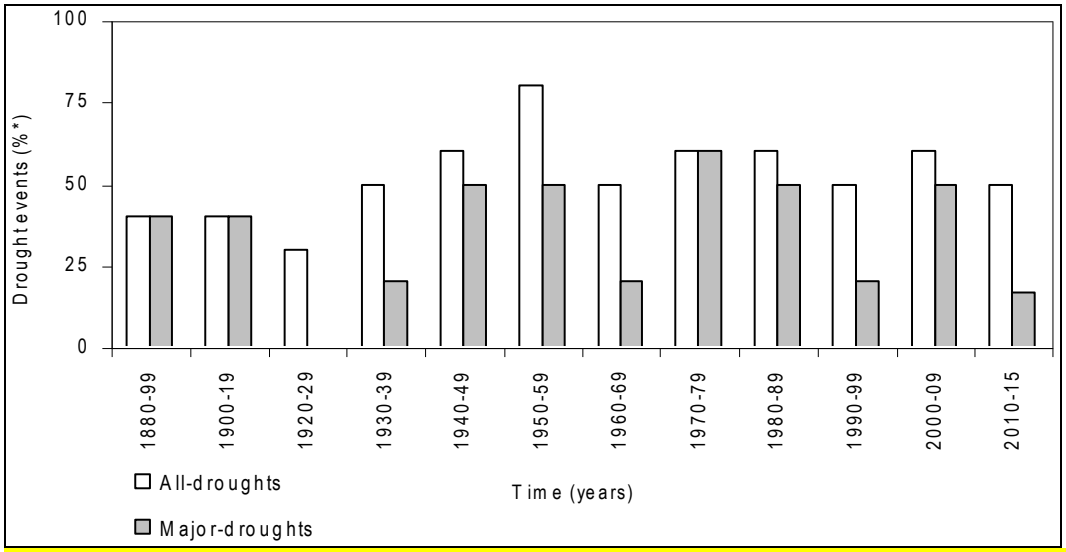

Figure 6: Chronicles of documented drought-events across the Maasai-inhabited rangelands of Kajiado County, Kenya. Source: M. Mwangi, 2016a

Worth mentioning, as expected for the ASALs across Africa, the following characterize much of the greater region, and indeed the Maasai-inhabited savannas: spatiotemporal variability of CRR, recurrent and/or prolonged droughts, and highly variable rainfall (M. Mwangi, 2012, 2016a; Nicholson, 2014; Opiyo, Nyangito, Wasonga, & Omondi, 2014). Presently, drought is the most deleterious climatic factor devastating the Maasai-inhabited savanna rangelands of Kenya, and indeed the ASALs across the GHA (see M. Mwangi, 2016a, 2018): thus, a scenario of intense, recurrent, and/or prolonged droughts across these savannas will unfold, and is unfolding, upon landscapes already devastated by the same. Therefore, as these social-biophysical pressures persist, higher odds exist of disruption of the proper operation of Maasai's livelihoods, of the survival of economically important terrestrial wild vertebrate fauna, and of the sustainability of key/shared ecoservices. The foregoing points raise important concerns *vis-à-vis* the outcomes on ecoservice-interactions as social-biophysical conditions persistently shift. Thus, an informed understanding of ecoservice-interactions becomes important if the deleterious effects of climate change are to be alleviated.

Under conditions of increased occurrences of droughts, the existing ecoservice-tradeoff between water needs for arable-farming and livestock and for domestic and wild water-dependent ungulates will, *ceteris paribus*, intensify. Intensified ecoservice-tradeoffs among wild and domestic faunas under similar ecological-gild and/or trophic-level will plausibly unfold under such scenario. Worth highlighting, persistent hotter and drier conditions occasioned by the changing climate will affect grazers, both wild and domestic, for example via reduced forage quality (Craine, 2013), and therefore, intensified competitions among the same is to be expected across the Maasai-inhabited rangelands. Moreover, since mammalian grazers have high exposure and sensitivity to climatic changes (e.g., Craine, 2013; Ribeiro, Sales, De Marco, & Loyola, 2016), a severely diminished dependency on cattle-dominated livelihood strategies/diversifications among the Maasais will, *ceteris paribus*, ensue and is to be expected, if not already occurring. Other effects of the changing climate such as altered growing seasons and species range of both domesticated and wild plants (e.g., IPCC 2001, 2007, 2014) will plausibly occasion disruption of environmental signals, for example those regarding CRR, which may disrupt the timing of seasonal movements and other vital activities (e.g., breeding time) of some wild ungulates: this, by extension will stir ripple effects toward the carnivores that prey on the same.

Under that same scenario, lion's predation on Maasai's livestock will plausibly become more frequent and, *ceteris paribus*, consequent increased retaliatory killings of this megacarnivore will ensue. Maasai-carnivore conflicts of this nature will plausibly intensify under conditions of climate

change and amidst rapid encroachments of competing land-use/resource-extraction types and increasing human populations into these rangelands.

Worth pointing out, the documented increased habitat-suitability for agricultural pests projected for Africa (e.g., Biber-Freudenberger, Ziemacki, Tonnang, & Borgemeister, 2016) coupled with the persistent intensive agriculture encroachments is plausibly occasioning increased use and imports of pesticides into Maasai-inhabited savannas of Kenya: suffice that, an increased use of agrochemicals across rangelands is, *ceteris paribus*, expected to ensue. Whether this last point translates to increased incidences of inadvertent or deliberate poisoning of wild faunas, particularly under the present landscape of unregulated use of pesticides in Kenya, necessarily unveils a critical concern *vis-à-vis* the urgency with which Maasai-wildlife conflicts need to be resolved. It must also be pointed out that climate change occasioned species extinction of both flora and fauna is generally widespread at local scales, and will plausibly increase as global warming persist (Wiens, 2016): whether such deleterious effect is unfolding across Maasai rangelands need to be established.

In addition to the challenges posed by climatic changes, the broader region (i.e., GHA) have had to contend with rapid permeation of various cross-scale unfavorable socioeconomic and sociopolitical conditions (e.g., Brooks *et al.*, 2005; Eliza *et al*., 2015; Scheffran *et al*., 2014; Schilling *et al*., 2012, 2014). Thus, as the aforementioned encroachment of arable-farming persists, especially the irrigated forms, competitions for water and dry-season forage should be expected. Logically, encroachments on or around the environs neighboring the various wetlands and water-catchments spaces across these rangelands (e.g., LEDP, *op*. *cit*.; M. Mwangi, 2012) degrades the integrity of CRR, which translates to diminished resource for the faunas relying on the same. For example, intensive irrigated farming, and indeed water-diversion along the streams or catchment areas, decreases downstream flow, which coupled with the widespread usage of agrochemicals (as is the norm in present intensive arable-farming) plausibly occasions longer residual time of the pollutants that seep into these environments: a tradeoff at different spatial and/or temporal scales is thus generated. Suffice that, land-use/tenure and conservation policies have inadvertently created ecoservice-tradeoffs as regards the wellbeing of Maasai's livelihoods and of wild faunas across these rangelands.

Collectively the findings of this study reveal that the drivers of the manifest ecoservice-interactions are diverse and closely interlinked and include the specific mode of resource governance, land-use change, environmental changes, the way ecoservice is used, and types of stakeholder involved. As climate continues to change, amidst shifts in various social-biophysical conditions, the starkness with which the impaired ecoservices and dominance of ecoservice-tradeoffs becomes clear. Therefore, the need for informed understanding of pathways toward achieving sustainability of ecoservices, and of the associated livelihoods and wildlife, cannot be overemphasized. The current study reveals that it is through simultaneous assessment and systematization of the causal and proximate social-biophysical conditions linked to the presently pressing ecoservice-interactions, and their various links, that informed goals can be set, critical indicators defined, and evaluation and prioritization of plausible interventions made.

4. CONCLUSIONS, EMERGING THEMES, AND RECOMMENDATIONS

4.1 Conclusions and Emerging Themes

The current study engaged the *Drivers-Pressures-States-Impacts-Responses* (DPSIR) model to integratively and simultaneously examine the causal social-biophysical components and links driving shifts in the interactions of livelihoods and terrestrial wild faunas via ecosystem services (ecoservices) across the Maasai-inhabited savanna rangelands of Kenya. Challenges enfeebling livelihoods, threatening wildlife, and impairing ecosystem services, and the plausible scenarios under changing social-biophysical conditions, and practical interventions were explicated. The study reveals that livelihood strategies/diversifications contextually interact with diverse social-biophysical conditions,

particularly those related to land-use/resource-extraction, to occasion diverse and shifting ecoservice-interactions. Contextual ecoservice-interactions are evident in traditional and emerging livelihood strategies of the Maasai people, with sharing of provisioning ecoservices predominating in the former; emergence of heretofore rarely-extracted ecosystem goods become evident as livelihoods increasingly diversify. Critical rangeland resources (CRR) and land-space constitute the key shared resources *vis-à-vis* Maasai livelihoods and wild faunas. The study indicates the existence of nuisance lions as a human generated reality. The predominance of tradeoffs *vis-à-vis* the shared ecoservices among Maasai livelihoods and wild faunas is revealed. In these rangelands, faunas under similar ecological-gild and/or trophic-level reveal predominance of ecoservice-tradeoffs: that is in social-ecological terms. Collectively, the predominance of tradeoffs is linked to challenges associated encroachments of various land-use/resource-extraction types.

The study indicates that under recurrent and extreme droughts occasioned by climate change, the existing ecoservice-tradeoff between water needs for arable-farming and livestock, and amongst water-dependent ungulates will, *ceteris paribus*, intensify. Similarly, intensified ecoservice-tradeoffs among wild and domestic faunas under similar ecological-gild and/or trophic-level will plausibly unfold under that scenario. Under the same scenario, lion's predation on Maasai's livestock will intensify; and *ceteris paribus*, increased retaliatory killings of the nuisance terrestrial wild faunas will ensue.

The future state of livelihoods and of terrestrial wild faunas is closely hinged on ecoservice types and the intensity and rapidity with which they are exploited. Worth pointing out, although the links of the changing climate, the state of livelihoods, ecoservices, terrestrial megafaunas, and associated governance institutions and structures is intricate, the generated states and impacts are easily explicable via existing and underlying links. Collectively, the generated ecoservice-interaction is dictated by the way the relevant ecoservices are experienced, accessed, controlled, managed (and changed) by diverse stakeholders. Thus far, it is clear: persistent shifts in cross-scale social-biophysical conditions will alter, and are altering, in ways yet unknown, the existing ecoservice tradeoffs/synergies, and therefore the very sustainability of the Maasai's livelihoods and the survival of terrestrial wild megafaunas.

From the current study, the strengths of the DPSIR model are clear: it simultaneously captures cross-scale drivers and pressures, incorporates the various existing states and the associated causal-links into cross-scale concerns of livelihoods and terrestrial wild faunas. It informatively guides in simultaneously identifying practical interventions and priorities toward achieving sustainability of ecoservices and of linked livelihoods and terrestrial wild faunas. Moreover, the study reveals that, by using the DPSIR model, feasible solutions to the existing critical concern of achieving sustainability of ecoservices and of the linked livelihoods and wild fauna biodiversity across these rangelands is decipherable by unveiling the actual location and causal-links of the existing discordant emanations: this is achievable by first unraveling the types and dynamics of cross-scale social-biophysical drivers and pressures linked to the disharmonious relations among land-/resource-users, both man and fauna, and/or of impaired integrity of ecoservices. From the foregoing, the DPSIR model thus suffices as a practical tool to guide and support diverse stakeholders in understanding and managing existing disharmonies in coupled socio-ecological systems such as those exemplified across the Maasai-inhabited savanna rangelands of Kenya. Collectively, the current study reveals that it is through simultaneous assessment and systematization of the causal and proximate social-biophysical conditions linked to the presently pressing ecoservice-interactions that informed goals can be set, critical indicators defined, and evaluation and prioritization of plausible interventions made.

4.2 Specific Recommendations

As the climate continues to change, amidst the rapid permeation of diverse social-biophysical pressures, the existing ecoservice-interactions among Maasai's livelihoods and terrestrial wild faunas will variously shift, with plausible predominance of ecoservice-tradeoffs. Therefore, interventions

toward ensuring sustainability of ecoservices and of linked livelihoods and wild faunas should simultaneously be adaptive to shifts in those interactions and to the changing geography of the various social-biophysical landscapes. Moreover, since the various ecoservices buttressing the proper operation of the Maasai's core livelihood strategies/diversifications also buttress the very survival of terrestrial wild faunas, those interventions should, therefore, be place-based, cross-sectoral, and aligned with or mainstreamed into the existing policies/practices. Additionally, since LUC is a dominant causal factor occasioning shifts in interactions of Maasai's livelihoods and wild fauna, it suffices that it's by assessing the drivers of LUC and the associated pressures linked to Maasai-wildlife interactions that informed interventions can be made.

Apropos the present increased megacarnivores predation on Maasai's livestock and the intensified CRR competition among livestock and wild ungulates, practical interventions are those that simultaneously incorporate the needs of various land-/resource-users, while simultaneously accounting for the spatiotemporal variability and accessibility of the shared ecoservices. Concerning the evident retaliatory killings of lion (*P. leo*), an urgent need exists for the state to recast this megacarnivore, and indeed other nuisance wild faunas as assets to the Maasai people; and to disclaim them as pests (i.e., wild faunas not the state). Regarding the increased lion's predation on Maasai's livestock, and *ceteris paribus*, the consequent increased retaliatory killings of this megacarnivore, under the scenario of recurrent/extreme droughts, practical interventions entailing a paradigm shift from the relevant existing policies/practices (e.g., regarding conservation, natural resources extraction) to incorporate the causal-links of the persistent human-wildlife conflicts, and to embrace a system approach becomes crucial. The urgency with which such practical interventions should be implemented, particularly as regards the menaces associated with wild faunas (e.g., predation, attacks, and transmission/spread of diseases and pests), in the context of the existing complex socio-ecological systems, cannot be overemphasized. The need for such paradigm shift become crucial, because, as this study reveals, the various ecoservices buttressing the proper operation of the Maasai's core livelihood strategies/diversifications also buttress the very survival of wild faunas dispersed across these rangelands.

The revealed nexus of Maasai livelihood strategies/diversifications and terrestrial wild faunas via ecoservice-interactions, particularly in the context of sustainability/vulnerability dichotomy, is clearly informative towards the formulation of practical interventions. The current study provides an important entry point for practical policies/practices *vis-à-vis* that nexus if effective mitigation of and/or adaptation to the deleterious impacts of climate change, and of diverse social-biophysical conditions, is to be achieved. Therefore, interventions that anticipate achieving sustainability of ecoservices and of linked livelihoods and wild fauna across these rangelands should account for that nexus. The DPSIR model provides a practical framework by which to explore the interactions of traditional and emerging livelihood strategies/diversifications, economically important terrestrial wild vertebrate fauna, and shared ecosystem services across the Maasai-inhabited rangelands; to unveil the cross-scale social-biophysical drivers and pressures, and the causal-links thereof, occasioning those disharmonious emanations and indeed other persistent critical challenges; and to devise informed interventions.

Worth pointing out, the cornucopia of existing documentations regarding human-wildlife interactions *vis-à-vis* these savannas need to be located, systematized, and pooled together for the purposes of informing such interventions, and indeed to curate resources that would facilitate swift adaptive research, policy and/or capacity-building initiatives. Consequently, effort to benchmark for ecologically and socioeconomically desirable (best practices) livelihood strategies/diversifications, and natural resources management *vis-à-vis* these rangelands becomes necessary. This necessity becomes imperative because the potential future of the existing core livelihood strategies/diversifications, key ecoservices, and wild fauna under different projections and scenarios of climate change and shifts in various sociopolitical and socioeconomic landscapes remains poorly understood and scantly documented.

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As per international standard or university standard ethical approval has been collected and preserved by the authors.

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