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Importance of Livestock Production from Grasslands for National and Local Food and Nutritional Security in Developing Countries

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ABSTRACT

Grazing lands cover more than a quarter of the world's land surface, often on land that is unsuitable for other forms of use. Despite the perception that productivity is inherently low, the contribution of grasslands in food security in developing countries is significant. However the challenges of spatial and temporal variability of primary productivity need to be managed and mobility of livestock is key to this. Appropriate land management and governance arrangements are essential for facilitating this mobility and for creating the circumstances in which technical options for reducing variability and risk in livestock keeping can be deployed and to allow more commercially-oriented systems to develop.

Key Words: Rangelands, pastoralism, land management, food security

Introduction

Land grazed by animals covers 32 million km^2, more than a quarter of the earth's land surface and pastoralism is the most widespread human land-use system on earth. With increasing population growth and associated food demand, FAO (2009) projects the world will need to increase food production by 70 to 100% by 2050. Livestock contribute about 12.9 percent of calories and 27.9 percent of protein directly to global diets, through provision of milk, meat, eggs and offal (FAO 2011).

The main message of this paper is that biomass availability controls milk production in rangeland systems and hence the rest of this paper focusses on management of grasslands. In particular we discuss the challenges and opportunities for managing the contribution of grasslands to food security. We first discuss the myth that pastoral systems are inherently unproductive and cannot contribute to food security. Second we discuss how the high variability in many grasslands is challenging from a management perspective but also makes them supremely suitable for extensive livestock production. Third we discuss longer term trends in net primary production in grasslands, as this is the chief source of feed for livestock produced in them. Fourth we highlight three interventions to ensure that grasslands are managed sustainably in the future.

The myth that pastoral systems are unproductive and cannot contribute to food security

In regions such as East and West Africa, milk and meat from pastoral systems contribute to both domestic and regional food availability. In West Africa, 32% of the livestock produced in the region are from pastoral (rangeland) systems. There is large scale movement of animals from the Sahel to the large population centres on the coast. In countries with extensive rangeland areas, such as Kenya, 80% of all red meat produced in the country is raised in rangelands, and this production accounts for 13% of agricultural GDP. The estimated 47 million people across Africa who raise livestock in these rangelands depend primarily on milk for domestic food security, and indeed raise their animals primarily for milk production. The value of this milk is more difficult to capture as most of it is consumed within households but it is likely double the value of meat (Barrow and Mogaka 2007). Several studies in the Horn of Africa have demonstrated the crucial impact that milk consumption has on the welfare of pastoral children in particular. The most comprehensive review on this topic (Sadler, Kerven et al. 2010) documents the importance of milk for pastoralists, including the strategies they use to manage production from different species over the seasons, given the variable climate conditions and forage availability.

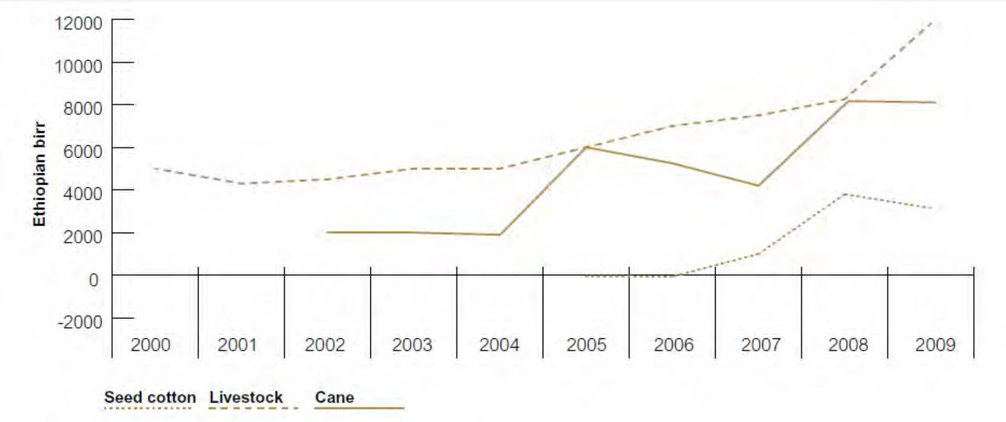

Fig. 1. Revenue per hectare from livestock, cotton and sugar cane in Awash Valley, Ethiopia. (Behnke and Kerven, 2013).

While many, including influential decision makers, regard pastoralism as an outdated and unproductive form of land use that does not contribute to food security or economic development this is far from the truth. The value of production in grasslands tends to be underestimated in many countries. Often grasslands are viewed as available for expansion of the area used to grow crops; however this ignores the importance of the livestock production that takes place across these grasslands. The study by Behnke and Kerven (2013) showed that compared to growing cotton or sugar cane under irrigation livestock production from pastoralism generated more income (Figure 1).

Table 1. Livestock exports from Ethiopia

Year	Live animals	Value (US $ '000)	Meat (t)	Value (US $ '000)
2005-06	163,000	27,252	7,717	15,598
2006-07	234,000	36,507	7,917	18,448
2007-08	298,000	40,865	5,875	15,471
2008-09	150,000	77,350	6,400	24,480
2009-10	334,000	91,000	10,000	34,000
2010-11	472,000	148,000	16,877	63,200
2011-12	800,000	207,100	17,800	78,000
2012-13	680,000	150,000	16,500	68,000

Source: National Bank of Ethiopia

In addition the livestock sector is changing rapidly in the region with a growing demand for meat both domestically and for export (Table 1) most of which is supplied from pastoral areas. This growing demand is driving a shift in these systems to be more commercially oriented.

Variability in net primary production at national and local scales

One of the key features of grasslands is their spatial and temporal variability and heterogeneity, a result primarily of seasonal and interannual climate variability. Precipitation is both low (ranging between 200 to 600 mm annually) and highly variable. As precipitation is the primary limiting factor, vegetation growth closely follows rainfall amount, frequency and duration (Vetter, 2005). Understanding this is critical to making recommendations for management, and also understanding processes of land degradation. This reality has led to the so-called "non-equilibrium" theory of rangelands, which recognizes that livestock populations will rarely reach "equilibrium" levels given the high variability, and so rangelands must be managed for this variability. Mobility of animals to find grazing area and water is considered key.

The relation between above ground biomass production and rainfall is about 8 kg/ha for every mm of rainfall above 20mm in East Africa (Deshmukh, 1984, p181). Availability of forage and shortages (whether from drought, constrained access or change in palatability, as well as differences in soils) are the primary driver of variability in livestock production in pastoral areas, and most rangelands include a mix of vegetation types and levels of productivity.

In severe or prolonged droughts, forage and water scarcity combine to lead to increased livestock mortality rates. Nkedianye et al (2011) report mortality rates of 14-43 per cent in southern Kenya in 2005, while livestock losses were as high as 80 per cent in 2009. Huho et al (2011, p780) cite 30 per cent losses in 2001 and losses in Northern Kenya of 30-40 per cent of cattle and sheep/goats in 2005. Figure 6.2 shows for Kajiado, Kenya, the relationship between total livestock biomass and normalized difference vegetation index (NDVI) to assess how droughts affect livestock populations. Total biomass was surprisingly poorly related to short term variation in NDVI, which is a good indicator of drought, but related very well to a five year running average of NDVI.

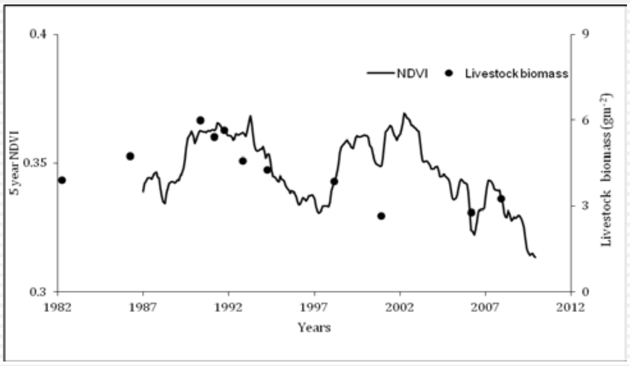

Fig. 1. Relation between total animal biomass (dots, g/m2) and the five year running average of NDVI from 1987 to 2009, Kajiado district, Kenya. A livestock biomass of 6 g/m2 corresponds to a stocking density of about 1 tropical livestock unit (TLU)/4 ha. Source: unpublished International Livestock Research Institute (IRLI) and Department of Resource Surveys and Remote Sensing (DRSRS) data.

Livestock population dynamics in such areas are therefore not only determined by short-term losses of livestock during drought, but also track the history of resource availability over a longer time period. For example, given low reproduction rates, it may take four or five years for a herd of cattle to recover after a major drought. Data from the Kadjiado rangelands show cycles of livestock biomass, connecting to El Niño events in 1989, 1998 and 2006, with peaks of one Tropical Livestock Unit (TLU) per four hectares and troughs of one TLU per eight hectares. Higher forage availability around El Niño or other wet years (reflected in NDVI measures) results in livestock population growth and so a phase of higher livestock biomass density. However, this pattern did not occur following the El Niño year of 2006. But this event was preceded and then followed by severe droughts that lasted more than one rainy season. This rapid succession of droughts, although interrupted by an El Niño year, kept the livestock population in a low biomass phase. The cattle in Kadjiado district were severely affected by the 2008–09 drought with an estimated mortality of 70 to 80 per cent (Worden, pers. comm.). Such mortality would have reduced the livestock biomass further to around 1 g/m^2, or one TLU per 25 ha, the lowest stocking density in memory. By contrast, for Laikipia in northern Kenya, the relationship between livestock biomass and NDVI was better for a two, rather than five, year running average (International Livestock Research Institute (ILRI) unpublished analysis). All this suggests that multiple factors, such as herd composition, access to remote grazing areas, as well as stocking densities and migration from other areas, affect the NDVI and population density relationship (Nkedianye et al, 2011).

Net primary productivity in grasslands: Africa trends and future scenarios

Understanding and tracking the condition of grasslands, including degradation and rehabilitation, is a difficult task. Grasslands and associated rangeland ecosystems cover large areas, with drylands accounting for nearly half of global terrestrial land cover (White et al. 2002). Both field monitoring and remote sensing face several challenges, for example the complexity of speciose wetter savannas and the low and transient productivity of arid systems (Wessels et al. 2007). Even if these difficulties are surmounted, the long timescales over which degradation and rehabilitation occur, and the different time-scales of management and climatic drivers (Ruppert et al. 2012) remain. Finally, the establishment of unequivocal baselines for high quality rangeland condition is frustrated by various global rangeland change drivers, the relative importance of which remains controversial and poorly understood (D'Odorico et al. 2015).

In recent decades climatic associations with degradation have become well established, namely the greater susceptibility of wetter, less variable equilibrium rangelands to management-induced degradation (especially overgrazing) than drier, more variable non-equilibrium rangelands (von Wehrden et al. 2012). But clearly, management is not the only factor driving degradation trends. Beyond overgrazing and fire suppression, increases in temperature and atmospheric CO_2 concentration and declines in the populations of shrub-browsing wildlife may each play significant roles in global changes in rangeland condition.

Recent simulations using the G-Range global rangelands model (http://www.nrel.colostate.edu/projects/grange/index.php), a modified spatial implementation of the well-known CENTURY model (Parton et al. 1993), indicate potential effects of various climate and CO2 change scenarios on the production capacity of rangelands in East Africa and the Greater Horn of Africa. Currently, hyper-arid to arid rangelands (desert, dry shrubland, semi-desert, and arid grasslands) contribute over half of forage production (4,383,581 t/yr) in the region, while semi-arid savannas produce most of the remainder (3,180,683 t/yr) (Table 2). While semi-arid savannas comprise both equilibrium and non-equilibrium rangelands, arid and hyper-arid systems are firmly the latter.

Under a specific scenario using the Hadley general circulation model (HadGEM2-ES; Collins et al. 2011) under Representative Concentration Pathway 4.5 (Moss et al. 2007) to represent changes in global climate and CO_2 concentration, for example, in the coming decade production of herbaceous forage is forecasted to decline by nearly 2 per cent (~74,000 t/yr) in hyper-arid and arid rangelands of East Africa and the Greater Horn (Table 2). Under the same scenario and timeframe, forage production in semi-arid savannas is similarly forecasted to decline by nearly 2 per cent (~63,000 t/yr) in the region. The major drivers behind these shorter-term changes are precipitation and temperature forecasted by HadGEM2-ES, especially since no changes in management were parameterized.

However, by around the year 2040, hyper-arid and arid rangelands are forecasted to rebound to nearly 2 per cent (~72,000 t/yr) above their current capacity to produce herbaceous forage. A less impressive recovery is forecasted in semi-arid savannas, in the vicinity (within 0.25 per cent) of current levels. The positive longer term responses can be largely explained by the likelihood of stable or increasing precipitation in the region, in spite of higher temperatures. Perhaps just as importantly, increasing atmospheric CO_2 concentration may largely account for the positive response in herbaceous forage production in hyper-arid to arid systems. If shrub encroachment is underestimated by these simulations, the outcome may be less positive, since shrubs may benefit more from increasing CO_2 than grasses, though grasses also benefit.

Table 2. Forage production projections from the G-Range global rangelands model for arid systems and semi-arid savannas in the Greater Horn of Africa

	Area, millions km²	Forage production, millions t/yr		
		Baseline 2006-15	Change 2016-25	Change 2036-45
Hyper-arid to arid	2.68	4.38	-0.07	0.07
Semi-arid savannas	1.97	3.18	-0.06	-0.01

In East Africa and the Greater Horn, consistent or increasing long-term average precipitation is likely to stabilize the production potential of rangelands in the region. As such, future decades do not appear entirely bleak. However, long-term trends are of little comfort to this affected by a major drought. Bad periods are going to happen, and need to be prepared for. Since management change is not reflected in the results presented here, management can either enhance or compromise these productivity trajectories. Effective rangeland management has a key role to play, especially where climate poses risks to rangeland productivity, often in equilibrium systems more susceptible to degradation on account of unsustainable intensification.

Interventions to enhance role of grasslands in food security

Governance solutions

One of the central lessons from grazing systems around the world is to maintain mobility. Resting the land, allowing regrowth to occur, is a primary mechanism underpinning the productivity of livestock systems ranging from private, intensive rotational grazing to communal, extensive nomadic pastoralism. A primary difference between these two extremes of system configuration is that the transaction costs required to negotiate and maintain livestock movements in communal systems—and thus resting of the land as well—are non-existent in private landholdings large enough for commercially viable grazing.

In East African pastoralist and agro-pastoralist settings, and many areas elsewhere, mobility is constrained by land use patterns and the negotiation of grazing rights, among other factors such as conflict and disease. The probability of degradation occurring is much higher in wetter equilibrium systems (von Wehrden et al. 2012), due not only to their ecological vulnerability, but also higher population density, higher stocking potential in wet years, attractiveness as parks, and potential for irrigated cropping (Reid, 2012). This litany of threats to livestock mobility and grazing access can together create biophysical conditions leading to severe land degradation. Though equilibrium systems are more susceptible, both wetter and drier rangelands can become degraded by overgrazing. Site-specific conditions such as soil type, plant species and plant community responses to grazing, landscape position, and topographical factors (e.g., slope) may each contribute to degradation risk.

However being able to move herds, sometimes long distances, is key to livelihoods and the ability to convert biomass production for human needs, particularly in non-equilibrium systems. Pastoralists herd management strategies in such settings emphasize the maximization of herd size when rainfall is good, minimization of losses during droughts, and rebuilding herds after losses (Robinson and Berkes 2010). Traditional pastoralist institutions were also adapted to these kinds of dynamics, emphasizing *access* to pasture resources over *ownership* and *management* of those resources (Robinson 2009). The unique characteristics of arid and semi-arid grassland environments have often not been appreciated in the design of policies, development programs and other interventions by external agents. The history of land tenure, governance, and institutional development in pastoralist settings is littered with examples of changes that reduced pastoralist mobility to the detriment of both livelihoods and rangeland condition. The particularities of grasslands and the requisites of the institutions needed to manage them seem to have been underappreciated by social scientists as well. It has been suggested, for instance, that some of the design principles for resource management institutions which emerged from the work of Elinor Ostrom (e.g., Ostrom 1999), such as the need for clearly defined boundaries—principles which have greatly influenced the design on community-based natural resources management programs in developing countries—do not apply to these kinds of systems in a straightforward way (Niamir-Fuller 1999, Moritz et al. 2013).

As suggested previously in this paper, the non-equilibrium paradigm should not be assumed to imply that human management can have no impact on grasslands and their net primary productivity. Pastoralist institutional systems were adept at maintaining net primary production, but not necessarily at proactively improving it. With the growth of human populations and the legitimate desire of dryland peoples for development and prosperity, the need for improving productivity of grasslands and increasing the contribution of grasslands to food security is great. Technical options for improving the productivity of grasslands do exist, although in many settings, these will have nothing to do with manipulation of gross stocking rate and attempting to match livestock numbers to some idea of carrying capacity. For the design of institutions which can enable appropriate technical management options, a key challenge is to ensure that the tenure and other institutions do not inappropriately restrict mobility. Attempts to create tenure and resource management systems that are appropriate to these dynamics are often stymied by what has been called "the paradox of pastoral land tenure": "How to define spatial and social boundaries around resources and user groups in situations where spatial and social flexibility are intrinsic and essential characteristics of resource use patterns?" (Fernandez-Gimenez 2002: 50). The definition of such boundaries and the securing of pasture resources from conversion to other uses and securing the rights to manage that resource are crucial to any management approaches that would attempt to maintain and improve net primary production in grasslands. Devising mechanisms to achieve this without unduly restricting the access and flexibility that is needed has proven elusive.

An important emerging research question is: What kinds of institutions can overcome the paradox of pastoral land tenure and enable effective management of grassland productivity?

Interventions to protect assets

While efforts at promoting community-managed governance structures that improve availability of and access to dryland grazing are critical, even the best organized systems for maximizing forage provision are vulnerable to the inevitable incidences of severe drought that leave vast swaths of the rangelands bare of sufficient forage to sustain available herds. These severe droughts, which result in widespread herd losses, can have a devastating and hard to reverse impact on pastoralist households who largely rely on livestock as their main source of livelihood, income, and nutrition. Where at least 75% of pastoralists obtain more than half of their income from sales of livestock and livestock products as well as from the home-consumption of livestock products (McPeak et al., 2009), the impact of droughts that cause a considerable spike in livestock mortality, greatly diminish the productivity of the surviving herd, and prompt a collapse in livestock prices, is considerable. Not only do affected households lose a key source of their nutrition as the availability of milk from their livestock dries up, but the considerable reductions to their income, and the unfavorable terms of trade they face, significantly heightens the food insecurity they face.

For this reason, pastoralist populations have generally been the greatest recipients of food aid. For example, in Northern Kenya, food aid receipt tops the list of interventions that households have had experience with and, for at least 25 per cent of the population, food aid comprises a quarter of their total income (Mcpeak et al., 2009). The provision of food aid however, is increasingly recognized as a costly and reactive intervention, and an inefficient means of ensuring food security (Maxwell et al., 2009; Barret et al., 2009). Pastoralists themselves, despite consistent receipt of food aid and on-going food insecurity, rank food aid as a low-priority welfare-improvement interventions (Ouma et al., 2011).

As a more proactive and development-oriented approach to helping pastoralists manage the drought-related livestock mortality risks that they faced and thus enhance their food security, an innovation capable of extending the risk-management benefits of insurance to pastoral populations has been successfully piloted in Kenya and Ethiopia and now being scaled out. By bypassing many of the transactions costs that limit the provision of regular insurance to environments such as the arid and semi-arid rangelands, index insurance makes it feasible to provide insurance coverage in instances in which it would otherwise be too costly. Under the index-based livestock insurance project (IBLI), launched in 2008 by the International Livestock Research Institute and partners (see http://ibli.ilri.org for range of information and publications based on the program), insured pastoralists receive a pay-out based on predicted livestock mortality, which is determined as a function of satellite-derived estimates of seasonal forage availability (Chantarat et al. 2013; Mude at al. 2012)

A rigorous research agenda aimed at assessing the impact of IBLI indicates a range of favorable impacts (Jensen et al. 2015). Among them are effects on household welfare directly linked to food security and highlighting the positive role IBLI could play in improving post-drought coping. As Janzen and Carter 2013 show, households with IBLI coverage experienced a 25% reduction in the likelihood of reducing meals as a coping strategy, especially (45%) among poorer households. In addition, IBLI resulted in a 36% reduction in the likelihood of distress livestock sales among insured households. IBLI has also shown to have a positive impact on improvements to mid-upper arm circumference (MUAC), a strong predictor of child malnutrition.

As the IBLI program evolves, revisions in contract design to try and intervene *before* loss in an effort to protect livestock assets have become more popular. While there exists a clear logic to the preference for asset protection vis-à-vis asset replacement insurance, the impact of such contracts would be limited by incomplete markets for feeds, forages and other critical livestock inputs in the rangelands.

Forage availability receiving growing recognition from donors as key to enhancing livestock production

As we have discussed, forage availability is the key driver of livestock density and productivity. Attempts to increase availability by introducing improved forages with higher levels of productivity or to introduce forage conservation strategies during times of surplus for use in times of scarcity have met with very limited success in dryland pastoral systems in Africa, unlike in more intensive, market oriented mixed crop-livestock systems or commercially oriented pastoral systems in some other parts of the world. However with growing interest in commercializing rangeland livestock production systems, as evidenced by for example, the growing export of livestock from the Horn of Africa, the interest in enhancing forage availability through new technologies such as introduction of drought tolerant forages and forage conservation techniques is growing.

Concerns, both valid and misguided, about rangeland degradation and "over-stocking" are combined with recognition that support for livestock production is a critical strategy to build resilience and lead to economic growth in extensive systems.

Dramatic restoration successes demonstrated through bunching animals and allowing them to graze intensely for a limited period before moving on, often referred to as holistic grazing management (Savory and Parsons 1980), may hold promise as a means of creating and maintaining productive communal rangelands but the approach remains controversial and has not been sufficiently validated by independent research. If elements of the holistic grazing approach can be borrowed while at the same time minimizing transaction costs, it seems likely that stepwise progress can be made toward effective distribution of grazing pressure in space and time. Even loosely planned grazing can allow some time for the land to rest. Retaining even small amounts of forage biomass enables faster regrowth, and improves infiltration, a significant constraint on clay dryland soils (Noy-Meir 1973). Fire management, too, deserves attention for inclusion in any grassland management toolkit, as appropriate, well-timed burns can control woody plants and improve forage production and quality with net neutral effects on soil quality (Aynekulu et al. 2014). Much of this work is new, and needs research investment not only to technical solutions but also in the governance issues raised above that will affect their adoption.

Much of this work is new, and needs research investment not only to technical solutions but also in the governance issues raised above that will affect their adoption.

Conclusions

The vast proportion of the world's land surface which are grasslands, the sheer number of the world's people who live in and depend on these grasslands, the need to feed a growing global population in part from production on these grasslands, and the significance to the world of potential environmental degradation on these grasslands, converge to highlight their importance. While the task of increasing livestock production in grasslands faces challenges, there are significant opportunities to improve management and productivity. Effective rangeland management will be the key to achieving such improvements, but this in turn will depend on innovative and effective local and landscape level governance arrangements and enabling policy environments. The latter, in particular, has been quite rare.

However, while effective rangeland management is necessary, it will not be sufficient to maintain productive rangelands in food-insecure regions. Technically effective rangeland management is futile during times of major drought, and when institutions are not up to the task. Drought response strategies, supplementary fodder systems, and livestock insurance can all play essential roles not only in thwarting food security crises, but also in preventing episodes of severe degradation. The role of livestock markets, fodder markets, livelihood diversification, and programs such as asset protection insurance have a role to play in how herds and the rangelands on which they depend are managed. These kinds of interventions can each individually contribute to improved production, more prosperous livelihoods, and national and local food security; however, the greatest potential lies in the synergies amongst them.

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