Livestock feed constraints in East Africa: spatialized metrics for availability and quality

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Abstract

The availability and quality of livestock feed are critical constraints to effective ruminant animal husbandry in sub-Saharan Africa (SSA), including East Africa. Progress has been made on feed option prioritization approaches at local level, notably through the development of the Feed Assessment Tool (FEAST). Based on the FEAST approach, we produced spatialized metrics of overall feed availability, seasonality and feed quality. These metrics were developed based on existing land cover, crop type, phenology and primary productivity spatial layers. The feed constraint metrics developed in this study are most relevant to humid and temperate locations that are dependent on local resources and as such we have excluded arid and semi-arid lands from our analysis. The feed constraint maps developed in this study will help decision makers to direct their livestock feed interventions to East African locations most in need.

Introduction

Livestock are kept by many farming households in East Africa and livestock play a central role in supporting household livelihoods through provision of income and nutrition. However, livestock productivity is generally low and as urbanization and population growth create increasing demand for livestock products, the current systems will need to undergo major changes to be able to sustainably produce enough to meet demand. Arguably the main limitation of the East African livestock sector is livestock feed supply. Livestock are generally fed opportunistically on seasonally available feed and often at levels far below productive potential. Increasing feed intake and feed quality through improved feeding strategies could be transformational for livelihood, nutritional and environmental outcomes of the livestock sector in East Africa, particularly in humid and temperate locations. Unfortunately this ambition is yet to be realised.

There are many options for improving livestock feeding. These include: use of planted forages, multi-purpose trees, feeding of commercial concentrates, preserving feed through hay and silage making, treating of crop residues to improve their quality and many more. Despite ample technical knowledge and promotion on the use of these improved feed options, their uptake by smallholder livestock keepers has been disappointing. Part of the reason for poor adoption has been the mismatch between what feed options offer and what the farmer requires. For example, in a feed scarce environment such as the Ethiopian highlands the main need is simply for adequate biomass so options that mainly offer incremental improvements in feed quality are unlikely to succeed. The idea of matching different feed options to local conditions has been the basis for development of feed targeting tools such as FEAST and Techfit (Duncan et al. 2012). These tools help farmers and local stakeholders to think through the suitability of available feed options for their own situation. However, such tools, although useful, require time and resources to implement and are prohibitively expensive to apply at scale. As a complement to the use of these tools, decision makers would benefit from having metrics which represent the severity of feed constraints across a wide spatial scale. Here we propose a new approach which involves processing a series of spatial layers to develop spatialized metrics of core feed constraints: total availability, seasonal availability and quality.

Methods

Concept

The approach draws on the concepts used to prioritize feed technologies at local level using a tool known as Techfit, which was developed in a cross-institutional collaboration of feed experts from across the world. The experts identified candidate feed technologies suitable for livestock keepers in low- and middle-income countries. Examples of technologies are: grasses for cut and carry, dual purpose legumes, hay making and multi-purpose trees for forage. Livestock feed experts scored each feed technology on the extent to which they can deal with each of three core feed constraints. These constraints are defined as (1) quantity: the amount of feed available per unit of livestock (2) seasonality: how much feed availability varies by season and (3) quality:

the overall nutritive value of feed available. Techfit also considers five enabling characteristics to evaluate technologies: availability of land, agricultural production potential, access to piped or standing water, access to capital, knowledge/skill, and input availability. Techfit eventually formed the basis for the feed option ranking method in FEAST approach. The logic is scalable and we are now developing regional “feasibility surfaces” for different feed options by mapping system constraints and enabling factors using global/regional data sets. In this study, we focus on spatializing the three feed constrains used in the Techfit approach. We limited the scope of evaluation to intensive and mixed crop-livestock systems in humid and temperate locations in East Africa– comprising 33 percent of the land area in that region.

Feed constraints

Monitoring feed availability, feed seasonality and the quality of feed composition are complex tasks, requiring information on biomass production, biomass allocation, purchasing power, animal husbandry decisions and animal density. Furthermore, all of these aspects are dynamic, changing over the course of a year. This complexity makes monitoring these feed conditions at wide spatial scales intractable. Instead of directly monitoring these feed conditions, we developed proxies based on the availability and composition of feed resources using remotely sensed and other spatialized data. We derived three proxies: animal edible dry-matter production per hectare, coefficient of variation of feed production and annual average crude protein (CP) as proxies for our three core feed conditions.

Proxies for animal feed conditions were derived based on estimates of land use, dry matter production (DMP), grass species type, modelled crop type and the location of protected areas. It was assumed that 66 percent of edible crop DMP was available to ruminant animals as crop residue. For grassland, it was assumed that all DMP was available for feeding and that 10 percent of DMP is usually extracted as animal feed resources from non-protected forests. The initial processing steps resulted in an estimate of edible DMP every 10 days over the year. The mean and coefficient of variation (CV) of edible DMP was then calculated from these data.

Annual average crude protein was calculated as a proportion of the total dry matter production. The calculation was based on feed basket proportions, grass type and mean crude protein content from measured feed composition values. The feed basket for a given location was determined by the proportions of grass DM and crop DM described above, as well as the grain percentage estimates by livestock systems presented in Herrero et al. (2013). The proportion of C4 and C3 grasses were extracted at a 50km resolution from the ‘present vegetation’ layer developed by Wei et al. (2014). Mean CP for a representative of each feed type was extracted from a regionally specific feed composition database. Aggregate feed basket CP percent was estimated using these representative values, weighted by the feed basket proportion.

In order to identify the occurrence of the three feed constraints, we categorised each proxy based on implications for livestock productivity. Locations were classified as having feed constraints when proxies were below threshold values that would result in limited livestock populations (due to annual feed availability) sub-maintenance feeding or stocking density decrease (due to feed seasonality) or suppressed feed intake (due to protein limitations). Daily DMP was used to identify locations at risk of sub-maintenance feeding, where a DMP of 8 tonnes per year was considered to be limiting for dairy production (below threshold of ‘poor’ forage yield used in Moran, 2005). DMP CV was taken as a risk factor for sub-maintenance feeding in the dry period, where a value of 30% has been estimated to reduce mean stocking rates proportionally (Goode et al. 2019); we argue that this level of variability in feed availability would limit the viability of rearing replacement stock for small-holder farmers. The threshold value for feed quality was set at 8% CP of DM, where feed quality below this threshold will limit a ruminant’s intake due to decreased rumen microbial activity and slower passage (Allison 1985; thresholds presented in Table 1).

Table 1. Feed condition proxies and feed constraint thresholds

	Feed condition proxy	**Constraint Threshold**	**Productivity implication**
Feed availability	Animal edible dry-matter production (tonnes DM ha^{-1} $year^{-1}$)	$8 \geq x \geq 0$	Limited livestock populations
Feed seasonality	Mean stocking density decrease (cows ha^{-1} $\downarrow$ / DMP ha^{-1} CV)	$x > 30$	Sub-maintenance feeding/herd dynamics
Feed quality	Protein requirements (CP % DMP)	$8 \geq x \geq 0$	Suppressed feed intake

Results

Feed constraints in East Africa

Feed availability was a constraining factor for the majority of the study area. Thirty-four percent of land area was constrained in feed availability (beyond threshold), of which 45 percent of the constrained land area was located in Tanzania, and 40 percent in Ethiopia. At a country level, constrained feed availability affected over 40 percent of the studied land area in Tanzania, 37 percent of Ethiopia, 28 percent of Uganda, 19 percent of Kenya and less than 10 percent of Rwanda and Burundi (Fig 1a).

Feed seasonality was also a widespread constraining factor in the study area – presenting risks of sub-maintenance feeding for part of the year. Sixty-three percent of land area was constrained in feed seasonality, of which 48 percent of the land area was located in Ethiopia and 40 percent in Tanzania. At a country level, feed seasonality constraints occurred in 82 percent of the studied land area in Ethiopia, 71 percent of Tanzania, 42 percent of Kenya and 33 percent of Uganda. Feed seasonality constraints beyond the threshold value occurred in less than 8 percent of studied land area in Burundi (Fig 1b).

Feed quality was less prominent as a constraining factor in many locations. Twelve percent of land area was constrained in feed quality, with 50 percent of the land area being located in Uganda and 37 percent of land area in Tanzania. At a country level, constrained feed quality occurred in 64 percent of the studied land area of Uganda, 19 percent of Kenya, 13 percent of Tanzania and 4 percent of land area in Burundi. Feed quality constraints beyond the threshold value occurred in less than 2 percent of land area in Rwanda and Ethiopia (Fig 1c).

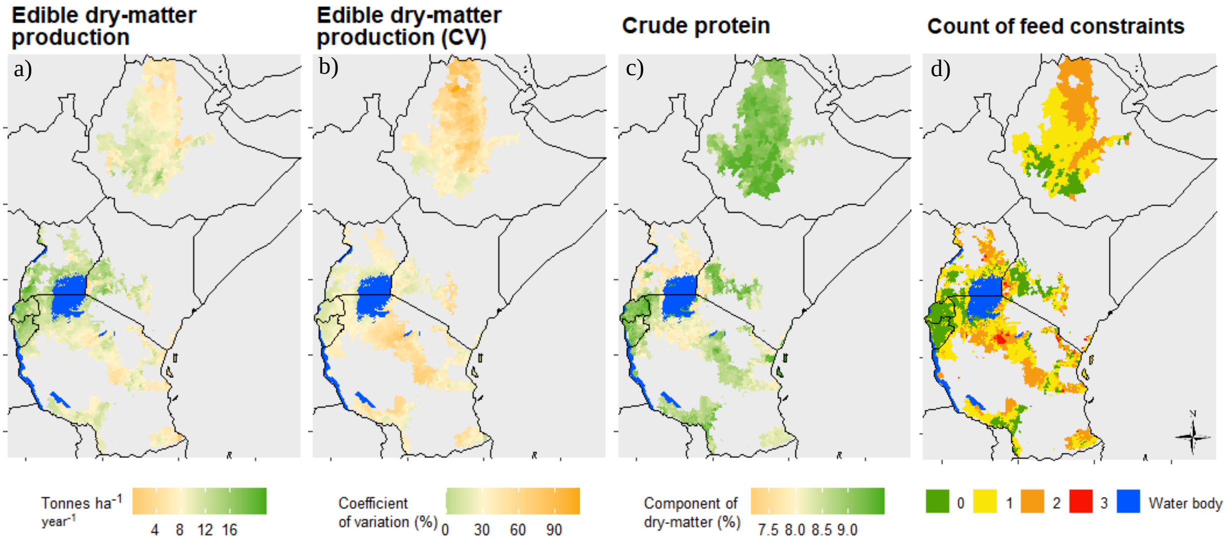

Fig 1. Spatialized feed constraint proxies across East Africa: a) feed availability, approximated by tonnes DM ha^{-1} year^{-1}; b) feed seasonality, approximated by DMP ha^{-1} CV; c) feed quality; approximated by crude protein as a percent of dry matter; d) count of feed constraints beyond threshold. Darker orange to red indicating greater intensity of constraint(s) and green indicating no constraint. Map values are only provided for humid and temperate locations. Arid and semi-arid lands and ocean are presented as grey

Multiple feed constraints occurred in 28 percent of studied land area (Fig 1d). All three feed constraints occurred at the same time in several locations of Tanzania, Kenya and Uganda (< 3% of land area within each country). Two feed constraints often occurred in the same location accross large portions of Ethiopia (33%), Tanzania (28%) and Kenya (16%). There were substantial areas that were categorised as having no feed constraints, most notably Rwanda (80%), Burundi (80%) and Kenya (42%). The highlands in Tanzania and southern regions of Ethiopia were also categorised as having no feed constraints (Fig 1d).

Discussion

Our current understanding of the occurrence of animal feed constraints has been informed by studies with limited spatial-temporal coverage. In this study, we have quantified feed availability, feed seasonality and feed quality across East Africa, identifying locations where feed constraints would limit livestock productivity.

Feed seasonality was a widespread feed constraint, which is a risk factor for sub-maintenance feeding in the dry season or reduced stocking rates. The lack of sufficient feed for the livestock population has implications for milk yield, feed use efficiency, liveweight gain, morbidity, mortality and animal fertility. Limited feed availability in the dry season can also result in a negative feedback loop of increased pressure of feed resources resulting in less feed available in subsequent years. This was most prominent in Ethiopia, and Tanzania where over 40 percent of the studied land area was constrained by feed seasonality.

Feed constraints often occurred in combination, which increases pressure on local livestock populations and increases the risk associated with livestock oriented livelihoods.

Locations where no feed constraints were identified tended to be high potential highland regions – most notably in Kenya and Tanzania. These locations are known to experience feed constraints, where land sizes are limited and competition for resources is greater.

Further research is needed to validate these findings in a diversity of locations. In addition, more work is needed to identify the severity of constraints and which technologies are best suited to remedy the constraints. The method employed in this study shows promise for studying the feed constraints of livestock species and locations where there is a dependence on local resources, but is of limited applicability in circumstances where a large portion of feed is imported or sourced as by-products from grain processing.

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