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Meat and milk production scenarios and the associated land footprint in Kenya

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A B S T R A C T

Increasing demands for meat and milk in developing countries and the associated production growth are driving the expansion of agriculture at the expense of environmental conservation and other land uses. While considerable attention has been directed at improving crop yields to alleviate the pressure on land, there has been far less attention on the implications of the expected intensification of livestock production. Here, we present and analyse the land availability and land footprints of livestock intensification for five scenarios representing various degrees of intensification of meat and milk production by cattle, sheep, goats and camels in arid, semi-arid and humid production systems in Kenya. The first three scenarios are defined by increasing levels of input and management, ranging from low (scenario S1), intermediate (S2) to high (S3) input feed crop cultivation and livestock production. Reference scenario S1 has production practices and output of meat and milk similar to current production practices. In scenarios S2 and S3, the total land used for livestock production remains the same as in S1. Two additional scenarios, S4 and S5, explore opportunities for lessening environmental pressure through reduction of the land footprint of meat and milk production. For each scenario, we quantify the potential availability of grassland and cropland for meat and milk production by cattle, sheep, goats and camel in the arid, semi-arid and humid production systems. A resource use indicator, land footprint (ha), is used to assess changes in land use associated with livestock production. We estimate that the potential increase in production due to intensification from scenario S1 to S2 is 51% for milk and 71% for meat. The potential increase due to improving production from scenario S1 to S3 is 80% for milk and 113% for meat. The area of grazing land, as a percentage of the total potentially available grazing land, decreases from 10% to 6% as productivity increases from scenario S1 to S5. Cropland usage increases from 4% in scenario S1 to 11% in scenario S5. Reduced land demand in scenarios S4 and S5 indicates the possibility that intensification may help reduce the pressure on land and hence promote environmental conservation. Overall, the results suggest that it is possible to increase production to meet increasing demands for meat and milk while also gaining land for environmental conservation through intensification. Realizing the potential presented by the intensification scenarios will be contingent upon successfully establishing and operationalizing enabling policies, institutional arrangements and markets and ensuring that relevant information, services, inputs, and other essential requirements are available, accessible and affordable to herders and farmers.

1. Introduction

Livestock production has significant land, water and carbon footprints. Agriculture appropriates about 40% of the global terrestrial surface (Foley et al., 2005). Livestock production alone accounts for 70% of the total agricultural land use, representing one third of all croplands and vast grazing areas (Steinfeld et al., 2006). The total feed biomass used by the livestock sector is considerable and amounts to about 4.7 billion tonnes (dry matter) per year, with about half being grasses and one fourth each being grains and occasional feed and stover (Herrero et al., 2013). Besides its extensive land footprint and significant biomass use, livestock rearing also accounts for almost one third of the agricultural water footprint (Mekonnen and Hoekstra, 2012) and about 15% of the anthropogenic greenhouse gas emissions (FAO, 2013). In some regions, continued horizontal expansion is a key factor in deforestation (Bilsborrow and Ogendo, 1992; Angelsen, 1995) and in others overgrazing causes severe land degradation (Steinfeld et al., 2006). Not surprisingly, the livestock sector is considered to be one of the leading

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contributors to the increase in environmental degradation (Steinfeld et al., 2006; Pelletier and Tyedmers, 2010).

Global meat and milk consumption is expected to grow significantly by 2030 (Steinfeld et al., 2006). This growth will be particularly pronounced in developing countries where the demand for meat and milk will more than double. The increase in consumption of animal products is driven primarily by population growth, increased purchasing power, and changes in dietary preferences favouring more animal source foods (ASFs), notably meat and milk (Delgado, 2003; Kastner et al., 2012). In addition, efforts to decrease undernourishment globally are also driving the demand for ASFs (Randolph et al., 2007).

In view of the already very large global natural resource use and environmental concerns related to livestock production, many researchers believe a doubling of production in developing countries will need to be met by a sustainable intensification (Pretty et al., 2011; Tarawali et al., 2011). Many developing countries still practice low input agriculture that relies on natural processes and expansion into forested lands, even in high-potential humid regions (Jankhe, 1982; Godfray et al., 2010). This is true for many countries in Africa, where low-input agriculture is still widespread, partly due to limited, or slow uptake of modern production technologies, leading to poor levels of meat and milk production per animal (Headey and Jayne, 2014). Because of poor yields and production for subsistence, production levels in most developing countries are insufficient to meet their domestic demands (Place et al., 2006).

Consequently, large differences exist in livestock productivity between the developed and the developing world, implying a huge untapped efficiency potential in the developing countries, particularly in Africa. Though many interventions have focused on bridging this productivity gap (Tilman et al., 2002), there is a growing realisation that the processes involved in intensification of production of ASFs often overlook environmental impacts (Tscharntke et al., 2012). Studies that assessed these impacts have mainly focused on the implications of increasing yields in croplands on the alleviation of the pressure on the available land (Foley et al., 2005; Koh and Lee, 2012). Very few studies have analyzed the consequences of reduced demand for land through increased productivity in both crop and livestock production (Wirsenius et al., 2010; Tilman et al., 2011).

The production and consumption of livestock commodities in Kenya is a case in point. The demand for livestock commodities is on the rise, and will likely continue to rise in the near future (Omore et al., 1999). Several studies have assessed farmer responses to increasing demand and showed how these are closely linked to the wider institutional, social and cultural context and how they relate to economic factors, which differ across farming systems (Feder and Umali, 1993; Marra et al., 2003; Owen et al., 2012). However, the availability of and demand for land to meet livestock production needs across the various farming systems has not been quantified for Kenya. Additionally, the implications of both cropland and livestock productivity improvements for various production systems have not been quantitatively analysed and documented. Understanding of these issues is essential for the development and deployment of sound policies and practices that ensure that increased livestock production through intensification is in synergy with other critical targets such as biodiversity conservation and improved nutrition in Kenya. This paper aims to enhance our understanding of land use and availability by examining the intensification potential of meat and milk production by four ruminant species, namely cattle, shoats (sheep and goats) and camels in Kenya. The specific objectives of this paper are two-fold: (1) assess the availability and suitability of land for meat and milk production in three production systems, and; (2) explore options for intensification to either expand production of meat and milk or relieve pressure on existing lands in Kenya.

2. Methods and data

In this paper we assess land availability, suitability and livestock production and the gains in land savings that can be expected from increasing the production of four ruminant livestock species under three intensification scenarios in Kenya as illustrated schematically in Fig. 1. We do not consider meat production from poultry and pigs as they currently constitute a minor proportion of the total meat production in Kenya relative to ruminants (Bett et al., 2012).

2.1. Identification of land available for livestock production

2.1.1. Selection and characterisation of analysis unit

We analyse the production systems for four ruminant species, namely cattle, shoats, and camels in Kenya. Each production system is characterised by specific agro-ecological factors (Pratt and Gwynne, 1977; Grandin, 1988; Rege, 2001). Land available for livestock production is estimated for each of the three agro-climatic regions, i.e. humid, semi-arid and arid. Each of these three distinct geographical regions is referred to as a production system.

The humid production system is located in areas with high potential for crop, fodder and livestock production, due to fertile soils, annual rainfall averaging over 800 mm, and modest pest and disease problems. It covers large parts of Central Kenya, the Central Rift Valley, Western Kenya and most of the Coastal strip (Ouma et al., 2000). The semi-arid production system has a medium potential for plant growth and livestock production, an average annual rainfall of 600–800 mm and a high prevalence of trypanosomiasis. This production system covers parts of Eastern Kenya, neighbouring the highland production systems to the north and south, and the coastal strip to the west. The arid production system has the lowest potential for biomass and livestock production. This system is characterised by an average annual rainfall of less than 600 mm, high variability in rainfall amount in both the wet and dry seasons, and high prevalence of various livestock diseases (Grandin, 1988; De Leeuw and Rey, 1995; Ndambi et al., 2007). The arid and semi-arid systems cover about 83% of the total land area of Kenya and are home to about 35% of Kenya's population. In contrast, the humid system covers only about 17% (Ruigu, 1988).

2.1.2. Land available for agriculture

The land area directly available for ruminant production in the three production systems in Kenya includes grazing lands, for grazing and browsing livestock, and feed crop areas, for cultivation of fodder and feeds. However, the potential land available for livestock production also includes grasslands suitable for crop production and currently used for grazing. The land currently available for livestock and crop production in each of the delineated production systems was estimated by masking the land use systems raster obtained from the FAO (2010) by the production systems polygon (Robinson et al., 2011). The detailed classification systems used in Robinson et al. (2011) are reclassified into the three agro-climatic zones above as described in Bosire et al. (2015). Fig. 2 illustrates the estimates of land area currently available for livestock and crop production in each of the three production systems under each of three production scenarios.

The total area of land $L_{total}[s]$, constituting production system s (arid, semiarid, humid) can be partitioned into the total grassland area ($L_{grassland}[s]$) plus other environmentally valuable areas, such as forests and other protected areas with restricted access for livestock rearing $L_{env}[s]$, cropland used for food and feed production $L_{crop}[s]$, and unproductive areas, including built-up, degraded and bare areas that are unsuitable for agricultural production ($L_{unprod}[s]$). Therefore, the total land area for livestock and crop production in each production system $L_{agric}[s]$ is determined by:

$$L_{agric}[s] = L_{grassland}[s] + L_{crop}[s]. \tag{1}$$

The cropland used for feed production $L_{feedcrop}[s]$ quantifies the feed–crop land footprint (Bosire et al., 2015) and is calculated as the proportion of cropland $L_{crop}[s]$ that is specifically used for feed crops, forages such as alfalfa and Napier grass. Likewise, the grassland used by livestock quantifies the grassland footprint $L_{grazing}[s]$. By adding the