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Assessing the potential of dual-purpose maize in southern Africa: A multi-level approach

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ABSTRACT

This paper explores the potential and challenges of increasing production of food and feed on existing maize fields in mixed crop-livestock systems in the semi-arid areas of southern Africa. It integrates results from different sources of data and analysis: 1. Spatial stratification using secondary data for GIS layers: Maize mega-environments combined with recommendation domains for dual-purpose maize were constructed for Malawi, Mozambique and Zimbabwe, stratifying the countries by demand factors (livestock densities and human population densities) and feed availability. Relative biomass contributions to feed resources from rangelands were compared to those from croplands to explore the usefulness of global datasets for feed supply estimations. 2. Verification through farming systems analysis: the potential demand for maize residues as feed (maize cropping patterns, maize yields and uses, feed deficits) was compared at contrasting sites, based on household survey data collected on 480 households in 2010. 3. Maize cultivar analysis: Genotypic variability of maize cultivars was compared to evaluate the potential contribution (stover quantity and quality) of dual-purpose maize to reduce feed deficits. The study results illustrate high spatial variability in the demand for and supply of maize residues. Northern Malawi is characterized by high livestock density, high human population density and high feed availability. Farmers achieve maize yields of more than 2 t/ha resulting in surplus of residues. Although livestock is important, southwest Zimbabwe has low livestock densities, low human populations and low feed availability; farming systems are more integrated and farmers make greater use of maize residues to address feed shortages. Central Mozambique also has low cattle densities, low human populations and low feed availability. More rangelands are available but maize yields are very low and livestock face severe feed shortages. The investigation of 14 advanced CIMMYT maize landraces cultivars and 15 advanced hybrids revealed significant variations in grain and stover yield and fodder quality traits. Where livestock densities are high and alternative feed resources are insufficient, maize cultivars with superior residue yield and fodder quality can have substantial impact on livestock productivity. Cultivars at the higher end of the quality range can provide sufficient energy for providing livestock maintenance requirements and support about 200 g of live weight gain daily. Maize cultivars can be targeted according to primary constraints of demand domains for either stover quantity or stover fodder quality and the paper proposes an approach for this based on voluntary feed intake estimates for maize stover.

1. Introduction

Food security for rural households in southern Africa is generally determined in terms of maize production, the region's major staple crop (Grant et al., 2012; Langyintuo et al., 2008; Calcaterra, 2002). Therefore, maize has been identified as one of the key agricultural commodities to enhance food production and food security at continental and sub-regional levels (AU, 2006). Nevertheless, maize yields remain low in many parts of southern Africa (except for

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South Africa), stagnating at around 1 t/ha for the last decade (Smale et al., 2011; Kassie et al., 2012). Past growth in total maize production has been achieved through land expansion instead of crop intensification. However, expansion of agricultural land is increasingly restricted given the reduction of available land and the large resource constraints facing farmers in the region (e.g. labor, capital).

At the same time, increasing importance of livestock as a source of revenue suggests that investments in this sector offer a clear opportunity to improve rural livelihoods and the overall agricultural growth of the region (Chilonda and Minde, 2007; Nin Pratt and Diao, 2008). A promising method of enhancing crop and livestock productivity is increasing the availability and quality of cereal residues as livestock feed (Amede et al., 2009; Alkemade et al., 2012). Feed availability is a major bottleneck for improving livestock production and productivity in the region (associated with animal health, Holness, 1999). This bottleneck can become more severe with the increasing expansion of cropland on communal rangelands, an essential source of livestock feed in the region (De Leeuw, 1997).

Improved dual-purpose maize varieties for food and feed provides a promising technological option to intensify both crop and livestock production by simultaneously increasing the availability and quality of grain production and livestock feed (Berhanu et al., 2012; Blümmel et al., 2012). The potential of these dual-purpose technologies in southern Africa would depend on: the environment, i.e. agro-ecological and socio-economic context of agricultural production (Notenbaert et al., 2012), farm management, i.e. crop-livestock farming systems (Ojiem et al., 2006); and genetics, i.e. quality and quantity of food and feed production of different maize cultivars (Sharma et al., 2010). The objective of this study is to assess the potential of dual-purpose maize on food and feed production and to better target promising cultivars by accounting for the environment, management and genetics on crop-livestock farms in southern Africa. This assessment is a multi-level analysis combining assessments of dual-purpose maize at landscape and farming system levels in mixed crop-livestock systems in Malawi, Mozambique and Zimbabwe, as well as including the genetic variability of prominent maize cultivars.

2. Material and methods

2.1. Countries and study sites

Countries were selected based on secondary data and expert consultation to represent contrasting mixed crop-livestock systems in southern Africa, including sites in Malawi, Zimbabwe and Mozambique (Chilonda et al., 2008).

Farming systems studies were implemented in each of the three countries at selected sites that represent contrasting maize-based systems with different challenges and opportunities for improved dual-purpose maize. The studies were part of the System-wide Livestock Programme (SLP) project on crop residue use, determinants and trade-offs, southern Africa case study (Homann-Kee Tui et al., 2012). Mzimba in northern Malawi has higher rainfall (av. 700–750 mm per year) and relatively high levels of human populations (57 persons per km^2) than the other two sites. Agricultural production is more intensified and oriented towards crop production. Nkayi in southwest Zimbabwe and Changara in Central Mozambique have lower rainfall (av. 600–650 mm persons year) and lower human population densities (23 and 19 persons per km^2, respectively); agricultural production is more extensive and livestock is more prominent in agricultural production than in the other site.

2.2. Analytical approach

The assessment of the environment, management and genetics of dual-purpose maize integrates three levels of analysis and research outputs that will generate a better understanding of the potential and viability of this technology on improving agricultural production in southern Africa (Fig. 1). These three levels of analysis are:

a. A nested landscape analysis to spatially identify the potential of dual-purpose maize, based on feed biomass production and demand in the three countries (i.e. environment).
b. A farming system analysis to understand and verify the feasibility of the previous spatial analysis based on resource allocation and management in three selected study sites (i.e. management).
c. A maize cultivar analysis to evaluate the potential contribution of different improved dual-purpose maize cultivars in enhancing feed supply (i.e. genetic).

2.2.1. Landscape analysis

This nested landscape analysis combines GIS databases to better understand the production and demand for feed in mixed crop-livestock systems at a country level. Firstly, data on the distribution of mixed crop-livestock systems is used to identify major areas where dual-purpose varieties could have a niche. Secondly, data on the agro-ecological potential of specific maize cultivars (Maize Mega Environments) is used to better target dual-purpose varieties. Thirdly, Recommendation Domains are used to further stratify the niche of this technology by supply and demand factors. Finally, spatial analyses of rangeland and cropland production are included to quantify the contribution of feed resources. These spatial databases were raster layers with different spatial resolutions (pixel size). To be able to combine them, they were converted to vector data, overlaid and integrated by using Raster to Polygon tool and other Geoprocessing tools in ArcGIS 10. The databases, which are all publicly available, include:

Mixed crop-livestock systems: Distribution of mixed crop-livestock systems were defined using the ILRI/FAO global livestock production systems classification (Robinson et al., 2011), based on criteria developed by Thornton et al. (2002) (<450 persons per km^2 to differentiate from landless intense systems; >60 days LGP and >20 persons per km^2 to differentiate from livestock-only systems).

Maize Mega Environments: The potential of maize varieties is based on the CIMMYT's Maize Mega Environments (MME; Bellon et al., 2005), developed for matching maize cultivars with climatic key variables such as day length, rainfall precipitation and temperature. These climatic variables were used as layers to stratify by agro-ecological potential (Hartkamp et al., 2000).

Recommendation Domains: Recommendation Domains (RDs) for better targeting of dual-purpose maize cultivars were developed following the approach of Notenbaert et al. (2012) based on three strategic demand and supply criteria: (i) livestock density (here cattle and small ruminants); (ii) human population density; and (iii) feed availability from crop residues of maize, small grains, legumes, sugar cane, roots and tubers. For each of the variables (livestock density, human population density, feed availability), two classes were defined, high (H) and low (L). To separate the two classes, cut off points were defined that represent the averages across mixed farming systems in southern Africa and combining the following data layers: (i) Livestock density of 9 Tropical Livestock Units (TLU)/km^2 − pixel size of 10 km × 10 km resolution, FAO layers (Wint and Robinson, 2007); (ii) Human population density of 36 PPL/km^2 − pixel size of 1 km × 1 km resolution, using the Global Rural Urban Mapping Project (GRUMP) layers (CIESIN, 2004); (iii) Feed availability of crop residues of 20 t/km^2 − pixel