Europ. J. Agronomy 58 (2014) 28–38

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Which farmers benefit most from sustainable intensification? An ex-ante impact assessment of expanding grain legume production in Malawi

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ARTICLE INFO

Article history:
Received 12 December 2013
Received in revised form 4 April 2014
Accepted 7 April 2014
Available online 7 May 2014

Keywords:
Farm typologies
Groundnut
Soybean
Maize
Crop model

ABSTRACT

Legume technologies are widely promoted among smallholders in southern Africa, providing an opportunity for sustainable intensification. Farms and farming strategies of smallholders differ greatly within any given locality and determine the opportunities for uptake of technologies. We provide an *ex-ante* assessment of the impact of grain legumes on different types of farms and identify niches for grain legumes in Malawi. After creation of a farm typology, detailed farm characterisations were used to describe the farming system. The characterisations provided the basis for the construction of simplified, virtual farms on which possible scenarios for expanding and intensifying grain legume production were explored using the farm-scale simulation model NUANCES-FARMSIM. Observed yields and labour inputs suggested that maize provides more edible yield per unit area with a higher calorific value and greater labour use efficiency than groundnut and soybean. Crop yields simulated by the model partly confirmed these yield trends, but at farm level maize-dominated systems often produced less food than systems with more grain legumes. Improved management practices such as addition of P-based fertiliser to grain legumes and inoculation of soybean were crucial to increase biological nitrogen fixation and grain yields of legumes and maize, and created systems with increased area of legumes that were more productive than the current farms. Improved legume management was especially a necessity for low resource endowed farmers who, due to little past use of P-based fertiliser and organic inputs, have soils with a poorer P status than wealthier farmers. Economic analyses suggested that legume cultivation was considerably more profitable than continuous maize cropping. Highest potential net benefits were achieved with tobacco, but the required financial investment made tobacco cultivation riskier. Grain legumes have excellent potential as food and cash crops particularly for medium and high resource endowed farmers, a role that could grow in importance as legume markets further develop. For low resource endowed farmers, legumes can improve food self-sufficiency of households, but only if legumes can be managed with P fertiliser and inoculation in the case of soybean. Given that low resource endowed farmers tend to be risk averse and have few resources to invest, the ability of poorer farmers to adopt legume technologies could be limited.

1. Introduction

In much of southern Africa, smallholder arable farming is dominated by maize production. Agricultural productivity in the region is poor, with annual national average grain yields varying between 0.3 and 2.2 Mg ha^{-1} in 2008–2012 in Malawi, Mozambique and Zimbabwe (FAOSTAT, 2014). In Malawi, poor crop productivity has partly been addressed by the Farm Input Subsidy Programme (FISP) (Dorward and Chirwa, 2011; Chibwana et al., 2012). The FISP has contributed to raising national maize productivity and reducing rural poverty but is not without controversy. Households participating in the FISP have been found to simplify crop rotations by allocating more land to maize and tobacco at the expense of other crops such as groundnut, soybean and bean (Chibwana et al., 2012). The over-reliance on maize has led to repeated recommendations for crop diversification using legumes.

Efforts to promote green manure legumes did not result in wide-scale adoption in Malawi, due to the land and labour investments required and the lack edible or marketable yield

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http://dx.doi.org/10.1016/j.eja.2014.04.002

(Snapp et al., 2002; Sirrine et al., 2010). Grain legumes, such as groundnut (*Arachis hypogaea* L.), soybean (*Glycine max* (L.) Merrill), cowpea (*Vigna unguiculata* (L.) Walp.), common bean (*Phaseolus vulgaris* L.) and pigeonpea (*Cajanus cajan* (L.) Millsp.), provide more promising entry points to diversify cropping systems and enhance soil fertility management due to their multiple benefits. Grain legumes provide key components of healthy diets including essential protein and minerals, help in reducing pest and disease build-up associated with monocropping of maize, and enhance N availability for subsequent crops. Substantial yield increases of cereal crops following legumes, in comparison with monocultures of cereal, have been observed widely across sub-Saharan Africa (MacColl, 1989; Ncube et al., 2007; Franke et al., 2008; Yusuf et al., 2009; Kamanga et al., 2010a). Grain legumes can also provide income and reduce farmers' dependence on non-edible cash crops tobacco and cotton. Rural development groups and government extension agents therefore widely promote the production and processing of grain legumes among smallholders in southern Africa, often as part of wider development efforts promoting sustainable agricultural intensification (Giller et al., 2013).

Throughout Africa we find a wide diversity of farms and farming strategies, which determine the opportunities for uptake of different technologies (Giller et al., 2011). Since it is impossible to develop unique recommendations for each household, farm diversity has been categorised to define recommendation domains (Kamanga et al., 2010a; Tittonell et al., 2010b). Targeting particular groups of farmers in a development project, deliberately or unintentionally as a result of a dissemination approach, is likely to affect project impact. Some development projects, for instance, adopt a value chain approach in which agricultural innovations are promoted and directly linked to market opportunities and increased value of produce. While farmer-market linkages are of great importance to achieve sustainable adoption of new technologies and stimulate development of the agricultural sector, such approaches easily bypass the poorest farmers who are oriented towards food self-sufficiency and lack resources to produce for markets.

In this paper we provide an *ex-ante* assessment of the impact of grain legumes on different types of households and identify niches for grain legumes in smallholder farming systems in Malawi to improve targeting of grain legume technologies in development programs. The methods used in this study can be applied to a wide array of agricultural technologies potentially suitable to smallholders. After creating a farm typology, detailed farm characterisations were used to describe the current state of farming. The characterisations provided the basis for the construction of simplified, virtual farms on which the exploration of possible scenarios is based (cf.Giller et al., 2011). The farm-scale simulation model, NUANCES-FARMSIM (FARM SIMulator) (van Wijk et al., 2009) was used to explore the potential for expanding and intensifying grain legume production.

2. Materials and methods

2.1. Study location and farm typology

The study was conducted in Mchinji district, 50–80 km west of the capital Lilongwe on the Zambian border. Mchinji lies at mid-altitude area (on average 1100 m above sea level), has a monomodal rainfall distribution with 950 mm rain annually on average, a growing period of 5–6 months starting late November and an annual mean temperature of 20 °C. Compared with other regions in sub-Saharan Africa, farmers have relatively good access to both local and urban markets due to high population densities in the district and the proximity of the capital Lilongwe (Franke et al., 2011).

To describe smallholders' farms and explore scenarios for legume technology adoption we employed the NUANCES framework (Giller et al., 2011). A survey of 77 households within a 10 km radius of Kachamba village (S13.746 E33.040) was conducted in November 2010. A structured questionnaire was used to collect information on household composition, landholding, livestock ownership, assets, housing, sources of income and production orientation. Households were selected randomly. In addition to four wealthier farmers interviewed in the random sample, another four were deliberately sampled since they were few in number. Livestock assets recorded included ruminants, pigs and poultry; household assets included farm tools, oxcart, wheelbarrow, radio, mobile phone, television, bicycle and car. Based on landholding, livestock ownership, household assets, and quality of housing, farmers were divided in three wealth classes: low resource endowment (LRE), medium resource endowment (MRE) and high resource endowment (HRE). Two other criteria for the farm typology were main source of income and production orientation. These criteria led to the manual grouping of farmers into five farm types. The approach was similar to a classification used in East Africa (Tittonell et al., 2005, 2010b), although the boundaries between farm types were different.

2.2. Detailed farm characterisations

From the larger sample, 14 farms were selected for detailed characterisation. Although the aim was to select three farms per farm type, the initial sample only contained two HRE farms with farming as a prime source of income (Type 2). A series of visits during the 2010/2011 growing season was made to each farm to assess biophysical and socio-economic variables related to crop production. Information about the household and cropping patterns were acquired and management was recorded for each crop. Moreover, information on livestock, the production and handling of animal and compost manure, and income and expenditures was collected. The area of each field was measured using a geographical positioning system (GPS), or manually if the field was too small for accurate GPS readings. The so-called gardens, small plots located in the low lying (dimba) areas next to a riverbed, were excluded because no major crops were produced here and plot sizes were very small. At the end of the growing season, farmers were visited a last time to collect grain yield data from each field. Soil samples were taken in December 2010 from fields selected based on the crop rotation and soil fertility as perceived by the farmer. This resulted in one to four fields selected per farm, depending on the size of the farm and the expected variability in soil fertility. Composite soil samples (0–20 cm depth) were taken with an auger at 10 points in each field. Samples were air-dried and sieved through a 2 mm sieve and sent to the Soil Productivity Research Laboratory (SPRL) in Zimbabwe for analysis of pH (H_2O), total N (Kjeldahl digestion), %C (Walkley-Black), available P (Olsen), cation exchange capacity (CEC) (extraction with ammonium acetate), exchangeable cations K (flame photometry), Ca and Mg (atomic absorption spectrophotometry) and particle size (Bouyoucos hydrometer). A detailed description of the methods and results of the characterisations is available (van den Brand, 2011).

2.3. Model description

Based on the results from the farm characterisations, simplified virtual farms were constructed, each representing a farm type. The farms were constructed based on data on land area, cropping pattern, soil fertility characteristics, and fertiliser and organic input use. The relative area covered by each crop was rounded to the nearest 10% of the farm area, facilitating the simulation of a crop rotation over a 20-year period. Soil available P and exchangeable