Integrating diverse grain legumes for increased land productivity on small farms in Malawi

Introduction

Malawi is a small country located in southern Africa with only 119,000 km^2 for a population of about 16.7 million people. With agriculture as the mainstay of the economy, Malawi's high population density of 140 people/km^2 requires that agricultural productivity and other ecosystem services must be optimized. As part of the Africa RISING (Research In Sustainable Intensification for the Next Generation) Feed the Future project, implemented by the International Institute of Tropical Agriculture (IITA) and its partners, including Michigan State University, action research that includes integration of legumes at scale to target food, income and nutritional security has been implemented in two central districts of Malawi (Dedza and Ntcheu) with farmers producing crops on small farms ranging 0.4-1 ha, with a small proportion of farms as large as 2 ha. Smallholder farming households in the target areas are distinctly diverse, driven by historical access to resources. Access to land drives the intensity of nutrient use among farms of different resource endowment and production orientation, leading to large variation in soil fertility status and crop productivity. Therefore, technological interventions to address the problem of poor productivity of smallholder agricultural systems must be designed to target socially diverse and spatially heterogeneous farms and farming systems.

Figure 1. Malawi

Description of the Agroecology system

Smallholder agriculture in Malawi is dominated by the staple maize crop that occupies at least 70% of the cropped lands. Grain legumes - groundnut, beans, soybean, pigeonpea and cowpea - are integrated in the maize-based systems as intercrops or rotations. The disproportionally mismatched allocation of land to maize compared to the collective land allocated to legumes means that meaningful crop rotations are not feasible. The resultant maize mono-cropping has been one of the primary drivers for land degradation. As one of the first steps towards rehabilitating croplands, technologies that contribute to building soil organic matter and specifically those based on harnessing the biological nitrogen fixation and related ecological benefits that accrue from intensified grain legume production will likely provide avenues for productivity gains in cereal-based cropping systems. In emphasizing integration of *grain legumes*, we are aware that high N harvest indices limit the magnitude of net soil N contributions. Our focus remains on grain legumes, however, as green manure alternatives that incontestably add more biomass and net N input, have been consistently ranked poorly by farmers and adoption has been insignificant in most cases. The multipurpose, pigeonpea has shown outstanding potential to support soil fertility gains while still

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providing a food and income source, and is the basis for a number of the legume-diversified sustainable intensification technologies that reinforce maize productivity in crop sequences or intercropping. Our work to achieve sustainable intensification, therefore hinges on integration of pigeonpea in intercropping with maize or in a novel intercropping system with other grain legumes (groundnut-pigeonpea), what is termed the doubled-up legume intercropping technology.

The doubled-up legume technology

We recognize that for sustainable intensification and farm productivity gains for Malawi's smallholder agriculture, crop spatial arrangements and crop sequences must be tailored to create a more balanced and diversified maize-legume production system. The doubled-up legume technology entails intercropping two grain legumes, exploiting the opportunity presented by complementary growth habits and plant architecture. The most successful doubled-up legume intercropping system involves pigeonpea intercropped with groundnut in an additive design, with little intra-specific competition (Figure 2). In this doubled-up system, groundnut and pigeopea are planted at the same time. Pigeonpea grows very slowly during the first 3 months after planting and only starts rapid growth when the groundnut component would be approaching maturity. After groundnut harvest, the remaining pigeonpea continues to grow as a sole crop until maturity.

Figure 2. Groundnut/pigeopea doubled up system that provides 'double' grain and soil fertility benefits (Photo credit: Jim Richardson, National Geographic).

For example in a groundnut-pigeonpea system, groundnut is planted at its normal 'sole cropping' density while pigeopea can range from 50-100% of its sole cropping density. This crop mixture is mainly a function of rainfall received. In more marginal areas, the crop mixtures are inclined towards the substitutive inter-cropping design so as to minimize on competition for nutrients and water between the crop components.

This system has 'double' legume grain and 'double' soil fertility benefits from biological N2-fixation. On-farm research across several sites in central and northern Malawi established that the doubled-up technology resulted in consistently larger increased soil fertility benefits and land productivity (land equivalency rations, LER>1).

Refining the doubled-up system

The doubled-up legume technology is inspired by traditional ecological knowledge, with optimizations based on research since the 1990s. Intercropping is one of the oldest agroecological techniques developed by smallholder farmers to get multiple crops from same cropped field, while also acting as risk management system in case of failure of one of the companion crops. Current research is focusing on refining the crop mixtures and component populations as a function of agroecological potential, and quantifying the extent of yield penalties that may occur under different conditions.

Groundnut and pigeonpea, the companion crops that constitute the most successful doubled-up technology system, have a very long history of cultivation in Malawi. They play important roles in Malawi's culinary tradition. The doubled-up legume technology is experimenting with a participatory approach to maximize the ecological potential/benefits from these crops.

The knowledge emanates from both traditional ecological knowledge and modern knowledge on ecological principles of intra-specific competition in intercrops. Crops with different architecture and growth habits are likely to be complementary, attributes that contribute to sustainable utilization of limited land resources and enhance agricultural productivity. This is particularly important for low input systems in Africa where component crops are often grown at sub-optimal populations with less pressure exerted on each other.

Community knowledge

Researchers from universities (Michigan State University, Lilongwe University of Agriculture and Natural Resources) and CGIAR centres, as well as officers from Government of Malawi Extension System organized farmers into action groups. Each of the action group was headed by a lead farmer who hosted a demonstration that we refer to as the 'mother trial'. At the mother trials, the doubled-up legume technology was implemented with all stakeholders participating in the establishment of the field plots, an essential component for co-learning. Participating farmers then experimented with the technology in their own fields. We call these 'baby farmers'.

Outcomes of the practices

The agroecology system that we have described has just been 'released' by the government of Malawi as a technology that can be mainstreamed across the country. This is a huge acknowledgment by the government on the need to harness ecological systems for enhanced functioning of resource constrained farms. Researchers and extension services are now collaborating on improving the functioning of the technology and tailoring it to different agricultural environments throughout the country.

The doubled up legume technology is contributing to increased availability of pigeonpea grain that is processed into different types of nutritious foods consumed by breast feeding mothers and their young children. This is especially critical in Malawi as livestock-based protein is scarce due to low populations of livestock. The shrubby pigeonpea produces large biomass (4-10 t/ha) that contributes to soil organic matter restoration on farms and increased productivity of the staple maize that is grown in rotations. An important component of the system is that it acts as a 'subsidy' to fertilizer application on the rotational maize crop as fertilizer application to maize can be reduced by 50% with minimal yield penalties.

Message from farmer to farmers

"The system results in pigeonpea left in the field after groundnut harvest covering the soil for longer, leaving landscape green and beautiful for longer"