Identifying Agro-Ecological Niches for Long-Duration Legumes: Modeling Maize-Legume Systems Under Variable Climate in Malawi

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Introduction

On-farm participatory research in Malawi has identified pigeonpea (*Cajanus cajan*) as a promising, multipurpose legume for improving fertility management in maize (*Zea mays*) systems. Benefits and risk in these cropping systems will depend on soil type and rainfall regime. This effect is difficult to quantify using short-term field trials. The current study uses the Agricultural Production Systems Simulator (APSIM) to evaluate maize-pigeonpea rotation and intercrop systems and answer the following questions:

1. What is the overall effect of legume diversification on maize yield over time?
2. Does the use of pigeonpea increase the risk of crop failure in rainfed maize-based systems?
3. To what extent does increased water use pigeonpea create trade-offs between soil fertility benefits and increased soil water use?

Methods

Field data: Yield, biomass, and soils data were collected from 2008-2010 at 19 farmer-managed field sites in 5 villages near Zombwe, in northern Malawi. Additional deep soil sampling conducted in July 2011

Model setup: Models were run for ten years continuously, then soil water and nitrogen variables were reset to their initial values.

Cropping systems: Continuous maize, maize-pigeonpea intercrop, and maize-pigeonpea rotation. Maize variety is MH 17, pigeonpea is long-duration cultivar.

Soil types: Three representative soil types were used. Topsoil properties were:

High Fertility (HF): 0.78% organic carbon (OC), 63% sand *Medium Fertility (MF)*: 0.58% OC, 70.4% sand

Low Fertility (LF): 0.58% OC, 79% sand

Weather data: Daily data from Zombwe (11.33°S, 33.82°E, 1143 m.a.s.l., data from 1946-2011) were used for evaluation. Data from Zombwe and Kasungu (13.03°S, 22.45°E, altitude 1036 m.a.s.l., data from 1927-2010) were used for model experimentation.

Model evaluation: Modeled maize yields were within one standard deviation of the mean in field trials. Relative yields among systems followed trends in field trials. Modeled pigeonpea yields were above mean but below the maximum yields observed in field trials.

Yields and Risk

Including pigeonpea in rotation or intercrop does increase maize yields, and benefits increase over time (Fig. 1). In early establishment years risk of low yields is higher in maize-legume systems, but this risk declines over time (Fig. 2).

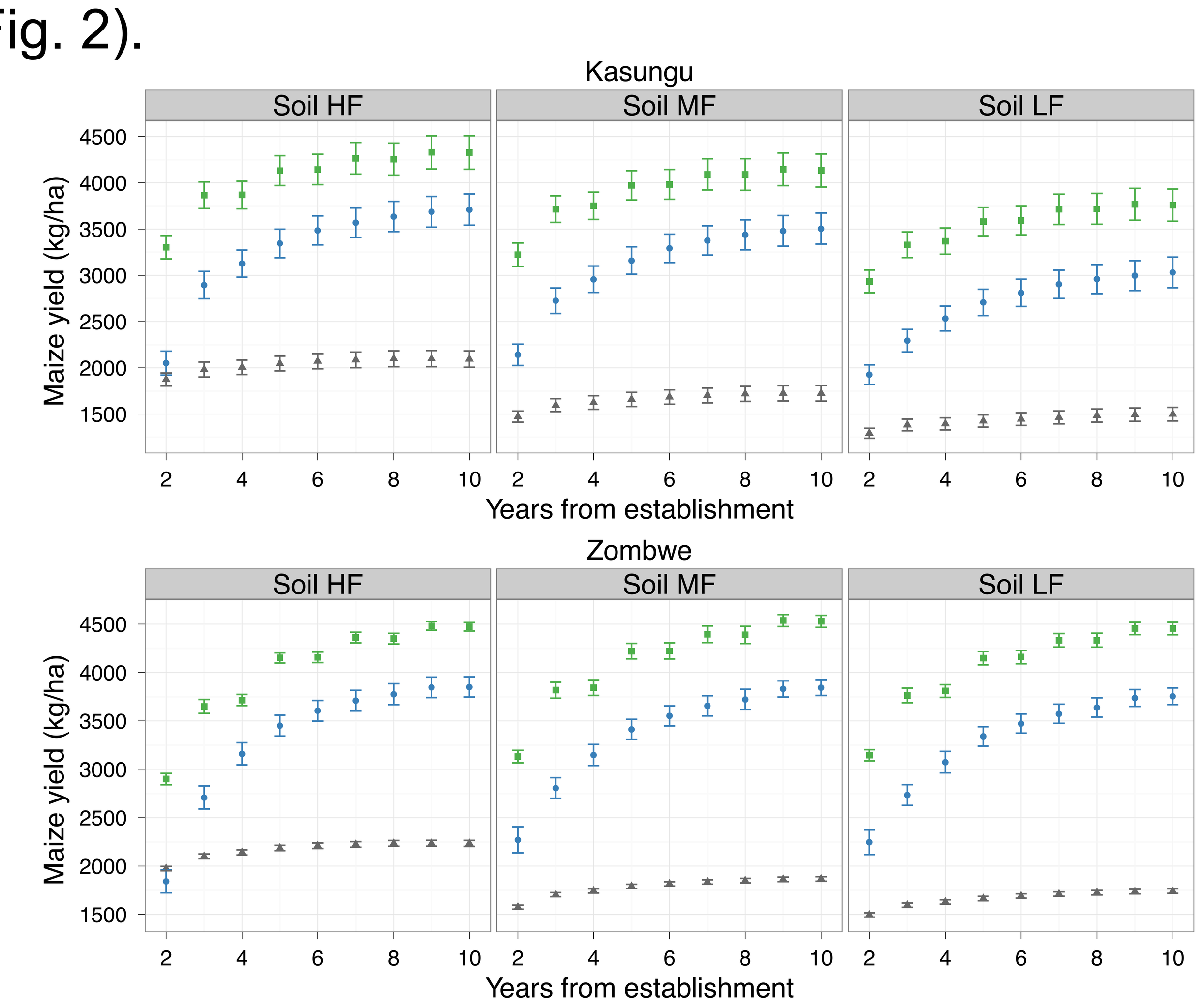

Figure 1. Mean maize yields for 10 years from system establishment. Points are mean model results averaged over 83 years at Kasungu and 66 years at Zombwe, northern Malawi. Error bars are standard errors of the mean over the same time period.

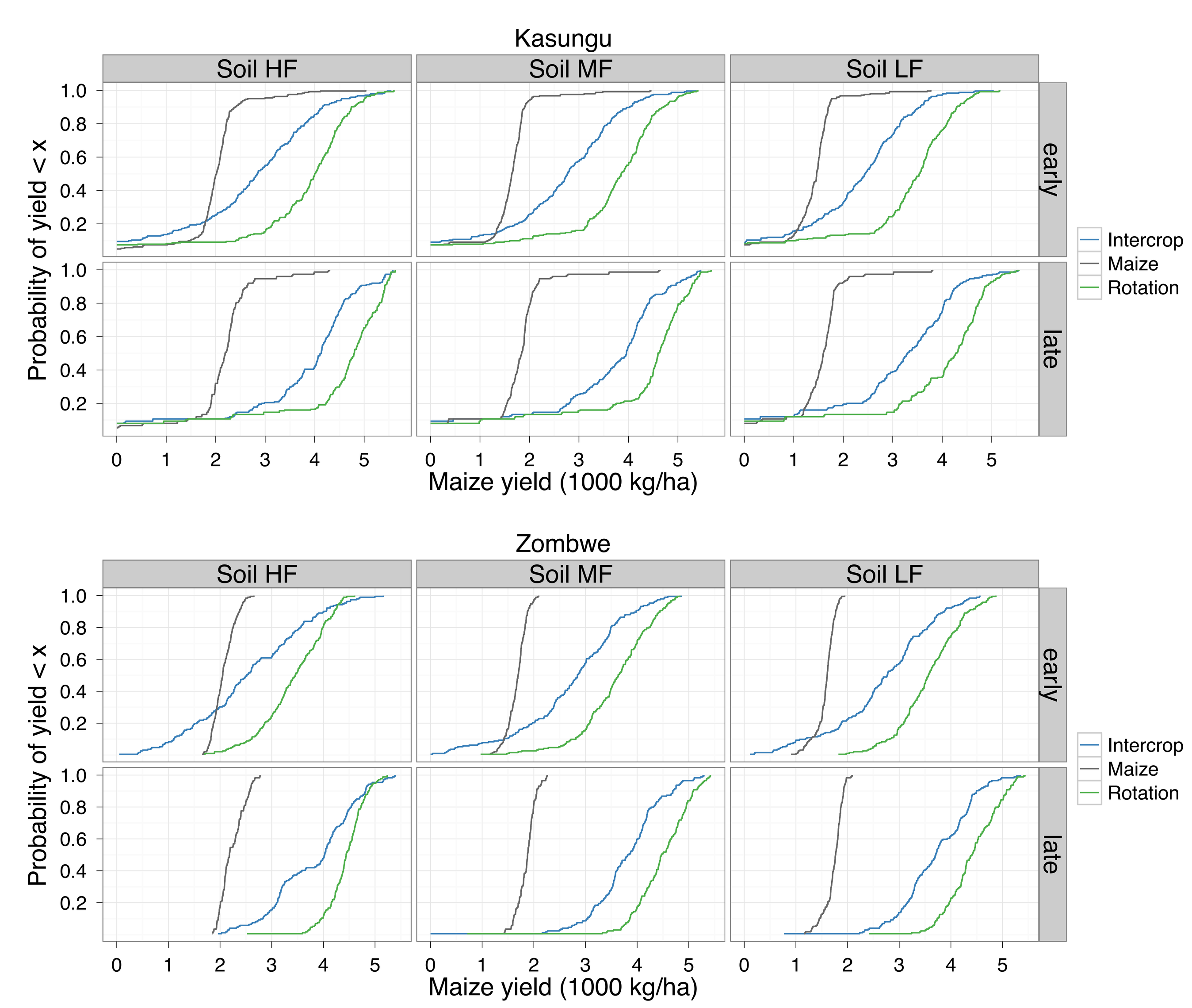

Figure 2. Cumulative probability distributions of modeled maize yields for three cropping systems in three soil types. Results plotted separately for each soil type and period from establishment. Periods early, mid, and late refer to years from system establishment: 2-4, 5-7, and 8-10 respectively.

Water and Nitrogen Trade-offs

The beneficial effect of legumes on modeled maize yield is due to reductions in N stress (Fig. 3). Including legumes increases water stress, leading to negative impact of legumes for rainfall amounts below 300mm (Fig. 4).

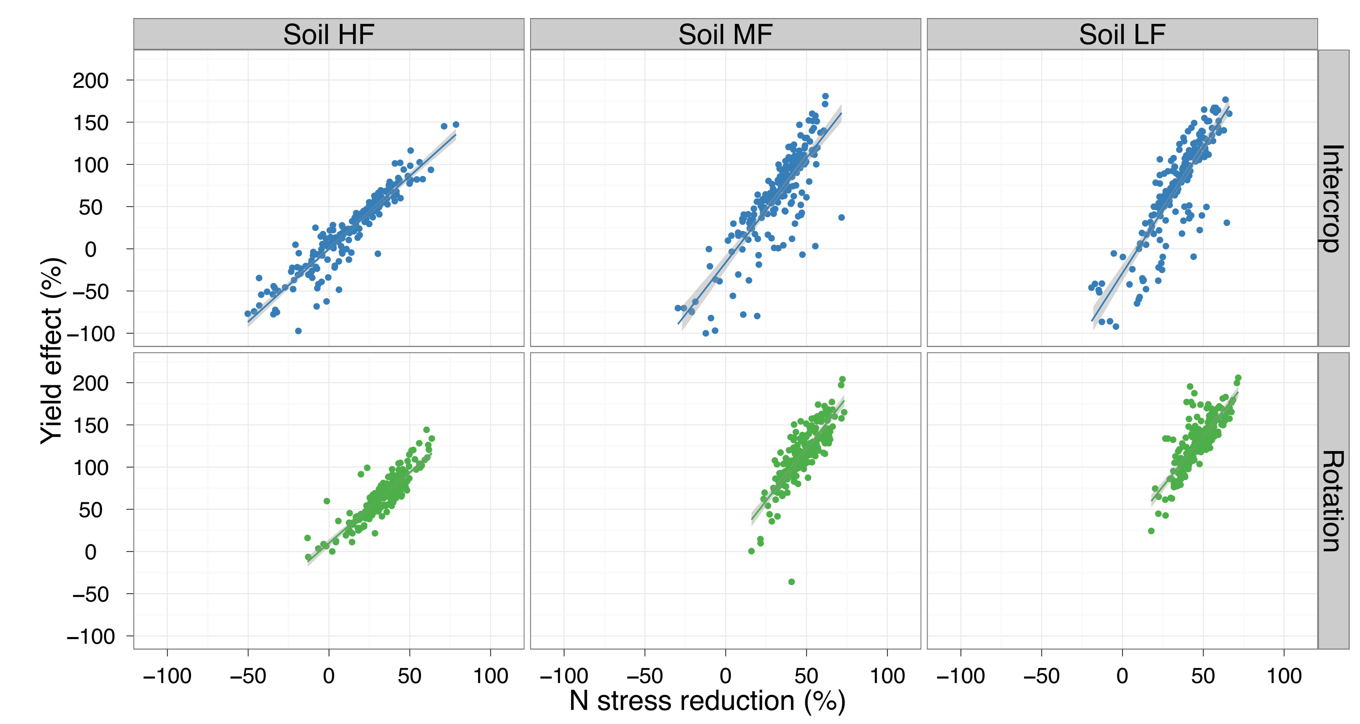

Figure 3. Effect of legume diversification on maize yields and cumulative nitrogen stress relative to continuous maize at the same fertility level. Continuous maize yield is zero. Results displayed are from early period (years 2-4 from system establishment). Regression lines are significant at p<0.05 and shaded region represents standard error of the regression.

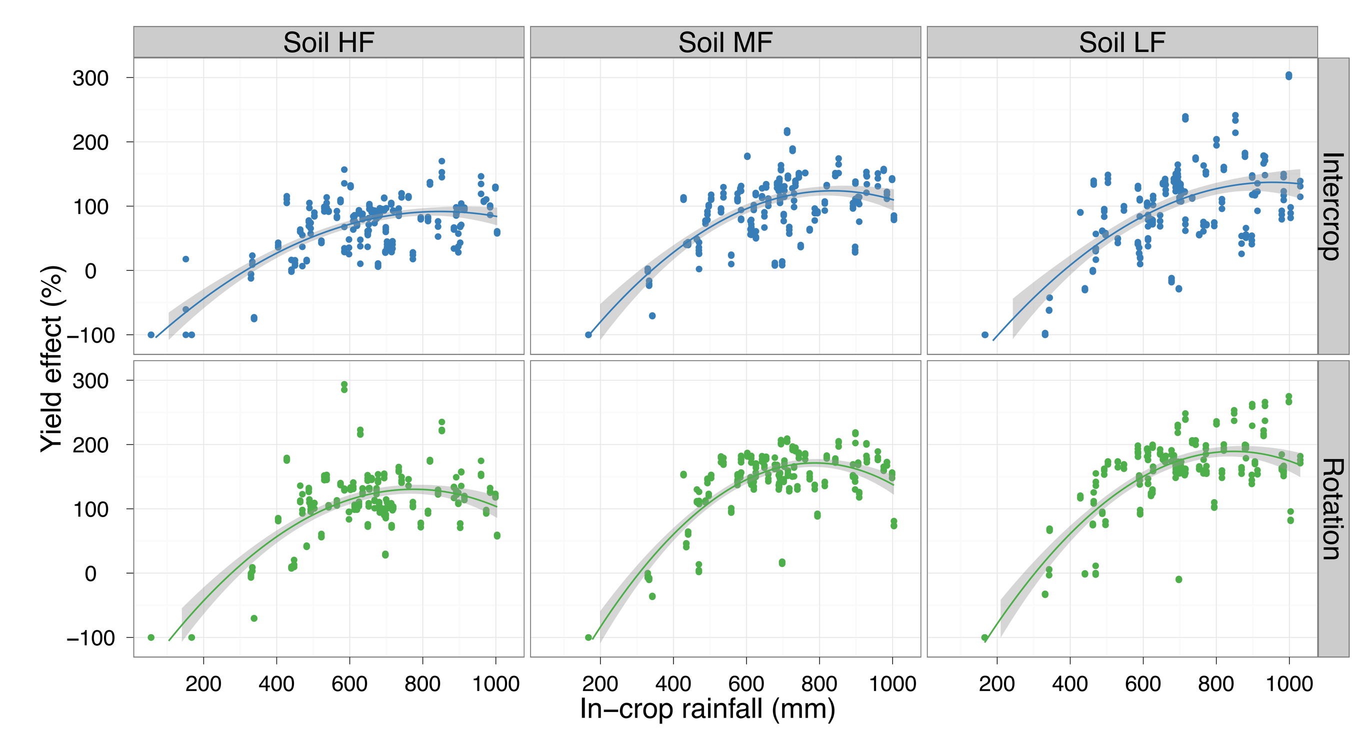

Figure 4. Effect of legume diversification on modeled maize yields, as influenced by in-crop rainfall at Kasungu. Continuous maize yield is zero. Results displayed are from early period (years 2-4 from system establishment). Regression lines are significant at p<0.05 and shaded region represents standard error of the regression.

Conclusions

Maize-pigeonpea cropping systems are viable, low-risk options for improving maize yields and soil fertility. Trade-offs between increased nitrogen and decreased soil moisture may pose a barrier to adoption in low-rainfall areas. Pigeonpea can be targeted to low fertility soils for maximum benefit.

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