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# Estimating demand for perennial pigeon pea in Malawi using choice experiments

Kurt B. Waldman [a,*], David L. Ortega [b], Robert B. Richardson [c], Sieglinde S. Snapp [d]

[a] Ostrom Workshop in Political Theory and Policy Analysis, Indiana University, USA
[b] Dept. of Agricultural, Food, and Resource Economics, Michigan State University, USA
[c] Dept. of Community Sustainability, Michigan State University, USA
[d] Dept. of Plant, Soil and Microbial Sciences, Michigan State University, USA

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ABSTRACT

Perennial crops have numerous ecological and agronomic advantages over their annual counterparts. We estimate discrete choice models to evaluate farmers' preferences for perennial attributes of pigeon pea intercropped with maize in central and southern Malawi. Pigeon pea is a nitrogen-fixing leguminous crop, which has the potential to ameliorate soil fertility problems related to continuous maize cultivation, which are common in Southern Africa. Adoption of annual pigeon pea is relatively low but perennial production of pigeon pea may be more appealing to farmers due to some of the ancillary benefits associated with perenniality. We model perennial production of pigeon pea as a function of the attributes that differ between annual and perennial production: lower labor and seed requirements resulting from a single planting with multiple harvests, enhanced soil fertility and higher levels of biomass production. The primary tradeoff associated with perennial pigeon pea intercropped with maize is competition with maize in subsequent years of production. While maize yield is approximately twice as valuable to farmers as pigeon pea yield, we find positive yet heterogeneous demand for perenniality driven by soil fertility improvements and pigeon pea grain yield.



## 1. Introduction

Population growth and rising consumption are dramatically increasing demands on agriculture and natural resources, which raises challenges for achieving global food security (Foley et al., 2011). Sub-Saharan Africa (SSA) has struggled to achieve food security for myriad reasons including poor quality soils, land degradation, low levels of fertilization, market failure, and poor infrastructure and transportation (de Graaff et al., 2011). The growing population in SSA is putting additional pressure to produce more food on the same amount of land, putting food security even further out of reach (United Nations, Population Division of the Department of Economic and Social Affairs, 2014). The Green Revolution strategies of intensive cultivation through improved crop germplasm and more wide-scale fertilizer use might not be enough to feed 9 billion people in the future (Godfray et al., 2010). A primary reason for this is that smallholder farmers rarely benefit from improved germplasm because they are farming on depleted soils that are often not responsive to fertilizer (Giller et al., 2006; Tittonell et al., 2007).

Declining soil fertility is exacerbated in Southern Africa by wide-scale continuous cultivation of maize, which mines the soil of nutrients and leaves farmers struggling to maintain yields, year after year (Snapp et al., 2010). Incorporating nitrogen-fixing legumes into the cropping systems has the potential to improve soil fertility and mitigate the nutrient mining impact of maize (Snapp and Silim, 2002a; Bezner-Kerr et al., 2007). In addition to providing much needed nitrogen, leguminous crops are high in protein making them valuable nutritionally. One legume with a wide variety of uses is pigeon pea (*Cajanus cajan*). In addition to the nitrogen-fixing properties and protein rich grain, pigeon pea provides a range of byproducts including leaves and stems used for fodder and the dried stems for fuel wood (Simtowe et al., 2010). Despite these benefits, adoption of leguminous crops and particularly pigeon pea in SSA remains low (Snapp and Silim, 2002a).

Low adoption of beneficial crops and improved varieties of crops in Africa may be related to the difficulty in transitioning from low-input, subsistence (extensive) agriculture to high-input, intensive, market-based production (Dingkuhn et al., 2006). In contrast to the types of intensive varieties developed in the Green Revolution, smallholder farmers in Africa may be more risk- averse and seek a diversity of crops and varieties that fit different farming system niches (Altieri, 2002). A diversification strategy that allows farmers to spread short-term risk and develop varieties that adapt to changing climatic conditions might improve the resilience of African smallholder systems

* Corresponding author.
*E-mail address:* waldmank@msu.edu (K.B. Waldman).

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(Morton, 2007). Perennial crops are one possible technology for investment in the long-term resilience of such systems.

Perennial crops present numerous tradeoffs to farmers. The primary tradeoff associated with perennial pigeon pea intercropped with maize is competition with maize in subsequent years of production. Since perennial crops yield less than annual crops, efforts to develop perennial wheat have focused on improved grain yield (Cox et al., 2006; Jaikumar et al., 2012; Hayes et al., 2012). However, Adebiyi et al. (2015) found that farmers in Michigan who experimented with perennial wheat described soil and environmental quality as their primary motivations for doing so. An emphasis on yield in a low-input, low-output developing country environment may not capture the tradeoffs perceived by farmers or the broader ecological benefits. According to Snapp et al. (2005), environmental benefits from cover crops predominantly accrue to society as a whole (e.g., erosion control), whereas (opportunity) costs are often local (e.g., planting a perennial crop may mean displacing a higher yielding annual). This has implications for the case of perennial grain crops, where society-level environmental services have been studied but local, farm-level benefits and costs are not known.

The main objective of this study is to assess the tradeoffs involved in annual versus perennial pigeon pea production from the perspective of Malawian smallholder farmers. We quantify the various attributes of interest and estimate demand for individual characteristics of perenniality. By exploring preferences for perennial pigeon pea we also contribute to the literature on farmer preferences regarding sustainable agricultural practices such as farmer awareness (D'Souza et al., 1993) and the long-term investment and payoff dimension (Caviglia-Harris et al., 2003). We also contribute to the literature on using choice experiments to measure smallholder preferences for crop diversity, including plant genetic resources (Birol et al., 2009), agrobiodiversity (Birol et al., 2006), local landraces (Smale et al., 2001) and hybrids (Smale and Olwande, 2014).

## 2. Background on Perennial Crops

Since a perennial crop does not need to be planted every year, less tillage is required which translates into less soil disturbance and erosion and the development of a larger root mass. The large root mass helps retain soil, prevent future erosion, and sequester more carbon since the roots remain in the ground year round. Perennial systems have more soil fauna diversity and natural belowground processes since they have more year round vegetation (Culman et al., 2010). Perennial crops also use less seed inputs since they require reseeding every three to five years as opposed to annual crops (Bell et al., 2008). As a result, the farm labor costs, energy usage, and technological inputs required for yearly tillage is lower in perennial crop systems (Pimentel et al., 2012). The larger root systems are effective at absorbing nutrients and improving water quality by preventing nutrient leaching (Culman et al., 2013). Perennial plant root structures reach more deeply into the soil and hold more soil water (Glover et al., 2010). This makes perennial crops potentially less risky in low rainfall environments, more resistant to flooding, and more resilient to climate variability.

In low-input, low-output smallholder farming systems that are common in developing countries, the tradeoffs associated with perennial as opposed to annual production are less clear. Farmers in developing countries face numerous production constraints such as labor bottlenecks at planting and harvesting time and lack of capital for purchased inputs. The risk of crop failure is higher when agricultural production takes place in more marginal environments, and where farmers face a high likelihood of depredation from both wild and domesticated animals. Since farmers lack capital to purchase farm inputs they potentially value the ecological advantages such as the soil fertility improvement or increased biomass for fodder, mulch or fuel wood more than a farmer in a developed country. There is emerging evidence that smallholder farmers value perennials, based on studies of agroforestry and semi-perennial cropping systems in Southern and East Africa (Faße and Grote, 2013; Orr et al., 2014; Snapp et al., 2010); however perennial traits of food crops have not been previously investigated.

Pigeon pea provides a unique opportunity to explore perennial traits in a food crop. Recommended production practices for pigeon pea in Malawi are consistent with agronomic recommendations throughout the region, where pigeon pea is treated as an annual crop (Malawi ministry of Agriculture, 2012; Snapp et al., 2003). However, smallholder farmers in Africa and beyond are known to 'ratoon' pigeon pea shrubs, which involves cutting back branches after the grain is harvested and then taking a second or even third crop from the regrowth (Tayo, 1985). This treats the pigeon pea shrub as a perennial, and many varieties of pigeon pea have the genetic potential to express perennial traits. Managing pigeon pea as a perennial crop is an understudied subject, and the vast majority of genetic improvement in pigeon pea has focused on developing shorter duration varieties for annual production (Lawn, 1989). There are exceptions, for example the potential for multiple harvests through ratooning of short-duration genotypes was the topic of a few studies carried out in the late 1980s (Chauhan et al., 1987). The existence of both annual and perennial forms of pigeon pea production provides a unique opportunity to explore with farmers the valuation associated with perennial attributes of a food crop.

Crop breeding efforts in Africa have emulated the successes of the Green Revolution by developing high yielding and input responsive germplasm as opposed to developing varieties that integrate traditional crop characteristics that remain essential for farmers (Dingkuhn et al., 2006). Cereal crops common in Africa, such as maize, sorghum and millet have generally been bred for intensive traits such as shorter stature, early-maturation, pest and disease-resistance, input-responsiveness, and the production of multiple crops per year (Stoop et al., 2002). Aside from appreciation of yield, farmers' preferences vary across Sub-Saharan Africa and include non-market criteria such as environmental adaptation (to low-input systems and heterogeneous environments), plant architecture (Isaacs et al., 2016; Trouche et al., 2010; Voss, 1992), cooking qualities (Demont et al., 2012), and other consumption properties (Waldman et al., 2014; Ortega et al., 2016). As such we estimate farmer demand for perenniality in the context of perennial pigeon pea production in Malawi.

## 3. Methods

### 3.1. Study Area and Sampling

The data used in this study are derived from farm household surveys conducted in three districts in Malawi's Central and Southern Regions: Dedza, Ntcheu and Zomba. These districts are highlighted in Fig. 1.

Dedza district is located south of the capital, Lilongwe, has total land area of 3570 km$^2$ and has a population of 624,445 according to the 2008 Malawi population Census. Ntcheu district, located to the south of Dedza district, covers an area of 2500 km$^2$ and has a population of 471,589. Zomba district, located in Southern region, has a total land

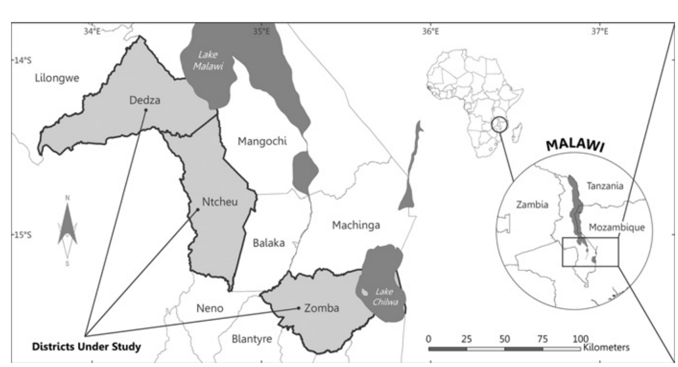


**Fig. 1.** Study area.