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Editorial

Effects of rising rural population density on smallholder agriculture in Kenya

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ABSTRACT

This study measures how Kenyan farmers and farming systems have responded to changes in population density and associated land pressures. Kenya is a relatively densely populated area, with 40% of its rural people residing on 5% of its rural land. We develop a structural model for estimating the impact of population density on input and output prices, farm size, and ultimately on smallholder behavior and agricultural intensification. Evidence is derived from a five-round panel survey between 1997 and 2010. We find a negative relationship between localized population density and farm size, and a positive relationship between population density and measures of land intensification up to roughly 500 persons/km^2. Beyond this threshold, rising population density is not associated with further increases in land intensification. Some measures of intensification actually show an alarming decline beyond this population density threshold. We also find a relatively weak relationship between population density and off-farm income. Overall, total household income per adult equivalent is found to decline significantly as population density rises. These findings raise serious policy questions about feasible pathways for rural poverty reduction in the context of increasingly land-constrained farming systems.

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Background

Reducing poverty and hunger have been overriding policy concerns for the past half century in sub-Saharan Africa. More than 70% of the poor live in rural areas and derive more than half of their livelihood from farming. Broad based agricultural growth has been widely understood to be the most powerful vehicle for reducing rural poverty and kick-starting broader structural transformation processes (Johnston and Kilby, 1975; Mellor, 1995). A major feature of the structural transformation processes achieved in green revolution Asia was that it was *small farm-led* and *broad-based* (Johnston and Kilby, 1975; Mellor, 1995). Smallholders tend to spend their incomes on locally produced goods and services, therefore stimulating the domestic non-farm economy and creating additional jobs that would support diversification out of agriculture and demographic transition (Hazell et al., 2010; Bryceson and Jamal, 1997). For these reasons, a smallholder-led growth strategy has been touted as having the brightest prospects for rapid and sustained reductions in poverty and hunger in sub-Saharan Africa (Lipton, 2005; World Bank, 2007; Hazell et al., 2007; Byerlee and de Janvry, 2009; Haggblade, 2009; Christiaensen et al., 2011; Eastwood et al., 2010; Headey et al., 2010; Wiggins et al., 2010).

However, the widely held view that agricultural development and structural transformation in sub-Saharan Africa can be achieved by largely replicating the smallholder-led growth processes in Asia have seldom adequately taken account of the salient differences in farm structure and land productivity between Asia and Africa. Evidence from most African countries shows limited land productivity growth in response to rising population density (Headey and Jayne, this issue). Unlike in Asia, where land productivity growth was achieved with the aid of extensive irrigation/water control and improved seed varieties, which made high application rates of fertilizer use very profitable, by contrast most of Africa relies on rain-fed production. Moreover, especially in densely populated areas, soils have been continuously cultivated and are facing fertility constraints that make them less responsive to inorganic fertilizer (Drechsel et al., 2001; Marenya and Barrett, 2009; Tittonell and Giller, 2012; Sheahan et al., 2013). For these reasons, the economics of fertilizer intensification are quite different in much of Africa compared to green revolution Asia. Agricultural growth in sub-Saharan Africa (SSA) has historically been based on area expansion, not yield growth (Evenson and Gollin, 2003; Charles et al., 2010). However, continued area expansion is increasingly problematic, because of increased recognition of

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global environmental damage caused by the conversion of grassland and forests to agriculture (Powlson et al., 2011), because land expansion in some parts of rural Africa is not economic given current states of infrastructure, prices and production technology (Chamberlin et al., this issue), and in some areas because there is little or no unallocated land for further expansion.

Unavailability of land for cropland expansion is particularly serious in countries with high rural population densities such as Kenya. In 2010, 40% of Kenya's rural people resided on 5% of its rural land. Mean population density in these areas is 411 persons/km^2 of arable land. Population per arable kilometer of land in the Tegemeo Institute's nationwide rural household sample in 2010 was 412 and 598 persons per arable km^2 at the 50th and 75th percentiles of the distribution. Farm sizes are small and shrinking gradually as households subdivide their land to the next generation. Outmigration to towns and to more sparsely populated rural areas with arable land might be a possibility but there are well-known constraints to migration by members of one ethnic group to lands traditionally held by other ethnic groups (Kanyinga, 2009; Jenkins, 2012). We are increasingly concerned that development policy in the region has not adequately addressed how a smallholder-led agricultural strategy must be adapted to address the limitations of small and declining farm sizes and the growing problems of land accessibility in the densely populated areas that remain dependent on rain-fed production systems.

The overarching question addressed in this paper is whether and how farming systems are intensifying in response to rising rural population density in many areas of Africa. Kenya provides a good case study to examine these issues because a large proportion of the rural population resides in densely populated areas experiencing population pressures. Our study relies on five waves of panel survey data on 1,146 farm households interviewed between 1997 and 2010. This geo-referenced survey data is merged with geographic information systems (GIS) data on soil quality, arable land availability, and more disaggregated data on current and historical population numbers at the villages where the panel households are located.

There are particular situations where population growth has been associated with agricultural intensification and improved soil fertility. For example, Tiffen et al. (1994) presents a case study of agricultural intensification in the semi-arid district of Machakos, Kenya, where agricultural intensification occurred alongside a five-fold increase in population density over several decades up to 1990.[1] However, the association between population density and agricultural intensity does not necessarily infer causality. There could be feedback effects reflecting underlying endogeneity. For example, in Papua New Guinea, Brookfield (1972) encountered intensive practices in situations where there was no population pressure and extensive practices in areas where land was in great demand. To address these potential endogeneity issues, we develop a structural model for estimating the total impact of population density on smallholder households' behavior and various measures of agricultural intensification such as farm input use and farm output per unit of land and labor. The study provides an explicit modeling framework for determining the factors explaining farm productivity growth (or lack thereof) within the context of potentially endogenous population density changes. Most of the earlier studies examining the impact of population density on agricultural production in the region treated population density as exogenous (Benin, 2006; Pender and Gebremedhin, 2006; Pender et al., 2006). Our analysis may therefore avoid sources of coefficient bias and provide more accurate policy insights regarding a smallholder-led development strategy for densely populated areas.

Conceptual framework

Smallholder agriculture systems in sub-Saharan Africa are characterized by semi-commercial farms that produce multiple crops. These systems combine two fundamental units of microeconomic analysis, the household and the firm, that are highly interdependent. As opposed to the purely subsistence systems, in semi-commercial systems some farm inputs are purchased and some outputs are sold in the markets. To analyze the semi-commercial systems, we start with the theoretical framework proposed by Singh et al. (1986), popularly known as the *agricultural household model*. The framework captures the farm household's consumption and production interdependences in a theoretically coherent manner. In this framework, the objective of farm households is assumed to be maximization of expected household utility subject to budget and other resource constraints. Agricultural production either contributes to household's resource constraint through consumption or through cash generation if farm output is sold at market. Thus, agricultural production is incorporated as part of the household's budget constraints. Later, de Janvry et al. (1991) extended the original Singh et al. (1986) agricultural household model to include market failures while Omamo (1998) incorporated transactions costs. In the extended agricultural household model, the household problem is to maximize its utility:

$$\max U = U(X_a, X_m, X_l) \quad (1)$$

where the commodities are agricultural goods (X_a), market-purchased goods (X_m), and leisure (X_l). Utility is maximized subject to several constraints, among them: a cash constraint, production technologies for own-farming and nonfarm self-employment activities; exogenous effective prices for tradables; an equilibrium condition for self-sufficiency of farm production; and an equilibrium condition for family labor. First-order conditions of this model give a system of factor supply and demand functions, which in turn allows the estimation of factor inputs and supply functions.

At the minimum, the theory posits that the desired supply is a function of the expected output price, and supply shift variables such a vector of input prices, and the expected output and input prices of other production possibilities. Since the objective of this study is to examine how human population density affects smallholder agricultural production, the immediate task is to conceptualize how population density enters the input demand and output supply functions. A diagrammatic presentation of the channels through which population density influences smallholder production inputs and outcomes is presented in Appendix A. Assuming markets are allowed to operate freely and the appropriate price signals are transmitted to producers, escalating population density is hypothesized to affect agricultural production through three pathways, namely, decreasing land holding sizes, increasing labor supply, and increasing demand for food. Regarding the first two pathways, declining farm sizes are hypothesized to trigger changes in relative factor prices, consequently triggering changes in the land–labor ratio. The price of the scarce factor (land) is bid higher while the relative price of the more abundant factor (labor) declines. Regarding the third pathway, population growth directly affects the demand for agricultural products and exerts upward pressure on food prices thereby inducing a supply response. Other factors held constant, increasing demand for food triggers increased demand for non-mobile factor inputs thereby exerting putting more pressure on their prices as well.

According to the "induced innovation" theory, a change in the relative price of factors influence the factor use proportions (Hicks,

[1] Critics argue, however, that Machakos' land intensification was facilitated by exogenous factors unrelated to population density (e.g. Zaal and Oostendorp, 2000).