Emerging Land Issues in African Agriculture:

Implications for Food Security and Poverty Reduction Strategies

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Paper presented as part of Stanford University's *Global Food Policy and Food Security Symposium Series,* sponsored by the Center for Food Security and the Environment and the Freeman Spogli Institute for International Studies,
January 12, 2012, Stanford, California

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Executive summary:

Despite the fact that sub-Saharan Africa in 2012 contains much of the world's unutilized and underutilized arable land, a significant and growing share of Africa's farm households live in densely populated areas. Based on two alternative spatial databases capable of estimating populations at the level of one square kilometer and distinguishing between arable and non-arable land, we find that in at least four of the 10 countries analyzed, 25% of the rural population resides in areas exceeding 500 persons per square kilometer, estimated by secondary sources as an indicative maximum carrying capacity for areas of rain-fed agriculture in the region. The apparent paradox of a large proportion of Africa's rural population living in densely populated conditions amidst a situation of massive unutilized land is resolved when the unit of observation moves from land units to people.

A review of nationally representative farm surveys shows a tendency of (1) declining mean farm size over time within densely populated smallholder farming areas; (2) great disparities in landholding size within smallholder farming areas, leading to highly concentrated and skewed patterns of farm production and marketed surplus; (3) half or more of rural farm households are either buyers of grain or go hungry because they are too poor to afford to buy food; most households in this category control less than one hectare of land; and (4) a high proportion of farmers in densely populated areas perceive that it is not possible for them to acquire more land through customary land allocation procedures, even in areas where a significant portion of land appears to be unutilized.

Ironically, there has been little recognition of the potential challenges associated with increasingly densely populated and land-constrained areas of rural Africa, despite the fact that a sizeable and increasing share of its rural population live in such areas. Inadequate access to land and inability to exploit available unutilized land are issues that almost never feature in national development plans or poverty reduction strategies. In fact, especially since the rise of world food prices after the mid-2000s, many African governments have made concerted efforts to transfer land out of customary tenure (under the control of traditional authorities) to the state or to private individuals who, it is argued, can more effectively exploit the productive potential of the land to meet national food security objectives. Such efforts have nurtured the growth of a relatively well-capitalized class of "emergent" African farmers. The growing focus on how best to exploit unutilized land in Africa has arguably diverted attention from the more central and enduring challenge of implementing agricultural development strategies that effectively address the continent's massive rural poverty and food insecurity problems, which require recognizing the growing land constraints faced by much of its still agrarian-based population. The final section of the paper considers research and policy options for addressing these problems.

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1. Introduction

In his 2010 Presidential Address of the Agricultural and Applied Economics Association, Thomas Hertel raised the specter of a Malthusian "perfect storm" hitting the world's arable land base. Could the rising demand for food, increased use of farmland for fuel, more extreme weather events, and reactive responses by rattled governments quickly exhaust the world's remaining arable land? There is widespread agreement that accelerating productivity growth on existing farmland has the brightest prospects for relieving these pressures. But under very plausible scenarios, the global demand for new farm land could rise sharply, potentially triggering a rush for new arable land. Ironically, Sub-Saharan Africa, the most food insecure continent in the world, has the largest and cheapest supply of unutilized arable land in the world (Fischer and Shah, 2010).[2]

From this global context, this paper assesses the potential impacts of rising demand for agricultural land in Africa in the context of the continent's longstanding challenges: how to address its hunger problems and the livelihoods of its poor people, the majority of whom live in rural areas.

This study is motivated by the need to understand the nature and magnitude of land constraints in African agriculture, the impacts of *status-quo* policies on food security and poverty, and the implications for development strategy. To our knowledge, there has been little recognition of the potential challenges associated with increasingly densely populated and land-constrained areas of rural Africa. Nor has there been sufficient discussion of how institutions and policies relating to land access would need to be modified to provide the greatest prospects for achieving broad-based agricultural growth and reducing rural poverty.

We begin by casting these issues within two important conceptual models of development economics: the *structural transformation* and *induced innovation* processes. The structural transformation process has long been considered by development economists to be the main route through which poverty and hunger in Africa would be overcome. A major feature of the structural transformation processes achieved in other parts of the

[2] Fischer and Shah's assessment is reported in Deininger and Byerlee 2011 (p.xxxiv). Of the 445.6 million hectares of uncultivated arable land in the world, 201.5 million hectares are in sub-Saharan Africa, over 60% more than in Latin America, which has the next most uncultivated arable land.

world was *broad-based* and *small farm-led* agricultural growth (Johnston and Kilby 1975; Mellor 1976, Lipton 2005).[3] This paper examines the potential for this kind of growth in light of evidence that a growing proportion of the rural population is either landless or resides on farms under one hectare, dependent on rain-fed agriculture in semi-arid conditions, largely unable to feed themselves, and increasingly vulnerable to pressures on customary authorities to relinquish land to non-local interests. The paper also draws upon theories of induced innovation to explain how rising land pressures in many parts of Africa are likely to be affecting the evolution of farming systems and the welfare of African farmers.

We then present recent MSU work estimating the impacts of rising population densities on household behavior and welfare, drawing on household panel survey data from several countries in eastern and southern Africa. The final section of the paper considers the implications of these findings for agricultural and poverty reduction strategies in Africa.

2. Data

This study draws on two types of data. First, we utilize regional databases describing detailed spatial distributions of rural populations and arable land. Estimates of rural population density are derived from two sources: the Global Rural-Urban Mapping Project (GRUMP) at Columbia University[4] and the AfriPop Project hosted at the University of Florida.[5] Both datasets provide gridded estimates of local population densities based on census data at the most localized units available, and then mapping these populations into grid cells corresponding to that reporting unit (obtained by dividing the county into, e.g., one square kilometer units). GRUMP and AfriPop differ principally in the means of allocation: the GRUMP separates the urban and rural components of local population, with the rural portion being equally allocated to all rural grid cells contained in the most disaggregated spatial reporting unit of the most recent census. The AfriPop dataset uses remotely-sensed data on landcover to weight this allocation, such that cells corresponding to areas with evidence of human settlement receive higher allocation weights (than, say, a cell that corresponds to forest or desert). Given the different sets of assumptions built into the construction of these datasets, we use both datasets to give robustness to our analytical conclusions.

[3] In recent years a small number of scholars have questioned whether Africa's development will follow this structural transformation trajectory (e.g., Collier and Dercon 2009), an issue that we take up later in this paper.
[4] Data available from http://sedac.ciesin.columbia.edu/gpw/index.jsp See Balk et al (2004) for a description of the methods used to compile the dataset.
[5] Data available from http://www.clas.ufl.edu/users/atatem/index_files/AfriPop.htm. See Tatem et al (2007) for a description of the methods used to compile the dataset.

Information on the portion of arable land within each grid cell was obtained from the Global Agro-ecological Zones (GAEZ) 3.0 database.[6] The GAEZ data consist of gridded estimates of local land and agro-climatic resources -- including soils, terrain, land cover, and a variety of climatic indicators -- as well as derived estimates of agricultural suitability and potential yields for a variety of commodities under given management levels. Drawing from the land cover components of the GAEZ database, we assembled three definitions of “arable land”: areas classified as (a) under cultivation; (b) under cultivation or grassland; and (c) under cultivation or grassland or forest/woodland. The reasoning behind our adoption of multiple definitions was to evaluate the robustness of our analyses to alternative definitions, with classification (a) reflecting currently available farmland, and (b) and (c) reflecting potential available farmland if sufficient costs are incurred to convert grassland and forest land to farming.[7]

Within a GIS, we combined the data on arable land and rural population at the level of one square kilometer grid cells covering all of sub-Saharan Africa.[8] Use of this data allows for much greater localized variation in rural population densities than would be possible if estimated at more aggregated spatial units. As we will see, this leads to some surprising conclusions.

The second source of data is drawn from farm household surveys. These datasets are generally nationally representative and carried out by the official national statistical agencies or by local universities. In particular, this study utilizes data from Kenya and Zambia between 1997 and 2010. The nationwide Egerton University/Tegemeo Institute Rural Household Survey is a panel dataset tracking roughly 1,240 small-scale farm households in 5 survey waves over the 13-year period from 1997 to 2010. The nationally representative Zambia dataset was implemented by the Central Statistical Office and tracks

[6] Data and information available at: http://www.iiasa.ac.at/Research/LUC/GAEZv3.0/ See Fischer et al (2010) for methodological details of the database’s construction.

[7] Some grid cells specified as already under cultivation appear to have been misclassified as savannah or woodland; thus, moving from definition (a) to (b) and (c) implies a tradeoff between errors of omission and commission; analyses of land pressures based on the broader definitions of “potentially arable” may be seen as lower bounds on actual pressures. Land pressures would be intensified further after accounting for land required for grazing and fallow. Rotational systems involving fallowing will be necessary in many areas of Africa, e.g., Myiombo woodlands, where soils are leached and acidic. Under currently available technologies, there would be major constraints on sustainable intensification which involved the elimination of fallows (Holden, Otsuka, and Place 2012). Land issues that are particular to pastoral communities are outside the scope of this study.

[8] We excluded grid cells categorized as rural that contained less than 10% arable land or exceeded 2,000 persons per km^2 based on the assumption that population densities over this level were approaching peri-urban status or were mis-categorized.

over 6,000 small- and medium-scale households (0.1 to 20 hectares) surveyed in 2001, 2004 and 2008. Details of both data sets are contained in Jayne et al (2010).[9]

3. Conceptual Framework: the Role of Land in Affecting Development Trajectories

Structural transformation

Smallholder-led structural transformation is considered by most development economists to be the major pathway from a semi-subsistence agrarian society to a more prosperous, food secure, and diversified economy. The pioneering work of Johnston and Mellor (1961), Johnston and Kilby (1975) and Mellor (1976) first documented the structural transformation process in the regions of Asia that experienced Green Revolutions. The structural transformation process starts with an exogenous productivity shock (e.g., the creation and mass adoption of new farm technology), causing a build-up of purchasing power by millions of small farmers. These millions of farmers subsequently spend and re-cycle more money through the economy, igniting demand and employment growth in non-farm sectors, which in turn increases the demand for food and other farm products in a virtuous cycle in which the rural and urban labor forces provide a market for each other. Rising demand for food and fiber products attracts private investment flows into the storage, transport, processing, and retailing stages of commodity value chains, further expanding employment and diversifying the economy. Over time, broad-based income growth causes the share of food in overall consumption to fall, making available more disposable income to fuel the development of non-farm sectors. As the demand for non-farm goods and services rise, the labor force responds by shifting gradually from the farm to non-farm sectors, the demand for education and job skills rises, and the economy becomes increasingly diversified and urban. Rural households are pulled off the farm by better paying non-farm jobs, not pushed into low-paying desperation jobs in the towns due to poor prospects in agriculture.

Recently, the feasibility of a small-farm based structural transformation in Africa has been questioned by some scholars (e.g., Collier and Dercon 2009), and, by their actions, a growing number of African policy makers.[10] These views have been bolstered by

[9] Each of these surveys instruments, which contain the details of the types of information collected and used in this study, can be viewed and downloaded at http://www.aec.msu.edu/fs2/kenya/index.htm, and http://www.aec.msu.edu/fs2/zambia/index.htm.

[10] For example, Zambia's 1995 Land Act provides the rationale for state conversion of substantial portions of land from customary tenure (where smallholder farming is located) to state land to enable land to be more productivity utilized by local entrepreneurs, investors, and farming blocks. Curiously, the Zambian government's position is that conversion to state land is necessary to provide the means for the state to invest in requisite transport infrastructure, irrigation and electricity to support farm intensification; the reasons why

frustration over the slow rate of development in African agriculture. There is increasing receptivity to viewing large-scale farm development in Africa at least as a complement if not an alternative to broad-based smallholder-led agricultural growth.

Yet, clearly, agricultural growth alone is not sufficient for poverty reduction; the distribution of the growth is critical. Johnston and Kilby (1975); Mellor (1976), and more recently Deininger and Squire (1998), and Vollrath (2007) have demonstrated that relatively egalitarian land distribution patterns have tended to generate more broadly based growth, and consequently higher rates of economic growth than in cases where land distribution was highly concentrated. The basic reason for this is that broad-based agricultural growth tends to generate greater second-round expenditures in support of local non-tradable goods and services in rural areas and towns. These multiplier effects tend to be much weaker when the source of agricultural growth is concentrated in relatively few hands. Another argument for small-farm led development has to do with the productivity advantages of farms operated primarily with family labor as opposed to hired labor (Hayami and Otsuka 1993; Binswanger, Deininger and Feder 1995; Vollrath 2007). Thus the rate of growth is likely to be affected by the distribution of assets in the agricultural sector, particularly land.

Moreover, evidence indicates that not only does the initial distribution of assets affect the rate of economic growth, but it also affects the poverty-reducing effects of the growth that does occur. For example, Ravallion and Datt (2002) found that the initial percentage of landless households significantly affected the elasticity of poverty to non-farm output in India. In a sample of 69 countries, Gugerty and Timmer (1999) found that, in countries with an initial "good" distribution of assets, both agricultural and non-agricultural growth greatly benefitted the poorest households with positive poverty reducing effects. In countries with a "bad" distribution of assets, however, economic growth was skewed toward wealthier households, causing the gap between rich and poor to widen. It is especially noteworthy that in this latter group of countries, agricultural growth was associated with greater increases in inequality than was non-agricultural growth. Mellor, Johnston, Lipton and others clearly documented that productivity growth on millions of small farms in Green Revolution Asia was crucial to structural transformation and rapid poverty reduction. They contrasted the Asian experience with parts of Latin America, which also achieved agricultural growth, but not in an inclusive way. Latifundia estates expanded production impressively in many cases while millions of small peasant farms remained mired in poverty and were often dispossessed of their land.[11] A major lesson for

similar intensive public investments are not considered in agricultural development strategies for customary lands or in national poverty reduction strategies are not addressed in the document.

[11] Land and credit policies biased toward large-scale agriculture have been found to dispossess small farmers of their land, encourage mechanized rather than labor-intensive production, and largely fail to reduce rural poverty even during periods of rapid agricultural growth (Lopez and Valdes 2000; World Bank 2009). Latin America has the most concentrated farm structure of all regions of the world. Landholding size Gini

Africa from these contrasting experiences of smallholder-led Asia and estate-led Latin America is that if we want agricultural growth to rapidly reduce poverty, it must be broad-based.

Land intensification and yield gaps

The brightest prospects for agricultural-led structural transformation would be if it could be achieved through productivity-enhancing yield growth on currently utilized farmland. Productivity growth on existing farmland would both ease the demand for new farmland being brought into production as well as help to conserve the world's remaining forests from being destroyed to meet rising food needs (Hertel 2011). Land productivity growth could occur either through yield growth or shifts in crop area to higher-valued crops or a combination of both. Farm surveys are already showing evidence of gradual increases in the share of cropped area devoted to high-return agricultural activities in some regions, especially on relatively small farms.[12] Much greater potential for this form of productivity growth will depend on the pace of food and input market development, improvements in physical infrastructure, investments in commodity value chains for high-value commodities, and stable marketing and trade policies.

The potential for yield growth of the basic staples is enormous. Actual yields in Sub-Saharan Africa show a persistently yawning gap compared to attainable yields, i.e., yields that could be attained if available technologies and management practices were used (Fischer, Byerlee and Edmeades 2009; Licker et al 2010). Maize yields even in the breadbasket regions of Africa average roughly 25% of attainable yields, and seldom exceed 40% (Deininger and Byerlee 2011). Given that roughly half of all cropland in sub-Saharan Africa is devoted to staple grains, closing the yield gap even partially could simultaneously improve the world's supply-demand food balance and contribute to rural poverty reduction in Africa.

However, given current food and input prices, it is unclear how far yield gaps could be narrowed in a way that would be profitable for farmers. Recent studies from the region show that recommended fertilizer application rates are often not profitable or are highly risky given the soil conditions and drought-prone environments that farmers live in (Xu et al. 2009; Marenya and Barrett 2009; Smaling et al 2003; Sheahan 2011, Burke 2011).

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coefficients reported by Vollrath (2007) range from 0.81 for Latin America, to 0.59 for South Asia, to 0.49 for Sub-Saharan Africa.

[12] Farm survey data from Kenya and Zambia show that fresh fruits and vegetables, dairy, and other forms of animal production are rising as a share of total farm production, and that this trend is associated with improvements in the reliability of food markets (Jayne *et al.* 2010). In Kenya, horticulture production as a share of total farm production is especially high on small farms, suggesting that land-constrained households may, at the margin, be devoting more of their scarce area to crops with relatively high returns (Kimenju and Tschirley, 2009).

Other studies conclude that optimal fertilizer application rates on maize appear to be much lower than official recommendations, and that these optimal levels are fairly close to observed application rates on farmers' fields given existing input and output prices and response rates (Matsumoto and Yamano 2009; Sheahan 2011). Improvements in agronomic practices and measures to reduce transport costs could promote the profitability of fertilizer use and lead to higher optimal application rates. Along with output market development, these interventions could help farmers to close the currently high yield gap.

Another factor that would help farmers around the world close the yield gap is increased global food prices (Hertel 2011). If global food prices should rise, as they are projected to do for at least the next 10 years (e.g., OECD 2011),[13] farmers may have great incentives to intensify their use of modern inputs and use more intensive management practices. The issue of which African farmers would be able to respond to these price incentives and the potential income distributional effects is treated later.

Rising population densities and induced innovation

Increasing rural population density is a third factor that may contribute to closing the yield gap in African food production. The ways in which increasing population density affects the evolution of farming systems was first laid out in the pioneering work of Esther Boserup (1965). Growing population densities, land scarcity, and access to markets generally leads to the intensification of land use, the development of land and labor markets, investments in land-augmenting practices such as irrigation and drainage, and the gradual emergence of individual property rights for land. These ideas were later formalized in Hayami and Ruttan's (1971) theory of induced innovation, which explains how changes in relative prices of land, labor, and capital affect the evolution of farming system to make more productive use of the scarce factor of production. Seminal works in the induced innovation literature (e.g., Binswanger and Pingali 1988; Binswanger and McIntire 1987) argued that increases in rural population density in sub-Saharan Africa should induce a number of changes including greater intensification of land through the use of fertilizer and improved seed, decreased fallows, investment in land-augmenting technologies such as irrigation and drainage, more labor time devoted to each unit of land cultivated (e.g., weeding labor per unit of land rises), the development of land, labor and informal financial markets, increased landlessness, and declining availability of common land for livestock (Table 1). Given this kind of innovation, Binswanger and McIntire argue that through input intensification farmers can raise land productivity (i.e., either increased yields or shifts to crops that offer higher net returns per unit of land), and maintain or raise labor productivity growth even in the context of rising labor/land factor proportions. This

[13] Reasons commonly stated for a secular rise in global food prices include rising incomes in populous middle-income countries such as China and India, the rising use of food for fuel, and the apparent tightening supply/demand balance in world oil markets.

literature has explained how agricultural systems in many parts of Africa have over the past century transitioned from one end of the continuum in Table 1, shifting cultivation, to the other side of the continuum, intensive annual or multiple cropping with less and less land being held in fallow to restore soil productivity.

Outstanding policy questions deriving from rising land pressures

However, the induced innovation literature for the most part has not considered what lies beyond the last stage of Boserup's farming systems continuum in the context of more intense land pressures and ever smaller farm sizes in increasingly densely populated rural areas. Can land intensification and productivity growth be sustained in a linear trajectory as population density rises without incurring diminishing returns from soil nutrient depletion, the elimination of fallows, and scale-diseconomies on ever smaller farm sizes?

There are several reasons why declining farm size below a minimum level might be associated with higher production and marketing costs. The first reason concerns soil nutrient depletion. Using cross sectional data from 37 African countries, Dreschel et al (2001) confirm a significant relationship between population density, reduced fallow periods, and soil nutrient depletion in SSA farming systems. In their view, rising rural population density is a major cause of declining per capita food production in many parts of SSA. Restoring and improving soil fertility requires much more than nitrogen, phosphorus, and potassium, hence greater use of conventional inorganic fertilizers, while necessarily, certainly will not be sufficient to reach attainable yields. Second, the efficiency advantages of small farms in relation to large-scale farms do not apply when comparing, for example, 4 hectare vs. 0.5 hectare farm sizes. There may be scale economies in input procurement, output marketing, and ability to obtain financing which may disadvantage small farms (Collier and Dercon 2009). Survey data regardless of location in SSA indicate that farms below one hectare tend to be net buyers of staple food (Jayne *et al.* 2010). The FAO/IFDC argues that the "carrying capacity" of land for SSA agriculture ranges between 100-500 persons per km^2 depending on agro-ecological potential for intensive production and market access conditions (Henao and Baanante 1999). The evidence presented below shows that a surprisingly high percentage of the rural population lives in areas exceeding this upper range.

In fact, most of Sub-Saharan Africa has witnessed a gradual but steady decline in mean farm size over the past 50 years as rural population growth has outstripped the growth in arable land. Table 2 shows the changes in the ratio of land cultivated to agricultural population over the past 5 decades for a number of African countries. About half of the countries in Table 2 show a substantial decline in land-to-labor ratios in agriculture. In Kenya's case, for example, cultivated land per person in agriculture has declined from 0.462 hectares in the 1960s to 0.219 hectares in the 2000-08 period. A consistent story emerges from farm survey data; most but not all countries show a gradual decline in median and mean farm size over time. More comprehensive evidence of mounting population pressures and land constraints in smallholder agriculture and why they sometimes exist in environments of apparent land abundance are reserved for the following section.

The following basic model allows us to synthesize the challenges for farming areas facing rising land pressures in a structured way. Labor productivity in agriculture (Y/L) is defined as the product of two terms: net farm income per unit of land (Y/A) and the ratio of land to labor (A/L).

$$(1) \qquad \frac{Y}{L} = \frac{Y}{A}\frac{A}{L}$$

We focus on labor productivity in agriculture because it is normally considered to be the closest reflection of returns to labor in agriculture. *Y* is defined as net farm income (gross value of output minus all input costs such as seed, fertilizer, hired labor, etc., except own family labor). In most of the countries shown in Table 2, *A/L* appears to be declining over time, as rural population grows at a faster rate than arable land.[14] This implies that in order for labor productivity to rise over time, the net value of output, *Y/A* (net value of output per unit land) must rise faster than the ratio *A/L* declines.

Raising the growth rate of *Y/A* puts a major burden on technology and changes in farmer management practices to outpace the decline in *A/L*, which may be especially challenging in the decades to come due to likely changes in weather patterns (Schlenker and Lobell (2010). To reduce the dependence on technology to save the day, some extensification of land might be needed (i.e., *A* may need to rise over time to sustain labor productivity growth in agriculture. Hence, important questions arise over the feasibility of area expansion, *A*, and whether and how arable land can be conserved for current and future generations of rural African farmers as part of a long-term and broad-based structural transformation development strategy. These questions relate front and center to current policy issues about how best to utilize Africa’s available arable lands.

[14] See Appendix 1 for data on rural population growth rates in SSA countries.

4. Evidence of Land Constraints in SSA

Distribution of arable land by rural population

There is a widespread view that sub-Saharan Africa is a land abundant region with low rural population density. Tables 3a and 3b present the distribution of rural population density in 10 countries according to the Global Rural-Urban Mapping Project (GRUMP) and AfriPop spatial databases described in the data section. Use of this data allows for much greater localized variation in rural population densities than has been typically reported previously using more aggregated spatial units.

Both data sources indicate great variation in rural population densities. While the bottom 50% of the rural population in all countries live in relatively sparsely populated areas, conforming to conventional perceptions, a sizeable proportion of the rural population are in heavily populated areas exceeding 500 persons per km2. According to the GRUMP data in Table 3a, over 25% of the rural population lives in areas exceeding 500 persons per km^2 in 4 of the 10 countries examined in this study. According to AfriPop (Table 3b), at least 25% of the rural population lives in areas exceeding 500 persons per km^2 in 5 of these 10 countries. Because rural population growth is rising faster than land under cultivation in most countries, these proportions are most likely rising over time. Recall that according to a joint FAO/IFDC report, the maximum carrying capacity of the land for intensive cultivation in most areas is 500 persons per km2 (Henao and Baanante 1999); while this threshold cannot be considered to be precise for all areas, e.g., those with multiple cropping seasons and/or irrigation potential, it does give an first-order approximation of land supporting capacity for the dryland farming conditions on which the vast majority of Africa's rural population is located. [15]

A visual representation of the dispersion in rural population density on arable land is shown for Kenya in Figure 1. Roughly 40 percent of Kenya's rural population resides on five percent of its arable land. On the other end of the continuum, three percent of the population controls 20 percent of the nation's arable land. An alternative visual impression of the dispersion of population density is shown in Figures 2 and 3 for Kenya and Zambia, respectively. Reasons for the large variations in rural population densities are examined later in this section.

[15] Binswanger and Pingali (1988) show that after accounting for soil and climate conditions as well as potential technological options, it is possible to compute standardized *agroclimatic population densities* for various countries measuring the number of people per million kilocalories of production potential. They report that when countries are ranked conventionally by population per square kilometer of agricultural land, Bangladesh comes first, India comes seventh, Kenya falls somewhere in the middle, and Niger is near the bottom. When ranked by agro-climatic population density, the rankings change dramatically: Niger and Kenya are more densely populated than Bangladesh is today, and India ranks only twenty-ninth on the list.

Moreover, the effects of increasing crowded rural areas are not confined to those living in such areas. At least some part of rapid urbanization and its associated problems of the spread of slums, health and sanitation problems, and congestion are due to inadequate living standards in rural areas giving rise to migration. Jayne and Muyanga (forthcoming) show that the net outflow of adult labor is four times higher from the top 20% of villages ranked by population density than from the bottom 20% of villages. Therefore, the question of appropriate development strategies for densely populated rural areas would appear to be increasingly relevant to a significant portion of Africa's population.

Trends in farm size and land concentration in customary lands[16]

Despite widespread acceptance that "pro-poor" agricultural growth is strongly associated with equitable asset distribution, surprisingly little attention has been devoted to quantifying land distribution patterns within Africa's small-scale farming sector.[17] To examine the degree of concentration of land within African farming sectors, Table 4 presents basic information on farm size and distribution within the smallholder farm sector in six countries for which nationwide survey data was available. As shown in column b, mean farm size in the small farm sector range from 2.76 hectares in Zambia to 0.71 hectares in Rwanda in 2000. The three Rwanda surveys indicate that mean household land access has declined significantly over the past 15 years.[18]

On a per capita basis, farm sizes range from 0.56 hectares per person in Zambia to 0.16 hectares per person in Rwanda in 2000 (Table 4, column c). Mean farm size figures mask great variations in land access within the smallholder sector. After ranking all smallholders by household per capita farm size, and dividing them into four equal quartiles, households in the highest per capita farm size quartile controlled between eight to 20 times more land than households in the lowest quartile. In Kenya, mean landholding size for the top and bottom land quartiles were 1.10 and 0.08 hectares per capita, respectively. These figures already include rented land, which is marginal for most countries examined. We also find across all a tendency for the poorest households to control the least amount of land, and to have relatively high labor-to-land ratios within their households. In this respect, Africa's rural poor are similar to those in much of Asia as reported by Sen (1990).

In each country, the bottom 25 percent of small-scale farm households are approaching landlessness, controlling less than 0.12 hectares per capita. In Ethiopia and Rwanda, the bottom land quartile controlled less than 0.03 hectares per capita. It is important to stress

[16] Much of the material in this section draws from Jayne *et al.*, 2003.
[17] Some notable exceptions include Haggblade and Hazell, 1988, and Holden, Otsuka, and Place 2009.
[18] Andre and Platteau (1998) present an in-depth case study which shows acute competition over land and suggest a connection between land disputes and the civil war in 1994.

that these surveys contain only households engaged in agricultural production; households not engaged in farming are not in the sample.

Nevertheless, it is possible that the bottom land quartile may contain mostly "Sunday farmers" who are engaged primarily in off-farm activities for their livelihoods. To examine this possibility, we compute income shares from crop production, animal and animal-derived production, and off-farm income for each land quartile. As expected, off-farm income shares are highest for the bottom land quartile and decline as landholding size rises. However, in none of the five countries do households in the bottom land quartile earn more than 50% of their total income, on average, from off-farm activities, despite having very small farms. In Zambia, Rwanda, Mozambique and Ethiopia, the off-farm income shares for households in the bottom land quartile were 38.5%, 34.5%, 15.9% and 12.7%, respectively. By contrast, this figure was 50% in Kenya, which can be attributed to that country's relatively developed and diversified economy, and which affords land-constrained rural households greater opportunity to earn a livelihood through the labor market.

Survey evidence also indicates declining landholding sizes over time. A nationally representative survey of Kenya's small-scale farm sector in 1977 carried out by the Central Bureau of Statistics reports mean farm size ranging across provinces from 2.10 to 3.48 hectares (Greer and Thorbecke, 1986). By contrast, mean farm size in Egerton University's nationwide surveys from 1997 to 2010 show mean farm size to be 1.97 hectares per farm; these longitudinal surveys show a decline in farm size even within that 13-year period.

Using survey data from Kenya, Jayne and Muyanga (forthcoming) examined how population density is related to the amount of land inherited from the previous generation. Respondents in a nationwide survey in 2007 were asked how much land was owned by the father of the household head. The previous generation had considerably larger farms (3 times larger) than those of the current survey respondents themselves. Then, after ranking respondents' answers according to the population density of the village, the mean size of parents' farms was found to vary from 7.80 hectares in the low-density quintile of villages to 4.41 hectares in the high-density quintile. Survey respondents were also asked about the amount of land inherited by the household head from his father. This ranged from 1.49 hectares in villages in the low-density quintile to 0.89 hectares in the high-density quintile, where the mean amount of land inherited by survey respondents was roughly one-fifth of the total landholding size of the father. An important policy question might be how the current generation of adults in the high population density areas with 1.30 hectares of land or less are going to subdivide their land among their children when they reach their old age (the average age of household heads was 48 years in 2010) and whether farming can provide a viable livelihood for those remaining on the land. These findings are consistent with Yamano et al (2009) who found that roughly a quarter of young men and women in rural Kenya start their families without inheriting any land from their parents, forcing them to either commit themselves to off-farm employment or buy land from an increasingly active land sales market. We speculate that, because farm sizes in the high density areas are already quite tiny and cannot be meaningfully subdivided much further, an increasingly smaller fraction of people born on farms in Kenya will be able to remain there. This may point to even higher rates of rural-to-urban migration in the future, or at least from agriculture to non-agriculture.

In all countries, the various Gini coefficients displayed in Table 4 column (d) also indicate a high degree of dispersion in farm size. The Ginis are comparable to those estimated for much of Asia during the 1960s and 1970s (Haggblade and Hazell, 1988). Given relatively homogeneous production technology, if land is allocated according to household size or labor availability, we should find more equal land distribution in household *per capita* or *per adult* land holdings than *per household* land holdings. This would imply that the Gini coefficients of land holding by per capita and per adult measures should be smaller than those of landholding per household. This is not the case in any of the five countries examined. The Gini coefficients of per capita and per adult land holdings are virtually unchanged in Kenya, Ethiopia, and Rwanda, and are even higher in Mozambique and Zambia when family size is accounted for in the estimates of land distribution inequality.

What is the evidence on trends in landholding inequality over time within the small-farm sectors? This is difficult to assess because of inevitable differences in sample design and variable definitions across surveys; results must therefore be interpreted cautiously. However, Haggblade and Hazell's (1988) survey of available landholding Gini estimates for Africa, Asia, and Latin America during the 1960s and 1970s provides some grounds for comparison. They report that the basic sampling unit is landholdings, not households, and thus landless households are excluded from these calculations. At least in this way, their estimates are consistent with the data reported in this study. Their sample includes three of the same country/farm sector combinations as in this study: Ethiopia, from 1976/77 survey data; Kenya's small-scale farming sector, from 1960; and Mozambique's smallholder sector from 1970.

On the basis of these comparisons, it appears that landholding concentration within the small-scale farm sector has increased slightly to moderately over the past 20 to 30 years. The Gini coefficients for landholdings per farm increased from 0.50 to 0.55 between 1960 and 1997 in Kenya; from 0.41 to 0.45 between 1970 and 1997 in Mozambique; and from 0.44 to 0.55 between 1976/77 and 1995/96 in Ethiopia. Ethiopia's case in particularly intriguing because it had undergone a radical land reform program during the 1970s there, yet land concentration appears to have increased.

Probably the most robust case for changes in land concentration is in Rwanda, where relatively consistent survey methods were used by the Ministry of Agriculture across three surveys for 1984, 1990, and 2000. Changes in the distribution of land access in Rwanda are shown in Table 4. Civil disruption undoubtedly has had a critical effect on land distribution over this period. We find that mean household land access (use rights plus rented land) has declined by 43% over this 16-year period, from 0.28 to 0.16 hectares per capita. In absolute terms, the decline in farm size has been borne mostly by the relatively large farms. Mean land access for households in the highest land quartile declined from 0.62 to 0.43 hectares per capita, while it declined from 0.07 to 0.02 hectares per capita for the bottom land quartile. In relative terms, however, the dispersion in land access across the distribution has widened. There was a nine-fold difference in mean land access per capita between the top and bottom land quartiles in 1984, but this has worsened to a 21-fold difference in 2000. While Gini coefficients from 1984 are not available, the Gini coefficients of household access to land between 1990 and 2000 increased from 0.43 to 0.52. These results, though tentative, indicate that land concentration may be worsening over time in many of the region's small-scale farming sectors.

Relationship between farm size and household income

The importance of these findings for rural growth and poverty alleviation strategies depends in part on the degree to which land allocation patterns influence household income and poverty. If non-farm activities are able to compensate for small landholdings and provide land-poor households with adequate alternative income sources, then disparities in land ownership should not necessarily be a policy problem. To examine these issues, we present bivariate graphs relating household per capita landholding size to household per capita income, including non-farm income and crop income from rented land (Figure 4). The three dashed vertical lines show the 25^{th}, 50^{th}, and 75^{th} percentiles of sampled households along the x-axis. For example, 25% of the sample households in Kenya have between zero and approximately 0.10 hectares per capita, while the top quartile owns on average 1.1 hectares per capita.

In each country, we find a positive association between household per capita land holdings and per capita income (the sum of crop, livestock, and off-farm income). The association between household income and land is especially steep among households whose land size is below the median level in each country (the middle dotted line in each country graph in Figure 4). Because the vertical axis showing per capita income is in log form, we can read differences in numbers as percent changes. For instance, the line for Kenya starts at the log of per capita income at 9.2 and has a kink at 9.6. The difference between these two points is 0.4, which indicates a 40 percent increase in per capita income when household per capita land size increases from zero to 0.25 hectares. The same increase in land holdings (from zero to 0.25 hectares) increases per capita income by more than 40 percent in Rwanda, just less than 40 percent in Mozambique, and about 30 percent in Ethiopia. In all four countries, the association between land and income becomes weaker somewhere within the third land size quartile, and nearly disappears in the fourth quartile.

What do such land-income relationships mean for feasible smallholder-led development pathways? Improving access to land among the most land-constrained smallholder households would be a seemingly effective way to reduce poverty. For small farms, a very small incremental addition to land access is associated with a large relative rise in income. The structural transformation processes in Asia, as documented by Johnston and Kilby (1975) and Mellor (1976), show that a smallholder-led agricultural strategy was necessary to rapidly reduce rural poverty and induce demographic changes associated with structural transformation. An inclusive smallholder-led strategy is likely to provide the greatest potential to achieve agricultural growth with broad-based reductions in rural poverty in most of sub-Saharan Africa as well. However, it is not at all clear how such a smallholder-led agricultural strategy must be adapted to address the limitations of very small and declining farm sizes in densely populated areas that are dependent on rain-fed production systems with only one growing season per year.

Of course, nothing presented so far necessarily confirms that inadequate access to land is a binding constraint on smallholder agriculture in Africa. It might be possible that rural households could acquire more land if they chose to. And perhaps factors of production other than land are the more binding constraint on agricultural intensification.

Is land expansion possible for smallholder farmers?

Zambia provides an interesting case study for exploring rural households' perception about the availability of unallocated land for future expansion of agricultural production. Zambia has one of the lowest national population densities in sub-Saharan Africa and it is widely believed that there is major potential for area expansion.

One of the questions asked of households in the nationally representative 2001 Post Harvest Supplemental Survey (CSO 2001) was "Is there unallocated arable land that is available to households in your village?" Nationwide, 44.1% of households felt that there was unallocated arable land that was available in their village area. Table 5 presents respondents' answers to this question by province. Also included in the table is the amount of unutilized arable land in each province according to Central Statistical Office estimates in 2004.

The responses in Table 5 initially suggest that many households in Zambia perceive that there is unallocated land available in their villages. This view is particularly strong in the sparsely populated areas of Northwestern and Northern provinces, which incidentally also have the biggest portions of arable and available land, and to a lesser extent in Central Province. Central province is third in terms of available arable land. However, in the major agricultural provinces of Eastern and Southern provinces, less that 40% of respondents reported that unallocated arable land was still available in their areas. These two provinces have, other than Western province, the lowest amount of unutilized arable land.

One might expect that the “no” responses would be concentrated in the most densely populated provinces, and the yes responses would be concentrated in sparsely populated areas. This is not uniformly the case in Zambia. For instance Western Province has the second lowest population density in Zambia but it contained the greatest proportion of respondents indicating that no additional land was available. This is most likely because many parts of Western Province are unsuitable or only marginal suitable to crop cultivation, hence population density underestimates the degree to which population is concentrated in a few productive areas.

Because 94% of Zambia’s land is in the customary tenure system, it is often implied that there should be great scope for area expansion by African farmers. Metcalfe (2005) and others, however, feel that this conclusion should be heavily qualified:

> "Although it is sometimes stated that 94% of Zambia falls under customary tenure from that proportion must be deducted the 8% of the country designated as national parks and further 8% designated as forest reserves. From the remaining 76% must be deducted 2% for urban areas and 12% as unspecified areas (e.g., state farms, property, military, research stations, etc.). Finally, from the remaining 64% the Game Management Areas (GMAs) that make up 23% of Zambia’s land area must be considered" (p. 7).

These figures put into context the generally held notion that 80% of arable land in Zambia remains uncultivated, and that 94% of its land is under customary tenure, implying that it is available for smallholder agricultural development. According to Chizyuka et al. (2006), land falling under customary administration is 62% of the country territory or 46,500 square kilometers, but this includes mountainous areas, marshes and swamps, areas that are permanently flooded, infested with tsetse flies, and/or too arid to be suitable for intensive crop production. These authors conclude that, in reality, a much smaller amount of viable arable land is available for future generations of Zambian smallholders than is often thought.

A paradox of land pressures amid land abundance?

Several conclusions emerge from the evidence presented so far. First, while many parts of SSA are very sparsely populated, often leading to relatively low population densities when computed over all rural area, a growing proportion of its population reside in fairly densely populated areas of 500 persons per km2 or greater. This may resolve the apparent paradox of land constraints amid the appearance of land abundance and massively under-utilized land.

However, the major disparities in the population densities of 1km grid cells within each country examined raises questions about how such extreme differences have arisen and why hasn't migration tended to equilibrate these differences over time? Why is much of Africa's rural population concentrated tightly in particular areas while vast areas potentially suitable for agriculture remain largely unutilized? This question requires more intensive investigation but for now, we forward three major factors explaining the observed great variation in rural population densities:

1. *Natural clustering of population to the most hospitable and fertile areas.* These areas include the highlands of eastern and southern Africa, the humid tropics of West Africa, and coastal areas near natural ports and river confluences. After accounting for the biophysical potential of land (an exercise being undertaken currently), we anticipate that the variation in rural population density will decline compared to those shown in Tables 3a and 3b.
2. *Pattern of prior public investment.* Potentially arable land can remain underutilized because it has yet to receive the requisite public investment in physical infrastructure (e.g., roads, electrification, irrigation), water, schools, health facilities and other services required to raise the economic value of land and thereby attract migration and settlement in these areas (Govereh 1999). Several governments have shown a willingness to devote state resources to develop land for large-scale commercial investment but much less so for smallholder-led agricultural development.
3. *Colonial segregation of Africans into reserves.* A major factor in countries with a colonial settler history such as Kenya, Malawi, Zimbabwe, and Zambia, has been the historical and post-independence continuation of colonial tenure systems separating "customary lands" from "state lands" (Deininger and Binswanger 1995; Woodhouse 2003). Many areas under customary tenure are facing emerging land constraints borne of steady rural population growth since independence. By contrast, much of Africa's unutilized arable land is under state authority, which is not readily accessible for settlement by smallholder populations under prevailing land allocation institutions. Post-independence governments have often allocated land to non-farming elites in exchange for political support, contributing to land underutilization while nearby farming areas exhibit signs of land pressures and degradation (Kanyinga, 1998; Mbaria 2001; Stambuli 2002; Namwaya 2004). It is perhaps not surprising then that median farm sizes are quite small and declining for the vast majority of the farming population, as indicated in Table 4, while large tracts of land in other parts of the country remain unutilized. This dual land-tenure structure has impeded natural migration from processes 1 and 2.

Many of the "state vs. traditional chiefs" conflicts that have featured prominently in post-independence Africa (Herbst, 2000) have centered on attempts by the state to wrest control of customary lands. Politicians' arguments for converting customary land to state land normally focus on the need to allocate land to commercial entrepreneurs and capitalized "emergent" farmers with the ability to use it productively, although as shown earlier there is very little evidence to suggest that large-scale farms are more efficient than small-scale farms. In areas where traditional authorities have succeeded in retaining control over customary land, there are still numerous reports of land being allocated to local elites having no legitimate claim to land in that area under traditional norms (Deininger and Byerlee).[19]

Regardless of whether land is retained under customary or state control, several scholars argue that African farmland is facing an "enclosure" process in the absence of efforts to reverse it (Woodhouse 2003; Stambuli 2002). Woodhouse argues that much of Africa is facing increased commodification and individualization of land driven by population growth and increased pressure on remaining arable land regardless of land tenure regime. This process appears to be intensified by the post-independence continuation of converting unutilized customary land into titled property or state land for future allocation. While one might be tempted to regard this as evidence of emerging land markets in Africa, in most cases the processes of allocation are opaque; little public information about land transaction prices have emerged in any country that could serve as a basis for price discovery more broadly. Meanwhile, many customary (i.e., smallholder) farming areas are facing intensifying land constraints borne of steady rural population growth since independence, which is only made more acute by transfers of land from customary to state land. An important literature in Kenya has documented the rapacious disempowerment of local communities from their traditional lands, first by the colonialists and later by the successive post-colonial governments (Juma, 1996; Kanyinga, 1998; Okoth-Ogendo, 1976). Post-independence Kenyan governments have largely retained the same institutions despite recognizing the importance of land rights and even elevating it to a crucial post-independence challenge (Republic of Kenya, 1965). While the modes of land access were primarily through inheritance and the market, access to state land (and land converted from customary to state land) has been a major instrument of patronage favoring the political elite.[20] For these reasons, it is perhaps not surprising that median farm sizes are quite small and declining for a large proportion of the smallholder population, while large tracts of land in other parts of the country continue to be allocated by the state to local elites and foreign investors.

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[19] For example, in a recent study of "emergent" farmers (10-100 hectares) in Zambia, Sitko, Nkonde, and Jayne (2012) found that most of the 186 farmers interviewed purchased or obtained a 99-year lease from local authorities in customary lands. Of these, the majority entered into farming later in life after earning enough money from urban employment to purchase land. These farmers are cultivating an average of 27% of the land obtained, while over 90% of the surrounding small-scale farmers in the area own less than 5 hectares.

[20] Namwaya (2004) reports that over 600,000 hectares of land, or roughly one-sixth of Kenya's total land area, are held by the families of the country's three former presidents, and that most of this land is in relatively high-potential areas.

5. When Do Agricultural Growth and Poverty Reduction Converge and When Do They Diverge?

Returning now to several debates discussed in Section 3, some scholars and a growing number of African governments believe that greater support for investment in large-scale agriculture may be the best use of public funds for poverty reduction. Other analysts have argued that overcoming Africa's food security and poverty problems is primarily a challenge of improving the uptake of productivity-enhancing green revolution technologies. Consider, for example, Roger Thurow's (2010) conclusion:

> *"Thus, more and more eyes are turning to Africa, agriculture's final frontier. Africa was largely left out of the green revolution, the postwar movement to push up crop yields in the hungriest parts of the world by promoting the use of new seeds and new farming technology. And so agricultural production on the continent could jump quickly if farmers there simply used existing seed, fertilizer, and irrigation technology. And if more efficient networks were developed to distribute and sell the harvests, boosting agricultural yields in Africa could be a major step toward feeding not just the continent but also the rest of the world."*

This section explains why the uptake of improved technology may indeed boost agricultural yields and yet do very little to address rural poverty that is associated with pervasive constraints on access to land and other productive assets. The recent experiences of Zambia and Malawi illustrate how agricultural growth that is not broad-based may have very little effect on rural poverty. Both countries have succeeded in doubling maize production between the early and late 2000s. In both countries, the marked increase in maize production coincides with the scaling-up of government input subsidy programs. The national use of fertilizer and hybrid maize seed in both countries has roughly doubled between 2004 and 2010 and yield growth in both countries has been the primary source of the production booms (see Mason et al 2011, and Ricker-Gilbert, Jayne and Chirwa 2011 for details). In Zambia's case, farmers have benefited from the purchase of maize at above-market prices (roughly $275 per ton) through the Food Reserve Agency (FRA). Together the input subsidy and maize price support programmes in Zambia accounted for over 60 percent of the Ministry of Agriculture's public budget over the past five years and over 2% of the country's GDP in 2010. These two programs also accounted for 90–96 percent of the total budget allocated to the ministry's Poverty Reduction Programmes (PRPs) during the 2006–2011 budget years. In Malawi, the input subsidy program alone has exceeded 10% of the national budget in at least 2 of the past 5 years.

In spite of the impressive growth in grain yields and production, rural poverty in both countries has declined very little over this time span. In Zambia, the rural poverty rate was 77.3 percent in 2004, 76.8 percent in 2006; while official poverty rate estimates for 2010 have not yet been released, preliminary estimates suggest that the rural poverty rate remains in the range of 74–78 percent. So, why is it that maize production has increased so impressively without making a serious dent in rural poverty?

Table 6 show data from the nationally representative 2011 Crop Forecast Survey to show how maize production has varied according to farm size. Column A of Table 1 shows the number of farmers in five farm size categories. Overall Zambia has an estimated 1,471,221 small- and medium-scale farmers ('smallholder' farmers), defined as farmers cultivating between 0.1 and 20 hectares. Approximately 42 percent of them are cultivating less than one hectare of land; 33.3 percent of the smallholder farms are cultivating 1–2 hectares; 2.9 percent are cultivating 5–10 hectares, and 0.5 percent are cultivating over 10 hectares (column B). Farmers cultivating less than 2 hectares accounted for 75 percent of the total number of farmers in Zambia's smallholder farm sector.

Column C shows the estimated total maize production within each of the farm size categories over a 'baseline' period (the three years covering the 2005/06 to 2007/08 crop seasons). Column D shows the estimated maize production for these five farm size categories in the 2010/11 crop season. Overall, maize production increased from an average of 1,383,735 tonnes in the baseline period to 2,786,896 tonnes in the 2010/11 season.

Column E shows the change in maize production over this period for each farm size category. Farmers cultivating less than one hectare contributed an additional 96,989 tonnes to national maize production in 2010/11 compared to their average maize production during the 3-year period 2005/06-2007/08. By dividing the additional maize production in column E by the number of farms in each category as shown in Column A, we derive the additional maize production per farm for each of the farm size categories, as shown in Column F. When expressed on a per farm basis, it is apparent that farmers cultivating less than one hectare produced 157.2 additional kilograms of maize per farm in 2011. Farmers cultivating 1–2 hectares contributed 326,145 additional tonnes of maize in 2010/11, which amounts to 666 kilograms of additional maize per farm. Farmers cultivating 2–5 hectares contributed an additional 640,425 tonnes to national maize production in 2010/11, or 2.03 additional tonnes per household. The 2.9 percent of the farmers cultivating 5–10 hectares contributed an additional 297,871 tonnes to national maize production in 2010/11, which amounted to 7.04 tonnes of additional maize production per farm. And lastly, the 0.5 percent of farmers cultivating 10–20 hectares increased their maize production in 2010/11 by 6.3 tonnes per household in compared to the earlier baseline period.

The data in Table 6 show that very little of the increase in national maize production in 2010/11 came from the bottom category of farmers (less than one hectare cultivated) even though they account for over 40 percent of the smallholder farms in Zambia and are among the poorest of the rural poor. Given that their maize output increased by an average of just three 50-kg bags per household between 2005/06-2007/08 and 2010/11, the national maize bumper harvest is unlikely to have resulted in significant reductions in hunger and poverty among this group of farmers. The main increase in national maize production (column E) came from farmers in the 1–2, 2–5 and 5–10 hectare cultivated area categories. When expressed in per farm terms, however, the major increases in maize production were enjoyed by farmers cultivating over 5 hectares—farm households which constitute only 3.4 percent of all the smallholder farms in Zambia. Table 6 clearly shows that the increase in maize production per farm is strongly related to farm size. However, the relatively small increases in average maize production among the smallest farms is likely to have improved their food security status substantially as a result of their harvesting even a few more 50-kg bags of maize in 2010/11 than in the earlier period.

Table 7 uses the same Crop Forecast Survey data to examine the amount of subsidised FISP fertiliser received during the 2010/11 crop season by farmers within the same five categories. The number and percentage of farms in each category in 2010/11 are shown in columns A and B, respectively. The percentage of farms receiving FISP fertiliser in each category is presented in column C. Slightly over 14 percent of the farmers cultivating less than one hectare received FISP fertiliser in the 2010/11 crop season. The average quantity of fertilizer they received was 168 kg. Therefore, across all 596,334 households in the category, the average household received 24.1 kg of FISP fertiliser (column D). By contrast, over 50 percent of farmers in the 10–20 hectare cultivated category received FISP fertiliser in 2010/11, receiving 657 kg per farm. Therefore, the average amount of FISP fertiliser received by farmers in the 10–20 hectare category was 346 kg, about 14 times more per farm than those in the less than one hectare category.

Column E shows the percentage of households selling maize. This ranges from 22.2 percent among the smallest farm size category to 86.8 percent among the largest. In terms of quantities of maize expected to be sold, column F shows that, on average, about 135 kg of maize will be sold for every farm in the less-than-one hectare category, compared to 1.7 tonnes per household in the 2–5 hectare category, and over 15.1 tonnes per household in the 10–20 hectare category. Clearly, the benefits of the FRA maize support prices are disproportionately enjoyed by the relatively large farmers over 5 hectares, even though they constitute only 3.8 percent of the smallholder farm population.

The smallest farmers in Zambia—those cultivating less than 2 hectares who account for over 70 percent of all the smallholder farms in the country —participated only marginally in the maize production expansion of 2010/11. These farmers received relatively little FISP fertiliser and sold very little maize, hence they were unable to benefit from the FRA producer price of 65,000 kwacha per bag. The farmers benefiting the most from the government's expenditures on supporting maize prices were clearly those selling the most maize. In contrast, about 30 percent of the relatively poor smallholder households actually had to purchase more maize and maize meal than they produced to meet their families' food needs and hence were adversely affected by a support price policy that raised maize prices in the countryside. This disaggregated picture of Zambia's maize production expansion may reveal why rural poverty rates remain so high despite the record maize harvests in the past several years. Similar conclusions emerge from Malawi (Ricker-Gilbert, Jayne and Chirwa 2011).

The composition of the Zambian government's public spending on agriculture reveals that the lion's share of its budget was devoted to maize price supports and input subsidies, which were captured primarily by larger farmers (Figure 5). The types of scale-neutral public investments that can promote productivity even on one-hectare farms, e.g., improved seed and agronomic research, farmer education and extension, physical infrastructure, etc., receive about 20% of the public budget to agriculture across all ministries.

This disaggregated picture of the distributional effects of growth – at least how it was achieved in Zambia and Malawi – demonstrate the limitations of current approaches for achieving green revolutions in Africa. Conventional approaches such as those focusing largely on farm price supports and input subsidy programs may increase aggregate farm output but have tended to produce concentrated benefits that are correlated with farm size and asset wealth (Jayne, Mather, Mghenyi 2010), and therefore have done very little to reduce rural poverty rates. The Zambia and Malawi experiences stress the need not only to promote the use of improved technology but to do so in a way that somehow reaches – directly or indirectly – farms in the bottom half of the asset distribution. Taking action to expand access to land for smallholder farm production, as a complement to input promotion and farm productivity programs, may be fundamental to effective national agricultural development and poverty reduction policies.

Hertel (2011) concludes that there is substantial scope for endogenous intensification of production in response to higher product prices, particularly in Africa, where fertilizer application rates are low. Higher farm prices may indeed provide incentives for profitable intensification to close the high yield gaps observed in the region (Fisher, Byerlee and Edmeades 2009). The findings reported here for Zambia confirm previous evidence that the African farming sector can quickly and robustly respond to higher food prices, but that the response is likely to be concentrated among the largest farmers with the largest farms and the greatest potential to respond to price incentives. Moreover, there are likely to be severe food insecurity problems if farm intensification in Africa is driven by higher food prices, because of the large proportion of resource poor farmers who have insufficient access to land and other assets to produce a surplus through either intensification or extensification, and are likely to remain net buyers of food (Jayne, Mather, Mghenyi 2010). Policy strategies to effectively broaden the base of farms that can respond to future price signals and agricultural growth opportunities may increasingly require explicit consideration of egalitarian approaches to expand and broaden access to unutilized arable land in the region.

This raises questions, therefore, about the potential impact of promoting large-scale investment in farmland in response to heightened global demand for food. Can the promotion of large farms complement a small farm-led development approach, or at least co-exist with it, without choking off the prospects for the latter? The recent World Bank report on land by Deininger and Byerlee (2011) is guardedly optimistic for areas of Africa that have abundant unutilized land coupled with huge "yield gaps" on existing farmland. In such cases, they conclude that there may be a positive role for large-scale farm investment without imposing major dislocation costs on local populations. They stress that due diligence must be exercised to ensure that investment in farm land by outside interests does minimal disruption to local interests and conclude that there is good potential for mutually beneficial outcomes especially in land abundant areas with low population densities.

There are of course general equilibrium effects to be considered in such an approach. If large-scale farm investment were successful in raising national production by, say, 10%, how would this affect food prices, wage rates, and the course of future investment in the agricultural sector? Could large-scale agricultural provide gainful employment for workers, and possibly even raise agricultural wage rates? Would the pattern of private marketing investment be shifted to procure supplies from large-volume sellers, and would this marginalize the small-scale rural peasantry? Most importantly, how would the increased power of a large-farm sector affect the political economy of public resource allocation?

6. Evidence on Impacts of Land Constraints

This section addresses how rising population density is affecting farmer behavior and the evolutions of farming systems. This is the subject of a five-country study, currently in progress, under the Guiding Investments in Sustainable Agricultural Markets Project funded by the Bill and Melinda Gates Foundation. Insights from all five countries should be available by August 2012. At this stage, only the Kenya results are complete. This section summarizes the findings of econometric analysis of the impact of increasing population density on some selected indicators of farm productivity and welfare in Kenya (Jayne and Muyanga, forthcoming 2012).

Because population density is likely to be endogenous to many aspects of farming system evolution, first-stage models of population density are estimated using an instrumental variables approach, followed by the second-stage control function results using correlated random effects. The major determinants of population density in 2009 were found to be distances to infrastructural facilities, the population of the location in prior decades, and amount of arable land in prior decades, village-level rainfall and variability of rainfall, soil quality, and the agro-ecological potential of the area. For example, if households in Location A are one kilometer closer to motorable roads, water sources, and healthcare facilities than households in Location B, the population density in Location A is estimated to be 0.32, 0.57 and 0.17 percent higher than in Location B. If Location A's long-run average annual rainfall is 100mm higher than Location B, the population density of Location A is estimated to be roughly 11 percent higher than Location B. Increased rainfall variability is associated with lower population density. As expected, land quality as represented by the potential kilocalories obtainable from each $10km^2$ pixel of both cultivated land increases population density by 7.2 percent.

Next we present the second-stage control function regression results of the impact of increasing population density on selected agricultural production and household welfare outcomes. Because of space limitations, we focus on only a few outcome variables of interest.

Landholding size and cropped area

Landholding sizes and area in hectares cultivated per adult equivalent in the main season decline with population density. Controlling for all observed variables, an increase in population density by 100 persons per km^2 is associated with 9 percent smaller farm sizes. A similar increase in population density reduces area cropped per adult equivalent by about 8 percent. These relationships are highly statistically significant. A more complete presentation of these relationships is revealed when we look at the post-estimation simulations of the relationships between these outcome variables and population density, holding all other factors constant. Figures 6a and 6b show that landholding size and area cultivated per adult equivalent varies inversely with population density.

Input use intensity

The cost of purchased inputs per hectare (fertilizers, seeds, hired labor, and land preparation costs) is used as an indication of land intensification. The intensity of purchased inputs per hectare is found to be a non-linear concave function of population density. Input intensity rises with population density to around 650 persons per km2; beyond this population density threshold, input intensification declines. Further, the intensity of purchased input use rises as land rental rates rise, and declines with increased distances to motorable roads, signalling increased input costs. The intensity of purchased input use also declines as we move from the relatively high-rainfall highlands to the semi-arid lowlands.

Figures 6(c) and (d) show the simulated relationship between input use intensity on the y-axis and population density on the x-axis, controlling for all the other variables. Both fertilizer use and the use of all purchased inputs per hectare is an increasing function of the population density up to roughly 660 persons per km^2, and then declines beyond that. Slightly less than 20% of the farm households in the sample are currently beyond this threshold (Figure 4c). As shown in Figure 4d, the general input use intensity starts to decline somewhere after 475 persons per km^2; about 35 percent of the households in the sample live in villages beyond this population density threshold.

What would explain these threshold effects? Market participation studies consistently show that farm sales are related to farm size (Barrett 2008). If farm sizes decline beyond a given point due to sub-division and land fragmentation caused by population pressures, households are less likely to generate the cash from crop sales that would allow them to purchase modern productivity-enhancing inputs. Less intensive input use then reinforces small farms' difficulties in producing a surplus. Furthermore, access to farm credit also tends to be restricted for farmers with limited land and other assets that could otherwise act as collateral. For these reasons, population density threshold effects may be very plausible and may explain why in Kenya a number of important farm productivity indicators tend to decline beyond a certain level of population density. This threshold is likely to be depend on agricultural potential and perhaps market access; further testing of how these variables may modify the relationship between population density and farm behavior is the subject of ongoing research.

Household farm income

After controlling for other observed factors, net farm income per hectare is found to rise with population density up to about 680 persons per km^2, but fall off slightly thereafter. Net farm income per adult equivalent, by contrast, shows a more sharp decline at a lower population density threshold of about 550 persons per km^2, following a pattern very similar to input use intensification. All of these relationships are highly statistically significant. The post-estimation simulation results are presented in Figures 6(e) and (f). Lower distances to motorable roads are associated with higher farm incomes. Farm wage rates, land rental rates, and fertilizer prices are all significantly inversely associated with farm incomes per adult equivalent; only the first two input prices are significantly associated with farm incomes per hectare.

These results apply to both crop and animal operations; results are similar when the dependent variable is net crop income or net animal income. Intensive animal operations such as zero-grazing dairy is significantly more commonly practiced in the high density areas, producing higher levels of animal income per land unit. However, this is only possible up to a certain population density level, beyond which farm sizes become too small for economical operations. This evidence of a decline in partial land productivity at high levels of rural population density is alarming, as it implies that land productivity growth cannot be sustained simply by using other inputs more intensively per unit of land. Animal income and milk production also show a similar plateau and drop off at 650 persons per km^2. As Kenya's rural population continues to grow,[21] a greater proportion of the country's rural areas will soon reach this apparent land productivity plateau. Currently, most of the districts with mean population density greater than 650 persons per km^2 are in Nyanza and Western Provinces, with most in Central Province approaching this threshold. In 2009, the 16 districts with greater than 650 persons per km^2 accounted for 14.2% of Kenya's rural population and 1.3% of its rural land.

Household asset wealth and incomes

Lastly, we discuss the relationships between population density and household asset wealth and total income per adult equivalent. The results show an unambiguously and statistically significant negative relationship between household assets and population density. Holding constant differences in asset wealth due to differences in infrastructural conditions, input prices, rainfall quantity and variability, soil quality, agro-ecological potential and survey years, we find that an increase of 100 persons per km^2 is associated with a 7 percent

[21] Fortunately, Kenya's rural population growth rate has been declining from its peak at 3.4% in 1984 to 2.3% in 2008 according to the 2009 official census.

decline in asset wealth per adult equivalent. This relationship is shown graphically in Figure 4(g).

By contrast, total household incomes tend to rise with population density up to a now familiar threshold and thereafter decline. The post estimation simulations show a clearer picture of these relationships. Total household incomes per adult equivalent rise with population density up to roughly 550 persons per km^2 and decline thereafter, as shown in Figure 4(h). Higher population density is associated with smaller farm sizes, other factors constant. Small farm sizes may be associated with diseconomies of scale in input acquisition. Other factors constant, smaller farm sizes reduce the potential to produce surpluses, which may in turn cause capital constraints that impede the demand for purchased inputs and new technologies. These processes may explain why our results indicate adverse effects of population density, beyond some threshold, on indicators of farm intensification, farm income per unit of labor, and wealth.

7. Conclusions and Policy Implications

Despite the fact that sub-Saharan Africa in 2012 contains much of the world's unutilized and underutilized arable land, a significant and growing share of Africa's farm households are living in densely populated areas. These areas are characterized by small and declining farm sizes for the majority of people living in them. Ironically, inadequate access to land and inability to exploit available unutilized land are issues that almost never feature in national development plans or poverty reduction strategies. To our knowledge, there has been little recognition of the potential challenges associated with increasingly densely populated and land-constrained areas of rural Africa, despite the fact that a sizeable and increasing share of its rural population live in such areas.

Nationally representative farm surveys consistently show the following regularities: First, there are great disparities in landholding size within smallholder farming areas. While the top 10% of the rural population reside on farms ranging from 5 to 25 hectares, half or more of Africa's smallholder farms are below 1.2 hectares in size, and a quarter of the farms are below 0.5 hectares, with limited or no potential for area expansion (Jayne *et al*. 2003). Second, because of this pattern of landholding size distribution, farm production and marketed surplus are similarly skewed. In most nationally-representative surveys in the region that we have analyzed, the top 5% of farmers (not counting large-scale commercial farmers) account for 50% of the marketed grain surplus (Jayne *et al.* 2010). Third, and in stark contrast, half or more of rural farm households are unable to produce enough grain to feed themselves and are either buyers of grain or go hungry because they are too poor to afford to buy food. Most of the households owning less than one hectare of land fall into this category regardless of their agro-ecological or market access conditions, and their incomes tend to be below the poverty line. After controlling for agro-ecological conditions, small farm size is highly correlated with income poverty (Jayne *et al.* 2003). Fourth, a high proportion of farmers in densely populated areas perceive that it is not possible for them to acquire more land through customary land allocation procedures, even in areas where a significant portion of land appears to be unutilized (Stambuli, 2002; Yamano *et al.* 2009; Jayne *et al.* 2009). Land markets, both formal and informal, appear to on the rise (Woodhouse 2003; Holden, Otsuka, and Place 2009). In Kenya, roughly a quarter of young men and women born in rural areas start their families without inheriting any land from their parents, forcing them to either commit themselves to off-farm employment or buy land from an increasingly active land sales market (Yamano et al., 2009). And fifth, survey evidence points to increasing concentration of landholdings over time as well as declining mean farm size (Jayne et al., 2003).

These concerns lead to policy questions about appropriate and feasible smallholder-led agricultural strategies in the context of land-constrained farming systems and limited off-farm employment opportunities to absorb redundant labor in densely populated rural areas. Associated issues for research revolve around whether many farms are becoming, or have already become, "too small" to generate meaningful production surpluses and participate in broad-based inclusive agricultural growth processes given existing on-shelf production technologies. Evidence presented earlier about population density being inversely related to soil fertility and farm size might suggest the presence of threshold effects in the relationship between population density and farm productivity, especially labor productivity, as the intensification of labor and capital per unit of land may lead to diminishing returns to labor and capital beyond some point. Other reasons for declining agricultural productivity beyond some threshold level of rural population density may include reduced fallows leading to soil fertility depletion, and the tendency to produce little or no surplus production on very small farms with many residents, leading to difficulties of purchasing needed cash inputs in the presence of incomplete rural financial markets. All of these dynamics may be mutually reinforcing in the threshold relationships between population density, farm sizes, and farm productivity. These relationships are likely to be strongly conditioned by variables such as agro-ecological and market conditions. Future research is needed to empirically investigate these conditioning influences.[22]

[22] Evidence that may be in contradiction to these ideas is the experience of Machakos, Kenya (Tiffen *et al* 1994). They documented that, over the period from 1930 to 1995, rural population increased six-fold but agricultural productivity increased ten-fold following decades of sustained private investments in land. Reviewing this experience, Zaal and Oostendorp (2002) conclude that increased rural population density provided some incentives for Bosrupian intensification, but that exogenous factors such as the coffee price boom in the 1970s was at least as important.

Certainly, most of sub-Saharan Africa's land area is not characterized by such dilemmas. Most of the continent is sparsely populated. However, based on two alternative spatial databases capable of estimating populations at the level of one square kilometer and distinguishing between arable and non-arable land, a high proportion of rural people nevertheless live in densely populated areas. This apparent paradox is resolved when the unit of observation moves from land units to people. In at least four of the 10 countries analyzed, 25% of the rural population resides in areas exceeding 500 persons per square kilometer, which, by at least one account (Henao and Baanante 1999), is estimated to be the maximum supporting capacity for areas of intensive crop cultivation in the region.

The evidence presented here suggests that there tends to be a fallacy in concluding that most of the people in rural sub-Saharan Africa live in land abundant conditions. This has created the false perception that the development challenge for the region is how to productively utilize the continents' underutilized land resources. In the past several decades, and especially since the rise of world food prices, there have been concerted efforts to transfer land out of customary tenure (under the control of traditional authorities) to the state or to private individuals who, it is argued, can more effectively exploit the productive potential of the land to meet national food security objectives. Such efforts have nurtured the growth of a relatively well-capitalized class of "emergent" African farmers, most of whom did not start out in agriculture but rather bought land earned from salaried employment in the towns (Sitko, Nkonde, and Jayne forthcoming). These farmers are well represented in many African countries' powerful farm lobbies, disproportionately enjoy the benefits of input subsidy and price support programs due to their relatively large farm sizes, and become major forces lobbying for the continuation of such programs.

Moreover, some African governments are increasingly receptive to devoting state resources to develop land for large-scale commercial investment (e.g., investments in irrigation, electrification, and road infrastructure). Ironically, policy debates in the region seldom address whether similar public investments in customary tenure areas could generate even greater payoffs in terms of agricultural productivity growth and poverty reduction. Instead, rural poverty is increasingly being viewed as a problem to be addressed through social safety nets, food assistance, and input subsidy programs, even though the evidence shows that the benefits of such programs are often also disproportionately captured by the rural non-poor (Morris et al 2007; Xu et al 2009; Ricker-Gilbert, Jayne, and Chirwa 2011; Banful 2011).

The growing focus on how best to exploit unutilized land in Africa has arguably diverted attention from the more central and enduring challenge of implementing agricultural development strategies that effectively address the continent's massive rural poverty and food insecurity problems, which require recognizing the growing land constraints faced by much of the rural population. It may be increasingly relevant to ask whether structural transformation processes may be retarded in situations in which the distribution of rural assets are so highly skewed that a large strata of the rural population may be unable to benefit from agricultural growth incentives that would otherwise generate broad-based growth multipliers. In most of the national household surveys from Africa that we have reviewed in Section 3, the distribution of land and other productive assets within the smallholder sector is at least as skewed as in much of Asia at the time of their green revolutions. Estimates of land concentration would certainly be worse if we accounted for the large-scale farm sectors in these countries.

The literature on growth linkages indicates that the first-round beneficiaries of agricultural growth generate important multiplier effects by increasing their expenditures on a range of local off-farm and non-farm activities that create second-round benefits for a wide-range of other households in the rural economy (Johnston and Mellor 1961; Mellor 1976). In much of Africa, the consumption growth linkages have been found to be especially important (Delgado and Minot 2000). The extent and magnitude of these second round effects depend on how broadly spread the first-round growth is. The initial distribution of land and other productive assets will clearly affect the size of these multipliers. If dynamic labor and services markets can be developed, then other employment opportunities should be easier to create in the very locations where the larger smallholders are investing and raising their output and productivity. Pro-active public sector investment and policy support in developing these labor and service markets will be a key determinant of the magnitude of the growth linkages to be derived from agricultural growth.

Viewed in a static way, one could conclude that the only way out of poverty for the severely land-constrained rural poor is to increase their access to land. Viewed within a dynamic structural transformation framework, this group's brightest prospect for escape from poverty will most likely involve being pulled off the farm into productive non-farm sectors. Farming will be increasingly unable to sustain the livelihoods of people born in rural areas without substantial shifts in labor from agriculture to non-farm sectors. Education, which played a crucial role in Asia by allowing households to exit agriculture into more lucrative off-farm jobs, is relatively low in most areas of rural Africa by world standards. Investments in rural education and communications are likely to become increasingly important to facilitate structural transformation.

Therefore, while greater equity in landholdings is important to kick-starting inclusive rural growth processes in the short- and medium run, an important long-run goal will be to pull the rural poor out of agriculture and into skilled off-farm jobs through investments and policies that support the processes of structural transformation.

Widespread anecdotal evidence suggests that potentially the greatest threat to broad-based agricultural growth is the process of customary lands being sold or leased to a small but growing class of African elites. These processes of elite capture of the political process appear to be moving quite rapidly in a number of African countries. Before his assassination in 2003, the Economic Advisor to the President of Malawi, Kalonga Stambuli, wrote that:

> *I have seriously deplored the social injustice and economic marginalization associated with land conversion from communal tenure to leasehold tenure mostly enjoyed by the elite who also enjoyed a monopoly in the production of export crops. Most deplorable is the fact that the abundance of idle land among estates explains much of the low equilibrium trap to which our countries have been subjected. The economic hegemony of the agricultural elite was compounded by state enterprise expansion into the private sector, over-regulation, a stifling bureaucracy, and totalitarian politics. Inadequate amounts of land available to farmers remains a major constraint to supply response.*[23]

These anecdotal reports are consistent with research pointing to the growing commodification and individualization of land in customary areas (e.g., Woodhouse 2003).

Implications for Development Strategy

1. *African governments and international donors could greatly relieve Africa's growing land problems (and related food security and poverty problems) by focusing on efforts to sustainably improve crop and animal productivity.* Closing the "yield gap" through productivity growth can relieve the severity of land pressures in densely populated areas and buy needed time for longer-run investments such as education and health improvements to enable more rural people to integrate into gainful off-farm employment. Higher food prices are likely to provide greater incentives for intensification of input use and contribute to yield growth. Peak oil projections may also fundamentally change the economics of global food production in ways that are difficult to predict with accuracy now.[24] Despite scepticism in some quarters about the prospects for achieving smallholder-led development (Collier and Dercon 2009), this path has been the way out of hunger and poverty for much of Asia and, historically,

[23] Email from K. Stambuli to Professor Michael Weber, Michigan State University, February 13, 2003, subject: "Elitist Land and Agricultural Policies".

[24] Peak Oil projections are based on the summation of individual producing nations' petroleum production over time. In its *State of the World 2005,* Worldwatch Institute observes that oil production is in decline in 33 of the 48 largest oil-producing countries. See http://en.wikipedia.org/wiki/Peak_oil for a review of over 150 reports.

most other areas of the world (Lipton 2005). Successful small farm intensification will also help to conserve the world's remaining forest land and biodiversity. For all of these reasons, it would seemingly be in governments' and donor agencies' interests to redouble their efforts to support small farm productivity growth.

2. However, *closing the yield gap will in many cases require a reallocation of public expenditures from price supports and input subsidy programs to investments that can support productivity growth on one hectare farms.* While the long-term strategy is to effectively shift marginal farms out of agriculture and into productive non-farm jobs, this cannot happen by pushing farmers out of the sector; broad-based rural productivity growth will be required to pull households from the farm into non-agriculture. Hence the need to provide greater public funding for activities that can achieve productivity growth on one hectare farms. These include farmer extension programs that effectively transfer improved technologies and agronomic practices onto farmers' fields: planting on time, the use of conservation tillage practices, scouting for appropriate use of herbicides and pesticides, right plant population, soil testing to identify the nutrients that need to be added back to the soil, appropriate fertilizer cocktails for addressing soil nutrient deficiencies, including lime where acidic soils lock up phosphorus, use of coated nitrogen to reduce leaching, improving soil structure and organic content, investing in drainage, and of course public investments to generate improved seed varieties. Widespread adoption of these practices will raise the response rates of fertilizer application and are necessary to meaningfully close the wide yield gaps observed in the region (Fischer, Byerlee and Edmeades 2009).
3. *Commission comprehensive land audits in each country:* Current land allocation decisions are being made in an information void. Very few, if any, African countries keep accessible databases on the amount of unutilized and underutilized arable land available in each country's customary and state lands. Nor has there been any government report showing the amount of customary land that has been transferred into private title or leasehold tenure in the past several decades. A comprehensive and transparent land database would raise public awareness and provide the means to assess the costs and benefits of alternative approaches to guide future land policy decisions.
4. *Consider applying a land tax or user fees*, with the lowest (or zero) rates being put on intensively utilized land and highest rates on unutilized arable land. Similar taxes could be considered for water use to support the efficient use of these scarce resources.
5. *Especially because land appears to a relatively abundant resource in many parts of Africa, an extensification strategy of pulling more land into productive use by the existing farm population that currently lack adequate access to land is likely to be part of the solution to addressing Africa's food and hunger challenges.* In many parts of the region, governments may be able to improve access to land for rural households through a coordinated strategy of public goods and services to raise the economic value of customary land that is currently remote and under-utilized. This would involve

investments in infrastructure and service provision designed to link currently isolated areas with existing road and rail infrastructure and through allied investment in schools, health care facilities, electrification and water supply, and other public goods required to induce migration, settlement, and investment in these currently under-utilized areas. Such investments would also help to relieve population pressures in areas where the carrying capacity of the land has been exceeded. The approach of raising the economic value of land through public investments in physical and marketing infrastructure and service provision was pursued successfully by Southern Rhodesia and Zimbabwe starting in the 1960s with its "growth point" strategy in the Gokwe area, once cleared of tsetse fly. Public investments in this once desolate but agro-ecologically productive area induced rapid migration into Gokwe from heavily populated rural areas, leading to the "white gold rush" of smallholder cotton production in the 1970s and 1980s (Govereh, 1999).

Some areas for future research

(1) How are land-constrained farming systems evolving differently from more land-abundant farming systems? Is there evidence of changing relative factor prices and factor proportions in densely vs. sparsely smallholder production systems? How does this affect the programmatic implications for rural development and poverty reduction strategies?

(2) Can the general equilibrium effects of intensifying land access problems in sub-Saharan Africa be quantified? For example, to what extent are urban migration and the attendant problems of slums, health and sanitation problems, congestion, etc., exacerbated by the new generation's declining ability to access sufficient land to earn a livelihood in agriculture? To what extent do land access problems account for the growing emigration of young Africans from densely populated areas (e.g., Ethiopia, Kenya, Malawi) to the Middle East, South Africa, and Europe?

(3) What kind of farming systems lies beyond the continuum defined by Boserup, and Binswanger and Pingali, where population density has reached not only the level required to induce sedentary agriculture, land intensification, and the substitution of capital and labor for scarce land, but where population density has continued to rise well beyond this point? How would a scenario of higher world food prices affect land intensification incentives and the potential supporting capacity of rural lands disaggregated by agro-ecological potential and market access conditions?

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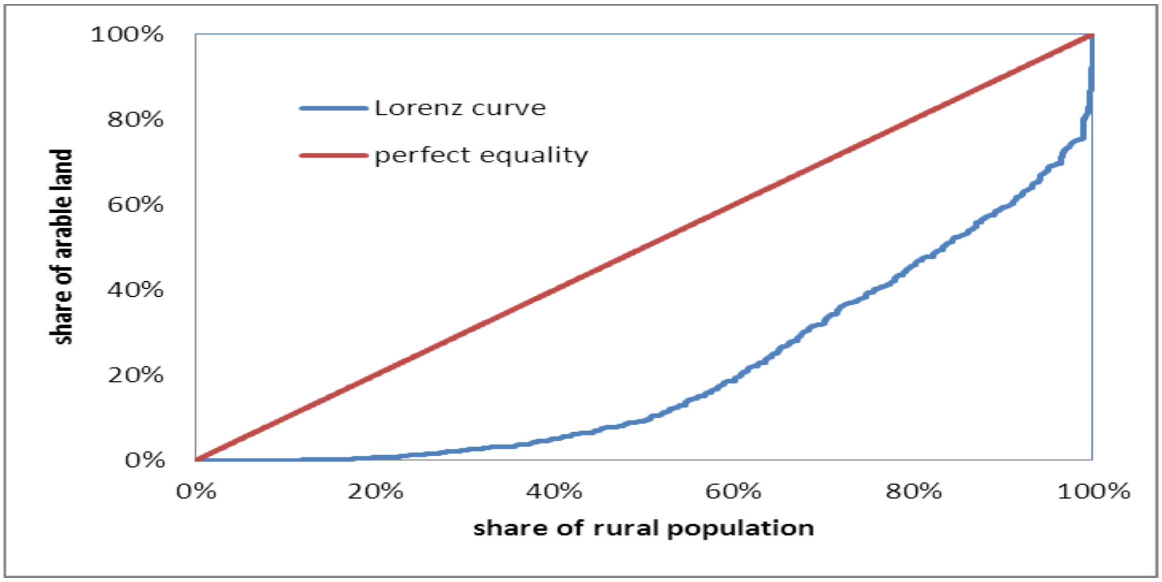
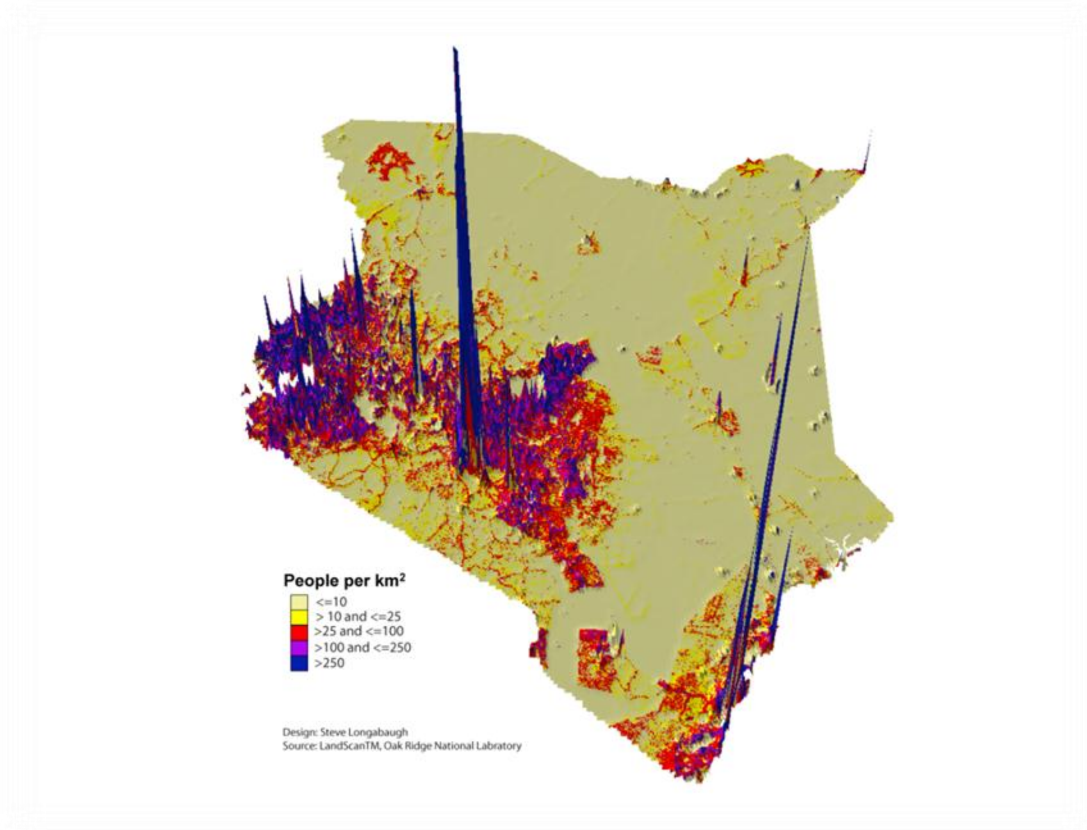
Figure 1. Lorenz curve showing the percentage of arable land by percentage of rural population in Kenya, 2009.



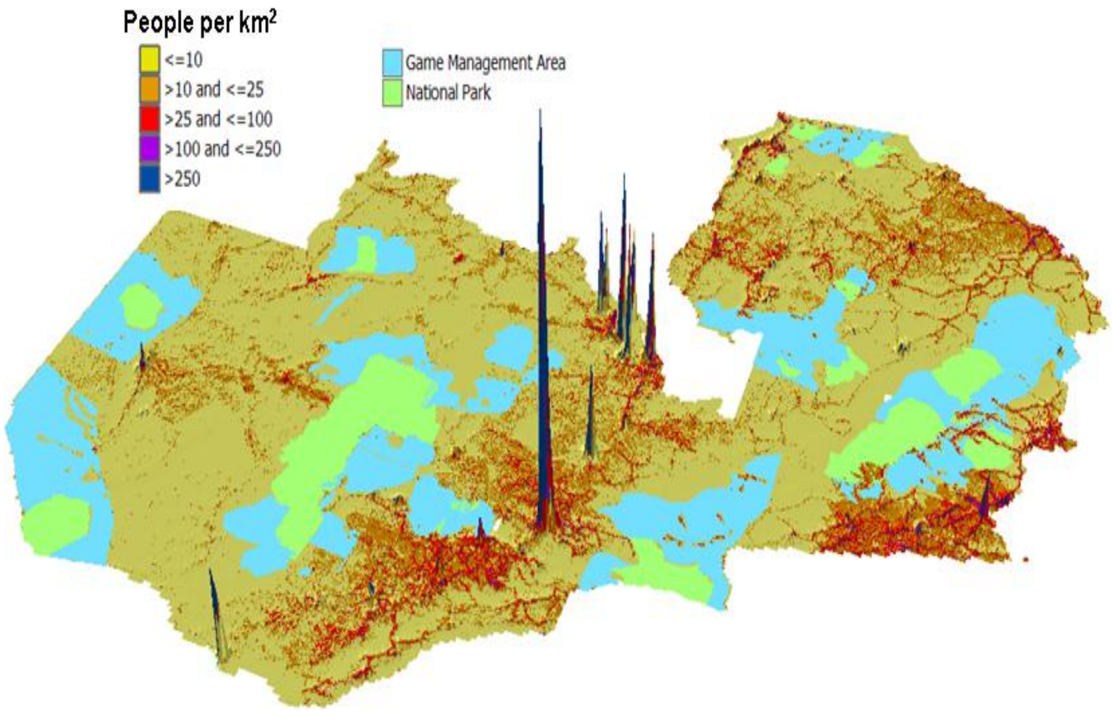
Gini coefficient: 0.51. Source: population data from 2009 Kenya National Bureau of Statistics Census; arable land from Columbia University Global Rural-Urban Mapping Project (GRUMP). A Lorenz curve shows the degree of inequality that exists in the distributions of two variables, and is often used to illustrate the extent that income or wealth is distributed unequally in a particular society.

Figure 2. Population density in Kenya



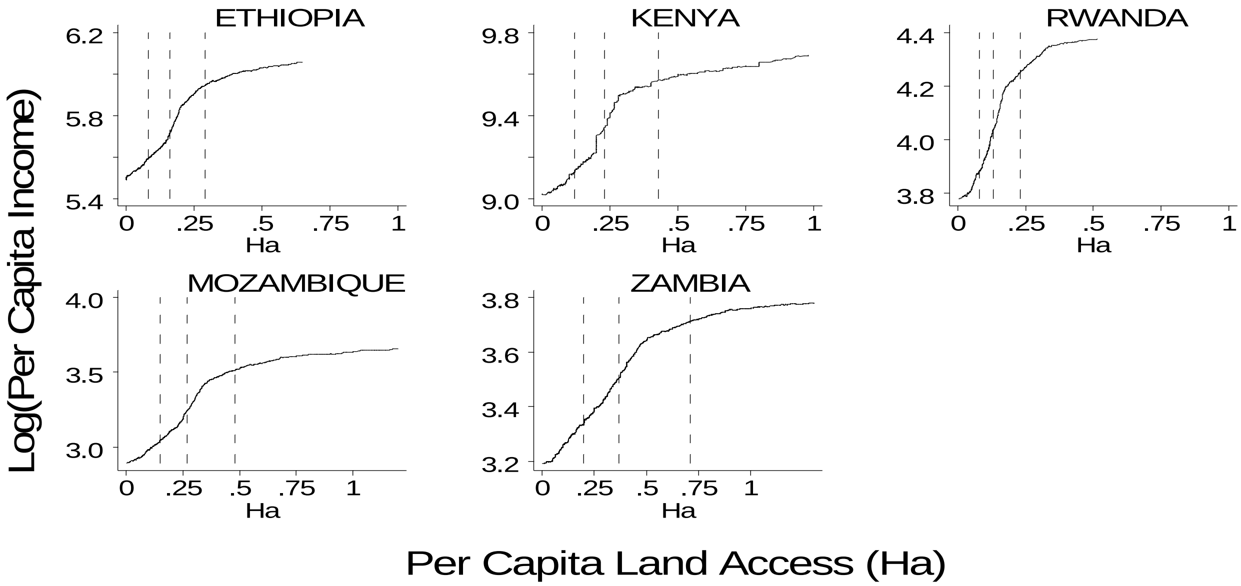
Source: LandScan data for 1999 Census, Kenya

Figure 3. Population density in Zambia



Source: LandScan data based on 2000 National Census.

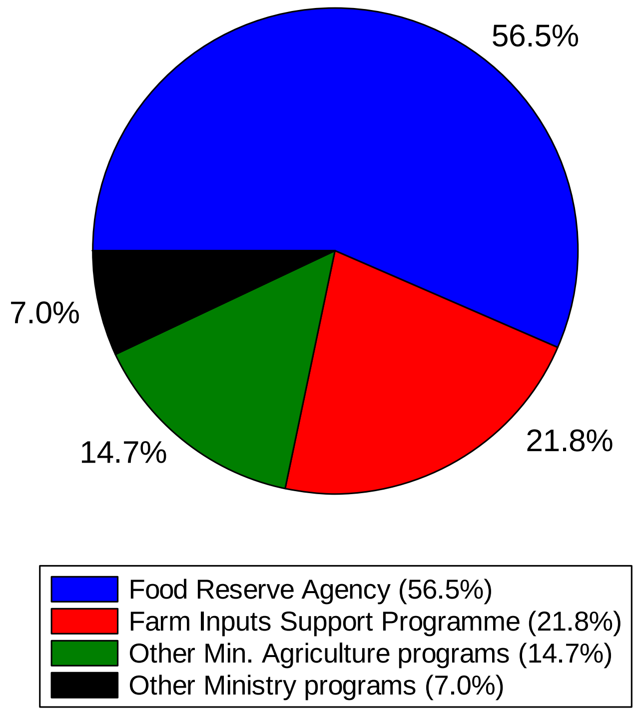
Figure 4. Log of per capita landholding size and per capita household incomes



Note: The vertical lines are drawn at 25th, 50th, and 75th percentiles of per capita land owned for each country. The top 5 percent of observations are excluded from the graphs because lines are sensitive to a few extreme cases.

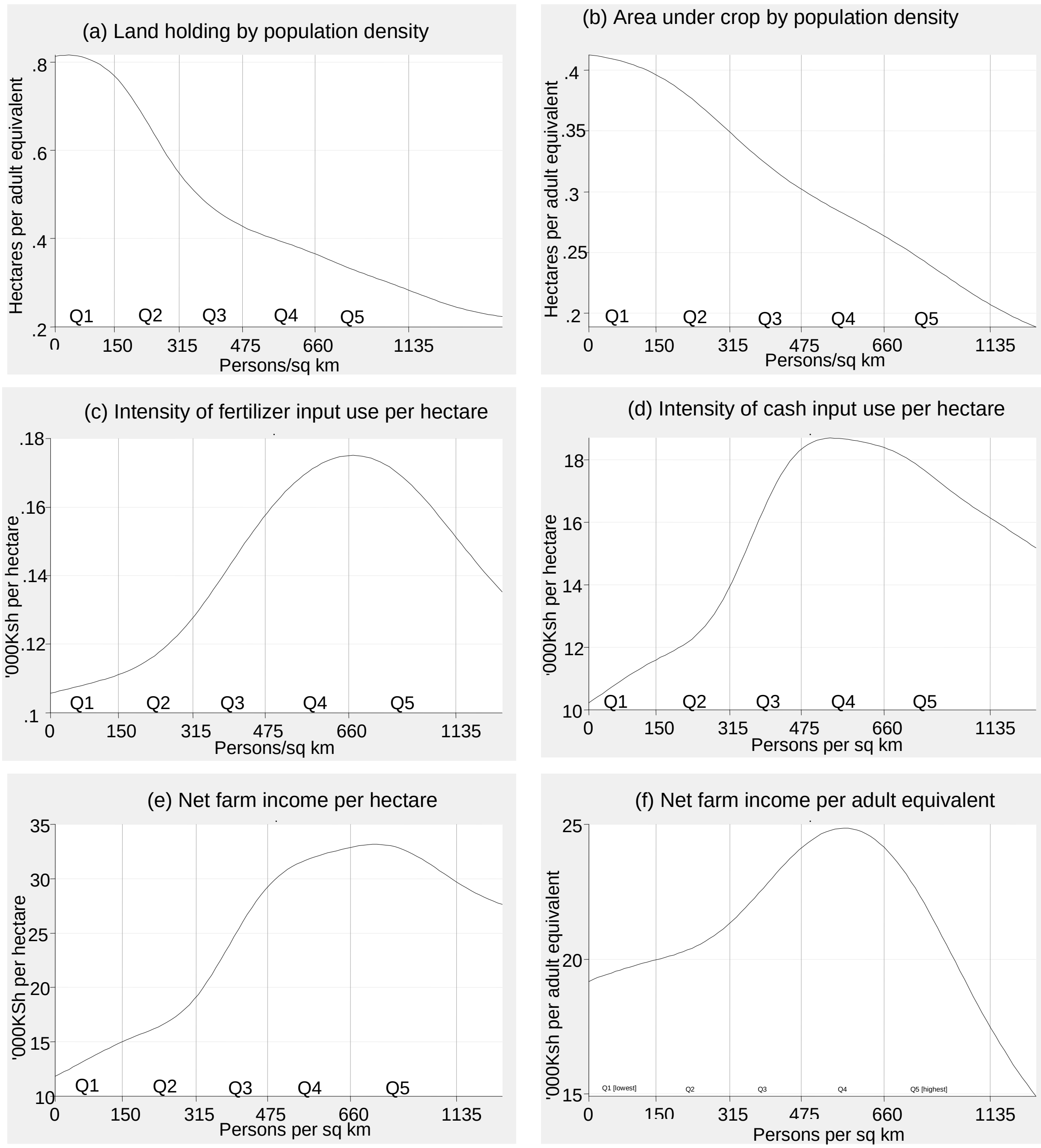
Source: Jayne et al., 2003.

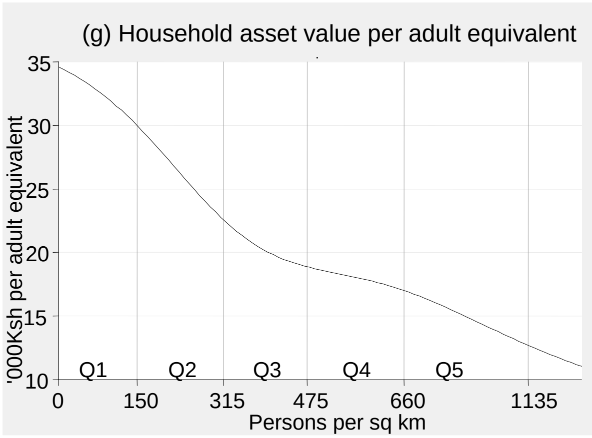
Figure 5. 2010 Budget allocation to Agriculture, Government of Zambia



Source: Ministry of Finance published budget figures including supplemental spending.
Notes: Expenditures to agriculture accounted for 15.3% of total government budget in 2010. Other Ministry of Agriculture programs included the Zambia Agricultural Research Institute (0.3% of total agricultural budget), Veterinary and Tse Tse Control programs (1.0%), seed control and certification (0.2%), provincial agricultural research stations (0.1%), Policy Analysis Unit (0.7%). Agricultural programs in other ministries includes feeder roads, Central Statistical Office, Forestry, farm block, and resettlement programs.

Figure 6. Simulations from Kenya econometric results showing the relationship between population density and variables of interest




(g) Household asset value per adult equivalent
'000Ksh per adult equivalent
35
30
25
20
15
10
Q1
Q2
Q3
Q4
Q5
0
150
315
475
660
1135
Persons per sq km

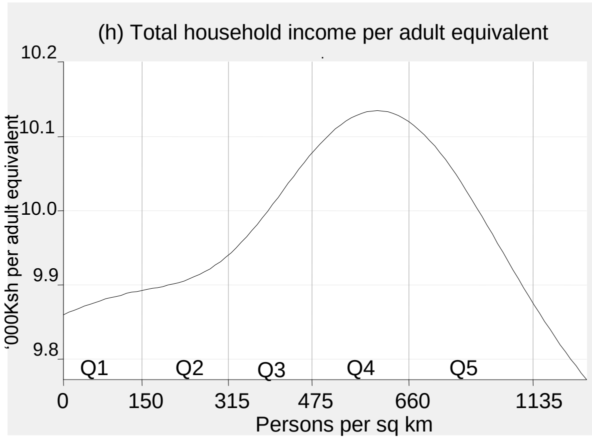

(h) Total household income per adult equivalent
'000Ksh per adult equivalent
10.2
10.1
10.0
9.9
9.8
Q1
Q2
Q3
Q4
Q5
0
150
315
475
660
1135
Persons per sq km

Table 1. Farming operations in different farming systems

	Forest fallow system	Bush fallow system	Short-fallow system	Annual cultivation system	Multiple cropping system
Labor-land ratios (reflecting pop. density)	Low	→	→	→	high
Land preparation	no land preparation	use of hoe to loosen soil	plow	animal-drawn plow	animal drawn plow and tractor
fertilization	ash	ash	manure, green manure	green manure, inorganic fertilizer	Intensive use of inorganic fertilizer
weeding	minimal	required as length of fallow decreases	weeding	intensive weeding	intensive weeding

Source: condensed and adapted from Binswanger and Pingali (1988).

Table 2. Hectares of arable land per person in agriculture (10 year average) in selected countries

	1960-69	1970-79	1980-89	1990-99	2000-09[1]	2000-09 land-person ratio as % of 1960-69
Ethiopia	0.501	0.444	0.333	0.224	0.218	43.5%
Zambia	0.643	0.607	0.398	0.342	0.297	46.2%
Kenya	0.462	0.364	0.305	0.264	0.219	47.4%
Uganda	0.655	0.569	0.509	0.416	0.349	53.3%
Malawi	0.480	0.466	0.357	0.304	0.307	64.0%
Zimbabwe	0.613	0.550	0.452	0.420	0.469	76.5%
Rwanda	0.212	0.213	0.195	0.186	0.174	82.1%
Mozambique	0.356	0.337	0.320	0.314	0.294	82.6%
Ghana	0.646	0.559	0.508	0.492	0.565	87.5%
Nigeria	0.982	0.860	0.756	0.769	0.898	91.4%

Source: FAO STAT (2010)

Notes: [1]Data on land utilization is only available for the period 2000 to 2008. Land-to-person ratio = (arable land and permanent crops)/(agricultural population). For the periods 1960-69 and 1970-79, agricultural population is estimated by multiplying rural population by an adjustment factor (mean agricultural population 1980-84/mean rural population 1980-84). This is because data on agricultural population was only collected from 1980 onward.

Table 3a. Rural population density distribution on land categorized as arable, GRUMP 2010

	Percentiles of all pixels with arable land ranked by population density							Mean across
	5th	10th	25th	50th	75th	90th	95th	all pixels
Ethiopia	48	70	113	151	237	517	695	239
Ghana	32	44	70	128	653	1453	1775	440
Kenya	38	71	185	393	648	960	1170	465
Malawi	63	84	136	230	374	587	812	307
Mozambique	7	14	30	68	494	965	1394	287
Nigeria	36	45	91	194	458	1274	1687	401
Rwanda	162	229	346	450	558	780	1354	519
Tanzania	11	16	36	59	143	886	1546	228
Uganda	50	84	163	277	438	658	915	349
Zambia	7	12	23	332	944	1186	1210	450

Note: These estimates are based on all 1 km2 grid cells ("pixels") categorized as rural and with at least 10% of the grid cell being arable land and below 2000 persons per km2.
Data sources: Year 2010 population estimates from GRUMP; arable land is the share of all pixels classified as "cultivated" in the GAEZ 3.0 database.

Table 3b. Rural population density distribution on land categorized as arable, AfriPop 2010

	Percentiles of all pixels with arable land ranked by population density							Mean across
	5th	10th	25th	50th	75th	90th	95th	all pixels
Ethiopia	39	57	97	149	265	528	867	251
Ghana	17	31	89	365	990	1527	1755	585
Kenya	30	58	158	338	632	1077	1388	463
Malawi	56	71	105	166	246	351	487	217
Mozambique	6	9	26	50	101	764	1260	208
Nigeria	25	35	65	173	691	1361	1657	447
Rwanda	148	201	306	470	723	1083	1327	564
Tanzania	11	19	44	107	314	752	1106	262
Uganda	45	71	130	232	474	913	1238	375
Zambia	6	9	19	44	640	1361	1693	376

Note: These estimates are based on all 1 km2 grid cells ("pixels") categorized as rural and with at least 10% of the grid cell being arable land and below 2000 persons per km2.
Data sources: Year 2010 population estimates from AfriPop 2010; arable land is the share of all pixels classified as "cultivated" in the GAEZ 3.0 database.

Table 4. Land Distribution within the smallholder farm sectors in Selected African Countries

Country (year of survey)	(a) sample size	(b) Mean farm size (ha)	(c) Farm Size (hectares per capita)					(d) Gini Coefficients		
			mean	Quartile				Land per household	Land per capita	Land per adult
				1	2	3	4			
Kenya, 1997	1146	2.28	0.41	0.08	0.17	0.31	1.10	0.55	0.56	0.54
Kenya, 2010	1146	1.86	0.32	0.07	0.12	0.25	1.12	0.57	0.59	0.56
Ethiopia, 1996	2658	1.17	0.24	0.03	0.12	0.22	0.58	0.55	0.55	0.55
Rwanda, 1984	2018	1.20	0.28	0.07	0.15	0.26	0.62	--	--	--
Rwanda, 1990	1181	0.94	0.17	0.05	0.10	0.16	0.39	0.43	0.43	0.41
Rwanda, 2000	1584	0.71	0.16	0.02	0.06	0.13	0.43	0.52	0.54	0.54
Malawi, 1998	5657	0.99	0.22	0.08	0.15	0.25	0.60	--	--	--
Zambia, 2001	6618	2.76	0.56	0.12	0.26	0.48	1.36	0.44	0.50	0.51
Mozambique, 1996	3851	2.10	0.48	0.1	0.23	0.4	1.16	0.45	0.51	0.48

Note: Numbers for Ethiopia, Rwanda, Mozambique, and Zambia, including Gini coefficients, are weighted to be nationally representative.
Sources: Kenya: Tegemeo Rural Household Surveys, Tegemeo Institute, Nairobi Kenya. Ethiopia: Central Statistical Authority surveys 1995 and 1997, Government of Ethiopia, Rwanda: 1990 Ministry of Agriculture Survey. Malawi: Profile of Poverty in Malawi, 1998, National Economic Council, Malawi, 2000. Zambia: Central Statistical Office Post-Harvest Surveys. Mozambique: 1996 Ministry of Agriculture and Rural Development (MADER) Smallholder Survey.

Table 5. Perceptions of Availability of Arable Land in Zambia and Population Density, by Province, 2001.

Province	Is there unallocated arable land?		Arable & unutilized	Arable and unutilized minus already cultivated land (kms^2) (i.e., unutilized)
	% Responding Yes	% Responding No		
Central	57.9	42.1	65,800	64,679
Copperbelt	39.2	60.8	23,172	22,720
Eastern	32.6	67.4	6,769	3,935
Luapula	38.6	61.4	28,120	27,031
Lusaka	40.0	60.0	11,756	11,587
Northern	68.3	31.7	102,751	149,543
Northwestern	96.0	4.0	151,992	102,203
Southern	33.6	66.4	6,321	4,493
Western	23.3	76.7	1,877	879
Zambia	44.1	55.9	398,560	387,022

Source: Supplementary Survey to the Post Harvest Survey, 2001, Central Statistical Office, Lusaka, Zambia.

Table 6: Smallholder maize production growth from the baseline period (2006–2008 harvest years) to 2011, by farm size category

			Total smallholder maize production			
Total area cultivated	Number of farms, 2006-08 to 2011	% of farms	Annual mean during 2006-2008 baseline period (MT)	2011 harvest (MT)	Absolute change (D-C) (MT)	Increase in maize output per farm (E*1,000/A) (MT)
	(A)	(B)	(C)	(D)	(E)	(F)
0-0.99 ha	616,867	41.9%	212,335	309,324	96,989	157.2
1-1.99 ha	489,937	33.3%	381,293	707,438	326,145	665.7
2-4.99 ha	315,459	21.4%	490,102	1,130,527	640,425	2,030.1
5-9.99 ha	42,332	2.9%	196,848	494,719	297,871	7,036.6
10-20 ha	6,626	0.5%	103,156	144,888	41,732	6,298.4
Total	1,471,221	100%	1,383,735	2,786,896	1,403,161	953.7

Sources: MACO/CSO Crop Forecast Surveys, 2005/06-2007/08, 2010/11

Table 7. FISP fertiliser received (2010/11 crop season) and maize sales, 2011, by farm size category

Total area cultivated (maize + all other crops)	Number of farms	% of farms	% of farmers receiving FISP fertilizer	kg of FISP fertilizer received per farm household	% of farmers expecting to sell maize	maize sales (kg/farm household)
	(A)	(B)	(C)	(D)	(E)	(F)
0-0.99 ha	596,334	39.6%	14.3%	24.1	22.2	135
1-1.99 ha	499,026	33.1%	30.6%	69.3	47.7	609
2-4.99 ha	354,116	23.5%	45.1%	139.7	64.0	1,729
5-9.99 ha	49,410	3.3%	58.5%	309.7	82.1	6,613
10-20 ha	6,999	0.5%	52.6%	345.6	86.8	15,144
Total	1,505,885	100%	28.6%	77.1	42.7	950

Source: MACO/CSO Crop Forecast Survey, 2010/11

Appendix 1.

	Period	Ethiopia	Ghana	Kenya	Malawi	Mozambique	Nigeria	Rwanda	Tanzania	Uganda	Zambia
Rural population	1960-69	2.2	1.8	2.9	2.3	1.9	1.4	2.5	2.7	3.1	1.5
growth rate (%/year)	1970-79	1.9	2.0	3.1	2.8	1.7	1.9	3.0	2.5	2.8	1.8
[A]	1980-89	2.7	2.3	3.4	3.8	0.3	1.7	3.5	2.5	3.0	3.1
	1990-99	2.8	1.5	2.8	1.9	1.6	1.3	-0.4	2.6	3.1	3.5
	2000-09	2.3	0.8	2.3	2.3	1.3	1.1	2.2	2.2	3.1	2.3
Urban population	1960-69	5.4	4.7	6.6	5.7	6.7	5.6	5.5	7.0	7.4	8.2
growth rate (%/year)	1970-79	3.9	3.1	7.9	7.2	10.7	5.1	7.1	9.3	4.2	6.0
[B]	1980-89	5.0	4.6	5.1	6.6	5.9	4.8	4.6	5.7	7.2	3.0
	1990-99	4.7	4.5	3.7	5.0	6.7	4.4	10.4	4.6	4.1	1.6
	2000-09	3.7	3.8	3.8	5.5	4.7	4.0	5.7	4.5	4.2	2.6
Percentage of population	1960-69	7.4	25.8	8.6	5.0	4.6	19.5	2.8	6.1	5.4	23.2
residing in urban areas (%)	1970-79	9.4	30.0	12.7	7.5	8.7	25.3	3.9	10.8	7.0	34.5
[C]	1980-89	11.4	33.1	16.9	10.2	16.5	31.5	5.0	16.6	9.1	39.7
	1990-99	13.7	39.8	18.9	13.2	25.6	38.5	8.5	20.4	11.6	37.3
	2000-09	16.0	47.4	20.7	17.2	34.1	45.8	16.7	24.1	12.5	35.1
data sources:											
[A] http://data.worldbank.org/indicator/SP.POP.GROW											
[B] http://data.worldbank.org/indicator/SP.RUR.TOTL.ZG?page=5											
[C] http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS/countries											

Data sources:
[A] World Bank, http://data.worldbank.org/indicator/sp.pop.grow
[B] World Bank, http://data.worldbank.org/indicator/sp.rur.totl.zg?page=5
[C] World Bank, http://data.worldbank.org/indicator/sp.rur.totl.zs/countries