Population Growth and Agricultural Change in Africa: A 50-Year Assessment

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I. Introduction

This is a study of the relationships between population growth and changes in land use and agriculture in Africa over the past half century, focusing on the differences between the Least Developed Countries (LDCs) and the Other Developing Countries (ODCs), as defined by the United Nations. The progress of the least developed countries (especially in Africa) towards international development objectives, including the Millennium Development Goals, is affected by changes in many factors, including population, human capital formation, domestic and international investment, foreign trade and aid, and remittances from migrants,but the implications of population change for the agricultural sector has received little attention, notably at the macro or national level. Since agriculture still accounts for half or more of Gross Domestic Product and occupies a considerably larger share of the labor force in most African countries, it is time to take stock of how these countries have evolved over the past half century (since data first became widely available at the country level), and what this may tell us about their prospects for the future, including food security.

The larger study from which this is adapted (Bilsborrow and Salinas, 2012) was conducted at a time of particular urgency when it was begun in early 2011 due to the near record rise in global food prices, which threatens ongoing progress toward the Millennium Development Goals, especially MDG1 on reducing poverty to half its 1990 level by 2015. Thatpossibly unprecedented rise in food prices attracted considerable attention in the media as well as from international organizations and scholars: FAO reported a rapid increase in global food prices (Bradshur, *NY Times*, February 9), pushing 44 million more people into extreme poverty, with rice prices rising early 40% in a single year from early 2010, and corn nearly doubled in price. Such media reports coincided with the release of a major report on the status of world agriculture commissioned by the United Kingdom, the "Foresight Report on Food and Farming Futures". The Director of the report, John Beddington, concluded: "We have 20 years to arguably deliver ….40% more food, 30% more fresh water; and 50% more energy…" but we will need to do so with much less environmental degradation, which will be a major challenge (BBC, February 25, 2011).

Responding to this will be a challenge due to the accumulated environmental damage already to the planet from massive deforestation and damage to watersheds, soil degradation from erosion and excessive use of agrochemicals, leading to serious water contamination of most of the major rivers and estuaries of the world; and ongoing and anticipated global climate change, expected to cause an increase in extreme climate events and changing the productive capacity of lands all over the world, especially in Sub-Saharan Africa. These current problems combine with the 2013 United Nations population projections showing a global population of 9.6 billion in 2050--2.7 billion or 33% more than in 2013, including a more than doubling of the population of Africa (UN, 2013)--make an evaluation of the extent of the linkages between population processes and trends over time in agriculture especially timely. What has the relationship been in the past half century in Africa? What does this suggest for the future? This present study takes advantage of extensive data on agriculture compiled mainly by the UN Food and Agricultural Organization (FAO) since 1961. The analysis will cover the relationships to the extent possible with the data available. The focus will be on determining what the broad relationships are over time in the sense of breaking down the period since 1961 into sub-periods to ascertain if the relationships between population and agriculture changed from one time period to another.

The organization of this paper is as follows: Section II reviews key theoretical perspectives, while Section III briefly describes the data, data sources, main measures used, and the countries studied. Section IV describes and presents the main population variables used, along with projections for the 21st century. Sections V-VI present the empirical findings, on the extent to which changes over time in population have been associated with changes in land use and agriculture in Africa at the country level for the two groups of countries. Section VII summarizes the main findings, indicates gaps in data and methods and further research needs at the macro level, and raises fundamental policy issues for Africa and the international community.

II. Theoretical Perspectives

Over the course of human history, population growth and redistribution through migration have been the major anthropogenic forces altering the face of the earth (Wolman and Fournier, 1987; Turner II, 1990). This has led to various theories and explanations of the linkages between demographic (and other) factors and changes in land use (LU), including those of Malthus (1798), Boserup (1965), and others (see reviews and citations in Bilsborrow, 1987; Pingali and Binswanger, 1987; Bilsborrow and Geores, 1992; Geist and Lambin, 2001; Lambin et al., 2001). Underlying the recent surge in LU studies, almost all at the micro or household level[1], are diverse theoretical approaches from multiple disciplines, including demography, sociology, economics, geography, and agricultural sciences, which together call for a multidisciplinary approach. These theories cannot all be even summarized here, so we focus on the two most directly relevant ones, Malthus and Boserup.

The first modern scholar credited with theorizing about the relationships between population and agriculture was Thomas Malthus. Most people think of Malthus as postulating that population growth ultimately leads to "positive checks", including famine, increased mortality and population decline, since human populations tend to grow geometrically whenever there is a temporary food surplus, while food production can only increase arithmetically due to the law of diminishing returns to labor on a fixed amount of land. As a policy if not moral prescription, Parson Malthus therefore pushed for people to adopt "negative" controls over population growth, postponing marriage and controlling fertility. The key assumption of Malthus, and one which he could hardly be faulted for in his time at the end of the 18th century, was that technology was constant, so that the only way to accommodate and feed a rising population was to increase the land area in use. This expansion tends to come at the expense of forests and marginally productive lands (e.g.,drylands), also causing environmental loss. Thus Malthus viewed population increase as leading to the expansion of agriculture "horizontally", referred to as "land extensification" (Bilsborrow, 1987).In fact, of course, technology did change, dramatically, in both agriculture and industry, beginning in the decades after Malthus' writings, which he could not have anticipated.

[1] Some pertinent examples for Africa, mostly at the micro-level, include Lele and Stone (1989); Myers (1989); Goliber (1989); ODI (1991); Mortimore (1993); Kalipeni (1994); Tiffin et al (1994); Shapiro (1995); Codjoe and Bilsborrow (2011); and especially Teller and Hailemariam (2011). See also Kumar (1973) and Higgins et al (1982), which projected difficulties for most Sub-Saharan countries to feed its population even in 2000 without food aid, under circumstances prevailing at the time, even with plausible advances in agricultural technology.

Well after Malthus, the historian Arnold Toynbee developed his stimulus-response theory of history, which contributed to the thinking of the economist, Ester Boserup (1965, 1981), who developed her counter argument to Malthus: She hypothesized that population growth could, under the right conditions, *induce technological changes* that would increase output per unit of land. This "*agricultural intensification*" or intensification of land use occurs as farmers seek, and even invent, methods to increase land productivity. Most of these methods are also *labor intensive*, taking advantage of the additional labor resulting from population growth(Bilsborrow and Geores, 1992, 1994).[2]Measures of land use intensification available at the country level include use of fertilizer, pesticides and herbicides; area under irrigation; and agricultural labor per hectare of agricultural land. The extent to which the use of these inputs rises with increases in population (density) may be seen as indicating the adoption of methods aimed at increasing output per unit of land area, or *land intensification*. While these methods usually involve increasing inputs of labor per unit of land, this is not the case with one other category of ways to increase output per unit of land--the use of tractors and other agricultural machinery, which tend to be labor-saving.

III. Data and Methodological Approach

The time frame for this study is 1961 to 2008 in general, since the main data source available as this study began in 2011 was the UN Food and Agricultural Organization, and land use data from FAO are generally not available before 1961, when the extensive cross-country data files begin.[3]

Based on a preliminary view of changes in land use and other variables for Africa, we determined that examining the changes over the whole nearly half century period is desirable but not sufficient for detecting *changes in trends over time.* For this we considered using two approximately equal time periods—e.g., 1961-1985 and 1985-2008—but a preliminary examination of the data suggested that three sub-periods would be more useful. Using three time intervals, moreover, has the advantage of revealing *changing patterns* between time periods, that is, is the pattern of change accelerating or decelerating? It also allows a more careful look at the

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[2]Boserup never said nor wrote that population growth would embody the seeds of its own solution, as interpreted by Julian Simon (1981, 1996), only that, under appropriate conditions, it *could*. The idea that innovation could be induced, whether by changes in relative market prices or changes in relative factor proportions, such as through population growth, is inherent in the economists' theory of induced innovation (Binswanger and Ruttan, 1978), which was applied to agricultural change by Binswanger and McIntire (1987) and Ruttan and Hayami (1989).

[3]As with all studies based upon cross-country data for many developing countries, this one too must confront questions of data quality, including gaps in data, differences in definitions and concepts used from country to country, and occasionally even consistency over time within countries. One particular country requires explanation regarding the latter: Data are available from FAO for Ethiopia PDR for 1961-80, and then for Ethiopia in its current form which excludes the new state of Eritrea carved out of Ethiopia in the early 1990s. Since both of these countries have data for both 1995 and 2008 values for both countries can be summed for these years to produce a value which can be compared with those of earlier years to show changes over the entire period.
In addition, Africa has more countries with gaps in data (two), or strange jumps in the data, which could be real due to major disruptions of civil war (Rwanda) or possibly artificial (Benin in 2008 compared to 1995, with most of the change in a single year, 2000-2001). Unusual changes were also evident in examining annual data series (not shown in this document but available) for Burkina Faso in 2007-8 (big increase in Arable &Permanently cropped land), Lesotho in 1976-77 and Mauritania in 1972-3 (big decreases), Gambia in 1998-99 and 2000-1 and Mali in 1992-3 (increases), and Sierra Leone in 2000-2 and 2005-6 (increases).

most recent period. Thus most of the studies of changes over time in this paper use the following three time periods: 1961-1980, 1980-1995, and 1995-2008, and the two country groupings for Africa, LDCs, numbering 32, and ODCs, numbering 17 (total of 49 countries in Africa).

Tables presenting the main data are presented in the Appendix. Population variables will be considered as *potential* explanatory or independent variables, to see if they, or changes in them, appear to be linked to land extensification or intensification.

Levels of variables and especially trends over time will first be described briefly for population, land and agricultural variables for the two groups of Africa LDCs and ODCs. Differences in patterns of change over time—between 1961-80, 1980-95, and 1995-2008--will be examined, as this may show accelerating/decelerating patterns. But the focus will be on investigating relationships between trends in the key population and agricultural/land use variables.[4]

IV. Population Variables and Trends

In this research, we considered the following population variables, to examine the extent to which changes in them are related to changes in land used, agriculture over the past half century:

- *Total population*, which reflects the effects of food consumption demand of the total population and hence potential pressures for agricultural production (net of exports and imports of food);
- *Rural population*, which reflects part of the total population on the consumption side (excluding urban population), as well as the pressures of the rural population to use the land to produce food for the national market (plus international market);
- *Economically active population in agriculture*, which is the population most linked to actual land use;

Detailed data on the *total population* of each of the African countries under study are presented in the Appendix (deleting small islands from Africa countries). The annual exponential rates of population growth for each country in each of the three time periods (between the four benchmark years, 1961, 1980, 1995 and 2008), as well as median rates of growth for the whole group at the bottom of the Table 1summarizes the data for all the African LDCs available, with data for each individual country in each of the two groups (LDCs and ODCs) presented in Appendix tables A1.a,b). Tables A1.a,b show the population size and average annual rate of population growth for each country for each of the three intervals (and for the 47 year period as a whole). Most of the 31/32African LDCs at least tripled their population over the 47 year period.[5,6]Median rates of annual population growth for Africa LDCs over the three time periods

[4]Given the effects that outliers can have on measures of central tendency, notably means, especially when the number of observations is small most of the discussion in this document is based on *medians*, to eliminate distorting effects of outliers.

[5]Indeed, seven of the African LDC countries increased their total population by four times or more (led by tiny Djibouti and Gambia, followed by Niger, Uganda, Democratic Republic of the Congo, Tanzania and Zambia. Only four African LDCs failed to triple their initial population—Equatorial Guinea, Lesotho, Mali and Sierra Leone. The rest or 21/22 of the 31/32 countries grew by 3 to 4 times, corresponding to mean annual growth rates of 2.34% and 2.95%, respectively.

were 2.7% in 1961-80, 2.9% in 1980-1995, and 2.7% in 1995-2008, showing virtually no overall change in population growth rates, and no tendency for a decline in the most recent. This is linked to the high fertility rates persisting in most of the Africa LDCs, where the mean total fertility rate[7] or TFR was still 5.4 in 2005-10 compared with 3.4 for the ODCs in Africa (UN, 2011).

Data for the African ODCs are presented in table A1.b. [8] Median rates of population growth were 2.6%, 3.0%, and 2.0%, respectively, in the three sub-periods, showing a clear decline in the most recent period, in contrast to the LDCs in Africa which had no such decline up to 2008. This shows a substantially widening gap population growth rates in the most recent period since 1995, due to the widening gap in fertility rates as the ODCs enter stage III of the demographic transition, with declining fertility rates as well as declining mortality rates. Thus in recent years, the ODCs in Africa have had declining rates of population growth while growth rates have generally remained high in the African LDCs. What this means for land use and the future will be examined below.[9]

The data on growth rates for all three of the population growth variables for all three time periods are summarized in Table 1, showing the comparable values for all three periods and the total 47-year time period for the two groups of countries. Data were available for the EAP in agriculture only for the latter two time periods.

Table 1. Trends in population growth of African countries

	Total population growth				Rural population growth				EAP in agriculture		
	1961-1980	1980-1995	1995-2008	Total	1961-1980	1980-1995	1995-2008	Total	1980-1995	1995-2008	Total
Africa LDCs	2.7	2.8	2.7	2.7	1.8	2.1	2.3	1.9	2.5	2.2	2.4
Africa ODCs	2.6	3	2	2.5	1.8	1.6	0.9	1.5	1.3	0.4	0.9

The implications of these contrasting trends in fertility and population growth are intriguing to see in the United Nations Population Division (medium) population projections for all countries of the world (see UN [2011] and un.org/desa/population), illustrated in Figure2 below. The differences are striking, with the mean population growth being 2.0 % per year for the African LDCs versus 1.1 % per year for the ODCs. Nearly three-fourths of the African LDCs (23 of 32) are projected to double or more their population by 2050, with Malawi, Niger, Tanzania, and

[6]The number of African LDCs is 32 when Eritrea and Ethiopia are considered separately, which was only possible t in the last two years and for one time period. For comparison with earlier years, their data are combined in 2008 and referred to in the text as "Ethiopia".

[7]The total fertility rate or TFR is the number of births that women will have in their lifetime if current prevailing age-specific rates remain constant during their child-bearing years.

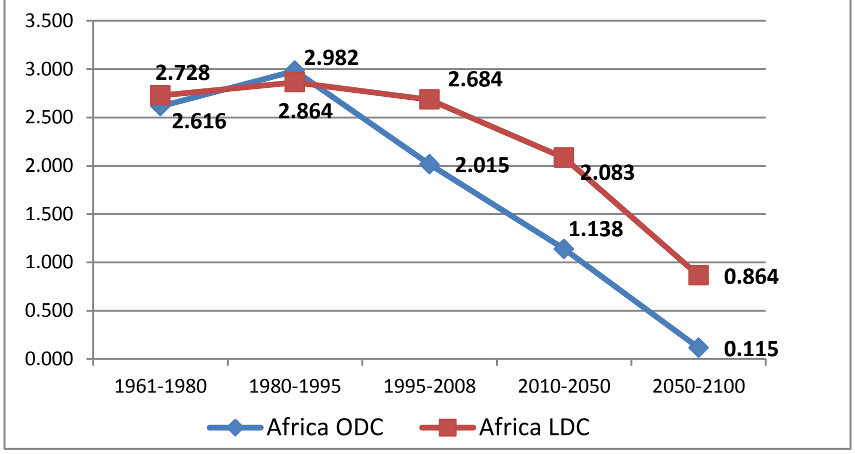
[8]Almost all of the 17 countries tripled their population, but three quadrupled it or more (Cote d'Ivoire, Libya, Kenya) and five did not triple it (Egypt, Morocco, South Africa, and Tunisia).

[9] Differences in the results are minimal from using rural population, and are available from the authors. Using the economically active population was not as useful since it was only available for the last two sub-periods for most countries, and led to weaker results.

Zambia expected to triple it or more. If the population sizes reached by some countries in this list are not staggering by 2050, compared to their 2010 populations, then surely they are by 2100, with Burkina Faso, Madagascar, Malawi, Niger, Sudan, Uganda, and Zambia having over 100 million in habitants, the Democratic Republic of the Congo with over 200 million, and Tanzania with over 300 million. Not a single LDC country in Africa will begin to decline in total population size before 2050 in the medium projection.

This situation contrasts with that of the ODCs in Africa, with only five(or less than one-third, compared to ¾ of the African LDCs) anticipated to double or more their population by 2050—Congo, Cote d'Ivoire, Ghana, Kenya and Nigeria. Nearly half (seven) will begin to decline in absolute size after 2050, so as to have smaller populations in 2100 than in 2050.

Figure 1. Rates of Population Growth



V. Changes in Population and Land Use: Extensification of Agriculture

In this section, the analysis will examine potential linkages between total population growth and agricultural land use for Africa. Dependent variables to be investigated are quantitative measures of extensification of land use: land in arable and permanent crops (A&P land) and land in pasture. The main hypothesis being examined is whether population trends are associated with increases in land area in agricultural use, or land extensification--the Malthusian proposition (section II). First, it is important to review trends in land extensification across the two LDC and ODC groups of African countries.

Trends in proportion of land in arable and permanent crops

For the LDCs in Africa, the median proportion of A&P land in total land rose from 0.071 in 1961 to 0.081 in 1980, 0.087 in 1995, and 0.118 in 2008— over the 47 year period. Clearly this indicates there was land available to be drawn upon to increase the agricultural land area in most of Africa during this time. The increase was substantial in all three periods, but greatest in the most recent period.

Looking at changes at the country level for Africa (note all LDC countries in Africa are in Sub-Saharan Africa), how many countries experienced increases/decreases in each of the three periods? Were changes more common in earlier or later periods? Once Djibouti is eliminated due to data being available for only one year, the situation of Ethiopia and Eritrea is taken into account (see section III), and the lack of data for Equatorial Guinea between1980 and 1995 is recognized, this leaves 29 LDC countries for the first time period, 28 for 1980-95, and 30 for 1995-2008(see table A.3a). For the 47-year period as a whole, not a single country experienced a decrease in A&P land, though four had essentially no change, six small increases of 10-24%, three of 25-49%, nine of 50-99%, and eight others more than doubled their A&P land. These eight were Benin, Burkina Faso, Guinea, Malawi, Mali and Rwanda (doubling but not tripling their agricultural area), plus Gambia and Sierra Leone, which more than tripled and quadrupled their agricultural land areas, respectively.

Breaking down the changes further for the three time periods, in the first one, 1961-80, 14 countries had changes under 10% or even decreases, 13 grew by 10-50%, and two by over 50% in the 19 years--Benin and Tanzania. In the second period, 11 had changes under 10%, 15 of 10-50%, and two over 50% (Mali and Mauritania, the latter over 100%, if the data can be believed) in the 15 years. Finally, in the last 13 year time period, 10 had changes under 10%, 14 of 10-50%, and six of over 50%, including three over 100%, i.e., more than doubling their A&P land in only 13 years—Gambia, Guinea and Sierra Leone. Comparing the three periods, there is clear evidence of increasing land extensification from the first to the second to the later period (taking into account the declining number of years). Indeed, median rates of annual increase in the three periods were 0.5%, 1.0%, and 1.4%,showing a consistent tendency towards more land extensification over time. This provides *prima facie* evidence that population growth and rising demands from that as well as economic expansion (which was minimal in most of these countries during the time period) increased pressures to increase the land area to produce more food, and that land was available for that purpose, or made available (e.g., from deforestation, or increasing use of marginal lands).This may suggest that an increasing number are moving close to their limits in their capacity to increase agricultural land in the future to feed their growing populations, but the slowing population growth itself may contribute to this slower increase.[10]

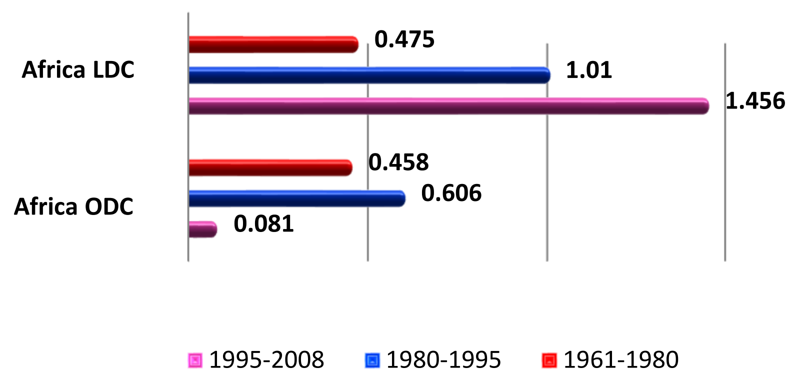
For the 17 African ODCs, diversity reigns (table A2.b), with Cote d'Ivoire, Gabon, Ghana, and Zimbabwe doubling or more their A&P land area (suggesting they are not near their limits yet), while at the other end of the spectrum, Botswana reduced A&P land, and the rest had modest changes, suggesting they may be approaching their limits of agricultural land, and/or that their lower rates of population growth may be contributing to less pressures to increase A&P land. Median rates of annual growth in land area were 0.5%, 0.6% and 0.1%, in the three periods.

Summarizing the changes for African LDCs and ODCs (see Figure2), land extensification occurred at a modest pace for the LDCs, possibly reflecting the pressures of rapidly growing total and rural populations in most countries, which continue to have high fertility and population growth. In contrast, among the ODCs, extensification of agriculture was similar to that for LDCs in the first two periods *but was absent in the most recent period*, possibly reflecting the easing of

[10]Thus the *only countries that had significant growth* (over 20%) in this most recent period (excluding a few where the increase only compensated for a decrease in the previous period) were Ghana, Nigeria and Zimbabwe.

increasing pressures on the land due to lower fertility and therefore slower population growth. Comparing the LDCs and ODCs, we see extensification proceeding in the LDCs at accelerating annual rates of 0.5%, 1%, and 1.4% in the three time periods, compared to decelerating rates of 0.7%, 0.6% and zero among the African ODCs. Note the overall rates of population growth were 0.86% per year for LDCs and 0.56% per annum for ODCs in Africa.[11]

Figure. 2 Changes of A&P Land



Population growth and extensification of the land area as measured by changes in A&P land

Since Arable & Permanently cropped land (A&P land) is the best measure of the expansion of the agricultural land area, a major hypothesis of this study is tested by addressing the following question: Is there a positive relationship between *total* population growth and A&P land? And if any such relationship exists? And is it changing over time?

The main method used for exploring this bivariate relationship here is to correlate rates of change in A&P land with both total population growth and rural population growth. The expectation, following Malthus, is that countries with higher population growth will be stimulated to have greater expansions in their agricultural land area. Because of the key importance of this potential relationship and the availability of A & P data, in this section and only in this section, we examine the correlations with rural population growth as well as total population growth.

We first examine the correlations between total and rural population growth and change in A&P land. The analysis involves, first, correlating changes in A&P land with total population growth for each group of countries, for each time period, and for the full 47 years.

[11] Note that the differences do not appear until near the end of the observation period, since the 1990s. This may account for the sanguine view of population growth effects in Africa and the developing world in general presented by Lam at the PAA annual conference in 2010 (Lam, 2011).

Correlations between population growth and A&P land in LDCs

For the African LDCs, the correlation between total population growth and annual growth in A&P land was only 0.00 in 1961-80 but was 0.20 in 1980-95 and 0.12 in 1995-2008, with the overall correlation being a trivial -0.03. (For reference, for n=30 observations, the statistically significant Pearson's r at the 0.05 level is 0.31, so none is statistically significant.) At the same time, the correlations between rural population growth and increase in A&P land were 0.18, 0.12, and 0.00, with the overall correlation being nil (-0.08). The lack of a strong correlation is not surprising, given serious concerns about data quality and comparability of data across countries. Experimentation with computing correlations with particular countries of dubious statistics excluded did not materially change the results, viz., excluding Ethiopia, Equatorial Guinea (a fairly high income country, and hence marginal to this study), or indeed all countries with overall negative changes in A&P areas over the whole time period (both Lesotho and Equatorial Guinea). Thus countries with declining land areas could hardly be expected to have been stimulated to decrease their area due to population growth.

Table 2. Correlations between total and rural population growth and change in A&P land, African LDCs and ODCs

	Correlations between A&P land and total population		Correlations between A&P land and rural population	
	LDCs	ODCs	LDCs	ODCs
1961-1980	0.00	-0.16	0.18	-0.47
1980-1995	0.20	0.32	0.12	0.66
1995-2008	0.12	0.10	0.00	0.16
1961-2008	-0.03	0.15	-0.08	-0.05

Looking at the Africa LDCs one by one, some countries with high population growth indeed did significantly expand their agricultural land areas, viz., Burkina Faso, Gambia, Malawi, Rwanda, Madagascar, Tanzania and Uganda, but can we say that their availability of land in 1961 was greater than that of others which also grew rapidly in rural population while changing theirland area by less than the median for the group, specifically, Chad, Dem. Rep. of the Congo, Ethiopia, Niger, Senegal, Somalia, Togo and Zambia? And others with slower rural population growth than the median increased their A&P land by more than the median: Benin, Guinea, Guinea Bissau, Mali, Sierra Leone, Mozambique and Sudan. While overall, the correlations are weak, the declining correlation over time is also exactly what one would expect if the availability of unused land was declining, since countries, even with growing population pressure on the land, would need to adopt other responses as the supply of potentially usable but unused land became depleted, leading to more intensification of agriculture

Reflections on trends in rates of population growth and change in A&P land between LDCs and ODCs in Africa

The results above appear discouraging, if one was anticipating strong relationships between population change and land extensification. But apart from serious concerns about data quality and comparability across countries, which can be expected to weaken any real relationships, it may be useful to further examine the changes in A&P land and rural population for Africa

The pattern of slower population growth being associated with less land extensification over time is thus evident both across space (regions) and time: It is evident in comparing the African ODCs and LDCs across the three time periods (and using either total or rural population growth or EAP land). *This provides support for the hypothesis that slower population growth alleviates pressures on land extensification*, and provides some evidence in support of Malthusian effects. Thus, even though this relationship is weak for individual countries, overall there is some evidence for Malthusian land extensification being linked to population growth.

Trends in land in pasture and relation to population change

Besides A&P land, land in permanent pasture (and meadows) is also part of the land used for agriculture. It is not expected to be as closely tied to demographic factors as A&P land, and certainly much less to rural population since taking care of cattle, sheep and other pasture animals requires little labor. But since the major use of pasture world-wide is for the production of beef (along with meat products, especially milk), pasture land should be expected to grow with total population, as the latter implies increasing demands for meat (though changes in tastes and income growth are also major determinants of increasing demands for meat, milk, etc.—see, e.g., UCS, 2011). The analysis here is hence based entirely on ascertaining if there is any evident relationship, and if so, when, between total population growth and pasture area. This assumes a fairly fixed relationship between pasture area and number of animals--a tenuous assumption as it could change with increased use of feed lots instead of free range pastures for raising cattle, as well as other factors over time. For the Africa LDCs (data not shown but available from the authors), a third of the countries had no change (11), with seven having actual declines in pasture area, including Ethiopia, Gambia, Haiti, Lesotho, Rwanda, Senegal, Sierra Leona and Togo. Countries that increased pasture area were Benin, Burundi, Central African Republic, Djibouti, Madagascar, Malawi, Mali, Niger, Sudan, Tanzania, Uganda and Zambia, with Niger and Burundi increasing their area by almost 40%. Median rates of annual growth in pasture area were 0.1% (1961-1980), 0.3% (1980-1995) and 0.5% (1995-2008), showing some tendency towards faster growth in more recent years.

For the 16 available African ODCs, a decline occurred in six, while the rest had an increase in pasture land, but none by as much as 50%. Median growth rates were virtually zero in all three periods.

Thus us with A&P land above, the main difference between ODCs and LDCs in Africa is the lack of an increase in pasture land in the last time period, 1995-2008, in the ODCs, while pasture land continues to grow along with population in the LDCs (medians rates of growth for the ODCs being 0.8%, 0.2% and zero compared to. 0.2%, 0.5% and still 0.5% in 1995-2008 for the LDCs).

Given the modest changes in pasture land and the expected weak linkage to population change, correlations for the two groups of countries are examined only for the whole 47 year period. The result of this analysis finds no evidence of a significant positive correlation for the LDCs: the overall correlation between population growth and change in pasture area was 0.05, compared to 0.10 for ODCs in Africa.

VI. Population and Land Use Intensification

As noted in section II, population growth may have impacts on agriculture through not only land extensification but also land intensification--the more intense use of agricultural land by whatever means available to increase land productivity. During the 20th century, and especially since the 1950s when the Green Revolution began, most of the increase in agricultural output worldwide has resulted from increased land productivity, with less and less of the increase over time coming from land extensification. For example, annual increases in land productivity in wheat from 1970 to 1977 ranged from 0.2 percent for Africa to 4.2 percent for the Near East, with the mean for all developing countries being 2.8. For rice, the range was 0.4 for Africa to 2.4 for Latin America, with the mean being 1.5 percent per annum (Bilsborrow, 1987, Table 7). During the recent period of 2000-2005, agricultural production rose by 3.3-3.4 per cent annually overall (UCS, 2011: 101), while the mean un weighted increases in A&P land in 1995-2008 were 1% for the all LDCs in the world and zero for the all ODCs. This illustrates how far the Africa region is lagging behind others in increasing agricultural productivity. While overall, the increase in the value of output per unit of land can be affected greatly by changes in the composition of crops grown (to higher value crops), seeds used, improvements in crop rotation and other management practices, here we only examine particular technologies that may be adopted to increase land productivity. Based on the theoretical discussion in section II and data availability in section III, the following indicators of changes in technology were used to test for evidence of changes in the intensity of agricultural land use in Africa[12]:

- Total fertilizer use per hectare of A&P land;
- Irrigated land area;
- Pesticide use per hectare of A & P land (available only since 1990);
- Use of agricultural machinery, such as tractors; and
- Agricultural labor productivity (e.g., value added per economically active population in agriculture).

Only results for changes in fertilizer and irrigated area are reported here.

Trends in fertilizer use and relationship to population growth

[12]Other alternative measures exist, such as irrigated land as a share of total A&P land, but are not available for as many countries as are the indicators used here. These include production per ha or yields for key staple (cereal) crops of main producing countries in each region, which is available for scattered countries from FAO, along with (changes in) mean fallow times and percent of land in multiple cropping (see discussion in Bilsborrow, 1987). In addition, a shift in the distribution of agricultural land from pasture land (and meadows) to A&P land is also a prime example of increased land use intensity, but is best examined at the individual farm level from agricultural surveys, which is not possible to do for a large number of countries.

Tables A4.a,b show fertilizer use (total consumption in metric tons) and changes over time for all the groups of countries. Fertilizer is measured as total tons consumed by the country, from FAO data. Not surprisingly, the data are spotty, with only 17 of the 38LDCs in Africa having data for all four benchmark years. Moreover, changes over time within those 17and the others often wildly fluctuate, and therefore must be considered of suspect reliability. Nevertheless, to avoid massive purging of countries, somewhat "loose" criteria were adopted.[13]Based on these criteria, data were examined for 27 African LDCs. These data showed that fertilizer use rose little or was stable in 16 of the 27 countries, rose modestly in five, and rose by several times in six countries.

The data for the African ODCs are not surprisingly better, with fewer missing data points and fewer unlikely jumps from one year to another. Only one country (Namibia) did not provide data to FAO. Of the 16 countries, eight had little or no increase, five modest increases, and three large increases.

To study the relationships between (total) population growth and fertilizer use, LDCs were first classified into three or four groups according to their rate of population growth over the 47 year period. Categories used were (a)under 1.9%, 1.9 to 2.8%, and over 2.8% (the overall median being 2.4%); (b) under 2.0, 2-2.49, 2.5-2.99, and 3.0+; and (c) under 2.5, 2.5-2.89, and 2.9+. The use of (c) results in the distribution of values in table 3 below.One expects values to be concentrated along the main diagonal, if the hypothesized positive relationship is true, so that countries with higher population growth are induced, following Boserup *et al.*, to increase their use of fertilizer more. However, there is evidently is no meaningful (expected) relationship between population growth and increased fertilizer use. Sometimes an assessment of "outlier" countries can help clarify such tables. In this case, the most "perverse" countries (in the sense of being most contrary to the hypothesis) were Lesotho and Mali (with low observed population growth and high increases in fertilizer use)--included in the upper right cell of the table, along with Gambia and Tanzania, in the lower left cell. A plausible explanation of Lesotho and Mali is that both have substantial labor (both seasonal and long-term) migrations to neighboring countries, which could be depressing population growth values below "normal" values. Indeed, Mali has one of the very highest levels of fertility in Sub-Saharan Africa (total fertility rate of 6.5), and while Lesotho's TFR is only 3.4, it is well known to have massive labor migration to South Africa.

Table 3. Relationship between change in fertilizer use and total population growth, Africa LDCs.

Annual rate of population growth	**Change in fertilizer consumption**			
	Neg.	Low	Medium	High

[13]Because of this, the computation of annual rates of growth in fertilizer use is a poor indicator of changes over time. But it is preferable for geographic coverage to include as many countries as possible, so the approach adopted was to leave out only those countries with no data or only one data point, or with only one plausible data point (Rwanda). To assess whether fertilizer use was rising, if it was not significantly higher in the latest available year than in *each* of the previous available years for a country, it was taken to be roughly stable over time, even if much higher than the first available year; this would indicate it was no longer rising even if it did earlier and over the period as a whole. This approach gives an impressionistic view of the extent to which fertilizer use was rising and continues to rise. With the data available, this is the best that can be done for multiple countries in the region.

< 2.5	1	5	1	2
2.5 – 2.89	0	5	2	2
> 2.9	2	3	2	2

For the ODCs in Africa, with only 16 countries even a 3 x 3 table is stretching the data. Various cell limits were experimented with for annual rates of population growth over the period as a whole, as above for the LDCs, with the final one adopted being under 2.4, 2.4-2.59, and 2.6 +, showing the concentration of values for ODCs, though there are a few outliers (table A1.b). Again, no relationship was observed between population growth and fertilizer use, with the 3 x 3 cell values being (the 3 columns being low or stable, rising, and rising rapidly), as follows: top line, 2, 3 and 0; second line being 4, 0, 1; and bottom line 2, 2 and 2. Evidently, there is no relationship observed among ODCs either. While various other factors such as overall farm income growth in the country, increasing education of farmers, changes in access to technology, access to foreign exchange to import fertilizer, and political stability in the countryside could have affected changes in fertilizer consumption, obscuring any relationship between population growth and fertilizer use.

Trends in irrigation and relationship to population change

As noted in section II and above, increasing population pressure on the land is hypothesized by Boserup (1965) and Bilsborrow (1987) to stimulate increased use of irrigation. Appendix Tables A5.a,b provide the broadest cross-country data on irrigation levels and trends, again from the FAO, for African LDCs and ODCs. For the LDCs, 14 of the countries had to be excluded *a priori* from the discussion of trends, based on criteria used above for fertilizer, leaving 18 of the 32 to discuss. Of these, six had little change in irrigated area, while 10 had a significant change, ranging from well over 50% to doubling, mostly since 1980, and two had larger increases, with the irrigated area rising multiple times (Malawi, Mali and Zambia).

For the African ODCs, only four countries did not have data or usable data, leaving 13. Of these, four had little or no increase in irrigated area, seven moderate increases, and two large ones, Kenya and Zimbabwe[14]. Overall, increases in irrigation were a bit greater for the ODCs than the LDCs.

Levels of irrigation across countries are related to many factors, including availability of reliable rainfall, soils, per capita income, and indeed rural population density (Bilsborrow and Geores, 1994). But the relationship with population density is a static one. What can we say about the linkages between population growth and changes *over time* in irrigated land?

[14]Many of the countries with substantial increases in irrigated area had little increase in fertilizer use, and conversely, a topic which begs for further exploration in the context of multiphasic theory, which postulates that there may be tradeoffs, with changes in one reducing the likelihood of changes in the other (Davis, 1963; Bilsborrow, 1987).

First, for the Africa LDCs, a table was prepared, as above for fertilizers.[15]This allows examining whether within this group of countries, differences in population growth have been associated with different rates of expansion of the irrigated area over the past several decades. The data can be arrayed as in table 4:

Table 4. Relationship between population growth and change in irrigated land area, Africa LDCs

Rate of population growth	**Change in irrigated land area**		
	Low	Medium	High
Under 2.1 %	1	2	1
2.1-2.49%	1	2	0
2.5-2.89%	3	3	0
Over 2.9 %	1	1	3

Evidently, there is at best only a very slight positive relationship over time between growth in population and trends in irrigated area among the African LDCs.[16] Note the principal off-diagonal contrary countries are Mali in the upper right cell (discussed above) and Congo DR in the lower left cell, where sustained increases in irrigation may have been difficult to achieve in a state which was functionally broken most of the time.

For the 13 available ODCs in Africa, little relationship exists. Thus the three population growth categories used were, as before, under 2.4% per annum, 2.4-2.59%, and over 2.5%. The numbers of cases in the three columns (see Table 4 above) were 1, 3 and 0 in the first row; 2, 2 and 1 in the second row; and 1, 2 and 1 in the bottom row.

Summary of findings on intensification

Although data are presented here for only two measures of intensification of agriculture—those with the most cross-country data available, five measures were all examined empirically (including use of insecticides, use of tractors, and an overall measure of value added per agricultural worker). Beyond the results above for use of fertilizer and expansion of the irrigated area, no evidence is observed of a relationship between population growth and insecticide use or growth in value added per worker. A slight positive relationship is found between population growth and increased use of tractors (not presented), but increased use of tractors is dominated by income changes more than population growth. Overall, there appears at best a weak positive relationship between population growth and intensification (either fertilizer use or irrigation).

[15]For each country a change in irrigation score was assigned for the period, based on the country having data for at least two years (preferably not only the first two years of the four, and the values being different—otherwise the presumption is that the country only collected the data once and is deleted). The same scores were assigned for change in irrigation in LDCs and ODCs. Each country was also assigned a population increase category, but with different category limits for LDCs and ODCs in order to discriminate better within each group.

[16]Of the counties with the highest population growth, only one (Malawi) had a large increase in irrigated area, with Gambia, Togo and Uganda havinglittle change. At the same time, the four countries with large increases in irrigated area were distributed across the different population growth strata.

However, the lack of a significant relationship may be due to the lack of data for more countries, and lack of better quality data, especially the African LDCs.

Overall, population growth rates were highest over time in the LDCs, but the growth in all forms of intensification was greater in the ODCs. It seems likely that this is due to their being far more able to *afford* purchasing additional inputs due to both higher levels of per capita (and rural) incomes as well as higher rates of growth in those incomes on average over the observation period. With this important caveat in mind, the data here suggest that population growth is associated with minimal if any Boserupian effects on inducing compensating technological change in agriculture.

VIII. Conclusions and Implications

The main purpose of this monograph was to investigate the extent to which trends in population have been related to changes in agriculture and land use in Africa over the past half century and into the 21st century. The focus was on comparing and contrasting, following UN classifications, Least Developed Countries (LDCs) and Other Developing Countries (ODCs), differing in levels of economic development and poverty and population trends. The question is, are these countries evolving in different ways demographically which have had different effects on trends in land use and agricultural technology, which suggest diverging prospects for their agricultural futures?

A brief view of theoretical perspectives focused on Malthus and Boserup, Malthus hypothesizing that population growth tended to stimulate expansion of the agricultural land area (*land extensification*), and Boserup postulating instead increases in adoption of technologies that increase output per unit of land (*land intensification*). Following a description of the main sources of data, their shortcomings, the analytical approach, and the population variables, UN population projections for Africa are presented to 2100. Population growth rates were found to be starting to diverge significantly between the LDCs and ODCs in Africa only in the latter part of the study period of 1961-2008, limitingthe ability of this study to distinguish impacts. This, along withdata gaps and other shortcomings, especially among the LDCs, hampered the empirical effort.

Nevertheless, substantial increases in the land area used in agriculture were observed in almost all African countries over the observation period, principally in Arable and Permanently Cropped Land (A&P land), and less in pasture land. As with population trends, diverging patterns of increase in A&P land also began to emerge between the African LDCs and ODCs at the end of the study period. Thus median increases in A&P land for the LDCs in Africa were 0.5%, 1.0% and 1.5%, in 1961-80, 1980-95, and 1995-2008, while they were 0.5%, 0.6%, and 0.1%, respectively, for the ODCs. Thus it was only in the last sub-period, 1995-2008, that significant and increasing differences in both population growth and land extensification were evident. Thus the LDCs in Africa still had high population growth (median of 2.7% annually) accompanied by accelerating land extensification (rising from a median of 1.01% per year in 1980-95 to 1.46% in 1995-2008); meanwhile in the ODCs, annual population growth fell to 2.0 in 1995-2008 and was continuing to fall, while land extensification ceased. This provides a *prima facie* case that, overall, higher population growth has been associated with greater land extensification, as Malthus hypothesized, and that the growing gap in land extensification trends between LDCs and ODCs in Africa appears linked to the diverging demographic trends.

For land intensification, a number of possible measures were examined. Unfortunately, most have far more serious data gaps and deficiencies than measures of A&P land. Little evidence was found for linking population growth and changes in land intensification, based on results for changes in fertilizer use or land in irrigation. Therefore, there has been little evidence to date of Boserupian effects of population growth stimulating land intensification in Africa.

A major handicap to conducting this multi-cross-country research is the lack of adequate data for many countries, which is due in turn to the lack of agricultural censuses, especially for the LDCs in Africa. This situation has, surprisingly, *not improved* over the past half century, despite repeated calls for better and updated data (see FAO Website on the World Census of Agriculture, discussed in Bilsborrow and Salinas, 2012). More and better agricultural census data are needed for better research to create a sounder knowledge base for policy-making concerning agriculture, land use and the environment, food security, and reducing rural poverty.

An additional and increasingly urgent need is for more agricultural research in African countries (and elsewhere)—to complement the excellent research in the 17 CIGAR centers around the world, focusing on the development of new seeds and other ways of enhancing the productivity of the world's principal food crops (evolving out of the Green Revolution started by Borlaug). But meanwhile governments throughout the developing world have cut back on their own agricultural research as well as agricultural extension services, reducing the dissemination of improved seeds and methods in their country—another example of urban bias in development policy (Lipton, 1977). Thus *Nature* reports: "growth in public agricultural research spending peaked in the 1970s and has been withering ever since. Today it is …actually decreasing in some countries in sub-Saharan Africa…." (2010, p. 531).Wealthy nations cut their global bilateral aid to developing countries for agricultural research from $6 billion in 1980 to $2.8 billion in 2006 (Brassher and Martin, *NY Times*, May18, 2008), while adjusted for inflation, the World Bank cut its aid to agriculture from $7 billion in 1980 to $2 billion in 2004.

Another policy implication of this study is apparent from the diverging trends in population and land use in Africa. Thus most ODCs appear to be emerging onto a sustainable path of fertility decline, declining population growth, little further increase in land area, and (though not dealt with here explicitly) economic development and poverty reduction. On the other hand, past and projected population increases in the LDCs in Africa imply high continued fertility and population growth for decades to come (especially in most of Sub-Saharan Africa), which implies increasing needs to just increase food production. This study suggests that this is likely to come mostly from further land extensification (and at the expense of tropical forests) rather than intensification of agriculture. This implies an urgent need to strengthen female education and improve the provision family planning services to reduce high levels of fertility in these countries.

With the possibilities of increasing agricultural production around the world via land intensification and land extensification (albeit in a decreasing number of countries), most analysts at FAO and other agricultural experts are sanguine about the prospects of increasing food production sufficiently to feed the expected larger world population. But this does not guarantee that all will have enough to eat, due to supply bottlenecks, costs of food distribution, and especially the continuation of widespread poverty in many countries, especially in tropical Africa. Thus, the problem of feeding Africa requires policies to both reduce fertility as soon as possible, and to expand agricultural research and extension to intensify agricultural.

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