Population and agriculture in the dry and derived savannah zones of Ghana

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ABSTRACT

This paper examines the role of population in agricultural practices in food crop production in Ghana. Perspectives from Malthus and Boserup (land use extensification and intensification) and multiphasic response theory are drawn upon to postulate linkages between population and these two forms of response in land use. Data from a 2001 household survey of 504 households in 24 rural localities in two ecologically, climatologically, and culturally different regions of Ghana, *viz,* the dry and derived savannahs are drawn upon in this study. Descriptive statistics, correlation matrices and multiple regression are used to explore relationships between population and land use in each region and together. Results show that both agricultural extensification and intensification are common in the derived savannah compared to the dry savannah, and that this is at least partly attributable to the former being characterised by better soils, larger farms, better access to agricultural and non-agricultural economic activities, and more schooling. While there was no evidence of Malthusian impacts on land extensification, this could result from the lack of available, unused land. Boserupian intensification was evident in household size linkages with the intensity of labor use. There is also evidence of the theoretically proposed tradeoffs (hypothesized in multiphasic response theory) between extensification and intensification in the derived savannah and the two areas combined, between more land and lower labor intensity and between more tractor use and shorter fallow periods. The paper concludes with important caveats and suggestions for future research, as well as some policy implications for Ghana.

Keywords: Population; food crops; Ghana; land use, agricultural intensification, Malthus vs. Boserup, multiphasic response theory, household surveys**.**

Introduction

Prior to the 1960s, Ghana was self sufficient in food crop production. The first Ghanaian government led by Dr. Kwame Nkrumah used agricultural wealth as a springboard for the country's overall economic development. However, as a result of a drop in prices of cacao, a key export commodity in the late 1960s, farmers were faced with fewer incentives to produce as well as a deterioration in necessary infrastructure and services. Farmers also had to deal with increasingly expensive inputs, such as fertilizer, because of overvaluation of the currency, the cedi. Food production therefore fell, with a decline in the food self-sufficiency ratio from 83% in 1961-66 to 71% in 1978-80, coupled with a four-fold increase in food imports in the decade prior to 1982. By 1983, when drought hit the country, food shortages were widespread, and export crop production reached an all-time low. The 1990s and 2000s saw Ghana making modest gains in food crop production.

The leading staple foods produced in Ghana from the 1960s to the present include cassava, followed by yam, plantain, maize, sorghum, millet and rice, in that order (Codjoe, 2007). Together with the main export crop, cacao, these crops constitute most of the national crop production. While roots and tubers are predominantly grown and consumed in the southern regions, grain crops are mostly cultivated in the north. Legumes are also primarily grown in the north and used as cash crops. Since 2004, Ghana has expanded the production of fruits and vegetables. These include pineapple, citrus, banana, cashew, pawpaw mango, tomato, pepper, okra, eggplant and onion. In addition, horticultural exports were mainly dominated by pineapples, but also include mangoes and bananas, which have increased in recent years, but remain on a small-scale (WFP 2009).

Over the years, the Government of Ghana has implemented policies that add value to Ghana's raw agricultural products (e.g. cocoa, cotton, oil palm, etc), but this has been on a very limited scale. In recent times, intensive efforts have been made by the government to process some of these products; e.g., the volume of cocoa beans processed locally rose from 20% to 48% of national output between 2004 and 2009 (Government of Ghana, 2010). In addition, a Special Initiative has been established by the Government for oil palm and cassava starch, to expand and add value to non-traditional exports, diversify the economy, create employment, and improve local livelihoods.

Challenges in food production in Ghana have been attributed to physical conditions (for instance the drought and bushfires of 1982-1983, poor rainfall distribution and its erratic nature, degradation of land resources), deficient agricultural policies, low priority given to food production in the past, inadequate support for the agricultural sector and an emphasis on capital-intensive agriculture and industry to the neglect of the larger traditional farming sector. Other challenges include the failure to appreciate the roles and needs of women in agriculture, the persistence of low agricultural technology, a lack of pricing and marketing incentives for farmers and, insufficient research and financial support for small farmers.

Ghana's population of 6.7 million in 1960 grew to 18.9 million in 2000 (Ghana Statistical Service, 2002), almost three-fold, and is estimated to have reached 23.8 million by 2009 (Population Reference Bureau, 2009). The high rate of population growth (about 2.2% per annum) has been mainly due to a declining mortality and moderately declining fertility. Thus, rapid population growth has had consequences for food crop production in Ghana (Benneh and Agyepong 1990).

Studies on population and agricultural practices in Africa have considered either Malthusian or Boserupian theories, and assessed which is dominant in a particular setting (Demont et al. 2007), i.e., intensification of agricultural practices based on Boserupian thinking or extensification from a Malthusian perspective: Malthusian perspectives include those of Mott and Mott (1980), Goliber (1989), Kalipeni (1994), and Shapiro (1995), while Boserupian ones include Tiffen et al. (1994), Mortimore (1989, 1993), and Shipton (1989). This study contributes to the literature by examining both together, as well as a wide range of other factors that could affect population-agricultural practices. We use household-level survey data to examine the population-agricultural nexus in two ecologically, climatologically, and culturally diverse regions of Ghana, *viz,* the dry and derived savannahs. This study has implications for food production policy, which is especially important in a poor and environmentally-challenged country such as Ghana which continues to have high population growth and use rudimentary farming methods.

Theories and concepts

Research on the population-agricultural practice nexus has been dominated by the Malthus (1960) and neo-Malthusian views which analyze population growth as a threat to the inherent limit of arable land to provide food, shelter and sustenance. It argues that food production can grow only at a linear rate while population tends to grow geometrically. Thus, population growth ultimately outstrips the capability of the economy to meet the rising needs for food, due to the ecological constraints imposed by natural resources. It postulates that if preventive measures or checks are not put in place (especially fertility control), poverty, disease, famine and war, called "positive checks", would automatically place a check on population growth (Meadows et al. 1972; Tolba, 1986; Repetto, 1987; World Resources Institute, 1989; Ehrlich and Ehrlich, 1990; Camp, 1992, Gilbert, 1999). Other proponents of this view, described by Mortimore (1993) as the degradational pathway, state that increasing population exerts pressure on limited resources, destroying the carrying capacity and subsequently lowering the standard of living (Timberlake 1985; Harrison 1987; Myers 1989; Lele and Stone 1989). In Africa especially, high population growth has been argued to have adversely affected the environment (Mott and Mott 1980; Goliber 1989; Kalipeni 1994; Shapiro 1995).

Proponents of the alternative view (Mortimore 1993) draw on Boserup's (1965) intensification thesis. Writing after the agricultural and industrial revolutions (almost two centuries after Malthus), Boserup suggests that increasing population density can stimulate technological innovations that increase land use intensity (see also Tiffen et al 1994; Simon, 1996; Pingali et al., 1987; ODI, 1991; Bilsborrow and Geores, 1992; Turner et al., 1993; Mortimore and Turner, 2005). The ODI (1991), in a study of the Machakos District (Kenya) beginning in the 1930s and spanning about sixty years, demonstrated that an increase in population resulted in increased farm and livestock output, culminating in food security and agricultural intensification, including fertilizers as well as soil and water conservation techniques.

The approach of Boserup is akin to induced innovation theory, which focuses on how economic and market-related opportunities and policy could also simulate the innovations described by Boserup (Binswanger and McIntire 1987; Lein 1993; Ruttan 1994; Angelsen and Kaimowitz 2001; Roy et al., 2006).

Apart from these theories which have dominated the population-agriculture-environment nexus debate over many years, Davis' (1963) theory of the multiphasic response has provided a broader perspective to the debate. According to Davis, when population grows and is manifest in larger household sizes, families need to respond to avoid a decline in their standard of living. This response could be in the form of marriage postponement, fertility reduction within marriage, or migration to seek greener pastures to support the family.

The approach of Davis focused on demographic factors, and thus excluded economic responses of households. As a result, Bilsborrow (1987) expanded Davis' approach by including agricultural extensification, intensification and rural-urban migration, playing itself out as follows: First, households tend to exhaust economic options available to them. Thus, when nearby arable land is available, agricultural extensification would tend to be the main response (Bilsborrow and Carr, 2001; Carr 2005; Carr 2008; 2009). On the other hand, if nearby arable land is not available but there is access to agricultural technology (Sheridan, 1988; Grigg 1992; Zimmerer, 1993), and produce and labor markets (Rudel 1983; Carr 2006; Sader et al. 1997; Nepstad et al. 2001), or supportive policies (Lele and Stone 1989; Hecht et al. 2006), such as those that favor secure land tenure (Futemma and Brondizio 2003), then agricultural intensification could occur.

Second, temporary or seasonal out-migration could be used by households as a strategy when the conditions for extensification and intensification are untenable or have been exhausted (Barbieri and Carr 2005; Aide and Grau 2004). Third, permanent out-migration would tend to be used when all the scenarios discussed above are insufficient or impossible, since out-migration is disruptive to family life, whether moving to other rural areas with arable land available or to urban areas with job opportunities (Bilsborrow 1998, Bilsborrow and Geores 1992). Fourth and last in a traditional society - due to its involving even larger social-behavioural changes - marriage and fertility behavior may change (viz., the Davis responses described above).

It should be pointed out that existing empirical work examining the relationships between population and land use from the Malthusian-Boserupian and especially multiphasic response perspectives has been mainly at the macro or country level (e.g., Bilsborrow and Carr, 2001; Carr et al. 2006). This paper, in contrast, examines the relationships at the household level. It will draw upon Malthusian, Boserupian and multiphasic response theory to examine the relationships between population and agriculture in two demographically, ecologically and economically distinct regions in Ghana. As far as we know, this is the first effort to quantitatively examine these relationships using all three theoretical frameworks at the *household* level in a developing country. In our conclusions, we will indicate some significant limitations of the data and the study.

The study area

The study areas covered in this paper represent two distinct savannah zones in Ghana, selected to examine whether their distinctive characters (discussed below) influence the population-agricultural practice nexus. As shown in Figure 1, the dry savannah is located in Northern Ghana and the derived savannah is in the Middle belt. The dry savannah experiences only one rainy season, from May to August, followed by a long dry season, and has a mean annual rainfall of 115 centimetres. The derived savannah, however, experiences a double maxima rainfall regime, with two rainy or wet seasons, from May to August and September to October, and a mean annual rainfall of 143 centimetres.

[Figure 1: About here]

Regarding soils, Lixisols are found in both the dry and derived savannahs. In the derived savannah, they are moderately well supplied with organic matter and nutrients. Moisture holding capacity is moderately good and soils are easily tilled by machine or hand. The derived savannah also has patches of Plinthosols - poor humus, fine sandy topsoil which has poor drainage and is subject to seasonal water logging or flooding and hence has little agricultural value. Differences in rainfall seasonality/ levels and soils have implications for agricultural production in the two savannah zones: the two rainfall regimes allow for two crop-growing seasons in the derived savannah while only one is possible in the dry savannah.

Methodology

Field survey

The paper used data from a survey undertaken in November 2001 to February 2002 among 504 households in 12 localities each in the Kassena-Nankana district (representing the dry savannah) and the Ejura-Sekyedumase district (representing the derived savannah). A (mostly) structured questionnaire was administered by direct interview with the respondents. To avoid biases, the interviewers were extension workers of the Ghana Ministry of Food and Agriculture (MOFA) from different agricultural districts than those in which they lived.

For the sample, the 2000 Ghana Population and Housing Census Report on communities was used to select communities. Most were very small in population size: 97% and 82% of the communities in the dry and derived savannah zones, respectively, had populations under 800 persons in 2000 (GSS, 2002).

Twelve communities each in the dry and derived savannah with a population of 800 persons or more were randomly selected for the study. As shown in Table 1, the communities in the dry savannah include Telania, Navrongo, Bonia, Kanania, Atibabisi, Yuwa Afarigabisi, Nabango, Paga, Mirigu, Badania, Manyoro and Janania, while in the derived savannah they were Ejura, Sekyedumase, Anyinasu, Dromankuma, Frante, Kasei, Hiawoanwu, Aframso, Drobon, Nkwanta, Ashakoko and Bonyon. Random sampling was again used to select the houses for interview, following a complete listing of the houses in the communities: 21 households were randomly selected from each community. Every farmer in a selected household was interviewed. The questionnaire gathered information on household characteristics, including age, sex, education, occupation, religion, and ethnicity of all members, along with household size, present/absentee household members, ownership of livestock, land tenure, farm size and land use, use of agricultural inputs (tractor, fertilizer, labor), length of fallow, year first farmed, cultivation of new lands, and soil water holding capacity.

[Table 1 about here]

Sex distribution was the same in the two regions, at 51% female. Regarding age, 37.2%, 56.2% and 6.6% of the respondents in the dry savannah, were, respectively, less than 15 years of age, between 15 and 64, and 65 and above. In the derived savannah, 41.6% were less than 15, 54.0% were 15-64, and 4.4% were 65 and over. Furthermore, 63.7%, 13.4%, 17.4%, 2.9%, and 2.7% of the respondents in the dry savannah, respectively, had no formal education, elementary, secondary, vocational and tertiary education. In the derived savannah, 43.4% of the respondents had no formal education, 24.1% had elementary education, 28.2% had secondary education, 0.7% had vocational education, and 0.9% had tertiary education. Thus, education was more skewed towards no education and higher education in the dry savannah. Finally, 69.9% of the respondents in the dry savannah had farming as their major occupation, 9.6% were traders, 4.8% were in professional/managerial occupations, and 2.5% produced handicrafts. In the derived savannah, the distribution was similar, with 72% mainly farmers, 11%, traders, 3.0% professional/managerial occupations, and 3.5% in handicrafts.

Variables

The description of variables and how they are measured is presented in Table 2.

[Table 2: About here]

As shown in Table 2, there are two sets of dependent variables for agricultural extensification and intensification. The extensification variables are (a) cultivation of *new farmland* within the five years preceding the survey (NLAND), and (b) mean hours of *tractor use* per hectare of farmland in the year (TRACT). The intensification variables are *mean years allowed for land to fallow* in the past five years (FLNGT), *labor input per hectare* in the year (LADEN), and mean inorganic *fertilizer use per hectare* in the year (FERTI). Ecological area (ECOLO), i.e., dry or derived savannah, is included in the model to control for ecological zone.

The first set of independent variables are household variables. The educational level (EDUCA) of the head is measured as follows: no schooling (1); basic/junior high (2); and secondary/senior high or higher (3). The number of household members (HSIZE) is used to assess the role of population (household size) at the micro level. Proportion of adult males (PMALE) and females (PFEMA) were also included since it may be not mere household size that determines agricultural practices but the proportion of adults of either or both genders as well. In addition, age of farmer (AGEFM) is included to control for life cycle stage.

Bilsborrow (1987) postulated that temporary/seasonal out-migration or even permanent out-migration may be used by households as a livelihoods strategy after the conditions for agricultural extensification and intensification have been exhausted. As a result, this study considers households with a migrant (MIGRT), defined as a member living elsewhere for more than six months at the time of survey. In fact, migrants from northern Ghana have been migrating over the years to the transitional zone, mainly to farm (Manshard, 1961), although a few have been petty traders and artisans. Migrants are primarily from the Mole-Dagbani, Gurma, Grusi and Mande-Busanga ethnic groups (Codjoe 2006). The first migrate from northern Ghana during the minor farming season to farm in the transitional zone. They stay in the transitional zone until the major farming season in northern Ghana and then migrates back to the north. The second group, with southern Ghana as their final destination, transit in the transitional zone to farm, earn money and continue south. The final group are migrants who are unable to continue their journey south and thus end up settling permanently in the transitional zone. All these categories of migrants from northern Ghana live mainly with relatives in the transitional zone.

Household affluence is measured by ownership of livestock (LIVST), i.e., cattle, sheep and goats, due to the fact that the study communities are basically rural. Affluent households can more easily increase investment on their farms and/or increase the size of their holdings. They are also more able to afford agricultural inputs (such as fertilizer) which provide opportunities to practice agricultural intensification.

The second set of independent variables are farm variables. The first one is total household farm size (FSIZE) in the year, measured in hectares. Second is the water holding capacity of soils (SOILS), determined by using a disc infiltrometer to penetrate the top soil, following Bonsu (1992) and Agyare (2004). The water holding capacity of the soils was classified (values in parentheses) into short (<5 cm/h), moderately long (5-10 cm/h), or long (>10 cm/h). The third is land tenure (LTENU), which is used because the dominant type of land tenure in any community can greatly affect agricultural practices. The study communities include some with flexible land tenure systems, i.e., *"abunu"* (splitting into two; farm proceeds shared in ratio of 1:2 between farmer and landowner) or *"abusa"* (splitting into three, with farm proceeds shared in ratios of 1:3); sometimes members may put more land under cultivation. But in areas with stringent land tenure systems or situations where land may not be hired out, land accessibility may be difficult. The paper considers three kinds of land tenure systems, namely, tenancy or renting (1); customary/communal ownership (2); and family/individual ownership (3).

Finally, the year the farmer first farmed (FIRST) in the study area was also used in the model. This refers to the farmer's experience and not necessarily the duration of use of the land parcel.

Descriptive analysis of differences in agricultural extensification, intensification, and other factors between the dry and derived savannah zones

A descriptive analysis of the data shows, first, that far more households in the derived savannah (52%) compared to the dry savannah (10%) cultivated new agricultural lands within the five years preceding the survey (Table 3). As a result, households in the derived savannah (0.7 ha), cultivated new agricultural lands on average seven times as large as the new lands of dry savannah households (0.1 ha). This indicates that more new lands were available and cultivated, and therefore more agricultural extensification is practiced in the derived savannah compared to the dry savannah. Indeed, the total amount of new land added in the 5 years prior to the survey in the dry savannah was only 0.1 ha times 10% of households, vs. 0.7 ha times 52% of households. If there are 12 x 21 = 252 households per study area, this means a total land increase of only 2.5 ha compared to a total amount of land of 2.1 x 12 x 21 = 592.2 ha in the sample in the north. Thus 2.5 ha/592.2 = .004% or less than one half of one percent over the 5 years in the dry savannah. In contrast, in the derived savannah, the total new land is 0.7 x 0.52 x 252 households = 91.7 ha. This compares with a stock of land at the time of interview of 6.0 x 12 x 21 = 1512 ha, so the increase is 6.1%. Actually, the way to interpret these numbers is that the new land constituted less than half a percentage of the land at the time of the survey in the dry savannah and about 6% in the derived savannah.

The use of tractors (12.7 and 3.2 hours per ha) is also much higher in the derived savannah. Overall, 88.5% of households in the derived savannah compared to 27.5% in the dry savannah engaged in a form of agricultural extensification, confirming that there is much more agricultural extensification in the derived savannah.

[Table 3: About here]

Regarding the intensification variables, mean fallow years per household is only slightly higher in the derived savannah (2.7 years) than the dry savannah (2.3

years). Given the much smaller size farms in the dry savannah, population density per hectare (4.8 vs. 2.4) and mean household labor input per ha is higher in the dry savannah (3.0 vs. 1.3), even though household size is higher in the derived savannah (8.1 vs. 6.8 persons per household). On the other hand, use of inorganic fertilizer (243 vs. 88 kg per ha) is higher in the derived savannah. Households with no or short fallow, using fertilizer, or relatively high labor inputs per ha are more prevalent in the derived savannah (97.3) compared to the dry savannah (46.4%), confirming an assertion in an earlier paper that the use of technological inputs such as inorganic fertilizer and improved seed varieties is widespread in the derived savannah (Codjoe et al., 2005). This suggests that agricultural intensification is more pronounced in the derived compared to the dry savannah.

As far as household characteristics are concerned, the proportion of household heads with no schooling is higher in the dry savannah (65.7% vs. 43.1%). As mentioned earlier in this paper, the derived savannah serves as a migrant-receiving area for migrants from the dry savannah. Thus, declining fallow, declining soil productivity, and thus declining agricultural production may be key issues contributing to out-migration of youth from the dry to the derived savannah. In addition, derived savannah households tend to have larger household sizes (likely due to higher fertility) because household members are used more as part of the labor force on farms. However, the proportions of adult males (31.2% vs. 28.9%) and females (33.8% vs. 30.9%) in households are higher in the dry savannah. The mean age of farmer is also higher in the dry savannah (54.3 vs. 50 years).

The dry savannah has a higher proportion of households with (out) migrants (60% vs. 36%) and a higher proportion of household members who have migrated (24.9%) vs. 12.7%), which also contributes to a lower mean household size. This probably indicates that dry savannah households use out-migration as a survival strategy (Arguello 1981) in the face of dwindling opportunities for agricultural extensification or intensification. In addition, households in the derived savannah are more affluent, due to agricultural and non-agricultural activities being better. Thus, derived savannah households owned on average more cattle (22.7 vs. 5.1), sheep (8.5 vs. 5.6) and goats (8.9 vs. 6.0), and thus, total livestock (13.4 vs. 5.6).

Regarding farm characteristics, derived savannah households had considerably larger farm holdings, with a mean farm size of 6.0 ha vs. 2.1 ha. The analysis of soils shows that 32.3% and 12.2% of dry and derived savannah farms, respectively, had soils with long water holding capacity and therefore were prone to flooding. With regard to land tenure arrangements, there was almost a universal ownership (customary/communal, family or individual) of farmlands in the dry savannah (89%) compared to the derived savannah (78%), where many migrants from the north are hired as farmhands. A further breakdown of land ownership for the dry and derived savannah zones, respectively, is as follows; customary/communal (20% and 16%), family (69% and 34%) and individual (2% and 31%). It is important to note that tenant farmers (22% in derived vs. 11% in dry) tend to put more pressure on soil fertility to secure high yields in order to pay land rents. As a result, they engage in little long-term investment in improving soil fertility. Finally, 29.3% and 20.8% of the farmers in the dry and derived savannahs, respectively, first farmed in their current communities in the 1960s or earlier, showing that there has been less turnover of farms in the dry savannah.

The paper also uses correlation matrices to explore the main relationships between agricultural extensification (cultivation of new land and tractor use) and intensification (fallow years allowed, labor and fertilizer use per ha) variables, before moving on to use multivariate analysis to examine the factors determining each as dependent variables.

Provisional insights from correlation matrices

Before launching into multivariate analyses, it is generally useful to examine correlation matrices. Apart from exploratory cross-tabulations (not shown), correlation matrices were used to investigate preliminary relationships between key variables, for each area and both areas together. This can provide important insights which might be missed if this step is skipped. Note that the key (dependent) intensification variables are fallow time (shorter time reflects more intense use), labor intensity, and fertilizer use. We examine the relationships for the drier, poorer region on the north (dry savannah) first, followed by the derived savannah and then both together. The way to interpret the correlations is that Malthus posits positive relationships between household size and extensification variables, while Boserup anticipates positive linkages between household size and intensification. The multiphasic response approach, on the other hand, focuses on the tradeoffs between the two extensification variables and among the three intensification variables, and also between any intensification variable and any extensification variable. Finally, households experiencing out-migration should have less pressure to either extensify or intensify.

Table 4 shows the correlation matrix on extensification variables. In the dry savannah, there is really nothing to say about factors affecting new land since only a small number of households experienced a mean trivial amount of land (0.1 ha per household) added over the five years. Thus there is nothing to analyze, and indeed not a single correlation coefficient was significant at the usual 5% criterion level. In contrast, tractor use did vary across households, and was negatively related to labor intensity—a theoretically expected inverse relation consistent with multiple response theory, although it is not correlated with household size (no Malthusian effects), and only marginally to labor intensity (10% level). It is positively correlated with education, first farm (younger, more modern cohort), and renters. The unexpected positive relationships between use of fertilizer and tractor use very likely indicates that higher income, better endowed households are more likely to use both tractors and fertilizer.

[Table 4 about here]

In the derived savannah, new land is positively linked to longer fallow and lower labor intensity, both reflecting an extension-intensification tradeoff (per multi-response theory), and to higher education and younger farmers. Tractor use is negatively related to labor intensity and fallow time, also reflecting the same tradeoff. The positive correlation with fertilizer use has been observed and explained before, as have the positive relationships with farm size and tenancy.

Finally, examining the correlations for both areas together, with more significant relationships expected due to the larger sample size, some very strong and theoretically significant correlations are observed: New land is positively related to fallow time and negatively to labor intensity, while tractor use is also negatively related to labor intensity, all reflecting extensification-intensification tradeoffs; both are also related positively to fertilizer use, as described above reflecting linkages with income. It is also intriguing that both extensification variables are positively correlated with household size, suggesting some Malthusian effects may be present.

With respect to the other, potential independent variables in the table, new land is positively correlated with education, migration, first farm status, and farm size. The latter would suggest that land concentration is rising. Finally, tractor use is also positively correlated with farm size, and first farm, and negatively with the proportion female (as they work in agriculture without tractors), livestock (tractors used instead for cultivating?), and tenancy status. The positive link with tenant status again implies more intense use of tractors by renters. It is logical that households with an out-migrant seem more likely to use tractors. The small positive correlation with acquiring more land may reflect use of remittances for those purposes, though the survey did not collect information on that.

The correlation matrix on intensification variables can be reviewed more succinctly (see Table 5). Thus, the first important relationship to observe for dry savannah is the inverse relationship between labor intensity and fallow time, both indicating Boserupian intensification. The inverse sign may suggest some tradeoff between these two as alternative ways of intensifying land use—the more one is done, the less the pressure for the other—as hypothesized by the multiphasic response theory. The positive relationship between fallow time and farm size is also fully expected by theory, as is the positive relationship between labor intensity and both household size (Boserupian) and females (given the important role of rural women in agriculture in Ghana: see Codjoe 2010). The negative correlation between labor intensity (measured per hectare) and farm size is a mathematical necessity, and hence not substantively meaningful. The positive relationship between labor intensity and (poorly drained) soils may reflect the poverty of the region, so that even poor soils do not deter intense income-seeking efforts in the north. Finally, regarding use of fertilizer, the negative relationship with labor intensity suggests some substitution of one for the other, as alternative ways of seeking to increase agricultural output (and hence income) from intensification, a la the multiple response approach. Fertilizer use is also positively linked to education, as expected, and to the recency of when the farmer started farming (more modern farmers), and negatively to age of farmer, suggesting it is a modern form of technology not used much by older farmers. Its link to tractor usage has been discussed above—both likely linked to income.

[Table 5 about here]

Some of the correlations are quite different in the derived savannah, characterized by better soils, larger farm sizes, better opportunities for agricultural and non-agricultural activities, higher schooling and surely higher household incomes (see Table 3 above). First, there is a positive relation between fallow time and new land, suggesting the latter eased pressures on land use, per multiple response theory. But there is no labor-fallow tradeoff, as there was in the dry savannah zone, though longer fallow is linked to less use of fertilizer, as hypothesized by multiple response theory, as both reflect less pressures to intensify land use, which may reflect the reality of this zone of higher family incomes and more plentiful land. Households with more tractor use had shorter fallow periods, perhaps reflecting the advantages of tractors in reducing the drudgery of agriculture. On the other hand, fallow time is not linked to farm size and has positive correlations with household size and better soils (note the way the variable is defined, with long water holding capacity being poor soils), contrary to Boserup, and suggesting little pressures on the land.

Moving on, labor intensity appears negatively related to both new land and tractor use, and also negatively to fertilizer use, all as hypothesized by the multiphasic approach. Labor intensity is also positively correlated with household size, per Boserup, and negatively to farm size, as expected. Finally, looking at the last intensification variable, fertilizer use is correlated negatively with fallow time and labor intensity (both mentioned above), likely reflecting that both are linked to household income. Overall, the picture is more complex in the derived than in the dry savannah in terms of intensification, but this is surely due to there being far more extensification in the zone.

Finally, when the two disparate areas are combined, the key negative multiphasic response relationship (tradeoff) between fallow time and labor intensity still exists, as does that between fallow time and new lands (tradeoff between intensification and extensification). There is also the expected positive correlation with farm size, but that with household size is perplexing, and may be cleared up in multivariate work. Overall, labor intensity is related negatively to new land and tractor use (more evidence of an extensification-intensification tradeoffs, per multiphasic response theory), positively to household size and females (reflecting Boserup), and negatively to farm size and migration—the latter again consistent with multiphasic response theory. Finally, fertilizer use is positively linked to tractor use (reflecting correlations with income), education, migration (compensating for lost labor), poor soils, rental ownership status (as described above, renters work the land harder, also lower fallow), and first farm, and negatively to labor intensity and age of farmer—as discussed above for the two zones. Finally, a word about migration. For both zones, fertilizer use is positively correlated with out-migration, suggesting it increases to compensate for the loss of labor (or in response, causation cannot be inferred). Out-migration is also negatively correlated with labor intensity, as it should be since it reduces household labor supply.

While speculating about tradeoffs and relationships from Tables 4 and 5 based on simple correlations can be instructive, it is the multivariate results that provide more definitive results since they simultaneously take into account all the potential explanatory factors considered in the correlation matrix. To them we now turn.

Results from multivariate analysis

Extensification

We first examine here the factors that determine extensification in the two zones of Ghana, as well as the linkages between extensification and intensification, controlling for other factors that may affect extensification. Extensification is measured by increase in land in the past 5 years (NLAND) and tractor hours/ha (TRACT). We discuss the results for dry savannah first, then derived savannah, then both pooled, using the dummy variable ECOLO to control for ecological zone. First, we may recall the discussion above regarding New Land, that the results for *dry savannah* should be ignored, which is just as well as there is nothing of interest, with only two minor control variables having any significant effects. For tractors, in contrast, there are useful results (Table 6A), although no evidence of any extensification-intensification tradeoff. Rather there is a positive correlation with fertilizer use, which we have noted before likely reflects both being related to higher household incomes and education (also a positive and significant determinant of fertilizer use in the multivariate model). The only other statistically significant variable is land tenure, showing that renters use tractors more, probably to work the land harder to pay rent.

For *derived savannah*, where both the dependent variables representing extensification are much larger, the results are more interesting, as would be expected since there is much more non-zero variation to explain (Table 6B). First, for New

Land, the expected tradeoff (following Davis and Bilsborrow) is observed, between more land and lower labor intensity. The only other significant effect is of education, as we would expect--those with more education likely having higher consumption aspirations and incomes and accordingly seeking more land. For TRACTORS, again a tradeoff is seen, with more tractor use associated with shorter fallow periods (nearly at the 5% level), a key measure of intensification. Again, a strong positive relation with fertilizer is evident, along with small negative ones with both land tenure (renters using tractors more, as explained above) and livestock, the latter due to pasture land not needing tractor cultivation.

[Tables 6A-C about here]

For both areas together, the results are presented in Table 6C, showing first how additional land is linked to lower labor density, indicating some tradeoff, nearly at the 5% significance level, but is not linked to fallow time or fertilizer use. While the evidence on tradeoffs thus is not very strong, Tables 6A and 6B show that this is due to the lack of new land in the dry savannah, and that a real tradeoff exists where there was a meaningful increase in land—the derived savannah. Education of the farmer is also positively linked to acquiring new land. The age of the farmer appears to have a negative impact on acquisition of new land overall, but this was true only in the dry savannah so could be a statistical artifact. The ECOLO variable captures the overall impact of ecological zone, showing that the derived savannah has a strong positive relationship with new land, which is expected given the far higher values of extensification observed there, discussed above.

For tractors, there are also some intriguing results, beginning with the tradeoff between tractors and duration of fallow—more tractors, shorter fallow times, possibly due to those households with more tractor access wanting to take advantage of it by cultivating land that might have otherwise remained fallow. As noted above, the positive relationship between tractor time and fertilizer use is likely due to both being linked to household income. The positive link between tractor time and proportion male reflects the fact that it is men who drive the tractors, while the negative relationship with livestock reflects pasture land not involving use of tractors in general. The land tenure variable shows that renters use tractors more, working the land more intensively, as discussed earlier. Finally, the results for ECOLO show that there is a very significant difference between the two areas, with households in the derived savannah region having more tractors.

But are the results above sensitive to which and how many of the intensification variables are included in the model? The short answer is no, with all of the results for New Land in Tables 6A-6C being the same (results not shown). For tractors as the dependent variable, slight differences exist, but results regarding evidence of tradeoffs and the effects of ecological zone were the same. When only fertilizer is included (with fallow time and labor intensity dropped), all results are identical, but when either only fallow time or only labor intensity is included, the proportion male and livestock both cease to be significant. On the other hand, when only fallow time is included, farm size becomes positive and significant, as expected; and when only labor intensity is included, then soils becomes positive and significant, indicating a tendency to work poor soils harder with tractors. This is plausible since it implies using them more extensively (less intensively), since they yield less. In sum, the tests of the sensitivity of results to the inclusion or not of alternative intensification (tradeoff) variables does not alter the main conclusions regarding the existence of evidence of tradeoffs and strong effects of ecological differences between the zones on extensification. But it shows that the effects of some of the control variables are sometimes significant and usually with the expected sign—education, proportion male, livestock, land tenure, and soils. Hence, they are shaky since they depend on which intensification variables are included.

For an overall conclusion on extensification, first, the cross-sectional evidence on households in both zones together shows that there was evidence of extensification in the key sense of increase in land in farms only in one of the two study regions, the derived savannah, with over half the households increasing their farm land, and by a mean of over 10% (0.7/6.0), which is remarkable in such a short time period. The fact that mean household size was quite a bit higher in this zone compared to the dry savannah is on the surface consistent with a Malthusian interpretation. However, this is not supported by the evidence from the multivariate model since households with more members did not tend to increase their land area more in either zone. Rather those who were more educated or were young farmers or were in the more ecologically favourable derived savannah zone were the ones who tended to increase land area. This suggests that both socio-economic characteristics of the household (head) and of the land area are more important than household size. What we do not know is whether the derived savannah also had, five years prior to the survey, more available land that could potentially be brought into farm use—a key contextual variable—and whether this was therefore a key factor underlying the increase in New Land.

Tractor use was far higher in the derived savannah, where mean household size was higher, but this reflects the different ecological conditions there as well as higher education and incomes. All three of these factors were more important than household size in the extensification of agriculture in these two zones. Why this may be so is discussed in the conclusions with respect to the limitations of the paper.

Intensification

Tables 7A-C show the results for intensification. As before, first, we discuss the results for dry savannah, followed by derived savannah and finally for both areas together, controlling for ecological zone with the dummy variable ECOLO. In each case, we first describe the results when both extensification variables are included in the model (NLAND and TRACT), and then note if any results change when only one of the two variables is included. This process tests whether tradeoffs with extensification are mostly related to only one of the two extensification variables, which might be obscured when both are included together.

For dry savannah, we see that fallow is linked only to farm size, which means that larger farms have longer fallow periods, which is to be expected. Neither of the extensification variables has any statistically significant effect on fallow time, nor is household size related negatively to fallow, as Boserup would expect. On the other hand, labor intensity is positively affected by household size, as well as the proportions of adult males and females, which is fully consistent with Boserup. The negative effect of farm size is also expected. Finally, the last intensification variable fertilizer is positively linked to tractor use, likely due to income effects (both linked to higher household incomes) being stronger than substitution or tradeoff effects. The same variable's positive correlation with farm size is theoretically unexpected since fertilizer use is expected to result in smaller but more intensely used farms, but may again be related to household income. Fertilizer is negatively linked to age of farmer probably because older farmers prefer rudimentary techniques of farming, and the negative correlation with tenant farmers is also expected because tenant farmers tend to use more agricultural intensification to cover their rent.

The results for derived savannah are richer, showing, first, that fallow time is longer with *less* tractor use, indicating lack of a tradeoff—longer fallow correlated with less tractor use, and shorter fallow with more. The positive correlation with soil quality is strange, since better soils should be worked harder (shorter fallow), other things equal. The findings for labor intensity are far more interesting: First, it is negatively linked to both extensification variables, indicating tradeoffs a la the multiphasic response theory, and the three demographic measures (i.e., household size, and proportions of adult males and females) are all positively linked to labor intensity, implying per Boserup that higher population numbers result in higher intensity of labor use. The analysis further shows that the larger the farm size, the less the labor intensity (per hectare), which is also expected, and education is positively related to labor effort. To finish, there are strong positive relationships between fertilizer use and tractor use, for reasons described above, but the relationship with livestock begs for an explanation.

[Table 7A-C about here]

Finally, the results for both areas together are described (Table 7C), showing, first, powerful effects of ecological zone, with derived savannah being associated with significantly longer fallow time, less labor intensity and much higher fertilizer use (all as expected from the data in Table 3). For fallow time, the results are identical as those for derived savannah, showing longer fallow time linked to better soils and less use of tractors. Thus more tractor use is correlated with shorter fallow, which finds an explanation above, but indicates no tradeoff between fallow time and tractors. But their complementarity here does not contradict multiphasic response theory, only that soil conditions dominate both. Moving to labor intensity, tradeoffs are evident in the statistically significant, negative signs in Table 7C with respect to both added land and tractors. Moreover, the key demographic control variables also have expected signs, with household size and adult males and females all strongly and positively related to labor intensity (manifest Boserupian effects). Larger farm size is also linked to less labor intensity (per hectare), as expected. Labor intensity is linked positively to education, consistent with the hypothesis that it relates to consumption aspirations, and negatively to age of household head, as older ones often no longer have other young adults in the household to assist them. The negative relationship with duration of use is as expected, as longer duration results in the land having less fertility. An unexpected relationship is observed for soils, with poorer soils worked more intensively, but for renters the sign is correct, with renters working the land harder.

Finally, the results for fertilizer indicate, as mentioned above, that it is very likely positively linked to tractor use through income being a major determinant of both. It is also negatively linked to household size, perhaps capturing some tradeoff with labor intensity which is strongly related to household size. Among the other control variables, fertilizer use is linked negatively with proportion male (perhaps due to females applying fertilizer more often than males, as observed in the derived savannah by Codjoe 2010). The positively association with livestock may reflect another association with household income.

For both areas together, when only tractors are included in the model (dropping new land), the results are the same except for labor intensity, where the effects of several control variables become weaker (education, age of head and duration of use), but these are of secondary interest compared to the other key variables discussed above. Finally, the results for fertilizer are the same except household size is a bit less significant, but still important.

Conclusions and Caveats

Two main perspectives, (neo-) Malthusian land extensification and Boserupian forms of land intensification, have long dominated thinking about the population-agricultural land debate. However, a broader perspective is offered by the theory of the multiphasic response, originally developed by Davis' (1963) postulating purely demographic responses to population increase (e.g., reducing fertility) but expanded by Bilsborrow (1987) to include both Malthusian land extensification and Boserupian land intensification. Bilsborrow also suggested that contextual factors would be crucial in determining which of the possible responses of households would be adopted, and that households would tend to exhaust all economic options available before changing fertility. With respect to contextual effects, in situations where arable land is available, agricultural extensification would tend to dominate, but if arable land is unavailable but access to agricultural technology is available (as well as produce and labor markets and even supportive policies: c.f. Boserup (1981) and Lele and Stone (1989), then agricultural intensification would dominate. However, out-migration would be used as a strategy in the event when extensification and intensification options are exhausted. It is worth noting that all of these theoretical approaches refer concretely to *household responses* to increasing population pressures (larger household sizes, higher population-land ratios). Nevertheless, recent existing quantitative research examining these relationships over time has focused on the macro (mainly country) level. This paper is thus innovative in attempting to explore the relationships at the micro or household level, using household survey data.

This paper examines the practice of agricultural extensification and intensification in two regions of Ghana which are quite distinct ecologically, climatologically, and culturally. The results show that both agricultural extensification and intensification are widespread in the derived savannah zone compared to the dry savannah, due to the former being characterised by better soils, larger farms, better agricultural and non-agricultural activities, more schooling and higher household incomes. No evidence in support of (neo-) Malthusian effects of population (larger household sizes) on extensification is observed, though there appears strong evidence of Boserupian effects on intensity of labor use in both study zones. Some evidence of tradeoffs is observed between extensification and intensification and between different forms of intensification in the derived savannah and in both zones pooled (e.g., between increased land and lower labor intensity, and between more tractor use and shorter fallow periods).

It is important to recognise some important limitations of the study, which imply caveats pertaining to the substantive findings—for example, the lack of Malthusian effects may result from the lack of unused available land in the two study sites. Describing these limitations should help in pointing researchers toward improved studies in the future. First, we have observed strong differences between the two study regions. But the use of only two ecological zones cannot provide adequate scope to examine ecological and other contextual (e.g., demographic, economic, social, ethnic, regional policy) effects, so future research should seek larger resources to cover households distributed over numerous and diverse areas. Some of the explanatory variables are also not ideal, for example, the change in land area is based only on a short 5-year time period, and data on (unused but potentially usable) land available 5 years ago was not available, though would have been a key contextual variable. Finally, the results on linkages between land use and migration are weak, reflecting the limited attention to migration in the survey: To examine these relationships, it is desirable to have data on when people left the study household (and when they arrived), land size and use in at least a general sense before and after migration, and whether and when remittances were received and their use and impacts.

But perhaps the biggest shortcoming is that the survey data are cross-sectional, with only one retrospective question on change over time in new land asked in the survey. Thus a theoretically and empirically better approach would be to examine the relationships between *changes in* household size and population density (persons per ha.), changes in farm land area, and changes in agricultural practices, both extensification (e.g., tractor use) and intensification (changes over time in labor intensity, fallow time, use of fertilizer and other inputs, changes in crops or to new hyprid seeds which benefit from higher labor inputs or which provide higher incomes per ha., and increases in irrigation (Bilsborrow and Geores 1992). At minimum, changes in household size over time require household reconstruction, which requires complete data on dates of births, deaths and in- and out-migrations from sample households over some appropriate time period (e.g., 5 or 10 years), but such data were not collected in the survey. Unfortunately, there are very few surveys indeed which collect both the detailed demographic and detailed land size and use data needed to examine these linkages adequately over time. This is so even for a single round survey, though having two or three rounds of data would provide far superior data, and avoid memory errors.

Finally, in considering some policy issues for Ghana, it is evident that better access to modern agricultural technologies could significantly improve agricultural land use in Ghana. For instance, as the study areas have both animal husbandry and crop raising, it appears that promoting use of organic fertilizer could provide benefits without the costs of chemical fertilizers. Studies of soil fertility and its relationships to extended land use over time, and use for growing the same crop, could also help lead to better land use recommendations by the agricultural extension services, which need expansion in any case. The lack of any meaningful increase in agricultural land in the dry savannah and only small increase in the derived savannah also may indicate that Ghana now has little available unused agricultural land to draw upon in the future, that improved access to family planning in rural areas of the country is desirable to moderate future population pressures on the land.

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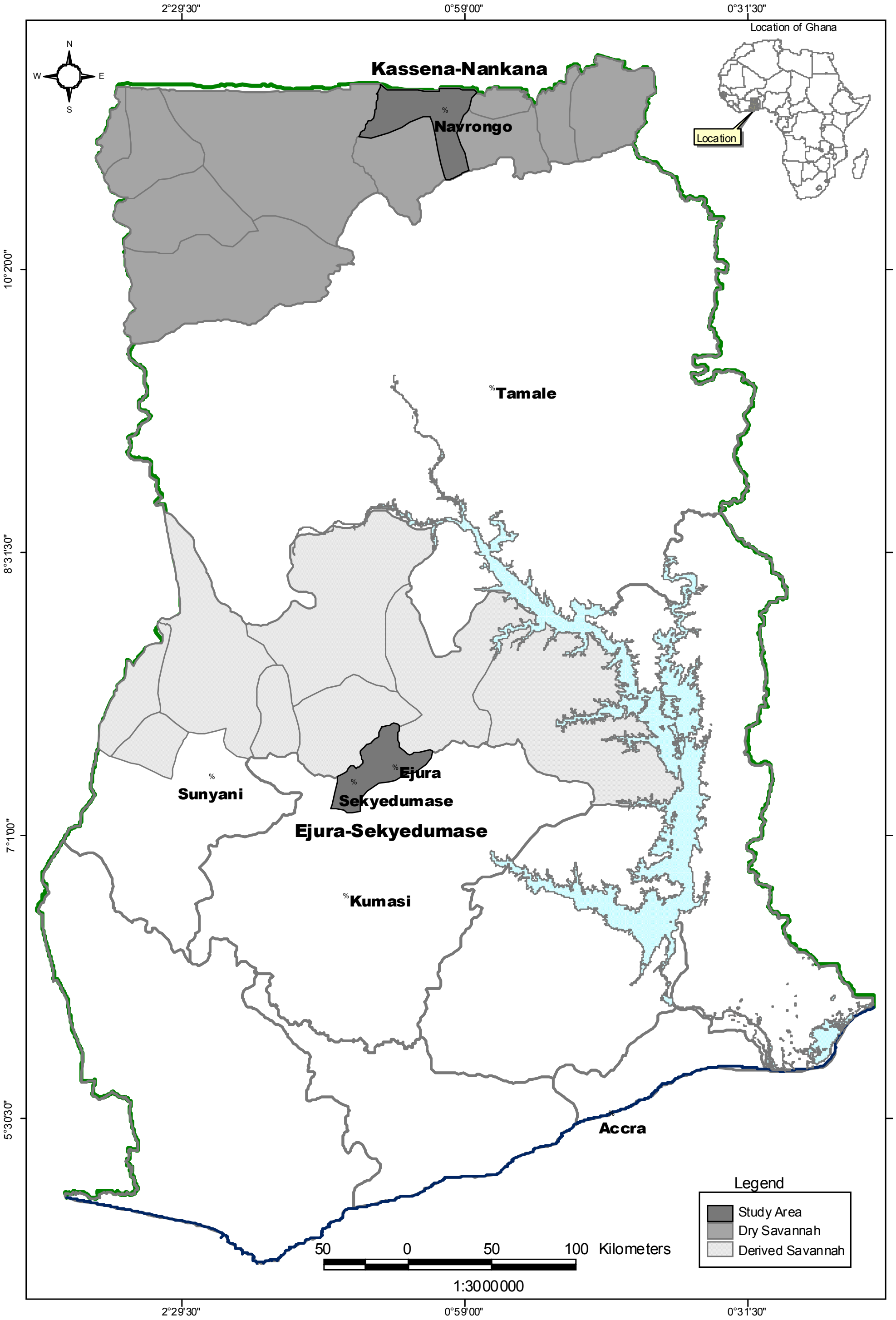

Figure 1: Map of Ghana showing study areas

Table 1: Sample areas and sizes.

Dry savannah			Derived savannah		
Community	**Population (2000)**	**Farmers in sample**	**Community**	**Population (2000)**	**Farmers in sample**
Navrongo	15,983	52	Ejura	29,478	97
Paga	7,819	55	Sekyedumase	10,085	79
Telania	2143	87	Anyinasu	4,707	92
Kanania	1,421	56	Dromankuma	2,291	79
Mirigu	1,271	89	Frante	2,043	93
Bonia	1,187	63	Kasei	1,836	72
Janania	1,138	56	Hiawoanwu	1,823	72
Atibaabisi	958	84	Aframso	1,336	102
Badania	878	61	Drobon	1,335	100
Manyoro	812	47	Nkwanta	871	68
Nabango	785	67	Ashakoko	806	70
Yuwa	519	65	Bonyon	803	67
Total	**34,914**	**782**	**Total**	**57,414**	**991**

Table 2: Description of Variables and Aggregation method used in the Model

Abbreviation	Variable	Description and Measure
Dependent variable		
Intensification		
FLNGT	Fallow length	Mean years allowed for land to fallow in past five years
LADEN	Labor	Labor input per hectare in the year
FERTI	Fertilizer	Mean inorganic fertilizer used by household per hectare of farmland in the year
INLEV	Intensification level	Household with no or short fallow, using fertilizer, or relatively high labor inputs per ha
Extensification		
NLAND	New land	Cultivated new farm land within five years preceding survey: Yes = 1; No = 2
TRACT	Tractor	Mean hours of tractor use per hectare of farmland in the year
EXLEV	Extensification level	Household cultivated new farm land, used tractor, combined both or did not use any of the two
Ecological area variable		
ECOLO	Ecological area	Ecological area household is located: Dry savannah = 1; Derived savannah = 2
Household Characteristic		
EDUCA	Education	Educational level of household head: No schooling = 1; Basic/Junior High School = 2; Secondary/Senior High School or Higher = 3
HSIZE	Household size	Number of household members
PMALE	Male	Proportion of adult males in household
PFEMA	Female	Proportion of adult females in household
AGEFM	Age	Age of farmer
MIGRT	Migration	Household has a member staying elsewhere for more than six months at time of survey: Yes = 1; No = 2
LIVST	Livestock	Household ownership of livestock, i.e., cattle, sheep and goat. Cattle scored three, sheep, two and goats, one reflecting level of importance in community. The household score is then determined based on scoring
Farm Characteristic		
FSIZE	Farm size	Household farm size (in hectares)
SOILS	Soil	Water holding capacity of soil: Short = 1; Moderately long = 2; Long = 3
LTENU	Land tenure	Land tenure system of household. Tenancy = 1; Customary ownership = 2; Family ownership/Individual ownership = 3
FIRST	First farmed	Year farmer first farmed: Before 1960s = 1; In 1960s = 2; In 1970s = 3; In 1980s = 4; In1990s = 5; In 2000s = 6.

Table 3: Mean values of variables by agro-ecological zone

Variable	Dry savannah	Derived savannah
Extensification		
Household cultivated new farmlands within five years of the survey (%)	10	52
Size of new farmlands (for households that increased) cultivated in the past five years (ha)	0.1	0.7
Mean tractor use per hectare (hours/year)	3.2	12.7
Household used any of the extensification variables (Cultivation of new farm land or tractor) (%)	27.5	88.5

Intensification		
Mean fallow length per household in the past five years (years)	2.3	2.7
Mean household labor input per hectare	3.0	1.3
Mean fertilizer use per hectare (kg)	88	243
Household with no or short fallow, using fertilizer, or with relatively high labor inputs per ha (%)	46.4	97.3
Household characteristics		
Household heads with no schooling (%)	65.7	43.1
Mean household size	6.8	8.1
Mean household size per hectare	4.8	2.4
Male adult household members (%)	31.2	28.9
Female adult household members (%)	33.8	30.9
Mean age of farmer (years)	54.3	50.0
Households with migrants (%)	60.3	36.1
Household members who have migrated (%)	24.9	12.7
Mean cattle per household (Mean household score in parentheses)	5.1 (15.3)	22.7 (68.1)
Mean sheep per household (Mean household score in parentheses)	5.6 (11.2)	8.5 (17.0)
Mean goat per household (Mean household score in parentheses)	6.0 (6.0)	8.9 (8.9)
Mean livestock per household (Mean household score in parentheses)	5.6 (27.1)	13.4 (94.0)
Farm characteristics		
Mean household farm size (ha)	2.1	6.0
Soil (percent with long water holding capacity)	32.3	12.2
Land tenure system (percent ownership)	89	78
First farmed in the 1960s or earlier (%)	29.3	20.8

Source: Field Survey, 2001 & 2002.

Table 4: Correlation matrix of extensification variables (Cultivated new land and Tractor) and their determinants by agro-ecological zone

Variable	**Dry savannah**		**Derived savannah**		**Both Zones**	
	New land	**Tractor**	**New land**	**Tractor**	**New land**	**Tractor**
Fallow	-0.015	0.007	0.161**	-0.199***	0.189***	0.033
Labor	-0.037	-0.116*	-0.124*	-0.127**	-0.224***	-0.301***
Fertilizer	0.124*	0.597***	-0.002	0.565***	0.345***	0.779***
New land	-	0.097	-	0.007	-	0.325***
Tractor	0.097	-	0.007	-	0.325***	-
Education	0.106	0.207***	0.128*	-0.123*	0.137***	0.036
Household size	-0.018	-0.032	0.024	0.115*	0.076*	0.166***
Males	-0.062	-0.023	0.029	0.076	-0.036	-0.012
Females	0.043	-0.014	-0.051	-0.071	-0.060	-0.103**
Age of farmer	-0.138	-0.101	-0.067	0.078	-0.145***	-0.067
Migration	0.086	0.027	-0.100	0.046	0.088*	0.191***
Livestock	0.037	-0.060	-0.013	-0.018	-0.062	-0.109**
Farm size	0.032	0.030	0.071	0.120*	0.206***	0.311***
Soil	-0.014	-0.085	-0.059	0.144*	0.064	0.207***
Land tenure	-0.098	-0.429***	0.038	-0.157**	-0.074	-0.233***
First farm	-0.078	0.137**	0.111*	-0.018	0.099**	0.135***

*$p<0.10$; **$p<0.05$; ***$p<0.01$*

Table 5: Correlation matrix of intensification variables (Fallow, Labor and Fertilizer) and their determinants by agro-ecological zone

Variable	**Dry savannah**			**Derived savannah**			**Both zones**		
	Fallow	**Labor**	**Fertilizer**	**Fallow**	**Labor**	**Fertilizer**	**Fallow**	**Labor**	**Fertilizer**
Fallow	-	-0.138***	0.111*	-	0.075	-0.168***	-	-0.094***	0.084*
Labor	-0.138***	-	-0.168***	0.075	-	-0.203***	-0.094***	-	-0.357***
Fertilizer	0.111*	-0.168***	-	-0.168***	-0.203***	-	0.084*	-0.357***	-
New land	-0.015	-0.037	0.124*	0.161**	-0.124*	-0.002	0.189***	-0.224***	0.345***
Tractor	0.007	-0.116*	0.597***	-0.199***	-0.127*	0.565***	0.033	-0.301***	0.779***
Education	0.045	-0.050	0.172***	0.017	0.199***	-0.038	0.035	0.002	0.085*
Household size	0.030	0.253***	0.007	0.131**	0.192***	0.004	0.127***	0.142***	0.110**
Males	0.061	0.074	-0.032	-0.037	0.011	-0.058	-0.011	0.066	-0.082*
Females	0.025	0.169***	-0.032	0.115*	0.101	0.004	0.054	0.162***	-0.076*
Age of farmer	0.126**	-0.011	-0.156**	0.049	-0.013	0.050	0.050	0.034	-0.108**
Migration	0.035	-0.060	0.109*	-0.101	0.045	0.005	0.059	-0.095**	0.199***
Livestock	0.050	-0.096	0.026	-0.026	-0.034	0.074	-0.031	-0.009	-0.057
Farm size	0.311***	-0.460***	0.210***	0.074	-0.254***	0.032	0.162***	-0.324***	0.276***
Soil	-0.082	0.257***	-0.106	-0.194***	-0.030	0.103	-0.086*	0.046	0.180***
Land tenure	-0.044	0.100	-0.414***	-0.110*	-0.104	-0.091	-0.117***	0.049	-0.223***
First farm	-0.066	-0.041	0.175***	-0.003	0.023	0.010	0.007	0.080*	0.175***

*$p<0.10$; **$p<0.05$; ***$p<0.01$

Table 6A: Parameters of multiple regression models explaining the determinants of agricultural extensification in the dry savannah

Variable	**New land**		**Tractor**	
	Beta	***S.E***	***Beta***	***S.E***
FLNGT	-0.025	0.023	-0.098	0.071
LADEN	0.004	0.015	-0.061	0.046
FERTI	0.001	0.001	0.017***	0.002
EDUCA	0.025	0.019	0.138**	0.059
HSIZE	-0.004	0.009	0.034	0.028
PMALE	0.000	0.002	0.003	0.005
PFEMA	0.001	0.002	0.003	0.005
AGEFM	-0.005***	0.002	0.008	0.005
MIGRT	0.073	0.049	-0.106	0.153
LIVST	0.000	0.001	-0.005	0.003
FSIZE	0.016	0.019	-0.093	0.059
SOILS	-0.002	0.015	-0.027	0.046
LTENU	0.031	0.036	-0.333***	0.113
FIRST	-0.028***	0.008	-0.009	0.026
Constant	0.282	0.222	0.871	0.699
R^2	0.098		0.430	

**p<0.10; **p<0.05; ***p<0.01*

SE: Standard Error

Table 6B: Parameters of multiple regression models explaining the determinants of agricultural extensification in the derived savannah

Variable	**New land**		**Tractor**	
	Beta	***S.E***	***Beta***	***S.E***
FLNGT	0.034	0.022	-0.368*	0.189
LADEN	-0.045**	0.020	-0.035	0.175
FERTI	0.000	0.000	0.032***	0.003
EDUCA	0.074**	0.035	-0.333	0.305
HSIZE	0.005	0.009	0.097	0.078
PMALE	0.002	0.002	0.031	0.019
PFEMA	0.000	0.003	-0.014	0.022
AGEFM	-0.002	0.003	-0.005	0.024
MIGRT	-0.103	0.072	0.449	0.619
LIVST	0.000	0.001	-0.015*	0.008
FSIZE	0.001	0.006	0.032	0.050
SOILS	-0.011	0.024	0.290	0.208
LTENU	-0.018	0.032	-0.515*	0.278
FIRST	0.015	0.018	0.011	0.152
Constant	0.651*	0.378	0.535	3.253
R^2	0.082		0.394	

$*p<0.10$; $**p<0.05$; $***p<0.01$

SE: Standard Error

Table 6C: Parameters of multiple regression models explaining the determinants of agricultural extensification in both zones

Variable	**New land**		**Tractor**	
	Beta	***S.E***	***Beta***	***S.E***
FLNGT	0.018	0.016	-0.368***	0.117
LADEN	-0.020*	0.012	-0.063	0.087
FERTI	0.000	0.000	0.029***	0.002
EDUCA	0.040**	0.019	-0.064	0.141
HSIZE	0.004	0.006	0.071	0.047
PMALE	0.001	0.001	0.020*	0.011
PFEMA	0.001	0.001	-0.004	0.011
AGEFM	-0.004**	0.002	0.004	0.012
MIGRT	-0.038	0.043	0.236	0.325
LIVST	0.000	0.001	-0.013**	0.005
FSIZE	0.001	0.004	0.036	0.034
SOILS	-0.007	0.014	0.148	0.102
LTENU	-0.008	0.023	-0.452***	0.172
FIRST	-0.012	0.009	-0.018	0.066
ECOLO	0.379***	0.064	2.508***	0.481
Constant	0.044	0.209	-3.349**	1.568
R^2	0.227		0.649	

$p<0.10$; $**p<0.05$; $***p<0.01$
SE: Standard Error

Table 7A: Parameters of multiple regression models explaining the determinants of agricultural intensification in the dry savannah

Variable	**Fallow**		**Labor**		**Fertilizer**	
	Beta	***S.E***	***Beta***	***S.E***	***Beta***	***S.E***
NLAND	-0.227	0.226	0.083	0.350	3.825	7.088
TRACT	-0.039	0.061	-0.114	0.094	15.246***	1.898
EDUCA	-0.023	0.060	0.028	0.093	-0.698	1.885
HSIZE	0.005	0.023	0.353***	0.036	0.059	0.730
PMALE	0.003	0.005	0.046***	0.007	0.054	0.151
PFEMA	0.004	0.005	0.046***	0.007	-0.020	0.148
AGEFM	0.000	0.006	-0.007	0.009	-0.342*	0.176
MIGRT	-0.031	0.153	-0.361	0.237	5.206	4.791
LIVST	-0.003	0.003	-0.009*	0.005	0.014	0.100
FSIZE	0.222***	0.045	-0.719***	0.069	6.329***	1.391
SOILS	-0.023	0.046	-0.015	0.071	0.118	1.434
LTENU	-0.033	0.115	-0.036	0.178	-11.194***	3.597
FIRST	-0.010	0.027	-0.035	0.042	0.327	0.854
Constant	0.244	0.699	0.480	1.081	42.459*	21.871
R^2	0.157		0.554		0.450	

**p<0.10; **p<0.05; ***p<0.01*

SE: Standard Error

Table 7B: Parameters of multiple regression models explaining the determinants of agricultural intensification in the derived savannah

Variable	**Fallow**		**Labor**		**Fertilizer**	
	Beta	***S.E***	***Beta***	***S.E***	***Beta***	***S.E***
NLAND	0.322	0.208	-0.474**	0.228	-4.168	10.224
TRACT	-0.059***	0.020	-0.042*	0.022	9.998***	0.983
EDUCA	0.029	0.107	0.451***	0.117	2.219	5.253
HSIZE	0.016	0.026	0.168***	0.028	-2.276*	1.272
PMALE	-0.002	0.007	0.021***	0.007	-0.602*	0.332
PFEMA	0.012	0.008	0.026***	0.008	0.103	0.371
AGEFM	-0.003	0.009	-0.005	0.010	0.393	0.430
MIGRT	0.010	0.222	0.277	0.244	-2.200	10.934
LIVST	-0.004	0.003	0.000	0.003	0.299**	0.146
FSIZE	0.012	0.016	-0.117***	0.018	0.310	0.797
SOILS	-0.182**	0.074	-0.066	0.081	2.210	3.629
LTENU	-0.055	0.099	-0.219*	0.109	0.785	4.883
FIRST	-0.026	0.054	-0.042	0.059	2.395	2.667
Constant	2.754**	1.152	0.231	1.263	69.467	56.653
R^2	0.116		0.296		0.358	

*$p<0.10$; ** $p<0.05$; *** $p<0.01$
SE: Standard Error

Table 7C: Parameters of multiple regression models explaining the determinants of agricultural intensification in both zones

Variable	**Fallow**		**Labor**		**Fertilizer**	
	Beta	***S.E***	***Beta***	***S.E***	***Beta***	***S.E***
NLAND	0.182	0.151	-0.347*	0.204	-1.698	6.785
TRACT	-0.064***	0.016	-0.056**	0.022	10.241***	0.741
EDUCA	0.001	0.058	0.141*	0.079	1.895	2.627
HSIZE	0.018	0.018	0.226***	0.024	-1.587**	0.794
PMALE	0.001	0.004	0.031***	0.006	-0.379**	0.190
PFEMA	0.006	0.004	0.033***	0.006	0.006	0.199
AGEFM	0.002	0.005	-0.016**	0.007	0.117	0.231
MIGRT	-0.033	0.134	-0.095	0.182	2.862	6.038
LIVST	-0.003	0.002	-0.003	0.003	0.256***	0.096
FSIZE	0.019	0.013	-0.155***	0.017	0.217	0.572
SOILS	-0.129***	0.042	0.115**	0.057	-0.070	1.881
LTENU	-0.015	0.071	-0.185*	0.097	-2.021	3.222
FIRST	-0.011	0.027	-0.067*	0.037	1.524	1.235
ECOLO	0.987***	0.190	-0.554**	0.258	74.227***	8.583
Constant	0.137	0.650	1.082	0.879	-52.121*	29.228
R^2	0.129		0.375		0.674	

*$p<0.10$; **$p<0.05$; ***$p<0.01$

SE: Standard Error