Development Pathways and Land Management in Uganda: Causes and Implications

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Abstract

This paper investigates the patterns and determinants of change in livelihood strategies ("development pathways"), land management practices, resource and human welfare conditions in Uganda since 1990, based upon a community-level survey conducted in 107 villages. The pattern of agricultural development since 1990 involved increasing specialization and commercialization of economic activities, consistent with local comparative advantages and market liberalization. Six dominant development pathways emerged, all but one of which involved increasing specialization in already dominant activities: expansion of cereal production, expansion of banana and coffee production, non-farm development, expansion of horticultural production, expansion of cotton, and stable coffee production. Of these, expansion of banana and coffee production was most strongly associated with adoption of resource-conserving practices and improvements in resource conditions and welfare. Other strategies are needed for areas not suited for this pathway.

Other factors also influenced land management and resource and welfare outcomes. Road development was associated with improvements in many welfare and some natural resource conditions, except forest and wetland availability. Irrigation was found to reduce pressure to expand cultivated area at the expense of forest and wetlands, and is associated with improvement in some welfare and resource indicators. Government and non-governmental organization programs were found to contribute to improvements in several resource and welfare indicators, though there were some mixed results. Such programs may cause declines in one area by focusing on improvements in another area. Thus, trade-offs appear to be inherent in many efforts to improve agriculture or protect resources. Population growth had an insignificant impact on most indicators of change, though there is some evidence of population-induced agricultural intensification. The findings support neither the pessimism of some neo-Malthusian observers or the optimism of some neo-Boserupian observers regarding the impacts of population growth.

Keywords: Sustainable development, land management, development pathways, Uganda

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1. INTRODUCTION

Land degradation, low and declining agricultural productivity, and poverty are severe interrelated problems in Uganda. Although Uganda's soils were once considered to be among the most fertile in the tropics (Chenery 1960), problems of soil nutrient depletion, erosion, and other manifestations of land degradation appear to be increasing. The rate of soil nutrient depletion is among the highest in sub-Saharan Africa (Stoorvogel and Smaling 1990), and soil erosion is a serious problem, especially in highland areas (Bagoora 1988; Zake and Magunda 1999). Land degradation contributes to the low and in many cases declining agricultural productivity in Uganda. Farmers yields are typically less than one-third of potential yields found on research stations, and yields of most major crops have been stagnant or declining since the early 1990's (Sserunkuuma, et al. 2001). Low and declining agricultural productivity in turn contributes to poverty and food insecurity in Uganda. Forty-four percent of Ugandans lived below the poverty line in 1997 (APSEC 2000). Food insecurity is reportedly increasing in many rural parts of the country, with low and declining yields of food crops seen as a primary cause (*Ibid.*).

Poverty and food insecurity can in turn contribute to land degradation. Poor and food-insecure households may be forced to plant crops on steep slopes or unable to afford to keep land fallow, invest in land improvements, or use costly inputs such as fertilizer. Poverty and credit constraints may also cause farmers to take a short-term perspective (Pender, 1996). On the other hand, poor people may have more incentive to conserve their land, since this may be their most significant asset, and the opportunity cost of investing in land improvement may be lower for poorer people. Nevertheless, the constraints imposed by poverty and food insecurity may outweigh these factors, thus completing a vicious cycle of land degradation-declining productivity-poverty-further land degradation.

Finding and implementing ways to break out of this cycle is an urgent need in Uganda and many other developing countries. The key to sustainable development is for both public and private stakeholders to invest in an appropriate and socially profitable mix of physical, human, natural and social capital in rural areas, taking into account the diversity of situations in Uganda. In order to do that, information is needed to help identify the potential development pathways and sustainable land management practices in different parts of the country, and technological, institutional and policy strategies to exploit those opportunities.

This paper identifies the development domains, development pathways, changes in land use and land management practices occurring in a selected region of Uganda since 1990, based upon a community-level survey conducted in 107 villages in Uganda. [ii] It investigates the determinants and impacts of these changes on natural resource conditions and human welfare.

2. RESEARCH QUESTIONS, HYPOTHESES AND METHODOLOGY

The central hypothesis of this study is that the opportunities and constraints for sustainable development depend upon the comparative advantages that exist in a particular location. For example, opportunities for development of high value perishable commodities, such as horticultural crops or dairy, are likely to be greatest in areas with relatively high market access and agricultural potential. In such areas, investments in appropriate forms of infrastructure, human capital and institutions may yield high social returns and facilitate a process of sustainable development. In areas more remote from markets or having lower agricultural potential, alternative livelihood strategies, such as extensive livestock production or forestry activities may have more comparative advantage. The agricultural and land management practices that are most profitable and sustainable are also affected by differences in livelihood strategies. Efforts to promote sustainable land management practices are thus more likely to be effective if they take into account such comparative advantages.

To focus on the concept of comparative advantage and its relationship to sustainable development and to adoption of sustainable land management practices, we use the concepts of "development domains" and "development pathways". We define a development domain as a geographical region having similar comparative advantages, based upon similar agro-climatic conditions, access to markets and population density. A development pathway is defined as a common pattern of change in livelihood strategies. This concept is similar to the concepts of farming systems and livelihood strategies, but is more general than farming systems since it incorporates non-farm as well as farm activities (as does the concept of livelihood strategies), and is dynamic since it refers to changes and not merely livelihood strategies pursued at a particular point in time. We use these concepts to guide the research questions addressed by this research and the methods used to answer the research questions.

Key Research Questions

1. What are the dominant development pathways occurring in different development domains in Uganda since 1990, and their relationship to land use and land management?
2. What factors determine the development of particular development pathways and changes in land use and land management?
3. What are the implications of different development pathways, policies, programs and other causes of change for natural resource and human welfare conditions?

Hypotheses

As mentioned above, we hypothesize that different development pathways are determined by differences in comparative advantage, and that these are largely determined by differences in agricultural potential, access to markets and infrastructure, and population density. Agricultural potential largely influences the absolute advantage (productivity) of a location in production of particular agricultural commodities, while access to markets and infrastructure and population pressure help to determine the comparative advantage (profitability) of particular livelihoods, given the absolute advantages (Pender, Place and Ehui 1999). For example, an area with suitable climate and soils may have an absolute advantage in producing high value perishable vegetables, but have little comparative advantage in this if it is remote from markets and roads. Improvements in market or road access are thus expected to favor production of higher value perishable commodities as well as non-farm activities, and should contribute to higher incomes and welfare (Pender, Scherr and Durón 2001). Improved access to markets and infrastructure has more ambiguous theoretical impacts on land use, land management practices and resource conditions, depending upon the relative impacts on costs of productive factors (*Ibid.*; Angelsen 1999), and because of ambiguous effects of output prices on incentives to conserve land (LaFrance 1992; Pagiola 1996).

Population density is expected to influence the labor intensity of agricultural production, including the choice of commodities as well as production technologies and land management practices, by affecting the land-labor ratio (Boserup 1965; Pender 2001). Population growth may cause expansion of agricultural production into forest or grazing areas, reduction in fallow, or induce adoption of land-saving commodities or technologies, investments in land improvement, and adoption of labor-intensive land management practices, among other changes (*Ibid.*; Pender, Gebremedhin, Benin and Ehui 2001; Tiffen, et al. 1994). Without improvements in technologies, markets or infrastructure, population-induced intensification is unlikely to improve welfare, though it may improve resource conditions by inducing land conservation (*Ibid.*, Pender 1998; Pender 2001; Scherr and Hazell 1994).

Other factors that may influence development pathways and land management include the presence of technical assistance programs and other organizations (Pender and Scherr 2002; Jagger 2001) and irrigation. Programs and organizations may influence development pathways and land management directly, by attempting to promote particular livelihoods and practices, or indirectly, by investing in forms of physical, human or social capital that affect farmers' abilities and constraints. Irrigation may enable intensification of crop production and/or adoption of higher value cash crops. We investigate the impacts of these factors as well as the impacts of agro-climatic zones, market access and population pressure.

Identification of Development Domains in Uganda

Different development domains in the study region of Uganda (which excluded parts of the west and north of the country) were classified based upon available secondary information related to agricultural potential, market access and population density. Within the study region, six agro-climatic zones were classified, based upon the average length of growing period, rainfall pattern and elevation[iii]: the bimodal high rainfall zone (mostly the Lake Victoria crescent), the bimodal medium rainfall zone (most of central and parts of western Uganda), the bimodal low rainfall zone (lower elevation parts of southwestern Uganda), the medium and low potential unimodal rainfall zone (much of northern Uganda), and the southwestern and eastern highlands (1500 m.a.s.l. and above). The parishes of Uganda (second lowest administrative unit and lowest mapping unit available) were also classified according to the level of market access and population density.[iv] Overlaying these three dimensions of agricultural potential, market access and population density, we can classify different development domains of Uganda (Figure 1). There are 24 possible domains, though only 16 are represented to any significant extent in Uganda.

Data Sources

A community level survey was conducted in 107 communities during 1999 and 2000. The communities were selected using a stratified random sample of LC1's (the lowest administrative unit in Uganda, usually consisting of only one village) from the different development domains shown in Figure 1, excluding parts of north and west Uganda. One hundred communities were selected in this way. Seven additional communities were purposively selected in southwest and central Uganda, where international agricultural research centers are conducting research related to land management.

Within each selected LC1, a survey was conducted with a group of individuals representing the community. Respondents were selected to represent different ages, genders, occupations and villages of residence within the LC1 (if there was more than one village in the LC1). The LC1 survey collected information on the major concerns and priorities of community members, population change, access to infrastructure and services, presence and activities of programs and organizations, and other issues. A village-level survey was also conducted with a group of village representatives within each LC1. If there was more than one village in the LC1, one village was randomly selected for the village survey. The village survey collected information on livelihood strategies, perceptions of change in human welfare and natural resource conditions, land use, land management, and other issues. Where information about changes was sought, the focus was on changes between 1990 and 1999. We used a common method of ranking perceptions of change in all cases: +2 = major increase (or improvement), +1 = minor increase, 0 = no change, -1 = minor decrease, -2 = major decrease. The survey information was supplemented by secondary information collected from the 1991 population census, available digitized map information and geo-referenced maps of the boundaries of the communities drawn with assistance of community representatives and incorporated into a geographic information system by Ruecker (2001).

Analysis of Data

Analysis of the survey data included analysis of descriptive statistics to identify general patterns and trends of development and land management in the study region[v], factor analysis to identify the development pathways and econometric analysis to investigate determinants and impacts.

The factor analysis used data on the primary activities of men in 1999 and changes in the three main activities since 1990 to identify the development pathways. We did not use information on women's occupations for the classification because women's primary occupation is dominated by household maintenance activities, with little variation across communities, while changes in women's occupations were quite similar to changes in men's. We used the principal component factor method, and rotated the first six factors using the varimax method. The first six factors have a clear interpretation as development pathways. After the first six factors, clear patterns were difficult to identify and interpret.

The econometric analysis focused on determinants of the development pathways (as measured by the factor scores from the factor analysis) and changes in land use, land management practices, purchased input use, and various indicators of change in natural resource conditions and human welfare. For the regressions explaining the development pathway factor scores, least squares regressions were used. For all other regressions, the dependent variable was an ordinal index measuring change (taking integer values from –2 to +2), and ordered probit regressions were used.

The econometric model for the development pathways is given by:

1) $$d_{iv} = a_i + b_i \Delta x_v + c_i z_v + e_{iv}$$

where d_{iv} is the factor score on factor i (the ith development pathway) of village v, Δx_v is a vector of changes in explanatory variables (such as change in population and access to roads) between 1990 and 1999, z_v is a vector of fixed factors (such as the agro-climatic zone and market access classification), e_{iv} is an unobserved error term for factor i and village v, and a_i, b_i, and c_i are parameter vectors to be estimated by least squares regression.

The econometric model for the other response variables (changes in land use, land management, and resource and welfare indicators) is given by:

2) $\Delta y^*_{jv} = h_j + k_j \Delta x_v + l_j z_v + \sum_i m_{ji} d_{iv} + v_{jv}$

3) $\Delta y_{jv} = -2 \ \ if \ \ \Delta y^*_{jv} < \alpha_{-2j}$

4) $\Delta y_{jv} = -1 \ \ if \ \ \alpha_{-2j} \leq \Delta y^*_{jv} < \alpha_{-1j}$

5) $\Delta y_{jv} = 0 \ \ if \ \ \alpha_{-1j} \leq \Delta y^*_{jv} < \alpha_{1j}$

6) $\Delta y_{jv} = +1 \ \ if \ \ \alpha_{1j} \leq \Delta y^*_{jv} < \alpha_{2j}$

7) $\Delta y_{jv} = +2 \ \ if \ \ \Delta y^*_{jv} \geq \alpha_{2j}$

where Δy_{jv} is the value of response variable j in village v, Δy^*_{jv} is an unobserved continuous variable that predicts Δy_{jv}, v_{jv} is an unobserved error term that is assumed to be normally distributed, and h_j, k_j, l_j,$m_{ji,}$ α_{-2j}, α_{-1j}, α_{1j} and α_{2j} are parameters to be estimated, using maximum likelihood estimation. The other variables are the same as defined above.

The fixed explanatory variables included in these models (z_v) include dummy variables for the agro-climatic zones, market access class, population density class, and whether there is irrigation in the village. The explanatory variables representing changes include change in the natural logarithm of household density[vi], change in distance to the nearest tarmac road, change in distance to the nearest rural market, the number of government programs, the number of non-governmental organizations (NGO's), and the number of community-based organizations (CBO's) operating in the village.[vii]

There are some potential problems with these regression models. Population growth and presence of organizations may respond to development opportunities as well as being causal factors affecting development. Thus there is the potential for reverse causality to affect the interpretation of our results. To address this problem we used predicted values of growth in ln(number of households) and numbers of programs and organizations in one version of each of the regressions, and report the robustness of our statistically significant findings to this alternative specification.[viii] In most cases we find that our results are robust.

The development pathway variables might also be subject to this problem of reverse causality in the regressions where they are included as explanatory variables. Unfortunately, we are not able to use the same approach to address this problem, because the same variables that determine development pathways also can affect land management directly, controlling for the development pathway. We do not have any solution for this identification problem. Thus, our interpretation of the "effects" of the development pathway variables on land management and outcomes should be tempered by the realization that we are only reporting correlations, and that causality may go in the opposite direction.

We tested for multicollinearity and found that the maximum variance inflation factor was less than 3, indicating that this is not a major concern. Heteroskedasticity also could be present, affecting the standard errors. We used the Huber-White estimator for standard errors, which is robust to heteroskedasticity. All means and regression coefficients were also corrected for sampling weights and stratification, so that the statistical results are representative of the study region as a whole.

3. RESULTS

Development Pathways in Uganda

Using factor analysis we identify six dominant development pathways in the study region of Uganda (Table 1). The first principal component factor is strongly associated with production of cereals or other storable annual crops, and with expansion of cereal production. We label this factor as representing a pathway of "increasing production of cereal crops." The second component is strongly associated with banana production and increasing importance of bananas and coffee ("increase of banana and coffee production" pathway). The third component is strongly associated with non-farm activities, and increasing importance of such activities ("increase of non-farm activities"). The fourth component is strongly associated with production of horticultural crops, and with increasing importance of horticulture ("increase of horticulture"). The fifth component is strongly associated with production of cotton or tobacco, and with expansion of cotton production ("increase of cotton"). The sixth component is positively associated with coffee production and negatively associated with root crop production, but does not have any strong associations with changes in occupations ("stable coffee production").

Using econometric analysis, we investigate the factors associated with these different development pathways (Table 2). Increased importance of cereal production is most common in the bimodal medium rainfall agroclimatic zone and in higher population density areas. It is also associated with greater numbers of community-based organizations, most of which focus on poverty reduction or community service provision, but which may be indirectly facilitating increased cereal production.

We find weak associations between expansion of banana and coffee and agro-climatic zones (more in banana intensive bimodal low and high rainfall zones) and access to rural markets (more where access has improved). No other factors were statistically significantly associated with this pathway.

Increased non-farm activities are, not surprisingly, more common where roads and rural markets have developed, and where non-governmental organization programs (NGO's) are operating (though latter result not robust when using predicted presence of organizations). Such organizations often focus on reducing poverty through promoting income diversification, education and training. Non-farm development is also weakly associated with higher population density and population growth.

Increased horticultural production is not surprisingly associated with access to irrigation, and is more common in the bimodal medium rainfall zone than in several other zones. It is also weakly associated with higher population density, probably because of the high labor intensity involved in producing horticultural crops.

Increased cotton production is not strongly associated with any of the factors investigated. It is weakly negatively associated with the presence of community-based organizations (CBO's), though this result is not robust. More general factors, such as changes in cotton prices or marketing, appear to be more important in determining cotton development than the localized factors investigated in this study.

The pathway of stable coffee production is most common in the bimodal high rainfall zone close to Lake Victoria and in the eastern highlands. In both of these zones coffee has long been a dominant economic activity, and this has not changed since 1990. Not surprisingly, coffee production is more common in higher market access areas. The presence of CBO's is negatively associated with stable coffee production, though this result is not robust.

In general, we find that the factors hypothesized to determine the comparative advantage of different development pathways—including agricultural potential, access to markets and infrastructure, and population density—are significantly associated with the development pathways; though different factors are important for different pathways. Agroclimatic conditions are particularly important for distinguishing areas of cereal expansion from perennials areas. Higher population density favors intensified production of cereals, horticulture and non-farm activities. Access to irrigation is critical for horticultural development, and improved access to roads and markets are important for non-farm development. NGO's appear to foster non-farm development, while CBO's are associated with expanded cereal production.

Changes in Land Use

The most common use of land is for cultivation. Cultivated area has been expanding in all zones outside of the highlands. However, controlling for other determinants of change, increases in cultivated area are more common in the southwest highlands than in other zones (Table 3). Other factors that have a statistically significant influence on cultivated land use include the presence of irrigation (reduces expansion), banana and coffee expansion (increases expansion), and improved access to roads (increases expansion). Surprisingly, greater population growth is not significantly associated with increased use of land for cultivation.

Settlements are increasing everywhere. Not surprisingly, expansion of settlements is associated with higher population density and population growth. It is also associated with the increased cereal production development pathway, but negatively associated with stable coffee production.

Forest area has been declining in all zones, and is no longer very common in any zone. Improvement in road access is strongly associated with reduced forest area while, surprisingly, population growth is associated with less deforestation. Place, Ssenteza and Otsuka (2001) found similar results for the effects of road access and population growth on deforestation in central Uganda. The negative impact of road access on forests is consistent with findings from studies of deforestation in other parts of the world. The puzzling positive association between population growth and forest cover may be due to the fact that some areas where population growth is rapid, such as the bimodal low rainfall zone, are areas where there was relatively less natural forest to begin with.

Planted woodlots are becoming more common, especially in areas of lower market access; in coffee, cereals and non-farm pathways; where NGO programs are operating; and where road access has improved. They are less likely to be increasing in horticultural areas, perhaps because the value of land for crop production is higher in these areas.

Wetlands are declining, especially in areas of better market access, where road access has improved, or where stable coffee production is the development pathway. They are declining less in the cotton development pathway. Irrigation is weakly associated with preservation of wetlands and forest, probably because it reduces pressure to expand cultivated area.

Overall, of the factors influencing changes in land use, improvement in access to roads appears to have the most effect, contributing to expansion in cultivated land, grazing area and woodlots, and to reduction in forests and wetlands. Road development may thus be helping to stimulate economic activity at the expense of conserving natural resources. Irrigation favors more intensive land use and therefore less expansion of cultivated area and greater preservation of forest and wetlands. The development pathways have differential associations with land use. Development of banana and coffee production is associated with expansion of cultivated area; while horticultural production is associated with less growth in woodlot area; and stable coffee production areas more commonly have increasing areas of woodlots but declining area of wetlands.

Changes in Land Management Practices

Adoption of land management practices differs across the agroclimatic zones of Uganda (Table 4).[ix] There are also significant differences across the development pathways in land management. Several soil and water conservation practices—including mulching, composting, manuring, and incorporating crop residues—are increasing more in areas of banana and coffee expansion than in other development pathways. These practices are apparently well suited to the coffee-banana system. Manuring is also increasing more in areas of stable coffee production than other areas. Mulching and manuring are increasing less in the cotton pathway than other pathways. Use of improved seeds is reportedly less common in the horticultural and cotton development pathways, though the reason is not clear.

Market access and changes in access to roads and markets have also influenced land management practices. Increasing use of manure is weakly associated with better market access. Improvements in road access are also associated with less use of compost or incorporation of crop residues. Increases in the value of land or labor resulting from improved access may account for these changes. Improved access to rural markets is associated with less use of manure, but surprisingly not with increased use of inorganic fertilizer.

Differences in population growth are not significantly associated with changes in any of the land management practices investigated, though adoption of improved seed is greater in more densely populated areas (but only weakly statistically significant and not robust).

The presence of irrigation is weakly associated with greater adoption of fertilizer and less use of mulch. Fertilizer may thus be more favored where there is sufficient water availability, while mulch may be used to conserve soil moisture in moisture-stressed environments.

The presence of programs and organizations has limited measurable impact on most land management practices. Presence of government programs is not surprisingly associated with greater use of improved seed but, surprisingly, with less use of fertilizer.

Overall, the different factors have diverse impacts on land management practices. The results support the hypothesis that development pathways have an important influence on land management, and indicate that access to roads, markets and irrigation also can have significant impacts. The effects of population pressure on intensification are fairly limited, contradicting the Boserupian perspective, perhaps because farmers in most areas have alternative options available, such as expanding agricultural area and earning income from non-farm activities.

Changes in Natural Resource Conditions

Few factors are associated with perceived changes in soil conditions, especially in soil fertility (Table 5). This is probably because major declines in soil fertility were perceived in most communities, suggesting that the dominant causes are more general ones, such as limited use of fertilizer or organic inputs throughout Uganda, rather than factors that vary greatly across communities. This finding is supported by a recent study of changes in soil fertility since the 1960s, which found evidence of widespread decline in several objective indicators of fertility (Ssali 2002). The only factor found to significantly affect changes in soil fertility is improved access to roads, which is associated with improvement (or less decline) in soil fertility. This supports the idea that soil fertility decline is due to poor development of markets or extension, both of which depend upon such infrastructure development.

Increasing problems of soil erosion are most common in the bimodal high rainfall zone and eastern highlands. Expanded annual crop production on steep slopes may be the reason in both cases. Erosion is worsening more in the non-farm development pathway than other pathways. This may be due to less adoption of conservation investments or practices in this pathway as a result of labor constraints.

Few factors significantly account for changes in the availability of grazing land. There is a tendency for the availability and quality of grazing land to decline more in the bimodal high rainfall region and in the cereal expansion pathway, though these results are only weakly statistically significant. The quality of grazing land is less likely to decline in irrigated communities, where road access has improved, or where CBO's are operating. On the other hand, development of rural markets is associated with a worsening of grazing land conditions.

Changes in the availability or quality of forests and woodlands differ due to several factors. Forest quality is being preserved more in the southwest highlands than in other zones. This may be due to remoteness, insecurity or greater efforts to preserve forests in some of these areas. Forest availability is declining more in the cereals expansion pathway and less in the stable coffee production pathway than other pathways. Quality of forest is declining least in the banana-coffee expansion pathway. Better conditions of forests in perennial crop production areas may be because of greater availability of tree products on farms in these areas, reducing pressure on forests. Forest availability is declining more where road access has improved, consistent with the finding concerning forest area discussed earlier. NGO's appear to contribute to preservation of forest quality, likely due to an emphasis of many programs on resource and environmental conservation.

Changes in availability or quality of natural water sources also differ across different agro-climatic zones, development pathways, and market access conditions. Water quality has improved most in the bimodal high rainfall zone. Both natural water availability and quality are more likely to improve in the non-farm development pathway than most other pathways, while water availability is also improving more (or declining less) in the banana-coffee expansion pathway. In the non-farm development pathway, reduced dependence on agriculture may be reducing pressure on natural water sources. In the banana-coffee expansion pathway, greater adoption of soil and water conservation practices, plus the shading effects of these perennial crops, are likely helping to conserve water. Increased access to roads is associated with improved water quality, while improved access to rural markets is associated with worsening water quality.

In general, changes in natural resource conditions are affected by agro-climatic conditions, population pressure, changes in road and market access, and programs and organizations in complex ways. Improved road access has apparently had a beneficial impact on several resource conditions, including soil fertility, grazing land and water quality, but it has also contributed to deforestation and decline of wetlands. Irrigation appears to reduce pressure on grazing lands and forests. Several resource conditions are worsening more in the cereals expansion pathway than in other pathways, while several are improving more in the banana-coffee expansion pathway, probably as a result of greater soil and water conservation efforts in the latter case. NGO's and CBO's have had a positive impact on some resource conditions. Other factors have more mixed or limited associations with changing resource conditions.

Changes in Human Welfare

Many indicators of perceived changes in human welfare show improvement in Uganda, particularly those related to access to goods and services, despite widespread perception of declining yields and worsening resource conditions. However, perceived changes in indicators of food security also show a downward trend, consistent with perceived declines of yields and land quality. As with other outcomes, these changes vary across communities as a result of differences in agro-climatic conditions, market access, development pathways, and other factors.

There are mixed patterns of changes in different welfare indicators in different agroclimatic zones, controlling for other factors (Table 6). The availability and quality of drinking water have improved more in high market access areas than in low market access areas, probably because of the lower costs of providing such services in high access areas. We find no statistically significant difference in other indicators of welfare changes between high and low access areas.

Road development is associated with improvement in many welfare indicators, including improvements in the proportion of households having adequate food, general food availability, housing quality (increased use of metal roofs), drinking water quality, ownership of consumer durables, and availability of energy sources. Road development (and associated improvement in transportation and other services) appears to be a primary reason for improvements in many aspects of welfare in Uganda.

Population pressure (both high population density and population growth) is associated with declining farm size (results not reported due to space limitations) and reduced drinking water quality, but also with improvements in housing quality. Surprisingly, population growth is positively associated with improvement in the proportion of households having adequate food. One might hypothesize that this is due to reverse causality; i.e., improvements in food security may attract immigration into areas where this is occurring (or worsening food security may cause emigration from other areas). However, this finding is robust when replacing population growth with predicted population growth in the regression, suggesting that reverse causality is not the explanation. An alternative explanation, consistent with the theory of Boserup, is that more rapid population growth stimulates intensification of food crop production, perhaps at the expense of cash crops or other activities. The positive association found between change in maize yields and population growth (not reported) is consistent with this explanation.

Irrigation is associated with improvements in some welfare indicators, including the proportion of households having adequate food and availability of energy sources. On the other hand, it is also associated with less improvement in other indicators, including improvements in housing quality, child nutrition, and ownership of consumer durables. Perhaps irrigated areas were already better off in terms of some of these indicators, and therefore show less improvement as a result.

There are significant differences in welfare outcomes among the development pathways. Many welfare indicators have improved more in the banana-coffee expansion pathway than in other pathways, including food availability, child nutrition, and availability and quality of drinking water. In the cereals expansion pathway, child nutrition has improved more than in most other pathways, but the availability of energy sources has also declined more, probably as a result of deforestation associated with this pathway. The horticultural development pathway is associated with greater availability of energy sources, while stable coffee production is associated with reduced energy availability. The cotton development pathway is associated with increased drinking water quality but reduced ability to cope with drought.

The presence of programs and organizations also has impacts on welfare indicators. Government programs are associated with improved drinking water quality, probably because some of these programs focus on developing water supplies. NGO's and CBO's are associated with improvements in child nutrition but also with reduced availability of energy sources. The latter finding may be due to the emphasis of many NGO's on environmental protection, which often includes opposition to cutting trees or charcoal production. This is consistent with the finding of Nkonya et al. (2001) that such programs promote greater enforcement of community bylaws regulating natural resource management.

In general, of the factors investigated, road development has the strongest and most consistently positive impact on a wide variety of indicators of improvement in human welfare. Welfare outcomes are also more favorable in some development pathways, particularly the banana-coffee expansion pathway. Other factors have more mixed effects, depending on which indicators are considered.

4. CONCLUSIONS

The general pattern of agricultural development occurring in Uganda during the 1990's involved increasing specialization and commercialization of economic activities in different locations, based upon differences in comparative advantage. This development pattern has been associated with changes in land use and agricultural practices, including expansion of cultivated area, settlements and woodlots at the expense of fallow, forest and wetlands; increased adoption of purchased inputs (though still low) and some soil and water conservation practices. Despite adoption of inputs and some conservation practices, crop yields, food security, and natural resource conditions are perceived to have degraded throughout much of Uganda. Nevertheless, many aspects of human welfare appear to have improved, stimulated by improvements in roads and access to services, various programs, and other factors.

Six dominant development pathways emerged, almost all of which involve increasing specialization in already dominant activities. These include expansion of cereals production, expansion of banana and coffee production, non-farm development, expansion of horticulture, expansion of cotton, and stable coffee production. Of these pathways, expansion of banana and coffee was most strongly associated with adoption of soil and water conservation practices and improvements in resource conditions and human welfare. Promotion of this pathway may be a potential "win-win-win" development strategy, benefiting the environment while contributing to economic growth and poverty reduction. This pathway is not suited to all parts of Uganda, however, and has been developing most in the bimodal low and high rainfall zones. One causal factor associated with this development pathway is increased access to rural markets, suggesting that continued development of rural markets will be an important component of a strategy to promote this development pathway. Other strategies will be needed for other areas not suited for this development pathway.

Road development, and associated development of transportation and other services, appears to be a critical factor contributing to improvements in many natural resource conditions (except forest and wetland availability) and human welfare indicators. In areas where natural forests or wetlands are important, there may be trade-offs between welfare and environmental objectives in pursuing road development. In other areas, road development can be a win-win-win strategy.

Irrigation appears to reduce pressure to expand cultivated area at the expense of forest and wetlands, contributes to adoption of fertilizer, and is associated with improvement in several resource and welfare indicators. However, irrigation is also associated with less improvement in some welfare indicators, though this may be because irrigated areas were better off initially in terms of these indicators. Further research is needed on these issues, but there appears to be potential to improve both resource and welfare conditions through appropriate investments in irrigation.

Government and non-governmental programs and organizations appear to have contributed to improvements in several resource and welfare conditions, increased quality of forests and grazing land, increased quality of drinking water, and improvements in child nutrition. However such programs also are associated with some negative outcomes, such as declining availability of energy sources. The environmental focus of many programs and organizations may be reducing availability of energy sources, reflecting a trade-off between environmental and welfare objectives.

Population growth had limited impacts on most indicators of livelihood strategies, land use, land management, or resource and welfare outcomes. There is some evidence that population growth contributed to agricultural intensification, consistent with Boserup's theory. However, impacts of population growth on resource conditions were generally insignificant, while associations with welfare indicators were mixed. In general, the impacts of population growth were not as negative as Malthusian pessimists believe, nor as positive as Boserupian optimists often argue.

These results imply that some "win-win-win" opportunities may exist to promote more sustainable development in Uganda; for example, by promoting the banana-coffee development pathway and associated land management practices where this pathway is suited. However, trade-offs are often apparent; such as the trade-off between conserving forest and wetlands vs. promoting economic development by investing in road development. Such trade-offs should be adequately recognized as development strategies are considered in Uganda and elsewhere.

Figure 1--Development Domains in Uganda

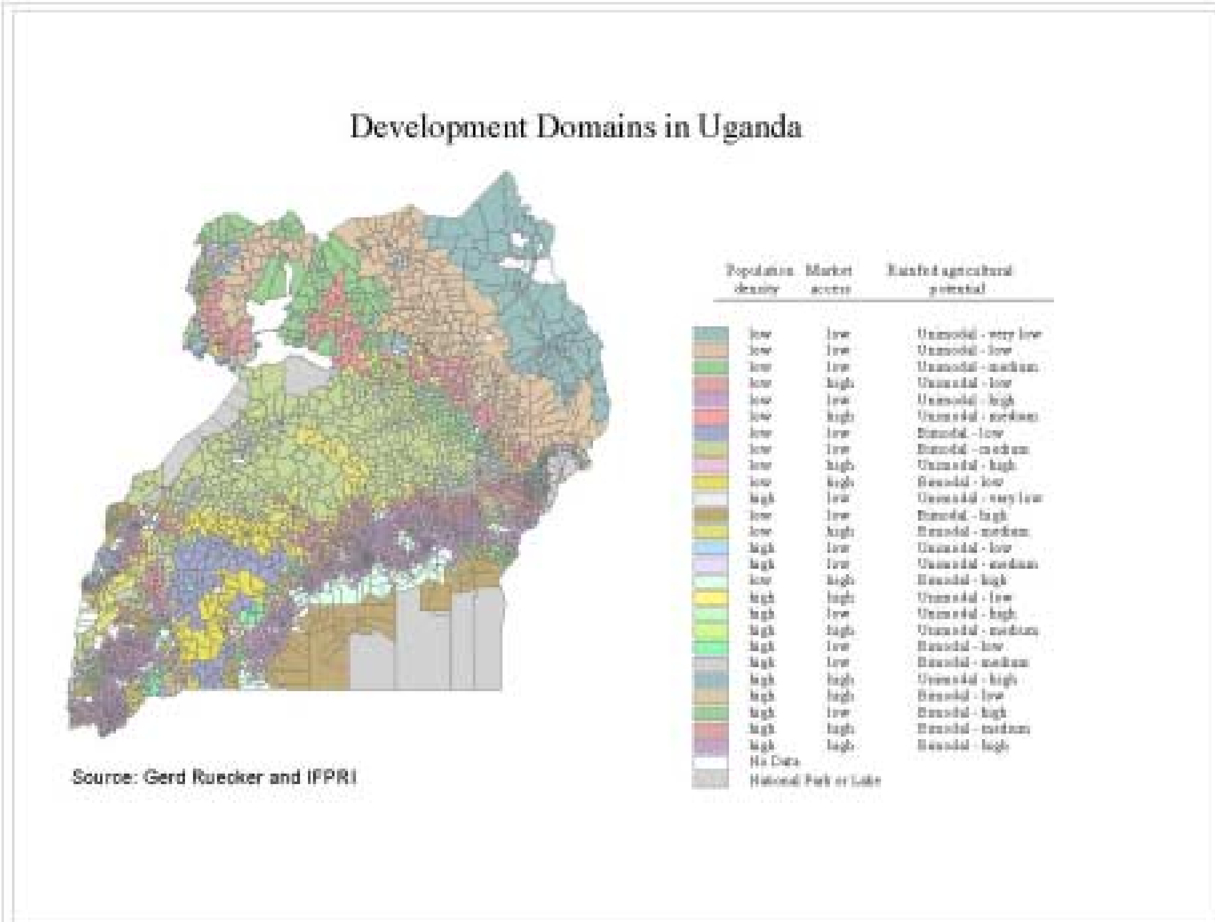

Table 1--Identification of Development Pathways (Factor Analysis Results)[a]

	Rotated Factor Loadings					
Variable	1	2	3	4	5	6
Primary occupation of men[b]						
- Cereals or other storable annuals	**0.823**	-0.158	-0.135	-0.016	-0.126	-0.132
- Horticultural crops	-0.097	-0.007	-0.078	**0.759**	-0.031	-0.107
- Bananas	-0.112	**0.692**	-0.107	-0.108	-0.109	-0.008
- Coffee	-0.300	-0.204	-0.044	-0.054	-0.098	**0.839**
- Cotton or tobacco	-0.141	-0.051	-0.026	-0.041	**0.824**	-0.064
- Root crops	-0.451	-0.280	-0.158	-0.119	-0.205	**-0.571**
- Cattle	-0.137	0.196	0.103	-0.102	0.068	-0.076
- Non-farm activities	-0.086	-0.104	**0.833**	0.158	-0.009	-0.029
Change in importance of top three occupations of men[c]						
- Cereals	**0.761**	-0.058	0.056	-0.039	0.091	-0.152
- Other storable annuals	0.376	0.249	0.338	-0.086	-0.158	0.105
- Horticultural crops	0.053	-0.020	0.121	**0.807**	-0.007	0.078
- Bananas	-0.024	**0.771**	0.108	-0.028	0.028	-0.156
- Coffee	-0.197	**0.536**	-0.048	0.242	-0.036	-0.109
- Cotton	0.139	0.011	-0.013	0.009	**0.755**	0.034
- Root crops	0.092	-0.442	0.244	-0.062	-0.035	-0.291
- Livestock	0.270	0.148	-0.436	0.167	0.171	0.308
- Non-farm activities	0.088	0.190	**0.702**	-0.134	0.004	0.068

[a] Principal components factor method used. Factors rotated using varimax method. The six retained factors account for 56% of the variance, and represent factors with eigenvalues greater than 1.2

[b] Dummy variable = 1 if primary occupation is the indicated occupation, 0 if not.

[c] Ordinal variable with –2 = major decrease in importance, -1 = minor decrease, 0 = no change, +1 = minor increase, +2 = major increase.

Table 2. Determinants of Development Pathways (least squares regressions)[a]

Explanatory Variable	Increase of Cereals (Factor 1)	Increase of Bananas and Coffee (Factor 2)	Increase of Non-farm Activities (Factor 3)	Increase of Horticulture (Factor 4)	Increase of Cotton (Factor 5)	Stable Coffee Production (Factor 6)
Agro-Climatic Zones (cf. Unimodal)						
- Bimodal low	0.544*	0.578*	-0.837*	0.659	-0.201	0.556
- Bimodal medium	0.741***[R]	-0.089	0.110	0.316**	0.202	0.356
- Bimodal high	-0.106	0.528*	-0.577	0.011	-0.411	0.748**[R]
- Southwest highlands	-0.166	0.333	0.027	0.048	0.128	0.618
- Eastern highlands	0.780	0.460	-0.388	0.638	-0.375	1.057***
High market access	-0.044	0.081	0.129	-0.044	0.040	0.710***[R]
High population density (> 100/km^2)	0.468**[R]	0.022	0.420*	0.223*	0.279	0.276
Irrigation in village	0.082	0.066	-0.138	0.553**[R]	-0.263	0.323
Change in ln(number of households)	0.552	0.399	0.847*	-0.120	0.555	0.017
Change in distance to tarmac road (miles)	0.0069	0.0067	-0.0240***[R]	-0.0041	0.0034	-0.0034
Change in distance to rural market (miles)	-0.0359	-0.0658*	-0.0408**[R]	0.0015	-0.0287	0.0150
No. of government programs	0.182	-0.180	0.184	-0.019	0.114	-0.205*
No. of NGO programs	-0.117	-0.036	0.406***	-0.101	-0.080	0.064
No. of community-based organizations	0.414***[R]	0.119	0.126	-0.084	-0.175*	-0.280***
Intercept	-1.079***[R]	-0.456	-1.017***	-0.200	-0.181	0.972***[R]
R^2	0.274	0.186	0.310	0.157	0.102	0.324

[a] Coefficients and standard errors adjusted for stratification and probability weights. Standard errors robust to heteroskedasticity.
*, **, *** mean statistically significant at the 10%, 5% and 1% level, respectively.
[R] means the coefficient is of the same sign and statistically significant at 10% level in two-stage least squares regressions to predict change in ln(no. of households) and numbers of programs and organizations.

Table 3. Determinants of Changes in Land Use (ordered probit regressions)[a]

Explanatory Variable	Cultivated	Forest	Woodlots	Wetlands	Settle-ments
Agro-Climatic Zones (cf. Unimodal)					
- Bimodal low	0.152	0.222	0.195	1.299	0.309
- Bimodal medium	0.532	-0.496	-0.242	-0.029	0.115
- Bimodal high	0.364	-0.161	-0.267	-0.246	1.058*
- Southwest highlands	1.251**[R]	0.856	0.555	1.390*	0.502
- Eastern highlands	-0.180	-0.308	0.368	0.248	0.239
High market access	0.405	-0.144	-0.548**	-0.963**[R]	0.215
High population density (> 100/km^2)	0.012	0.125	0.263	0.247	0.795**[R]
Irrigation in village	-1.475***[R]	0.948*	0.307	0.804*	0.121
Development Pathways					
- Increase of cereals	0.009	-0.223	0.234*[R]	0.165	0.317**[R]
- Increase of banana and coffee	0.408***[R]	0.153	-0.110	-0.097	0.097
- Increase of non-farm activities	-0.111	-0.039	0.221*[R]	-0.171	0.122
- Increase of horticulture	0.144	0.069	-0.340**[R]	0.054	0.019
- Increase of cotton	0.067	-0.130	0.091	0.313***[R]	-0.116*
- Stable coffee production	-0.143	0.118	0.474***[R]	-0.262**	-0.260*[R]
Change in ln(number of households)	-0.047	1.335**[R]	-0.645	0.315	1.500**
Change in dist. to tarmac road (miles)	-0.0401**[R]	0.0535***[R]	-0.0227***[R]	0.0363***[R]	-0.0142
Change in dist. to rural market (miles)	-0.0950	0.0352	0.0340	-0.0112	-0.0396
No. of government programs	0.233	-0.130	-0.088	-0.311	0.327*
No. of NGO programs	-0.247*	-0.104	0.269**	0.144	-0.087
No. of community-based organizations	0.192	-0.191	0.172	-0.404*	0.091
Prob. > F	0.0004	0.1286	0.0001	0.0132	0.0005

[a] Dependent variable takes values of –2 (major decrease), -1 (minor decrease), 0 (no change), +1 (minor increase), +2 (major increase).
Coefficients and standard errors adjusted for stratification and probability weights. Standard errors robust to heteroskedasticity.
*, **, *** mean statistically significant at the 10%, 5% and 1% level, respectively.
[R] means the coefficient is of the same sign and statistically significant at 10% level when predicted values used for change in ln(no. of households) and numbers of programs and organizations.

Table 4. Determinants of Changes in Land Management Practices and Use of Inputs (ordered probit regressions)[a]

Explanatory Variable	Mulch	Compost	Manure	Plowing in Crop Residues	Fertilizer	Improved Seeds
Agro-Climatic Zones (cf. Unimodal)						
- Bimodal low	0.963*	0.818	0.124	0.060	0.101	1.116**
- Bimodal medium	-0.135	0.153	-0.043	-0.443	0.058	1.066***[R]
- Bimodal high	0.067	1.225**	1.111***	0.544	0.806	0.658*
- Southwest highlands	0.002	1.315*	0.537	-0.436	-0.483	-0.088
- Eastern highlands	0.538	2.007**[R]	1.106***[R]	1.587**[R]	1.284**[R]	0.039
High market access	0.087	0.909	0.478*	-0.466	-0.091	-0.145
High population density (> 100/km^2)	0.253	0.163	0.009	-0.357	-0.546	0.560*
Irrigation in village	-0.673*	-0.685	-0.084	0.033	0.815*	0.342
Development Pathways						
- Increase of cereals	0.100	0.152	0.180	-0.045	0.127	0.128
- Increase of banana and coffee	0.268**[R]	0.474**[R]	0.249*	0.443***[R]	-0.041	0.196
- Increase of non-farm activities	0.215*	0.207	0.062	0.374**[R]	0.128	-0.137
- Increase of horticulture	0.240	-0.075	-0.075	0.096	-0.006	-0.281**[R]
- Increase of cotton	-0.108**[R]	-0.197	-0.167**[R]	-0.020	0.122	-0.478***[R]
- Stable coffee production	0.023	0.062	0.254*[R]	0.132	0.126	-0.020
Change in ln(number of households)	-0.741	-0.230	0.367	0.349	0.055	0.156
Change in dist. to tarmac road (miles)	-0.0104	0.997***[R]	0.0161	0.0383*[R]	-0.0114	0.0185**[R]
Change in dist. to rural market (miles)	-0.0723	0.094*	0.0869**	0.0424	0.0757*	-0.0016
No. of government programs	0.331	0.172	0.059	-0.149	-0.557***[R]	0.390***
No. of NGO programs	0.017	0.259*	-0.124	0.067	0.069	-0.244*
No. of community-based organizations	-0.215	-0.260	-0.309*	0.166	0.021	-0.432**
Prob. > F	0.0229	0.0000	0.0000	0.0004	0.0040	0.0054

[a] Dependent variable takes values of –2 (major decrease), -1 (minor decrease), 0 (no change), +1 (minor increase), +2 (major increase).
Coefficients and standard errors adjusted for stratification and probability weights. Standard errors robust to heteroskedasticity.
*, **, *** mean statistically significant at the 10%, 5% and 1% level, respectively.
[R] means the coefficient is of the same sign and statistically significant at 10% level when predicted values used for change in ln (no. of households) and numbers of programs and organizations.

Table 5. Determinants of Perceived Changes in Resource Conditions (ordered probit regressions)[a]

Explanatory Variable	Soil Fertility	Soil Erosion	Availability of Grazing Land	Quality of Grazing Land	Availability of forest	Quality of Forest	Availability of Natural Water Sources	Quality of Natural Water Sources
Agro-Climatic Zones (cf. Unimodal)								
- Bimodal low	-0.750	-0.022	-0.072	-0.054	0.413	0.593	-0.221	0.331
- Bimodal medium	0.024	-0.236	0.336	-0.113	-0.414	0.071	-0.718	0.589
- Bimodal high	-0.704	-1.037**	-0.780*	-0.769*	0.838*	0.860	-0.182	1.377**
- Southwest highlands	0.183	-0.239	0.135	-0.094	0.593	1.790***[R]	0.366	1.081
- Eastern highlands	-0.532	-1.193*[R]	-0.328	0.121	-0.366	0.465	0.358	0.743
High market access	-0.478	0.051	0.031	0.098	-0.298	-0.079	0.330	0.378
High population density (> 100/km^2)	-0.387	-0.364	0.108	-0.144	0.120	-0.673*	0.355	-0.364
Irrigation in village	0.225	0.145	0.075	0.646*[R]	0.292	1.025**	-0.117	-0.060
Development Pathways								
- Increase of cereals	-0.223	-0.193	-0.281*	-0.243*	-0.430***[R]	-0.145	0.149	-0.001
- Increase of banana and coffee	0.102	0.152	-0.173	0.068	0.168	0.285**[R]	0.377**[R]	-0.039
- Increase of non-farm activities	-0.242	-0.414**[R]	-0.098	-0.213	0.085	0.204	0.322**[R]	0.510***[R]
- Increase of horticulture	0.073	-0.035	-0.047	-0.226	0.081	0.184	0.015	-0.239
- Increase of cotton	0.264	0.031	0.018	0.070	-0.116	-0.081	0.025	0.062
- Stable coffee production	-0.167	0.042	-0.104	0.047	0.270*[R]	0.118	-0.301*	-0.040
Change in ln(number of households)	-1.101	0.109	0.794	0.640	0.866	0.736	0.275	-0.119
Change in dist. to tarmac road (miles)	-0.0219**[R]	0.0041	0.0024	-0.0209**[R]	0.0322**[R]	0.0307	-0.0152	-0.0144**[R]
Change in dist. to rural market (miles)	0.0231	-0.0317	0.0001	0.1532**[R]	0.0427	0.1169*	0.0540	0.1312**[R]
No. of government programs	-0.091	-0.275	-0.0761	-0.256	-0.064	-0.299	0.138	0.071
No. of NGO programs	0.219	0.279*	0.135	0.164	0.071	0.290*[R]	-0.193	-0.007
No. of community-based organizations	-0.117	0.190	0.272	0.360**	-0.117	-0.078	-0.214	-0.135
Prob. > F	0.0007	0.1321	0.3269	0.0117	0.2479	0.0547	0.1799	0.0005

[a] Dependent variable takes values of –2 (major deterioration), -1 (minor deterioration), 0 (no change), +1 (minor improvement), +2 (major improvement). Coefficients and standard errors adjusted for stratification and probability weights. Standard errors robust to heteroskedasticity.

*, **, *** mean statistically significant at the 10%, 5% and 1% level, respectively.

[R] means the coefficient is of the same sign and statistically significant at 10% level when predicted values used for change in ln(no. of households) and numbers of programs and organizations.

Table 6. Determinants of Perceived Changes in Welfare Conditions (ordered probit regressions)[a]

Explanatory Variable	Prop. of Houses with Metal Roof	Prop. of Households With Adequate Food	Food Availability	Nutrition of Children	Quality of Drinking Water	Ownership of Consumer Durables	Ability to Cope with Drought	Availability of Energy Sources for Cooking or Heating
Agro-Climatic Zones (cf. Unimodal)								
- Bimodal low	1.191**	-1.080**	-1.575***[R]	-0.505	-0.732*[R]	1.095**	0.582	1.214**
- Bimodal medium	0.849*	0.167	-0.243	0.001	-0.270	0.764**[R]	0.247	0.901*[R]
- Bimodal high	0.726	0.096	-0.818*[R]	-0.467	0.530	0.815**[R]	-0.283	-0.590
- Southwest highlands	1.844**	-0.594	-1.960**[R]	-2.131***[R]	0.269	-0.432	0.611	1.351**
- Eastern highlands	0.412	-0.698	-0.868	-0.201	1.264	1.500**	-0.358	-1.745**
High market access	0.385	0.254	-0.111	-0.050	0.941***	0.424	0.227	0.174
High population density (> 100/km^2)	1.082***[R]	-0.502	-0.454	-0.163	-0.209	0.324	0.231	-0.795**
Irrigation in village	-0.804**	0.827**[R]	-0.593	-0.688*[R]	-1.137***[R]	-0.892**	-0.416	0.698*
Development Pathways								
- Increase of cereals	0.077	0.044	0.077	0.314**[R]	0.109	0.020	-0.194	-0.429***
- Increase of banana and coffee	0.109	-0.004	0.628**[R]	0.414***[R]	0.308**[R]	0.155	0.246	-0.024
- Increase of non-farm activities	-0.065	-0.178	-0.017	0.007	0.173	-0.016	0.184	0.056
- Increase of horticulture	0.177	-0.207	0.054	-0.027	0.083	0.141	-0.118	0.196**
- Increase of cotton	-0.141	0.030	0.006	0.142	0.228*[R]	-0.137	-0.201**[R]	-0.009
- Stable coffee production	0.129	-0.041	0.100	-0.020	-0.193	0.044	-0.062	-0.263**
Change in ln(number of households)	1.376**	1.501***[R]	0.529	-0.585	-1.231**[R]	-0.558	0.854	-0.560
Change in dist. to tarmac road (miles)	-1.134***[R]	-0.0319***[R]	-0.0321***[R]	0.0038	-0.0212***[R]	-1.223***[R]	-0.021*[R]	-0.0183*
Change in dist. to rural market (miles)	-0.302	0.0590	0.073	0.0353	0.0518	-0.094	-0.004	-0.0265
No. of government programs	0.016	0.252	-0.068	0.030	0.475***	0.186	-0.036	0.092
No. of NGO programs	-0.061	-0.068	0.044	0.329**[R]	0.228	-0.015	-0.219	-0.360***
No. of community-based organizations	-0.194	0.166	-0.030	0.449**[R]	-0.080	0.025	0.047	-0.252*
Prob. > F	0.0000	0.0027	0.0133	0.0303	0.0001	0.0000	0.0626	0.0000

[a] Dependent variable takes values of –2 (major deterioration), -1 (minor deterioration), 0 (no change), +1 (minor improvement), +2 (major improvement). Coefficients and standard errors adjusted for stratification and probability weights. Standard errors robust to heteroskedasticity.

*, **, *** mean statistically significant at the 10%, 5% and 1% level, respectively.

[R] means the coefficient is of the same sign and statistically significant at 10% level when predicted values used for change in ln(no. of households) and numbers of programs and organizations.

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Endnotes

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[ii] The selected region includes 32 districts covering the southern half of the country and parts of the north. The sampling frame for the survey is discussed in more detail in Pender, Jagger, Nkonya and Sserunkuuma (2001).

[iii] For this study, Ruecker (2001) classified agricultural potential based upon the agro-climatic potential for perennial crop production, considering the average length of growing period (LGP), rainfall pattern (bimodal vs. unimodal) and elevation. Potential for annual crop production was also mapped and the maps were found to be very similar. Seven agro-climatic zones were identified within the study area: the bimodal high rainfall zone (10-12 months LGP, less than 1500 m.a.s.l.—the Lake Victoria crescent), the bimodal medium rainfall zone (8-9 months LGP—most of central and parts of western Uganda), the bimodal low rainfall zone (6-7 months LGP—lower elevation parts of southwestern Uganda), the high potential bimodal rainfall southwestern highlands (1500 m.a.s.l. and above), the high potential eastern highlands (1500 m.a.s.l and above), the medium potential unimodal rainfall zone (6-7 months LGP—parts of northern and eastern Uganda), and the low potential unimodal rainfall zone (less than 6 months LGP—much of northeastern Uganda). In the analysis, we combined the unimodal low and unimodal medium potential regions, since we expect that similar development pathways and land management practices will be pursued in these areas.

[iv] To classify market access, we used the measure of potential market integration estimated by Wood et al. (1999), which is a measure of travel time from any location to the nearest five towns or cities, weighted by the population of the towns or cities. Areas of high market access are mainly in the Lake Victoria region, the densely populated southwestern and eastern highlands, and parts of the north and west close to major roads and towns. Population density was classified based upon rural population density of parishes in 1991 (greater or less than 100 persons per square km.).

[v] Detailed quantitative information on development trends and land management is provided in Pender, et al. (2001).

[vi] We use household density rather than population density because we judge that our recall data on number of households is less subject to error than recall data on population. We take the natural logarithm of household density because this variable is more normally distributed than household density, which generally improves the specification in linear regression models (Mukherjee et al. 1998). Note that the change in ln(household density) is the same as change in ln(number of households), since the area does not change, so this eliminates any error associated with error in measuring area of the LC1.

[vii] Ideally we should use the change in number of programs and organizations rather than simply the current number of programs. However, since there were few programs and organizations operating in 1990 (Jagger 2001), the current number will be highly correlated with the change, and thus a good proxy for change.

[viii] The exogenous or predetermined factors used to predict change in ln(number of households) and number of organizations included the fixed factors mentioned above, the change in distance to the nearest tarmac road and to the nearest rural market, the number of households in the community in 1990, and whether community members used any of a variety of infrastructure and services in 1990 (tarmac road, murram road, seasonal road, bus, minibus, pickup truck, motorbike, trading center, or rural market). It was expected that earlier population levels and access to such infrastructure and services would affect opportunities and constraints in the villages, and therefore could affect migration to or from villages (hence population growth) and the likelihood of new organizations or programs locating there. This assumption was supported by the significance level and coefficient of variation for these auxiliary regressions, which were statistically significant in all cases and had R^2 values of 0.28 or higher. These regression results are available from the authors upon request.

[ix] We report only results of regressions for land management practices used by at least 10% of households (except fertilizer) and for which the F test for all coefficients being equal to zero was rejected at the 10% level.