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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, agricultural productivity, 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. This pattern was associated with changes in land use and agricultural practices, including expansion of cultivated area, grazing lands and woodlots at the expense of forest and wetlands; increased ownership of cattle but declining ownership of other livestock; and increased adoption of purchased inputs (though still low) and some soil and water conservation practices. Despite some agricultural intensification, crop yields, food security, and a wide range of natural resource conditions (especially soil fertility) appear to have degraded throughout most of Uganda. At the same time, many indicators of human welfare and access to goods and services have improved.

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, productivity and welfare. Other strategies are needed for less-favored areas not suited for this pathway.

Road development appears to have contributed to improvements in many welfare and some natural resource conditions, except forest and wetland availability. There are thus likely trade-offs among resource and welfare outcomes when pursuing road development where forests or wetlands are important. Elsewhere, road development can be a "win-win" development strategy. Irrigation was found to reduce pressure to expand cultivated area at the expense of forest, wetland and fallow, and is associated with improvement in several welfare and resource indicators; it may also be a "win-win" strategy. Government and non-governmental organization programs were also found to contribute to improvements in several indicators of productivity, resource and welfare, though there were some mixed results. Such programs may cause declines in one area (e.g., yields of a traditional crop or energy availability) by focusing on improvements in another area (e.g., improvement of another crop or protection of forests). 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. Population growth had an insignificant association with changes in resource conditions, and mixed association with welfare indicators. In general, 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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John Pender,[1] Pamela Jagger,[1] Ephraim Nkonya,[1] and Dick Sserunkuuma[2]

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. Stoorvogel and Smaling (1990) estimated annual average soil nutrient losses in Uganda of more than 70 kg. of nitrogen, phosphorus and potassium (NPK), among the highest rates of depletion in sub-Saharan Africa. Wortmann and Kaizzi (1998) estimated even higher rates of soil nutrient mining for most cropping systems in central and eastern Uganda in the mid-1990s, based upon farm level data. Soil erosion is also viewed as a serious problem, especially in highland areas, though the evidence is limited (Magunda and Tenywa 1999; Zake and Magunda 1999; Zake et al. 1997; Bekunda and Lorup 1994; Bagoora 1988). Other forms of land degradation, including soil compaction, surface crusting, water logging, leaching and declining vegetative cover, are also reported to be serious problems in different parts of the country (Sserunkuuma et al. 2001).

Land degradation undoubtedly 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 (Ibid.). *Matooke* (banana) yields have reportedly been declining in central

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Uganda for the past decade, contributing to a shift in production to the southwest; while farmers in the densely populated southwest highlands have been abandoning land and in some cases leveling conservation bunds to harvest the fertile soil they contain (FAO 1999). Such changes may be due to other factors besides land degradation, such as pest and disease problems, changes in climate patterns, or rising labor costs and off-farm opportunities (Sserunkuuma et al. 2001; Gold et al. 1999). Nevertheless, land degradation is an important part of the story, and may interact with such other factors to accelerate declining agricultural productivity.

Low and declining agricultural productivity contributes to poverty and food insecurity in Uganda. Forty-four percent of Ugandans lived below the poverty line in 1997 (APSEC 2000). Although poverty rates are declining they are still very high, especially in rural areas, and the poorest fifth of the population (most of whom live in rural areas) have become poorer (Ibid.). 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 (Sserunkuuma 2001; results reported later in this paper).

Poverty and food insecurity can in turn contribute to land degradation. Poor and food-insecure households may be unable to afford to keep land fallow, invest in land improvements that reduce land availability or are expensive to construct and maintain, or use costly inputs such as fertilizer. Poverty and food insecurity may also cause farmers to take a short-term perspective or expand crop production on steep and fragile terrain (Ibid.). However, poverty does not inevitably cause land degradation. For example, poor people may have more incentive to manage their land well, since this may be their only 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 often 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. Much has already been accomplished since the mid-1980s as a result of improved peace and security, macroeconomic stabilization, market liberalization, privatization and decentralization of many functions formerly controlled by the central government. These policy changes have contributed to substantial economic growth and poverty reduction since the late 1980's (APSEC 2000). However, as recognized by the Plan for the Modernization of Agriculture, much more remains to be done to achieve sustainable agricultural development and modernization in rural Uganda.

The key to further 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 key development opportunities and constraints in different parts of the country, the factors affecting farmers' ability to overcome the constraints and exploit the opportunities for sustainable development, and the role that government policy makers, government and non-governmental organizations and other stakeholders can play in helping to achieve these potentials. Helping to fulfill this information need is the primary objective of this paper and of the larger research project of which this is a part.

This paper identifies the development pathways, changes in land use and land management practices occurring in the selected region of Uganda since 1990, based upon a community-level survey conducted in 107 LC1's and villages.[3] It tests hypotheses about the determinants and impacts of these changes on agricultural productivity, natural resource conditions and human welfare, drawing upon the hypotheses identified in the earlier characterization phase of the work and discussed by Sserunkuuma et al. (2001).

The remainder of this paper is organized as follows: Section 2 presents the key questions, conceptual framework and hypotheses being addressed in this paper, and the research methods used to address them. Section 3 reviews the patterns and trends of agricultural development and land management in the study region and the factors hypothesized to affect these trends, based upon descriptive analysis of the community survey data. Section 4 identifies the development pathways occurring in the study region and tests hypotheses about the factors causing these development pathways and changes in land management, and implications for agricultural productivity, resource conditions and human welfare. Section 5 discusses conclusions and policy implications.

2. RESEARCH QUESTIONS AND METHODOLOGY

A 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 (e.g.,

[3] The districts included in the project study area include Kabale, Kisoro, Rukungiri, Bushenyi, Ntungamo, Mbarara, Rakai, Masaka, Sembabule, Kasese, Kabarole, Kibale, Mubende, Kiboga, Luwero, Mpigi, Nakasongola, Mukono, Kamuli, Jinja, Iganga, Bugiri, Busia, Tororo, Pallisa, Kumi, Soroti, Katakwi, Lira, Apac, Mbale, and Kapchorwa.

irrigation, roads), human capital (e.g., extension programs focusing on horticulture or dairy livestock management), and institutions (e.g., development of contract farming or dairy cooperatives, market information systems) may yield high social returns and facilitate a process of sustainable development. The agricultural and land management practices that are most profitable and sustainable are also likely affected by such comparative advantages. For example, where dairy development is occurring, there are likely greater opportunities to promote zero grazing livestock systems linked to intensive crop production and based on confined feeding and recycling of animal wastes than in areas where more extensive livestock production is practiced. 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 broadly as well as to adoption of sustainable land management practices, we use the concept of "development pathways." We define a development pathway as a common pattern of change in livelihood strategies, such as expansion of intensive dairy production (Sserunkuuma et al. 2001). 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 this concept to guide the research questions and key hypotheses addressed by this research, the conceptual framework used to generate the hypotheses, and the methods used to test the hypotheses and answer the research questions.

RESEARCH QUESTIONS

The key research questions for this study relate to the development pathways that exist in the study region of Uganda, their relationship to land use and land management, their causes and implications:

- What are the dominant development pathways occurring in the study region of Uganda since 1990 and their relationship to land use and land management?

- What factors determine the development of particular development pathways and changes in land use and land management? In particular, how have government policies, technical assistance programs, and other policy relevant factors affected these changes?

- What are the implications of different development pathways, policies, programs and other causes of change for agricultural productivity, natural resource and human welfare conditions?

To address these questions, we have developed a conceptual framework to guide our development of hypotheses and choice of research methods.

CONCEPTUAL FRAMEWORK[4]

The conceptual framework is illustrated in Figure 1. Land management is determined by private decisions made at the farm household level, as well as by collective decisions made at the village or higher levels.

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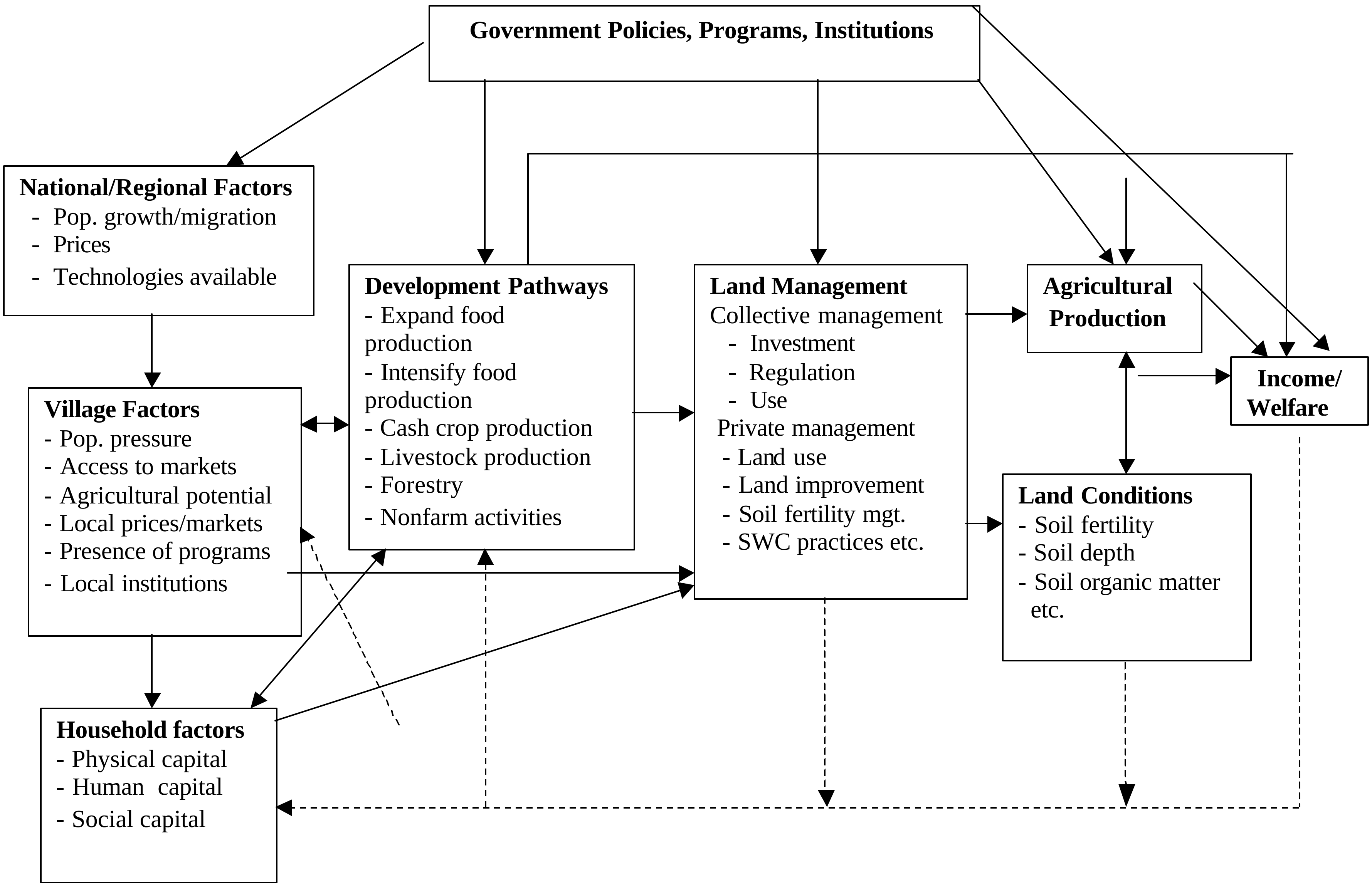
[4] This section is adapted from Sserunkuuma et al. (2001).

Figure 1--Factors affecting Development Pathways, Land Management, and their Implications



For example, farm households choose what crops to plant and how to manage soil fertility or conserve soil and water on their own land; but these decisions may be affected by regulations on land use set by local councils. Communities may also regulate use of communal grazing areas or other common lands, or may make collective investments in improving such resources, such as planting improved grasses or trees.

These household and collective decisions will determine current agricultural productivity and affect the condition of land resources (thus influencing future agricultural productivity), which in turn affect the level of farm income and household welfare. It is important to recognize that it is such outcomes (productivity, resource wealth, and household welfare), and not adoption of specific land management practices *per se*, that are likely to be of most concern to rural people and to policy makers. It is thus critical to consider the ultimate impacts of any policy or technology on these outcomes, and the extent to which there may be trade-offs or complementarities among these objectives. For example, a strict regulatory approach (e.g., preventing farmers from planting annual crops on steep lands) may be effective in reducing soil erosion but may also have severe implications for agricultural production, food insecurity and poverty. On the other hand, there may be "win-win-win" strategies available that promote greater productivity and incomes as well as improved resource conditions. For example, promoting intensification of annual crops in less steep areas and perennial production on steep lands may reduce land degradation while increasing agricultural productivity and farm incomes.

Land management decisions are determined by many factors operating at different scales (plot, household, village, region, nation, and international). Many of these factors influence land management directly; for example, the type of soil, topography of the land and the climate will have a large impact on whether soil erosion is likely to be a problem and what options are feasible to address it. Demographic and socioeconomic factors—such as population density and access to markets—also influence land management. Some of these effects are direct; for example, access to markets determines the profitability of alternative practices. But some effects are indirect. For example, population pressure leads to smaller farm sizes and often to more fragmented holdings, which may reduce farmers' ability or incentive to fallow or to invest in land improvements.

One important indirect way in which biophysical and socioeconomic factors affect land management is by determining which development pathways are pursued in a particular location and by particular households. Development pathways may be influenced by many village level factors, such as agricultural potential, access to markets, population density, and presence of government programs and organizations. These factors largely determine the comparative advantage of a location by determining the costs and risks of producing different commodities, the costs and constraints to marketing, and the opportunities and returns to alternative activities, such as farming vs. non-farm employment. These factors may have generalized village level effects on development pathways, such as through their impact on village level prices of commodities or inputs, or they may affect farm household level factors, such as average farm size. Household level factors such as households' endowments of physical assets (farm size, land quality, livestock, savings), "human capital" (education, training, farming experience), and "social capital" (cultural norms, family and ethnic relations) may also determine the development pathway and land management practices pursued by particular households.

Government policies, programs and institutions may influence development pathways and land management and their implications for productivity, resource conditions, and household welfare at many levels. Macroeconomic, trade, and market liberalization policies will affect the relative prices of commodities and inputs in general throughout a nation. Agricultural research policies affect the types of technologies that are available and suitable to farmers in a particular agro-ecological region. Infrastructure development, agricultural extension, conservation technical assistance programs, land tenure policies and rural credit and savings programs affect awareness, opportunities, or constraints at a village or household level. Policies or programs may seek to promote particular development pathways (e.g., non-traditional export cash crop production), or may seek to address constraints arising within a given development pathway (e.g., credit needs arising in cash crop production). Programs may attempt to address land management approaches directly, for example by promoting particular soil fertility management practices. Policies and programs may also be designed to affect development outcomes directly, for example, through direct management of land by the government, or through nutrition or income enhancement programs.

Currently available information does not provide policy makers with much guidance as to which of these intervention points will be most effective in achieving better land management, improving agricultural productivity, ensuring sustainable use of resources, and increasing incomes and food security. Much public action aimed at improving land management focuses on influencing household adoption of particular technologies. Yet this may be ineffective if the technologies are not suited to the development pathways that have potential in a given location. It may be more effective in many cases to first focus on the larger development strategies for particular development pathways, before focusing too much on particular land management technologies.

In the next section we discuss our hypotheses about the potential development pathways in rural Uganda, the factors determining them, and the implications of development pathways and other key factors for land management, agricultural productivity, and resource and human welfare outcomes.

RESEARCH HYPOTHESES

First we consider hypotheses about the development pathways that exist in rural Uganda, their causes and implications. Then we consider hypotheses about other factors that may have important impacts on land management, productivity and resource and welfare outcomes.

Development Pathways and their Causes[5]

Sserunkuuma et al. (2001) hypothesize nineteen possible development pathways that may exist in rural Uganda, based upon consideration of the types of economic activities possible (crop production, livestock, forestry, non-farm activities), the orientation of agricultural production (subsistence vs. cash), the period of production for crops (perennial vs. annual crops), the costs of storing (storable vs. perishable) and marketing the commodities produced (transportable or not), and the labor intensity of land/labor use (extensive vs. intensive). These pathways include expanding (without significant intensification) or intensifying (without area expansion) subsistence perennial food production (e.g., *matooke*), expanding or intensifying subsistence annual food production (e.g, sorghum or millet), expanding or intensifying storable perennial cash crop production (e.g., coffee), expanding or intensifying perishable perennial cash crop production (e.g., *matooke* or fruits), expanding or intensifying storable annual cash crop production (e.g., cotton, maize, beans), expanding or intensifying perishable annual cash crop production (e.g., vegetables), expanding extensive livestock production (e.g., cattle, small ruminants in grazing systems), increasing intensive livestock production (e.g., dairy, pigs,

[5] This subsection is adapted from Sserunkuuma et al. (2001).

poultry), increasing production of high value forest products (e.g., timber), increasing production of low value forest products (e.g., fuelwood and charcoal), rural industry linked to agriculture (e.g., coffee processing, input supplies, trading), rural industry not linked to agriculture (e.g., crafts, mining, construction), and migration to urban areas for employment.

Many factors may determine the comparative advantage of these development pathways in different locations. Three factors are hypothesized to be particularly important: agricultural potential, access to markets, and population density. These factors can thus be used to identify different "development domains" in Uganda, each having somewhat different potentials in terms of feasible development pathways.

Agricultural potential is an abstraction of many factors—including rainfall level and distribution, altitude, soil type and depth, topography, presence of pests and diseases, presence of irrigation, and others—that influence the absolute (as opposed to comparative) advantage of producing agricultural commodities in a particular place. There are of course variations in potential depending upon which commodities are being considered. Furthermore, agricultural potential is not a static concept but changes over time in response to changing natural conditions (such as climate change) as well as human-induced conditions (such as land degradation). For simplicity of exposition, however, we discuss agricultural potential as though it were a one dimensional and fixed concept.

Access to markets is critical for determining the comparative advantage of a given location, given its agricultural potential. For example, a community with an absolute advantage in producing perishable vegetables (i.e., higher productivity in vegetable production) may have little or no comparative advantage (low profitability) in vegetables if it is far from roads and urban markets. As with agricultural potential, market access is also a multi-dimensional and dynamic concept (distance to roads, condition of roads, distance to urban centers, degree of competition, access to transport facilities, access to international markets, etc.).

Population density affects the labor intensity of agriculture by affecting the land/labor ratio, and may also induce innovations in technology, markets and institutions, or investments in infrastructure (Boserup 1965). Population pressure thus affects the comparative advantage of labor-intensive pathways of development, as well as returns to various types of investments.

Consideration of these factors suggests potentials for several types of crop-oriented development pathways in Uganda. These include expansion and intensification of high value storable traditional export crops like coffee and cotton in areas with climate and soils suited to their production, expansion and intensification of perishable crops like fruits and vegetables in areas of high market access and sufficient rainfall or irrigation, and expansion and intensification of maize for the regional market in areas with sufficient rainfall. Expanding and intensifying production of other bulky food crops for subsistence purposes or for the local market (e.g., *matooke*, cassava, sweet potatoes) may also be viable development pathways, even if Uganda does not have a regional or international comparative advantage, since such commodities tend not to be tradable over long distances. Such products may have potential as cash crops close to urban centers or for subsistence purposes in more remote areas. Whether the development pathways used for crops are extensive or intensive will depend upon whether land of suitable potential is available for expansion, which depends upon population density and agricultural potential of particular areas, and the availability of suitable technologies for extensification or intensification.

Similar considerations apply to production of livestock and livestock products. Intensive production of perishable products such as dairy and fish farming are likely to be suited mainly to areas of high market access and high population density. Extensive production of high value livestock that are relatively easy to transport, such as cattle and small ruminants, can occur in areas far from markets, and tends to have a comparative advantage in areas that are low in potential for crop production. Dairy products may also be produced in such extensive systems in lower potential areas, but high access to collection and processing facilities or to urban markets is essential. Other animals such as pigs and poultry can be raised for subsistence purposes in many areas, but intensive production for the market is likely to occur mainly close to urban areas, due to economies of scale in production, relatively high costs of transporting them relative to their value, the perishability or ease of damage of some of the products (e.g., eggs) or the use of purchased compound feeds (especially for poultry). In areas where subsistence food production continues to be important (especially in annual cropping systems where tillage by draught animals is suitable), mixed-crop livestock production is likely to be important (or may develop as population density rises in pastoral systems), with farmers keeping animals for plowing, consumption purposes and as a form of savings. This is because the benefits of exploiting complementarities between crop and livestock production rise as population density rises, particularly where markets are not well developed (McIntire et al. 1992).[6]

Forestry production is likely to be suited to high rainfall areas of low population density, since land scarcity in high-density areas usually causes intensive food or cash crop production to have higher value and higher priority. Even in low-density settings, there are often conflicts between extensive livestock production and forest preservation (NEMA 1998). Production of high value forest products such as timber or pine resin may be economical in remote locations (if

[6] These changes can be affected by cultural views. For example, in Ankole farmers are reluctant to use cattle for plowing, preferring not to use them as "beasts of burden." The nature of the soil (i.e., how heavy or light) also affects whether animals can be used for tillage.

suitable road and transport infrastructure exists), while low value products such as fuelwood must be produced close to markets, unless they are used only for subsistence purposes. Conversion of fuelwood to charcoal can extend the marketable range of fuelwood products, however.

In most cases, rural non-farm activities are linked to agriculture. This includes activities related to processing agricultural commodities, commodity trading, and provision of agricultural inputs. Potential for development of these activities thus depends on commercial agricultural development. These activities are more likely to be significant sources of employment in higher population density areas close to urban centers and towns.

There is also potential for rural people to be employed in rural non-farm activities that are not linked to agriculture, such as making crafts, construction, and employment in urban areas. All of these activities are more likely to be important in areas with relatively good road and market access.

Development Domains in Uganda[7]

We mapped different development domains in the study region of Uganda (excluding parts of the west, northwest, north and northeast) based upon available secondary information related to agricultural potential, market access and population density (Ruecker, 2001), and used this information in selecting our survey sample, and analyzing the results.

For this study, Ruecker (2001) classified agricultural potential based upon the agro-climatic potential for perennial crop production, based upon the average length of growing period, rainfall pattern (bimodal vs. unimodal), maximum annual temperature, and altitude (Figure 2). Potential for annual crop production was also mapped and the maps were found to be

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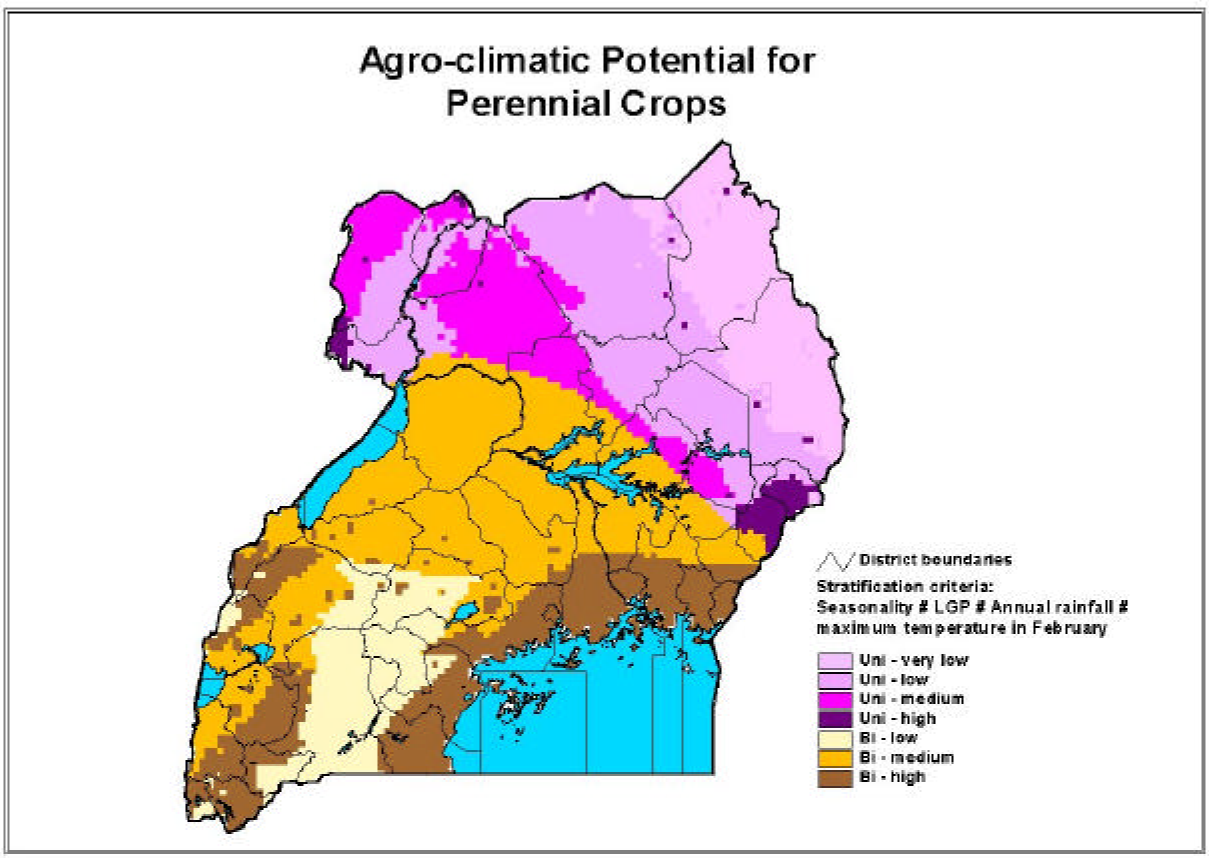
[7] This subsection is adapted from Sserunkuuma et al. (2001).

very similar. Seven zones were identified within the study area: the high potential bimodal rainfall area at moderate elevation (the Lake Victoria crescent), the medium potential bimodal rainfall area at moderate elevation (most of central and parts of western Uganda), the low potential bimodal rainfall area at moderate elevation (lower elevation parts of southwestern Uganda), the high potential bimodal rainfall southwestern highlands, the high potential eastern highlands, the medium potential unimodal rainfall region at moderate elevation (parts of northern and eastern Uganda), and the low potential unimodal rainfall region at moderate elevation (much of northeastern Uganda). In the stratification used for the survey and in the analysis and discussion of the results, 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.

These regions of Uganda were also classified according to the level of market access and population density. 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., which is about the average rural population density in Uganda).

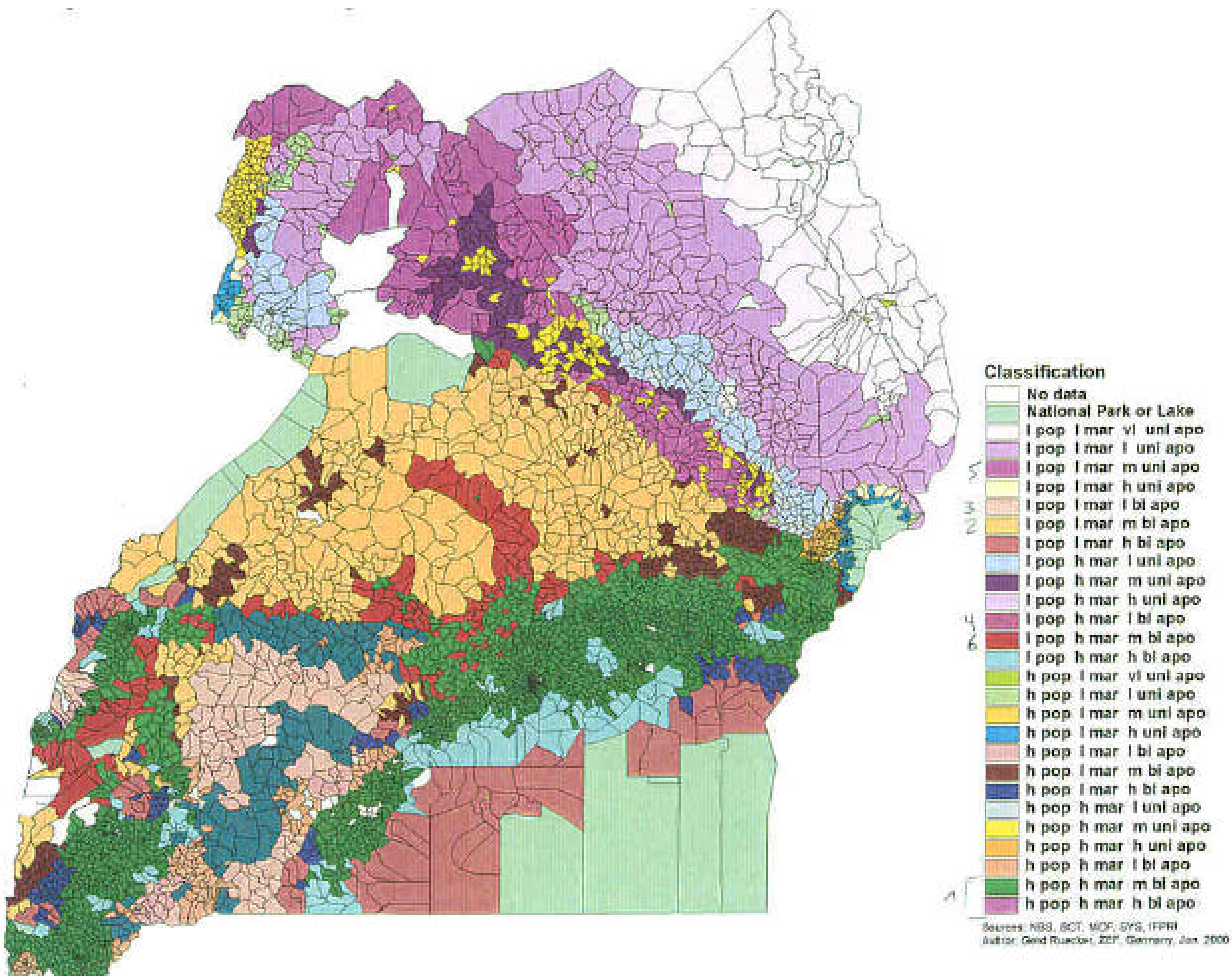
Overlaying these three dimensions of agricultural potential, market access and population density, we can classify different development domains of Uganda (Figure 3). There are 24 possible domains (combining the unimodal medium and low potential zones), though only 16 are represented to any significant extent in Uganda. Because of correlation among the factors, some possible combinations do not occur. For example, it is difficult to find places with low market access and high population density (except in parts of the highlands) or high market access and low density (except in lower potential areas).

Figure 2--Agro-climatic Potential for Perennial Crops



Source: Gerd Ruecker, Center for Development Research, 2000

Figure 3--Development Domains in Uganda



Source: Data from Gerd Ruecker, Center for Development Research, 2000

Impacts of Development Pathways

Different development pathways may have many different impacts on land management, productivity, and resource and welfare outcomes. We will not attempt to provide an exhaustive set of hypotheses about these impacts, but rather illustrate general principles with some examples.

In less densely populated low market access areas, such as in much of the bimodal low and medium rainfall zones and unimodal rainfall zones to the north and west, expansion of subsistence food production using traditional methods is likely to be a common strategy, and adoption of labor-intensive means of land management such as constructing soil bunds or composting is likely to be limited. Adoption of purchased agricultural inputs such as fertilizer and improved seeds is likely to be lower in lower in these areas than where cash crop production for the market is important. Expansion of cultivation and livestock in these areas is likely to create pressure on forests, grazing lands and wetlands, with negative impacts on these resources. Improvement in per capita incomes and welfare are likely to be limited in such areas.

In densely populated remote areas, such as in parts of the highlands, opportunities for area expansion are much more limited, and intensification of subsistence production is likely to be an important pathway. In this situation, labor-intensive methods of land management are more likely to be adopted than in more extensive development pathways. There may be opportunities for increased integration of crop, livestock and forestry or agroforestry activities on the farm, particularly in higher potential areas where production of leguminous trees or cover crops in spatial or temporal niches can enhance the productivity of crop and livestock production. Such practices can help to conserve and improve land conditions; nevertheless, pressure on land and limited opportunities for fallowing may still lead to problems of land degradation and declining productivity. Unless there is also significant development of market-oriented development pathways (such as intensified production of storable cash crops) or adoption of more productive technologies, stagnation or decline in per capita incomes and human welfare in such intensive systems is likely (Pender 1998 and 1999).

In densely populated areas with good market access and high rainfall, as in most of the Lake Victoria crescent, many development pathways are possible, but the most profitable ones likely involve intensive production of high value perishable annual crops, perennial crops or livestock products, or development of non-farm activities. Where such development pathways are being pursued, commercialization and cash incomes are likely to be increasing, facilitating farmers' ability to purchase inputs such as fertilizers, improved seeds and pesticides. Adoption of such inputs is thus expected to be associated with these development pathways. The effect of these pathways on the labor intensity of production depends on their effect on relative costs of land and labor, both of which are likely to be increasing in these areas. Where land values are rising faster than labor costs, intensification of labor per unit of land can be expected, thus facilitating adoption of labor-intensive methods such as mulching, manuring and composting. The types of land management practices pursued also will depend on the types of commodities produced. For example, in perennial banana-coffee systems, the availability of crop waste materials and the need to conserve soil moisture may promote the use of mulching and composting. Where intensive livestock production is occurring, such as dairy development, increased use of stall feeding and recycling of animal wastes to the soil through manuring and composting is likely. Such changes can bring about improvements in soil fertility, though this is not assured given increasing export of nutrients via commercialization, and there can be negative impacts on water quality and other environmental conditions (particularly where agro-chemical use is rapidly increasing). Incomes and human welfare indicators are more likely to be improving in areas where these development pathways are being pursued than in most other areas.

In areas with good market access but lower rainfall, as in parts of the bimodal low and medium potential zones close to roads, similar development pathways are possible as in the higher rainfall areas, provided there is adequate investment in irrigation or water management, especially for perennials or horticultural crops. Given water constraints, production of annual cash crops more suited to lower rainfall conditions, such as cotton or cereals, may be more important than in higher rainfall areas. Land management practices are likely to give priority to water management and soil moisture conservation in such areas. Given production of cash crops and good market access, farmers are likely to be able to use purchased inputs, though use of inorganic fertilizer may be limited by soil moisture considerations in more drought-prone areas. There is likely good potential for integrating livestock with crop production, particularly in annual crop systems where draft animals can be used for tillage, and this can contribute to use of manure and compost for soil fertility management. Such land management practices can contribute to improvements in soil fertility and other land conditions to the extent that they are adopted. Nevertheless, there is risk of declining soil fertility as commercialization proceeds in such areas, since more soil nutrients will be exported and these may not be adequately replenished by recycling of manure and other nutrients alone. Increased use of fertilizer is likely to be needed in such circumstances. To the extent that water, soil fertility and other production constraints can be overcome, yields and incomes may improve in these areas as a result of increased production for the market.

Impacts of Other Factors

Many other factors besides the development pathway pursued can also affect land management practices and outcomes. Of particular importance are likely to be population pressure, market access, irrigation, and technical assistance programs and other programs and organizations influencing land management directly or indirectly.

Population Pressure

As mentioned previously, population growth is expected to cause expansion of cultivated area in less densely populated areas where expansion is feasible, or to increase the labor intensity of agriculture where expansion is less feasible (Boserup 1965). Increases in the labor intensity of agriculture can take the form of declining use of fallow, adoption of more labor-intensive methods of cultivation (e.g., increased hoeing and hand weeding, composting, mulching), labor-intensive investments in land improvement (e.g., construction of soil bunds, tree planting), or adoption of more labor-intensive commodities (e.g., horticultural crops) (Pender 1999).

Population pressure may also induce increases in the capital intensity of agriculture, particularly in forms of capital that are complementary to labor (e.g., use of draft animals and some inputs); increases in the "knowledge intensity" of agriculture, through adoption or adaptation of technologies (e.g., improved seeds, integrated pest or soil nutrient management); or have more indirect (but still important) effects by stimulating migration, changes in livelihood strategies, investments in infrastructure, or inducing technical or institutional change (Ibid.). In general, intensification is expected to lead to increases in yields, unless accompanied by land degradation. However, it is expected to lead to declining labor productivity, per capita income and welfare (as a result of diminishing returns to labor), unless population growth induces technical change, improvement in infrastructure and market access, or other improvements in opportunities (Ibid.).

The impacts of population growth on resource conditions may be mixed. At low levels of population density, population growth likely leads to worsening resource conditions as cultivated and grazing area expands at the expense of forest, woodland, and other land uses. As intensification proceeds, however, land conditions may improve as farmers invest in labor-intensive land improvements (Ibid; Tiffen et al. 1994; Scherr and Hazell 1994). However, population pressure may also encourage farmers to abandon conservation measures, particularly those such as terraces that reduce cultivated area (Herweg 1992); as well as encouraging production on steeper and more fragile terrain, degradation of common property resources, overuse of inputs, and other problems. Thus the impacts of population growth on resource conditions may be either positive or negative, depending on the context.

Market Access

Increases in the profitability of agricultural products resulting from infrastructure investment, market development, or changes in market prices will promote expansion of agriculture into marginal areas if the costs of productive factors or outputs are unaffected by the change (Angelsen 1999). However, if the costs of factors rise (as a result of constrained supply of some factors), a reduction in agricultural area is possible as productive factors are concentrated on the most profitable lands (Ibid.). If expansion of agricultural land is limited, increased profitability will cause intensification of labor and/or capital per unit of land, though the effects on capital relative to labor depend on the nature of factor markets and the nature of the change. Improved market access and market development will tend to promote production of cash crops and lead to increased farm incomes and wealth. Market access can also contribute to human welfare in other ways, by increasing access to goods and services. The implications for resource management and environmental conditions may be mixed. For example, changes in commodity prices have a theoretically ambiguous effect on soil conservation investments (LaFrance 1992; Pagiola 1996). Market development may increase externalities associated with demand for water and agricultural chemicals.

Irrigation

As with improvements in market access, irrigation can enable production of higher value crops such as horticultural crops, as well as enabling multiple crops per year and higher yields of food crops. If this increases the costs of productive factors, it may limit expansion of agricultural production, as in the case of improved market access. Irrigation may promote investments in complementary soil and water conservation investments and practices, such as investments in terracing and drainage (Pender and Kerr 1998). It may also encourage farmers to adopt productive inputs such as fertilizer, particularly where soil moisture constraints limit farmers' willingness to use fertilizer (Pender et al. 1999). Irrigation is likely to contribute to increased food production and/or incomes and thus to food security of those with access to it. It also tends to increase demand for labor (as a result of multiple cropping and adoption of labor intensive crops and practices) and thus can also benefit farm laborers. However, irrigation may have negative effects on people downstream, as a result of reduced access to water or increased use of agrochemicals. Poorly designed irrigation systems without adequate drainage can lead to salinity problems in the soil. Surface irrigation can also contribute to increased problems of malaria, by providing breeding sites for mosquitoes.

Programs and Organizations

Programs and organizations can have varied impacts on land management, agricultural productivity, and resource and welfare outcomes, depending upon the type and emphasis of the program or organization, the activities it pursues, the degree of participation achieved, the effectiveness of the participation, and other factors. Most programs and organizations operating in rural Uganda are either government sponsored, non-government organizations that are organized and financed external to particular communities (NGO's), or community-based organizations (CBO's).[8] These programs and organizations are usually focused on providing infrastructure or public services, agricultural extension, environmental protection, or poverty reduction (Jagger 2001). Government programs and NGO's are involved in all of these areas, though a larger proportion emphasize infrastructure and public services than other activities. CBO's in contrast, are mainly focused on poverty alleviation and providing community support services (for example, assistance with funeral arrangements).

Programs and organizations oriented towards technical assistance in agriculture and/or environmental protection likely have the most direct effects on land management. In some cases (e.g., Sasakawa Global 2000, the IDEA project, and the Ministry of Agriculture extension program) these programs are promoting increased use of purchased inputs such as improved seeds and fertilizer. In other cases, especially among NGO's (e.g., AT Uganda, Africa 2000 Network, African Highlands Initiative) they are promoting low external input agricultural technologies, such as mulching, composting, cover crops and agroforestry practices. We expect that NGO's are having a positive impact on adoption of such land management practices, though

[8] Other categories include religious organizations, research organizations, and private businesses and organizations.

this may be true of some government programs as well. We expect less direct impact of CBO's on land management, since they are less focused on this.

Programs and organizations oriented towards infrastructure and public service provision are expected to have direct effects on many aspects of human welfare, by increasing access to transportation, education, health, water, and other important goods and services. They may also have important indirect effects on land management and natural resource conditions. For example, improvements in education may increase farmers' receptiveness or ability to respond to technical assistance; while improvements in health can increase farmers' ability to undertake labor-intensive practices. By affecting land management, such programs can also indirectly affect natural resource conditions. We expect these kinds of effects to be important for both government and NGO programs, but less so for CBO's which are less focused on this.

Programs focused more on poverty reduction (emphasizing income generation activities, social development and assistance to disadvantaged people) also can have important direct effects on welfare and indirect effects on land management and resource conditions. Such programs may influence the development pathways of particular households, and thus influence land management and resource conditions as discussed above regarding impacts of development pathways. They also affect household level endowments of physical, human and social capital that can constrain or promote various land management practices (e.g., income generation and social development may increase farmers' access to credit and affect their ability to purchase inputs or acquire livestock). These impacts can in turn affect resource conditions. We expect these kinds of impacts to be most important for CBO's, but also important for some government programs and NGO's.

RESEARCH METHODS

Data Sources

Many of the above hypotheses are tested using analysis of survey data collected in 107 communities during 1999 and 2000. The communities were selected using a stratified random sample of communities from the different development domains shown in Figure 3.[9] One hundred LC1's were selected in this way. Additional communities were purposively selected in southwest Uganda, where the African Highlands Initiative is conducting research, and in Iganga, where the International Center for Tropical Agriculture (CIAT) is conducting research.

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 location of the community, the major concerns and priorities of community members, population change, access to infrastructure and services, presence and activities of programs and organizations, land rights and restrictions, local bylaws, and collective resource management.

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 and land tenure relations; factor markets (land, labor, credit); crop and livestock management, production and commercialization; and commercialization of tree products. Where information about changes was sought, the focus was on changes since 1990, and we also asked respondents for their

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[9] At least four communities were selected from each stratum. Details on the numbers of communities selected in each stratum and the sampling weights are available from the authors.

perceptions of the reasons for change. 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 and available digitized map information incorporated into a geographic information system (GIS). The boundaries of the communities were also mapped with community members, digitized and incorporated into the GIS.

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 (presented in Section 3), factor analysis to identify the development pathways (Section 4) and econometric analysis to test the research hypotheses (Section 4).

The factor analysis used data on the primary activities of men and changes in the top three activities to identify the development pathways. We did not use information on women's occupations for the classification. This was not because we regard women's occupations as less important, but 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. Using only men's occupation was thus a reasonable way to simplify the classification problem. We used the principal component factor method, and rotated the first six factors using the varimax method (Stata 1997). As discussed in Section 4, 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 livestock use, land use, land management practices, purchased input use, crop yields, 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 least squares regression was therefore inappropriate. We instead used ordered probit regressions, which is appropriate for ordered response data (Amemiya 1985).

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 livestock use, land use, land management, crop yields, 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) $$\Delta y_{jv} = -2 \;\; if \;\; \Delta y^*_{jv} < \boldsymbol{a}_{-2j}$$

4) $$\Delta y_{jv} = -1 \;\; if \;\; \boldsymbol{a}_{-2j} \le \Delta y^*_{jv} < \boldsymbol{a}_{-1j}$$

5) $$\Delta y_{jv} = 0 \;\; if \;\; \boldsymbol{a}_{-1j} \le \Delta y^*_{jv} < \boldsymbol{a}_{1j}$$

6) $$\Delta y_{jv} = +1 \;\; if \;\; \boldsymbol{a}_{1j} \le \Delta y^*_{jv} < \boldsymbol{a}_{2j}$$

7) $$\Delta y_{jv} = +2 \;\; if \;\; \Delta y^*_{jv} \ge \boldsymbol{a}_{2j}$$

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 natutal logarithm of household density, [10] change in distance to the nearest tarmac road, change in distance to the nearest rural market, the number of government programs, the number of NGO programs, and the number of CBO's operating in the village.[11]

There are some potential problems with these regression models. Population growth and presence of organizations may respond to development opportunities as well as being a causal factor affecting development. Thus there is the potential for reverse causality to affect the interpretation of our results. For example, we might find high population growth in communities pursing intensification of cash crops, not because population growth caused this development, but rather because this development potential attracted immigrants to such communities. The standard econometric approach to this problem is to use a two-stage model, in which the potentially endogenous explanatory variable (population growth in this case) is replaced by the

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[10] 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.

[11] 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.

predicted value of that variable. If the predicted value is determined only by exogenous factors (i.e., factors not influenced by the response variable being considered), that will purge the regression of the problem of reverse causality. To address this problem we therefore 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.[12] In most cases we find that our results are robust (see Section 4).

The development pathway variables might also be subject to this problem of reverse causality in the regressions where they are included as explanatory variables. For example, declining yields of *matooke* may induce farmers to shift to other economic activities such as production of other crops or livestock. Unfortunately, we are not able to use the same approach to solve this problem, because the same variables that determine development pathways also can affect land management directly, controlling for the development pathway. Because of this, including predicted values for the development pathway in the other response regressions would lead to perfect multicollinearity and the model would not be estimable. 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

[12] 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.

realization that we are only reporting correlations, and that causality may go in the opposite direction.

Another potential problem is (imperfect) multicollinearity among the explanatory variables, which reduces the ability to disentangle the effects of particular variables. We tested for this problem using variance inflation factors, and found that the maximum variance inflation factor was less than 3, indicating that multicollinearity is not a major concern.[13] 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. DEVELOPMENT TRENDS AND LAND MANAGEMENT PRACTICES IN UGANDA

Uganda has undergone enormous change and revitalization since the mid-1980s. In general terms, human welfare has improved throughout the country, particularly with respect to the accessibility of health and education services. Along with a general improvement in various welfare indicators there are perceptions of worsening natural resource conditions. This general finding may be an emerging trend for developing countries (for example, see Pender et al. 1999; Pender et al. 2001) and has important implications for land management policy. However, although there is a general trend of improving welfare and declining natural resource conditions, there is a high degree of variability throughout the various development domains in Uganda.[14] In

[13] The variance inflation factor (VIF) measures the extent to which the variance of a coefficient is inflated by multicollinearity (Mukherjee, et al., 1998). According to one rule of thumb, a maximum VIF of less than 10 indicates that multicollinearity is not a major problem (Ibid).

[14] Recall that development domains are defined by agricultural potential, market access and population density.

this section we present evidence on some of the patterns and trends in development and land management in Uganda.

HUMAN WELFARE AND NATURAL RESOURCE CONDITIONS

Human welfare indicators for 1999 indicate that over 90% percent of primary school age children are in school, 61% of houses have a metal roof (an indicator of housing quality), and 65% of households have children eating at least two meals per day on average (Table A1). Since 1990 there have been significant improvements in many aspects of human welfare. Housing quality, literacy, school attendance, the quality of drinking water, child and maternal mortality, the availability of educational services, the average level of durable goods owned by households, the availability and quality of health services, the availability of energy sources for lighting, access to transportation and the availability of consumer goods are all perceived to have improved on average (Tables A2 and A3). However, farm sizes have declined and the proportion of households without adequate food, general food availability, households' ability to cope with drought, and availability of energy sources for cooking and heating are perceived to have declined on average.

While many aspects of human welfare are perceived to be improving, the condition of natural resources is perceived to be deteriorating in general. Since 1990, the availability and quality of cropland, grazing land, forests and woodland are reported to be decreasing in general (Table A4). Soil fertility is declining everywhere, and the decline is usually reported as major. Soil moisture holding capacity is also perceived as declining and soil erosion problems worsening. Natural water sources are reportedly becoming less available, and biodiversity of wild plants and animals is perceived to be deteriorating in most places.

Beyond these general findings some interesting and divergent trends in welfare and natural resource indicators are evident in the different development domains of the country. The unimodal rainfall areas of northern Uganda are characterized by lower rainfall and, in most cases, low market access and low population density. In these areas food security is below average for the country. Only 41% of households are reported to eat two or more meals per day on average. Only small changes in food security and housing conditions have been observed in unimodal areas since 1990. However, there have been major improvements in primary school education since 1990; almost all children of primary school age were in school in 1999. The availability of health services, transportation and consumer goods are also improving in this region, as in other parts of Uganda. Soil fertility in unimodal areas is decreasing, but has changed the least compared to other regions since 1990. Similarly, although grazing land and woodland are deteriorating, they are deteriorating at a lesser rate than elsewhere in the country.

The bimodal low agricultural potential zone includes mainly the southwest cattle corridor between the Lake Victoria region and the southwest highlands region. It is characterized by low rainfall and generally low population density, while much of this region has relatively good market access. There have been significant improvements in both primary and secondary education; the region has the second highest proportion of households with children of secondary school age in school (Table A1). As in many other parts of the country, the availability of educational services has substantially improved in this zone, as has availability and quality of health services, access to transportation, and several other indicators of welfare. However, food insecurity is serious and worsening in this region. In nearly two-thirds of households in this region, adults eat fewer than two meals per day on average, and this proportion has been increasing. Food availability is also decreasing in general. At the same time nutrition of children and infant and child mortality have improved. These outcomes may be linked to good market access throughout much of the region and general improvements in the quality of health services. Soil fertility and soil moisture holding capacity are deteriorating, and the availability of grazing land is decreasing.

The bimodal medium and high potential zones, which include most of western and central Uganda and which have generally good market access (especially in the high potential Lake Victoria crescent), are experiencing more positive human welfare outcomes. In 1999, food security indicators were highest in these zones, with 24% (bimodal medium) and 33% (bimodal high) of households with children eating less than two meals per day. In both zones, adult literacy and school attendance were close to national averages. The bimodal high rainfall zone has experienced the most significant improvements of any zone in availability and quality of drinking water and availability of health services. In this favored region, high levels of market access are reflected in major increases in access to transportation, ownership of durable goods and availability of consumer goods.

High and rapidly growing population densities may be causing land degradation in the bimodal high potential region. Cropland degradation is reflected in declining soil fertility, declining soil moisture holding capacity, and worsening soil erosion. The availability and quality of grazing land are also deteriorating, as well as the diversity of wild plant and animal species. In the less densely populated bimodal medium potential zone, most indicators of land degradation are not as strong as in the bimodal high rainfall region. However, the availability and quality of forest and woodland resources is deteriorating more so than in other regions of the country.

Food insecurity is a severe and worsening problem in the densely populated southwest highlands. Ninety five percent of households reportedly do not have adequate food throughout the year (compared with an average of 61% country wide), food availability and child nutrition have declined the most in this zone, and the proportion of households without adequate food has increased substantially since 1990. The proportion of households with primary school age children in school is equivalent to the country average, though secondary school attendance is the lowest of any zone. Nevertheless, there has been major improvement in school attendance and housing quality in this zone. The availability and quality of health services are perceived to have improved in general in this zone, but the general health of people has declined. Natural resources in the southwest highlands have undergone major deterioration since 1990. There have been major declines in average farm size, availability of cropland, soil fertility and soil moisture holding capacity. Parts of the southwest highlands appear to be in a poverty and resource degradation trap, with poor and worsening human welfare and natural resource conditions.

In the relatively high potential and densely populated eastern highlands, most human welfare indicators for 1999 are close to averages for the country. However, there has been significant change in this region since 1990, including worsening of food security indicators coupled with general improvements in education, health, and transportation services. Changes in many welfare indicators in this region are similar to those of the southwest highlands. Also, like the southwest highlands, soil fertility depletion and erosion are worsening and contributing to food insecurity and poverty. The availability of grazing land is also decreasing, and the deterioration of biodiversity indicators is the worst in the country. However, the eastern highlands appear to be benefiting from emerging markets within the country as well as close proximity to Kenyan markets. Since 1990 the eastern highlands have experienced major improvements in the average level of household durable goods, the availability of energy sources such as kerosene for lighting, and improvements in the availability of consumer goods.

In addition to comparing zones of different agricultural potential, it is instructive to examine human welfare and natural resource indicators in the context of variations in market access and population density. There is very little difference in indicators of education and educational change between low and high market access areas (Table A1), but there has been greater improvement in the availability of education in low population density areas than high density areas since 1990 (Table A2 and A3). Health services have improved more in low market access areas since 1990. Housing quality, particularly the proportion of households with metal roofs, has increased more in high market access and high population density areas, as has the availability and quality of drinking water. These trends suggest government investment is taking place in less-favored areas, but not in all sectors.

Indicators of natural resource conditions show land degradation occurring most intensively in high market access and population dense areas. In addition to major decreases in average farm size, soil fertility and moisture holding capacity are deteriorating more in these areas. Other resources are also being affected, with greater decline in the availability of energy for heating and cooking, the availability of grazing land, and plant and animal biodiversity in high market access and high population density areas (Tables A3 and A4). These trends suggest that population and market pressure are important factors affecting natural resource degradation.

LIVELIHOOD STRATEGIES

Examining data that reflect current occupations and occupational change allows us to say something about emerging trends in livelihood strategies. In 1999, cereal crop production, coffee production, root crop production, and banana production were the most common primary activities undertaken by men (Table A5). Other important occupations for men in some communities include production of other storable annual crops such as pulses and oilseeds, horticulture, cash crops such as cotton and tobacco, keeping cattle and various non-farm activities (mainly trading, brewing beer and making charcoal) (Tables A6 and A7).

Women have less diversified occupations than men (Table A9). Eighty percent of villages indicated household maintenance activities as the primary activity for women. Women are also involved in producing other crops (especially food crops), tending livestock, and non-farm activities (crafts, brewing beer and trading) (Tables A10 and A11).

Livelihood strategies vary throughout the country. In the unimodal rainfall areas root crop production is the most common primary activity for men. Cereal crop production and cotton are also important livelihood strategies for both men and women. Occupations are not highly diversified in this zone. Trading, crafts and brewing beer are not important for men or women in this region, although keeping livestock other than cattle is a tertiary activity for some women. There has been very little occupational change for either men or women in this area since 1990 (Tables A8 and A12). This may be in part due to the fact that although yields for cassava, maize and other crops have decreased, they have decreased less so than in other agroclimatic zones (Table A13).

In the bimodal low rainfall zone the production of other storable annual crops, banana production and keeping cattle are important activities for men. For women, the production of storable annual crops is an important activity; second only to household activities and maintenance. The importance of fast growing crops such as pulses and oilseeds has increased since 1990, possibly due to increased problems of drought. Yields are decreasing in this region, with above average decreases in groundnut, cassava and sweet potato yields (Table A13). There has been an increase in the importance of keeping cattle in this region, and the proportion of households owning either local and crossbred cattle has increased (Table A14). This area appears to be moving towards the intensification of dairy production (using crossbred cows) as well as expanded extensive livestock production (using local breeds), as hypothesized by Sserunkuuma et al. (2001). Trading in this region is an important secondary occupational strategy, likely due to relatively good market access in some parts of the southwest cattle corridor.

In the bimodal medium rainfall zone, the traditional coffee-banana system is declining while production of cereals, root crops, other annuals, and cattle are increasing in importance. By contrast, banana and coffee are increasing in importance in the high potential bimodal areas. Yields for food crops (including banana) are decreasing in the bimodal rainfall areas, though the use of purchased inputs (including fertilizer, pesticide and improved seed) has increased (Table A13 and A19). The importance of keeping cattle as a livelihood strategy has increased in both the bimodal medium and high potential zones. Ownership of crossbred cattle is increasing in the bimodal high rainfall areas, suggesting a movement towards dairy production (Table A14). Off-farm activities, including trading (in the bimodal high zone) and beer brewing (bimodal medium) are important activities for men, indicating more diversified livelihood strategies in these regions.

In both the southwest and eastern highlands production of cereals and bananas are the most common primary activities for men, though arabica coffee production is also a very important activity in the eastern highlands (Table A6 and A7). Women in the southwest highlands have the most diversified livelihood strategies of all regions, with cereal production being their most important activity. Cereal crop yields are declining the most in the southwest and eastern highland agricultural potential zones, supporting the hypothesis of persistent land degradation in these areas. Keeping cattle is an important secondary activity for men in both highland regions, but the proportion of households with crossbred cattle has increased in the eastern highlands while not in the southwest highlands (Table A14). Proximity of the eastern highlands to markets may be facilitating the development of dairy production. Ownership of other livestock has decreased in both highland areas, but especially in the southwest highlands.

Areas with good market access and high population densities appear to have similar trends in livelihood strategies. For example, coffee production is clearly associated with high market access and high population density areas. Conversely root crop production (mainly cassava) is most common as a main activity in the less-favored low market access and low population density areas. Production of other storable annual crops (pulses and oilseeds) is a primary occupational strategy for women only in high market access and high population density areas, and has increased in importance as a livelihood strategy for both men and women in these areas (Tables A8 and A12), even though yields for beans in these areas have decreased since 1990 (Table A13). Keeping cattle is more common in low market access and low population density areas. Crossbred cattle are increasing in high market access areas. Keeping other livestock (including goats, chickens, sheep and rabbits) is decreasing in high market access and high population density areas. Many of these changes support the hypotheses about comparative advantages of different livelihood strategies in different development domains proposed by Sserunkuuma et al. (2001).

LAND USE AND LAND MANAGEMENT

Significant changes in land use and land management have occurred since 1990. The area under cultivation, settlements and planted woodlots is increasing, while fallow area, grazing land, natural forest, woodlands and wetlands are decreasing (Table A15). A wide variety of soil and water conservation methods are used throughout the country, though the proportion of households using even the most common methods is relatively low. For example, on average only 30% of households incorporate crop residues, 22% use mulching, and 22% use trash lines (these being the most common conservation practices) (Table A16). Tree planting, use of animal manure, mulching, and composting have increased significantly since 1990, while use of fallow, fallow strips and zero tillage are declining (Table A17). Use of some purchased inputs, particularly improved seeds, animal vaccines and medicines is relatively common, with more than half of farm households estimated to use these inputs (Table A18). Use of fertilizers and herbicides is uncommon, with fewer than 10% of households using them. Use of all kinds of purchased inputs is generally increasing, but especially use of purchased animal feed/fodder and improved seeds.

In the unimodal rainfall areas land under fallow is perceived to have declined significantly, yet fallows were still averaging 1.1 years in the late 1990s, the longest in the country. Grazing land has also declined in this area while settlements and cultivated land are increasing. Incorporation of crop residues, trash lines, hedges and live barriers are the most common soil and water conservation technologies. There has been little change in the proportion of households using these and other soil and water conservation technologies since 1990. There is above average use of fertilizer, pesticides and animal medicines in this zone, but below average use of herbicides and purchased fodder. Use of fertilizers, herbicides, and purchased fodder has increased significantly, however.

In bimodal low potential areas settlements and cultivated area are increasing, and grazing lands are decreasing. Mulching and tree planting on farmlands are the most common soil and water conservation technologies being used in this area. Nearly 60% of households use mulching, probably because of the need to conserve soil moisture for banana production in this relatively dry region. Use of improved seeds is somewhat more common in this zone than elsewhere, while the use of purchased fodder, vaccines and animal medicines is below average. The use of purchased fodder has been decreasing since 1990, while use of other purchased inputs has become more common.

The largest increase in cultivated area and decline in fallow are observed in the bimodal medium agricultural potential zone. Smallholders may be expanding or shifting cultivated area to maintain production levels as land degradation, pests and other factors reduce yields. Incorporating crop residues and constructing trash lines are the most common soil and water conservation technologies in this area. Changes in the use of soil and water conservation technologies are not significant. Given declines in yields and changes in land use in this area, there may be opportunities to improve land management through the promotion of soil and water conservation technologies. Use of most inputs is close to average in this zone. Use of improved seed, purchased fodder and animal medicines has significantly increased since 1990.

Land use change has been significant in the bimodal high potential areas. Area under cultivation is increasing, grazing land is declining, wetlands are decreasing (probably due to drainage for cultivation or brick making), and there have been major increases in settlement area. Planting trees, mulching and the use of animal manure are the most common land management practices (used by about one-third of farmers). Surprisingly, use of all purchased inputs is average or below average in this region, despite relatively high access to markets and technical assistance programs in this region. However, there has been a major increase in the use of fertilizer in this region since 1990, and use of improved seeds has also increased significantly.

Land scarcity is extreme in the densely populated southwest highlands region. Fallowing for one year or more is no longer commonly practiced in any of the sample communities in this zone, and fallow strips are used by only 6 percent of households. In the late 1990s the average fallow was 0.3 years among households that use short-term fallow, decreasing from 0.8 years in the late 1980s. Since 1990, area under settlements and planted woodlots has increased, while all other land uses have remained constant or declined on average. Mulching, manuring, composting, trash lines and incorporation of crop residues are relatively common soil and water conservation practices practiced by at least one-fourth of farm households in the southwest highlands. The use of fallow strips has declined somewhat; while there has been little change of most other conservation practices. Purchased input use in the southwest highlands is close to the average for the country for most inputs. Use of purchased fodder, herbicides and fertilizer have increased significantly since 1990 in this zone.

Land is also very scarce in the eastern highlands, which are also densely populated. Fallowing is practiced by less than 10% of households, and the average fallow period for households using fallow has declined from 1.4 years in the late 1980's to 0.6 years in the late 1990's. As in the southwest highlands, settlements and planted woodlots are the only land uses that are increasing. A wide variety of soil and water conservation practices are used in the eastern highlands. Use of grass strips, contour plowing, incorporation of crop residues, manuring, tree planting, and soil bunds are all relatively common. Use of animal manure, incorporation of crop residues and planting grass strips have increased since 1990, while use of other practices has not changed significantly. The eastern highlands zone has the highest proportion of households using many purchased inputs, including fertilizer, herbicides, improved seed, fodder, animal vaccines and animal medicines. The use of fertilizer, pesticides, vaccines and animal medicines has increased significantly in this zone since 1990. Proximity to the Kenya market is likely a main reason for relatively high and increasing use of purchased inputs in this zone.[15]

Access to markets and population density appear to have significant impacts on land use and many land management practices. In low market access and low population density areas there have been larger decreases in the proportion of land area under fallow, grazing areas, and forest/woodland; probably because more of such land uses were still available in these areas in the early 1990's. Settlement areas increased the most in low population density areas, likely for the same reason. Tree planting is more common in high market access and densely populated areas, probably because of better markets for tree products in such areas. Mulching, composting, and manuring are also more common in high market access and high population density areas. Use of these practices has also increased more in high access and densely populated areas since 1990. These results are consistent with the Boserup hypothesis that greater land scarcity and land values (whether population or market induced) promote greater investment in land conservation and improvement. However, incorporation of crop residues is more common in less densely populated areas, probably because use of annual crops and tillage is greater in these areas, which are generally drier and have lighter soils than more densely populated areas of Uganda. There appears to be little relationship between the proportion of households using most other soil and water conservation technologies and either market access or population density. Use of improved seeds and purchased fodder are significantly more common in more densely populated areas, and purchased fodder is also more common in areas of higher market access.

[15] The use of purchased inputs in the eastern highlands is relatively high compared to the rest of Uganda, but is still low by international standards.

The use of herbicides, purchased fodder and animal vaccines is increasing more rapidly in high market access and high population density regions of the country.

These results suggest that higher market access and higher population density are causing a general pattern of agricultural intensification involving decreased use of land for fallow, grazing area, forest or woodland; planting of trees and adoption of several soil and water conservation practices; and increased use of several purchased inputs. Interestingly, however, fertilizer use does not appear to be strongly affected by better access to markets or population pressure, except in the eastern highlands region as a result of access to the Kenya market. The limited impact of market access on fertilizer use ay be because of the dominance of the banana-coffee system in high market access areas of central Uganda, which has traditionally used little inorganic fertilizer.

POPULATION

There is no doubt that population is increasing rapidly throughout much of Uganda. Recall data on the number of households in LC1s in 1990 and 1999 from the community survey indicate an average annual rate of growth of 4.9% (Table A21). This growth rate seems very high and should be validated with secondary data. The highest rates of growth are observed in the unimodal rainfall areas and the bimodal high potential areas, while the bimodal medium potential areas have the lowest growth rate. There has been greater population growth in low population density areas. People may be migrating to these areas in response to small farm sizes and land degradation in other areas. This may explain why extensive land uses such as fallow, grazing and forest/woodland are declining more rapidly in less densely populated areas.

PRESENCE OF PROGRAMS AND ORGANIZATIONS

Since the late 1980's there has been a remarkable increase in the number of programs and organizations operating in communities in Uganda, including various government programs, non-government organizations from outside local communities (NGOs), community-based organizations (CBOs), and foreign, religious, and private for-profit organizations (Table A22). Government programs are more common in the bimodal high potential zone and southwest highlands. These organizations generally deal with issues such as water supply, natural resource management, health and educational services. They are relatively equally common in low vs. high market access areas, and low vs. high population density areas. NGOs are most common in the bimodal high and bimodal low potential zones, and are much more common in high market access and high population density areas. Whether NGOs are actively seeking out higher potential and higher access areas to implement their programs is an interesting question worth further study. CBOs are most common in the southwest highlands, one of the poorest regions of the country.

Programs and organizations that deal with agriculture and veterinary services and the environment (i.e. those that are likely to address the proximate causes of land degradation) are most common in the bimodal high potential zone (Table A23). Land degradation is a serious problem in this area. However, land degradation is also a serious problem in other areas such as the southwest highlands, which have fewer programs or organizations with a main focus on the environment. Programs and organizations that deal with income generation, poverty eradication and social development are most common in the unimodal and southwest highland areas, some of the poorest areas of the country.

DEVELOPMENT OF INFRASTRUCTURE AND SERVICES

Between 1990 and 1999 there was a considerable increase in the use of services, particularly of private transportation (Tables A24 and A25). In the bimodal high agricultural potential zone, the use of minibus transport became more common, while public bus transport became less common. The use of public motorbike transport (locally known as "boda boda") increased throughout Uganda. There were also increases in the use of other private services such as grain mills and input supply dealers, with the changes in input supply dealers taking place mainly in low market access, low population density areas. Both primary and secondary private school development was significant in the bimodal low and bimodal high agricultural potential regions, and in the unimodal areas the use of health clinic services has improved significantly. There has been a general trend toward privatization of services over the past 10 years, though government involvement has increased in some areas, especially primary education.

Interestingly, although there has been a marked increase in use of infrastructure and services, particularly in the areas of transportation and health, there has been little change in distance to infrastructure and services (Table A26). Of note are small improvements in the distance to tarmac roads in the bimodal low, medium and high zones, though there was no change in distances in the southwest and eastern highlands. There were surprisingly small changes in distance to the nearest trading center given increases in the importance of trading as a livelihood strategy. Distance to nearest grain mill improved throughout the country – especially in the southwest highlands (decreasing from an average of 10.4 miles in 1990 to 5.4 miles in 1999) – as a result of private investment in mills. There is no discernable change in the distance to fuelwood sources even though people perceived decreases in the availability of fuelwood for cooking. Changes in distance to health services are minimal – suggesting that the general improvement in health is related to improvements in quality of health services rather than proximity of facilities.

EMERGING TRENDS IN DEVELOPMENT AND LAND MANAGEMENT

The general picture of development in Uganda between 1990 and 1999 is of significant improvement in many aspects of human welfare but persistent degradation of land and other resources. Food insecurity is still a major problem, especially in the less rainfall assured areas of the country. Land degradation is most serious in the densely populated highland regions. The average annual rate of population increase is very high and may be one of the main factors influencing land degradation throughout the country.

There have been a variety of changes in livelihood strategies. There have been increases in the production of storable annual crops such as maize, pulses and oilseeds, indicating a move towards crops with a shorter growing season. Cattle production has increased in several regions, and ownership of crossbred cattle has also increased, indicating the development of dairy production. Livelihood strategies are diversifying as trade and other non-farm employment become more important, particularly in high population density regions.

With respect to land management there have been increases in purchased input use and the adoption of some soil and water conservation technologies. High market access areas are benefiting from privatization and market liberalization that make inputs easier to obtain. However, use of purchased inputs is still fairly limited (especially for fertilizer) and may not be substantially affecting average yields. In the high potential bimodal areas and eastern highlands, where rates of input use are among the highest in the country, soil fertility and other aspects of land degradation are perceived to be worsening. The proportion of households adopting new soil and water conservation technologies is low, and suggests the need for programs and organizations to provide extension support to catalyze adoption of these technologies. At present, the involvement of such programs and organizations is limited, and in the case of NGO's, is biased towards higher potential areas in the Lake Victoria crescent.

4. DETERMINANTS AND IMPLICATIONS OF DEVELOPMENT PATHWAYS AND LAND MANAGEMENT

In this section, we investigate the development pathways and changes in land use and land management occurring in Uganda, their determinants and implications for agricultural productivity, natural resource conditions and human welfare. First, we identify the dominant development pathways using factor analysis of the community survey data, and then investigate their determinants and implications using econometric analysis.

DEVELOPMENT PATHWAYS IN UGANDA

Using factor analysis of the primary occupations of men and changes in the top three occupations since 1990, we identify six dominant development pathways in the study region of Uganda (Table 1).[16] 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

[16] As discussed in Section 3, the primary occupation of women is almost always household maintenance activities, except in the southwest highlands. Changes in most occupations for women are similar to those for men. Thus we focused on the occupations of men as a reasonable way of simplifying the classification problem.

("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").

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

	Rotated Factor Loadings					
Variable	1	2	3	4	5	6
Primary occupation						
- 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						
- 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

The first five development pathways represent a pattern of increasing specialization in an already important activity. Given the extent of market liberalization in Uganda during the

1990's, it is not surprising that increasing economic specialization based upon local comparative advantages took place.

Using econometric analysis, we investigate the factors associated with these different comparative advantages (Table 2).

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.

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 income generation or poverty reduction. Promoting increased cereal production may be part of the activities of some of these organizations.

Increased banana and coffee production is more common in the bimodal high and bimodal low rainfall zones than in other agroclimatic zones, and more common where rural markets have developed (though these associations are only weakly statistically significant).

Increased non-farm activities are, not surprisingly, more common where roads and rural markets have developed. Non-governmental organization programs (NGO's) are also associated with increased non-farm activity. In many cases, such programs focus on reducing poverty through promoting income diversification, education and training. Non-farm development is also weakly associated with higher population density.

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 when using two-stage least squares to predict the number of organizations. Other more general factors, such as changes in cotton prices or marketing problems may be more important in determining development of cotton production than the localized factors that were 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. Perhaps such organizations focus their efforts more in poorer subsistence areas where coffee production is less common. That would explain why these results are not robust when using a two-stage estimation.

In general, we find that the factors hypothesized to determine the comparative advantage of different development pathways—including agricultural potential, market access, population density, development of infrastructure, and social capital (as measured by organizational presence)—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 critical for non-farm development. NGO programs appear to foster non-farm development, while CBO's promote cereal production.

CHANGES IN LIVESTOCK USE

Closely associated with changes in livelihood strategies may be changes in livestock ownership and use. Ownership of local cattle varieties is increasing more in areas where cereal production is increasing (Table 3), possibly because of complementarities between cattle and cereal production (e.g., use of oxen for draft power and grain straw as fodder, benefits of manure in crop production). In addition, problems of pests and diseases affecting animals are often greater in more humid perennial crop areas than in dryer cereal growing areas. Consistent with this, we find declines (or less increase) in cattle ownership in areas where banana and coffee crops are increasing. Conversely, farmers may invest in cattle as a store of wealth in areas where coffee production is declining due to coffee wilt disease or other problems. Local cattle use is also declining where horticultural production is increasing, perhaps because cattle are less beneficial for (and may cause damage to) horticultural crops. Local cattle use is increasing more in communities having access to irrigation, perhaps due to greater availability of crop residues for feed.

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

Explanatory Variable	Local cattle	Crossbred Cattle	Goats	Sheep	Pigs	Chicken
Agro-Climatic Zones (cf. Unimodal)						
- Bimodal low	-0.143	2.003***[R]	-0.547	-0.508	-0.034	0.201
- Bimodal medium	0.370	0.739	-0.627	-0.268	0.008	0.297
- Bimodal high	-0.605	1.843***[R]	-0.965*	0.341	0.311	-0.112
- Southwest highlands	-0.434	-2.379**[R]	-1.835**	-0.059	-0.347	-1.057*
- Eastern highlands	-0.851	2.709***[R]	-0.844	-1.379**[R]	0.039	0.322
High market access	0.076	0.716	-0.015	-0.992***[R]	0.645**[R]	0.772***[R]
High population density (> 100/km^2)	-0.047	0.071	-0.041	-0.476	-0.078	-0.235
Irrigation in village	0.883**[R]	0.474	0.539**	-0.140	0.296	-0.520
Development Pathways						
- Increase of cereals	0.528***[R]	-0.018	0.164	-0.049	0.025	0.044
- Increase of banana and coffee	-0.215*[R]	-0.283	-0.103	-0.158	0.084	-0.136
- Increase of non-farm activities	0.186	0.447**[R]	-0.032	-0.071	-0.131	-0.052
- Increase of horticulture	-0.215**[R]	0.084	0.004	0.161	-0.078	0.116
- Increase of cotton	0.080	-0.000	0.003	0.145	-0.334***[R]	0.035
- Stable coffee production	-0.002	0.084	0.044	-0.050	0.149	-0.011
Change in ln(number of households)	0.364	0.447	-0.396	0.324	-0.207	-0.074
Change in dist. to tarmac road (miles)	-0.0036	0.0884***[R]	-0.006	0.0259	-0.0349***[R]	-0.0103
Change in dist. to rural market (miles)	0.0069	-0.0408	-0.091***	0.0674	0.0011	-0.0300
No. of government programs	-0.138	0.454**[R]	0.025	-0.319*[R]	-0.127	0.279**
No. of NGO programs	-0.161	0.l013	-0.193	0.157	0.254	0.124
No. of community-based organizations	-0.196	-0.027	0.060	-0.131	0.005	-0.042
Prob. > F	0.0003	0.0002	0.3360	0.2985	0.0023	0.2893

[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.

Adoption of crossbred cattle is increasing, especially in the bimodal low and high rainfall zones and the eastern highlands, but not in the southwest highlands, probably as a result of increased dairy production in these zones. Use of crossbred cattle is also increasing in areas where non-farm activities are important, which, as we saw previously, are generally areas where market access is improving. However, controlling for development pathway, adoption of crossbred cattle has been greater where there has been less improvement in roads. This finding is surprising, since we would expect improved road access to favor dairy development. Government extension programs have favored dairy development, and may help to explain dairy development even in areas further from markets.

Sheep ownership is declining in the eastern highlands relative to other zones, in areas of higher market access, and where more government programs are operating. This may be due to displacement or replacement of sheep by crossbred cattle in such areas. Demand for sheep meat may be growing more slowly than demand for beef or milk as a result of lower income elasticity of demand.

Ownership of goats is declining in the southwest highlands, perhaps because of scarce fodder resources or efforts to limit damage to vegetation caused by goats. Increased goat ownership is more common where there is irrigation, and where rural markets are developing.

Ownership of pigs and chicken is increasing more (or declining less) in areas of higher market access. This is consistent with our hypothesis that opportunities for intensive production of such small animals are likely to be greater in areas close to urban markets. Consistent with this, ownership of pigs has also increased more commonly where road access has improved. Pigs have declined in cotton producing areas. Perhaps feed sources are scarce in these areas as a result of an emphasis on cotton production. Government programs are positively associated with increased chicken production.

As with the development pathways, changes in ownership and use of different types of livestock are affected by different factors. Agroclimatic conditions and changes in market access strongly influence adoption of crossbred dairy cattle. Market access also favors intensive livestock such as pigs and poultry, but reduces extensive livestock activities such as sheep herding. Government programs have also apparently contributed to intensive livestock activities. The development pathways are associated with changes in livestock use, particularly of cattle.

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 4).

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

Explanatory Variable	Cultivated	Fallow	Grazing	Forest	Woodlots	Wetlands	Settle-ments
Agro-Climatic Zones (cf. Unimodal)							
- Bimodal low	0.152	0.257	0.285	0.222	0.195	1.299	0.309
- Bimodal medium	0.532	0.140	0.188	-0.496	-0.242	-0.029	0.115
- Bimodal high	0.364	0.501	-0.516	-0.161	-0.267	-0.246	1.058*
- Southwest highlands	1.251**[R]	0.881	-0.118	0.856	0.555	1.390*	0.502
- Eastern highlands	-0.180	0.432	0.097	-0.308	0.368	0.248	0.239
High market access	0.405	0.130	0.128	-0.144	-0.548**	-0.963**[R]	0.215
High population density (> 100/km^2)	0.012	-0.211	0.239	0.125	0.263	0.247	0.795**[R]
Irrigation in village	-1.475***[R]	0.632	0.169	0.948*	0.307	0.804*	0.121
Development Pathways							
- Increase of cereals	0.009	-0.032	-0.230*	-0.223	0.234*[R]	0.165	0.317**[R]
- Increase of banana and coffee	0.408***[R]	-0.108	-0.022	0.153	-0.110	-0.097	0.097
- Increase of non-farm activities	-0.111	-0.056	-0.034	-0.039	0.221*[R]	-0.171	0.122
- Increase of horticulture	0.144	-0.529*[R]	-0.471*[R]	0.069	-0.340**[R]	0.054	0.019
- Increase of cotton	0.067	0.013	-0.060	-0.130	0.091	0.313***[R]	-0.116*
- Stable coffee production	-0.143	0.271	0.202	0.118	0.474***[R]	-0.262**	-0.260*[R]
Change in ln(number of households)	-0.047	0.163	0.029	1.335**[R]	-0.645	0.315	1.500**
Change in dist. to tarmac road (miles)	-0.0401**[R]	-0.0219	-0.0367**[R]	0.0535***[R]	-0.0227***[R]	0.0363***[R]	-0.0142
Change in dist. to rural market (miles)	-0.0950	0.0933	0.0443	0.0352	0.0340	-0.0112	-0.0396
No. of government programs	0.233	-0.242	-0.025	-0.130	-0.088	-0.311	0.327*
No. of NGO programs	-0.247*	0.030	-0.094	-0.104	0.269**	0.144	-0.087
No. of community-based organizations	0.192	-0.171	0.147	-0.191	0.172	-0.404*	0.091
Prob. > F	0.0004	0.5430	0.4379	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.

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, 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 increased cereal production, but negatively associated with stable coffee production.

Fallow land is declining everywhere. We find few factors that lead to a statistically significant difference in this tendency. The one exception is expansion of horticultural production, which is (weakly) associated with decrease in fallow. The findings are similar for grazing land, which is also declining everywhere, but more so in horticultural communities. Interestingly, grazing land is declining less where road access is improving.

Natural 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 Uganda. The negative impact of road access on forest cover 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, and so have less deforestation despite rapid population growth.

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 coffee production is the development pathway. They are declining less in the cotton 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 reductions 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 declining fallow, grazing and woodlot area; and stable coffee production areas more commonly have increasing areas of woodlots but declining area of wetlands.

CHANGES IN LAND MANAGEMENT PRACTICES

Land management practices, such as fallowing; use of mulch, manure or compost; or investments in trees, soil bunds or other land improvements can also be affected by the factors determining comparative advantage and development pathways. The effects of these factors on changes in many land management practices were investigated, though in some cases, the results were not very statistically significant due to changes being fairly small for some practices (e.g., improved fallow, zero tillage, and contour plowing), or changes being similar everywhere (e.g., declines in use of fallow everywhere). Here, we focus only on land management practices for which the analysis had significant explanatory power.[17]

Adoption of land management practices differs across the agroclimatic zones of Uganda (Table 5). Several soil and water conservation practices are increasing more in the eastern highlands than in other areas; including composting, manuring and incorporating crop residues.

[17] That is, we report only results of regressions for land management practices for which the F test for all coefficients being equal to zero was rejected at the 10% level.

Table 5. Determinants of Changes in Land Management Practices (ordered probit regressions)[a]

Explanatory Variable	Fallow Strips	Planting Trees	Mulch	Compost	Manure	Plowing in Crop Residues	Soil Bunds
Agro-Climatic Zones (cf. Unimodal)							
- Bimodal low	1.360**	0.557	0.963*	0.818	0.124	0.060	0.078
- Bimodal medium	-0.293	-0.093	-0.135	0.153	-0.043	-0.443	-11.57***[R]
- Bimodal high	-0.112	0.848	0.067	1.225**	1.111***	0.544	-0.430
- Southwest highlands	-1.198	0.038	0.002	1.315*	0.537	-0.436	-13.71***
- Eastern highlands	0.259	1.348*	0.538	2.007**[R]	1.106***[R]	1.587**[R]	0.982
High market access	-0.616	1.073***[R]	0.087	0.909	0.478*	-0.466	-1.794*
High population density (> 100/km^2)	0.189	-0.224	0.253	0.163	0.009	-0.357	2.345**
Irrigation in village	0.799**	0.303	-0.673*	-0.685	-0.084	0.033	0.026
Development Pathways							
- Increase of cereals	0.234	0.166	0.100	0.152	0.180	-0.045	-0.132
- Increase of banana and coffee	-0.437**[R]	-0.007	0.268**[R]	0.474**[R]	0.249*	0.443***[R]	0.578**[R]
- Increase of non-farm activities	-0.023	-0.162	0.215*	0.207	0.062	0.374**[R]	-0.870**[R]
- Increase of horticulture	-0.022	-0.129	0.240	-0.075	-0.075	0.096	-1.203***
- Increase of cotton	0.240**	0.027	-0.108**[R]	-0.197	-0.167**[R]	-0.020	-1.903
- Stable coffee production	-0.463**[R]	0.213	0.023	0.062	0.254*[R]	0.132	-0.042
Change in ln(number of households)	-1.920**	0.282	-0.741	-0.230	0.367	0.349	-4.907***
Change in dist. to tarmac road (miles)	0.1038***[R]	0.0781*[R]	-0.0104	0.997***[R]	0.0161	0.0383*[R]	-0.0214
Change in dist. to rural market (miles)	0.0180	0.1715	-0.0723	0.094*	0.0869**	0.0424	-0.3374***
No. of government programs	-0.051	-0.021	0.331	0.172	0.059	-0.149	0.578*[R]
No. of NGO programs	0.213	0.137	0.017	0.259*	-0.124	0.067	0.401
No. of community-based organizations	-0.018	-0.163	-0.215	-0.260	-0.309*	0.166	0.487*
Prob. > F	0.0232	0.0005	0.0229	0.0000	0.0000	0.0004	0.0000

[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.

Composting and manuring are also increasing in bimodal high potential areas more than in other zones. Use of fallow strips is generally declining, though not as much in the bimodal low potential areas as in other areas. Investment in soil bunds is occurring to a lesser extent (or not at all) in the bimodal medium rainfall zone and in the southwest highlands. In the latter case, farmers are reportedly destroying soil bunds to harvest the fertile soil that they contain (Olson 1995; Sserunkuuma et al. 2001).

There are significant differences across the development pathways in adoption of soil and water conservation practices. Many soil and water conservation practices—including mulching, composting, manuring, incorporating crop residues, and constructing soil bunds—are increasing more in areas of banana and coffee expansion than other development pathways. 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. By contrast, use of fallow strips is declining more in banana and coffee producing areas and less in cotton areas. Fallow strips are apparently more suited to cotton production, while mulching and manuring are more suited to banana and coffee production. Incorporation of crop residues is becoming more common in non-farm development areas. Investment in soil bunds is lower in both non-farm and horticultural development pathways, perhaps because of higher labor opportunity costs in such areas.

Higher population density is associated with increased investment in soil bunds, consistent with the Boserupian hypothesis of population-induced land improvement (Tiffen et al. 1994; Pender 1998). However, more rapid population growth is associated with reduced investment in soil bunds, probably because increasing land scarcity increases the opportunity costs associated with the land that such bunds occupy. Thus the impacts of population growth on a particular type of land improving investment depend upon the way it affects land and labor costs, as well as the labor and land intensity of the investment. Population growth is also associated with reduced use of fallow strips, consistent with the Boserupian hypothesis of population-induced intensification of land use.

Market access and changes in access to roads and markets have also influenced land management practices. Tree planting has increased more in areas with higher market access, probably because of greater marketability of tree products in such areas. However, improved road access is associated with less increase in tree planting (though this result is only weakly statistically significant). Increasing use of manure is weakly associated with higher market access. Improvements in road access are also associated with less use of fallow strips, 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, perhaps because of greater use of chemical fertilizer where access is improving. However, improved rural market access is associated with increased investment (or less decline in investment) in soil bunds.

The presence of irrigation is associated with less decline in use of fallow strips. Since irrigation enables more intensive use of cultivated land (as noted earlier), it may reduce pressure to abandon fallow practices on rainfed land.

The presence of programs and organizations has limited measurable impact on various land management practices. There are weak statistical associations between the presence of government programs or community-based organizations and investment in soil bunds, and between the presence of NGO programs and increase in composting. The weakness of these associations may be due to the crude measure of organizational activity (number of organizations by type) used in the analysis. Further research on the impacts of programs and organizations, using more refined measures, is needed.

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 support some (but not all) of our hypotheses about the impacts of population pressure and market access on land management practices. In general, the effects of a particular factor on land management appear to be very context-dependent, making generalizations difficult.

CHANGES IN PURCHASED INPUT USE

Use of purchased agricultural inputs such as fertilizers, improved seeds, pesticides and herbicides has generally increased in Uganda, though it remains low by international standards. We find few factors strongly associated with changes in use of fertilizer, pesticides, or herbicides (Table 6).

Table 6. Determinants of Changes in Purchased Input Use (ordered probit regressions)[a]

Explanatory Variable	Fertilizer	Improved Seeds	Pesticide	Herbicide
Agro-Climatic Zones (cf. Unimodal)				
- Bimodal low	0.101	1.116**	-0.680	-0.215
- Bimodal medium	0.058	1.066***[R]	-0.351	0.387
- Bimodal high	0.806	0.658*	-0.223	0.528
- Southwest highlands	-0.483	-0.088	-1.296**[R]	-0.281
- Eastern highlands	1.284**[R]	0.039	0.566	0.074
High market access	-0.091	-0.145	0.144	0.267
High population density (> 100/km^2)	-0.546	0.560*	0.082	-0.064
Irrigation in village	0.815*	0.342	-0.007	-0.677
Development Pathways				
- Increase of cereals	0.127	0.128	0.043	-0.145
- Increase of banana and coffee	-0.041	0.196	0.200	0.156
- Increase of non-farm activities	0.128	-0.137	-0.006	-0.073
- Increase of horticulture	-0.006	-0.281**[R]	0.073	0.242
- Increase of cotton	0.122	-0.478***[R]	-0.167	0.092
- Stable coffee production	0.126	-0.020	-0.082	0.209
Change in ln(number of households)	0.055	0.156	-0.194	0.145
Change in dist. to tarmac road (miles)	-0.0114	0.0185**[R]	-0.0174	-0.00195
Change in dist. to rural market (miles)	0.0757*	-0.0016	-0.0419	0.0537
No. of government programs	-0.557***[R]	0.390***	0.130	-0.085
No. of NGO programs	0.069	-0.244*	-0.240	0.082
No. of community-based organizations	0.021	-0.432**	0.127	-0.018
Prob. > F	0.0040	0.0054	0.3509	0.6627

[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.

Fertilizer use has increased most in the eastern highlands, while pesticide use has declined in the southwest highlands. In the eastern highlands, farmers have greater access than other zones to fertilizer and other inputs from Kenya, and at lower costs. In the southwest, some NGO programs are promoting integrated pest management and other low input approaches, and are apparently achieving some success. Surprisingly, increased fertilizer use is less common where more government programs are operating. Some of these programs may be promoting alternatives to fertilizer (though we find no strong associations of government programs with fallowing, manure or compost use). Further research is needed to understand and explain this association.

Changes in use of improved seeds are associated with several factors. Increased use of improved seeds is more common in the bimodal low and medium rainfall zones than other zones, perhaps because some of the types of crops that are suited to these zones are ones for which successful improved varieties have been introduced in recent years. Mosaic-resistant cassava is one example. Increased use of improved seeds is less common in the horticultural and cotton development pathways, perhaps because these areas were already using improved seeds and/or because there have been fewer successful new varieties of these types of crops. Surprisingly, use of improved seeds has increased less where road access has improved. Government programs are associated with increased use of improved seeds, while CBO's and NGO's are (weakly) associated with less use. The negative effect of CBO's and NGO's is puzzling, as is the negative effect of increased road access; further research is needed to validate and explain these results.

CHANGES IN YIELDS

Despite increases in use of purchased inputs and several soil and water conservation practices, survey respondents reported declining yields of all crops in all zones of the country.

The most commonly cited reasons for declining yields are increased incidence of pests and diseases, declining soil fertility and changes in weather. Although these reported trends may be overly pessimistic, and need to be verified by other data sources, it is useful to try to understand factors leading to differences in these reported trends, since there are significant differences across communities.

There are substantial differences in yield trends for some crops across agroclimatic zones, especially for millet, cassava, and sweet potatoes (Table 7).

Table 7. Determinants of Perceived Changes in Crop Yields (ordered probit regressions)[a]

Explanatory Variable	Maize	Millet	Beans	Ground-nuts	Cassava	Sweet Potatoes	Bananas
Agro-Climatic Zones (cf. Unimodal)							
- Bimodal low	-0.110	-1.145	0.036	-0.680	-1.799***[R]	-0.969**	-1.070**
- Bimodal medium	0.269	-2.185***	-0.617	-0.584	-1.325***	-0.003	-1.070***
- Bimodal high	-0.139	-1.513**	-0.779*	-0.930*	-1.339***[R]	-1.032**	-0.477
- Southwest highlands	-0.994*	-2.542***	-1.134*	-1.171	-1.004	-1.157**	-0.583
- Eastern highlands	-0.444	-3.707***[R]	0.482	-1.852*[R]	-2.423***[R]	-2.430**[R]	-0.339
High market access	-0.211	0.413	0.330	-0.180	0.595*	-0.578	-0.033
High population density (> 100/km^2)	0.511*	-0.585	-0.106	0.406	0.646**[R]	0.279	-0.966**[R]
Irrigation in village	0.109	0.552	-0.043	-0.019	-0.797*[R]	-0.467	0.098
Development Pathways							
- Increase of cereals	-0.289**	-0.354	-0.083	-0.064	0.173	-0.053	-0.032
- Increase of banana and coffee	-0.256	-0.342	-0.040	-0.164	-0.040	0.129	0.328*[R]
- Increase of non-farm activities	-0.042	-0.074	0.101	0.086	-0.124	-0.025	0.150
- Increase of horticulture	0.015	0.159	0.045	-0.135	0.035	0.031	0.094
- Increase of cotton	-0.032	0.218	0.263*[R]	0.078	-0.042	0.002	0.260*
- Stable coffee production	-0.030	-0.319	-0.115	-0.303**[R]	-0.100	-0.081	-0.176
Change in ln(number of households)	1.151**[R]	-1.107	0.130	0.640	0.054	0.686	-0.387
Change in dist. to tarmac road (miles)	-0.0045	-0.340***[R]	-0.0037	0.0597***[R]	-0.0328**[R]	0.0377***[R]	-0.0239**[R]
Change in dist. to rural market (miles)	-0.0576	0.0479	0.0724	0.0263	0.0103	0.0874*[R]	0.1356**[R]
No. of government programs	0.129	-0.942***	-0.050	-0.041	0.307**[R]	0.246*	-0.639***
No. of NGO programs	-0.178	-0.486**[R]	-0.033	-0.047	-0.142	-0.197	0.210
No. of community-based organizations	0.180	-0.007	-0.273	-0.298	-0.106	-0.117	0.117
Prob. > F	0.0946	0.0006	0.0622	0.0823	0.0207	0.0008	0.0155

[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.

Yields of these crops (and apparently others, though the statistical significance is low) have declined more in the bimodal rainfall zones and in the highlands than in the unimodal rainfall zone. This suggests that changes in rainfall patterns and/or pests and diseases (which were cited by many respondents in bimodal areas in the characterization studies of Sserunkuuma et al. (2001) and Bashaasha (2001)) are at least partly responsible for declining yields in the bimodal rainfall areas. Yield declines for several crops have been worst in the eastern highlands. Yield declines for bananas have been worst in the bimodal medium and bimodal low rainfall areas, controlling for other factors. Moisture stress for bananas may be particularly severe in these areas, which are not the most suitable for banana production (especially the bimodal low rainfall region).

There are a few differences in yield trends across the development pathways. Maize yields have declined more in the cereals expansion pathway, possibly as a result of expanding production onto less suitable lands and/or depletion of soil fertility. Banana yields have declined less in the banana-coffee expansion pathway, probably as a result of greater land and pest management effort in these areas (Gold et al. 1999). Bean yields have declined less in the cotton pathway, while groundnut yields have declined most in areas of stable coffee production.

Population growth is associated with smaller decline of maize yields, probably as a result of intensified maize production where population is growing rapidly. The decline in cassava yields is less common in more densely populated areas, again perhaps because of greater intensity of management. By contrast, declining banana yields are more common in more densely populated areas. This suggests that farmers are shifting effort from bananas to cassava in densely populated areas, perhaps because of the pest problems and soil infertility affecting banana production, while mosaic resistant cassava is more resistant to disease than traditional cassava and more tolerant of low soil fertility than bananas.

Improvement in access to roads is associated with smaller decline in yields of millet, cassava and bananas, but with greater decline in yields of groundnuts and sweet potatoes. A positive association between road access and agricultural production (at least for some crops) is consistent with the findings of Deininger and Okidi (2001) based on a production function estimation using household data from Uganda. Improved access to rural markets is associated with greater decline in yields of sweet potatoes and bananas. It is difficult to give a simple explanation for why road and market access would contribute to yield declines in some cases and stem yield declines in others. It may be that by promoting increased effort for some crops, road and market development reduce farmers' effort for other crops.

Programs and organizations also have mixed associations with yield trends. Yields of cassava and sweet potatoes are less likely to decrease where government programs are operating, while yields of millet and bananas are more likely to decline. Yields of millet are also more likely to decline where NGO programs worked. These impacts may reflect the emphasis of the programs. If extension programs offer better technologies for some crops than for others, farmers may devote more effort to managing the crops using improved technologies, leading to better yields for those at the expense of other crops. For example, introduction of mosaic resistant cassava may have led farmers to manage cassava more intensively and bananas and millet less intensively, with differential impacts on yields.

The impacts of different factors on yield trends can be complex and sometimes unexpected, and measuring yield trends with confidence is difficult. Further research using household and plot level data is needed to clarify and explain these impacts.

CHANGES IN NATURAL RESOURCE CONDITIONS

One reason cited by many survey respondents for declining yields is land degradation; especially soil fertility depletion. As discussed in Section 4, many indicators of perceived changes in land and other resource conditions suggest a general pattern of natural resource degradation in Uganda. Here we investigate the factors that may explain differences across communities in such changes.

Few factors are associated with perceived changes in soil conditions, especially in soil fertility (Table 8).

Table 8. Determinants of Perceived Changes in Resource Conditions (ordered probit regressions)[a]

Explanatory Variable	Soil Fertility	Soil Moisture	Soil Erosion	Availability of Grazing Land	Quality of Grazing Land
Agro-Climatic Zones (cf. Unimodal)					
- Bimodal low	-0.750	-1.118**	-0.022	-0.072	-0.054
- Bimodal medium	0.024	-0.809**R	-0.236	0.336	-0.113
- Bimodal high	-0.704	-1.893***R	-1.037**	-0.780*	-0.769*
- Southwest highlands	0.183	-1.518**	-0.239	0.135	-0.094
- Eastern highlands	-0.532	-0.344	-1.193*R	-0.328	0.121
High market access	-0.478	-0.312	0.051	0.031	0.098
High population density (> 100/km^2)	-0.387	-0.462	-0.364	0.108	-0.144
Irrigation in village	0.225	0.121	0.145	0.075	0.646*R
Development Pathways					
- Increase of cereals	-0.223	-0.304**	-0.193	-0.281*	-0.243*
- Increase of banana and coffee	0.102	0.315*R	0.152	-0.173	0.068
- Increase of non-farm activities	-0.242	0.133	-0.414**R	-0.098	-0.213
- Increase of horticulture	0.073	-0.052	-0.035	-0.047	-0.226
- Increase of cotton	0.264	0.161	0.031	0.018	0.070
- Stable coffee production	-0.167	-0.011	0.042	-0.104	0.047
Change in ln(number of households)	-1.101	-0.294	0.109	0.794	0.640
Change in dist. to tarmac road (miles)	-0.0219**R	0.0053	0.0041	0.0024	-0.0209**R
Change in dist. to rural market (miles)	0.0231	0.0145	-0.0317	0.0001	0.1532**R
No. of government programs	-0.091	-0.196	-0.275	-0.0761	-0.256
No. of NGO programs	0.219	-0.194	0.279*	0.135	0.164
No. of community-based organizations	-0.117	0.192	0.190	0.272	0.360**
Prob. > F	0.0007	0.0099	0.1321	0.3269	0.0117

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

Explanatory Variable	Availability of forest	Quality of Forest	Availability of Natural Water Sources	Quality of Natural Water Sources	Diversity of Wild Plants Available	Diversity of Wild Animals Available
Agro-Climatic Zones (cf. Unimodal)						
- Bimodal low	0.413	0.593	-0.221	0.331	0.531	0.502
- Bimodal medium	-0.414	0.071	-0.718	0.589	0.485	-0.083
- Bimodal high	0.838*	0.860	-0.182	1.377**	-1.240**[R]	-0.599
- Southwest highlands	0.593	1.790***[R]	0.366	1.081	1.282*	1.615**[R]
- Eastern highlands	-0.366	0.465	0.358	0.743	-7.537***[R]	-1.222
High market access	-0.298	-0.079	0.330	0.378	0.271	0.150
High population density (> 100/km^2)	0.120	-0.673*	0.355	-0.364	-0.757**[R]	-0.709*
Irrigation in village	0.292	1.025**	-0.117	-0.060	-0.180	0.368
Development Pathways						
- Increase of cereals	-0.430***[R]	-0.145	0.149	-0.001	-0.150	-0.078
- Increase of banana and coffee	0.168	0.285**[R]	0.377**[R]	-0.039	-0.076	0.136
- Increase of non-farm activities	0.085	0.204	0.322**[R]	0.510***[R]	-0.360**[R]	-0.233
- Increase of horticulture	0.081	0.184	0.015	-0.239	-0.305**[R]	-0.340**[R]
- Increase of cotton	-0.116	-0.081	0.025	0.062	0.168	0.165**[R]
- Stable coffee production	0.270*[R]	0.118	-0.301*	-0.040	-0.033	0.019
Change in ln(number of households)	0.866	0.736	0.275	-0.119	0.386	-0.088
Change in dist. to tarmac road (miles)	0.0322**[R]	0.0307	-0.0152	-0.0144**[R]	-0.0243**[R]	-0.0329***[R]
Change in dist. to rural market (miles)	0.0427	0.1169*	0.0540	0.1312**[R]	-0.0095	0.0620
No. of government programs	-0.064	-0.299	0.138	0.071	-0.077	-0.211
No. of NGO programs	0.071	0.290*[R]	-0.193	-0.007	0.109	-0.107
No. of community-based organizations	-0.117	-0.078	-0.214	-0.135	0.020	0.137
Prob. > F	0.2479	0.0547	0.1799	0.0005	0.0000	0.0001

[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.

This is probably because major declines in soil fertility were cited in most communities, suggesting that the dominant causes are more general ones, such as a generally poorly developed extension system and input markets, rather than factors that vary greatly across communities. 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.

Perceived changes in soil moisture are, not surprisingly, different in different agroclimatic zones. In general, soil moisture is declining more in bimodal than in unimodal rainfall areas. This is consistent with the finding above that yields are declining more in bimodal areas, and suggests that climate changes in the bimodal areas may be an important cause of declining yields. Soil moisture is also declining more in the cereal expansion pathway, perhaps as a result of tillage practices for cereals. Soil moisture is declining less in the banana-coffee expansion pathway than other pathways, probably due to greater adoption of soil and water conservation practices in the banana-coffee expansion pathway.

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 such as soil bunds in this pathway, as we observed earlier.

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. These results suggest that intensification of cash crop production or development of non-farm activities, which are likely stimulated by these factors, can reduce pressure on grazing lands. 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 programs 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 case of the non-farm development pathway, development of non-farm activities may be reducing pressure on water resources for agriculture. In the banana-coffee expansion pathway, greater adoption of soil and water conservation practices, plus the shading effects of these perennial crops, may be the main reasons for less negative impact on water availability. Increased access to roads is associated with improved water quality, while improved access to rural markets is associated with worsening water quality.

Changes in biodiversity, as perceived by community members as changes in diversity of wild plant and animal types, are associated with similar factors. The diversity of wild plants and animals is declining less in the southwest highlands than in other zones, consistent with the finding noted above that forest quality is better preserved in this zone. The diversity of wild plants is declining most in the eastern highlands and bimodal high rainfall areas. Plant and animal diversity is declining more in more densely populated areas, as one would expect. Horticultural development is associated with greater decline in plant and animal diversity. Plant diversity is also declining more in non-farm development areas, while animal diversity is declining less in cotton areas. In general, biodiversity appears to be declining more in more intensive farming systems. However, diversity of both plants and animals is surprisingly declining less in areas where road access is improving. Perhaps improved access reduces the need to collect wild plant species or hunt animals for food or other purposes.

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, and plant and animal biodiversity; but it has also contributed to deforestation. Irrigation appears to reduce pressure on grazing lands and forests. Population pressure is associated with declining forest quality and biodiversity. 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

As noted earlier, many indicators of perceived changes in human welfare show improvement in Uganda, despite widespread perception of declining yields and worsening resource conditions. 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 9).

Table 9. Determinants of Perceived Changes in Welfare Conditions (ordered probit regressions)[a]

Explanatory Variable	Prop. of Houses with Mud Floor	Prop. of Houses with Metal Roof	Average Farm Size	Prop. of Households With Adequate Food	Food Availability	Nutrition of Children
Agro-Climatic Zones (cf. Unimodal)						
- Bimodal low	-0.139	1.191**	-2.096**[R]	-1.080**	-1.575***[R]	-0.505
- Bimodal medium	-0.002	0.849*	0.153	0.167	-0.243	0.001
- Bimodal high	-0.097	0.726	-2.356***[R]	0.096	-0.818*[R]	-0.467
- Southwest highlands	-1.682**	1.844**	-0.881	-0.594	-1.960**[R]	-2.131***[R]
- Eastern highlands	-0.491	0.412	0.071	-0.698	-0.868	-0.201
High market access	-0.103	0.385	0.332	0.254	-0.111	-0.050
High population density (> 100/km^2)	0.194	1.082***[R]	-1.006**	-0.502	-0.454	-0.163
Irrigation in village	-0.355	-0.804**	-0.457	0.827**[R]	-0.593	-0.688*[R]
Development Pathways						
- Increase of cereals	0.018	0.077	-0.077	0.044	0.077	0.314**[R]
- Increase of banana and coffee	0.407**[R]	0.109	0.644**[R]	-0.004	0.628**[R]	0.414***[R]
- Increase of non-farm activities	-0.045	-0.065	-0.323	-0.178	-0.017	0.007
- Increase of horticulture	0.226	0.177	-0.370	-0.207	0.054	-0.027
- Increase of cotton	-0.027	-0.141	0.017	0.030	0.006	0.142
- Stable coffee production	0.214	0.129	0.215	-0.041	0.100	-0.020
Change in ln(number of households)	0.026	1.376**	-1.396**	1.501***[R]	0.529	-0.585
Change in dist. to tarmac road (miles)	-0.0327***[R]	-1.134***[R]	-0.0493***[R]	-0.0319***[R]	-0.0321***[R]	0.0038
Change in dist. to rural market (miles)	-0.0572	-0.302	-0.0395	0.0590	0.073	0.0353
No. of government programs	0.235	0.016	-0.223	0.252	-0.068	0.030
No. of NGO programs	0.024	-0.061	-0.192	-0.068	0.044	0.329**[R]
No. of community-based organizations	0.360**	-0.194	-0.499*	0.166	-0.030	0.449**[R]
Prob. > F	0.0002	0.0000	0.0003	0.0027	0.0133	0.0303

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

Explanatory Variable	Infant Mortality	Availability of Drinking Water	Quality of Drinking Water	Ownership of Consumer Durables	Ability to Cope with Drought	Availability of Energy Sources for Cooking/Heating
Agro-Climatic Zones (cf. Unimodal)						
- Bimodal low	0.570	-0.109	-0.732*[R]	1.095**	0.582	1.214**
- Bimodal medium	0.207	0.234	-0.270	0.764**[R]	0.247	0.901*[R]
- Bimodal high	0.922**[R]	0.765	0.530	0.815**[R]	-0.283	-0.590
- Southwest highlands	0.726	-0.022	0.269	-0.432	0.611	1.351**
- Eastern highlands	-0.448	0.309	1.264	1.500**	-0.358	-1.745**
High market access	-0.438	0.691**	0.941***	0.424	0.227	0.174
High population density (> 100/km^2)	-0.164	0.055	-0.209	0.324	0.231	-0.795**
Irrigation in village	0.937**	-0.095	-1.137***[R]	-0.892**	-0.416	0.698*
Development Pathways						
- Increase of cereals	0.284*[R]	-0.075	0.109	0.020	-0.194	-0.429***
- Increase of banana and coffee	-0.263	0.293**[R]	0.308**[R]	0.155	0.246	-0.024
- Increase of non-farm activities	-0.202	0.020	0.173	-0.016	0.184	0.056
- Increase of horticulture	0.010	-0.048	0.083	0.141	-0.118	0.196**
- Increase of cotton	0.067	-0.092	0.228*[R]	-0.137	-0.201**[R]	-0.009
- Stable coffee production	0.042	-0.199	-0.193	0.044	-0.062	-0.263**
Change in ln(number of households)	0.250	-0.0107	-1.231**[R]	-0.558	0.854	-0.560
Change in dist. to tarmac road (miles)	-0.0037	-0.0072	-0.0212***[R]	-1.223***[R]	-0.021*[R]	-0.0183*
Change in dist. to rural market (miles)	0.0229	0.0386	0.0518	-0.094	-0.004	-0.0265
No. of government programs	-0.097	0.234	0.475***	0.186	-0.036	0.092
No. of NGO programs	0.274*	0.175	0.228	-0.015	-0.219	-0.360***
No. of community-based organizations	0.002	0.070	-0.080	0.025	0.047	-0.252*
Prob. > F	0.1304	0.1216	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.

In the bimodal low rainfall zone, housing quality (as indicated by houses with a metal roof), ownership of consumer durables and availability of energy sources have improved more than in most other zones; while average farm size, the proportion of households with adequate food, food availability and drinking water quality have declined more than in most other zones. Housing quality, ownership of consumer durables and availability of energy sources have also improved in the bimodal medium potential zone compared to unimodal areas. In the bimodal high rainfall zone, infant mortality and ownership of durable goods have improved (relative to unimodal areas), while average farm size has declined more than in all other zones and food availability has also declined. In the southwest highlands, use of metal roofs has increased more than in other zones, but use of mud floors has declined the least. Food availability and child nutrition have declined the most in this zone, while availability of energy sources has declined less than in most other zones. In the eastern highlands, ownership of durable goods has improved the most, while availability of energy sources has declined the most.

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, food availability, housing quality (increased use of metal roofs and reduced use of mud floors), farm size (less likely to decline), 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 and reduced drinking water quality, but also with improvements in housing quality, as measured by increased use of metal roofs. 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 between maize yields and population growth noted earlier is consistent with this explanation.

Irrigation is associated with improvements in several welfare indicators, including the proportion of households having adequate food, reduction in infant mortality, and availability of energy sources. On the other hand, it is also associated with less improvement in other indicators, including improvements in housing quality (use of metal roofs), 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 housing quality (less use of mud floors), average farm size (less decline), food availability, child nutrition, and availability and quality of drinking water. In the cereals expansion pathway, child nutrition has improved and infant mortality declined 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.

Programs and organizations also have impacts on welfare indicators. Government programs are strongly associated with improved drinking water quality, probably because some of these programs focus on developing water supplies. NGO programs are associated with improvements in child nutrition and reduced infant mortality, but also with reduced availability of energy sources for heating and cooking. 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. CBO's are also associated with improvements in child nutrition but reduced availability of energy sources. In addition, they are associated with improvements in housing quality, as indicated by reduced use of mud floors. These findings are consistent with the emphasis of most CBO's on poverty reduction.

In general, 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.

5. CONCLUSIONS AND IMPLICATIONS

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 ownership of cattle but declining ownership of other types of livestock; and increased adoption of purchased inputs (though still low by international standards) and some soil and water conservation practices. Despite adoption of inputs and some conservation practices, crop yields, food security, and natural resource conditions appear to have degraded throughout much of Uganda. Nevertheless, many aspects of human welfare have improved, stimulated by improvements in roads and access to services, various government and non-government 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, improvements in resource conditions, agricultural productivity (at least of bananas) 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 achieving such a “win-win-win” development strategy. Other strategies will be needed for less-favored areas not as 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, wetlands and fallow strips, 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 many productivity, resource and welfare conditions; such as increased (or less decline in) yields of cassava and sweet potatoes, reduced soil erosion, increased quality of forests and grazing land, increased quality of housing and drinking water, improvements in child nutrition and reduction in infant mortality. However such programs also are associated with some negative outcomes, such as declining yields of some crops (millet and bananas) and declining availability of energy sources. It may be that by promoting development of some crops such programs cause farmers to devote less effort to other crops, leading to some trade-offs in impacts on productivity. 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 (e.g., the associations of population growth with reduced use of fallow strips and greater maize yields and food availability), consistent with Boserup's theory. However, population growth also appears to have reduced investment in soil bunds, probably because land scarcity reduces the ability of farmers to afford conservation structures that reduce cultivated area. This contradicts the predictions of Boserup's followers (e.g., Tiffen, et al. 1994) that population growth stimulates investment in land improvement, but is similar to findings from Ethiopia (Pender, et al. 2001). Impacts of population growth on resource conditions were generally insignificant, while associations with welfare indicators were mixed. Population growth is associated with improvement in housing quality, but also with declining farm sizes and worsening drinking water quality. In general, the impacts of population growth were not as negative as Malthusian pessimists often argue, nor as positive as Boserupian optimists argue.

It should be emphasized that these results are based upon rough qualitative measures of impacts as well as fairly crude measures of some of the causal factors (such as the number of organizations of each type). Further research using household level data is needed to validate these findings and to enable greater confidence in the explanations for the changes and impacts reported here.

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APPENDIX TABLES

Table A1--Human Welfare Indicators, % of households/people in 1999[A]

Welfare Indicator	AVERAGE	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Households without adequate food throughout the year	60.5	66.4	71.8	48.7	52.5	95.1	60.3	56.5	62.1	60.1	60.6
Households with adults eating < two meals per day on average	49.5	62.2	66.5	39.5	47	58.3	40.1	48.6	49.8	51.6	48.3
Households with children eating < two meals per day on average	35.3	58.9	46.7	24.4	33	48.9	23.1	31.4	36.9	38.6	33.6
Houses with mud floor	89.5	95.3	86.4	91.1	82.2	97	99.3	93.8	87.7	91.3	88.5
Houses with walls of mud and wattle	64.5	59.7	76.8	59.6	54.6	92.1	93.1	70.1	62.1	64.4	64.5
Houses with walls of grass	1.8	0	1.9	0.1	0.9	9.7	4.2	0.6	2.3	0.6	2.5
Houses with metal roof	61.1	21.7	78.7	45.8	83	80.4	37.5	33.6	72.6	39.1	72.7
Adults able to read and write	65.4	70.6	64.8	64.1	64.9	67.4	54.2	62.1	66.8	65.1	65.6
Children of primary school age in school	92	97.7	92.3	93.6	87.5	92.2	95.6	93.5	91.3	92.7	91.6
Children of secondary school age in school	41.5	32.3	45.5	39.8	51.7	27.7	41.9	37.9	43	38.2	43.2

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A2 – Human Welfare Indicators, Change in % of Households/People Since 1990, rank[A,B]

Welfare Indicator	AVERAGE	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Hhds without adequate food throughout the year	0.73	0.27	0.17	0.69	0.55	1.31	1.7	0.69	0.75	0.35	0.93
Hhds with adults eating < two meals per day	0.57	0.21	1.07	0.52	0.58	0.7	1.09	0.55	0.58	0.24	0.75
Hhds with children eating < two meals per day	0.31	0.07	0.88	0.33	0.26	0.18	0.84	0.14	0.38	0.01	0.46
Houses with dirt floor	-0.35	-0.19	-0.54	-0.32	-0.53	-0.04	-0.25	-0.29	-0.37	-0.26	-0.39
Houses with walls of mud and wattle	-0.84	-0.63	-0.59	-0.62	-1.46	-0.26	-0.36	-0.63	-0.92	-0.6	-0.96
Houses with walls of grass	-0.42	-0.15	-1.33	-0.54	-0.32	-0.17	-0.41	-0.39	-0.42	-0.52	-0.36
Houses with metal roof	1.46	0.65	1.72	1.36	1.66	1.87	1.5	1.1	1.6	1	1.69
Adults able to read and write	0.82	0.5	0.83	0.69	0.9	1.17	1.11	0.75	0.84	0.71	0.87
Children of primary school age in school	1.87	2	1.86	1.94	1.75	1.87	2	1.85	1.88	1.92	1.85
Children of secondary school age in school	0.62	-0.27	0.97	0.81	0.79	0.52	0.55	0.59	0.64	0.55	0.66

A, Means and errors are corrected for sampling stratification and sampling weights.
B. Values represent the average of rank data where 0=no significant change, +1=minor increase, +2=major increase, -1=minor decrease, -2=major decrease.

Table A3--Perceptions of Change In Welfare of Households in Village since 1990, mean rank[A,B]

Welfare Item	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Average farm size	-1.58	-1.41	-1.92	-1.23	-1.95	-1.48	-1.55	-1.41	-1.65	-1.28	-1.74
Availability of adequate food	-1.16	-0.53	-1.38	-0.96	-1.33	-1.65	-1.50	-0.87	-1.28	-0.77	-1.36
Availability of drinking water	0.21	-0.09	-0.08	-0.16	0.82	0.13	-0.31	-0.33	0.43	-0.11	0.37
Quality of drinking water	0.58	0.4	-0.22	0.22	1.08	0.83	0.66	0.1	0.78	0.28	0.74
Nutrition of children	0.07	-0.1	0.61	0.44	-0.04	-0.69	0.11	0.12	0.04	0.27	-0.04
Infant mortality	0.83	0.57	1.05	0.74	1.06	0.65	0.55	0.96	0.78	0.92	0.78
Child mortality	0.78	0.22	1.04	0.68	1.07	0.74	0.55	0.73	0.8	0.8	0.77
Maternal mortality	0.62	0.56	1.33	0.51	0.75	0.31	0.23	0.34	0.73	0.5	0.68
Availability of educational services	1.18	1.59	1.31	1.16	1.12	1.08	0.5	1.2	1.18	1.57	1.14
Quality of educational services	-0.22	0.03	-0.06	-0.22	-0.64	0.26	0.45	-0.15	-0.25	-0.08	-0.29
Average level of hhd. durable goods	1.42	0.68	1.75	1.55	1.75	0.87	1.8	1.21	1.52	1.17	1.56
General health of people	0.39	0.32	0.3	0.83	0.75	-1.48	1.04	0.66	0.28	0.54	0.31
Availability of health services	1.13	1.02	1.07	1.13	1.31	0.91	0.8	0.98	1.19	1	1.2
Quality of health services	0.93	0.66	0.91	1.01	1	0.83	1.05	0.9	0.94	0.81	0.99
Ability to cope with drought	-0.29	-0.29	0.1	-0.31	-0.58	0.39	-0.86	-0.39	-0.25	-0.56	-0.3
Avail of energy for heat and cooking	-1.28	-1.3	-0.97	-0.88	-1.77	-1.04	-1.95	-1.13	-1.35	-0.99	-1.44
Avail of energy for light	0.85	1.38	0.61	0.78	0.88	0.39	1.36	1.03	0.78	0.96	0.79
Access to transportation	1.45	1.4	1.43	1.2	1.73	1.39	1.61	1.35	1.5	1.32	1.52
Avail of consumer goods	1.5	1.44	1.51	1.4	1.74	1.17	1.5	1.45	1.52	1.49	1.5

A. Means and errors are corrected for sampling stratification and sampling weights.
B. Values represent the average of rank data where 0=no significant change, +1=minor improvement, +2=major improvement, -1=minor deterioration, -2=major deterioration.

Table A4--Perceptions of Change in Resource Conditions in Village since 1990, mean rank[A,B]

Natural Resource Item	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Abandoned farmland	0.1	0	0.01	-0.04	0.33	0.09	-0.09	0.04	0.13	0.05	0.13
Avail. of crop land	-1.47	-1.31	-0.86	-1.19	-1.81	-1.83	-1.39	-1.41	-1.5	-1.35	-1.53
Soil fertility	-1.61	-1.3	-1.79	-1.39	-1.87	-1.65	-1.8	-1.28	-1.74	-1.37	-1.73
Soil moisture holding capacity	-1.14	-0.26	-1.18	-0.99	-1.67	-1.22	-0.7	-0.78	-1.3	-0.72	-1.36
Soil erosion	-0.98	-0.54	-0.19	-0.99	-1.41	-0.61	-1.7	-0.9	-1.01	-0.58	-1.19
Availability of grazing land	-1.07	-0.85	-0.98	-0.87	-1.52	-0.65	-1.41	-0.99	-1.11	-0.89	-1.17
Quality of grazing land	-0.51	-0.15	0.1	-0.56	-1	0	-0.3	-0.55	-0.5	-0.34	-0.6
Availability of forest/woodland	-0.74	-0.39	-0.09	-1.03	-0.94	-0.35	-0.5	-0.79	-0.72	-0.7	-0.76
Quality of forest/woodland	-0.48	-0.62	-0.02	-0.88	-0.35	0	-0.36	-0.68	-0.4	-0.5	-0.47
Avail. of natural water sources	-0.24	-0.12	-0.21	-0.49	-0.18	0	0	-0.35	-0.19	-0.38	-0.17
Quality of natural water sources	0.04	-0.32	-0.42	-0.06	0.39	0.17	-0.45	-0.23	0.16	-0.14	0.14
Diversity of wild plant types	-1.29	-1.1	-0.75	-1.08	-1.91	-0.57	-2	-1.08	-1.37	-0.79	-1.55
Diversity of wild animal types	-1.31	-1.26	-0.79	-1.4	-1.79	-1.13	-1.91	-1.25	-1.34	-1.02	-1.47

A. Means and errors are corrected for sampling stratification and sampling weights.
B. Values represent the average of rank data where 0=no significant change, +1=minor improvement, +2=major improvement, -1=minor deterioration, -2=major deterioration.

Table A5--Primary Activities for Men in 1999, percent of villages[A]

Primary Activities of Men	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cereal crop production	30.1	20.6	7.6	36.3	30.4	34.9	40.8	27.1	31.4	23.5	33.6
Other storable annual crop production	3.9	0	35.5	4.2	0	0	0	1.7	4.7	3	4.3
Horticultural crop production	1	0	7	0	0	0	4.6	1.7	0	1.5	0
Banana production	13.8	0	25	2.8	14.1	43.4	29.6	21	14.5	12.2	14.6
Coffee production	19.2	7.3	10.5	12.7	38.1	4.3	25	5.1	25.1	4.3	27.1
Cotton production	6.6	17.7	0	9.9	0	8.7	0	8.5	5.8	9.6	5.1
Root crop production	16.8	47.1	0	22.3	10.6	0	0	39.1	7.5	37.1	6.2
Keeping cattle	1.6	0	14.5	0	1.8	0	0	1.7	1.6	4.7	0
Trading	2.6	7.3	0	0	5	0	0	0	3.7	0	4
Brewing beer	2.2	0	0	7.1	0	0	0	3	1.8	0	3.3
Charcoal making	1	0	0	0	0	8.7	0	0	1.6	0	1.7
Production of tobacco	1	0	0	1	0	0	0	0	2	4.1	0

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A6--Secondary Activities for Men in 1999, percent of villages[A]

Secondary Activities of Men	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cereal crop production	17.7	29.4	27.9	23.7	11.9	4.3	0	35	10.6	28.9	11.9
Other storable annual crop production	18	32.5	7.6	14.5	7	47.8	0	11.9	20.6	17	18.6
Horticultural crop production	4.4	0	0	8.5	5	0	4.6	0	6.2	0	6.6
Banana production	9.8	7.3	22.1	8.5	11.9	0	25	3.7	12.2	6.3	11.5
Coffee production	10.8	0	0	0	24.2	17.4	25	6.5	12.6	0	16.5
Cotton production	2.6	19	0	0	0	0	0	5.5	1.4	4.7	1.5
Root crop production	12.2	11.7	0	21.6	7.1	13.1	0	20.5	8.8	14.9	10.9
Keeping cattle	9.3	0	14.5	8.8	6.1	17.4	45.4	11.7	8.3	13.2	7.3
Keeping other livestock	1	0	0	0	1.8	0	0	0	1	1.7	0
Trading	5.5	0	7	5.7	7.1	0	0	2.2	6.9	5.1	5.8
Brewing beer	3.2	0	0	8.8	0	0	0	1.7	3.8	5.6	2
Brick making	3.3	0	0	0	10	0	0	0	4.6	0	5
Fishing	0	0	0	0	1	0	0	1	0	1	0
Stone crusher	2.2	0	0	0	6.8	0	0	0	3.1	1.7	2.5

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A7--Tertiary Activities for Men in 1999, percent of villages[A]

Tertiary Activities of Men	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cereal crop production	12.3	35.4	7	15.6	4	0	29.6	25.2	7	20.7	8
Other storable annual crop production	13.4	11.8	10.5	19.1	3.1	21.7	45.4	27.4	7.6	23.1	8.3
Horticultural crop production	1.9	0	0	4.2		0	20.4	2	1.8	0	2.9
Banana production	4.6	7.3	21	0	0	13	0	3.1	5.2	2.6	5.6
Coffee production	1.7	0	14.5	0	0.1	0	0	3.9	1	3	1
Cotton production	4.7	17.7	0	7.5	0.2	0	0	13.3	1	11.2	1.3
Root crop production	16.9	6	7.6	13	0	43.5	0	6	21.4	10.7	20.1
Keeping cattle	14.9	14.6	17.5	28.9	18	8.7	0	9.5	17.2	9.6	17.7
Keeping other livestock	5.4	0	0	7.1	5	0	0	0	7.7	2.5	6.9
Non-farm salary employment	1	0	7.6	0	10.1	0	0	0	1	1.6	0
Farm employment outside village	1	7.3	0	0	0	0	4.6	0	1.4	0	1.5
Trading	10.7	0	14.5	4.6	0	8.7	0	7.7	11.9	13.2	9.4
Crafts	1.6	0	0	0	5	0	0	0	2.3	0	2.5
Brewing beer	4.9	0	0	0	15.1	0	0	0	6.9	0	7.4
Brick making	2.2	0	0	0	5	4.3	0	1.9	2.3	1.6	2.5
Sugar cane production	3.3	0	0	0	10.1	0	0	0	4.6	0	5

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A8--Change in Importance of Three Most Important Activities for Men Since 1990, mean rank[A,B]

Activities of Men	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cereal crop production	0.64	-0.07	1.06	1.03	0.31	0.66	0.87	0.71	0.53	0.55	0.64
Other storable annual crop production	0.65	0.66	0.78	0.51	0.5	0.87	0.45	0.14	0.92	0.41	0.83
Horticultural crop production	1.02	N/A	2	1.67	-1	-1	1.38	2	0.84	2	0.95
Banana production	0.37	0	0.33	-0.88	0.94	0.46	0	0.11	0.43	0.37	0.37
Coffee production	0.26	0	0.28	-0.67	0.54	-0.4	0	0.58	0.2	-0.24	0.3
Cotton production	0.09	0	N/A	0.23	N/A	0	N/A	0.15	0	-0.16	0.51
Root crop production	0.59	0.18	0	0.86	0.31	0.92	N/A	0.65	0.54	0.47	0.69
Keeping cattle	0.74	-1	0.54	1.21	0.86	0	1.34	0.73	0.75	0.75	0.74
Trading	0.75	2	-0.38	0.11	0.95	2	0	-0.48	0.96	0.34	0.94

A. Means and errors are corrected for sampling stratification and sampling weights.

B. Values represent the average of rank data where 0=no significant change, +1=minor increase, +2=major increase, -1=minor decrease, -2=major decrease.

Table A9--Primary Activities for Women in 1999, percent of villages[A]

Primary Activities of Women	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cereal crop production	10.7	13.3	0	13	1	34.9	0	5.9	12.7	7.5	12.5
Other storable annual crop production	4.3	0	10.5	4.2	0	17.4	0	0	6.1	0	6.6
Banana production	1.7	0	0	0	0	13	0	1.9	1.6	5	0
Cotton production	1.1	0	0	0	0	8.7	0	0	1.6	0	1.7
Root crop production	2.2	0	0	0	5	4.3	0	1.9	2.3	1.6	2.5
Household maintenance activities	79.9	86.7	89.5	82.7	93.9	21.7	100	90.2	75.6	85.9	76.7

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A10--Secondary Activities for Women in 1999, percent of villages[A]

Secondary Activities of Women	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cereal crop production	29.2	61.7	32	24.5	16	34.8	40.7	42.3	23.8	35.4	26
Other storable annual crop production	14.6	6	36.1	8.8	13.9	26	20.4	8.1	17.3	14.6	14.6
Horticultural crop production	3.4	0	7	4.2	5	0	0	1.7	4.1	1.5	4.5
Banana production	10.5	7.3	18	11.3	13.1	0	18.5	3.8	13.5	5.1	13.4
Coffee production	1.1	0	0	0	0	8.7	0	0	1.6	0	1.7
Cotton production	1	0	0	0	0	0	20.4	2	0	0	1
Root crop production	31.8	17.7	0	38.2	50.9	8.8	0	32.9	31.3	31.9	31.7
Keeping other livestock	1	0	7	0	0	0	0	1.7	0	1.4	0
Household maintenance activities	8.2	7	0	13	1	21.7	0	7.9	8.3	10	7.2

A...Means and errors are corrected for sampling stratification and sampling weights.

Table A11--Tertiary Activities for Women in 1999, percent of villages[A]

Tertiary Activities of Women	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cereal crop production	12.8	11.8	0	22	6.8	17.3	0	24.9	7.8	23.7	7.1
Other storable annual crop production	35	42.7	32	40.9	38.3	8.7	25	39	33.3	41.1	31.8
Horticultural crop production	1	0	0	0	0	0	25	2	0	0	1.1
Banana production	3.5	0	24.4	0	2	8.7	0	5.6	2.7	2.9	3.9
Coffee production	1.3	0	0	4.2	0	0	0	0	1.8	0	2
Cotton production	2.4	17.7	0	0	0	0	0	5.5	1.2	7.1	0
Root crop production	17.4	7.3	7.6	28.7	8.9	26.1	25	13.4	19.1	11.9	20.3
Keeping cattle	1.1	0	7.6	0	0	0	20.4	2	1	3.3	0
Keeping other livestock	6.8	14.6	0	0	14.9	0	0	3.4	8.2	2.7	9
Trading	2.8	0	7.6	0	6.8	0	0	0	3.9	3.3	2.5
Crafts	6.4	0	21	0	15.1	0	0	0	9	0	9.7
Brewing beer	3.2	0	0	4.2	2	8.7	4.6	2.2	3.6	0	4.9
Household maintenance activities	6.4	6	0	0	5	30.4	0	1.9	8.3	4	7.7

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A12 – Change in Importance of Three Most Important Activities for Women Since 1990, mean rank[A,B]

Activites of Women	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cereal crop production	0.77	0.34	0.42	0.83	1.1	0.9	1.5	0.54	0.93	0.6	0.9
Other storable annual crop production	0.73	0	1.09	0.74	1.02	0.58	0	0.37	0.86	0.33	0.96
Horticultural crop production	1.07	N/A	2	2	0	N/A	1.19	1.46	0.93	2	0.95
Banana production	0.22	0	0.66	-1.25	0.99	0.4	-0.12	0.85	0.02	0.41	0.14
Coffee production	-0.86	N/A	N/A	-2	N/A	0	0	0	-1.06	N/A	-0.86
Cotton production	0	0	N/A	N/A	N/A	0	N/A	0	0	0	0
Root crop production	0.62	0	1	0.81	0.49	0.88	0	0.98	0.49	0.71	0.59
Keeping cattle	0.57	N/A	-1	N/A	N/A	N/A	2	2	-1	0.57	N/A
Keeping other livestock	-0.03	-1.5	0	N/A	2	N/A	N/A	1.1	-0.32	1.05	-0.29
Trading	2	0	2	N/A	2	N/A	N/A	N/A	2	2	1.99
Household maintenance activities	0.47	-0.07	0.12	0.62	0.45	1.06	0.77	0.55	0.45	0.4	0.52

A. Means and errors are corrected for sampling stratification and sampling weights.
B. Values represent the average of rank data where 0=no significant change, +1=minor increase, +2=major increase, -1=minor decrease, -2=major decrease.

Table A13--Trend of Change in Yield Since 1990 or Year When Began Growing Variety, mean rank [A,B]

Crop	AVG	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Bean	-0.96	-0.43	-0.73	-0.85	-1.13	-1.39	-0.52	-0.96	-0.97	-0.88	-1
Groundnut	-1.11	-0.39	-1.39	-1.05	-1.32	-1.54	-1.69	-0.91	-1.21	-1	-1.18
Maize	-0.62	-0.52	-0.76	-0.44	-0.6	-1.09	-0.84	-0.55	-0.65	-0.62	-0.62
Millet	-0.68	-0.16	-0.44	-0.59	-0.93	-1.13	-1.62	-0.53	-0.78	-0.54	-0.8
Sorghum	-0.56	-0.2	-0.21	-0.23	-0.76	-1.3	-1	-0.31	-0.66	-0.39	-0.66
Cassava	-0.81	-0.29	-1.3	-0.86	-0.81	-0.89	-1.67	-0.95	-0.75	-0.93	-0.74
Sweet Potato	-0.74	-0.28	-0.99	-0.43	-0.95	-1.22	-1.38	-0.46	-0.86	-0.53	-0.86
Banana	-1.33	-1.07	-1.23	-1.57	-1.35	-1.03	-1.21	-1.35	-1.33	-0.13	-0.41
Tomato	-0.58	-0.37	-0.54	-0.32	-1.02	-0.29	-0.14	-0.1	-0.72	-0.29	-0.7
Cabbage	-0.96	-0.43	-0.73	-0.85	-1.13	-1.39	-1.52	-0.96	-0.97	-0.88	-1

A. Means and errors are corrected for sampling stratification and sampling weights.
B. Values represent the average of rank data where 0=no significant change, +1=minor increase, +2=major increase, -1=minor decrease, -2=major decrease.

Table A14--Change in Proportion of Households Owning Livestock Since 1990, mean rank[A,B]

Livestock type	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cattle (local)	0.33	0.55	0.33	1.04	-0.31	0.09	-0.05	0.49	0.26	0.47	0.26
Cattle (crossbred)	0.23	0.07	0.3	0.09	0.5	0	0.45	0.07	0.3	0.11	0.3
Goats (local)	-0.16	0.61	-0.15	0.15	-0.4	-1.13	0.07	0.15	-0.28	0.1	-0.29
Pigs (local)	-0.15	-0.66	0.19	-0.45	0.43	-0.48	-0.44	-0.86	0.14	-0.62	0.09
Pigs (exotic)	0.03	0	0	0	0.1	0	0	0	0.05	0	0.05
Chicken (local)	-0.31	-0.29	-0.06	-0.08	-0.22	-1.21	-0.45	-0.51	-0.23	-0.28	-0.33
Sheep (local)	-0.29	0.04	-0.42	-0.22	-0.3	-0.61	-0.59	0.11	-0.45	0	-0.44
Rabbit (local)	-0.01	0.15	-0.06	0.03	-0.04	-0.22	0.2	0.05	-0.04	0.02	-0.03
Duck (local)	0.02	-0.03	0		0.06	0	0	0.12	-0.03	-0.02	0.02
Turkey (local)	0.05	0.12	0	0.05	0.07	0	0	0.13	0.02	0.09	0.03

A. Means and errors are corrected for sampling stratification and sampling weights.

B. Values represent the average of rank data where 0=no significant change, +1=minor increase, +2=major increase, -1=minor decrease, -2=major decrease.

Table A15 –Change in Proportion of Land Area Under Various Uses Since 1990, mean rank[A,B]

Land Use	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Cultivated land	0.66	0.33	0.97	1.04	0.83	-0.35	-0.05	0.79	0.6	0.85	0.55
Fallow	-1.23	-1.41	-1.25	-1.39	-1.08	-1.04	-1.2	-1.43	-1.15	-1.36	-1.17
Grazing area	-0.93	-0.94	-0.61	-0.86	-1.16	-0.69	-0.91	-1.04	-0.88	-1.01	-0.89
Forest/woodland	-0.63	-0.39	-0.34	-1.01	-0.58	-0.35	-0.41	-0.75	-0.58	-0.66	-0.62
Planted woodlots	0.27	0.15	0.36	0.17	0.22	0.7	0.45	0.18	0.31	-0.09	0.37
Wetland	-0.37	-0.19	0	-0.3	-0.71	-0.17	0	-0.09	-0.49	-0.22	-0.45
Settlements	1.37	1.07	1.47	1.09	1.66	1.57	1.34	1.12	1.47	1.03	0.54
Wasteland	0.01	0	0.18	0	0	0	0	0	0.02	0.02	0.01

A. Means and errors are corrected for sampling stratification and sampling weights.

B. Values represent the average of rank data where 0=no significant change, +1=minor increase, +2=major increase, -1=minor decrease, -2=major decrease.

Table A16 – Percentage of Households Using Soil and Water Conservation Technologies in 1999[A]

SWC Technology	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Fallowing	14.8	38.3	18.1	21.5	4.2	0	8.15	24.6	10.7	31.5	6
Fallow strips	5	0	19.9	8.5	0.4	6.2	0	6.5	4.4	11.3	1.7
Planting trees (on farmland)	19.3	10.2	32.6	11.1	31.5	11.4	29.3	6.9	24.5	10.8	23.8
Mulching	27.5	5.6	58.7	13.7	33.7	53.9	13.6	10.7	34.8	17.3	32.9
Composting	9.1	0.2	10.2	0.4	14.2	24.6	14.3	2.5	11.9	3.8	11.9
Animal manure	21	11.5	18.9	7.1	31.5	36	35.2	6.7	27	8.4	27.6
Crop residue	30.2	83.1	10	29.6	13	25.4	49.2	44.4	24.3	44	23
Grass strips	7.3	16.9	1.1	4.6	2	8.4	57.5	7.2	7.3	3.4	7.7
Hedges or other live barriers	5.9	20.2	3.4	2.3	5.9	1.7	0	4.6	6.4	5.5	6
Trash lines	21.5	49.2	0	26.1	9.4	26.5	8.4	22.1	21.3	30.7	16.7
Ridges/tied ridges	3.8	4.4	7.8	1.7	6.5	0	0	1.2	4.9	1	5.3
Infiltration ditches	6.4	11	16.1	2.2	4.7	8.4	15.6	5.4	6.9	4.9	7.2
Zero tillage	4.5	18.9	0	2.2	3.8	0	0	8.1	3	8.3	2.5
Contour planting	9.7	0.6	0	15.7	11.1	0	40.8	13.5	8.1	8.6	10.2
Contour plowing	6.2	6	0	9.3	4	0	40.8	9.8	4.7	9.4	4.5
Soil bunds	6.3	3.7	8.1	0.7	9.9	8.7	21.6	5	6.8	2.2	8.4

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A17--Change in Proportion of Households Using Soil and Water Conservation Technologies Since 1990, mean rank[A,B]

SWC Technology	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Fallowing	-0.69	-0.85	-0.57	-0.97	-0.67	-0.17	-0.2	-1.03	-0.56	-0.79	-0.64
Fallow strips	-0.16	0	-0.23	-0.02	-0.21	-0.48	0	0	-0.22	-0.11	-0.18
Improved fallow	0	0	0	0	0	0	0	0	0	0	0
Alley cropping	0	0	0	0	0	0	0	0	0	0	0
Planting trees (on farmland)	0.42	0.22	0.58	0.2	0.75	0.17	0.7	0.11	0.55	0.21	0.53
Mulching	0.25	0.07	0.69	0.09	0.39	0.17	0.45	0.15	0.29	0.11	0.32
Composting	0.3	0.07	0.3	0.05	0.56	0.44	0.41	0.06	0.39	0.12	0.39
Animal manure	0.47	0.15	0.31	0.18	0.91	0.39	0.91	0.14	0.61	0.18	0.63
Crop residue	0.13	0.07	0.23	0.02	0.18	0.09	0.81	0.15	0.12	0.1	0.14
Grass strips	0.13	0.07	0	0.12	0.1	0.17	0.61	0.11	0.14	0.12	0.13
Hedges or other live barriers	0.07	0.21	0.19	0	0.06	0	0	0.01	0.09	0.03	0.09
Trash lines	0.13	0	0	0.11	0.18	0.26	0.2	0.05	0.17	0.12	0.14
Ridges/tied ridges	0.13	0.15	0.19	0.09	0.21	0	0	0.02	0.17	0.02	0.19
Infiltration ditches	0.16	0.22	0.35	0.05	0.18	0.17	0.2	0.11	0.18	0.12	0.18
Zero tillage	-0.06	-0.47	0	-0.18	0.18	0	0	-0.29	0.03	-0.26	0.04
Contour planting	0.09	0	0	0.07	0.21	0	0	0.07	0.1	0.08	0.09
Contour plowing	0.08	0	0	0.1	0.16	0	0	0.1	0.07	0.08	0.08
Soil bunds	0.18	0.07	0.19	0	0.43	0	0.41	0.12	0.2	0.04	0.25

A. Means and errors are corrected for sampling stratification and sampling weights.

B. Values represent the average of rank data where 0=no significant change, +1=minor increase, +2=major increase, -1=minor decrease, -2=major decrease.

Table A18 – Percentage of Households Using Agricultural Inputs in 1999[A]

Input	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Fertilizers	8.7	11.0	9.6	8.2	7.4	9.3	11.3	11.0	8.0	8.2	9.0
Pesticides	43.2	56.0	46.7	39.5	39.9	50.1	46.4	48.1	41.6	38.1	45.4
Herbicides	8.1	3.8	3.8	4.6	5.1	7.8	27.6	12.7	6.7	4.8	9.6
Improved seeds	61.6	57.9	72.6	70.2	46.7	53.1	76.3	64.9	60.5	47.7	67.8
Purchased feed/fodder	10.5	1.4	4.5	10.1	0.4	9.3	41.3	20.6	7.3	1.6	14.5
Animal vaccines	54.5	52.5	35.2	56.3	50.2	48.4	81.4	58.8	53.5	51.0	56.5
Animal medicines	57.3	93.6	33.9	54.7	56.3	55.8	75.1	68.1	53.9	55.3	58.2
Traditional pesticides	3.6	40.1	0	1.7	0	34.8	0	26.1	0.7	0.1	9.9
Traditional medicines	6.8	40.1	0	1.7	0.1	34.8	0	26.1	0.7	0.1	9.9

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A19 –Change in Proportion of Households Using Agricultural Inputs Since 1990, mean rank[A,B]

Input	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern Highlands	Low	High	Low	High
Fertilizers	0.72	0.74	0.79	0.48	1.90	1.09	0.25	0.67	0.74	1.60	0.56
Pesticides	0.44	0.14	0.74	0.53	0.54	0.20	0.25	0.14	0.56	0.55	0.41
Herbicides	0.65	2.0	1.00	0.32	0.76	1.23	0.80	0.41	0.75	0.76	0.63
Improved seeds	1.00	0.11	1.00	1.11	0.98	0.36	1.57	0.70	1.10	0.96	1.03
Purchased feed/fodder	1.29	0.82	-0.50	1.12	0.38	1.73	1.8	1.89	1.01	-0.01	1.45
Animal vaccines	0.42	0.05	0.18	0.60	0.13	0.28	1.0	0.63	0.36	0.19	0.54
Animal medicines	0.74	0	0.53	0.89	0.82	-0.04	1.25	0.45	0.83	0.86	0.69
Traditional pesticides	-0.29	-1.99	N/A	0	-0.68	0.66	0	-0.41	-0.24	-0.68	-0.160
Traditional medicines	-0.20	0	N/A	-1	0	0.10	N/A	0.08	-0.75	0	-0.22

A. Means and errors are corrected for sampling stratification and sampling weights.
B. Values represent the average of rank data where 0=no significant change, +1=minor increase, +2=major increase, -1=minor decrease, -2=major decrease.

Table A20--Average Fallow Period, Late 1980s and Late 1990s, years [A]

Fallow Period	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Late 1980s	2.19	3.3	1.74	2.82	1.87	0.8	1.41	2.77	1.96	2.97	1.79
Late 1990s	0.72	1.12	0.88	1.05	0.39	0.28	0.61	1.03	0.59	1.35	0.39

A Means and errors are corrected for sampling stratification and sampling weights.

Table A21 – Average Number of Households per LC1 and Growth Rate, 1990 to 1999

Households and Growth Rate	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	Southwest highlands	Eastern highlands	Low	High	Low	High
Households in LC1, 1990	108	95	72	99	152	67	60	84	118	81	122
Households in LC1, 1999	160	148	129	128	236	92	93	122	175	124	178
Average Annual Growth (%)	4.91	5.54	7.29	3.21	5.5	3.96	5.48	4.67	4.93	5.32	4.72

Table A22 – Number of Programs and Organizations per LC1 by Type

Type of Institution	AVERAGE	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	Southwest highlands	Eastern highlands	Low	High	Low	High
Program											
Government	0.64	0.74	0.36	0.39	1.10	1.17	0.30	0.58	0.66	0.60	0.66
Organization											
NGO	0.85	0.79	1.11	0.40	1.33	0.70	0.55	0.42	1.03	0.53	1.01
CBO	0.62	0.07	0.85	0.33	0.52	2.13	0	0.25	0.78	0.48	0.70
Foreign	0.08	0.07	003	0.07	0.04	0.09	0	0.07	0.08	0.13	0.05
Religious	0.06	0.23	0	0.03	0.07	0	0	0.16	0.02	0.11	0.04
Private	0.04	0.07	0	0.03	0.07	0	0	0.05	0.04	0.02	0.05

Table A23: Number of Programs and Organizations per LC1 by Main Focus[A] (n=85)

Main Focus of Program / Organization	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	Southwest highlands	Eastern highlands	Low	High	Low	High
Ag. and vet. extension	0.34	0.37	0.28	0.28	0.46	0.14	0	0.17	0.41	0.29	0.36
Environment	0.21	0	0.34	0	0.45	0	0.5	0.04	0.29	0.03	0.31
Water	0.41	0.37	0.08	0.54	0.53	0.14	0.5	0.39	0.42	0.37	0.43
Credit	0.11	0.08	0.07	0	0.19	0.1	0	0.03	0.14	0.09	0.11
Education	0.31	0.42	0.54	0.28	0.24	0.33	0	0.39	0.28	0.35	0.29
Health	0.17	0.08	0.19	0.23	0.18	0.19	0	0.17	0.17	0.11	0.21
Income gen.	0.22	0	0.66	0.37	0.05	0.48	0	0.15	0.25	0.29	0.19
Poverty eradication	0.29	0.31	0.11	0.15	0.42	0.29	0	0.06	0.39	0.14	0.37
Social development	0.33	0.47	0.16	0.37	0.23	0.52	0.09	0.43	0.29	0.5	0.24
Women's empowerment/ emancipation	0.11	0.17	0.08	0	0.18	0	0.5	0.03	0.15	0.06	0.14

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A24 – Percentage of Villages Using Infrastructure and Services in 1999[A]

INFRASTRUCTURE OR SERVICE	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Tarmac road	98	100	100	95	100	96	100	93	100	94	100
All weather murram road	90	100	79	90	86	100	50	88	90	94	87
Seasonal road	83	85	86	93	66	96	95	96	78	98	80
Bus service	68	93	68	79	34	100	41	83	62	84	60
Minibus service	100	100	100	100	100	100	95	100	100	100	100
Pickup truck service	94	88	100	95	91	100	100	88	97	90	97
Motorcycle service	80	44	93	75	98	91	25	56	90	68	87
Trading center	100	100	100	100	100	100	100	100	100	100	100
Rural market	99	100	93	100	100	100	100	100	99	98	100
Input supply dealer	97	100	100	96	96	100	100	96	98	98	97
Grain mill	99	100	86	100	100	100	100	98	99	97	100
Coffee processing plant	53	15	68	38	91	35	25	30	63	28	26
Other agricultural processing plant	16	19	7	29	7	9	5	24	12	22	12
Primary school public	99	100	100	97	100	100	100	97	100	100	99
Primary school private	31	15	50	20	47	26	25	27	33	29	32
Secondary school public	91	88	100	95	82	100	95	86	93	90	91
Secondary school private	80	76	93	78	88	70	55	79	81	76	82
District Farm Institute	13	0	0	7	32	0	0	0	18	4	17
Community center	31	27	18	37	37	13	25	29	31	33	29
Health clinic	92	100	93	95	90	83	86	90	93	91	93
Dispensary	86	100	93	96	73	78	70	91	84	93	82
Health Center	70	94	73	64	58	91	50	83	65	77	66
Primary irrigation water source	16	13	0	13	24	9	30	4	20	6	20
Major fuelwood source	100	100	100	100	100	100	100	100	100	100	100

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A25–Percentage Change in Villages Using Infrastructure and Services between 1990 and 1999[A]

INFRASTRUCTURE OR SERVICE	AVG.	AGRICULTURAL POTENTIAL						MARKET ACCESS		POPULATION DENSITY	
		Unimodal	Bimodal low	Bimodal medium	Bimodal high	SW highlands	Eastern highlands	Low	High	Low	High
Tarmac road	5	0	7	8	5	0	0	1	6	1	6
All weather murram road	0	0	0	-4	2	0	0	2	-2	0	-1
Seasonal road	0	0	1	0	0	0	0	0	0	9	0
Bus service	1	24	-7	4	-13	4	0	20	-7	14	-6
Minibus service	31	66	21	30	13	48	29	48	24	44	25
Pickup truck service	10	0	14	15	11	9	0	11	11	10	11
Motorcycle service	67	19	78	54	80	5	25	41	78	38	83
Trading center	8	12	7	7	11	0	0	11	6	7	8
Rural market	1	0	0	4	0	0	0	0	2	0	2
Input supply dealer	8	29	10	0	3	7	5	16	5	14	5
Grain mill	6	12	1	4	8	0	5	6	5	7	15
Coffee processing plant	10	0	18	3	24	5	0	11	10	-1	-24
Other agricultural processing plant	4	6	-68	4	5	0	0	6	3	6	2
Primary school public	0	0	0	0	2	0	0	0	1	2	0
Primary school private	1	-4	3	8	-5	13	25	5	2	8	0
Secondary school public	4	0	0	4	7	0	4	0	5	1	4
Secondary school private	45	61	43	43	41	53	30	45	46	36	49
District Farm Institute	3	0	0	6	5	0	0	0	4	2	2
Community center	2	-13	-7	11	2	0	-5	2	1	5	-1
Health clinic	23	53	7	24	16	18	0	34	18	31	16
Dispensary	7	6	25	-1	-1	13	0	9	4	17	1
Health Center	9	0	12	4	22	0	5	0	14	2	13
Primary irrigation water source	4	0	0	0	10	0	0	-1	4	0	4
Major fuelwood source	0	0	0	0	0	0	0	0	0	0	0

A. Means and errors are corrected for sampling stratification and sampling weights.

Table A26 – Average Distance to Various Infrastructure and Services (if used) in 990 and 1999, miles[A]

INFRASTRUCTURE OR SERVICE	AVERAGE 1990	AVERAGE 1999
Tarmac road	17.8	16.6
All weather murram road	2.1	1.9
Seasonal road	0.3	0.3
Bus service	5.5	5.8
Minibus service	3.7	3.4
Pickup truck service	4.4	4.1
Motorcycle service	5.6	1.9
Trading center	2.0	1.7
Rural market	3.7	3.3
Input supply dealer	9.2	6.4
Grain mill	6.4	4.3
Coffee processing plant	9.5	8.7
Other agricultural processing plant	5.3	4
Primary school public	1.3	1.2
Primary school private	2.0	3.6
Secondary school public	6.4	5.4
Secondary school private	8.5	5.5
Agricultural college	102.9	N/A
District Farm Institute	13.6	26.3
Community center	3.8	3.7
Health clinic	3.3	2.5
Dispensary	4.5	4.3
Health Center	10	7.7
Primary irrigation water source	0.4	0.4
Major fuelwood source	0.5	0.5

A. Means and errors are corrected for sampling stratification and sampling weights.

LIST OF EPTD DISCUSSION PAPERS

01 *Sustainable Agricultural Development Strategies in Fragile Lands,* by Sara J. Scherr and Peter B.R. Hazell, June 1994.

02 *Confronting the Environmental Consequences of the Green Revolution in Asia*, by Prabhu L. Pingali and Mark W. Rosegrant, August 1994.

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