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PATHWAYS OF DEVELOPMENT IN THE HILLSIDES OF HONDURAS: CAUSES AND IMPLICATIONS FOR AGRICULTURAL PRODUCTION, POVERTY, AND SUSTAINABLE RESOURCE USE

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ABSTRACT

Based on a survey of 48 communities in central Honduras, this paper identifies the major pathways of development that have been occurring in central Honduras since the mid-1970s, their causes and implications for agricultural productivity, natural resource sustainability, and poverty. Six pathways of development were identified: 1) *basic grains expansion* communities—where basic grains production is the dominant activity and increased basic grains production has occurred; 2) *basic grains stagnation* communities—where basic grains production is dominant but has stagnated or declined; 3) *coffee expansion* communities—where coffee production is important and has been increasing in importance; 4) *horticultural expansion* communities—where substantial adoption and expansion of horticultural crops has occurred; 5) *forestry specialization* communities—where forestry activities are important and basic grains production is stagnant or declining; and 6) *nonfarm employment* communities—where nonfarm employment is a major and increasing source of income. The pathways were distinguished by factors determining comparative advantage, including agricultural potential, population density, and access to markets and technology. Changes in agriculture and resource management differ significantly among these pathways, though poverty was found to decline to a similar extent across all pathways. It appears that the key causes of change in productivity and resource management are different and more pathway-dependent than the key causes of change in poverty, which depends to a great extent on provision of public services. Basic infrastructure and public services are badly needed throughout most of central Honduras, while efforts to address sustainable agricultural development may not be sufficient to solve poverty problems. There may not be large tradeoffs between achieving more sustainable development and reducing poverty, since the causes are different. The findings also imply that a "one-size-fits-all" approach to technical assistance is unlikely to be successful, since different approaches show promise in different pathways.

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1. INTRODUCTION

In Central America, rapid population growth and agricultural expansion and intensification in steep hillside areas have led to growing concerns about deforestation, soil erosion, watershed degradation, loss of soil fertility, sedimentation of reservoirs, and other resource problems (Leonard 1987; Scherr and Neidecker-Gonzales 1997). Despite the common perception that population growth and agricultural intensification are primary causes of land degradation and other problems, evidence from many parts of the world suggests that sustainable use of resources in fragile lands can be achieved at much higher population densities than exist in most of Central America (Templeton and Scherr 1997; Tiffen et al. 1994; Turner et al. 1993). Whether such pressures lead to resource and human welfare degradation or improvement depends upon a complex set of factors that can vary substantially from one community to the next; including population density,

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access to markets and infrastructure, the development of local markets and institutions, the nature and fragility of local resources, and the local incidence of government policies and programs (Scherr et al. 1996; Lopez 1998).

Accounting for such a complex set of factors and their impacts on resource management in the diverse circumstances of hillside areas is a major challenge for policy research. To address this challenge, we employ the concept of "pathways of development." A development pathway represents a common pattern of change in resource management, associated with a common set of causal and conditioning factors.[1] For example, two of the pathways in central Honduras identified in this study are expansion of basic grains production in areas far from roads and the urban market, and intensification of horticultural production in areas close to roads and the urban market.

The causes and consequences of such pathways are likely different, and the opportunities and constraints affecting natural resource management decisions likely also differ across development pathways. For example, labor-intensive approaches may be more effective in intensive basic grains production systems than in extensive grain systems or in areas with substantial non-farm employment opportunities. Capital-intensive technologies are likely to be more effective in more commercialized pathways. The policy and institutional requirements of sustainable development will depend upon the types of technologies that are appropriate in different development pathways. The appropriate technology and policy strategy to achieve sustainable development thus may differ across development pathways.

[1] This concept was inspired by the work on comparative patterns of economic development by Morris and Adelman (1988).

The principal research questions addressed by this study are:

1. What are the major pathways of development in the central region of Honduras, their causes, and implications for agricultural productivity, natural resource sustainability, and poverty?
2. How can policies and technologies facilitate more productive, sustainable, and poverty reducing pathways of development in this region?

2. CONCEPTUAL FRAMEWORK AND METHODOLOGY

CONCEPTUAL FRAMEWORK

The conceptual framework for this study is shown in Figure 1. In this framework, pressures from population growth, markets, new technology or other external factors induce change in local markets, prices and institutions within individual communities. These shifts are conditioned by initial community characteristics, such as their human and natural resource endowments, infrastructure, market linkages and local knowledge base. Local-level conditions and changes may induce different patterns of change in economic livelihood strategies--which we refer to as development pathways--resulting largely from differences in comparative advantage.

Across and within development pathways there may be differences in agriculture and natural resource management strategies at both household and collective levels, such as land use, land investment, land management intensity, input mix, conservation practices, and collective action. Within a given development pathway, these responses may be affected by many of the same factors that determine which pathway is being pursued (e.g., population pressure, access to market or technology), leading to both direct and indirect impacts of such factors. For example, increased access to markets may increase the likelihood that a community will produce high-value perishable vegetable crops, which will tend to favor use of modern inputs. Beyond this, increased market access may increase use of modern inputs directly by reducing farm level costs of inputs or increasing farmers' awareness of such inputs. It is important to consider both the direct and indirect impacts of such factors on responses and outcomes.

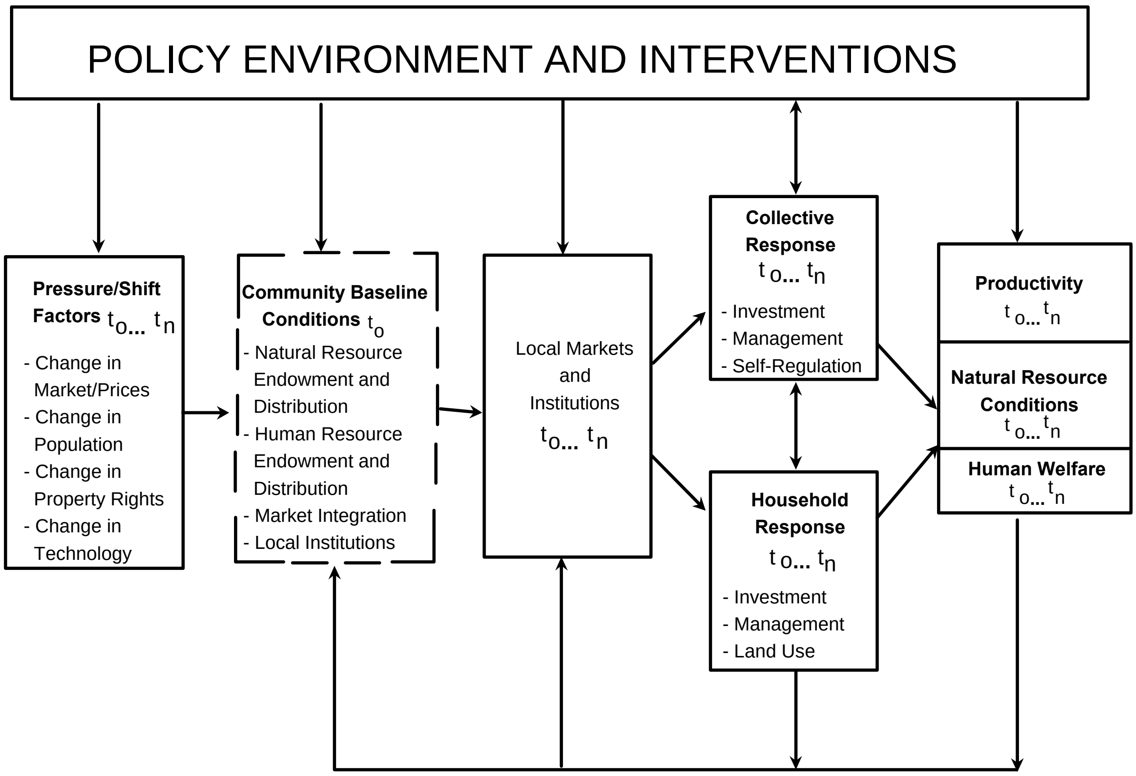
Collective and household level responses affect outcomes, including natural resource conditions, economic conditions and human welfare. These outcomes in turn can have feedback effects on local conditions, institutions, development pathways, and natural resource management (NRM) decisions.

Public policies can influence the process at various levels. For example, agricultural research and price policies affect shift factors. Resource regulations and infrastructure investment affect community conditions. Land titling and credit programs affect local markets and institutions. Technical assistance influences response patterns. Nutrition programs or state forest management directly affect outcomes. Policy research must consider which types and sequences of policy action are likely to be most effective in different circumstances.

RESEARCH HYPOTHESES

Several general hypotheses linking the driving forces of change to the nature and outcomes of change can be suggested:

Figure 1 Conceptual framework



Source: Scherr et al. 1996

1. Impacts of Population Growth

Population growth induces expansion of production into more marginal and fragile lands, particularly where unsettled land is available and property rights are not well enforced. Where land is limited, intensification of labor per unit of land will occur, including shortening of fallow cycles and adoption of more labor intensive products and practices (Boserup 1965). These changes may increase land productivity but, holding the state of technology and market development constant, may reduce labor productivity

(Salehi-Isfahani 1988) and per capita income (Pender 1998).[2] Effects on resource management and resource conditions may be mixed. Expansion into marginal lands can cause deforestation and land degradation, particularly where property rights are not well defined; while population growth induces labor intensive land improvements where land tenure is secure (Scherr and Hazell 1994; Tiffen et al. 1994). In addition, population growth may promote institutional changes such as development of individual property rights that contribute to improved resource management (Boserup 1965). Thus, there may be a U-shaped relationship between population density and resource conditions, with resource conditions first worsening and later improving as population rises (Scherr and Hazell 1994; Pender 1998).

2. Impacts of Improved Market or Technological Opportunities

Increases in the profitability of agricultural products, whether resulting from infrastructure investment, market development, changes in market prices, technological innovation, or government policies affecting these factors, will promote expansion of agriculture into marginal areas if the costs of productive factors are unaffected by the change (Angelsen 1996). However, if the costs of factors rise, 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.

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[2] Krautkraemer (1994) offers a contrary view of the implications of population-induced intensification for labor productivity, based on assuming that the production set is non-convex.

Market or technology development may promote a shift to cash crops, and will tend to increase farm incomes (unless offset by falling farm prices). 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 or technology development may increase externalities associated with demand for water and agricultural chemicals.

3. Pathways of Development

Although many pathways of change are theoretically possible, we hypothesize that a relatively small number of pathways represent much of the variation in the processes of change occurring in hillsides of Central America. These pathways are expected to be determined primarily by differences in comparative advantage, which is largely determined by agricultural potential, market access and population density (Pender, Place and Ehui 1998). More commercially oriented pathways (such as intensive production of vegetables) are expected to be found closer to urban markets, or where a comparative advantage in high value non-perishable commodities exists (such as coffee and some forest products). In areas of high market access, nonfarm development is also likely to be important. In areas more remote from markets and lacking comparative advantage in high value commodities, subsistence production of cereals and livestock is likely to continue to be important. Where population density is low, there may be greater comparative advantage in more extensive cereal and livestock production and/or in forestry activities. The problems, constraints, opportunities, and responses to change likely differ substantially across pathways; thus different technology, policy and institutional strategies are likely to be required for more productive, sustainable, and welfare-improving development to occur in different pathways.

METHODOLOGY

This study is based primarily on a survey of communities in the central region of Honduras. The central region, defined to include 31 *municipios* (counties) in the departments of Francisco Morazan and El Paraíso, was selected as the study region due to the predominance of hillsides, the presence of several important watersheds, concerns about poverty and resource degradation in the region, and the presence of the capital city of Tegucigalpa and major road networks within the region (Map 1). A stratified random sample of 48 of the 325 *aldeas* (villages) in the region was selected for the survey. The stratification was based upon 1974 rural population density of the *municipio* in which each *aldea* was located and the distance by road of the *municipio* county seat to Tegucigalpa.[3]

To identify the pathways of development, we adopted a simple classification system based on the primary and secondary occupations in the communities in 1996 and changes since the mid-1970s. Six pathways were identified (these are described below). In all but one of the sample communities, basic grains production was the primary or secondary occupation, so this could not distinguish the communities. The other major occupation (whether primary or secondary) was used to classify communities into five types (basic grains and livestock, horticulture, coffee, forestry, and non-farm employment communities). The basic grains and livestock communities were further disaggregated

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[3] Details on the study sample and the survey are available in Pender and Scherr (1997).

Map 1— Central Region of Honduras and location of the sample communities

between those where basic grains production had been increasing in importance ("basic grains expansion") and those where basic grains production had been constant or declining ("basic grains stagnation").

Although the classification for the other development pathways was based only on occupational data in 1996, we found in most cases that the dominant non-grain occupations in each pathway had been increasing in importance since the mid-1970's. For example, coffee production had increased in importance in all coffee communities (and coffee area in almost all), and had declined in none of them. Thus, we chose to label these communities as representing "coffee expansion". We found similar results for the other pathways, with the dominant non-grain occupation increasing or remaining constant in importance in all cases.[4]

The empirical analysis was based upon comparisons of descriptive statistics across the pathways, econometric analysis, and qualitative information from the survey. The general form of the econometric analyses, based on the conceptual framework in Figure 1, is as follows:

1. Pathway = f (driving factors, conditioning factors, policies/programs)

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[4] We considered alternative methods of classification, such as using principal components or cluster analysis. In a previous paper, Pender and Duron (1996) identified pathways of development based on principal components analysis of secondary data on causal and conditioning factors, responses and outcomes. We opted not to use that approach in this paper because 1) many of these factors were measured as discrete or ordinal variables and thus not appropriate for principal components analysis; and 2) we wanted to test hypotheses about the causes and implications of the pathways, so did not want to include such factors in the classification. We were also concerned about the sensitivity of cluster and principal components analysis to arbitrary decisions such as the number of variables included and their scaling, and felt that a simpler, more transparent classification would be more useful.

2. Household level responses = f (pathway, driving factors, conditioning factors, policies/programs)

3. Collective responses = f (pathway, driving factors, conditioning factors, policies/programs)

4. Outcomes = f (pathway, driving factors, conditioning factors, policies/programs)

Many of the dependent variables in this system are measured as discrete variables, including pathways (categorical), household responses (ordinal)[5], collective responses (binary), and some of the outcome variables (ordinal). Several different types of regression models are used, depending on the nature of the dependent variable.[6] In some regressions the dependent variable is measured at a single point in time (e.g., use of conservation practices in 1996), and in some the dependent variable is measured as a change (e.g., perceived change in resource conditions since the mid-1970s).

The explanatory variables used to explain determinants of pathways include factors affecting agricultural potential (altitude and number of rainfall days), population density, access to markets (distance to the urban market and to the nearest road), and access to technology (the presence of a technical assistance program). The cross-sectional regressions for household responses and outcomes include as explanatory variables the pathways, population density and density squared (the squared term

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[5] Most of the household response variables (such as adoption of various conservation practices) were measured by an ordinal index from 0 to 6: 0 = no households used the practice, 1=fewer than 10%, 2=minority, 3=about half, 4=majority, 5=more than 90%, 6=all.

[6] For example, we use multinomial logit to estimate determinants of the pathways, binary probit to estimate determinants of collective action, and ordered probit to estimate determinants of household responses and some outcome variables.

included to check for possible U-shaped relationships), the distance to the urban market and to the nearest road, adult literacy, and the presence of programs of technical assistance, credit, agrarian reform, and land titling.[7] In the regressions for changes, we replaced population density and density squared with the change in these measures between 1974 and 1988 (two census years), and replace the distance measures of market access with indicators of whether a road has existed in the community since the 1970s, or one was constructed since then.

Since the survey was conducted at a community level, we lacked data on intra-village variation in factors that may have affected measures of household level responses and outcomes, such as land distribution or plot quality. This is an inherent limitation of using community survey data to analyze household behavior and may introduce problems of omitted variable bias, if the unobserved intra-village factors are correlated with the included village-level explanatory variables. The only solution to this problem is to collect household level data, which was not within the scope of the present study.

Endogeneity of some explanatory variables—particularly population growth and the pathway variables—may be a problem. In all regressions including these explanatory variables, we ran the regressions twice, using actual and predicted values of these variables, to test the robustness of the findings.[8] We discuss which results are significant and robust below.

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[7] In regressions explaining changes in resource conditions, we also included efforts to regulate forest use by the national or municipal governments.

[8] In regressions using predicted values, the standard errors should be adjusted to account for the additional error induced by this. Analytical formula for the appropriate standard errors in a two stage model where the first stage is multinomial logit and the second stage (in many of the regressions) is ordered probit have not been derived in previous literature, as far as we have been able to determine. An alternative is to use

Given that the pathways of development are influenced by some of the same factors that influence responses and outcomes directly (e.g., population pressure and market access), these factors may have indirect as well as direct impacts on responses and outcomes, via their impact on the pathways themselves. To address this, we estimate the direct and indirect impact of marginal changes in such factors on various outcome measures. We focus this analysis only on outcomes that are measured as continuous outcome variables, since interpreting impacts on ordinal response variables is difficult.

3. PATHWAYS OF DEVELOPMENT IN CENTRAL HONDURAS

In five of the sample communities, horticultural production is the first or second most important occupation, and horticultural area has been increasing since the mid-1970s in all of these (Table 1). Horticultural area has not increased significantly in any of the other sample communities. More than half of fruit and vegetable production is commercialized only in this pathway. These five communities are classified as representing "*expansion of horticultural production*."

In 10 communities, coffee production is at least the second most important occupation, and in all of these, coffee production has been increasing in importance. More than half of coffee production is commercialized only in this pathway. These communities are classified as representing "*expansion of coffee production.*"

In three communities, forestry activities rank first or second in importance as an

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bootstrapping to compute the appropriate standard errors, but the small sample size (12 observations per stratum) made this option untenable. Thus, we do not report the results of the two-stage regressions, but only use them to check the robustness of the findings.

occupation. Basic grains production has been decreasing in importance as an occupation in all three communities, while forestry activities have increased or remained constant in importance. There is significant commercialization of timber or lumber only in this pathway, although commercialization of pine resin occurs in other pathways. These communities are classified as representing "*specialization in forestry.*"

In 10 communities, off-farm employment is the first- or second-ranked occupation. Off-farm employment has been increasing in importance in almost all of these communities, and in no case has it declined. Commercialization of most agricultural products is low in this pathway. These communities are classified as representing the "*nonfarm employment*" pathway.

In the remaining 20 communities, basic grains production is the most important occupation, and in nearly all cases, livestock production is the second most important. In five of these communities, the importance of basic grains production has been increasing. Basic grains and livestock production are most commercialized in this pathway. These five communities are classified as representing "*basic grains expansion*."

In the remaining 15 communities, the importance of basic grains production has been constant or declining. Commercialization of basic grain and livestock production is lower in these communities than in the basic grains expansion communities, though still significant sources of income. These are classified as "*basic grains stagnation*" communities.

Table 1 Development pathways in Central Honduras

Variable	Basic grains expansion	Basic grains stagnation	Horticultural expansion	Coffee expansion	Forestry specialization	Nonfarm employment
Number of communities in sample	5	15	5	10	3	10
Sample represents:						
- % of population of region	5	20	5	31	11	28
- % of area of region	6	15	4	34	22	20
Dominant economic activities						
- Basic grains	x	x	x	x	x	x
- Livestock	x	x				
- Horticultural crops			x			
- Coffee				x		
- Forestry					x	
- Nonfarm employment						x
Change in economic activities since 1975						
- Basic grains	↑	0↓	0↓	0↓	↓	↑↓
- Livestock	0↓	0	0	0↓	0↑	0↓
- Horticultural crops	0	0↑	0↑	0↑	0↑	↑↓
- Coffee	↑↓	0	0	↑	↑	0↓
- Forestry	0↓	0↓	0↓	0↓	0↑	↑↓
- Nonfarm employment	0	0↑	0↑	0↑	0	0↑
Index of proportion sold outside community[a]	-- Mean (robust standard error in parenthesis) --					
- Basic grains	3.4 (0.3)	1.9 (0.2)	0.0 (0.0)	0.6 (0.3)	2.0 (0.0)	1.1 (0.3)
- Cattle/cattle products	2.9 (0.8)	2.6 (0.5)	2.7 (0.9)	1.4 (0.5)	2.0 (1.4)	2.2 (0.8)
- Vegetables	0.0 (0.0)	2.0 (0.4)	4.0 (0.0)	1.9 (0.7)	0.0 (0.0)	1.1 (1.0)
- Coffee	1.1 (0.5)	0.0 (0.0)	0.0 (0.0)	4.0 (0.0)	2.0 (1.4)	1.4 (1.1)
- Pine resin	6.0 (0.0)	0.0 (0.0)	0.0 (0.0)	6.0 (0.0)	6.0 (0.0)	6.0 (0.0)

[a] Values of index: 0 = none, 1 = less than 10%, 2 = minority, 3 = half, 4 = majority, 5 = more than 90%, 6 = all

CHARACTERISTICS OF THE PATHWAYS

Various indicators of determining factors, responses, and outcomes are shown in Appendix Table 1 for the different pathways and the region as a whole. The basic grains pathways are at lower altitude and have lower rainfall than the other pathways. Population density was lowest in the forestry, horticultural and basic grains expansion pathways in the mid-1970s, but rapid population growth in the horticultural pathway caused this pathway to be among the most densely populated by the late-1980s. Access to the urban market and roads is lowest in the basic grains pathways and highest in the nonfarm employment and horticultural pathways. In the case of the horticultural pathway, this has been a result of road construction since the mid-1970s. Access to technical assistance and other government programs has been lowest in the basic grains expansion pathway and generally highest in the coffee and forestry pathways. Literacy is lowest in the basic grains and horticultural pathways.

Land use change has been moderate overall since the 1970s, but substantial changes are apparent in a few pathways. The area in annual crops grew in all pathways, but most rapidly in the horticultural and basic grains expansion pathways (Table 2). The expansion in annual crops occurred at the expense of tree cover in all pathways, but especially in the basic grains expansion and horticultural pathways. The area of de-vegetated land increased in the basic grains expansion pathway but declined in the others. Changes in area of pasture and fallow were generally relatively small, with the exception of fallow in the nonfarm employment pathway, which has increased significantly since the 1970s. Survey respondents attributed land use changes to population growth and burning practices (especially in the basic grains communities), increased knowledge about land management options and improved market access (especially in the horticultural pathway), increased profit potential of commercial crops (especially in the coffee pathway), over-exploitation of forests by loggers and community members (in the forestry pathway), poor soils (forestry pathway), decline in farming (nonfarm employment pathway), and other factors.

Table 2 Land use change from aerial photographs: 1970s - early 1980s[a]

Land use	Mean change in area as percentage of total area				
	Basic grains expansion	Horticultural expansion	Coffee expansion	Forestry specialization	Non-farm employment
	(Standard error in parentheses)				
Tree cover[b]	-12.5	-4.2	-1.3	-0.8	-1.6
	(--)	(1.4)	(3.8)	(--)	(5.6)
Cultivated	4.3	7.8	2.3	2.1	2.9
	(--)	(4.3)	(2.1)	(--)	(2.1)
Fallow	-0.3	-0.02	1.5	-0.9	3.3
	(--)	(0.4)	(0.9)	(--)	(2.0)
Pasture	0.7	-1.4	-1.4	-0.7	0.03
	(--)	(0.7)	(0.6)	(--)	(0.7)
Devegetated[c]	7.7	-2.4	-1.1	0.2	-4.8
	(--)	(3.0)	(2.6)	(--)	(5.0)
No. of cases	1	4	7	1	10

[a] Based on comparison of aerial photographs at a scale of 1:40,000 or less from the 1975-1995 period and from the 1990-1995 period. Recent photos were available for only 23 of the communities. Different dates apply to different communities.
[b] Tree cover includes land covered by forest as well as coffee, fruits, or other trees. No attempt was made to distinguish different tree types or forest density.
[c] Area with very little vegetation; sometimes recently deforested (with evidence of tree stumps) or with small shrubs.

Crop production practices vary substantially across the pathways. Continuous (no fallow) crop production is most common in the forestry pathway, despite low population density, probably due to limited availability of arable land. Continuous cultivation has increased in all pathways, but especially in the forestry and coffee pathways. Burning to prepare fields is most common in the basic grains pathways, but has declined significantly in all pathways. Crop production is most technified in the horticultural pathway, in which use of chemical fertilizer, insecticides, herbicides, improved seeds and irrigation is most common. Use of modern inputs has increased in most communities since the mid-1970s, but especially in the horticultural pathway.

The most common livestock are poultry, pigs and cattle. While chickens are common in all pathways, pigs are most common in basic grains communities and cattle in forestry and basic grains expansion communities. Use of all types of livestock has generally declined, though declines were more common outside of the basic grains pathways.

Use of organic inputs and annual conservation practices are generally uncommon in all pathways. The most common annual conservation practice is contour planting, which is practiced by significant fractions of farmers (but less than half) mainly outside the basic grains pathways. The most common land improving investments are live barriers, stone walls, tree planting and terraces; all of which have been adopted by less than half of households. Adoption varies by type of investment and pathway: live barriers and terraces are most common in the forestry and coffee pathways, stone walls most common in the forestry and basic grains stagnation pathways, and tree planting most common in basic grains expansion and coffee pathways.

Local collective action related to natural resources includes formal or informal regulation of use of common property resources, such as forests and water, and collective investments, such as planting trees near water sources or building stone walls to control runoff. Local regulation of common resources is strongest in the forestry and coffee communities, where external institutional presence has been the greatest.[9] Collective investments in tree planting and runoff control have been greatest in the basic grains expansion and nonfarm employment pathways, and no such investments were reported in any of the horticultural or forestry communities.

In terms of outcomes, maize yields are lowest in the basic grains pathways, but improvement in maize yields is more common in the basic grains expansion pathway than other pathways. Agricultural wages and wage improvement have been lowest in the basic grains pathways, and real wages have fallen in the basic grains stagnation pathway since the mid-1970s. Measures of poverty are high but declining in all pathways, with the greatest improvement occurring in the nonfarm employment pathway. Deforestation on steep slopes is greatest in the basic grains stagnation pathway, while there is also significant cultivation on steep slopes in the horticultural pathway. Perceptions of changes in resource conditions (cropland quality, forest area, forest quality, water availability and water quality) indicate a decline in most measures in all pathways, but resource degradation is most common in the basic grains and forestry pathways.

These indicators suggest that the pathways have distinct causes or conditioning factors, and different implications for resource management decisions, agricultural productivity, poverty and resource sustainability. Below we investigate these relationships using econometric analysis, controlling for the explanatory factors mentioned previously.

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[9] In Pender et al. (1998b), we report a positive association between the presence of external organizations and local organizational development in the study communities.

DETERMINANTS OF THE PATHWAYS

A multinomial logit model was used to investigate the determinants of the pathways (Table 3). The results (together with the descriptive statistics discussed above) imply that different determining and conditioning factors are critical for different pathways. In general, the factors determining comparative advantage are important distinguishing factors. Agroecological characteristics, especially altitude and rainfall, distinguish the basic grains pathways from most other pathways, while horticultural communities are at higher elevation than others. The basic grains expansion communities have lower population densities, are more remote from roads and markets and are less well served by external programs than all other pathways. Horticultural communities have relatively good access to roads and markets, but this access has come relatively recently, in contrast to most other communities outside the basic grains pathways. Technical assistance does not appear to have been a major driving factor behind the basic grains expansion or horticultural pathways; if anything, there are opportunities for more external presence in this pathway. By contrast, external presence appears to have been important in the coffee and forestry communities. Forestry communities are also distinguished from the other pathways by their low population density, relatively good access to markets, and high presence of forestry department officials. Nonfarm employment communities have the best access to the urban market, roads and public services.

Table 3 Determinants of the pathways

Coefficient	Multinomial logit regressions[a]				
	Basic grains expansion	Horticultural expansion	Coffee expansion	Forestry specialization	Nonfarm employment
	(Standard errors in parentheses)[b]				
Altitude at mid-point (m.a.s.l.)	-0.0187 (0.0127)	0.0187*** (0.0052)	0.00807 (0.00500)	0.00307 (0.0105)	0.00191 (0.00303)
Average number of rainfall days per year	0.1300** (0.0627)	0.0499 (0.0308)	0.1556** (0.0673)	0.1360 (0.0963)	0.0657*** (0.0210)
1974 population density (persons/km^2)	-0.2263* (0.1142)	-0.1429** (0.0626)	0.0049 (0.0495)	-0.1269 (0.1870)	-0.0236 (0.0190)
Distance to Tegucigalpa (km)	-0.0969* (0.0511)	-0.0605 (0.0557)	0.1810 (0.1111)	0.1425 (0.1461)	-0.0469 (0.0327)
Distance to nearest road (km)	1.133*** (0.347)	-59.03*** (4.76)	-0.975** (0.450)	-0.7625 (0.4728)	-69.86*** (3.15)
Presence of technical assistance program	-35.35*** (10.67)	-50.85*** (9.02)	15.89 (20.68)	10.08 (35.71)	-53.22*** (9.20)
Mean predicted probability of correct pathway[c]	0.83	0.71	0.68	0.14	0.79

[a] Reference category is basic grains stagnation pathway. Only 47 observations were used due to missing data on population density for one community.
[b] Coefficients and standard errors are adjusted to account for sampling weights, stratification, and finite population size. Intercept not reported.
[c] For example, the predicted probability that a community is in the basic grains expansion pathway is 0.83 for basic grains expansion communities. The mean predicted probability of the correct pathway for basic gains stagnation communities is 0.71.
Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level.

4. AGRICULTURE AND NATURAL RESOURCE MANAGEMENT

In this section we consider the factors determining the patterns and changes in agriculture and natural resource management, including household level crop production practices, conservation measures and collective action to manage common resources.

CROP PRODUCTION

Econometric analysis reveals significant variation among the pathways in crop production practices in 1996, even after controlling for other factors such as population density, access to markets, technical assistance and other programs (Table 4). Consistent with the descriptive statistics, use of continuous cropping is most common in the forestry pathway, while burning is most common in the basic grains stagnation pathway. Use of fertilizer, herbicides, improved seeds, and irrigation are all more common in the horticultural pathway than most other pathways.

Population density has a significant impact only on pesticide use. The impact is positive, with higher population density associated with increased use, but at a diminishing rate.[10] Somewhat surprisingly, continuous cropping, insecticides and herbicides are more common further from Tegucigalpa. Burning to prepare fields is more common further from a road (probably because it is illegal), while use of fertilizers, insecticides and improved seeds are more common close to a road, as one would expect. Technical assistance programs are associated with less burning and greater (i.e., more common) use of insecticides and herbicides. Agrarian reform programs are associated with greater use of burning (probably because smallholder beneficiaries are oriented towards basic grain production), fertilizer and irrigation, while land titling programs are associated with greater use of fertilizer, herbicides and improved seeds. Literacy is associated with greater use of burning, possibly because the opportunity cost of labor is greater where literacy is higher.

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[10] The relationship reaches a maximum at a population density of 100 persons per km^2, which is greater than the maximum population density of communities in the sample. The same is true in all subsequent analyses in which the coefficients of population density and population density squared are statistically significant.

Table 4 Determinants of cropping practices[a]

Variable	Continuous Cropping	Burning	Fertilizer	Insecticide	Herbicide	Improved seeds	Irrigation
Basic grains expansion	-.4258 (.7096)	-4.256 (R) (.782)	4.175 (R) (1.209)	2.847 (R) (.690)	-.894 (.725)	-.470 (2.984)	-.992 (.836)
Horticultural expansion	2.511 (1.123)	-4.435 (R) (.889)	1.342 (R) (.639)	2.186 (.906)	1.770 (R) (.691)	5.678 (R) (1.948)	1.951 (R) (.785)
Coffee expansion	.292 (.723)	-2.129 (R) (.580)	1.112 (R) (.583)	.004 (.645)	-1.203 (R) (.692)	2.179 (1.164)	-.215 (.617)
Forestry specialization	9.645 (R) (.547)	-3.959 (R) (.812)	.470 (.580)	-1.694 (.588)	-2.716 (.605)	2.341 (R) (1.052)	-.242 (.620)
Nonfarm employment	1.603 (.735)	-2.686 (.606)	-.544 (.583)	1.653 (R) (.653)	-.148 (.690)	.670 (1.039)	-1.174 (.631)
Population density, 1988 (per km^2)	-.0219 (.0218)	-.015 (.015)	-.0119 (.0155)	.0436 (R) (.0162)	-.0547 (.0173)	.0206 (.0216)	.0156 (.0153)
Population density squared	.00015 (.00011)	.000033 (.000077)	.000027 (.000072)	-.000245 (R (.000087)	.000241 (.000081)	-.000110 (.000107)	-.000100 (.000068)
Distance to Tegucigalpa (km)	.0274 (R) (.0093)	.00949 (.00936)	-.00502 (.00828)	.0251 (R) (.0089)	.0321 (R) (.0113)	-.00319 (.00761)	.00721 (.00927)
Distance to nearest road (km)	-.066 (.091)	.224 (R) (.077)	-.296 (R) (.058)	-.186 (R) (.065)	.131 (.082)	-3.793 (R) (1.555)	-.0094 (.0731)
Technical assistance program	.740 (.729)	-2.404 (R) (.602)	.048 (.631)	2.179 (R) (.629)	1.508 (R) (.560)	.484 (1.099)	-1.068 (.645)
Credit program	.425 (.655)	-1.839 (.544)	.698 (.460)	.586 (.534)	-.315 (.450)	-.754 (.881)	-.573 (.459)
Agrarian reform program	.030 (.482)	1.836 (R) (.482)	.732 (R) (.390)	.687 (.419)	.434 (.387)	-1.468 (.890)	1.031 (R) (.500)
Land titling program	.372 (.561)	.620 (.391)	1.021 (R) (.383)	.389 (.488)	1.407 (R) (.538)	2.419 (R) (.923)	.160 (.537)
Proportion of adults literate, 1988	.467 (2.107)	2.57 (R) (1.22)	-2.057 (R) (1.163)	1.794 (1.311)	-.817 (1.468)	1.535 (2.633)	1.169 (1.203)
Number of observations	45	45	47	46	46	47	46

[a] Based on ordered probit regressions with coefficients and standard errors adjusted for sampling weights, stratification, and finite population. Dependent variables take integer values from 0 (no one uses practice) to 6 (everyone uses).
Note: (R) indicates that the coefficient is statistically significant at the 5% level, and the same sign and significant at the 10% level when pathways are replaced by predicted pathways.

The preceding results are based on cross-sectional regressions, and may be affected by many possible sources of omitted variable bias.[11] Fortunately, we are also

[11] For example, the surprising positive association between distance to the urban market and adoption of some purchased inputs may be due to omitted land quality or climate characteristics that are correlated with distance to the market.

able to investigate determinants of change in some cropping practices, and these regressions will be less affected by omitted variables (at least those which do not change over time).[12] These results are presented in Table 5. Some of the results explaining changes in practices confirm results in the cross-sectional analysis. We find that burning has declined more commonly in the horticultural and nonfarm employment pathways than in the basic grains stagnation pathway. Population growth has a positive but diminishing impact on insecticide use. Road access and land titling programs contribute to increasing use of insecticides. Technical assistance is associated with reduced burning, while agrarian reform programs are associated with increased burning. However, some of the factors that have a significant impact in the cross-sectional regressions have an insignificant impact in the analysis of changes, reducing our confidence in those cross-sectional results. In some cases, we find significant impacts in the analysis of changes that we did not find in the cross-sectional analysis. For example, we find that increase in continuous cropping is more common in the basic grains expansion than the basic grains stagnation pathway (possibly because continuous cropping was initally already more common in the latter), and more common where technical assistance has operated. Such impacts could easily be missed in cross-section regressions.

[12] Unfortunately, our measures of change are relatively rough, in most cases only indicating whether a practice had increased, remained constant, or decreased. For some types of practices, such as use of fertilizers and herbicides, it was so common for use to increase that regression analysis was not possible. For other practices, such as use of improved seeds and irrigation, changes were so uncommon that regression analysis was not possible.

Table 5 Determinants of change in cropping practices[a]

Variable	Continuous cropping	Burning	Insecticide
Basic grains expansion	2.247 (R) (1.062)	-1.521 (.976)	2.575 (1.246)
Horticultural expansion	.729 (1.066)	-4.229 (R) (1.307)	.713 (3.972)
Coffee expansion	1.314 (.852)	-.939 (.748)	.326 (1.053)
Forestry specialization	.533 (.774)	-2.473 (.922)	.961 (.974)
Nonfarm employment	.261 (.505)	-2.520 (R) (.714)	-.725 (.492)
Change in population density, 1974-88 (per km^2)	.0401 (.0266)	.0128 (.0296)	.0409 (.0319)
Change in (population density squared)	-.000131 (.000173)	-.000222 (.000164)	-.000337 (R) (.000161)
New road access since 1975	-.970 (1.114)	2.003 (1.276)	16.62 (R) (3.17)
Already had road access in 1975	-.435 (.717)	.960 (.688)	3.511 (R) (1.037)
Technical assistance program	2.295 (R) (.775)	-1.482 (R) (.622)	1.921 (1.343)
Credit program	.188 (.574)	-2.150 (R) (.520)	-.842 (.612)
Agrarian reform program	1.016 (.602)	2.470 (R) (.505)	1.510 (.558)
Land titling program	.115 (.659)	.254 (.395)	12.13 (R) (1.39)
Change in proportion of adults literate, 1974-88	.343 (1.738)	-.224 (1.542)	-16.08 (R) (8.77)
No. of observations	38	43	43

[a] Based on ordered probit regressions with coefficients and standard errors adjusted for sampling weights, stratification, and finite population. Dependent variables take values of +1 (increase), 0 (no change), and -1 (decrease). There was insufficient variation in the change in other cropping practices for regressions to be feasible.

Note: (R) indicates that the coefficient is significant at the 5% level, and the same sign and significant at the 10% level when pathways are replaced by predicted pathways and population growth replaced by predicted population growth.

These results imply that changes in market access and technical assistance have been important factors influencing intensification of crop production, both directly (i.e., controlling for the pathways) and via their influence on development of the pathways themselves. Market access has had most influence on adoption of purchased inputs, while technical assistance and other programs have affected the use of labor intensive practices as well. Population growth appears to be of lesser importance in directly causing these changes. However, by influencing the choice of development pathway, differences in population density (and other initial conditions) still have an important influence.

USE OF ORGANIC INPUTS AND CONSERVATION MEASURES

Different pathways are associated with different types of conservation measures. Use of contour planting is more common in the horticultural and forestry pathways than the other pathways, controlling for other factors (Table 6). Minimum tillage is most common in the coffee pathway. Mulching is least common in the horticultural and nonfarm employment pathways. Terraces are most common in the coffee and nonfarm employment pathways, while live barriers are also most common in the coffee pathway (Table 7). These differences suggest that the potential for adoption of particular conservation measures varies across the pathways, and suggests the importance of a targeted approach to promotion of conservation measures in different pathways.

Population density has an insignificant direct impact on most conservation or organic measures, except use of cattle manure and tree planting. Both of these are more common at higher population density, but at a diminishing rate. This may be because the relative returns to such investments are higher at higher population densities, and/or the labor costs of the measures are lower (particularly for manuring).

Table 6 Determinants of annual conservation or organic practices[a]

Variable	Contour planting	Minimum till	Mulching	Incorporation of crop residues	Cattle manure	Chicken manure
Basic grains expansion	.158 (.844)	1.310 (1.528)	.659 (.852)	-.469 (1.134)	.462 (.793)	18.69 (3.83)
Horticultural expansion	3.60 (R) (1.34)	-2.697 (1.449)	-3.094 (R) (.908)	.360 (.919)	-.154 (.835)	-2.302 (1.224)
Coffee expansion	1.944 (.781)	1.721 (R) (.791)	.200 (.557)	.654 (.602)	.815 (.565)	1.029 (.766)
Forestry specialization	1.634 (R) (.774)	3.575 (.718)	-.359 (.712)	.106 (.905)	.254 (.713)	-8.037 (.571)
Nonfarm employment	.357 (.706)	.559 (.551)	-1.181 (R) (.532)	.092 (.699)	-.258 (.707)	.635 (.663)
Population density, 1988 (per km^2)	-.0214 (.0144)	-.0074 (.0187)	.0124 (.0176)	.0200 (.0165)	.0412 (R) (.0170)	.0225 (.0182)
Population density squared	.000067 (.000071)	.000016 (.000090)	-.000045 (.000081)	-.000089 (.000068)	-.000181 (R) (.000075)	-.000118 (.000082)
Distance to Tegucigalpa (km)	-.0408 (R) (.0096)	-.0562 (R) (.0149)	-.0254 (R) (.0102)	-.0307 (R) (.0103)	-.0136 (.0136)	-.0323 (.0196)
Distance to nearest road (km)	.1501 (.0820)	.397 (R) (.119)	.0234 (R) (.0874)	.183 (.104)	.0979 (.0813)	-15.96 (R) (1.64)
Technical assistance program	2.284 (1.024)	1.434 (.677)	-.951 (.489)	1.610 (R) (.635)	.949 (.608)	-.975 (.799)
Credit program	-1.063 (.629)	1.007 (.655)	.504 (.429)	-.769 (.584)	-.851 (.524)	.832 (.807)
Agrarian reform program	-.505 (.527)	.841 (.492)	1.025 (.402)	.388 (.470)	.045 (.414)	.727 (.630)
Land titling program	1.098 (R) (.452)	.116 (.655)	.464 (.503)	-.272 (.438)	.103 (.547)	-.513 (.529)
Proportion of adults literate, 1988	5.379 (R) (1.999)	-2.317 (1.909)	-2.929 (1.156)	3.467 (1.575)	3.09 (R) (1.49)	-2.725 (2.086)
No. of observations	46	47	47	45	47	44

[a] Based on ordered probit regressions with coefficients and standard errors adjusted for sampling weights, stratification, and finite population. Dependent variables take integer values from 0 (no one uses practice) to 6 (everyone uses). Note: (R) indicates that the coefficient is statistically significant at the 5% level, and the same sign and significant at the 10% level when pathways are replaced by predicted pathways.

Table 7 Determinants of land improving investments[a]

Variable	Terraces	Live barriers	Stone walls	Tree planting
Basic grains expansion	1.452 (.716)	1.827 (.834)	-.182 (.683)	1.258 (.751)
Horticultural expansion	1.635 (.985)	.854 (.595)	1.491 (.852)	-.278 (.782)
Coffee expansion	2.057 (R) (.884)	1.972 (R) (.676)	.408 (.515)	.898 (.643)
Forestry specialization	2.589 (.723)	2.886 (.941)	1.270 (1.226)	-.350 (.605)
Nonfarm employment	2.104 (R) (.726)	.322 (.485)	-.426 (.656)	-.312 (.618)
Population density, 1974[b] (per km^2)	-.0263 (.0293)	.0465 (.0182)	.0255 (.0227)	.0531 (R) (.0175)
Population density squared	.000302 (.000244)	-.000163 (.000128)	.000075 (.000131)	-.000307 (R) (.000117)
Distance to Tegucigalpa (km)	-.0237 (.0167)	-.0118 (.0091)	.0002 (.0125)	.0163 (.0089)
Distance to nearest road (km)	.142 (.097)	-.1292 (R) (.0623)	.0109 (.0667)	-.1001 (.0486)
Technical assistance program	2.227 (R) (.563)	1.604 (R) (.456)	1.531 (R) (.494)	-.720 (.438)
Credit program	1.766 (R) (.601)	-.580 (.437)	-1.372 (R) (.595)	.280 (.427)
Agrarian reform program	1.140 (R) (.415)	-.226 (.430)	-.372 (.510)	.819 (.385)
Land titling program	1.078 (R) (.541)	.817 (.456)	-1.274 (R) (.430)	-.687 (.462)
Proportion of adults literate, 1974[b]	3.081 (R) (1.289)	.028 (1.244)	2.274 (1.608)	1.215 (1.284)
No. of observations	46	46	46	46

[a] Based on ordered probit regressions with coefficients and standard errors adjusted for sampling weights, stratification, and finite population. Dependent variables take integer values from 0 (no one uses practice) to 6 (everyone uses).
[b] 1974 population density and proportion of adults literate used because some investments may have occurred before 1988.
Note: (R) indicates that the coefficient is statistically significant at the 5% level, and the same sign and significant at the 10% level when pathways are replaced by predicted pathways.

Several conservation measures are less common further from the urban market, including contour planting, minimum tillage, mulching, and incorporation of crop residues. This could be because the returns to such efforts are lower where returns to agriculture may be lower (due to lower market access), but it also may be due to lower intensity of involvement of programs promoting conservation in more remote areas. Minimum tillage is more common further from a road, perhaps because of difficulties plowing in more remote locations. Use of chicken manure and live barriers is more common close to roads. The effect of road access on chicken manure (which is marketed by commercial poultry operations) is similar to the effect of road access on inorganic fertilizer use, as one might expect.

As one would expect, several conservation measures are positively associated with technical assistance programs, including incorporation of crop residues, terraces, live barriers, and stone walls. Credit, agrarian reform, land titling programs and literacy are also positively associated with adoption of terraces. Credit and titling programs are negatively associated with use of stone walls. Perhaps farmers feel less need to build stone walls around their fields for tenure security if they have a title to land and access to credit based on land ownership.

COLLECTIVE INVESTMENT IN NATURAL RESOURCE MANAGEMENT

Collective investment in tree planting and to control runoff is higher at moderate rates of population growth than at low or very high rates.[13] This may be because low and high rates of population growth are associated with high rates of emigration and

[13] These results are reported in Pender et al. (1998b). The probit model was not estimable with the pathway variables included.

immigration, respectively; which may reduce the ability to achieve collective action by reducing the stability and homogeneity of the community (Baland and Platteau 1996). Higher initial population density reduces collective investments, possibly because the number of required participants and hence organizational costs of collective investments are higher where population density is greater. The presence of local organizations involved in NRM appears to stimulate collective investments in NRM, while external organizations are negatively associated with local collective investment. This latter finding suggests that external organizations may undermine local collective efforts, and implies that such organizations should take a cautious approach when intervening in local communities, to avoid such displacement.

5. DEVELOPMENT OUTCOMES

The above patterns of resource management are the proximate causes of change in the “critical triangle” of development outcomes: economic productivity or growth, sustainability of the natural resource base, and poverty alleviation (Vosti and Reardon 1997). These outcomes thus also vary by development pathway and other factors.

PRODUCTIVITY

In the cross-sectional analysis, we did not find significant and robust differences in land productivity (as measured by maize yields) among the pathways (Table 8). The only factor found to be significantly associated with maize yields was population density, with higher density associated with lower yields, though at a diminishing rate. This suggests that population pressure is causing a decline in soil productivity, perhaps

Table 8 Determinants of outcomes[a]

Variable	Productivity, 1996		Resource conditions, late 1970s[c]			Poverty, 1988	
	High maize yield	High male wage[b]	Proportion of steep land in forest	Proportion of steep land de-vegetated	Proportion of steep land cultivated	Proportion of houses with dirt floor	Proportion of households whose last child died
Basic grains expansion	-14.93 (9.18)	.117 (.130)	.292 (.169)	-.3698 (R) (.1402)	.0684 (.0423)	.0562 (.0609)	.0209 (.0168)
Horticultural expansion	7.147 (9.205)	.515 (R) (.160)	.320 (R) (.149)	-.433 (R) (.159)	.1670 (.0639)	.1062 (.0874)	.0113 (.0184)
Coffee expansion	5.503 (8.374)	.761 (R) (.136)	.3354 (R) (.0834)	-.3688 (R) (.0816)	.0551 (.0357)	.0879 (.0807)	.0212 (.0146)
Forestry specialization	-3.641 (8.440)	.377 (R) (.218)	.716 (R) (.217)	-.524 (R) (.216)	-.1193 (.0387)	.1528 (R) (.0823)	.0133 (.0121)
Nonfarm employment	11.65 (8.00)	.630 (R) (.103)	.255 (.156)	-.233 (.161)	-.0007 (.0290)	.0369 (.0702)	.0070 (.0192)
Population density, (per km^2)	-.659 (R) (.243)	.00482 (.00412)	-.00916 (.00374)	.00630 (.00379)	.00355 (.00156)	-.00282 (.00196)	.000292 (.000363)
Population density squared	.00285 (R) (.00116)	-.0000175 (R) (.0000178)	.0000591 (R) (.0000218)	-.0000498 (R) (.0000226)	-.0000161 (8.31e-06)	9.54e-06 (8.59e-06)	-1.50e-06 (1.62e-06)
Distance to Tegucigalpa (km)	.194 (.153)	.00730 (.00313)	-.00121 (.00524)	-.00011 (.00559)	.00090 (.00104)	.002153 (.001007)	-.000170 (.000210)
Distance to nearest road (km)	-1.838 (1.048)	-.0615 (R) (.0149)	-.0091 (.0181)	.0264 (.0174)	-.01172 (.00572)	-.00506 (.00702)	.00237 (.00183)
Technical assistance program	-12.253 (7.512)	.1623 (.0803)	NE	NE	NE	.1091 (.0644)	.0006 (.0176)
Credit program	-3.079 (6.143)	-.0944 (.0880)	NE	NE	NE	-.0831 (.0585)	-.0203 (.0137)
Agrarian reform program	4.597 (8.110)	-.0482 (.0868)	NE	NE	NE	.0269 (.0470)	.0229 (R) (.0081)
Land titling program	-3.814 (6.973)	.189 (.110)	NE	NE	NE	.0578 (.0519)	-.00535 (.00960)
Proportion of adults literate, 1988	-22.39 (15.87)	.473 (.371)	.410 (.361)	-.088 (.384)	-.1887 (R) (.0915)	-.390 (R) (.136)	-.0091 (.0424)
Proportion of land which is steep (30% slope)	NE	NE	1.289 (1.199)	-.674 (1.218)	-.972 (R) (.546)	NE	NE
No. of observations	45	46	37	37	37	47	47

[a] Based on least squares regressions with coefficients and standard errors adjusted for sampling weights, stratification, and finite population. Intercept not reported.
[b] The dependent variable is actually the natural logarithm of the daily wage in lempiras.
[c] Population density and proportion of adults literate are for 1974 in these regressions, for 1988 in the other regressions. Programs are not included as explanatory variables because they were usually present after the land uses were observed in aerial photographs.
Note: (R) indicates that the coefficient is statistically significant at the 5% level, and the same sign and significant at the 10% level when pathways are replaced by predicted pathways. NE means not estimated.

Table 9 Determinants of change in outcomes[a]

Variable	Productivity, 1975-96		Perceived natural resource conditions, 1975-96					Poverty, 1974-88	
	Maize yield	High male wage[b]	Cropland quality	Forest area	Forest quality	Water availability	Water quality	Proportion of houses with dirt floor	Proportion of households where last child died
Basic grains expansion	.995 (.939)	-.688 (.485)	1.570 (1.133)	-9.289 (.873)	-7.832 (.992)	-7.388 (R) (.670)	NE	.0503 (.0680)	-.0009 (.0406)
Horticultural expansion	1.792 (R) (.984)	1.885 (R) (.358)	2.670 (R) (1.169)	2.385 (R) (.949)	.806 (1.196)	-2.571 (R) (1.004)	-.679 (1.628)	.1275 (.0867)	.0113 (.0508)
Coffee expansion	.560 (.919)	.354 (.309)	1.404 (.958)	3.637 (.879)	1.960 (R) (1.124)	-.705 (.362)	-.203 (.307)	.0204 (.0482)	-.0029 (.0294)
Forestry specialization	-7.743 (.851)	.240 (.327)	-7.409 (.802)	.851 (.586)	-7.337 (.894)	-1.349 (.423)	-.679 (.284)	.0595 (.0471)	.0082 (.0362)
Nonfarm employment	.130 (.719)	1.069 (R) (.250)	.455 (.822)	1.674 (R) (.674)	.468 (.798)	-.959 (R) (.431)	-1.039 (1.081)	.0142 (.0396)	-.0349 (.0196)
Change in pop. Dens., 1974-88	-.0502 (.0363)	.0160 (.0074)	-.0501 (.0354)	-.0805 (R) (.0247)	-.0272 (.0405)	.0414 (.0186)	.0962 (.0435)	.00352 (.00250)	-.00031 (.00225)
Change in (pop. Dens. squared)	.000035 (.000196)	-.000071 (.000026)	.000076 (.000204)	.00040 (R) (.00013)	-1.51e-06 (.00026)	-.00022 (.00015)	-.00054 (.00035)	-7.79e-07 (.00002)	1.68e-06 (.00001)
New road access since 1975	-.103 (.844)	-2.707 (R) (.631)	-.168 (1.015)	.226 (1.034)	1.001 (.700)	1.128 (.779)	NE	-.151 (.087)	.0156 (.0732)
Already had road access in 1975	-.589 (.628)	-1.443 (R) (.375)	-1.077 (.874)	-1.569 (R) (.538)	NE	1.343 (.663)	1.210 (.883)	-.0213 (.0415)	.0036 (.0390)
Technical assistance program	.092 (.626)	.146 (.172)	1.080 (.906)	-1.029 (.587)	-.048 (.807)	-.377 (.581)	-.393 (.912)	.1452 (R) (.0399)	-.0074 (.0199)
Credit program	.146 (.649)	.275 (.214)	-.311 (.491)	-.718 (.556)	-.480 (.640)	.550 (.447)	-.826 (.991)	-.0435 (.0397)	-.0170 (.0229)
Agrarian reform program	-.699 (.788)	-.454 (.133)	-.248 (.766)	.989 (.703)	.222 (.833)	-.959 (.620)	-2.278 (R) (.717)	-.0010 (.0348)	.0252 (.0212)
Land titling program	-.191 (.427)	.053 (.106)	-.312 (.573)	-1.247 (R) (.567)	NE	.701 (.582)	1.357 (.620)	.0006 (.0455)	.0135 (.0267)
Change in proportion of adults literate, 1974-88	1.180 (1.427)	.867 (.576)	1.908 (1.496)	2.344 (2.301)	-.225 (2.287)	-2.812 (R) (1.614)	-1.529 (2.695)	.214 (.162)	.1166 (.1235)
Presence of national or municipal forest regulation	NE	NE	NE	-.205 (.668)	-.163 (.723)	.906 (R) (.258)	1.008 (R) (.398)	NE	NE
No. of observations	45	36	44	45	44	142	79	46	46

[a] Based on ordered probit regressions for change in maize yield and change in resource conditions, and least squares for other regressions. Coefficients and standard errors adjusted for sampling weights, stratification, and finite population. Dependent variables for ordered probit regressions take the values +1 (increase), 0 (no change), and -1 (decrease). Intercept not reported.

[b] The dependent variable is actually the change in the natural logarithm of the daily wage in lempiras.

Note: (R) indicates that the coefficient is statistically significant at the 5% level, and the same sign and significant at the 10% level when pathways are replaced by predicted pathways and population growth replaced by predicted population growth.

because of shortening fallow periods without sufficient use of organic or inorganic sources of soil fertility. This hypothesis could not be confirmed in the regression explaining changes in maize yields, since the population growth variables were found to have an insignificant effect (Table 9). The only significant and robust finding in that analysis was that growth in maize yields was more likely in the horticultural pathway than in any others. This is consistent with the finding above of increasing use of modern inputs in the horticultural pathway. Such inputs are not restricted only to horticultural crops in this pathway, but are also used in maize production.

Labor productivity, as measured by wage rates, is highest outside the basic grains pathways (Table 8). Real wages have also been growing more rapidly in horticultural and nonfarm employment communities (Table 9). Wages are lower further from a road, as one would expect. Surprisingly, however, we find that wage growth has been slower in communities that have access to a road than in those that do not.

NATURAL RESOURCE CONDITIONS

Natural resource conditions vary substantially across the development pathways. In the late 1970s, forests were most likely to be found on steep lands (with slopes over 30 percent) in the horticultural, coffee and forestry pathways (Table 8).[14] De-vegetation of steep lands is more common in the basic grains stagnation pathway than most other pathways, controlling for other factors, as was found in the descriptive statistics. Higher population density is associated with greater cultivation and less forest on steep lands, but

[14] Cross sectional regressions explaining land use on steep slopes were not possible for recent land use because of the limited number of communities for which aerial photos were recently available (23).

at a diminishing rate. Literacy is associated with less cultivation on steep lands. Perceived changes in natural resource conditions also varied across the development pathways. Cropland quality was most likely to improve (or least likely to decrease) in the horticultural pathway (Table 9). Forest area was most likely to increase in the horticultural and nonfarm employment pathways. However, water availability was more likely to decline in both of these pathways, as well as in the basic grains expansion pathway, than in the other pathways. Other factors also affect resource degradation. Population growth is associated with greater likelihood of deforestation, though at a diminishing rate. Road access and land titling are both associated with deforestation, as one might expect. Water quality was more likely to decline where there had been an agrarian reform program, while the presence of national or municipal efforts to protect forests was associated with improvement (or less reduction in) water availability and quality.

POVERTY

By most available measures, socioeconomic conditions improved in all pathways between 1974 and 1988. The measures that we examine through econometric analysis include the percentage of houses with a dirt floor and the percentage of households whose last child died.[15] We do not find statistically significant and robust differences among the pathways in these measures of poverty or changes in these measures, controlling for other factors (Tables 8 and 9). The only factor that we find significantly associated with the

[15] These measures are plausibly more affected by agricultural and resource management decisions and productivity than other available measures from the census data (such as availability of sanitation, water, and electricity), which are more related to public services.

proportion of houses with a dirt floor is literacy (negative effect). We find that the presence of an agrarian reform program is positively associated with child mortality, while technical assistance programs are associated with an increase (or less decrease) in the proportion of households having a dirt floor. These last two findings may be a result of such programs focusing in areas where poverty is severe and perhaps worsening.

Overall, these results do not show strong differences across the pathways in terms of changes in poverty, which has declined fairly broadly in the region. Perhaps public and NGO investments in social services have been more powerful determinants of changes in poverty than differences in comparative advantage and changes in agriculture occurring across the different pathways of development.

DIRECT AND INDIRECT EFFECTS

As mentioned previously, factors such as population pressure and market access may have both direct and indirect effects, by affecting which pathway of development occurs (indirect) as well as by affecting natural resource management given the pathway of development (direct). In Table 10, we present the predicted direct and indirect impacts on outcomes of an increase in population density and in distance from a road, based on the regression results presented in Tables 3 and 8. The predicted impacts of greater (by 1 person per square km.) population pressure are negative for maize yield and forest cover on steep lands. In most cases, the direct and indirect effects are in the same direction, and the direct effects are larger in magnitude. Surprisingly, wages and housing conditions are predicted to improve with increased population pressure. However, since these results are based on coefficients with low statistical significance, we cannot place high

Table 10 Predicted effects of population pressure and market access on outcomes

Factor	Effect	Productivity, 1996		Resource conditions, late 1970s			Poverty, 1988	
		Maize yield	ln (male wage)	Percentage of steep land in forest	Percentage of steep land de-vegetated	Percentage of steep land cultivated	Percentage of houses with dirt floors	Percentage of households where last child died
		(kg/ha)	*(Lps/day)*					
Higher population density (by 1 person/km^2)	Direct	-31.3	0.0037	-0.55	0.32	0.25	-0.22	0.02
	Indirect	6.6	0.0028	-0.37	0.29	0.03	-0.09	0.00
	Total	-24.7	0.0065	-0.92	0.61	0.28	-0.31	0.02
Further from road (by 1 km)	Direct	-119.4	-0.0615	-0.91	2.64	-1.17	-0.51	0.24
	Indirect	-366.2	-0.0930	2.52	-4.14	1.22	1.01	0.35
	Total	-485.6	-0.1545	1.61	-1.50	0.05	0.50	0.59

confidence in them. These results are more useful for understanding the general magnitude of direct and indirect impacts implied by the coefficients, than in making precise predictions.

The effects of poorer market access (by 1 km from the nearest road) are highly negative in terms of productivity and poverty, but positive in terms of preserving forest on steep lands. In contrast to the case of higher population growth, the indirect impacts of changed market access are stronger than the direct impacts. Market access appears to affect outcomes more via its impact on the pathways of development.

6. SUMMARY AND CONCLUSIONS

The general pattern of agricultural change in the central region of Honduras is toward increased specialization and commercialization of production based upon comparative advantage. Differences across the pathways in comparative advantage and other factors led to differences in land use, agriculture and resource management decisions. Given such differences, it is not surprising that we find also significant differences across the pathways in their outcomes for agricultural productivity and natural resource conditions. In general, productivity outcomes were more favorable in the horticultural, coffee and nonfarm employment pathways, while the implications for resource conditions were more mixed, with some resource conditions improving in these pathways and others becoming worse.

While many natural resource and environmental problems were getting worse in the central region, many aspects of human welfare were improving. In general, the changes in agricultural productivity and resource conditions were more mixed, and more often negative, than changes in measures of poverty. A major reason for this seems to be that the factors influencing these different outcomes are different. The factors influencing agricultural productivity and natural resource conditions are very location-specific. By contrast, welfare conditions are largely affected by provision of services by public agencies and NGOs, and these interventions were fairly broad in impact. In addition, migration has tended to reduce differentials in wages across communities (although large disparities remain), while general growth in economic opportunities resulting from market liberalization and changes in market conditions have led to increasing real wages in almost all pathways.

Although changes in natural resource conditions and human welfare are moving in opposite directions in much of the central region, this does not imply that there must be large tradeoffs between these objectives. As mentioned above, the differences in these outcomes appear to result from different causal factors, suggesting that these causes can be addressed separately.[16] In some cases, direct tradeoffs do exist—for example, increased use of irrigation and agrochemicals in the horticultural pathway leads to rising productivity and incomes, but also to problems of water scarcity and contamination. In these cases, careful consideration of the impacts on farmers' welfare is needed when considering measures to address the resource and environmental issues, and vice versa.

[16] Of course, to the extent that public expenditures are required to finance both efforts to improve public services and improvements in natural resource management, there will be tradeoffs in the use of such expenditures.

FINDINGS RELATIVE TO THE RESEARCH HYPOTHESES

Population Pressure

The results of the regression analysis and the explanations provided by survey respondents support the hypothesis that population growth induces deforestation and expansion of agricultural area at relatively low levels of population density. Survey responses also support the expected impact of population growth on reducing fallow periods, though surprisingly this was not supported by the regression analysis. In general we found few significant and robust impacts of population density or population growth on agricultural and resource management practices. Agricultural change in central Honduras appears to have been more market and technology induced than population induced.

Population pressure was found to be associated with deforestation on steep lands, as expected. This relationship had the hypothesized U-shape, although the predicted turning point is at levels of population density above those found in central Honduras. Population pressure was also associated with lower maize yields, contrary to the prediction that population pressure induces more intensive land use and thus greater land productivity (if not labor productivity). This result may be due to population-induced land degradation.

Population pressure was not significantly associated with wages or measures of poverty, perhaps because populations respond to differences in wages and poverty via migration. Large differences in the rate of population growth across the pathways are indicative of this. Thus the potentially negative welfare effects of population growth appear to have been mitigated, or at least shared among communities to some extent, as a result of migration.

Overall, these results support the concerns raised by many observers about the negative implications of population growth for agricultural productivity and the environment, although the impacts are not all negative or large. While we do find some evidence that population-induced investments in land improvement are occurring, these responses are not sufficient to compensate for all of the negative effects, particularly on soil fertility and forest resources.

Market Access

Access to markets, as measured by road access, is associated with deforestation and expansion of agricultural area. As expected, road access is also associated with greater use of purchased inputs. The impacts of market access on changes in resource conditions are mixed, as hypothesized. As mentioned above, deforestation is greater where there is good road access. On the other hand, the use of burning is lower in such areas, which will tend to lead to better resource conditions. Communities closer to the urban market were more prone to adopt several conservation measures; however, this may be a reflection more of access to information and technical assistance than access to markets or economic opportunities. The impacts of road access on measures of welfare are not as favorable as we expected to find. However, wage growth has been higher in the horticultural and nonfarm employment pathways, indicating that the indirect effects of market access (as a determinant of these pathways) must also be considered. Road and urban market access did not have significant direct effects on measures of poverty.

Overall, these results confirm our expectations that market access should lead to intensified use of agricultural inputs, while having mixed impacts on natural resource conditions. The findings do not show the impacts of market access on changes in wages and poverty that we expected, but this may be because these effects are mitigated by migration.

Access to Technology

The presence of technical assistance programs in agriculture has contributed significantly to several aspects of agricultural intensification and natural resource management, including reduced use of fallow and burning and adoption of many conservation measures. We found no significant impacts of technical assistance on most outcome measures. Overall, the results suggest that technical assistance has been most effective in promoting more labor intensive practices, but that these changes have not produced large measurable impacts on agricultural productivity, resource conditions, or poverty.

Pathways of Development

As hypothesized, we found that a relatively small number of development pathways exist in central Honduras and that these are largely determined by factors affecting comparative advantage, including agricultural potential, market access and population pressure. Basic grains and livestock production dominate in lower rainfall and more remote areas, while commercially oriented farming and non-farm employment activities are more common in areas closer to roads and the urban market. Higher population pressure distinguishes the basic grains expansion communities, where basic grains productivity and production has been increasing, from the basic grains stagnation communities, where productivity has been declining.

We found substantial differences in agriculture, resource management practices and outcomes across the pathways. Agriculture is most labor intensive in the forestry pathway, where arable land is scarce, and most capital intensive in the commercially oriented horticultural pathway. Although adoption of conservation measures is generally low throughout the central region, different measures showed potential in different pathways. For example, labor intensive investments such as terraces and live barriers appear to have more potential in the forestry specialization pathway than most other pathways, while fruit tree planting appears to have more potential in more extensive production systems, such as in the basic grains expansion pathway. The resource problems also vary significantly across pathways. For example, there are greater problems associated with agricultural burning practices and deforestation in the basic grains pathways than most other pathways, while water access and quality is a serious concern in the horticultural pathway. Agricultural productivity and wages also differ substantially across the pathways.

POLICY IMPLICATIONS

These research findings suggest several important implications for policymakers seeking to increase agricultural productivity, ensure resource sustainability, and reduce poverty in hillside areas of Honduras. The findings with regard to poverty suggest that basic infrastructure and public services are critical and badly needed throughout most of the central region, and that interventions to promote sustainable agricultural production are likely to be insufficient to address the problems of poverty in the region. Efforts to provide these services should be continued and expanded to poorly served areas, particularly more remote areas, regardless of what is done to address resource management issues.

Our findings with regard to technical assistance programs indicate the importance of increasing productivity as a primary objective if such programs are to have a substantial and long-term impact. The low adoption of most conservation measures despite substantial efforts to promote them is often due to their high labor costs and limited near-term economic benefits, according to survey respondents. This has often been the case with similar measures promoted elsewhere (for example, see Lutz et al. 1994).

Part of the problem with technical assistance appears to be a lack of targeting of different types of measures to different situations. A “one-size-fits-all” approach is unlikely to be successful, given the pathway-specific nature of opportunities and constraints. Production and conservation practices that are appropriate for labor intensive agriculture, such as in forestry communities, may not be appropriate in more extensive production systems such as in the basic grains expansion pathway, or in more external input-intensive production such as in the horticultural pathway. Less labor-intensive practices with income earning potential, such as fruit production, need to be developed and promoted in such pathways.

Credit, agrarian reform and land titling programs have had limited impact in central Honduras, probably because of their limited presence. The importance of education as a conditioning factor in adoption of some soil conservation measures suggests that educational improvement may have important “spin-off” benefits for resource conservation, in addition to its direct impacts on reducing poverty.

The widespread decline in use of burning is an example where policies and technical assistance programs seem to have had a large beneficial impact for environmental objectives. The increase in continuous cropping, access to alternative techniques (particularly use of herbicides), and shifts into cash crop production undoubtedly were also important contributing factors to this change.

In conclusion, there are many ways to promote more productive, sustainable, and poverty-reducing development in the central region of Honduras. While some of these can be applied across the board, most will need to be tailored more specifically to the particular problems and opportunities available in different development pathways.

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Appendix Table: Means of variables used in the analysis

Variable	Basic grains expansion	Basic grains stagnation	Horticul-tural expansion	Coffee expansion	Forestry specializa-tion	Nonfarm employ-ment	Region
	Robust standard errors in parentheses[a]						
Mid point altitude (m.a.s.l.)	848 (13)	866 (64)	1427 (37)	1168 (79)	1050 (144)	1161 (56)	1104 (33)
Percentage of area with >30% slope	6.46 (1.82)	7.39 (0.89)	6.39 (3.19)	7.11 (1.54)	4.51 (1.40)	3.12 (0.63)	5.72 (0.68)
Number of rainfall days per year	122.4 (7.8)	89.7 (4.5)	154.6 (24.5)	152.7 (10.5)	153.0 (22.9)	129.5 (7.9)	132.0 (6.2)
Population density (per km^2)							
- 1974	20.0 (6.8)	44.9 (7.0)	19.9 (6.2)	23.8 (5.6)	11.3 (3.9)	42.9 (10.6)	31.0 (4.1)
- 1988	19.6 (5.9)	47.0 (7.3)	42.8 (8.9)	35.5 (9.3)	18.4 (4.5)	44.7 (6.1)	38.3 (3.7)
Distance to Tegucigalpa (km)	103.2 (10.6)	69.9 (6.2)	50.6 (7.0)	76.9 (7.2)	76.6 (12.0)	40.2 (7.4)	64.7 (3.3)
Distance to road (km)	5.75 (2.01)	2.08 (0.79)	0.0 (0.0)	0.21 (0.17)	0.14 (0.12)	0.0 (0.0)	0.84 (0.16)
Percentage of communities							
- where road constructed since 1975	0.0 (0.0)	4.3 (3.5)	92.2 (6.9)	0.0 (0.0)	0.0 (0.0)	17.4 (13.3)	15.0 (6.0)
- that already had road access in 1975	0.0 (0.0)	63.6 (11.7)	7.8 (6.9)	87.2 (9.0)	71.6 (24.3)	82.6 (13.3)	66.2 (7.2)
- that still do not have road access	100.0 (0.0)	32.1 (10.8)	0.0 (0.0)	12.8 (9.0)	28.5 (24.2)	0.0 (0.0)	18.8 (4.0)
- with agricultural technical assistance	46.0 (21.3)	100.0 (0.0)	61.7 (28.0)	100.0 (0.0)	100.0 (0.0)	55.8 (17.4)	80.4 (6.9)
- with credit program	0.0 (0.0)	25.3 (9.8)	100.0 (0.0)	100.0 (0.0)	71.5 (24.2)	38.4 (17.3)	60.2 (7.9)
- with agrarian reform program	0.0 (0.0)	12.9 (5.9)	38.3 (28.0)	18.3 (11.3)	28.5 (24.2)	24.0 (14.9)	20.6 (6.6)
- with land tilling program	0.0 (0.0)	5.9 (5.0)	46.1 (27.8)	40.2 (14.0)	0.0 (0.0)	24.0 (14.9)	23.9 (6.9)
- with enforcement of forest regulations by national or municipal government	15.3 (13.0)	17.2 (6.7)	53.9 (27.8)	81.7 (11.3)	100.0 (0.0)	57.4 (17.8)	57.6 (8.0)
Percentage of adults literate							
- 1974	50.6 (8.9)	52.8 (4.5)	42.3 (3.2)	52.9 (5.2)	51.5 (3.3)	57.3 (5.3)	52.7 (2.5)
- 1988	56.0 (8.9)	54.8 (5.9)	48.8 (6.7)	65.7 (5.4)	64.3 (0.1)	68.7 (4.9)	62.0 (2.3)

Variable	Basic grains expansion	Basic grains stagnation	Horticul-tural expansion	Coffee expansion	Forestry specializa-tion	Nonfarm employ-ment	Region
Index of proportion of households using[b] (1996)							
- continuous cropping without fallow	2.77 (0.46)	3.08 (0.33)	4.50 (0.37)	4.18 (0.43)	6.00 (0.00)	3.76 (0.75)	3.96 (0.29)
- burning to prepare fields	3.23 (0.37)	4.03 (0.16)	1.31 (0.31)	2.29 (0.23)	1.71 (0.93)	2.85 (0.49)	2.66 (0.20)
- chemical fertilizer	3.85 (0.94)	1.49 (0.17)	4.31 (0.21)	3.71 (0.28)	3.00 (0.39)	1.76 (0.53)	2.78 (0.23)
- insecticides	3.23 (0.58)	2.48 (0.40)	4.31 (0.21)	3.45 (0.39)	1.14 (0.56)	3.16 (0.70)	3.05 (0.27)
- herbicides	3.53 (0.61)	3.17 (0.33)	3.53 (1.12)	2.57 (0.51)	1.14 (0.56)	1.68 (0.62)	2.48 (0.29)
- improved seeds	0.00 (0.00)	0.34 (0.24)	5.08 (0.56)	2.15 (0.61)	1.43 (0.48)	1.25 (0.59)	1.66 (0.32)
- irrigation	0.54 (0.21)	0.72 (0.21)	2.46 (0.83)	0.50 (0.20)	0.57 (0.28)	0.50 (0.23)	0.76 (0.17)
- oxen	1.23 (0.37)	1.88 (0.45)	2.31 (0.21)	1.74 (0.32)	1.57 (0.28)	1.85 (0.14)	1.81 (0.14)
- cows	3.23 (0.37)	2.55 (0.34)	2.38 (0.82)	2.33 (0.31)	3.43 (0.48)	1.91 (0.15)	2.43 (0.18)
- pigs	4.15 (0.40)	3.48 (0.31)	2.38 (0.82)	2.60 (0.31)	2.43 (0.28)	1.96 (0.34)	2.66 (0.19)
- chickens	4.61 (0.36)	4.39 (0.16)	3.62 (1.36)	4.16 (0.10)	4.86 (0.56)	4.15 (0.15)	4.24 (0.17)
- contour planting	0.31 (0.18)	1.19 (0.62)	2.69 (1.37)	2.52 (0.47)	2.15 (0.47)	1.88 (0.65)	1.94 (0.27)
- minimum tillage	1.23 (0.72)	0.53 (0.27)	0.08 (0.07)	1.23 (0.49)	2.58 (0.73)	0.77 (0.28)	0.98 (0.22)
- mulch	1.23 (0.72)	1.12 (0.33)	0.62 (0.42)	1.83 (0.62)	0.57 (0.48)	1.15 (0.53)	1.23 (0.26)
- incorporation of crop residues	0.61 (0.52)	1.65 (0.54)	0.93 (0.54)	1.45 (0.57)	1.14 (0.97)	1.04 (0.30)	0.98 (0.22)
- cattle manure	0.92 (0.54)	1.20 (0.61)	0.31 (0.21)	1.06 (0.28)	0.57 (0.48)	1.04 (0.50)	0.98 (0.22)
- chicken manure	0.00 (0.00)	0.24 (0.09)	0.62 (0.39)	0.73 (0.30)	0.00 (0.00)	2.01 (0.67)	0.89 (0.26)
- terraces	0.15 (0.13)	0.27 (0.15)	1.62 (0.28)	2.42 (0.49)	2.29 (0.85)	1.75 (0.57)	1.60 (0.26)
- live barriers	0.85 (0.13)	1.20 (0.22)	1.39 (0.60)	2.71 (0.50)	3.15 (0.73)	1.61 (0.48)	1.91 (0.24)
- stone walls	1.46 (0.39)	2.72 (0.40)	1.32 (0.55)	1.08 (0.24)	2.86 (0.97)	1.47 (0.52)	1.70 (0.25)
- tree planting	2.93 (0.63)	1.29 (0.30)	0.77 (0.32)	2.55 (0.53)	0.85 (0.47)	1.18 (0.34)	1.63 (0.21)

Variable	Basic grains expansion	Basic grains stagnation	Horticul-tural expansion	Coffee expansion	Forestry specializa-tion	Nonfarm employ-ment	Region
Index of proportion of households using[b] (1975)							
- continuous cropping	2.44 (0.39)	2.75 (0.43)	4.14 (0.28)	2.88 (0.55)	5.00 (0.69)	4.31 (0.55)	3.48 (0.31)
- burning to prepare fields	4.46 (0.29)	4.62 (0.21)	4.16 (0.14)	4.26 (0.18)	5.00 (0.69)	4.20 (0.21)	4.36 (0.09)
Index of change use[b] (1996-75)							
- chemical fertilizer	0.69 (0.18)	0.56 (0.13)	1.00 (0.00)	0.86 (0.12)	1.00 (0.00)	0.60 (0.20)	0.76 (0.06)
- insecticides	0.07 (0.43)	0.75 (0.10)	1.00 (0.00)	0.58 (0.24)	0.57 (0.28)	0.78 (0.16)	0.67 (0.11)
- herbicides	0.85 (0.13)	0.94 (0.05)	0.92 (0.07)	0.83 (0.12)	0.57 (0.28)	0.60 (0.19)	0.78 (0.07)
- improved seeds	0.00 (0.00)	0.06 (0.05)	0.46 (0.28)	0.27 (0.13)	0.43 (0.28)	0.18 (0.16)	0.23 (0.07)
- irrigation	0.23 (0.32)	0.20 (0.21)	-0.42 (0.45)	0.21 (0.13)	0.57 (0.28)	0.13 (0.29)	0.19 (0.11)
- oxen	-0.07 (0.43)	-0.28 (0.10)	-0.38 (0.29)	-0.63 (0.16)	-1.00 (0.00)	-0.85 (0.14)	-0.60 (0.09)
- cows	-0.69 (0.18)	0.11 (0.17)	-1.00 (0.00)	-0.63 (0.25)	-0.43 (0.48)	-0.85 (0.14)	-0.58 (0.11)
- pigs	0.08 (0.38)	-0.29 (0.29)	-1.00 (0.00)	-0.73 (0.13)	-1.00 (0.00)	-0.79 (0.14)	-0.66 (0.10)
- chickens	-0.39 (0.24)	-0.21 (0.09)	-0.84 (0.10)	-0.14 (0.12)	-0.43 (0.28)	-0.13 (0.09)	-0.27 (0.07)
Percentages of communities taking collective action to control runoff or improve common land	54.0 (21.3)	24.0 (9.4)	0.0 (0.0)	32.1 (15.4)	0.0 (0.0)	41.3 (17.4)	29.5 (7.7)
Typical maize yield (kg/ha)							
- in a bad year	886 (190)	649 (57)	1028 (93)	709 (188)	1249 (251)	905 (269)	834 (101)
- in a good year	1792 (376)	1667 (169)	2345 (182)	2259 (536)	2339 (209)	2504 (474)	2195 (210)
Index of change in typical maize yield[c] (1996-75)	0.54 (0.29)	-0.50 (0.25)	0.08 (0.56)	-0.36 (0.20)	-1.00 (0.00)	-0.41 (0.27)	-0.35 (0.13)
Adult male agricultural wage, 1996 (Lps /day)							
- low (slack season)	15.8 (2.0)	16.6 (2.0)	22.3 (1.4)	18.2 (0.7)	20.0 (0.0)	24.4 (1.0)	20.1 (0.8)
- high (peak season)	19.6 (2.6)	22.1 (1.0)	34.2 (7.1)	58.3 (6.3)	39.9 (14.0)	38.0 (3.1)	39.6 (2.9)

Variable	Basic grains expansion	Basic grains stagnation	Horticul-tural expansion	Coffee expansion	Forestry specializa -tion	Nonfarm employ-ment	Region
Ratio of 1996 to 1975 real adult male wage							
- low (slack season)	1.07 (0.25)	0.69 (0.21)	1.19 (0.13)	1.10 (0.19)	1.05 (0.16)	1.08 (0.11)	1.05 (0.08)
- high (peak season)	1.27 (0.27)	0.76 (0.21)	1.71 (0.33)	1.90 (0.71)	1.41 (0.30)	1.47 (0.24)	1.55 (0.26)
Percentage of households with a dirt floor							
- 1974	98.6 (0.9)	85.9 (2.4)	90.2 (3.3)	88.2 (5.2)	94.7 (3.4)	82.8 (3.9)	87.8 (2.0)
- 1988	88.6 (2.7)	77.8 (3.0)	80.2 (4.9)	82.6 (5.6)	93.1 (4.8)	66.6 (7.2)	78.5 (2.9)
Percentage of households in which last child died							
- 1974	10.2 (1.4)	8.0 (1.0)	5.7 (2.7)	7.9 (1.9)	6.7 (1.9)	10.2 (1.4)	8.4 (0.8
- 1988	6.1 (1.0)	4.1 (0.6)	3.8 (1.7)	3.6 (0.6)	3.6 (1.6)	4.2 (1.5)	4.0 (0.5)
Percentage of steep land (over 30% slope) in late 1970s							
- tree cover	66.1 (16.0)	27.3 (4.5)	76.1 (5.8)	77.1 (5.7)	100.0 (0.0)	64.6 (14.1)	66.1 (5.5)
- devegetated	25.8 (12.5)	60.0 (4.7)	3.4 (1.7)	11.2 (4.4)	0.0 (0.0)	28.0 (14.5)	23.1 (5.6)
- cultivated	2.5 (1.0)	6.2 (1.3)	17.7 (8.7)	6.4 (2.7)	0.0 (0.0)	5.0 (1.8)	6.9 (1.8)
- pasture/fallow	5.6 (3.5)	6.5 (1.6)	2.7 (1.7)	5.3 (1.5)	0.0 (0.0)	2.3 (1.6)	3.9 (0.8)
Index of change in[c] (1996-75)							
- cropland quality	0.54 (0.29)	-0.72 (0.24)	0.08 (0.56)	-0.36 (0.24)	-1.00 (0.00)	-0.48 (0.31)	-0.41 (0.14)
- forest area	-1.00 (0.00)	-0.82 (0.09)	-0.23 (0.14)	-0.14 (0.30)	-0.72 (0.24)	-0.32 (0.17)	-0.43 (0.12)
- forest quality	-1.00 (0.00)	-0.72 (0.24)	-0.46 (0.29)	0.01 (0.34)	-1.00 (0.00)	-0.44 (0.30)	-0.47 (0.15)
- water availability	-1.00 (0.00)	-0.73 (0.11)	-0.75 (0.14)	-0.62 (0.10)	-0.77 (0.06)	-0.83 (0.09)	-0.73 (0.05)
- water quality	NA	-0.48 (0.13)	-0.50 (0.13)	-0.60 (0.09)	-0.60 (0.0)	-0.69 (0.20)	-0.61 (0.09)

[a] Means and standard errors are adjusted to account for sampling weights, stratification, and finite population of communities
[b] Values of index: 0 = none, 1 = less than 10%, 2 = minority, 3 = half, 4 = majority, 5 = more than 90%, 6 = all
[c] Index values: -1 = decrease, 0 = no change, +1 = increase

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