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TROPICAL DEFORESTATION AND AGRICULTURAL DEVELOPMENT IN LATIN AMERICA

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PREFACE

Dr. Southgate is an associate professor in Ohio State University's Department of Agricultural Economics. In August 1990, he began a two-year assignment with the U.S. Agency for International Development (AID) and the Instituto de Estrategias Agropecuarias (IDEA) in Quito, Ecuador. He has also consulted for the Environment Department of the World Bank.

Dr. Southgate benefited greatly from interchange with current and former staff members of IDEA and of AID's Quito mission. He is particularly indebted to Dr. Morris Whitaker, of Utah State University, who first pointed out to him the linkages between agricultural land clearing and the scientific base for crop and livestock production, which are explored in this paper. Reported in the paper are findings that are significant in the context of the overall work program of the Environmental Policy and Research Division.

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ABSTRACT

If agricultural frontier expansion were caused exclusively by increasing demands for agricultural commodities, the prospects for containing frontier expansion in Latin America would be very bleak indeed. Throughout the region, populations are overwhelmingly young. With numbers of women capable of bearing children expected to rise for many more years, continued population growth is inevitable, even with the decline in fertility rates currently taking place in nearly every part of the Western Hemisphere. As the number of people demanding to be fed increases, pressure on natural resource inputs to agricultural production will mount.

This paper's regression analysis of the causes of agriculture's geographic expansion in twenty-three Latin American countries yields insights on how this pressure can be accomodated. Specifically, growth in crop and livestock yields, which is associated with investment in non-land assets in the agricultural sector, is shown to alleviate the pressure for frontier expansion associated with enhanced demand for food.

This finding suggests that there are important complementarities between agricultural development and conservation of tropical forests and other natural environments in Latin America.

TROPICAL DEFORESTATION AND AGRICULTURAL DEVELOPMENT IN LATIN AMERICA

Tropical deforestation arouses widespread concern. Available evidence suggests that global climate is being affected (Detwiler and Hall). In addition, biological diversity is threatened because tropical forests, which cover less than 10 percent of the Earth's land surface, harbor half the world's plant and animal species (Myers; Wilson).

In many countries, deforestation is the result of excessive timber extraction. As Repetto and Gillis (1988) emphasize, the royalties loggers pay for access to publicly owned primary forests in southeast Asia fall far short of stumpage values. Responding to opportunities to capture sizable rents, they are inclined to "cut and run." Deforestation in Latin America, by contrast, is primarily an agricultural phenomenon. Brazil and a few other countries have implemented projects to relocate farmers to tree-covered hinterlands. More frequently, conversion of forests into crop land and pasture is "spontaneous," being driven by various economic forces.

By and large, the existing literature on agricultural colonization in the Western Hemisphere addresses the "push" and "pull" factors affecting migration to individual sites in considerable detail. Moran's (1983) study of Altamira, a settlement on Brazil's Transamazon Highway, is illustrative of this approach. The geographic focus of this paper's analysis of farmers' and ranchers' encroachment on tropical forests and other natural habitats is much broader. Regression analysis is used to explore the linkages between agricultural development and frontier expansion at the national level. In particular, the possibility that deforestation in Latin America is symptomatic of agricultural <u>under-development</u> is explored.

The model and data base used to evaluate frontier expansion are described at the beginning of the paper. Next, the results of regression analysis are presented. Land clearing is shown to be inversely related to trends in crop and livestock yields. This finding prompts a brief discussion of the factors influencing agricultural productivity and leads to suggestions about how to conserve natural environments in Latin America and other parts of the developing world.

A Model of Agricultural Frontier Expansion

Simple Malthusian explanations of tropical deforestation, which are widely circulated, leave one with the sense that "surplus people" are heading for the developing world's agricultural frontiers in droves. This is indeed happening in some places, including parts of Latin America. For the most part, however, cities bear the burden of mounting demographic pressure in the Western Hemisphere. Even under the most miserable circumstances, urban dwellers rarely move to the Amazon Basin or the Caribbean lowlands of Central America. In addition, emigrants from the countryside, where fertility far outstrips mortality, usually go to cities and towns, not the agricultural frontier. As indicated in Table 1, urbanization is a more pronounced phenomenon in the region than population growth *per se*.

If there is a relationship between population growth and frontier expansion, then, it is primarily an indirect one. Domestic demand for agricultural commodities is rising in most countries primarily because the number of consumers is growing. In turn, increased demand for food enhances derived demand for land inputs to crop and livestock production.

Another potential source of demand growth is external. Pursuing

Table 1. Population Growth and Urbanization, Selected Latin American Countries

Country	Total Population in 1988	Annual Growth, 1980-88	Urban Population in 1988	Annual Growth, 1980-88
Brazil	144 million	2.2 percent	108 million	3.6 percent
Colombia	32	2.1	22	3.0
Costa Rica	3	2.3	1	1.9
Ecuador	10	2.7	6	4.7
Guatemala	9	2.9	3	2.9
Honduras	5	3.6	2	5.6
Mexico	84	2.2	60	3.1
Paraguay	4	3.2	2	4.5
Peru	21	2.2	14	3.1

Source: IBRD

development strategies that emphasized import substitution and industrialization, Latin American governments long discouraged exports by levying taxes and overvaluing domestic currencies (Valdés). In recent years, however, these distortions have been reduced in a number of countries. As a result, specialization has increased in the production and export of agricultural commodities in which the region holds a comparative advantage.

All else remaining the same, increased domestic or international demand for agricultural commodities leads to an outward shift in the sector's extensive margin. But the magnitude of that shift depends on two "supply side" factors. The first is a "land constraint." The second is the supply of "non-land" inputs in the agricultural sector (e.g., human capital and managerial talent).

The "land constraint" on settlers' behavior largely reflects property arrangements. Where all land, agricultural and non-agricultural, is privately owned, frontier expansion is influenced by some of the opportunity costs of land clearing. In particular, agents of deforestation are forced to take into account the income associated with timber production.

Along Latin America's agricultural frontiers, however, all opportunity costs of creating new crop land and pasture are, from a settler's perspective, external costs. Because destruction of natural vegetation is a prerequisite for formal or informal property rights (Mahar; Southgate et al.), nobody is in a good position to internalize forestry rents. In addition, a settler who is slow about clearing land is running the risk that somebody else will "jump" his claim. Accordingly, colonists deforest immediately whenever agricultural rents can be captured by doing so (Southgate).

Given the nature of frontier tenurial regimes in Latin America, the land constraint on colonists' behavior is important only if virtually all soils that lend themselves to crop or livestock production have been occupied by farmers and ranchers. As indicated in Table 2, this seems to have occurred in two Andean countries: Bolivia and Peru. In addition, the frontier is all but closed in Uruguay and five Central American countries: Costa Rica, Nicaragua, Honduras, El Salvador, and Guatemala. In Haiti, agriculture's extensive margin has advanced well beyond what natural conditions warrant. The

Table 2. Current versus Potential Agricultural Land Use in Selected Latin American Countries with Widespread Nutritional Deficits

Country	1987 Agricultural Land[1]	Potential Agricultural Land[2]
Bolivia	30,149,000 HA	30,031,000 HA
Colombia	17,480,000	43,973,000
Ecuador	7,646,000	12,532,000
El Salvador	1,343,000	1,320,000
Haiti	1,399,000	645,000
Honduras	4,315,000	3,267,000
Peru	30,845,000	33,565,000

Sources: 1. FAO, 1989A
2. OAS.

prospects for frontier expansion are also limited in the Dominican Republic and Jamaica.

Agriculture's geographic expansion is also affected by the availability of non-land assets for crop and livestock production. As those assets are formed, yields increase and substitution away from land takes place. Consequently, the pressure to convert forests and other natural environments into crop land and pasture is eased.

Principal factors affecting agriculture's geographic expansion having been identified, let us turn to specification of the dependent variable as well as the regression model itself. Since property arrangements oblige agricultural colonists to ignore the value of tree-covered land, the option of using the ratio of cleared area to remaining forests makes little sense. Instead, the appropriate dependent variable for a causal analysis of frontier expansion in Latin America is growth in the area used to produce crops and livestock. The regression model is:

$$AGLNDGRO = B_0 + B_1\ POPGRO + B_2\ EXPGRO + B_3\ YLDGRO + B_4\ NOLAND \quad (1)$$

The coefficients of population growth (POPGRO) and agricultural export growth (EXPGRO), which both tend to stimulate frontier expansion (AGLNDGRO), are expected to be positive. By contrast, the coefficient of yield growth (YLDGRO), which is associated with the formation of non-land assets in the agricultural sector and which diminishes incentives for colonization, is probably negative. Finally, NOLAND is a dummy variable indicating that closure of the agricultural frontier has occurred or is imminent. Its coefficient is expected to be negative.

Table 3. Data Used in the Regression Analysis

Country	Frontier Expansion[1] (AGLNDGRO)	Population Growth[2] (POPGRO)	Export Growth[3] (EXPGRO)	Yield Growth[4] (YLDGRO)
Argentina	-0.1% p.a.	1.4% p.a.	-8.5% p.a.	-0.5% p.a.
Belize	1.2	2.4	2.2	---
Bolivia	0.4	2.7	0.0	-1.4
Brazil	0.6	2.2	-3.5	3.2
Chile	0.1	1.7	17.5	3.6
Colombia	0.7	2.1	0.0	1.0
Costa Rica	1.1	2.3	5.2	1.5
Cuba	0.7	1.1	-4.3	-0.9
Dominican Republic	0.1	2.4	-7.4	0.1
Ecuador	2.0	2.7	11.4	-0.2
El Salvador	0.1	1.3	-8.5	-3.6
Guatemala	0.8	2.9	-2.5	-2.0
Guyana	0.1	-4.4	0.0	-3.9
Haiti	0.0	1.8	-8.0	1.0
Honduras	0.4	3.6	3.4	0.8
Jamaica	-0.3	1.5	0.0	3.5
Mexico	0.6	2.2	14.0	1.7
Nicaragua	0.8	3.4	-14.1	-4.8
Panama	0.7	2.2	-6.0	1.7
Paraguay	1.0	3.2	0.0	3.1
Peru	0.1	2.2	0.0	1.8
Surinam	3.2	1.1	0.0	-9.3
Uruguay	-0.1	0.6	-8.2	0.5
Venezuela	0.3	2.8	0.0	4.1

Sources:
1. FAO, 1989A and WRI
2. IBRD
3. FAO, 1989B
4. FAO, 1989A

Data

The twenty-four countries listed in Table 3 comprise the sample used in this study. Data on agricultural land use, population growth, exports, and agricultural yields for each country were obtained from annual publications of the Food and Agriculture Organization of the United Nations (FAO) as well as the International Bank for Reconstruction and Development (IBRD).

For twenty-one of the countries, data on crop land and pasture (FAO, 1989A) were applied to the following logarithmic formula in order to calculate the regression model's dependent variable:

$$AGLNDGRO = 100 [\log (1987 \text{ ag land}) - \log (1982 \text{ ag land})] / 5 . \quad (2)$$

This approach was not appropriate, however, for determining dependent variable values for Bolivia, Mexico, and Paraguay because land use data for those three countries are especially questionable.

Remote sensing studies conducted by the FAO suggest that annual deforestation currently amounts to 117,000 HA in Bolivia and 615,000 HA in Mexico (WRI). By contrast, FAO (1989A) reported that crop land expanded by just 24,000 HA and that pasture declined by 250,000 HA between 1982 and 1987 in the former country. According to the same source, Mexico had exactly 74,499,000 HA of pasture in 1972, 1977, 1982, and 1987.

In Paraguay, estimated deforestation is 212,000 HA per annum (WRI), which is generally consistent with a 210,000 HA, or 11 percent, increase in the area planted to crops between 1982 and 1987. However, pastures were supposed to have risen by 3,460,000 HA, or 21 percent, in the same period (FAO, 1989A). The latter change probably does not reflect an actual shift in the agricultural frontier. Instead, a large portion of Paraguay's range lands seems to have been reclassified as pasture.

Because of these incongruities between deforestation and agricultural land use data, AGLNDGRO values were calculated for Bolivia, Mexico, and Paraguay by dividing estimated deforestation (WRI) by 1987 agricultural land (FAO, 1989A). This substitute procedure probably understates actual frontier expansion since forests are not the only natural environment being penetrated by farmers and ranchers.

With respect to the regression model's first independent variable, POPGRO, the IBRD's (1990) estimates of annual population growth during the period, 1980 through 1988, were used.

Estimates of annual growth in agricultural exports were obtained by applying trade data (FAO, 1989B) for each of the twenty-four countries in the sample to the following regression:

$$[\log (\text{yr t exports}) - \log (\text{1983 exports})] = G (\text{yr t}) , \qquad (3)$$

where the range of "t" was 1984 through 1988. For two-thirds of the countries listed in Table 3, the regression coefficient, G, serves as a measure of EXPGRO. For the remaining eight countries, however, EXPGRO was held to zero because the null hypothesis regarding G was accepted with a confidence interval of 90 percent.

Calculation of the third independent variable in the regression equation involved two steps. First, FAO's (1989A) index of crop production in 1982 was divided by crop land in the same year (FAO, 1989A) to obtain yields for 1982. Yields for 1987 were obtained in the same fashion. Second, a procedure like the one described in equation (2) was applied to identify annual yield growth during the intervening five years:

$$\text{YLDGRO} = 100 [\log (\text{1987 yields}) - \log (\text{1982 yields})] / 5 . \qquad (4)$$

Consistent with observations made in the preceding section, the value of NOLAND was set equal to one for the following eleven countries: Bolivia, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Peru, and Uruguay.

Other than dummy variable values, the full data set used in regression analysis is presented in Table 3. As can be seen, AGLNDGRO varies considerably from country to country. Between 1982 and 1987, agriculture's extensive margin actually receded in Argentina, Jamaica, and Uruguay. In several other countries, frontier expansion was negligible.

Compared to EXPGRO and YLDGRO, POPGRO does not exhibit much variation. Only one country, Guyana, lost population, due to heavy emigration. Between 1980 and 1988, population growth exceeded 2.5 percent a year in seven countries. Annual rates of increase were between 1.5 percent and 2.5 percent in nearly half the sample.

Values of EXPGRO and YLDGRO are widely scattered. Agricultural exports declined in countries that suffered civil conflict, maintained policies that discouraged crop and livestock production, or both. In light of increased domestic consumption of agricultural commodities (and, in many countries, increased exports), yield trends have been disappointing. Only in Brazil, Chile, Jamaica, and Venezuela did annual percentage yield increases exceed rates of population growth. The ratio of crop and livestock output to agricultural land actually declined in nine countries.

Other than a weak correlation between EXPGRO and YLDGRO, multicollinearity is not a major problem in the data set. It is particularly interesting to note that there is no strong linkage between YLDGRO and the dummy variable indicating the presence of a serious land constraint (NOLAND). The governments of countries where that constraint holds have apparently been slow to encourage formation of substitute assets in the agricultural sector.

Regression Results

Indices of crop production being unavailable for Belize, that country had to be deleted from the sample used in the regression analysis. With data for the remaining twenty-three countries (Table 3), ordinary least squares estimation yielded the following results:

$$\begin{aligned}
\text{AGLNDGRO} = {} & \underset{\substack{(0.161)\\(2.876)}}{0.463} + \underset{\substack{(0.066)\\(3.773)}}{0.249}\ \text{POPGRO} + \underset{\substack{(0.014)\\(2.214)}}{0.031}\ \text{EXPGRO} \\
& - \underset{\substack{(0.033)\\(-6.000)}}{0.198}\ \text{YLDGRO} - \underset{\substack{(0.205)\\(-3.127)}}{0.641}\ \text{NOLAND}
\end{aligned} \qquad (5)$$

ADJ R^2 = 0.669 DW = 2.065 SSR = 3.489 F = 12.098

For a cross-sectional study, an adjusted R^2 of 67 percent is very good, particularly since aggregate national-level data for a heterogeneous group of countries have been used. Dummy variables for war, inclement weather, inflation risks, and the like could have been introduced. But to maintain a sharp focus on linkages between frontier expansion and agricultural development, this was not done. That the F-statistic exceeds 8.290 -- which is the minimum value for rejecting the hypothesis that there is no linear relationship between AGLNDGRO and the four independent variables (99 confidence interval) -- reenforces the conclusion that this paper's simple model is a satisfactory framework for analyzing encroachment on tropical forests and other natural environments in Latin America.

The signs of all parameter estimates are consistent with what one expects. The two rows of figures under the regression coefficients are standard errors and t-statistics, respectively. Using a two-tail test and a 99 percent confidence interval, one rejects the null hypothesis for the coefficients of POPGRO, YLDGRO, and NOLAND. At a 95 percent confidence interval, the null hypothesis is rejected for EXPGRO's coefficient as well.

Interpretation of the coefficients is straightforward. For example, if annual population growth changes from 1 to 2 percent, frontier expansion can be expected to rise by a factor of 0.249 percent a year. A similar increase in export growth causes AGLNDGRO to go up by 0.031 percent a year. By contrast, an X percent increase in yields offsets nearly four-fifths of the impacts of X percent population growth.

How to Contain Agricultural Colonization

If shifts in agriculture's extensive margin were driven exclusively by increasing or decreasing demands for agricultural commodities, the prospects for containing frontier expansion in Latin America would be very bleak indeed. Throughout the region, populations are overwhelmingly young. With numbers of women capable of bearing children expected to rise for many more years, continued population growth is inevitable, even with the decline in fertility rates currently taking place in nearly every part of the Western Hemisphere (IBRD). As the number of people demanding to be fed increases, pressure on natural resource inputs to agricultural production will mount.

Chile offers an excellent example of how to contain this pressure. If yields had not risen in that country during the 1980s, 17.5 percent annual growth in agricultural exports combined with 1.7 percent annual population growth would have induced frontier expansion exceeding 1.0 percent a year. However, yield increases, which resulted from unfettering market forces in the agricultural sector and from investing in research and extension, were also impressive. As a result, agriculture's extensive margin remained stable.

Ecuador is another country that faced the challenge of rapidly increasing demand for agricultural commodities during the last decade. The most crowded country in South America, its population grew by nearly 3 percent a year. In addition, annual increases in its agricultural exports amounted to 11.4 percent. The latter rate was exceeded only in Chile and Mexico.

Unfortunately, Ecuador's response to demand growth was entirely different from Chile's. Because agricultural yields actually declined, dedicating more land to crop and livestock production proved to be essential. At 2.0 percent per annum, the country had the second highest rate of frontier expansion in Latin America between 1982 and 1987. Surinam's rate (3.2 percent a year) was higher only because its initial base of crop land and pasture was tiny.

Unlike El Salvador, Nicaragua, and a few other nations, Ecuador cannot pin the blame for stagnating yields on civil conflict. In addition, the 1980s were generally a period of market liberalization in the country. Disappointing yield trends were instead a consequence of meager investment in non-land assets, as indicated by a weak scientific base underpinning crop and livestock production.

As Whitaker (1990) points out, research and extension networks are highly fractured in Ecuador. Separate entities created for agriculture, forestry, and other sectors of the rural economy do not cooperate on basic scientific research. Similarly, coordination among narrowly focused divisions of the extension service is limited. In addition, funding is meager. Real spending on agricultural research, for example, declined 7.3 percent a year from 1975 through 1988. Having fallen to 0.17 percent of agricultural GDP, research expenditures compare poorly with spending by neighboring countries (Whitaker).

Given the state of Ecuadorian agriculture's scientific base, yields are low in the country. This means that growing demands for crops and livestock have to be met by bringing more land, which is usually of marginal quality, into production. Two-thirds of the increased crop production occurring in Ecuador between the middle 1960s and the middle 1980s, for example, were accounted for by frontier expansion. Improved productivity explained only the remaining third (Whitaker and Alzamora).

Implications for Conservation Strategies

Some economists attempting to explain the loss of natural habitats in the developing world fall into a habit of analysis that is nearly as old as the discipline itself. Like those who advocate acreage controls to reduce agricultural commodity surpluses in the United States, they underestimate the degree to which non-land inputs can be substituted for land in the production of crops and livestock. If the option of substitution is ignored, then the predictions of a simple Ricardian model of the agricultural economy hold. That is, frontier expansion is the only possible response to market or demographic "shocks."

To be sure, formation of non-land assets should reflect an agricultural economy's factor endowments (Hayami and Ruttan). For example, investment in agriculture's scientific base is not particularly urgent where land and other natural resources are abundant. Unfortunately, investment of that type continues to be marginal in many Latin American countries where prospects for frontier expansion are limited. Put another way, agricultural under-development and encroachment by farmers and ranchers on fragile environments go hand in hand in the region.

Although it should be a primary element of any strategy to conserve renewable natural resources, increasing agricultural productivity will not be enough to save Latin America's natural habitats. A re-ordering of property rights is also necessary. As indicated earlier in this paper, vast stretches of the region's tropical forests are, in effect, open access resources in which individuals can secure property rights by removing natural vegetation (Mahar; Southgate et al.). As long as this tenurial regime remains in place, continued deforestation is inevitable.

In Latin America, as in other parts of the developing world, the wise use and management of renewable natural resources depends on a thorough overhaul of the policy environment. Resource users' property rights need to be strengthened. Subsidies and regulations that drive a wedge between prices and scarcity values also need to be removed. In addition, formation of non-land assets needs to take place so that agriculture and other sectors of the rural economy will be less dependent on natural resource inputs.

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