The Influence of Accessibility, Local Institutions, and Socioeconomic Factors on Forest Cover Change in the Mountains of Western Honduras

Authors: Southworth, Jane, and Tucker, Catherine

Source: Mountain Research and Development, 21(3) : 276-283

Published By: International Mountain Society

URL: https://doi.org/10.1659/0276-4741(2001)021[0276:TIOALI]2.0.CO;2

Mountain Research and Development Vol 21 No 3 August 2001: 276–283

Jane Southworth and Catherine Tucker

The Influence of Accessibility, Local Institutions, and Socioeconomic Factors on Forest Cover Change in the Mountains of Western Honduras

Tropical deforestation poses a threat to ecological sustainability and socioeconomic development in many parts of the world. Information on forest transformations is especially pertinent in sensitive ecological zones such as mountainous regions, where forest cover protects steep slopes and thin soils from erosion. Such areas are frequently unsuitable for agriculture, but inhabitants may have few alternatives to meet subsistence needs. Understanding the relationship between human behavior and forest change poses a major challenge for development projects, policy makers, and environmental organizations that aim to improve forest management. Knowledge of the areal extent of forest cover and the processes of change represents an integral step, but in many areas of the globe, these processes are still relatively unknown. This study addresses forest cover change in a community in the mountains of western Honduras. Between 1987 and 1996, 9.77 km^2 of land was reforested and only 7.48 km^2 was deforested, as determined by satellite image analysis. This reforestation is related to the current institutional, biophysical, and socioeconomic contexts. Forests remain primarily on steeper slopes, at higher elevations, and at a distance from settlements and roads. A county ban on logging has allowed regrowth of previously logged areas. Agricultural intensification appears related to abandonment of some marginal lands. Processes of privatization have been occurring; private forests reveal higher reforestation and lower deforestation rates than communal forests. Privatization, however, has favored the wealthy. Thus, the majority has had to depend on shrinking communal forests.

Keywords: *Reforestation; remote sensing; privatization; GIS; land tenure; Honduras.*

Peer reviewed: *January 2001.* **Accepted:** *March 2001.*

Introduction

The mapping of tropical forest biomes has received global attention due to the rapid rates of change that have been reported (Mayaux and Lambin 1995) and the significance of such changes to the world's climate system, biological diversity, and carbon cycle (Apan and Peterson 1998). The most frequently used technique for mapping tropical forests or change rates is visual and digital analysis of satellite data (Hall et al 1991). On-the-ground field studies alone are too costly an approach. Remote sensing from satellites allows the production of maps at a greater spatial extent and over frequent time steps while saving time needed in the field for map testing and correction, interviews, and vegetation analysis.

Several studies have used remote sensing to map patterns of deforestation and to analyze the rates of such changes in the tropics and elsewhere (Hall et al 1991; Roughgarden et al 1991; Woods and Skole 1998). Such studies have proven useful for establishing the causes of deforestation and the impact of forest cover changes on the region. Monitoring of change (be it deforestation or reforestation) is frequently perceived as one of the most important contributions of remote sensing technology to the study of global ecological and environmental change (Roughgarden et al 1991; Apan and Peterson 1998). This study incorporates remote sensing for mapping change but also integrates biophysical, socioeconomic, land use, and institutional data to interpret the forest change trends revealed by image analysis.

The study focuses on a major section of the county of La Campa in the mountains of western Honduras. This county offers an important opportunity for forest cover analysis due to the high amount of forest remaining, approximately 60%. La Campa has traditionally left forests under communal management, but pressures for privatization have led to the creation of private forests on more accessible portions of communal lands. At the local and national levels, agricultural intensification is related to technological change due to modernization, as well as to population pressure. The study also encompasses a surrounding area in the Department of Lempira (Lempira region) for a broader perspective on

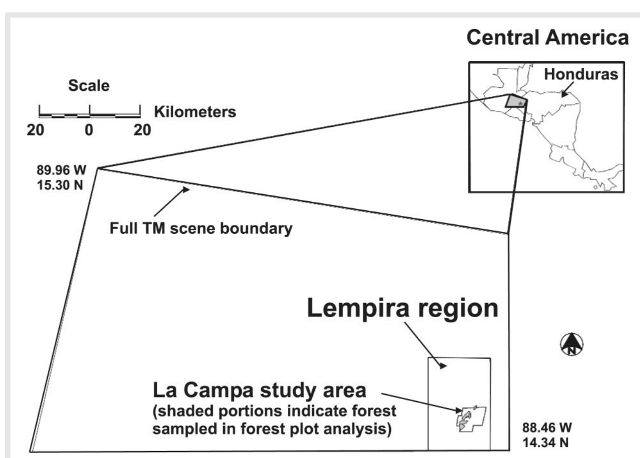


FIGURE 1 Location of the study area in the Lempira region, Honduras, showing area covered by satellite image. Latitude and longitude coordinates are in decimal degrees.

FIGURE 2 Mountain forests covering steep slopes in western Honduras. (Photo by Catherine Tucker, 2000)

the processes observed in La Campa (Figure 1). Few national-level studies of forest status exist for Honduras (eg, FAO 1968; SECPLAN/ DESFIL/ USAID 1989; AFE-COHDEFOR 1996), and regional or case studies that discuss forest change tend to focus on the high biodiversity areas of the northern coast or on the central and eastern pine forests (eg, Richards 1996; Sunderlin and Rodríguez 1996; Godoy et al 1997). The mountainous zones of western Honduras also merit analysis due to their naturally occurring forests, the potential for forest regrowth and production, and socioeconomic processes of change.

Methodology

Study area

The study site in La Campa features rugged topography, generally shallow soils, and vegetation dominated by pine and oak forests. Most forests occur on relatively inaccessible, steeply sloping terrain (Figure 2). Elevation in the area ranges from 1100 to 2849 m above sea level, with a mean elevation of approximately 1500 m. Subsistence production of maize and beans represents the most common agricultural land use. The higher elevations are becoming increasingly important for production of coffee, which is now one of Honduras' leading exports (IHCAFE 1998; Tucker 1999). Typical of the region, timber represents the most important natural resource. Pine trees (*Pinus oocarpa, Pinus patula* spp *Tecunumani,* and *Pinus pseudostrobus* above 1800 m) thrive on the acidic soils (Styles and McCarter 1988). Various species of oak (*Quercus* spp) grow where soils are deeper (Pineda Portillo 1984). Regional sawmills extracted lumber from La Campa starting in the 1960s until the county banned logging in 1987. As in the rest of western Honduras, agriculture and logging have substantially deforested the most accessible areas.

The climate of the study site is temperate, with a mean annual temperature of 21°C. The region experiences a wet season and a dry season; the rains usually begin between late April and early June and continue into September or October. La Campa receives an average of 1293 mm of rainfall per year (Tucker 1996), but annual precipitation varies greatly. Precipitation from May through September averages approximately 1040 mm of the annual total, or 80%. By contrast, the surrounding Lempira region, which is included in the change analysis, encompasses Celaque National Park, with cloud forest averaging over 2000 mm of rainfall annually (Zúniga Andrade 1990).

Fires tend to be concentrated in unusually dry years, often in association with burning of agricultural fields to clear debris prior to planting. Uncontrolled forest fires related to slash-and-burn agriculture appear to be declining due to the decrease in this type of activity. Intentional burning of pasture or communal forest has not occurred during the study period (1987–1996), and the communities actively fight forest fires. In addition, the Lempira region did not experience any large-scale logging during this period, although sawmills extracted lumber prior to 1987, engaging in intensive, selective logging that is no longer allowed. Illegal logging is not a notable activity given that the communities in the study area monitor forests and sanction all illegal logging.

Socioeconomic and interview data

The current work in La Campa builds on an in-depth understanding of land use and changes gained through extensive survey and interview research conducted in 1993–1994 and in the summer of 1995. This fieldwork involved socioeconomic and demographic surveys in 113 households. In addition, researchers conducted formal and informal interviews exploring forest uses and land cover changes with heads of households, local authorities, regional foresters, and representatives of national and nongovernmental institutions active in La Campa and surrounding counties.

Forest plot and training sample data

Fieldwork to ground-truth a 1996 Thematic Mapper (TM) satellite image and collect forest data took place in 1997 and 1998. In La Campa, 79 forest plots were sampled to collect data on vegetation, soils, and topography. These data included tree height, diameter at breast height (dbh, or 137 cm), canopy cover, ground cover, slope, aspect, and altitude, among other observations. Forest plots were selected randomly in representative communal and private forests to allow for comparison of forest based on type of land tenure. Researchers collected 131 training samples throughout the Lempira region to represent various land-cover classes (eg, urban, water, bare ground, young fallows, pasture, annual agriculture, perennial agriculture, and forest). Training samples are observations of specific land covers, selected on the basis of satellite image analysis. These observations are less detailed than forest plots but broadly describe larger areas with homogeneous land cover.

Satellite image analysis

Change detection based on satellite imagery is used to determine the change between 2 or more time periods in a particular region or for a particular land cover by providing quantitative information on spatial and temporal distribution. It is an important tool for monitoring and managing natural resources (Macleod and Congalton 1998). Four aspects of change detection are important when monitoring naturally occurring or human-induced phenomena: (1) detecting the changes that have occurred, (2) identifying the nature of the change, (3) measuring the areal extent of the change, and (4) assessing the spatial pattern of the change (Macleod and Congalton 1998). Estimation of change requires the acquisition of images for the same area over 2 or more time periods. The images are classified into land-cover classes (forest and nonforest in this study) and then overlaid using ARC/INFO™ software in order to calculate the rates and types of change across each image. TM data allow comprehensive coverage of large areas and identification of coarse but key classes of vegetation for global studies (Schimel 1995).

Landsat TM images were obtained for March 1987 and March 1996. The images were cut to exclude cloud cover in the southern half, which did not pertain to our analysis. Geometric rectification was carried out using 1:50,000 scale maps and the nearest neighbor resampling algorithm, with a root mean square (RMS) error of less than 0.5 pixels (<15 m). Using a similar procedure, the rectified 1996 image served as the basis to rectify the 1987 image. An overlay function verified that the 2 images overlapped exactly across the 2 image dates. Following rectification, calibration procedures corrected for sensor drift and other differences, such as variations in the solar angle and atmospheric conditions. Without such calibration, change detection analysis may evaluate differences at the sensor level rather than changes on the Earth's surface. The images underwent radiometric calibration, atmospheric correction, and radiometric rectification.

The training sample data were used to determine the land-cover classes on the ground and then train the satellite image to recognize them. Classes for agriculture, young fallows (approximately 1–3 years), cleared areas, bare soil, water, and urban areas were aggregated to create a nonforest class. Forest was defined as having 25% canopy cover and a dbh greater than 10 cm, as determined from forest plots. By default, this class includes both secondary and mature forest types; due to centuries of human habitation and forest use, very little primary forest remains in the region, with the exception of Celaque National Park. This classification methodology was well suited to the objective of the present study—identifying change in total forest cover. Differentiation of forest types was not a goal and would require extensive forest analysis. Land-cover maps of forest and nonforest cover for 1987 and 1996 were derived by independent supervised classification of the 2 Landsat images using a Gaussian maximum likelihood classifier. Only 2 cover classes were used to simplify the change analysis and to minimize the ground-truthing needed to develop the classification (Spies et al 1994). With classification accuracies exceeding 80%, classified images generally agree visually with actual land cover. Our classification accuracies (85.7% for 1987 and 87.9% for 1996) indicate high validity.

Following classification, changes in land cover between 1987 and 1996 were detected using an image grid addition technique across both images that resulted in 4 possible classes (ie, forest in both images, reforestation from 1987 to 1996, deforestation from 1987 to 1996, and nonforest in both images). Deforestation is defined as a complete removal of tree cover, and reforestation involves natural regeneration, as plantations are not a significant land-cover type in the study area. This postclassification grid analysis led to a newly classified image incorporating information from both images (Mertens and Lambin 1997), producing a categorical map (change image). This image is associated with a change matrix, which gives the area for each class and its changes over the time period.

GIS: Accessibility surface

Analysis of change classes addressed the influence of distance from the nearest road and the nearest settlement for the Lempira region, including La Campa. This was done by using ARC/INFO to create buffers at 1-km intervals up to a distance of 5 km from roads and settlements. These buffers were subsequently related to the change class image. A second analysis then incorporated this distance information along with elevation and slope information obtained from a digital elevation model to measure the importance of topography in the region. This step created an accessibility surface (scale of 2–29, with 29 = most inaccessible) based on distance, slope, and elevation (Figure 3). Subsequently, mean accessibility classes were calculated for each forest cover change class.

Land tenure

The 8 forests sampled in La Campa included 4 communal forests and 4 private forests. Researchers interviewed each of the private forest owners as well as multiple users of the communal forests to learn about forest uses, management practices, and levels of exploitation. Analysis of communal and private forest conditions incorporated data from the forest plots, the change image, and interviews.

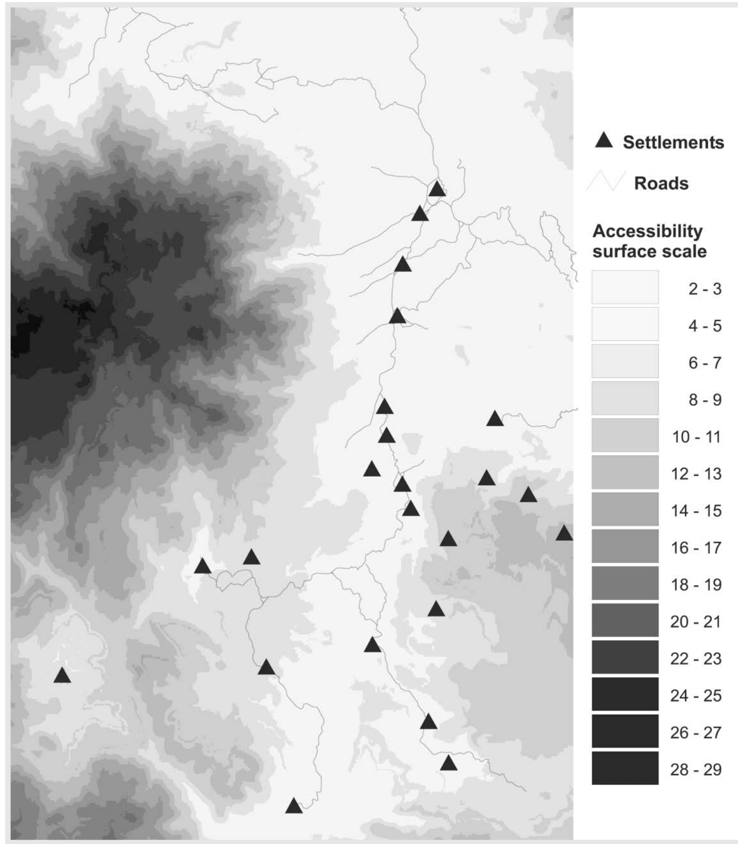
Results

Socioeconomic and interview data

La Campa households depend heavily on firewood from communal forests for cooking. Some private forest owners gather firewood from communal forests to reduce exploitation of their own land. Households also use forests to graze livestock, harvest timber for construction and fences, and collect mushrooms and medicinal plants (Tucker 1996).

Interviews and survey responses, as well as the change analyses, indicate that processes of agricultural intensification are occurring in La Campa. Population growth has been associated with these transformations; La Campa's population nearly doubled from 1961 to 1988 (the most recent census) (Tucker 1996). Intensification has included a shift from slash-and-burn agriculture to extended cultivation with shortened fallows, adoption of chemical fertilizers and soil conservation techniques, and expanded use of animal-drawn plows. Interviews revealed that adoption of fertilizers began in the 1960s and soil conservation in the 1980s. Of the 38 farmers interviewed in 1994 about their agricultural practices, 95% used chemical fertilizers on their crops. Elders reported that, during their youth (about 30–40 years ago), they cleared new fields annually from forest or old fallows and abandoned them after 1–3 years. Of the 108 households surveyed in 1994, 71% noted that they did not clear any new fields that year but planted only their existing fields. Cultivated fields had been planted for an average of 8 consecutive years, and preceding fallow periods averaged 12 years.

FIGURE 3 Accessibility surface analysis for the La Campa study area. (Compiled by Jane Southworth, 2000)



Satellite image change analysis

As determined by Landsat TM satellite image analysis, forest cover change across the study area between 1987

TABLE 1 Change matrix results for forest change in the La Campa study area and the larger Lempira region between 1987 and 1996 for forest (F) and nonforest (NF).

	La Campa	Lempira
NF in 1987 to F in 1996	9.77 km^2	91.78 km^2
NF in 1987 and 1996	23.72 km^2	326.30 km^2
F in 1987 and 1996	39.12 km^2	403.57 km^2
F in 1987 to NF in 1996	7.48 km^2	87.19 km^2
% forested area deforested by 1996[a]	16.06%	17.77%
% non-forested area reforested by 1996[a]	29.17%	21.95%
Total area of study site	80.09 km^2	908.84 km^2

[a]These values are calculated based on the area available for deforestation/reforestation at each location, that is, how much of the forested land at a specific location was deforested by 1996. This value is a direct function of the initial land area available in 1987 as either forest or nonforest.

TABLE 2 Comparison of forest change classes and mean accessibility classes.

Forest change class	Mean accessibility class (scale 2–29, with 29 = most inaccessible)	
	Lempira study area (SD)	La Campa (SD)
Forest in 1987 and 1996	11.03 (7.04)	6.75 (2.14)
Forest in 1987, nonforest in 1996 (deforested)	7.45 (5.28)	5.97 (2.02)
Nonforest in 1987, forest in 1996 (reforested)	7.25 (4.88)	5.66 (1.95)
Nonforest in 1987 and 1996	6.36 (3.94)	5.01 (1.50)

and 1996 shows an overall trend of reforestation. Within the 80.09 km^2 area, 9.77 km^2 was reforested, 7.48 km^2 was deforested, 23.72 km^2 remained cleared, and 39.12 km^2 remained forested (Table 1). Determining these rates of change as a percentage of cover change based on the initial area available, it can be said that 16.06% of available forested land in 1987 was deforested by 1996 and 29.17% of available cleared land in 1987 was reforested by 1996 (Table 1). Hence, in this study area, reforestation is the overall trend in forest cover change during this time period.

Within the larger Lempira study area of 908.84 km^2, 91.78 km^2 was reforested between 1987 and 1996 and 87.19 km^2 was deforested. The area remaining forested across both dates was 403.57 km^2, and the area remaining cleared across both dates was 326.30 km^2 (Table 1). Of the forested area in 1987, 17.77% was deforested by 1996, and of the area cleared in 1987, 21.95% was reforested by 1996. These results are not as significant as those at the smaller scale of La Campa, but they still represent a reforestation trend in the larger Lempira region.

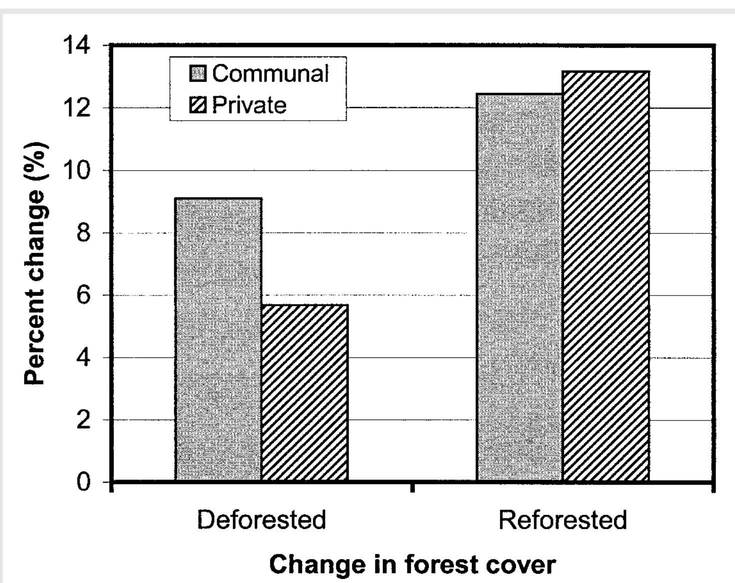


FIGURE 4 Percentage of forest cover change from 1987 to 1996 under the communal and private land tenure systems.

Accessibility analysis

Results from distance analysis for the Lempira region show that most clearing occurs within 5 km of major settlements; beyond this, forest cover dominates. Most reforestation and regrowth occurs at distances greater than 1 km from roads and settlements. At distances less than 1 km, agricultural fields dominate. The inclusion of slope and elevation within this analysis, by creation of the accessibility surface, provided greater explanatory power for the spatial distribution of forest cover change (Table 2). Forested areas remain in the most inaccessible regions, on steeper slopes and higher elevations that tend to be far from roads and towns. Clearings usually occur on gentler slopes and lower elevations, closer to roads and towns (Table 2, Figure 3), although deforestation is increasingly occurring in more inaccessible areas, especially those used for coffee production. This trend will only increase in the future as the limited areas of current coffee production expand.

Land tenure

The biophysical conditions of the forest cover and processes of forest cover change are related to land tenure (Figure 4). Private forests cover a smaller area, but on average they present greater tree species diversity, larger tree dbh, and greater tree height. Communal forests involve larger areas and on average present smaller dbh and shorter trees (Table 3). The 1997 forest fieldwork, designed to collect comparable data in private and communal forests, did not find these differences to be statistically significant (Tucker 1999). Subsequent fieldwork in 1998 and completion of the change analysis provided additional data to show that private forests have had lower rates of deforestation and higher rates of reforestation compared with communal forests (Figure 4).

Discussion

The various data sources point to interrelated factors in La Campa's forest cover trends. Reforestation is associated with regeneration of areas that were logged prior to the start of the study in 1987 as well as with privatization of some previously communal forest areas and abandonment of marginal agricultural lands. Deforestation, while less marked than reforestation, includes clearing of fallows for agricultural fields and clearing for new coffee plantations—often in areas of steeper slopes with more mature forests (Figure 5). Accessibility influences the location and extent of these transformations.

The transition of agriculture from a slash-and-burn system to more intensive cultivation appears to involve abandonment of some fields on slopes too steep for plowing. Intensively cultivated fields produce larger harvests in smaller areas than slash-and-burn fields; thus, farmers require less land to meet their subsistence needs (Netting 1993). The conditions in La Campa fit the scenario drawn up by Boserup (1967) as being conducive to agricultural intensification. With population growth and limited options to acquire new agricultural land, intensification and technological change become desirable once existing techniques no longer meet demands for increased production. If population density continues to increase, the authors expect that more marginal lands will be brought under production successively. Thus, abandonment of marginal agricultural fields is likely to be a temporary situation.

Steep slopes and increasing distances from roads and settlements represent constraints on accessibility for human use. Creation of private forests usually occurs close to roads; this accessibility facilitates monitoring. The phenomenon of increasing privatization of land evidently accounts in part for areas of reforesta-

TABLE 3 Communal versus private forest ownership: forest plot data by tenure.

	Private	Communal
Total estimated area of forests in study area (ha)	25.2	812.5
Total plots sampled	21	58
Mean tree[a] dbh (cm)	17.7	15.6
Mean tree[a] height (m)	11.3	10.0
Projected tree species/ha	11.1	9.3
Projected tree stems/ha	376	472

[a]These figures exclude saplings. Trees are defined as having a dbh of 10 cm or more; dbh was measured at 137 cm above the ground.

FIGURE 5 Coffee clearing at La Campa, with typical topography and surrounding vegetation. (Photo by Catherine Tucker, 1994)

tion being found in slightly more accessible regions than the deforested areas (Table 2). Communal forests remain on less accessible land, parts of which were logged in the 1970s and 1980s. Interviews and observations indicate that regeneration followed logging on steeper lands further from roads, while logged areas near roads or on more level land generally experienced conversion to agriculture. Communal forest conditions reflect not only residents' use but also historic intervention by outsiders.

Thus, reforestation has taken place where people once logged or cleared forests for agriculture, and they may do so again as economic and social conditions evolve. Current reforestation processes are also linked to changing human preferences and local institutional decisions. In recent decades, families have preferred to settle in villages to facilitate children's school attendance rather than establish isolated homesteads. This has concentrated pressure on the communal forests nearest settlements. Moreover, the countywide prohibition of logging has prevented new clearings and allowed natural regeneration since its imposition in 1987. People strongly support the logging ban; they perceive it as a necessary measure to protect forests from exploitation by outsiders and to preserve forest resources for subsistence uses. Even private forest owners have complied with the ban.

While accessibility influences processes of forest change, a variety of factors shape people's choices. Despite concerns about forest conservation, La Campa residents do clear certain forests for agriculture. Economic incentives and road improvements have been overcoming topographic and transportation constraints. With national programs and development funds, La Campa has prioritized road construction and increased market-oriented production of crops such as coffee. Interviews and observations of coffee plantings with farmers revealed incursions into relatively inaccessible zones of the highland forests (Table 2) in anticipation of new roads. Although the total area of coffee plantings by 1996 represented less than 2% of county land, the ongoing process promises to have a very significant impact on the landscape. The communal and private forests sampled in this study lie at lower elevations less suitable for growing coffee, and they have been less subject to road expansion.

The patterns found in the La Campa study site appear as well in the surrounding Lempira region, where the Cordillera de Celaque (Honduras' highest mountain peaks) continue to be covered in old-growth cloud forest. The national level, however, provides a more typical scenario, in which economic and demographic pressures associated with inequitable distribution of land and resources result principally in deforestation.

Conclusions

The following conclusions are based on the research carried out for this study:

- Reforestation is the dominant trend in forest cover change across the study area of La Campa.
- Agricultural intensification is a contributing factor to reforestation due to abandonment of less productive fields.
- Spatial patterns of change are related to accessibility and land tenure, with forests remaining in predominantly inaccessible regions and communal forests having lower reforestation rates than private forests.
- La Campa's local institutions have contributed to an increase in forest cover through imposing and enforcing a logging ban.

The implications of this research are particularly relevant for policy design and implementation since policy makers tend to reach decisions based on aggregate, macrolevel data. Such data can obscure areas such as La Campa, where reforestation trends contradict the expectation. In La Campa, national policies designed to slow deforestation could promote it if they compelled changes in local institutions that restrict forest exploitation (eg, logging). The greater threat to forests, however, appears to be economic development incentives that encourage deforestation.

Ongoing research will incorporate fieldwork data from spring 2000 and image analysis of a 2000 Landsat TM scene. This time step will reveal whether reforestation trends continue to exceed deforestation in the county. The differences between private and communal forests will probably become more pronounced as communal areas remain subject to increasing exploitation.

The reforestation trend discovered within this study's limited time span may represent a transitional stage. Wealthier households have claimed more land for private use than poorer households. Land privatization has decreased the area available for use by the majority, creating a situation in which ever more people depend on fewer communal resources. The processes of population growth, increasing socioeconomic inequality, and market-oriented agricultural production seem likely to lead to a dominant deforestation trend in the future.

AUTHORS

Jane Southworth
Center for the Study of Institutions, Population, and Environmental Change (CIPEC), 408 N Indiana Avenue, Indiana University, Bloomington, IN 47408, USA.
jsouthwo@indiana.edu

Catherine Tucker
Center for the Study of Institutions, Population, and Environmental Change (CIPEC), 408 N Indiana Avenue, Indiana University, Bloomington, IN 47408, USA.
tuckerc@indiana.edu

ACKNOWLEDGMENTS

This research was supported by the National Science Foundation (NSF) (SBR-9521918) as part of the ongoing research at the Center for the Study of Institutions, Population, and Environmental Change (CIPEC) at Indiana University. An NSF Dissertation Improvement Program Grant (SBR-9307681) funded the 1993–1994 research. Fieldwork benefited from the invaluable research assistance of Stephen McLaughlin, Jessica Fonseca, Martha Moreno, Paul Turner, Soledad Martínez, and Eduardo Bedoya. We thank Laura Carlson for help with the GIS analysis. Finally, we are grateful to Dr J. C. Randolph, Dr Elinor Ostrom, and Michael Kohlhaas for their comments on earlier drafts.

REFERENCES

[AFE-COHDEFOR] Administración Forestal del Estado—Corporación Hondureña de Desarrollo Forestal. 1996. *Análisis del Sub-Sector Forestal de Honduras*. Tegucigalpa, Honduras: AFE-COHDEFOR.
Apan AA, Peterson JA. 1998. Probing tropical deforestation: the use of GIS and statistical analysis of georeferenced data. *Applied Geography* 18:137–152.
Boserup E. 1967. *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. Chicago: Aldine.
[FAO] Food and Agriculture Organization of the United Nations. 1968. *Survey of Pine Forests: Honduras*. Final Report. Rome: FAO.
Godoy R, O'Neill K, Groff S, Kostishack P, Cubas A, Demmer J, McSweeney K, Overman J, Wilkie D, Brokaw N, Martínez M. 1997. Household determinants of deforestation by Amerindians in Honduras. *World Development* 25:977–987.
Hall FG, Botkin DB, Strebel DE, Woods KD, Goetz SJ. 1991. Large-scale patterns of forest succession as determined by remote sensing. *Ecology* 72:628–640.
Hall FG, Townshend JR, Engman ET. 1995. Status of remote sensing algorithms for estimation of land surface parameters. *Remote Sensing of the Environment* 51:138–156.
[IHCAFE] Instituto Hondureño del Café. 1998. *Boletín Estadístico 1970–1996*. Tegucigalpa: IHCAFE.
Macleod RD, Congalton RG. 1998. A quantitative comparison of change-detection algorithms for monitoring eelgrass from remotely sensed data. *Photogrammetric Engineering & Remote Sensing* 64:207–216.
Mayaux P, Lambin EF. 1995. Estimation of tropical forest area from coarse spatial resolution data: a two-step correction function for proportional errors due to spatial aggregation. *Remote Sensing of the Environment* 53:1–15.
Mertens B, Lambin EF. 1997. Spatial modeling of deforestation in southern Cameroon. *Applied Geography* 17:143–162.
Netting RMcC. 1993. *Smallholders, Householders*. Stanford: Stanford University Press.
Pineda Portillo N. 1984. *Geografía de Honduras*. Tegucigalpa: Editorial ESP.
Richards M. 1996. Protected areas, people and incentives in the search for sustainable forest conservation in Honduras. *Environmental Conservation* 23:207–271.
Roughgarden J, Running SW, Matson PA. 1991. What does remote sensing do for ecology? *Ecology* 72:1918–1922.
Schimel DS. 1995. Terrestrial biogeochemical cycles: global estimates with remote sensing. *Remote Sensing of the Environment* 51:49–56.
[SECPLAN] Secretaría de Coordinación, Planificación y Presupuesto/[DESFIL] Development Strategies for Fragile Lands/[USAID] United States Agency for International Development. 1989. *Perfíl Ambiental de Honduras*. Tegucigalpa: SECPLAN/DESFIL/USAID.
Spies TA, Ripple WJ, Bradshaw GA. 1994. Dynamics and pattern of a managed coniferous forest landscape in Oregon. *Ecological Applications* 4:555–568.
Styles BT, McCarter PS. 1988. The botany, ecology, distribution and conservation of *Pinus patula* ssp *tecunumanii* in the Republic of Honduras. *CEIBA* 29:3–30.
Sunderlin WD, Rodríguez JA. 1996. *Ganadería, bosques latifoliados y Ley de Modernización Agrícola en Honduras*. Bogor, Indonesia: [CIFOR] Center for International Forestry Research.
Tucker CM. 1996. *The Political Ecology of a Lenca Indian Community in Honduras: Communal Forests, State Policy, and Processes of Transformation* [doctoral dissertation]. Tucson: University of Arizona.
Tucker CM. 1999. Private versus common property forests: forest conditions and tenure in a Honduran community. *Human Ecology* 27:201–230.
Woods CH, Skole D. 1998. Linking satellite, census, and survey data to study deforestation in the Brazilian Amazon. *In:* Liverman D, Moran EF, Rindfuss RR, Stern PC, editors. *People and Pixels: Linking Remote Sensing and Social Science*. Washington, DC: National Academy Press, pp 70–93.
Zúniga Andrade E. 1990. *Las Modalidades de la Lluvia en Honduras*. Tegucigalpa: Editorial Guaymuras.