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Agriculture, Ecosystems and Environment 110 (2005) 14–28

Agriculture Ecosystems & Environment

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Population, conservation, and land use change in Honduras

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Available online 21 July 2005

Abstract

This paper examines the role of population density on land use allocation and change. We are especially interested in the management of fallow areas that have come under increasing pressure given restrictions imposed by the creation of protected areas like national parks. It is argued that these restrictions to reduce deforestation create a relative scarcity of land, and applies insights about the management of fallows from Boserup's classic work on agricultural intensification and population growth. This paper examines land use in the Cerro Azul Meambar National Park in Honduras. Land use allocation is evaluated using data from a social survey of 600 farms in the Park's buffer zone, and land use classifications based on Landsat satellite images. Change in land use is analyzed by comparing satellite image-based land use classifications in 1993 and 1999. The analysis indicates that differences in population density are an important factor in explaining land use allocation and change. Whether in areas of high population density or low, fallow areas are reduced when land is scarcer. In areas of low population density, reforestation efforts associated with Park management lead to the displacement of fallows. In areas of high population density fallows give way to more intensive land uses.

Keywords: Land use allocation; Fallow management; Forest conservation; Agricultural intensification

1. Introduction

By imposing land use restrictions where open access had previously been the norm, government efforts to conserve natural resources can lead to land scarcity. For example, many newly created protected areas are populated and managed for multiple uses. Under these circumstances the availability of land for cultivation is reduced by both increasing population density and restrictions on land use (Brandon et al., 1998). These forces create competing demands for land use change. On the one hand, land may be more intensively cultivated, and on the other hand it may be targeted for ecosystem restoration.

This paper examines land use allocation in an extensive agricultural system faced with a relative land scarcity. The inquiry was framed using Boserup's (1965) classic work that explicitly considered the role

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doi:10.1016/j.agee.2005.05.003

of fallows in the process of land use intensification under conditions of population increase and land scarcity. Her theory of land use change has been robust and is supported by research findings throughout the world (e.g. Barlett, 1982; Netting, 1993; Schelhas, 1996; Smith et al., 2001). However, policies restricting land use raise questions about the applicability of these ideas in areas targeted for natural resource conservation.

The paper focuses on land use change in the Cerro Azul Meambar National Park in Honduras. This park is a working landscape, i.e. both a conservation area and the site of production activities like agriculture and forestry. More than forty villages and about 20,000 inhabitants live in the Park's buffer zone. The area began to be heavily settled about 40 years ago and, until the creation of the park in 1987, provided relatively unrestricted access to forest land. The central focus of this paper is on changes in the management of fallow lands in the context of park policies that attempt to restrict forest conversion and also promote reforestation. The paper begins with a discussion of the relationships between population, conservation and fallow management. Then a brief description of the Cerro Azul Meambar National Park is followed by the results of an analysis of land use allocation and change, based on data from a social survey and the analysis of land cover based on satellite images from 1993 and 1998. It concludes with a discussion of the implications of the findings for land use management in protected areas.

2. Population, conservation, and fallow management

Fallow lands are a central element of the extensive agricultural systems described by Boserup (1965) in her now classic study of agricultural intensification.[1] According to her, slash and burn agricultural systems provide reliable food supplies with relatively low labor inputs under conditions of lower population density. In such systems patches of forest are cut and burned in preparation for the planting of agricultural staple crops for a couple of years after which new patches are cleared and the previously cropped land left to naturally regenerate for an extended period of time, eventually forming secondary forests. Thus, fallow land in different stages of regeneration covers extensive areas.

Such extensive agricultural systems provide favorable growing conditions as nutrients are released by burning the forest biomass. Furthermore, properly managed systems provide a stable food supply with relatively little labor input. In Boserup's assessment, slash and burn agriculture uses less labor than intensive fixed systems, as less effort is required to cut forest, burn it, and then plant and harvest a crop than to cultivate the land intensively. Because slash and burn systems with adequate fallow periods produce acceptable yields and do not make excessive labor demands, Boserup sees few incentives to change these systems as long as there is an abundant supply of land. Recent studies re-confirm the positive features of such systems, especially the complementarity between secondary forest fallows and agriculture (Smith et al., 2001).

As long as there is abundant forest to be cut and burned, this system can accommodate population growth; more land is simply brought into circulation. This response has been common in a variety of settings (Netting, 1993). As long as population density does not increase there is no need to significantly alter the production system. Population density increases when population grows and/or the supply of virgin or unoccupied land is exhausted. When this happens, extensive agricultural systems begin to be changed in significant ways.

One of the first adjustments to increased population density, according to Boserup, is shortening of the fallow cycle. That is, land is left fallow for shorter periods and crops are grown on particular parcels more frequently. These changes, Boserup claims, disrupt the system and reduce the most important benefits associated with extensive systems. Because lands are left fallow for shorter periods, less biomass is produced and when the vegetation is burned fewer nutrients are returned to the soil. The reduction of biomass left on the fields reduces the mulching effect and encourages greater growth of weeds and brush that interfere with cultivated crops. More labor is required to control the growth of undesirable weeds, brush, and grass, and at some point when the fallow cycle is very

[1] Boserup (1981, 1990) has extended this argument in more recent publications.

short it may become necessary to plow fields with animal traction in order to make them productive. With the addition of draught animals to the system, it becomes necessary to dedicate some portion of land to maintenance of these animals, reducing the land mass available for crop production. As a result, farmers must raise yields on their cultivated parcels, and to do this they begin to apply animal manure. In sum, an increase in population density forces the intensification of agricultural production and this intensification begins with changes in the management of fallow land.

Boserup's basic point was that producers adapt to the relative scarcity of resources by intensifying agricultural production.[2] Her objective in making this argument was to counter Malthusian claims that population growth would exceed the expansion of the food supply, leading to hunger and poverty. According to Boserup, increased population density creates the conditions for agricultural intensification that would prevent food shortage.[3] Most important for this discussion is that she identified population density as the key factor causing relative resource scarcity. Additional factors like market penetration, commercialization and technological change may have independent effects on the intensification of production. Boserup's work focused on the role of population density in stimulating production intensification in subsistence production systems. However, the effects of population density under conditions of increasing commercialization of subsistence production systems has not been extensively studied (Turner and Ali, 1996; Turner and Brush, 1987).

Whereas Boserup postulated a gradual exhaustion of the supply of uninhabited land available for cultivation, contemporary conservation efforts often lead to more sudden changes. For example, the creation of parks and other protected areas is a widespread phenomena which has gained momentum over the past few decades (Schelhas, 1994; Rudel, 2000; Pfeffer et al., 2001). Worldwide 25,000 sites protect more than 5% of the world's surface (McNeeley et al., 1994; Brandon et al., 1998). Such conservation leads to a reduction of land available for cultivation in two ways.[4] First, it eliminates unrestricted access to uninhabited land in an effort to preserve natural resources. For example, cutting and burning may be prohibited in some areas to preserve the forests. Second, conservation practices may also take land from fallow and incorporate it in reforestation efforts. In either case, if population remains stable or continues to grow, population density will increase and the amount of fallow land is likely to decrease (Bilsborrow, 1987; Smith et al., 2001). Based on this, it is hypothesized that if population density increases, the amount of land in fallow will decrease.

Conservation policies set boundaries and limit access to certain natural resources, thereby transforming existing tenure systems, or the system of rights and rules that applies to all resources in the park including land, water, and trees. Such policies limit access to resources and create conditions of relative scarcity and uncertainty about future access to resources. As such policies are implemented, individual access to natural resources is less certain than in common property or open access management systems which typically predate park regulatory regimes. As a consequence, local residents have an incentive to claim control over or rights of access to as wide an area as possible (Baland and Platteau, 1996; Geisler et al., 1997; Brandon, 1998; Pfeffer et al., 2001). Thus, it is hypothesized that producers faced with a limited land supply will augment the land base available for intensive production by broadening their definition of fallow land, especially at the expense of forest.

Fallows are also transitional areas between forest and permanent agriculture. Therefore, they are the most logical choice for restoration efforts. These areas offer numerous ecological benefits including the potential for natural regeneration and rapid stand

[2] Studies in Mexico have shown that intensification with irrigation can support fourteen times as many families as a slash and burn system (Netting, 1977).

[3] This conclusion is much debated. Those opposed claim that rapid population growth leads to poverty and environmental destruction. Specific problems identified include land scarcity, the reduction of fallows, deforestation, and production on land unsuited to agriculture (Cleaver and Schreiber, 1992; Blaikie, 1989; Blaikie and Brookfield, 1987). Others have found support for Boserup's claims that rising population density results in greater agricultural productivity, rising living standards, and the reversal of environmental degradation (Tiffen et al., 1994).

[4] A similar point has been made by others who have observed that intensification may be induced through coercive policies like tax increases or by requiring labor services, both of which were implemented by colonial regimes (Netting, 1977; Nell, 1972; Geertz, 1963).

recovery with many pioneer species useful as timber (Moran et al., 1994; Smith et al., 2001). For example, reforestation is most likely to be acceptable in areas of lower population density where demand for conversion of fallows to more intensive uses is limited and there is less local opposition to such efforts (Netting, 1993; Bates and Rudel, 2000). Thus, it is hypothesized that under conditions of limited demand for fallow conversion to more intensive uses, restoration efforts will lead to a reduction of fallows in areas of lower population density.

3. A case study of the Cerro Azul Meambar National Park

The three hypotheses posed above are evaluated in the context of the Cerro Azul Meambar National Park (CAMNP) in Honduras. The consideration of land use change in this park is useful because its management is based on the biosphere reserve model, or a system of mixed land use where people may live inside park boundaries but are subject to certain restrictions on resource use. Under these circumstances people must agree not to use resources in the core zone, and they have to agree to alter resource use patterns in other areas of the park. Park rules limiting access to resources create conditions of relative scarcity and uncertainty about future access to resources (Brandon, 1998).[5]

3.1. Description of the study area

The Honduran government created CAMNP in 1987 with the expansion of the protected area system. The Park's core zone includes all of Cerro Azul Meambar mountain above 1800 m to the peak of 2047 m. In 1992, COHDEFOR (the Honduran Forest Service) contracted a private non-governmental agency, Aldea Global, to manage the Park. As a first step in the development plan, Aldea Global proposed a set of boundaries that extended Park management beyond the limits established under National Law 87-87. COHDEFOR officially sanctioned these expanded boundaries, and by 1994 CAMNP grew to cover 31,376 ha. These 1994 management boundaries correspond to the typical biosphere reserve model of park management (Brandon, 1998; Batisse, 1986). The park's management plan divides it into three zones typical of biosphere models implemented throughout the world: (1) a core zone of 890 ha, or about 3% of the Park, which allows no permanent settlement and only very limited human use; (2) a 9129 ha (about 29% of the total) special use zone which allows no human habitation, limited and regulated human intervention; (3) a buffer zone covering 21,357 ha, or about 68% of the Park, which forms a band surrounding the core and special use zones (Fig. 1). This buffer zone, unlike the core and special use zones, permits human habitation and allows for regulated human use of natural resources. Altogether an estimated 19,600 people live in 42 communities within the park's buffer zone. Most of these communities have less than one thousand inhabitants and their economies are predominantly agriculturally oriented (Espinoza Riquelme, 1995; Pfeffer et al., 2001).[6] Although local residents are mostly small scale producers, outside and local landowners are engaged in relatively large scale cattle, pineapple and coffee production near the eastern, northern and southern perimeters of the Park.

The terrain of the Park is a significant feature. The Park is basically a large mountain with much steep terrain as indicated in Fig. 1. While much of the steepest land is found in the nuclear and special use zones, much steep land is also found in the buffer zone. For this reason the agricultural options are constrained in some important ways. For example, it is very difficult to plow this land. On the other hand, the climate and altitude of the area are conducive to coffee

[5] Officially designated protected areas are a relatively recent phenomenon in Honduras, where the government established it first "national park" in 1980. It elaborated a system of protected areas beginning in 1987 with the National Law 87-87, which declared all lands over 1800 m in altitude protected areas. As a result of this and other legislation there are now over 100 national parks and other protected areas covering about twenty-two percent of the Honduran land base. In addition, 41 additional sites have been proposed (National Congress of Honduras, 1987).

[6] The Park population is an estimate based on data for 17 communities involved in the Park program (Espinoza Riquelme, 1995). These represent 17 of the 42 communities in the Park, and the CAMNP study estimated their population to be about 14,000. To get an estimate of the total Park population we simply inflated this figure by a factor of 1.4 (i.e. 17/42).

production. Coffee is by far the most important cash crop in the Park.[7]

There are six major catchments within CAMNP of great national economic and political significance. The Park provides about 20% of the water flow into the El Cajón reservoir, and the hydroelectric plant at this reservoir generates about 85% of the Honduran electrical supply (Proyecto Aldea Global, 1995; Loker, 1998). Beginning in about 1995, the El Cajón Watershed Renewable Natural Resources Program implemented a reforestation project in those catchments within the Park that drain into the El Cajón reservoir. This project employs local residents to work in tree nurseries and to plant seedlings, and has been a significant source of employment in the area (Loker, 2000).

3.2. *Data and methods*

Two primary data sources were utilized for the analysis of land use change: a 1999 social survey of residents living in the Park buffer zone and satellite images from 1993 and 1998. The social survey was used to evaluate the factors that influence producers' allocation of land to different uses, and the satellite data was used to examine land use change over time.

3.2.1. *Social survey*

In 1999 with the assistance of students and faculty from the Honduran National Forestry School, interviews were conducted with 601 household heads randomly selected from lists of all households obtained from each village *patronato* (council). The eight communities included in the study were in or near the Park. The location of the communities is shown in Fig. 1. Male household heads were targeted after the discovery in earlier qualitative interviewing that they were much more informed about land use decisions than other household members. However, when male heads were not available, their spouses or the female heads of households were interviewed. As a result, 38% of the respondents were female. The analysis is restricted to six of the communities. One community, Pueblo Nuevo, was excluded from the analysis because it was outside the Park, and another, Meambar, because it was the only community in the study with a substantial livestock component, making patterns of land use there quite different from the remainder of the Park. These exclusions left 438 observations for analysis.

The wide-ranging survey interviews included questions about land use. Respondents were asked how much land they had in forest, fallow, coffee, pasture, horticultural crops, corn and beans (see Table 1). They were also asked how many years fallow could grow before it was considered secondary forest, and how many years land is left fallow before being cultivated again. The farmers' land use allocation was evaluated with a series of ordinary least squares regression models. First, the amount of land in fallow, forest, and corn/beans were regressed on total land and amount of land in coffee to estimate the substitution of coffee production for the other land uses. Next, the amounts of land in fallow and forest were regressed on total land and the amount of land in corn/beans in order to estimate the replacement of these staple crops with fallow and forest.

The quantitative analysis was supplemented with reports from qualitative data collected in 1998 in a subset of the villages included in the survey (Cerro Azul, Planes, and Palmital). Fifty-four open-ended interviews were conducted. Questioning was based on an interview guide consisting of a variety of open-ended questions about attitudes and behaviors related to trees and forests. Interviewees were also presented with a set of five photographs with varying levels of forest cover, and asked to describe what they saw in each picture, indicate the photo they liked best and explain why, and to indicate which of the examples they would most like to have for their own land and to explain why. Scenes in the photos ranged from dense forest to pasture with scattered trees.

3.2.2. *Satellite data*

Satellite data were used to evaluate changes in land use. Land use maps were developed for February 1993 and January 1998 based on Landsat Thematic Mapper

[7] The important point here is that intensification can be solely through the adoption of a cultivar like coffee that increases yields and/or income per unit of land and does not necessarily require the adoption of new technologies. Netting (1977) has noted that intensive agricultural production may be practiced with rudimentary tools. According to Netting (1993, p. 262): "Defining intensive agriculture in terms of yields per unit of land over time emphasizes output as the dependent variable, and it does not pre-judge the effect of economic inputs of labor, capital, or technological change. Increases in these independent variables, individually or in combination, on a constant land area, may intensify its use, but this must be demonstrated rather than assumed."

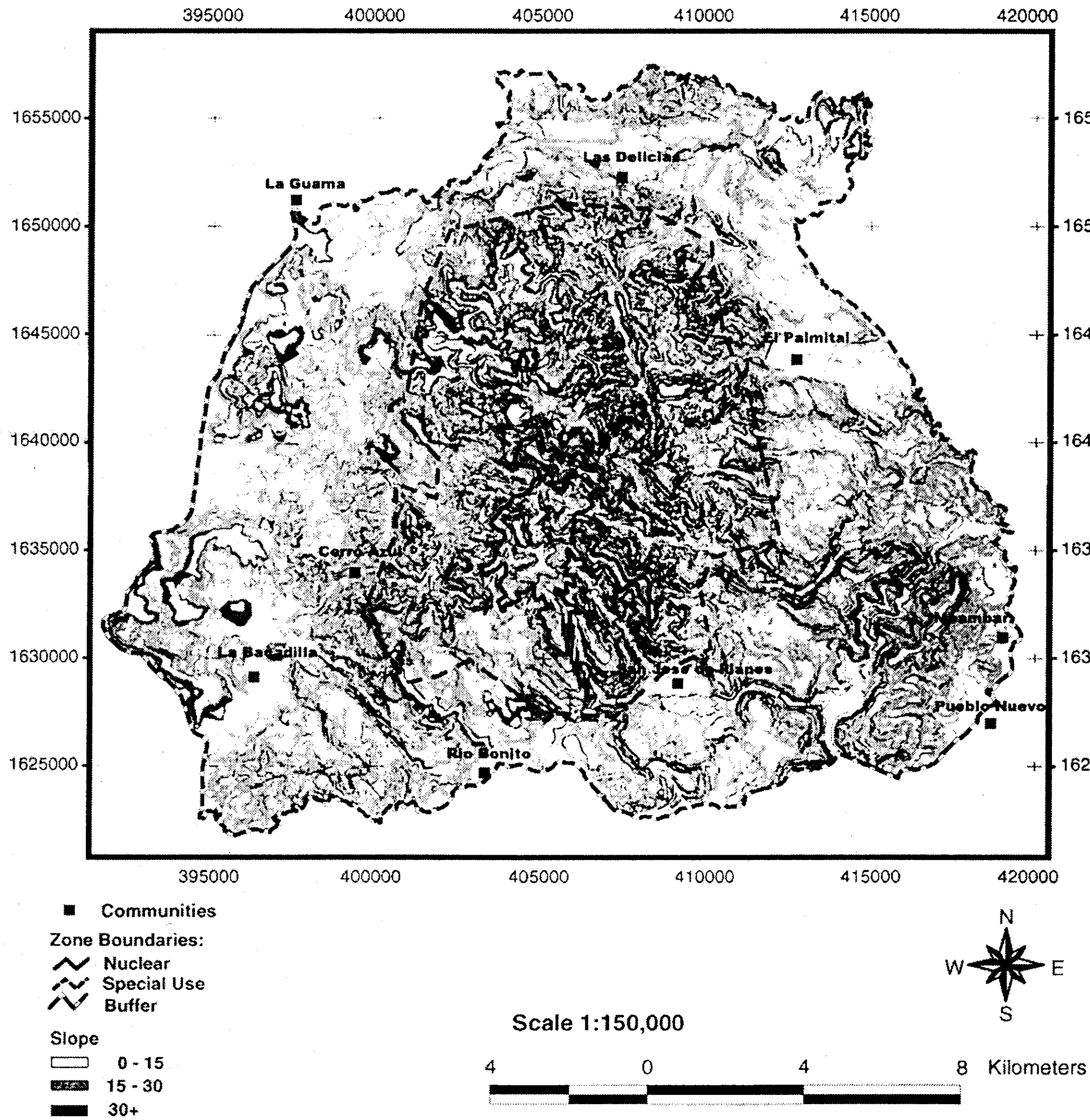

Fig. 1. Cerro Azul Meambar National Park and classification by degree of slope.

(TM) satellite images.[8] Based on information on land use from the qualitative interviews and previous experience (Gomez, 1998), a classification scheme was developed based on four land use types: forest, fallow, coffee, and agriculture. To create the maps using a supervised classification approach, an average of 20 global positioning system (GPS) readings were acquired for each land use type throughout the Park's buffer zone.

Differentiation of coffee from forest presented the greatest challenge. To aid in locating coffee plantations, a 1999 Indian Remote Sensing Satellite (IRS)

[8] We processed the images with Erdas Imagine 8.2 for PC.

Table 1
Population density and selected land use by village as reported by farm households in Cerro Azul Meambar National Park, 1999

Village	Population density[a]	Percent of total hectares[b]						Total hectares[c]
		Coffee	Corn/beans	Fallow	Forest	Other	Total	
Bacadilla	2.56	44.7	7.0	16.1	18.2	14.0	100.0	200
Cerro Azul	2.1	37.7	2.1	19.7	36.8	3.7	100.0	167
Rio Bonito	2.01	26.8	12.4	28.0	19.7	13.1	100.0	464
Planes	1.96	29.6	21.8	26.6	11.3	10.7	100.0	260
Palmital	1.72	9.8	23.7	21.6	22.0	22.9	100.0	321
Delicias	1.23	4.5	41.8	13.2	25.7	14.8	100.0	312
Total	1.87	23.2	19.7	21.8	21.4	13.9	100.0	1724

Source: Survey of 601 households in the Cerro Azul Meambar National Park, 1999.
[a] Persons per hectare.
[b] Percent of total hectares in village.
[c] Estimates of land use based on reports from social survey. Total hectares for each land use were extrapolated to the entire village by inflating the survey results from the sampling ratio for each village.

satellite image was used. Land cover for the region was mapped using spectral data acquired by Linear Imaging Self-Scanning Sensor (LISS-3) aboard the Indian remote sensing satellite IRS-1C. The LISS-3 acquired spectral data for our study site in January 1999 using four spectral bands with spatial resolution of 23.7 m. The high spatial resolution of this image facilitated identification of roads that usually led to land parcels where coffee was the dominant land use. In contrast, forested land is seldom marked by roads. The 1999 image was used as a guide to identify coffee plantations, to take GPS readings in 1999, and to make supervised classifications.

Accuracy of the classification was assessed in three ways: (1) visual inspection of the map for patterns consistent with direct observations, (2) comparison of the land use classification with land use data derived from the social survey, and (3) construction of an error matrix based on the comparison of a sample of direct observations with the land use classification. The land use classification was found to be reasonably satisfactory.

Visual inspection of the map indicated that the land use patterns mapped were consistent with direct observations and extensive feedback from consultations with Park personnel and residents. When land use reported by farmers was compared with the GIS classification, the overall patterns were very similar to coffee and agriculture (see Table 2). Discrepancies between the survey and the GIS classification appeared between forest and fallow, but these differences were anticipated as indicated in Hypothesis 2 above: producers faced with a limited land supply will augment the land base available for intensive production by broadening their definition of fallow land, especially at the expense of forest.

Table 2
Comparison of results of GIS buffer zone land use analysis with results from farm household survey, Cerro Azul Meambar National Park, 1999

Land use classification	1998 GIS	1999 Survey[a]
Agriculture	17.7%	19.2%
Corn/beans	–	18.6
Horticulture	–	0.6
Coffee	16.5	16.1
Forest	51.8	30.4
Fallow	13.7	31.0
Brush	–	22.3
Pasture	–	8.7
Other	0.3	3.3
Total	100.0%	100.0%
Hectares	21357	2580

[a] Includes Meambar area

Table 3
Land use classification error matrix

Land use (predicted)	Land use (observed)					% Error
	Coffee	Agriculture	Fallow	Forest	Total	
Coffee	11	0	0	6	17	35.3
Agriculture	10	22	3	1	36	38.9
Fallow	0	1	0	3	4	100.0
Forest	2	1	0	7	10	30.0
Total	23	24	3	17	67	–
% Correct	47.8	91.7	0.0	41.2	–	–

Overall accuracy (%) = 59.7. Kappa Statistic = 0.407. *Sources*: Field observations (observed) and satellite images (predicted)

Finally, an attempt was made to verify the land use classification with 67 geo-referenced ground observations (Congalton and Green, 1999). This method of accuracy assessment identified some errors. Overall accuracy was 60% (Kappa Statistic = 0.407). These statistics might have been higher if the sample of ground observations had been larger and better distributed across the land use classes. Two patterns of errors were most common. One type of error was to confuse coffee and agriculture. This occurred most frequently in areas recently planted to coffee. The other common error was to confuse coffee and forest, and this was most often done in areas of mature shade coffee (see Table 3).[9]

Since no direct assessment could be made of land use in 1993, local people were interviewed and questions posed about the age of specific coffee plantations and other significant land use changes and this information was then used to evaluate the quality of the 1993 classification.

3.3. *Land use allocation and change*

The land use distribution in the Park is presented in Fig. 2. Not surprisingly the nuclear and special use zones of the Park are dominated by forest with some incursions into the special use zone by agriculture in the northeast and southeast and from coffee in the west and southwest.[10] However, the main focus of analysis was on the buffer zone that forms the outer perimeter of the Park. The map in Fig. 2 clearly shows the mix of land uses in the Park. Coffee dominates the landscape in the west and southwest, agriculture prevails in the north and east. The southeastern part of the Park is mostly pasture (classified in our analysis as fallow) used for cattle production.[11]

Our classification of land use based on the analysis of the 1998 satellite image shows slightly more than half of all land in the buffer zone to be forested. It is apparent that the forest is highly fragmented in some areas, especially in the east. The other half of buffer zone land is roughly divided between fallow, coffee and other agricultural crops. Table 2 shows the distribution of the various land uses based on both our classification of the 1998 satellite imagery and our 1999 survey of farmers in the seven villages shown in Fig. 2.[12] The satellite image-based classifications of agriculture and coffee were very close to the farmer's own classifications.

However, the description of land as being in fallow or forest diverges significantly. Farmers report having much less land in forest and more than twice as much fallow land compared with the satellite image-based classification. This is likely a consequence of land use restrictions introduced with the creation of the Park and is consistent with the second hypothesis that producers faced with land scarcity will more broadly define fallow areas. Farmers are allowed to clear and cultivate fallow lands, but not primary or secondary forest. One local official noted that restrictions on forest clearing would make the supply of cultivable land more scarce, and that Park residents would be forced to rely on a fixed quantity of land to feed an expanding population. Interviewees seldom directly acknowledged the limitations imposed by the Park, but many did note their concerns about access to resources. For example, one woman recounted how her family had established its parcels in the area before it was a Park:

At that time that [her husband] chopped down [the trees] there weren't those types of problems, of laws, right? . . . Not to say problems, because by saying problems I would be against them.

She explained that the existence of the Park was not a direct threat to her family because they had cleared land before the regulations were established.

Regulatory guidelines defining fallow and forest are unclear, and under these circumstances farmers more broadly define land as fallow to maximize the

[9] When conducting our field work, methods of accuracy assessment advocated by Pontius (2000, 2002) were not yet published. These methods hold promise form more rigorous accuracy assessments in future work.

[10] While land in forest is not a "land use" per se, we use the category "forest" to refer to forested park land.

[11] Our land use classification combines pasture and fallow because of difficulties in distinguishing these land covers. Fallow and pasture, however, can have quite different ecological impacts. For example, they provide distinctive habitats and create different conditions for forest re-growth. Our social survey indicates that about 9 percent of all land is in pasture (see Table 2). In CAMNP most pasture is concentrated in the cattle producing areas that we exclude from the analyses presented below. For this reason we do not expect that including pasture in the fallow category biases our analysis significantly.

[12] Pueblo Nuevo, although shown on the maps, is excluded from the analysis because it does not fall within the Park's boundaries.

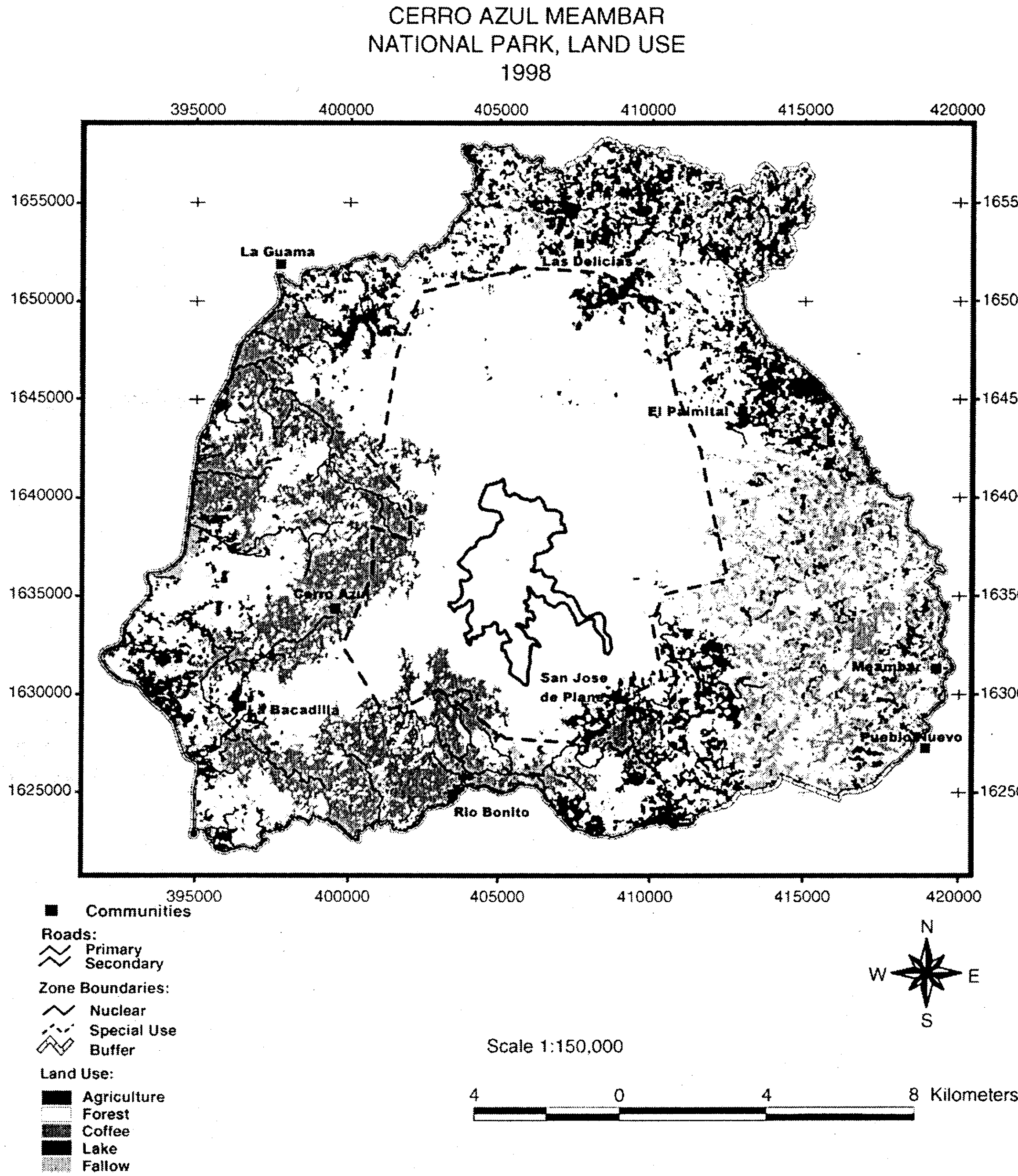

Fig. 2. Land use in Cerro Azul Meambar National Park based on Landsat Thematic Mapper™ satellite images.

land potentially available for cultivation.[13] This point is illustrated by how respondents described one of the photographs shown to them. This photo was of typical of dense secondary forest growth in the region. Farmers made remarks like the following after looking at this photo, "Son guamiles, no?" "Aquí no hay montaña. Estos son guamiles bajitos. Ya no es montaña"—"These are fallows, aren't they?" "Here you do not have forest. These are low fallows. This is not forest anymore". Farmers' descriptions of this photograph demonstrate that there is a very broad definition of fallow in the area.[14]

Fig. 3 illustrates the relationships between the different types of land use reported by the farmers and population density. As would be expected based on Boserup's thesis on the relationship between population density and agricultural intensification, there is a positive linear relationship between population density and the proportion of land dedicated to coffee production. Conversely, there is a clear negative linear relationship between population density and the proportion of land dedicated to staple production (corn and beans). These patterns clearly show the intensification of production associated with increasing population density. It also indicates the commercialization of production and of household consumption. Corn and beans are subsistence crops and are rarely offered for sale. Coffee, on the other hand, is almost exclusively a commercial crop and the primary source of cash income in the area.

Because Park regulations give producers greater latitude in managing fallow lands than forest, fallows are a crucial element in farmers' land use decisions. While Fig. 3 suggests that producers substitute coffee for subsistence crops, the management of fallow lands is a bit more complicated. The proportion of land in fallow displays an interesting inverted curvilinear relationship to population density. The proportion of fallow land increases until a population density of about two persons per hectare, whereupon it begins to decline. This suggests that in areas of lower population density, the intensification of production reduces the amount of land used for the production of staple crops and that this land goes into fallow. In areas of higher population density the demand for land to produce coffee increases as population density increases, and fallow lands are converted into coffee production.[15]

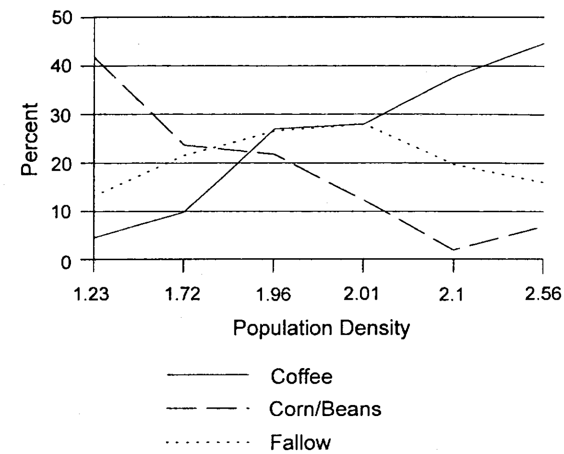

Fig. 3. Land use by population density, Cerro Azul Meambar National Park, 1999.

Fig. 3 presents aggregate patterns at the village level, but to gain a more complete picture of the relationship between different land uses, the allocation of land by individual landholders was also considered. This was done by first evaluating the effect on other land uses of adding an additional hectare of coffee,

[13] We asked the former Director of CAMNP to tell us the difference between *guamile* (fallow land) and secondary forest. He could not, explaining that these categories are not clearly defined in either laws or management practices (Personal interview with Alexis Oliva, 16 June 1999, Siguatepeque, Honduras). The local norm for distinguishing forest from fallow is 9.6 years (S.D. = 0.24). Jansen (1998) found that 38% of the fallows, or *guamiles*, in his study had been fallow 3 years or less, 69% for 5 years or less, and 89% for 10 years or less. He classifies areas with more than 10 years of re-growth as secondary forest.

[14] For more details on this point see Pfeffer et al. (2001).

[15] The relationship between land in forest and population density is less consistent, and it is difficult to see a clear relationship to other patterns of land use. In areas of lower population density (i.e., less than two persons per hectare), the proportion of farmers' land in forest declines as population density increases, but in areas of higher population density there is no linear pattern. This inconsistent pattern is likely related to variations in topography. For example, Cerro Azul, the area with the highest proportion of land in forest is also the area with the steepest terrain (see Fig. 1). Under such circumstances, it is likely that farmers retain so much land in forest because it is unsuitable for other uses. Of course, this topography magnifies the effect of population density on land scarcity.

taking into account the total size of the land holding.[16] The results in Fig. 4 indicate that farmers expand coffee production in very different ways depending on the population density of the area. In areas with higher population density, where the supply of land is more limited and already more intensively farmed, producers substitute coffee for fallow and forest. These results show that in more densely populated areas coffee production has a slightly greater effect on forest than on fallow. For each additional hectare of coffee, there is an average reduction of about one-third hectare of forest. These findings support the hypothesis that in more densely populated areas, the amount of fallow land will decrease. It was surprising, however, to find that forestland declined even more than fallow as farmers added to their coffee plantations. It should be noted that this is forest as defined by the farmers themselves, the restricted definition mentioned above which is limited to more mature forest. According to regulations it should not be cleared.

In areas with lower population density and more extensive production systems, coffee is substituted for subsistence production. Each additional hectare of coffee leads to a two-thirds hectare reduction of corn and beans. In general as noted above, as the proportion of land dedicated to coffee production increases, the proportion in corn and beans declines. However, most producers do not plant all their agricultural land in more intensively cropped coffee for two reasons. First, farmers with limited resources will not be able to muster the capital and labor needed for production at that scale. Second, because of the increased earnings associated with coffee, many farmers will not need to farm on a larger scale. In other words, a relatively small plot of coffee produces enough income to substitute for a much larger area dedicated to subsistence production. The findings indicate that each additional hectare of coffee production in 1999 yielded an average of US$ 113 (S.E. = 0.9) (1700 Lempiras) additional income, and that the average annual household income area in 1999 was

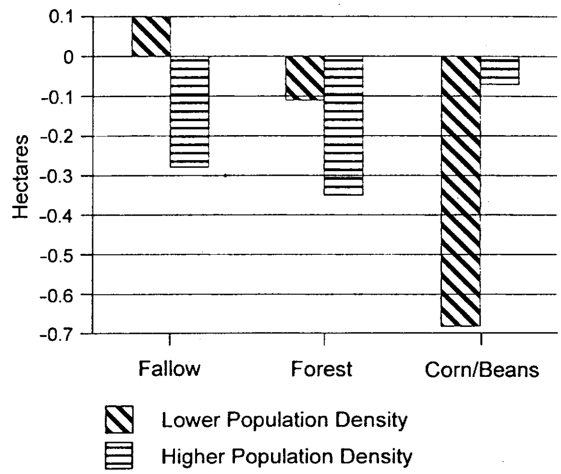

Fig. 4. Change in land use per hectare increase in coffee, Cerro Azul Meambar National Park, 1999.

about US$ 975 (S.E. = 7.0) (14,628 Lempiras). In contrast, corn and bean production on average makes no contribution to household cash income. Thus, it is interesting to consider what happens if farmers allocate less land to corn and bean production. In areas with lower population density, the amount of land in fallow increases by about one-fourth hectare for each hectare reduction in corn and beans (results not shown). As long as these areas are not in demand for coffee production, they would be expected to revert to forest over time. Indeed in lower population density areas with relatively less demand for land, forest increases by about one-tenth hectare for every hectare farmers reduce corn and bean production (results not shown).

The analysis of land use allocation shows that farmers plant land in coffee throughout the Park, and that the higher the population density the greater the proportion of land planted in coffee. In areas of higher population density, farmers tend to allocate less land to fallows and forest as they increase the scale of coffee production. In contrast, in less populated areas they put less land in corn and beans as coffee production increases.

Boserup also postulated a gradual process of agricultural intensification in response to increasing population density. In this process she claimed farmers would reduce fallow periods. Over time fallow would be reduced until land is continuously cropped with only seasonal fallows. This hypothesis was tested

[16] Our estimate of the effect on other land uses of adding an additional hectare of coffee or corn and beans was computed with the following regression equation: $Y = \beta_1$ (total acres) + β_2 (coffee, or corn/beans, or forest) + e, where Y is the number of hectares in fallow, forest, or corn and beans.

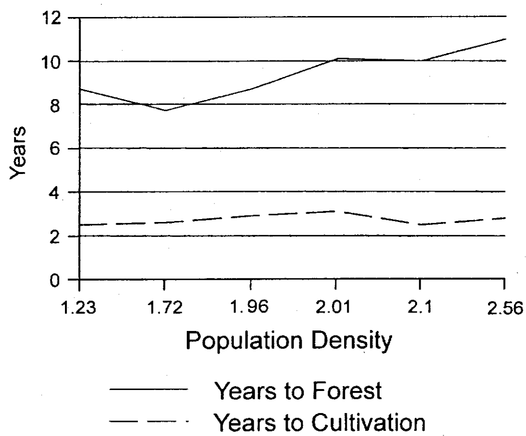

Fig. 5. Farmer estimates of years from fallow to cultivation and from fallow to forest in relationship to population density in farmers' community.

by asking farmers how many years land should be left fallow before cultivating it again. On average farmers responded that land should be left fallow for about 3 (S.D. = 0.09) years.[17] However, as indicated in Fig. 5, there was no significant relationship between population density and the number of years farmers thought land should be fallow ($F = 1.05$, $p = 0.34$). Farmers were also asked how many years it would take re-growth on fallow land to become secondary forest. The average response was 9.6 (S.D. = 0.24), and responses were significantly related to population density ($F = 3.17$, $p = 0.008$).

Fig. 5 indicates that as population density increases there is a mild but consistent increase in farmers' estimates of the amount of time it takes fallow to turn to forest. The findings in Fig. 5 must be interpreted in the context of forest conservation in the Park, which has two significant consequences. First, restrictions on forest clearing force producers to abandon the system of shifting cultivation in favor of continuous cropping of coffee. Since these conservation policies are implemented all at once throughout the Park and land use is intensified through coffee production, there is no gradual reduction in fallow periods that might be associated with extended processes of intensification. Second, farmers respond to restrictions on forest clearing by minimizing land classified as forest. As indicated above, they use a very broad definition of fallow. One way they inflate the fallow category is by extending the number of years required before fallow re-growth is considered secondary forest. This rhetorical shift is a more likely explanation of the positive association shown in Fig. 5 than differences in soil fertility. There is no association between population density and the number of years farmers think land should be fallow, so differences in soil depletion are unlikely to create differences in forest regeneration. Second, natural vegetation is similar throughout the Park at similar altitudes suggesting that differences in soil fertility are unlikely to account for variation in farmers' estimates of the time needed for the appearance of secondary forest.

Thus far the focus has been on land use distribution in 1999, but has this distribution changed over time? Of particular interest is the period since 1992 when the area was actively managed as a Park. The analysis of satellite imagery is useful for this question. Circular buffers, 50 km^2 were drawn around each village and Parkland use within each village area in 1993 compared with that in 1998. Table 4 lists the villages in descending order based on population density and the comparative land use data. Although the 50 km^2 buffer around each village is not the same as the area covered in the farmer survey data presented above, the patterns of land use allocation are similar to those displayed in Fig. 3. Of interest here is the change in the percentage distributions between 1993 and 1998. The findings in Table 4 show that a higher proportion of land in 1998 was in coffee in higher population density areas. The largest decrease was in land allocated to forest in the most densely populated areas. In contrast, as hypothesized, the proportion of land in forest increased in the most sparsely settled areas. As mentioned above, these areas have been part of a large reforestation project in the El Cajón watershed. It is interesting that the increased proportion of land allocated to forest in low population density areas is accompanied by little change in either coffee or agricultural production. It appears that the reforestation project converts fallow lands into forest. In fact, fallows exhibit the most consistent decline between 1993 and 1998 in the proportion of land allocated to any land use, but for different reasons. As hypothesized, in densely populated areas, agricultural

[17] Boserup and others consider frequency of land use or length of fallow to be a measure of intensity because it corresponds to total land productivity (Netting, 1993).

Table 4
Land use change 1993 to 1998 in selected areas, Cerro Azul Meambar National Park

Village	1998 percent of village total				Change in percentage distribution 1993 to 1998			
	Coffee	Agriculture	Fallow	Forest	Coffee	Agriculture	Fallow	Forest
Bacadilla (high)	29.7	12.1	3.4	54.8	11.6	0.3	−3.4	−8.5
Cerro Azul	34.4	5.5	1.8	58.3	16.7	−0.8	−2.7	−13.2
Rio Bonito	38.0	6.5	2.9	52.6	8.7	−1.6	−6.3	−0.8
Planes	6.5	16.3	10.7	66.5	2.9	−1.3	−5.9	4.3
Palmital	0.0	15.6	13.0	71.4	0.0	−1.7	−3.2	4.9
Delicias (low)	0.0	22.8	3.8	73.4	0.0	0.4	−5.1	4.7
Buffer Zone	16.5	17.7	13.7	51.8	−7.0	−1.7	−3.2	−0.3

Sources: Landsat Thematic Mapper satellite images, 1993 and 1998

intensification results in a decline of land under fallow. In addition and consistent with our hypothesis, where demand for conversion of fallows to more intensive use is limited, fallows will be targeted for re-forestation by conservation agencies like CAMNP interested in reclaiming lands from agricultural uses.

4. Conclusion

Human population growth has assured that less and less land is left uninhabited. At the same time, the conservation of natural resources has become more urgent. Consequently, newly initiated conservation efforts are often faced with the necessity of accommodating human needs in an attempt to manage working landscapes. However, this task is very difficult and environmental managers frequently face conflicts between human needs and the requirements of environmental conservation. These difficulties have been manifest in efforts to manage parks in tropical areas and have led to debates about how best to mount conservation efforts (Bates and Rudel, 2000; Brechin et al., 2002).

The analysis presented in this paper was motivated by the need to understand land use dynamics under such complex circumstances. An attempt was made to draw on Boserup's well-established insights on the relationship between population change and agricultural intensification to understand the impacts of contemporary conservation policies. The analysis of land use allocation and change in the buffer zone of the Cerro Azul Meambar National park in Honduras offers some practical conclusions.

It is clear that conservation efforts like reforestation or forest preservation are unlikely to succeed in areas of higher population density. In such areas environmental restoration is in direct conflict with agricultural intensification. In this case study, fallow areas are of particular importance since they might serve as the loci of reforestation efforts or for the expansion of coffee plantations. The analysis shows that in the Honduran park, coffee will win out in areas of higher population density. To the extent that restrictions on forest clearing make the supply of land even scarcer, they may have the unintended consequence of creating additional pressure for fallow conversion. However, the findings show that even efforts to protect the remaining forest are in jeopardy in these areas.

Areas with lower population density and a more extensive system of agricultural production are much more conducive to environmental restoration. The analysis shows that in such areas increasing population density contributes to the intensification of production as in the higher density areas. But in areas of lower population density, intensification of production by planting coffee also frees land for reforestation by the state. Producers place greater reliance on income from coffee to meet their consumption needs. As long as consumption levels remain modest, a significant portion of the land previously used to produce staple crops will remain fallow. This land may eventually be allowed to return to forest, or may be targeted for reforestation under government programs. Lower population density and less competition for resources are also likely to result in less local opposition to conservation efforts, as observed in many parts of Central and South America (Bates and Rudel, 2000). Either way, the result is an increase in forested land, the outcome that was observed in the less densely populated parts of the Cerro Azul Meambar Park between 1993 and 1998.

An important point for policy implementation is how to distinguish between "higher" and "lower" population density. This analysis suggests that the tipping point in this case study is about two persons per hectare. However, the exact point at which conservation policies would more likely be successful will vary depending on the local ecosystem, the types of agricultural intensification suitable to the local area, and the level of economic development. The important point of the analysis is that in Cerra Azul Meambar National Park population density plays an important and consistent role in stimulating agricultural intensification, and that the level of population density can be an important though not exclusive criteria for targeting the implementation of conservation policies (Schelhas, 1994, 1996).

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