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*Articles*

## Human and Non-human Primate Co-existence in the Neotropics: a Preliminary View of Some Agricultural Practices as a Complement for Primate Conservation

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*In this paper I address the general perception that agricultural activities are the principal threat to primate biodiversity in the tropics and argue that in Neotropical landscapes some agricultural practices may favor primate population persistence, and that this situation merits attention and investigation. To explore these issues, I examined three interrelated pressures upon tropical forests for the Mesoamerican and Amazon basin regions: human population growth trends, levels of poverty and human development and deforestation rates. I also present relevant results of recent surveys completed on the presence and activities of primate populations in agroecosystems in several landscapes in Mesoamerica. I further assess the possible benefits of primates to agroecosystems, and stress the value for primate conservation of some agricultural practices in the Neotropics. Human population in Mesoamerica (ca 48 million) and Amazon basin (ca 300 million) regions has been growing at a rate of 2.6-3.0% per year since the 1950's, and it is expected that populations will double in size in 25-35 years. According the United Nation's Human Development Index, high poverty and low human development are typical of the human population in both regions. Pressures upon the land for living space and for food production are paralleled by high deforestation rates in both regions, ca 440,000 ha/yr in Mesoamerica and ca 3.5 million ha/yr in the Amazon basin. Our surveys in landscapes in Mexico, Guatemala and Costa Rica found populations of five of the eight primate species existing in Mesoamerica, temporarily or permanently living in an array of 15 agroecosystems, suggesting these habitats may be important for their persistence. With this information at hand, I further assess the possible benefits of presence and activities of primates to agroecosystems, stress the value for primate conservation of some agricultural practices in the Neotropics, and point out needed areas for further investigation.*

**KEYWORDS:** Neotropical primates, agroecosystems, conservation

### Introduction

Pressures for land use have been a major cause of tropical rain forest loss and fragmentation throughout the world (Donald 2004), and a major cause of increases in rates of species extinction in recent decades (Laurance et al. 2002). Fragmentation of habitat and stochastic forces, along with the increasing rarity of suitable habitat, play an important role in further declines of animal populations and species at the local level (Helne et al. 2004a and references there in). The study of the consequences of habitat fragmentation on animal communities in the Neotropics rests mainly on a large body of research conducted in South America, where the biological richness of forest fragments has been examined with the aim of understanding how species richness is affected by isolation, edge effects, invasive species, and temporal isolation and management (Laurance et al. 2002). In this perspective the focus of landscape studies in the tropics has been the "habitat" and not the "matrix" (the non habitat surrounding the native habitat patches of interest), but recently attention has been directed to the value of matrix habitats for preserving large segments of biodiversity (Ricketts 2001; Lugo 2002; Murphy and Lovett-Doust 2004). Growing empirical evidence suggests that not all species decline toward extinction following fragmentation (Henle et al. 2004b), and that, in some cases, species resilience may be higher than expected (Davies et al 2000; Estrada et al. 2006a).

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In this paper I explore these issues by examining my own previously published work and that of others, and examine three interrelated pressures upon tropical forests for the Mesoamerican and Amazon basin regions: human population growth trends, levels of poverty and human development and deforestation rates. For this exercise, I use raw statistics from Food and Agriculture Organization (FAO) and from the United Nations Development Agency (UNDA) to depict patterns and trends.

I also briefly review the costs and benefits of proximity of primate populations to humans and present relevant results from recently published surveys of the presence and activities of primate populations in agroecosystems in Mesoamerica (Estrada et al 2006b). Moreover, I appraise the possible benefits of presence and activities of primates to agroecosystems, and stress the need for attention to some agricultural practices that have possible value for primate conservation in human modified landscapes in the Neotropics.

### **Agroecosystems**

Agroecosystems cover more than one quarter of the global land area (about 5 billion hectares) (Altieri 2003; Vandermeer 2003) agroecosystems are ecosystems in which people have deliberately selected crop plants and livestock animals to replace the natural flora and fauna. There are highly simplified agroecosystems (e.g. pasturelands, intensive cereal cropping, monocultures), and agroecosystems that support high biodiversity in the form of polycultures and/or agroforestry patterns (Moguel and Toledo 1999). However, diversity in many cases is not only maintained within a cultivated area. Depending on the level of biodiversity of closely adjacent native vegetation, farmers accrue a variety of benefits and ecological services from natural vegetation growing nearby (Altieri 2003). These may include harvesting edible native and naturalized vascular plants, game animals, medicinal and household plants, fuel for cooking, organic fertilizers, religious items, and ecological services such as retention of soil and of soil fertility, and water conservation (Altieri 2003; Vandermeer 2003). Such services and conservation of wildlife may be enhanced by the close coexistence of patches of native habitat and diverse assemblages of agroecosystems creating complex local landscape mosaics of vegetation (Estrada and Coates-Estrada, 2002; Ricketts 2001).

Although protection of undisturbed habitat in natural protected areas (e.g. parks and reserves) in the Neotropics is crucial for primate conservation, many of these areas alone may not meet long-term conservation goals (Chape et al. 2005). To begin with, average country landmass protected in Mesoamerica in the Amazon basin from Neotropics is only about 10-12% (see Earthtrends [www.earthtrends.wri.org](http://www.earthtrends.wri.org)), many of the natural protected areas may not be suitable for primate habitation (e.g. sand dune vegetation, high altitude forests, etc), and in others primate species may not be found within their boundaries (Estrada et al. 2006a). Other problems have to do with the fact that few of the areas are actually protected. More than 50% of the protected areas are less than 10,000 ha in size, only some have specific management plans, many are understaffed, some are paper parks, and most are poorly delimited. Research projects are only being carried out in few of these protected areas, deforestation rates in surrounding areas are particularly high, and in many cases protected areas are virtual islands of vegetation surrounded by altered landscapes (United Nations Environmental Program 2006; DeFries et al. 2005).

### **Human Population Growth Trends, Poverty and Deforestation Trends in the Mesoamerican and Amazon Basin Regions**

Current human population in Mesoamerica (8 countries – see Figure 1 for a list of the countries under consideration) is estimated to be about 48 million people, with a growth rate of 3% since 1950's, it is expected that the population will double in 20–35 years (FAO 2006; World Resources Institute 2006). Human population density in this region is  $82.8 \pm 92.1$  people/km<sup>2</sup> (world average 41.5 people/km<sup>2</sup>). In

Amazon basin countries (N = 9) human population approaches 300 million people and is growing at a rate of 2.6% per year. Average population density for these countries is estimated at  $20.2 \pm 15.0$  people/km<sup>2</sup>.

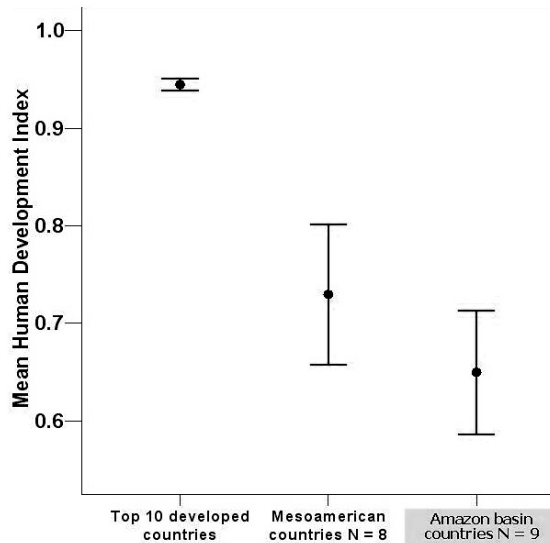


Fig. 1. Mean Human Development Index (HDI) for the top 10 developed countries in the world, and for the Mesoamerican and Amazon basin countries under consideration. The United Nations Development Program HDI combines indicators of life expectancy, educational attainment, and income into a composite human development index, involving 175 countries. The following are the 10 top ranking: Norway, Iceland, Sweden, Australia, Netherlands, Belgium, United States, Canada, Japan, Switzerland. Mesoamerican countries: Mexico (south), Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama. Amazon basin countries: Colombia, Venezuela, Ecuador, Peru, Paraguay, Brazil, Suriname, Guyana. See <http://hdr.undp.org/statistics> for details of how the HDI is calculated.

It is incongruous that amidst the enormous biological wealth of Mesoamerica and the Amazon basin regions, high poverty and low human development are, according to the United Nations' (UN) Human Development Index (HDI), predominant features of their human inhabitants (United Nations' Human Development Index 2006). The HDI focuses on three measurable dimensions of human development: living a long and healthy life, being educated and having a decent standard of living. Thus it combines measures of life expectancy, school enrollment, literacy and income to allow a broader view of a country's development than does income alone. A comparison of the mean HDI for the top 10 developed countries in the world with those of Mesoamerican and Amazon basin countries clearly shows a large gap and the need to improving living conditions for inhabitants of these two regions (Figure 1).

High human population growth combined with extreme poverty, (in the majority of the population and extensive colonization programs of forested areas), as well as global market demands, exert important pressures upon the land and the quality of life of its human inhabitants. This in turn, translates into extensive loss and fragmentation of primate habitats (Estrada et al. 2006a). Deforestation in Mesoamerica for the period 1990-2000 is estimated at 440,000 ha/yr, and similar trends in loss of forest cover are evident in the case of Amazon basin countries, where deforestation for the same period is estimated at 3.5 million ha/year (FAO statistics <http://faostat.fao.org>; [earthtrends.wri.org](http://earthtrends.wri.org)). Percent of forest cover remaining in each country is negatively related to human population density (Figure 2).

According to the United Nations' Human Development Program (UNDP) the lack of steady economic growth in many tropical regions harboring primate populations and habitats makes it difficult or impossible to significantly reduce rural poverty, which in turn will continue to foster enormous pressure on natural habitats and weakly protected reserves (UNDP 2006). As a result, conservation approaches are required not only within, but also outside of protected area boundaries. The matrix of surrounding agriculture habitat may play an important role in long-term primate and biodiversity preservation and must be considered in landscape-level approaches to conservation (Daily et al. 2003; Murphy and Lovett-Doust 2004; Ricketts 2001). They also provide food and cash income for millions of rural households and comprise the basis of regional and national economies in many tropical countries (Lenne and Wood 1999; Fox et al. 2000).

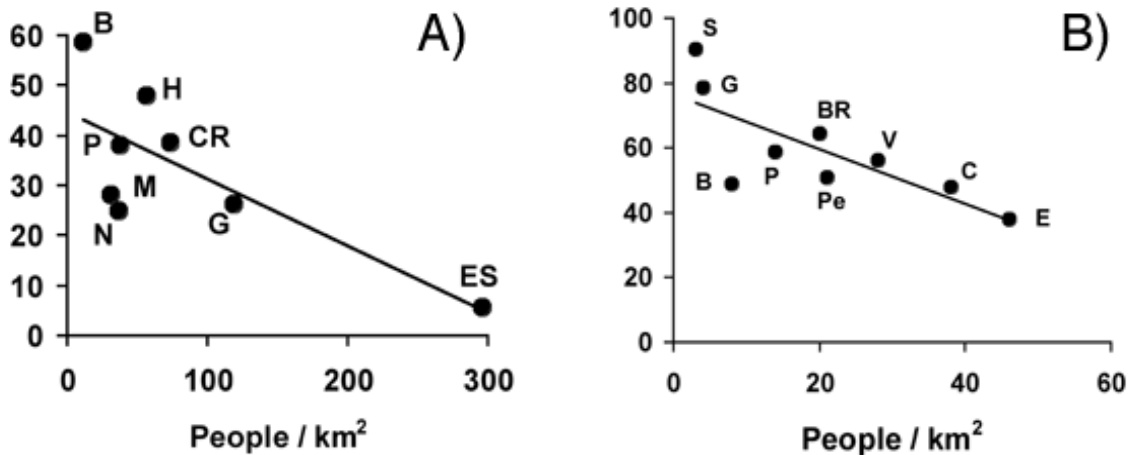


Fig. 2. Percent of forest cover as a function of total land and and population density in Mesoamerican (a) and Amazon (b) basin countries. (a) B Belize, P Panama, H Honduras, CR Costa Rica, M Mexico, N Nicaragua, G Guatemala, ES El Salvador; (b) S Suriname, G Guyana, B Bolivia, P Paraguay, BR Brazil, Pe Peru, V Venezuela, C Colombia, E Ecuador.

### Documentation of Primates in Agroecosystems

Recent evidence suggests that in human modified tropical landscapes, in some agroecosystems may be important to sustain vertebrate biodiversity, including primate biodiversity, by providing temporary habitat, increasing area of vegetation and availability of potential resources, and by providing shelter and connectivity for isolated segments of populations in a broad spectrum of animal species (Daily et al. 2003; Estrada et al. 2006b; Greenberg 2004; Harvey et al. 2004). However, few reports existing in the literature report presence and activities of primates in agroecosystems. For example, forest shaded cacao in Brazil has attracted attention because of its ability to harbor primates such as the golden-headed lion tamarin (*Leontopithecus chrysomelas*), an endangered species (Raboy et al. 2004; Rice and Greenberg 2000). Similarly in Gunung Palung National Park in Kalimantan primates such as leaf monkeys (*Presbytis rubicunda*) and gibbons (*Hylobates agilis*) are found in agroforests (Salafsky, 1993). Michon and de Foresta (1995) report the presence of seven primate species (macaques, leaf monkeys, gibbons and siamangs (*Hylobates syndactylus*) in rubber (*Hevea brasiliensis*) and dammar (*Shorea javanica*) agroforests, and five species in durian (*Durio zibethinus*) agroforests in Sumatra. It was noted that the density of these primates was similar to that in primary forest. A relict population of the Golden langurs (*Trachypithecus geei*) an endangered species in a limited area of Northeast India has been reported living in a rubber plantation in Kokrajhar district of Assam, India (Medhi et al. 2004). In Costa Rica and Nicaragua, howler monkeys (*Alouatta palliata*) have been found present in shaded coffee plantations (McCann et al., 2003; Somarriba et al. 2004), and in Los Tuxtlas, Mexico, howler (*Alouatta palliata*) and spider (*Ateles geoffroyi*) monkeys exploit forest-shaded cacao and coffee plantations (Estrada and Coates-Estrada 1996; Muñoz et al. in press).

### Costs of Primate Proximity to Humans

There is a general perception that primates living in human modified landscapes or at the edge of reserve boundaries are often agricultural pests and can pose considerable costs to cultivators living in their vicinity (Hill 2002; Naughton-Treves and Salafsky 2004). Such perception is based on a large body of literature from studies conducted in Africa and Asia reporting that members of the genera *Macaca*, *Papio* and *Cercopithecus* are among the most frequently cited primate pest species and they can impose considerable losses to farmers by destroying crops (Hill 2002; Loudon et al. in press; Naughton-Treves and Salafsky 2004; Paterson and Wallis, 2005). For the Neotropics, the very few reports available indicate that primates seem to constitute a minor pressure on subsistence and commercial crops (see Gonzales-Kirchner and Sainz de la Maza, 1998 for some examples in Costa Rica). A survey (January 2006) of the entire PrimateLit database of published reports making reference to or focusing on crop raiding by

primates resulted in 313 hits of which 59% were for Asia, 36% for Africa, and only 5% for the Neotropics. When crop raiding hits for each region are expressed as percent of total literature hits (regardless of research topic) for each region, crop raiding hits for Asia accounted for 2.65% (N = 7161), for Africa these were 1.32% (N = 8764) and for the Neotropics they accounted for 0.13% (N = 5454), supporting the notion that crop raiding may be significantly less common in the Neotropics than in the Paleotropics, where primate species assemblages lack terrestrial forms. Hence relationships between humans and primates coexisting in forest-agricultural landscapes seem to be less antagonistic in the Neotropics than in Africa or Asia. Other costs associated to the close proximity of humans and non-human primates forced by clearing of tropical forests for agricultural production are related to increases in the risk of disease and parasite transmission between human and non-human primates and other animals, and this issue is thoroughly reviewed by Chapman et al. (2005).

### Benefits of Primate Proximity to Humans

Studies of the ecological value of forest-dwelling primates have stressed their roles as potential pollinators, seed dispersers and as plant and seed predators. This reveals the importance of primate survival for continued forest dynamics and existence (Bollen et al. 2004; Chapman and Onderdonk 1998), and for local human population and economies, especially where humans use the seeds of tree species (see Lambert and Garber 1998). Economic value of primates has focused on their importance as a source of meat in many areas of Central and West Africa (see Refische and Koné 2005) and in Brazilian Amazonia, where annual consumption is estimated at 3.8 million primates (see Chapman and Peres 2001; Cormier in press). Trading primate meat has also been pointed out as an important component of local economies in some African countries. For example, it has been estimated that the exploitation of primates in the Tai region of Ivory Coast represents a market value of \$124,031-136,688 per annum (see Refische and Kone 2005; Anadu et al. 1988; Auzel and Wilkie 2000) and in southeast Asia (Clayton and Milner-Gulland 2000). Interestingly, no information exists on the potential ecological (e.g. seed dispersers, pollinators, enhancement of primary productivity, nutrient input) and economic benefits (e.g. increase in crop production) of the presence and activities of primates in agroecosystems.



Fig. 3. (a) Homogeneous landscape in southern Mexico, dominated by pastures and with little tree cover, (b) heterogeneous landscape constituted by pastures, forest fragments, arboreal agroecosystems, riparian vegetation and linear strips of arboreal vegetation planted by humans.

### Land-use Patterns for Agricultural Production

In many Mesoamerican and Amazon basin countries, land-use patterns for agricultural production can be divided into two major classes. One in which simplified agroecosystems such as pasturelands and/or other monocultures dominate the landscape, resulting in highly homogenous landscapes. Another one in which complex agroecosystems coexist with pastures and forest fragments resulting in heterogeneous landscapes (Fig. 3). These may harbor commercially important arboreal and non arboreal agroecosystems such as forest-shaded and tree-shaded coffee (*Coffea arabica*), cacao (*Theobroma cacao*), and cardamom (*Elettaria cardamomum*; Zingiberaceae), unshaded arboreal crops (e.g., allspice, *Pimenta dioica*, citrus, *Citrus* spp.), and non arboreal cultivars such as bananas, *Musa* spp. and corn (*Zea mays*), among others

(Estrada et al. 2006b). These landscapes may also harbor thousands of meters of linear strips of live fences (single or double rows of trees) planted by local people to delimit pastures and agricultural lots (Harvey et al. 2004).

| Agroecosystem                                     | Shade condition    | Number of primate species |
|---|--------------------|---------------------------|
| *Cacao  | Forest             | 3                         |
| *Cacao  | Legume trees       | 2                         |
| *Coffee   | Forest             | 3                         |
| *Mixed (cacao/coffee)                             | Forest             | 2                         |
| *Cacao  | Coconut and banana | 1                         |
| *Cardamom   | Forest             | 1                         |
| *Forestry plantation                              |                    | 3                         |
| *African palm                                     |                    | 2                         |
| Citrus  |                    | 1                         |
| Allspice  |                    | 2                         |
| Mango   |                    | 4                         |
| Mango/citrus/banana                               |                    | 2                         |
| Banana  |                    | 2                         |
| Mixed fruiting trees                              |                    | 4                         |
| Live fences                                       |                    | 5                         |
| Taxa  |                    | Number of agroecosystems  |
| <i>Alouatta palliata</i> (mantled howler monkey), |                    |                           |
| <i>A. pigra</i> (black howler monkey)             |                    | 14                        |
| <i>Ateles geoffroyi</i> (spider monkey)           |                    | 8                         |
| <i>Cebus capucinus</i> (capuchin monkey)          |                    | 7                         |
| <i>Saimiri oerstedii</i> (squirrel monkey)        |                    | 6                         |

Table 1. Primate species present in agroecosystems in human-modified landscapes in Mexico, Guatemala and Costa Rica. The asterisk indicates those agroecosystems in which primates were found temporarily or permanently residing. Agroecosystems other than cacao, coffee and cardamom do not require shade to grow. Also shown is the number of agroecosystems in which each primate taxa was found present. Table modified after Estrada et al 2006b.

### Primate Populations in Heterogeneous Landscapes

While pasture dominated landscapes may offer few possibilities of harboring primate populations in the Neotropics, such possibilities may increase in heterogeneous human-modified landscapes. Recent surveys of primate populations in such landscapes in several localities in southern Mexico, Guatemala and Costa Rica (see Fig. 4) report the presence of populations of five (*Alouatta palliata*, *Alouatta pigra*, *Ateles geoffroyi*, *Cebus capucinus*, and *Saimiri oerstedii*) of the eight primate species - *Alouatta coibensis*, *Aotus lemurinus*, *Sanguinus geoffroyi* - present in Mesoamerica in an array of 15 arboreal agroecosystems (Estrada et al. 2006b). The surveys also showed that populations of several of these species were permanently or temporarily residing in about half of the agroecosystems examined; others seemed to be used by primates as foraging and/or as stop-over sites when moving across the landscape (Table 1). Interestingly, populations of all primate species recorded in the agroecosystems investigated were found making use of live fences in their movements across the landscape (Table 1). While howlers and capuchins will also go to the ground to cross open areas, when such fences don't exist they strongly

prefer not to do so (Estrada and Coates-Estrada, 1996; Fragazy et al. 2004). Interviews with the farmers and ranchers indicated that primates are not pests for the majority of the agroecosystems in which they were found. In the few cases in which the monkeys damaged the crops (e.g. capuchin monkeys in cacao plantations and more occasionally howler monkeys in banana groves), depending on the level of damage, the response by humans ranged from tolerance to eradication of the monkeys from the plantations.

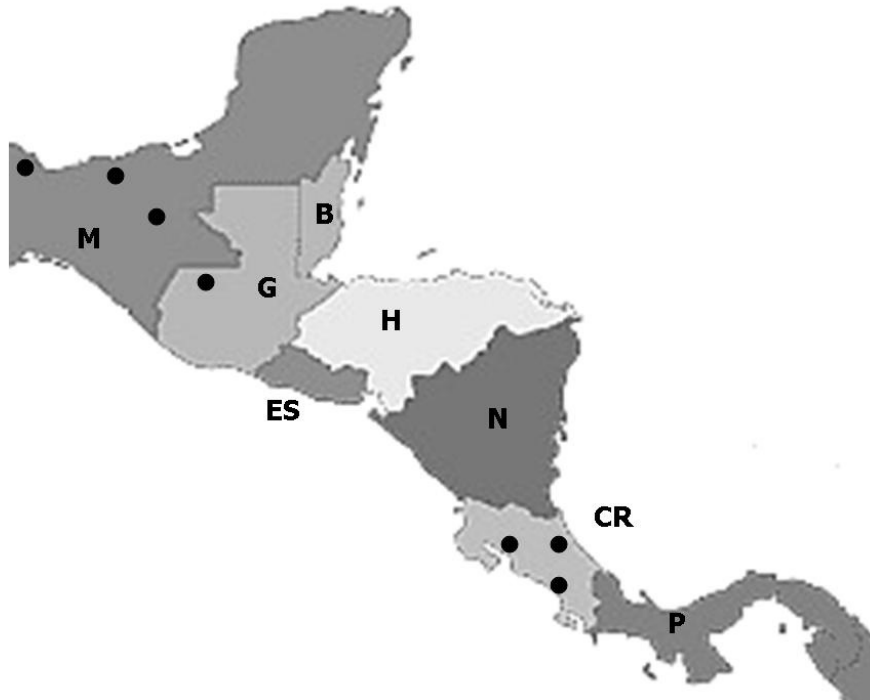


Fig. 4. Approximate location (black dots) in Mesoamerica of the agricultural landscapes investigated for presence and activities of primates. M Mexico, B Belize, G Guatemala, H Honduras, N Nicaragua, CR Costa Rica, P Panama

### Ecological Benefits of Presence and Activities of Primates in Agroecosystems

Movements and feeding activities of herbivorous monkeys in agroecosystems may result in removal of foliage and in the dislodging of branches and of other organic matter in canopy trees, providing shade to cultivars such as cacao and coffee, hence favoring primary productivity (Estrada and Coates-Estrada, 1993). Fruit-eating monkeys may disperse the seeds of shade trees in these agroecosystems favoring the persistence of species that are their sources of fruit, both in the plantation and in the surrounding landscape, favoring regeneration. For example, in some areas of southern Mexico seedlings of these species are harvested by humans for reforestation activities in the agroecosystem and in the surrounding land (A. Estrada, unpublished data). The foraging activities of insect-eating monkeys such as squirrel monkeys in African palm plantations and of golden-headed lion tamarins in cabruca cacao plantations may be important in ameliorating the impact of insect pests (Raboy et al. 2004).

Defecation by the monkeys may add important nutrients to the soil of the agroecosystems. For example, it has been reported that the waste excreta of howler monkeys tends to be nutrient-rich (Nagy and Milton, 1979), and that their dung contains 1.8–2.1% nitrogen (N) and 0.3–0.4% phosphorus (P) (based on dry mass measurements) (Milton et al. 1980). In contrast, concentrations of nutrients in leaf litter are ~1% N and 0.04% P for tropical moist forests (Feeley 2005). In a study conducted in Venezuelan forests, the total soil N concentration under the trees in which howlers defecated was 1.6 to 1.7 times greater than that in control sites (test plots in surrounding soil), and the P concentration was 3.8 to 6 times greater under the resting and feeding trees than in the surrounding soil, which probably enriched the soil and nutrient uptake of these trees (Feeley 2005). High dispersal of nutrients via howler feces in

agroecosystems such a forest-shaded cacao and coffee may result from the howlers' daily movements, benefiting not only the shade trees that sustain the howlers, but also the cultivated plants that grow directly underneath (Muñoz et al. in press).

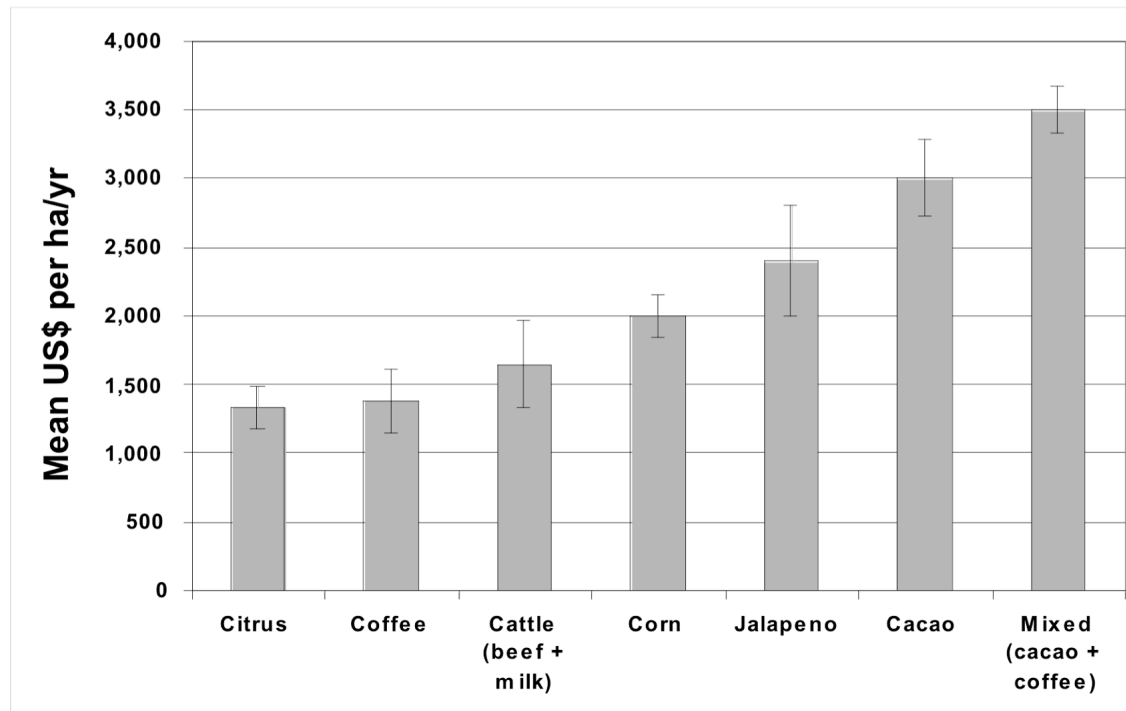


Fig. 5. Economic yield of various land-uses compared to pastures dedicated to cattle ranching, in the region of Los Tuxtlas, Mexico. Data based on a survey of 20 farmlands. Figure modified after Estrada et al. 2006b.

### Heterogeneous Landscapes and Economic Benefits to Humans

Economic surveys conducted by us in some of the landscapes investigated in Los Tuxtlas, Mexico, showed that the economic yield (US\$/ha/yr) of land-use practices other than pastures may be equal or may exceed the economic benefits of cattle ranching alone (Figure 5). With this information at hand, we could envision a diversified land use pattern that may result in a stronger family or community-based subsistence economy, allowing families to have additional sources of income. Further, arboreal agroecosystems in fragmented landscapes may not only provide goods such as food crops for local consumption and commercialization, but also varied ecological services such as habitat for wildlife, natural pest control, seed and seedling banks; they build soil, retain soil and sustain or may increase soil fertility, capture water and stop soil erosion (Altieri, 2003; Swift et al. 2004). In addition, they filter agrochemicals from farm fields, and capture atmospheric carbon (Altieri 2003; Schroth et al. 2004; Vandermeer 2003).

### Needed Research and Final Considerations

Research is necessary to increase surveys and to monitor primate populations in agroecosystems throughout the Neotropics. Studies of the foraging ecology and population productivity are also required to document how successful primates are in sustaining their populations by making use of man-made habitats. We also need to document and understand how primate species present in such landscapes respond to the presence of different types of agroecosystems and to their spatial configuration and management by humans, and to determine threshold levels of tree and forest cover within agroecosystems for successful primate habitation. Investigations about the ecological and economic impact of primate presence and activities in the agroecosystems and on their interactions with humans are also of significance here (Figure 6). If the primates are agricultural pests, studies are necessary to evaluate how



primate populations can be managed. Finally, assessments of how landscape connectivity can be enhanced to favor the medium and long-term persistence of primate populations using agroecosystems as temporary or permanent habitat are also of relevance (Figure 6).

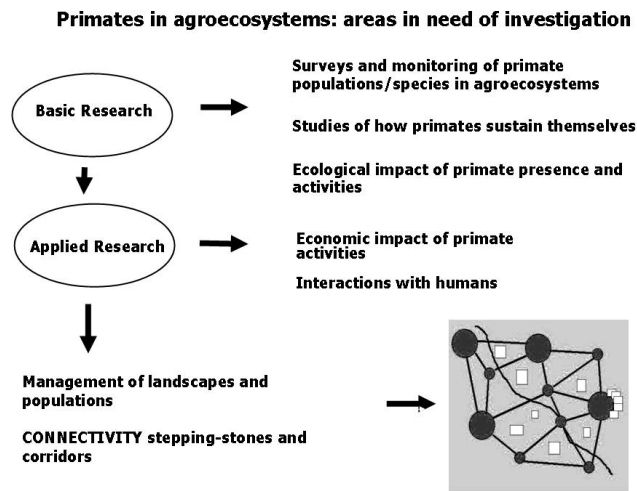


Fig. 6. Areas of research needed in the study of the conservation value of agroecosystems for primate populations in the Neotropics. Image at bottom right: black circles = forest fragments, white squares = agroecosystems, black continuous lines = lineal strips of arboreal vegetation (e.g. live fences). Black sinuous line = river.

geographic genetic variants of particular species, but are also important components of the local biodiversity, and thus merit conservation and study.

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While information presented in this paper suggests that some primate populations are able to persist in Neotropical human-modified landscapes, it is also important to point out that agroecosystems are no substitute for preserving primate populations in their native habitat. However, pressures from human population growth and local and global market demands for food and for other goods are rapidly transforming forested landscapes into a matrix of anthropogenic habitats. At local and regional scales these habitats may play an important role in long-term primate and biodiversity preservation in the Neotropics and must be considered in landscape-level approaches to conservation (Daily et al. 2003; Murphy and Lovett-Doust 2004; Ricketts 2001; Vandermeer 2003). Moreover, primate populations existing in altered landscapes are not only important

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