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Indigenous Forest Management in the Bolivian Amazon: Lessons from the Yuracare People

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Introduction

Societies have been making choices about their relationships with forests for many centuries. As reviewed by Perlin (1991), the dominant choice for the last 5,000 years across Asia and Europe, and more recently in the Americas, has been to cut down trees, use them for fuel and building materials, and replace them with crops or urban centers. In contrast, numerous neotropical cultures have evolved societies that sustain rather than destroy forest ecosystems (Chernela, 1989; Posey, 1992). Such ecologically oriented cultures are rapidly disappearing. Mutualistic relationships between forests and people in the tropics are changing as activities in the forest are modified by incentives structured by market forces, government forest policies, and by concomitant changes in the values of indigenous peoples. This study explores the changing relationship between the Yuracare people and the forest communities they sustain and use along the Rio Chapare in northern Bolivia. It finds that while certain external threats do affect the condition of the Yuracare's forests, a significant amount of local-level management continues to exist.

Historical and Ecological Setting

In the early 1990s, national policy in Bolivia shifted from ignoring the rights of indigenous people in the Amazon to taking them into consideration. The policy change came about in response to internal land tenure conflicts and political organization by indigenous groups (Paz et al., 1995). Years of conflict between families indigenous to the Amazon and settlers from more populated regions of Bolivia led to protest by native groups. In 1991, indigenous Amazonians of Bolivia staged a march "for their territories and dignity" (Paz et al., 1995). This political unrest, combined with the decentralization policies of international donor agencies, prompted the Bolivian government to overturn the "Law of Colonization." This Bolivian law (Art. N107765), promulgated in 1966, declared the lands of the Amazon to be uninhabited and open for colonization. With the negation of the old law, indigenous groups are now recognized and are currently being given legal authority over their traditional territories. The government plays a supervisory role by evaluating petitions for land tenure from indigenous groups in the Amazon.

As a prerequisite for acquiring title to the lands and waters they have used for the past 400 years, the Yuracare are required to create a management plan for the stewardship of the natural resources within their traditional boundaries (CERES, 1997). This requirement implies that the Yuracare lack forest management, a supposition that has never been questioned or explored. It has also invited external assistance and influence in defining and creating a "modern" management plan. In this paper, we assess whether the Yuracare truly lack a system of forest management, and secondly what sort of socio-economic forces are likely to influence them as they try to forge a forest management plan that will be acceptable to government decision makers.

The Yuracare people have one of the last remaining forests in Bolivia that is clearly under indigenous control. Approximately 400 Yuracare families live in the northeastern part of the Department of Cochabamba. They currently claim about 250,000 hectares of the Rio Chapare watershed as their territory. In 1994, the Yuracare began a collaboration with the Forest Trees and People Program (FTPP) of FAO based at the "Centro de Estudios de la Realidad Economica y Social" (CERES) with the goal of making an official forest management plan to respond to the Bolivian government's new policy.

CERES conducted an International Forest Resources and Institutions (IFRI) study to provide an initial understanding of the relationship between people and forests in the Yuracare culture (CERES, 1997). Three settlements along the Rio Chapare—Missiones, Trindidadcito, and Santa Anita—and their associated forests were studied by CERES (Figure 1). The settlements are located in three "life zones" (Holdridge, 1967), all of which may be broadly classified as lowland tropical moist forest. Missiones is positioned in the life zone referred to by Holdridge (1967) as "wet tropical forest." Here rainfall ranges from 2200 to 4400 mm per annum, and temperature ranges from 17 to 24^{o} C. Trinidadcito is in "moist tropical forest" and receives between 1900 and 2800 mm of rain each year, and temperatures remain relatively constant, 22 to 24^{o} C. Santa Anita receives 1250 to 1450 mm of rain each year, and thus supports a forest that is transitional between dry and moist (Holdridge, 1967).

[Figure 1 about here]

The Chapare river has as much influence on vegetation communities as rainfall. Alluvial soils have been deposited at all sites studied by CERES, and moisture and erosion have established a riparian forest community that is fairly homogeneous in species composition along the entire river. The most common tree genera are palms, *Astrocaryum* and *Scheelea,* and fruiting hardwoods, *Guarea*, *Inga, Rhipidocladum, Theobroma* (wild cocoa), *Virola,* and *Hura* (CERES, 1997). In disturbed areas early successional trees genera, *Inga* and *Cecropia* dominate the vegetation community.

Inventories by the Bolivian forestry organization, PRODES, determined that the potential for timber extraction in Yuracare territory was as high as 49 m^3 per hectare (Rojas, 1996). Bolivia's Department of Forestry (DIDF) set quotas on timber extraction in the Rio Chapare region based on these estimates, and encouraged the Yuracare to organize Forest Associations to meet these quotas. In response to this marketing incentive, the Yuracare did in fact organize their own Forest Associations and privatized the most valuable timber.

Themes, Definitions, Null Hypotheses, and Corollaries

In this paper we use data from the CERES-IFRI study to explore whether or not the Yuracare have a tradition of forest management. To address this question it is also necessary to examine what other important factors may be influencing the condition of the forest. Consequently, in addition to studying Yuracare institutions which might affect the forest, we also investigate the effect of moisture gradient, population pressure, and distance from market. Because the CERES-IFRI study includes data from both the natural and social sciences, we were able to include factors from both of these traditions. We use social science data to determine whether there are social norms in place that are directly aimed at forest stewardship. We use data from forest stand inventories to look for physical evidence of forest management by the Yuracare. The intensity of forest use varies along the river. By comparing the riparian forest at three sites that vary greatly in their distances to market and intensity of use (population pressure), we can begin to assess how the ingress of the Bolivian market economy is influencing the forest and the Yuracare's relationships with it.

Consistent with theory developed in the IFRI research program (Ostrom and Wertime, 1994), we define forest institutions as rules or social norms applied to forest goods and services. A rule is considered to be a social regularity with deontic content (implication of "must" or "must not") that is observable, interpretable, or that may be explained by a local person (Ostrom, 1992). The Institutional Analysis and Development (IAD) framework upon which IFRI is founded considers actions taken at several levels of social organization: operational, collective choice, and constitutional (Ostrom, 1990). In this case, the "operational" level refers to actions of individuals that affect the state of the forest (i.e., harvesting, transplanting, pruning, culling, etc.). "Collective choice" applies to actions of individuals that affect the operational level (i.e. prescribing, invoking, monitoring, enforcing, etc.). Finally, actions at the "constitutional" level affect collective choice by determining who prescribes, invokes, monitors or enforces rules.

We pose the following null hypothesis: Yuracare people living on the Rio Chapare of Bolivia lack forest management institutions. If this is true, and drawing from the design principles of Ostrom (1990), it follows that the Yuracare will <u>lack</u> constitutional, collective choice, or operational activities that:

1. Prevent destruction of important forest resources.
2. Encourage activities that conserve or restore forest resources.
3. Clearly define boundaries (Ostrom, 1990) and access to forest resources.

These are all typical forest management activities or norms that sustain forests (Aplet et al., 1993). Sustainable forests may result from either constraining use or from reforestation, and long-term resource management may contain elements of both strategies. Boundaries may be organized at may levels, such as individual (e.g., rights to specific trees), family (e.g., areas managed by a group of relatives), and regional (e.g., use defined by membership in an indigenous group).

Borrowing from cultural anthropology, the null hypothesis also predicts that the Yuracare will lack language pertaining to forest management, especially regarding aspects of sustainable use such as long-term planning and constraints on individual use. More specifically, the null hypothesis predicts that the Yuracare will demonstrate:

1. Little knowledge about forest resources in language or traditions.
2. No awareness of resource depletion, nor actions to remedy it.
3. No conceptual awareness of the role of individual constraint in sustaining a natural resource common.

Again these predictions relate directly to the potential of any society to sustain a biological resource base while they use it. The managers must have basic knowledge about the distribution and abundance of the resource to be managed, and knowledge of how that resource reproduces and grows. They must also be able to detect depletion, and to modify use in such a way that the resource can recover or hover around some equilibrium population size that sustains use over long periods of time.

Forest condition along the Rio Chapare should reflect ecology and human utilization as influenced by population density, market demand, and their institutions that control use of forest products (Figure 2). Because forests are relatively old systems, a long time horizon must be considered. Current forest biomass and diversity may reflect decisions and actions made decades (even centuries) in the past as well as those made recently. To evaluate the past and present social impacts on forests we use paradigms and techniques of forest ecology. Forest condition is defined by measurable physical and biological aspects of a plant community dominated by trees and other woody plants. Measurements include but are not limited to: central tendencies for biomass, basal area, species diversity, density of woody stems, canopy cover, as well as spatial distributions of disturbance, ground cover, and particular plant species (IFRI, 1997).

[Figure 2 about here]

Biomass of trees and species diversity might vary in response to population pressure, market demand, and according to forest management rules. However moisture gradients and stochastic patterns of seed dispersal and herbivory are equally viable explanatory factors for variation in forest structure and composition (Spurr and Barnes, 1980). How does one determine when forest condition reflects societal (institutional) outcome rather than ecological pattern? This sort of challenge can be solved with a research design that varies institutions over a similar ecology or a design that partitions ecology and sociology. In this case, we use a river moisture to tease apart the structuring forces of ecology and human use.

Moisture gradient hypothesis

We assume continuity in regional climate over the life of the forest (last 200-300 years), so the rainfall gradient documented for the Rio Chapare should affect basal area, species abundance and distribution. As mentioned above, Missiones receives more precipitation per year on average, than Trinidadcito, and Santa Anita receives the least. Trees should thus have largest diameters at breast height (dbh)[1] in Missiones where rainfall is plentiful; while progressively smaller values should be found in Trinidadcito and Santa Anita for within species comparisons.

Population density hypothesis

Of the approximately 1800 inhabitants along the Rio Chapare, populations of about 600 are permanent at Missiones and Santa Anita. In contrast, Trinidadcito has no permanent settlement and thus population pressure has been historically low there relative to the other two settlements. If density-dependent effects of resource utilization influence the forest, one would expect a pattern of "low-high-low" for measures of density (trees per hectare) and basal area of trees in Missiones, Trinidadcito and Santa Anita, respectively.

Market demand hypothesis

Opposite to the effects of moisture gradient, commercial timber species should show an increase in density and basal area with distance from Cochabamba, because market pressure declines with distance from a major trading center. The largest trees will be harvested where the cost to get them to market (distance) is the least. Commercial tree species should show a pattern of "low-medium-high" for basal area and density in Missiones, Trinidadcito and Santa Anita, respectively.

In addition to being influenced by moisture gradient, population density, and market forces, forested areas around each settlement have been partitioned into "communal" and "family-managed" units. Following the logic popularized as the "tragedy of the commons" (Hardin, 1968), communal forests would be expected to have lower densities and basal areas, while family-managed forests should be better conserved and stocked. Table 1 summarizes the ecological and socio-economic variables hypothesized to influence forest condition, and reveals that each alternative hypothesis has its own mutually exclusive outcome. Now we can compare the average density, dbh, and basal area of tree species used for commercial timber, domestic timber, and for fruits and medicines and see which factors best explain their current distribution and abundance.

[Table 1 about here]

Methodological Details and a Reference Forest

Institutional analysis and forest stand inventories, standard methods of the IFRI research program (Ostrom and Wertime, 1994), were completed for 5 forest sites (CERES, 1997). Information about social norms and institutions were obtained during visits with Yuracare families and at larger community gatherings, using participatory rural appraisal (PRA) activities and informal discussion. Data were entered on standardized IFRI forms. Forest plot data (IFRI, 1997) were aggregated by communal and family forest areas at Missiones and Santa Anita, but such tenure differences where not in place at Trinidadcito (not a permanent settlement).

Within each forest stand, trees were sampled in circular plots with a 10 meter radius. Plots were systematically placed at 100 meter intervals along one kilometer transects perpendicular to the river and exclusively in mature riparian forest. Areas cultivated with annuals and monocultures of perennials like bananas were purposefully excluded from the forest sampling effort. Transects were positioned in stands of trees that have remained under use by the Yuracare

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[1] This standard measurement of tree diameters is taken at 1.4 m and is used to calculate basal area = p * $(dbh/2)^2$.

over the past few centuries. Sample sizes were stratified according to the size of the forest remaining near each settlement. Because biological diversity typically increases with area sampled, we compared richness within one hectare areas, unless reported otherwise. We use species and family richness (number of tree species and families per hectare) as a measure of biological diversity in the different forest sites.

In order to put the human impact on the riparian forests of the Rio Chapare into context for the western Amazon region, we compared our data with those describing the riparian forests of Manu, Peru, a large protected area (Gentry and Terbourgh, 1990; Foster, 1990). Manu's stands serve as a pseudo-control or reference forest because they have been protected from timber exploitation and have not been used intensively by indigenous families for at least four decades. We predict that the riparian forests used by the Yuracare will differ from Manu as follows:

1. Basal area of trees will be consistently lower at all three settlement areas than at Manu.
2. Diameters at breast height (DBH) will be consistently smaller along the Yuracare than at Manu.
3. Tree diversity on the Rio Chapare will be substantially lower due to human use.

Results

Forest management institutions created by the Yuracare

The Yuracare have clearly defined boundaries, systems of monitoring resource condition, and rules that directly pertain to forest resources. Yuracare institutions control access and use of the forest at multiple levels: Clan (extended family), Corregimiento, and Territory. Tribal territory and clan areas are largely predicated on providing families within clans with sufficient game meat and other natural resources. Clans are the core of the Yuracare social system, consisting of an extended family made up of 10 to 20 nuclear families (husband, wife and children). Clans have organized themselves into eleven "Corregimientos"[2] along the River. Within each Corregimiento, "Kuklete" or family forest gardens are created, cared for, and monitored like private property. Families state that they "own their work," but not the land *per se*. While territorial tenure is important for the Yuracare people-forest relationship, permanent private land-holdings are not, because families strategically move within their Corregimiento and within the entire territory, creating forest gardens and obtaining forest resources. Thus, each family has a stake in organizing to maintain control over the whole watershed, and their institutions reflect this landscape-level concern for sustaining their resource base (Table 2).

[Table 2 about here]

Using a consensus approach, representatives from each clan, elect a "*Cacique Mayor Yuracaré*"[3] to lead them. Likewise each Corregimiento has several representatives that participate in a tribal council (*Consejo Indigena Yuracaré*). This council uses a system of one person-one vote, and majority rules, to make major decisions and plans that concern the Yuracare as a whole. Since territorial control is the major concern of the Yuracare, council meetings tend to focus on

[2] Corregimiento is related to the noun corregidor which refers to a Spanish magistrate. In this case, the term applies to a spatially defined unit of governance organized by a Yuracare clan (s).
[3] Cacique - political leader. Also name of colorful, loud, social birds in the neotropics from which feathers are used to decorate leaders.

political conflicts with other indigenous groups and on interactions with external agencies (e.g., government, church, NGOs).

Most forest management activities (operational) and decisions (collective choice) are made at the family level within clans. Families have an informal system for monitoring resources and their use within their Corregimiento. The approach is completely decentralized, but replicated within the entire territory. Information on resource distribution, such as the locations of timber species, excellent hunting areas, trees in fruit, and areas that are good for cultivation, is well established for each Corregimiento. Families in each Corregimiento do informal inventories of resources by walking and canoeing through out their region and discussing the spatial distribution of resources. Over the centuries this knowledge has been systematized and used to classify soils, to design a system of forest agriculture, and more recently to exploit commercial timber (Paz et al., 1995).

Exploitation of commercial timber created conflict and challenged Yuracare institutions, because at first certain individuals accrued more benefits than others. Clans have devised a system of tree ownership to distribute this wealth more equitably. In 1991, Forest Associations were formed in each Corregimiento to organize timber exploitation and to interact with government forestry departments and timber buyers.

Both constitutional and collective choice levels of organization are represented by social norms that prescribe actions pertaining to forest management in Yuracare culture. For example a frequently mentioned norm was that "ALL Yuracare must care for the forest." When asked why, the typical response was "so the animals will come." Rights and obligations are thus created and enforced by the Yuracare as a group. Operationally, "caring for the forest" includes protecting fruiting trees, and transplanting and selectively encouraging fruiting trees in order to increase densities of game. Yuracare also have game management rules including selective harvesting of the males, and no-hunting seasons. When rules are broken, sanctioning is traditionally accomplished via social reprimand and ostracism, but with the growth of commercial timbering, these mild social sanctions have been inadequate at times. For example, sometime in the last five years, a man harvested and sold trees belonging to another family and this required resolution between two clans. The norm-breaker was required to split his income from the sale of the trees with the original owner.

Well before the organization of Forest Associations, Yuracare language and traditional norms included explicit prescriptions for sustainable forest management. At the collective choice level they prescribe "use of forest trees and animals without depletion". This prescription is operationalized through a "mobile multiple use" relationship with the forest and through the creation of fruit tree gardens. Rather then use any one forest area intensively, families spread out the impact of timber harvesting, agriculture, hunting, and gathering in time and space. Movements include complex local and regional patterns, a full description of which is beyond the scope of this paper. However, seasonal variation in resource use and collection of resources over a large area probably prevent depletion of patchy resources in any one area. The Yuracare practice long-term biodiverse perennial agriculture in small forest patches. Areas with productive soils, "ti jukule," are first planted with yucca, then bananas, and then fruit trees (mango, chocolate, orange, coffee, grapefruit, palms, native fruit trees, etc.). The forest tree garden is used for 25 to 35 years eventually becoming mature rain forest, dominated by domestic and wild fruiting species. The Yuracare promote growth of the wild fruiting species by removing nearby seedlings that would compete for water and nutrients.

Yuracare institutions are highly responsive to external incentives. In 1992, the Yuracare decided to organize Forest Associations in each Corregimiento to coordinate with external government forest agencies and timber marketing associations. Two laws, the "Forest Law and the Law of INRA (Rights of Indigenous Peoples), have extended exclusive rights to forest exploitation to the Yuracare within their territory, but under certain constraints imposed mainly by government forestry agencies. The Forest Associations have worked to allocate resources, weaken constraints (e.g., relax rule against use of chain-saws), and to resolve conflicts among themselves. To reduce conflicts over valuable timber, the Yuracare Forest Associations privatized Mahogany and Spanish Cedar in community forest areas. Since these forests are already rather equally distributed among family areas via the Corregimiento system, the private goods within them were relatively easy to distribute.

Yuracare language and forest management

The Yuracare have many sayings that explicitly relate to sustaining a diverse tropical forest ecology. Their language is replete with statements about the Yuracare's role in a food chain based on fruiting trees. The following phrases are translations illustrating a linguistic familiarity with the ecological concept that forest fruit feeds game animals, and game animals provide food for the Yuracare:

1. "to be human one must eat meat"
2. "When the ambaibo (Cecropia) fruits, the animals get fat!"
3. "Yuracare must care for the forest"

In addition to stating that people should "use forest trees and animals without depletion," the Yuracare have the saying "Cuivalimatu tëpshë dulashtututi nomajsha" which translates as "one should plan for the future." Such language illustrates a familiarity with conservation principles that underly sustainable use.

When asked to name natural resources, wild forest fruits and animals had a higher proportion of indigenous names than timber and agricultural species (Figure 3). This result is not surprising given that Yuracare culture was totally dependent on forest resources prior to colonial influence. What is more important is that the Yuracare named 52 fruiting tree species that they actively monitor, protect, and promote. The Yuracare have spatial concepts of their forest resources as evidenced by maps they made during Participatory Rural Appraisal (PRA) exercises (Figure 4). While their geographic information system (GIS) may lack precision (e.g., not to scale), it accurately depicts locations of forest resources, forest cover classification, water resources, and use patterns.

[Figures 3 and 4 about here]

Variation in forest condition

As shown in Table 3, forest condition at the three sites on the Rio Chapare differ substantially. Despite having higher rainfall that would favor large mean basal area and good regeneration, Missiones had the lowest values for both of these important indicators of forest health. Forests in Missiones where timber exploitation was heaviest had a basal area of only 28 m^2/ha, while stands in Santa Anita averaged 38 m^2/ha.

[Table 3 about here]

In general, the mean basal area of trees along Rio Chapare increased with distance from market (Table 3). Basal area was not consistently lower on family plots, nor was it lower than the mean basal area at the Rio Manu protected area. Average basal area was largest for family plots at Santa Anita, a result best fitting predictions for distance from market. Diameter at breast was larger along Rio Chapare than Rio Manu (Table 3), and significantly smaller at Missiones than at Trinidadcito and Santa Anita (ANOVA, df = 4, p = 0.02).

Mean density of trees varied as a consequence of use along the Rio Chapare, and was only half the value for Rio Manu. While the Rio Chapare forests had from 310 to 366 trees per hectare, Manu had 650 trees per hectare. When the distribution of size classes are compared for the two river systems (Figure 5), a pattern consistent with market incentives and traditional forest management may be interpreted. Trees with diameters of 26 to 40 cm were clearly less abundant in the Rio Chapare sample than at Manu, probably a consequence of timber harvest. Large diameter (fruit trees), however were more abundant in the Rio Chapare sample than in the Manu sample. There were also more trees per hectare in the communal forests than in family forests,(not significant at the plot level), opposite to a "tragedy of the commons" scenario.

[Figure 5 about here]

Tree species diversity along the Rio Chapare was low relative to Manu (Table 3). While botanists found as many as 283 different species in one hectare samples at Manu, the maximum value on Rio Chapare was 60 species. Comparisons made at the family level (where identification skill is less likely to bias results) also suggest that forests along the Manu are more diverse than those associated with the Rio Chapare. Trees in one hectare at Manu represented 45 families while only 34 families were found in the Rio Chapare study in an area of more than 12 hectares.

Dbh of trees used indigenously averaged 10 cm larger than commercial species suggesting that market pressure has lowered the biomass of timber species, while species used for fruit, local building material, and medicines have been conserved (Table 4). Nine of the 10 most abundant tree species in the Rio Chapare samples were fruiting species used by birds and mammals that are traditional foods of the Yuracare. Still, several non-commercial species such as *Amendrillo* and *Crespito* had very low regeneration values, and *Yesquero* had no evidence of regeneration (Table 4). Two timber species of traditional importance, "Gabun" (Virola peruviana) and "Guayabochi" (Calycophyllum sproceanum) show little regeneration in the Missiones forest samples suggesting that they may be overexploited there. Seedlings and saplings of two medicinal trees, "Paraquina" (Ephedranthus amazonicus) and "Gabetillo" (Sloanea rufa) were also nearly absent in the Missiones plots.

[Table 4 about here]

Of the 34 tree species with economic importance to the Yuracare, 9 exhibited changes in density and dbh that would be expected along a gradient of soil moisture (Table 5). When biomass profiles (dbh and stem density) are compared (Table 5), commercial timber species were more likely to be depleted than traditional timber species. None of the traditional timber species showed the "low-medium-high" profile consistent with market pressure. Given the lack of market profiles in the more abundant traditional use species, it is possible that "depleted" species in this category are rare species. Eleven of 28 species with traditional uses (Table 5 B & C) showed reductions in density and diameter consistent with population pressure. Three species had similar average values at all sites, and only two species had profiles that did not fit any predicted pattern.

[Table 5 about here]

Commercial timber species had smaller diameters than fruit trees despite their low regeneration statistics (Figure 6). No fruiting species showed indications of depletion, while traditional timber species did. This suggests that sustainable stewardship is directed to those species that directly contribute to the Yuracare food chain, while timber species are not managed as intensely.

[Figure 6 about here]

Discussion and Conclusions

The distribution and abundance of tree species along the Rio Chapare reflects moisture gradients, population pressure, and market demand in predictable ways. It thus seems possible to detect single factors that are determining the abundance of a variety of species along a river gradient and to determine when social processes outweigh ecological ones.

The results of this study refute the idea that the Yuracare lack forest management institutions. In addition to cultural norms that prevent destruction of important forest resources, encourage activities that conserve or restore forest resources, and define boundaries and access to forest resources, the Yuracare make and modify rules for forest use (Ostrom, 1990). They also monitor physical condition and use of forest resources, and sanction abuse of, and resolve conflicts over, forest resources. Clearly, the Yuracare have constitutional, collective action, and operational activities that explicitly pertain to forest management, and their forest management system existed well before external government forestry agencies began to demand forest management plans. The Yuracare also have language and traditions that would be considered hallmarks of sustainable forest management: long-term planning and constraints on individual use.

All along the Rio Chapare the Yuracare have reduced tree density and diversity, but their selection for large fruiting trees has increased basal area and biomass. Because fruit abundance is positively correlated with basal area and dbh (Leighton and Leighton, 1982), Yuracare forest management should enhance resources for wildlife. Essentially their traditional forest management is a mutualism with fruiting trees and game animals. The Yuracare increase the reproductive success of fruiting trees which increases the density of game, which has potential to increase Yuracare survival.

While their long history of self-organization has helped them respond efficiently to recent incentives for timber exploitation, their tradition of conservation of fruit trees has not been extended to timber management. While they are capable of integrating with government forestry agencies to negotiate harvest quotas and constraints on harvest technology, they show little inclination to conserve or restore timber species. Perhaps it is just too early to judge, but our data suggest that several species are have been extirpated in the entire region, and that extirpation of traditional species is now occurring around Missiones where market demand and alternatives to traditional cultural patterns are greatest. Traditional interest in fruiting trees and dependence on forest resources is changing.

Paz (1991) suggested that timber extraction would have negative consequences for the Yuracare because the loss of timber species might cause a collapse in traditional resources used for subsistence. Presumably, Paz was thinking about the breakdown of potential ecological links between timber and fruiting species that sustain wildlife habitat and other important mutualisms (i.e., pollination, dens for game animals, etc.). At first glance, a collapse in forest resources seems unlikely because the Yuracare appear to be maintaining fruiting trees and other trees that sustain their valued food chain and traditional needs. Their "mobile multiple use" system also buffers them against depletion of common pool resources in the forest. Upon closer inspection, however, our results support Paz's conjecture. The parasitic relationship of timber exploitation is beginning to erode the Yuracare's mutualistic relationship. Biomass and diversity are being lost as market and institutional incentives favor the unsustainable harvest of timber species. Privatization of forest resources may also promote a more sedentary life which can put more pressure on resources as was shown by differences in forest condition at Trinidadcito and the permanent settlements.

Missiones, where population and market pressures are greatest showed the greatest declines in basal area and abundance of individual species relative to other forests studied on the Rio Chapare. As more Yuracare turn from hunting and tending forest gardens to embrace market economies and timber management incentives, the fruiting forest appears to play less of a role in their culture and language, and timber producing forest becomes more important. Given this change, forests along the entire Rio Chapare could become as degraded as those around Missiones

While Yuracare folk ecology refutes our null hypothesis, this does not imply that indigenous people have all the knowledge and institutional capacity required to manage forest resources. In this case conservation end points were only convergent for certain tree species (fruiting trees). Ecological cognition appears to prompt the Yuracare to be more risk adverse toward substitutions for fruiting species, while they seem less adverse to liquidation of many timber species. Timber harvesting has tested Yuracare tradition and deserves more study from a socio-anthropological context. For example, it is not clear how the different forest associations have resolved conflicts over privatization of timber species, or if any of the clans will institute a system of sustained-yield harvesting for timber trees. Given their traditional biases, they should monitor regeneration and focus timber exploitation on non-fruiting species that regenerate well.

Comparisons of colonial and indigenous settlements in the Amazon have consistently shown that forest degradation is typically greater under stewardship of colonial farmers than under the care of forest-dwellers with a long history of interacting with forest resources (Rudel, 1993; Chernala, 1989; and Atran et al., 1998). Encouragingly, some colonists in the Peten of Guatemala have adopted ecological values and actions of forest-adapted Itzaj Mayans rather than dissuading the indigenous people from forest sustaining practices (Atran et al., 1998). Atran optimistically interprets this finding as potential for indigenous knowledge to influence policy and planning at regional and national levels, and advocates that co-evolved relationships between indigenous people and forest species should be considered more carefully by policy makers.

The Yuracare have not fully evaluated the possible negative consequences of forest degradation, nor have they evaluated the bargaining power that might result from conserving their trees. The increase in basal area or biomass resulting from traditional Yuracare forest management can be viewed as a positive contribution to carbon storage, which is a global commons benefit. Ecological cognition and values of the Yuracare seem to be somewhat limited to trees that form the base of their food pyramid, yet their system has sustained people, wildlife, and a diverse forest for many centuries. Timber extraction has had negative impacts on both carbon storage (basal area) and biodiversity and a forest policy based on commercial timber threatens the sustainable aspects of a 400 year old relationship between people and forests along the Rio Chapare. Regional planners in Bolivia and external agents promoting timber harvesting need to make a more careful evaluation of the environmental impacts they are having on the mutualistic strategies inherent in the traditional Yuracare forest management.

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Table 1. Predicted relative values for stem density and basal area of tree species in forests associated with three settlements on the Rio Chapare, Bolivia. Pictograms of outcome are below each causal factor.

	Relative Mean Values for Stem Density and Basal Area		
Forest Structuring Factor	**MISSIONES**	**TRINIDADCITO**	**SANTA ANITA**
Moisture gradient ¯ - _	Large	Medium	Small
Human population pressure _ - _	Small	Large	Small
Market pressure _ - ¯	Small	Medium	Large
Tenure	Family plots > Community forest plots at all three sites		

Table 2. Framework of Yuracare Forest Institutions

Social Level	**Operational**	**Collective Choice**	**Constitutional**
Individuals Families Clans	Fruit tree planting Culling for fruiting trees Protection of fruiting trees Harvesting timber trees	Allocation of land to families. Where to develop family tree gardens vs. leave the communal forest.	Defining clan membership. Familial decision making. Selection of Clan leaders.
Corregimiento (sub-region)	Monitoring resource use Sanctioning abusers	Allocation of land/forest to different clans. Deciding on ownership of commercial tree species.	Membership in a Forest Association. Clan leaders comparing use within their areas.
Territory (watershed)	Monitoring commercial timber Sanctioning abusers	Families interacting with clan leaders and Cacique (Yuracare chief) to resolve tree tenure conflicts. Meetings held when needed.	Clan leaders comparing use within their areas with input from Forest Association and government.

Table 3. Tree Basal Area, Density, and Diversity at Rio Chapare Sites
(Comparison with "pristine" Rio Manu forest trees ≥ 10 cm DBH. All sites are on alluvial deposits.)

	Missiones		**Trinidadcito**	**Santa Anita**		**Rio Manu**
	Familiar	Comunal	Familiar	Comunal	Cocha Cashu[1]	
l Precipitation(mm)	2280 - 4400		1900 - 2800	1250 - 1450		2028
rea: ^{2}/hectare)	27	29	33	40.3	36	37
ectare	319	333	363	310	366	650
dbh ± se	24.7 ± 1.2	24.4 ± .7	27.1 ± .45	27.8 ± 2	26.4 ± 1.3	22.6**
iversity ee Species/ha: ee Families/ha: ee Families/>10ha:			 45-60* (for all sites) 23-29 (for all sites) 34 (for all sites)			 155-283 45 N/A
ns***	2	8	17.5	1.8	1.5	15.3
Land Use	Market and Family		Mobile Family	Family and ranching		Tourism

[1] "Pristine" upper Amazon alluvial floodplain forest (Gentry and Terborgh, 1990).
* Lower value may result from difficulty of identification at species level, although Family count is also lower.
** Calculated by taking mid-point values of size classes from Table 27.1 (Gentry and Terborgh, 1990).
*** *Astrocaryum, Iriartea, Scheelea*

Table 4. Estimates of trees ha^{-1} of commercial and non-commercial timber species on the Rio Chapare, Bolivia (Genera in parentheses). Data from the five IFRI forests were pooled because there were no statistical differences in tree or sapling densities by site. Estimates are derived from 386 plots totalling 12.12 hectares. Sapling estimates are based on a 1.1 hectare aggregate of 386 plots, each covering 28.3 m^2. Sampling was stratified by forest size, so these data are biased towards Trinidadcito where 57% of plots were completed.

Commercial Species	**Trees/ha**	**Mean%**	**Ave. dbh**	**Saplings/ha**
Trompillo (Guarea)	13	3.5	19	122
Gabun (Virola)	12	3.2	32	48
Verdolago (Terminalia)	6.1	2.3	33	11.8
Laurel (Ocotea)	1.9	< 1	22.4	11.8
Palo Maria (Calophyllum)	.74	< 1	36.5	.9
Cedro (Cedrela)	.14	< 1	15.6	1.6
Mara (Swietenia)	0	-	-	0
Total	**~ 34**	**mean = 26.4**		

Non-Commercial Species	**Trees/ha**	**Ave. dbh**	**Saplings/ha**
Jorori (Swartzia)	6.7	25.4	2.7
Guayabochi (Calycophyllum)	2.2	30.2	3.6
Yesquero (Cariniana)	0.4	66.0	0
Uropi (Claricia)	2.6	23.3	13.6
Almendrillo (Dipterex)	0.2	99.0	1.8
Ochoo (Hura)	9.2	45.3	9
Negrillo (Nectandra)	4.7	20.4	30
Cedrilllo (Spondias)	4.1	39.5	4
Cafesillo (Margaritaria)	7.3	29.8	21
Coloradrillo (Brysonima)	8.6	19.6	71
Crespito (Stryphnodendron)	1.5	24.0	1
Sangre de Toro (Virola)	3.5	24.7	3.6
Coquino (Pouteria)	4.7	25	10.9

Total	**~ 56**	**mean = 36.3**

Table 5. Biomass Profiles. Density (stems per hectare) and Mean DBH of tree species in different use categories in communal (C) and family (F) forest plots in three settlements along the Rio Chapare, Bolivia. The last column presents a verbal and pictorial representation of biomass or importance (a combination of Density and DBH data). For example, the species Hura crepitans shows an increasing value in density and mean DBH across a row (by settlement) and is thus represented by the pictograph (_ - ¯). This profile fits our predictions for market exploitation. In cases where density and DBH appear to decline in family forests in both Missiones and Santa Anita, the term "family use" is placed in the major effect column.

A. Commercial Timber Species

	Missiones				Trinidadcito		Santa Anita				Result
Species	Density		DBH		Density	DBH	Density		DBH		Major effect
	C	F	C	F			C	F	C	F	
Cedrela sp.	0	0	0	0	1	16	0	0	0	0	Depletion _ _ _
Dipterex odorata	1	0	150	0	1	48	0	0	0	0	Depletion _ _ _
Guarea sp.	14	12	17	22	15	20	7	9	23	13	Moisture ¯- _
Hura crepitans	5	7	42	45	12	51	7	13	30	57	Market _ -¯
Swietenia macrophylla	0	0	0	0	0	0	0	0	0	0	Depletion _ _ _
Terminalia amazonica	9	12	36	22	5	57	8	5	50	114	Market _ -¯

Table 5 (continued)

B. Traditional Timber Species

	Missiones				Trinidadcito		Santa Anita				Result
Species	Density		DBH		Density	DBH	Density		DBH		Major effect
	C	F	C	F			C	F	C	F	
Annona sp.	5	9	55	26	6	57	2	0	27	0	Moisture ¯ - _
Brysonima indorum	19	9	18	16	6	19	13	5	321	17	Family use
Calycophylum sp.	3	1	30	17	3	30	1	0	49	0	Family use
Carinianana estrellensis	0	1	0	61	1	71	0	0	0	0	Rare or depleted
Ceiba pentandra	1	0	92	0	0	0	0	0	0	0	Rare or depleted
Claricia racemosa	2	2	18	25	4	32	1	2	21	20	Population _ - _
Margaritaria nobilis	8	13	25	23	8	27	7	4	12	21	Similar - - -
Nectandra sp	7	4	26	21	5	22	7	16	2	17	Family Use
Ocotea sp.	1	3	19	33	3	21	0	1	0	10	Moisture ¯ - _
Pouteria bilocularis	1	0	14	0	7	29	1	1	36	19	Family use
Pouteria sp.	3	1	26	15	0	0	0	10	0	10	Moisture ¯ - _
Stryphnodendron sp.	1	1	13	22	1	23	1	1	21	31	Similar _ _ _
Virola peruviana	15	17	25	17	13	22	0	0	0	0	Moisture - - _
Virola sebifera	5	1	26	20	0	0	14	17	19	33	Family Use

Table 5 (continued)

C. Tree Species with Traditional Use for Fruits (F) and Medicines (M)

	Missiones				Trinidadcito		Santa Anita				Result
Species	Density		DBH		Density	DBH	Density		DBH		Major effect
	C	F	C	F			C	F	C	F	
Astrocaryum chonta (F)*	18	6	16	17	42	17	36	33	15	21	Population _ - _
Brosimum lactescens (F)	2	2	17	11	9	17	2	0	20	0	Population _ - _
Cordia nodosa (M)*	0	0	0	0	0	0	2	1	26	14	Market _ - ¯
Ficus insipida (M)	0	0	0	0	2	21	0	0	0	0	Population _ - _
Ficus sp. (M)	10	17	48	59	5	60	4	1	86	120	Moisture ¯- _
Inga sp. (F)	44	37	20	19	17	18	14	12	18	21	Moisture ¯- _
Leonia glycicarpa (F)	5	3	13	14	10	15	0	1	0	27	Other
Maclura sp. (F)	6	5	12	15	1	15	0	0	0	0	Moisture ¯- _
Scheelea princeps (F)	5	1			23	9	13				Population _ - _
Sloanea rufa (M)*	1	0	20	0	1	19	6	4	20	17	Market _ - ¯
Spondias mombin (F)	4	2	43	21	5	45	4	4	51	37	Similar - - -
Theobroma cacao (F)	1	2	19	13	5	16	26	15	15	15	Other
Theobroma speciosum (M)	5	2	14	19	11	18	5	1	12	12	Population _ - _
Triplaris americana (M)	5	4	13	15	2	16	0	0	0	0	Moisture ¯- _

*Also used for building materials.