Beyond the Map: Indigenous and Colonist Impacts and Territorial Defense in Nicaragua's BOSAWAS Biosphere Reserve

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Abstract

The conservation literature over the past 20 years reveals a shift in thinking about the compatibility of indigenous people and biodiversity in or near protected areas of the tropics. From an initial optimism, opinion has gradually become pessimistic. Indigenous tropical forest lowland farmers in Latin America and elsewhere are said to be no different than any frontier farmers, and conservationists cry out for more parks that exclude humans. However, most of the discussion has been ideological and anecdotal.

The area of the Bosawas International Biosphere reserve offers a chance to examine some of the issues quantitatively. Through the analysis of Landsat images, this study examines five issues regarding deforestation. The study recognizes three different populations that have populated the reserve and its immediate environs since its establishment in 1991: indigenous residents of two ethnicities (Miskitu and Mayangna), and mestizo colonists. The indigenous population was expelled during the most of the 1980s Contra war, and fallow areas were allowed an unusual opportunity to grow back to the point that satellite images in the late 1980s shows nearly the entire area as mature forest. After the war, both indigenous people and mestizos began to populate the reserve at approximately the same time, but in discrete areas of the reserve, and today both categories are estimated to have approximately equal populations.

Specifically the study examines five hypotheses: 1) That areas under indigenous management have a better outcome in terms of net forest loss per capita than areas under mestizo management; 2) that areas under indigenous management have a better outcome in terms of forest connectivity than areas under mestizo settler management; 3) that indigenous people are able to significantly halt or slow the advance of the agricultural frontier without violence through their own efforts if they are empowered to do so; 4) that the Mayangna tend to deforest less than Miskitu; 5) That the Bosawas boundary itself has affected the advance of the agricultural frontier. The study also presents and analyzes the current distribution of land uses within the reserve and its contiguous indigenous areas.

In terms of results, the study shows that the that indigenous residents have deforested significantly less than mestizos on a per capita basis, that forests under indigenous tenure have significantly more connectivity than forests under mestizo tenure, that demarcation of the indigenous territories has significantly slowed, and perhaps halted, the advance of the agricultural frontier, that Mayangna and Miskitu have approximately the same impacts on the forest on a per capita basis, and that the Bosawas boundary may have slowed for a time, but did not stop, the advance of the agricultural frontier.

INTRODUCTION

What's in a Title?

On May 24th, 2005, the Nicaraguan government awarded land titles to the territorial claims of five "ethnic" territories containing 86 indigenous Miskitu and Mayangna communities that either live entirely within Nicaragua's BOSAWAS International Biosphere Reserve or who dwell outside, but use important resources in the reserve. The indigenous struggle to gain title to the land has been going on for generations (Stocks 1996, 2000, 2003), but was given a sharp forward assist with documentation and mapping of the land claims (Stocks 2003) and especially the establishment of Law 445 in Nicaragua which provided a framework for territorial legalization (Stocks 2005). BOSAWAS is a biosphere reserve administered by Nicaragua's Ministry of Natural Resources and Environment. Because of this arrangement, the state, while giving the indigenous territories full rights over their agricultural lands and the lands necessary to their hunting and gathering activities, has agreed to a legal arrangement of co-dominion over certain other lands in which neither the indigenous territories nor the state can act independently. These areas were formally identified and zoned as conservation areas by the indigenous residents a decade ago, and they involve virtually all the highlands of the Isabelía Mountain Range, a Mayangna refuge for centuries. Thus, for better or for worse, the state and the six indigenous territories are partners in conservation.

From our perspective, it seems that an important area of biodiversity has a chance to survive because critical jurisdictional issues have been clarified with the titling process. The indigenous people are now fully empowered to defend their forest homeland from encroaching colonists. The parts of BOSAWAS occupied and defended by indigenous people are mostly forest covered; fauna thought for many years to be extinct north of Panama, notably the harpy eagle (*Harpia harpyja)* and the great hairy anteater (*Myrmecophaga tridactyla)* are found there. The indigenous ecological "footprint" is light. We do not believe that this conservation outcome is the result of low population density or lack of market connections. Rather—as this article will attempt to show—it is an artifact of well-established cultural patterns exhibited in residence patterns associated with close kinship and communal land tenure which lead to certain agricultural practices, particularly with regard to the treatment of cattle. This pattern diverges significantly from the patterns of mestizo colonists and with quite different effects on the forests of BOSAWAS.

Aside from the issue of culture and its relation to forest preservation in general, this article also discusses a more immediate and practical issue, whether the indigenous people of BOSAWAS can maintain a defense of the forest in the face of the powerfully developing agricultural frontier. We think they can and will show that they have done so. We would argue that participatory processes 10 years ago that were involved in territorial mapping, self study, zoning, the formation of territorial stewardship institutions and management planning created enough social capital[1] that the claims were defended "as if" they were indigenous property. The results shown in the analyses of satellite images which form the

[1] The term 'social capital' has been around since the 1980s (Portes 1999), and the literature since 2000 has been extensive. Social capital may be defined as a value inhering in groups that is augmented through increased social solidarity. In this case, we will use the term to refer to the value of a land ideology that has enabled a strong defense of forest resources (e.g., Katz 2000; McCay & Jentoft 1998).

center of this paper argue against the thrust of one strain of conservation ideology which has moved away from considering indigenous people as appropriate conservation partners and has placed more weight on parks without people administered by states. We will show that the state, in this case, has not been effective in protecting the flora and fauna of BOSAWAS and that indigenous people have been successful, at least for the present.

Clumsy Lovers

For the past 17 years the relationship between the 4th world indigenous people in the neotropical forests and tropical conservationists[2] has resembled an elaborate peasant ländler between married partners who continually step on each others' toes. From the 1989 call by the Coordinating Body of Indigenous Organizations of the Amazon Basin (COICA 1990) for collaboration between conservationists and indigenous Amazonians, something seems to have gone awry. Chapin's recent (2004) critique of the "BINGOs" (Big International NGOs) for pursuing mere lucre and turning their backs on indigenous people draws recent attention to this malaise and a recent article in *Orion* magazine on indigenous people excluded from national parks (Dowie 2005) adds substantially to the critique. The relationship seemed promising enough at first, at least to anthropologists (e.g.,Colchester 1994; Stevens 1997; Wilcox and Duin 1995.), and it is not only a logical partnership, but a seemingly necessary one; the great majority of tropical forest lands left outside of existing parks and protected areas in Latin America is occupied or used by indigenous peoples

[2] This term is not meant to be insulting or diminishing. After many years of interacting with conservation organizations, I fully realize that there is a range of opinion within that very large community of interest. However, there is a clear majority within the community who think of conservation as an issue of protecting biodiversity from people as the 3rd edition of Groom et al.'s (2005) conservation biology text makes clear. One chapter in 18 mentions working with local people and nowhere does the book contemplate indigenous people as owners of the land to be conserved..

whose “green” rhetoric (conservation ideology) is as fiercely protective of forest resources as the most extreme proponents of parks without people (e.g., Terborgh 1999).

All during the 1990s there was a growing sense of unease among conservationists and some anthropologists about the whether indigenous conservation rhetoric was accompanied by a commitment to conservation behavior (Redford 1991; Redford & Stearman 1993). This unease and much of the literature regarding it is well-captured in the October 2000 issue of Conservation Biology where those arguing for conservation alliances with indigenous people and those pointing to the dangers for conservation inherent in inhabited protected areas or indigenous territories exchanged views in a forum (Chicchón 2000; Colchester 2000; Redford & Sanderson 2000; Schwartzman, Moiera & Nepstad 2000; Schwartzman, Nepstad & Moiera 2000; Terborgh 2000).

Clearly, there is reason on both sides of the issue. Dassman’s (1975, 1976) “ecosystem people” clearly have different dynamics in their relationships with land and resources than the average Bronx resident. On the other hand, we know that native populations who encounter resource windfalls with which they have not co-evolved tend to annihilate them before cultural correctives can be evolved. We take this to be the underlying dynamic of the post-Pleistocene faunal history of the New World (Krech 1999). We also know that markets, monetarization and commodification have had impacts on many people’s relationships with the resources. As Jared Diamond (2004) recently reminded us, we have surely known of many self-regulating societies that are adaptive success stories over immense periods of time. We also know of societies that fail to adapt to changes in population, natural resource availability, climate, trade, and bellicose neighbors. What we observe in the world today is a function of the complex interactions between humans and habitats.

It is our perception that the ideological project questioning the notion of working with indigenous partners in conservation and advocating states as partners may have resulted in a dumbing-down of conservation practice. As a recent survey of conservation strategies points out, the organizations now know a great deal about <u>what</u> biodiversity should be conserved and <u>where</u> it is located, but less and less about <u>how</u> to go about conserving it (Redford et al. 2003). One of the inputs that is needed in order to assess the wisdom of working with indigenous partners is a body of case studies of indigenous conservation that measures impacts in an objective and quantitative way. The BOSAWAS International Biosphere Reserve in Nicaragua presents an opportunity to compare indigenous and mestizo colonist "footprints" in the same forest and to compare the relative ability of indigenous territories and the state to defend the forest.

BOSAWAS as a Test Case – Some Background

Located in North-Central Nicaragua, the BOSAWAS Biosphere Reserve with its ~7,500 km^2 core zone centered on the remote Isabelía Mountain Range, covers about 7% of Nicaragua. It was the staging ground for much of the Contra War, in which the United States clandestinely supported military operations against the state of Nicaragua by opponents (Contras) of the Sandinista regime. The Miskitu and Mayangna (Sumo) indigenous population of the BOSAWAS region, concentrated on the Coco River and its tributaries, either fled from the Sandinista army to Honduras where many of them were drafted into the ranks of indigenous Contras as a condition of their stay, or were removed by the Sandinista government to inland sites away from the frontier with Honduras and out of the BOSAWAS area. For 11 years, few inhabited the reserve except for Contra and Sandinista patrols, and small military posts, while abandoned pastures in the southern parts grew forests. In 1990, after nearly 10 years of war, the Sandinistas lost an election to the party of Violeta Chamorro; logging and mining companies that had been frozen out by the Sandinista government's emphasis on sustainable resource management and strong disincentives to private industry immediately began pressuring the government for logging and mining concessions. The north-central part of the country where Nicaraguan gold-mining and mahogany production had been located before the war was a prime target. In an effort to stave off the imminent destruction of the forest, Jaime Incer, a Nicaraguan naturalist, then director of the Institute for Natural Resource Management, convinced the Chamorro government to emit a decree creating the BOSAWAS Natural Reserve in 1991. In 1997, the reserve became a UNESCO international biosphere reserve.

The 1991 decree coincided with a number of population movements. One was the return from internal or external exile of the indigenous people to their communities in the northern part of the reserve along the Coco, Waspuk, Bocay, and Lakus Rivers. The other was the government response to the demands of ex-Contra and ex-Sandinista combatants for land. The government solution was to place the ex-combatant mestizo groups in different so-called "development poles" located on the southern boundary of the BOSAWAS Reserve. Invasions of the reserve by mestizo colonists began immediately (Kaimowitz & Fauné 2003).

A study of the mestizo population in 1997 (The Nature Conservancy 1997f) revealed that 99.5% of the colonists were from western Nicaragua or born in Honduras of parents from western Nicaragua. Fifty nine percent of them were from the Jinotega department and had simply moved north to the BOSAWAS area as land became scarce in Jinotega and as family members formerly connected with Contra forces settled in the reserve. Whereas in 1990 the area of the reserve held 167 mestizo families, by 1996 there were 1,977 colonist families, ~10,000 people (Table 1). By contrast, the indigenous residents of BOSAWAS numbered ~12,500 by then. However, the colonist population was growing by 17% each year until 1998 through immigration while the indigenous population only increased through natural fertility (Table 2). The indigenous population is, from records on birthplace, nearly entirely from the BOSAWAS Reserve area originally. Many of the younger people were born in Honduras or Nicaraguan refugee areas in the 1980s, but their parents were from the BOSAWAS area and they returned to it in 1991.

Table 1
Mestizo Migration into BOSAWAS in 5-year Increments
(The Nature Conservancy 1997f)

Period	Mestizo New Families in the Reserve	% of Total Mestizo Families Currently in the Reserve	Mean # of Families Migrating Into the Reserve Each Year
Before 1965	5	0.25	1.0
1966-70	33	1.67	6.6
1971-75	71	3.59	14.2
1976-1980	191	9.66	38.2
1981-1985	167	8.45	33.4
1986-1990	164	8.30	32.8

1991-1996	1346	68.08	224.3
Total	1977	100.00	

Between 1994 and 1998, the indigenous residents of the northern and eastern areas of BOSAWAS, in an effort to halt the invasions of their historic lands, mapped and documented their territorial watershed-level land claims with the assistance of The Nature Conservancy (Stocks 1996, 2003, Stocks et al. 2000). The boundaries of the territories that abutted the colonist invasions of BOSAWAS were physically demarcated. An effort was made to train and field indigenous forest rangers by both government and non-governmental organizations (NGOs), and that effort has continued sporadically until the present under various short-term funding mechanisms and sometimes with no funding whatever. The Nature Conservancy, particularly, continued its interest in BOSAWAS and some forest ranger patrolling has been funded under the Parks in Peril program between 2002 and the present, funded by USAID. Despite setbacks, the indigenous territories have continued to defend their demarcations through patrolling and information dissemination.

Indigenous Farmers and Colonist Farmers

By 1998, the population of colonists in the reserve was approximately equal to the population of indigenous people (Table 2). After 1998, there were no new lands to invade except within the demarcated territories; they were being patrolled by indigenous forest rangers and the invasion slowed.

Table 2[3]

[3] The population of Li Lamni Tasbaika Kum (~9,000 in 1998) does not live within the reserve and generally does not farm there either. Although part of their territory lies in the reserve, it is mainly used for hunting or

Population, Settlements, and Settlement Size

(Projected from The Nature Conservancy 1997 a,b,c,d,e,f)

Ethnic Group	Projected 1998 Population	# of Settlements	Average Size
Mestizo	12,248*	33	371
Miskitu	7,147**	19	351
Mayangna	6,029**	23	245
Total	25,424	75	339

* 17% annual growth counting natural fertility and immigration.

**3.5% growth counting natural fertility only

Because the populations of mestizos and indigenous people have remained at a rough parity until today, both growing through natural fertility, but not significantly through immigration, the reserve now presents a rare opportunity to compare the overall impact on forest cover of a population of mestizo farmers and a population of indigenous farmers.

While neither group enjoys road access to markets and they have similar educational levels, there are significant differences between the two groups in settlement patterns, agricultural practice and long-term livelihood strategy (Stocks 1998; The Nature Conservancy 1997 a,b,c,d,e,f). Mestizo settlers tend to live on their scattered individual parcels and stoutly defend the notion of private property. Indigenous residents tend to group together in communities where each family uses land under a common property regime. Areas of work are within a couple of hours of the settlement, but indigenous people do not live in their work areas, except for brief periods of intensive labor. This

constitutes an indigenous protected area. Thus this territory is not included in the table which only analyzes populations who live within the reserve.

settlement pattern means that the forests away from rivers under mestizo occupation can be predicted to be more fragmented than forests under indigenous occupation. The second major difference is that mestizo settlers affect land in a cycle that begins with annual crops and ends in pasture, while indigenous farmers cycle from crop to fallow and back every 5-7 years on the same piece of land. Cattle are raised by both groups, but indigenous people pasture the cattle in the community itself while mestizo settlers raise cattle on their parcels if they can afford them. Many cannot, and merely clear forest for pasture in the hope of a future sale to a better-off settler, a livelihood strategy quite different from indigenous residents who view their occupation as permanent. The inevitable result of forest conversion into pasture is the destruction of large amounts of forest.

Themes and Hypotheses

Given the similar population sizes but documented strong differences in culture between mestizo settlers and indigenous residents of the reserve in terms of agricultural practice, notions about land tenure, and livelihood strategy, we decided to analyze satellite data on forest cover for three separate time periods: 1) 1987 during the Contra War when much of the forest affected by earlier colonization had returned to tall secondary forest; 2) 1995/1996 when the critical demarcations were made that separated areas of indigenous claims from the areas settled by mestizo colonists; 3) 2001/2002 when the resulting separation of claims had been in existence for seven years and indigenous people might be expected to defend their claims. The areas studied (the polygons) are the following (See Figure 1 and Table 3):

1. Land cover change in five indigenous territories, Mayangna territories of

Mayangna Sauni As, Mayangna Sauni Bu, and Sikilta (a.k.a Mayangna Sauni Bas), and Miskitu territories of Miskitu Indian Tasbaika Kum, and Kipla Sait Tasbaika. These are respectively referred to by their acronyms MSA, MSB, SIK, MITK, and KST.

2. Land cover change in the original Saslaya National Park polygon.
3. Land cover change in a mestizo polygon derived by subtracting all lands within BOSAWAS south of the border formed by MITK, MSB, and SIK and excluding Saslaya National Park.
4. Land cover change in a two-kilometer strip north of the southern boundaries of MITK, MSB, and SIK, versus a two-kilometer strip south of the same boundary.
5. Forest connectivity in a representative polygon from mestizo and from indigenous forests in BOSAWAS with approximately equal amounts of deforestation.
6. Current vegetative cover for each indigenous territory vs. vegetative cover for the mestizo polygon.

Table 3

Territories and Populations in the Study Area

Territory	Primary ethnicity	Population and year of census	Est. Pop. 1995*	Est. Pop. 1996*	Est. Pop. 2002*	Official area (km^2)	GIS-defined area (km^2)
Mayangna Sauni As (MSA)	Mayangna	3,405 (94)	3,524	3,648	4,641	1,635.47	1,542.44
Mayangna Sauni Bu (MSB)	Mayangna	1,886 (95)	1,886	1,952	2,400	1,032.04	1,030.74
Mayangna Sauni Bas aka Sikilta (SIK)	Mayangna	338 (95)	338	350	430	405.66	403.11
Miskitu Indian Tasbaika Kum (MITK)	Miskitu	3,454 (95)	3,454	3,575	4,394	690.55	694.99
Kipla Sait Tasbaika (KST)	Miskitu†	3,431 (96)	3,311	3,431	4,070	1,136.32	1,141.15
Total Mayangna			5,748	5,950	7,471	3,073.17	2,796.28
Total Miskitu			6,765	7,006	8,464	1,826.87	1,836.03
Total indigenous in Bosawas			12,513	12,956	15,935	4,900.04	4,812.32
Mestizo Area		9,079 (96)	8,761	9,079	14,261‡	2170.5	2,170.50
Grand total Bosawas			21,184	22,035	30,196	7070.54§	6982.82
Li Lamni Territory‖	Miskitu	9103 (98)	8,180		10,446		1379.9

* Assumes 3.5%/year growth in indigenous territories and 17%/year in mestizo areas.

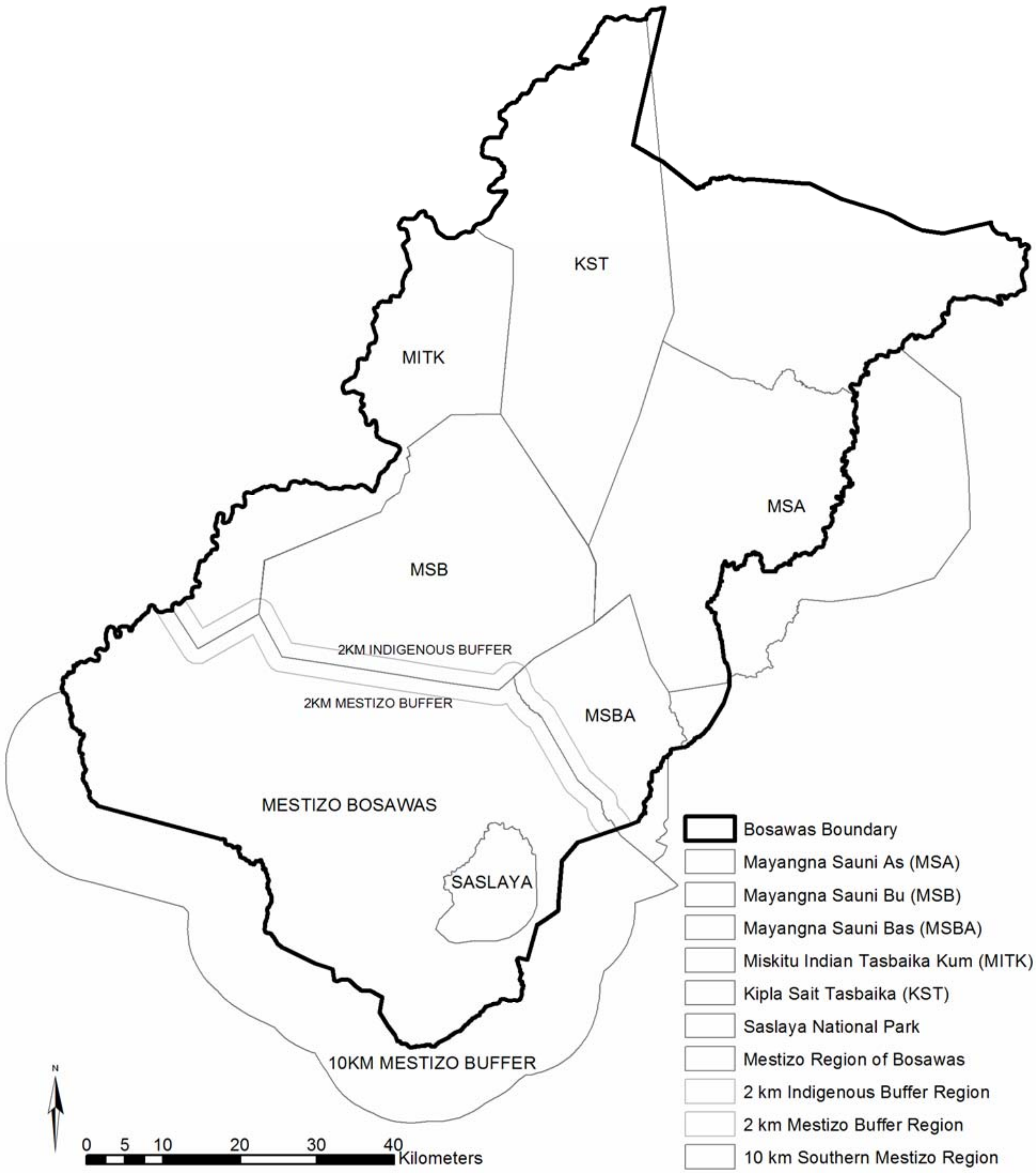
† 6% of the population is Mayangna

‡ Assumes documented 17% growth rate until 1998 and then 3.5% thereafter. There was no more free land outside the indigenous territories.

§ This area is different from the ~7500 km2 Bosawas "nuclear" area because several indigenous territories have land both inside and outside the formal Bosawas boundary, because the territory of Li Lamni Tasbaika Kum is not included in the analysis, and be

‖Li Lamni was not included in the published study because the population does not live in the Bosawas Reserve

Figure 1
Polygons Used in the Analysis



The study tests five hypotheses: 1) Areas under indigenous management have halted or slowed the advance of the agricultural frontier; 2) Areas under indigenous management have a better outcome in terms of net forest loss per capita than areas under colonist management; 3) Areas under indigenous management have a better outcome in terms of forest connectivity than areas under colonist management; 4) Within the areas of indigenous forest management, Mayangna tend to deforest less per capita than Miskitu; 5) The BOSAWAS boundary itself has affected the advance of the agricultural frontier.

METHODS

Imagery Used

We conducted land cover change and vegetation classification analyses using two Landsat scenes (path 16, rows 50 and 51) which cover the BOSAWAS reserve for the dates relevant to our hypotheses (Landsat TM5 imagery was used for 1987 and 1995/96, and Landsat ETM7+ imagery was used for 2001/02). We used imagery acquired during the wet winter season to ensure the least possible phenological variation, and in instances where suitably cloud-free imagery was not available for the same date for both scenes, the nearest possible image date was used. In cases where cloud contamination obscured portions of our study area, we used supervised classifications and hand digitization to create masked cloud regions which were excluded from our final analyses (Lillesand and Kiefer 2000). .

Land Cover Change (LCC) Methods

In order to best quantify widespread deforestation and forest-conversion, we explored a number of vegetation indices to identify and measure regions of substantial net vegetation loss, this being the primary type of land cover change relevant to our project hypotheses. Preliminary comparisons between the Normalized Differenced Vegetation Index (NDVI), the Normalized Burn Ratio (NBR), and other commonly used vegetation indices (e.g. SAVI, DVI, etc.) in regions of known land cover change (LCC), showed the NBR to be more sensitive and accurate in identifying these change regions, and we determined that the NBR also provided a clear delineation of the large agricultural patches visible in the imagery, and all subsequent land-cover change analyses were performed using the NBR index The NBR was originally developed as an alternative to the NDVI to identify regions of vegetation loss following fire (Key and Benson 2004). However, it also proves useful in identifying regions of net vegetation loss (i.e. primary rainforest loss via logging or conversion to agriculture or pasture lands). The formula for the NBR using Landsat TM data is as follows:

Near Infrared (B4) – Middle Infrared (B7) / Near Infrared (B4) + Middle Infrared (B7)

The NBR output consists of a range of values between -1 to 1, with values approaching -1 representing regions of maximum vegetation loss, and values approaching 1 representing regions of maximum vegetation cover and density. In our analyses the typical range of values was from ~ 0.2 (maximum disturbance or vegetation loss) to ~ 0.8 (maximum vegetation).

The natural land-cover regime in northern Nicaragua and in and around the BOSAWAS reserve is moist subtropical rainforest, consisting of a wide variety of species, little to no visible bare ground (in terms of the imaging capacity of space-borne multispectral satellite systems), and a canopy height ranging from ~10-30 meters. The NBR value for regions of intact primary (old growth) forest systematically exceeded ~0.65, and we determined that areas with NBR values below a given threshold demonstrated some type of disturbance that resulted in a net vegetation loss for the area in question (e.g. agricultural conversion, logging, fire, etc.). while the exact numeric threshold varied between images; this general schema facilitated a coarse classification into "disturbed" and "intact primary forest" classes. To this end, we converted reclassified NBR images into binary grids of change and no-change using a threshold based on the NBR values of known primary forest regions and visually apparent or known regions of cultural disturbance for each image. We mosaicked the north (row 50) and south (row 51) scenes for each temporal period into a single binary grid, converted these grids into ArcINFO coverages and clipped them using the extents of each of the indigenous territories (MSA, MSB, SIK, MITK, and KST), the boundary of Saslaya National Park, the mestizo colonist region of BOSAWAS, the 2km buffer regions along the mestizo/indigenous border running east/west in BOSAWAS along the southern MITK-MSB-MSBA boundaries, and the buffer region that runs along the southern border of BOSAWAS. We calculated land cover change area as a percentage of the total cloud free area and used the total area of the region to determine the projected total (km^2) of disturbed/deforested area in each region. We then used chi-square goodness of fit tests to determine if per capita deforestation (hectares) in indigenous controlled regions was significantly different from per capita deforestation in mestizo-controlled regions. In doing so, we treated the proportions of intact/disturbed forest in the indigenous region as a expected ratio compared to observed proportions of intact/disturbed forest in the mestizo regions.

To determine the significance of the differences in NBR values between indigenous and mestizo controlled regions in and around the BOSAWAS reserve, we generated equal numbers of random points in each of the indigenous territories, the mestizo region of

BOSAWAS, and the mestizo buffer region south of BOSAWAS (*n* = 500 per territory). We then compared the NBR values at each of the sample points for the time period when the indigenous demarcations were established (1995/96) and the time period after which these demarcations could be assumed to be protected by the indigenous groups (2002/02). Using SPSS statistical software, we performed independent samples t-tests to compare the mean NBR values of indigenous versus mestizo controlled regions, one-way ANOVAs with LSD post-hoc comparisons to compare the mean NBR values of Mayangna, Miskitu, and mestizo-controlled regions, and an independent samples t-test to compare the mean NBR values of the 2 km buffer regions north and south of the border within BOSAWAS created by MITK-MSB-MSBA.

The cloud contamination in the imagery made it difficult to quantify forest connectivity and fragmentation for entire territories, as the boundaries of cloud masks would substantially increase the edge: area ratios in otherwise intact forest regions. Instead, we established two approximately equal area polygons in cloud free regions with what we had observed to be typical patterns of disturbance, one within the mestizo-inhabited region of BOSAWAS and one within the indigenous territory of MSA, with which we could compare the relative connectivity of intact forest for the most recent time period (2001/02) between mestizo and indigenous regions. We calculated the average patch size of intact forest polygons and the average area-to-perimeter ratio for the two regions.

Field Data Collection and Supervised Classification (SUP)

We used field data collected during summer 2004 in the construction and validation of the vegetation classification model. These data were collected in the countryside surrounding the city of Siuna and the community of San Jose de Bocay, in the area of overlap between the 2001 (southern) and 2002 (northern) scenes. We recorded positional information, attribute data regarding land-cover class and approximate patch size and homogeneity, and ethnographic notes concerning land-cover species composition and typical crop-rotation cycles.

In the field, we decided on a seven-category classification scheme, based on the relative non-visibility of bare soil and observable species composition and canopy height. We established these seven classes based on similar classifications used in previous analyses (2), ethnographic information obtained before and during field data collection, and the relative spectral dissimilarity of the classes. The classes were primary forest, secondary forest, *guamil* (a term for agricultural plots that are left fallow and eventually return to secondary and then primary forest status), pasture, monoculture agricultural plots of staple crops (i.e. rice, beans, or corn), rivers, and settlements. We either recorded all field data as points in the center of homogenous patches of a given class, or as transects along homogenous patches which we later used to digitize individual points inside homogenous plots visible in unsupervised classifications of the imagery.

We used the 2004 sample points and transects as training data to generate maximum likelihood supervised classifications for the 2001 southern (n = 373) and 2002 northern (n = 372) scenes. Additionally, we held back a test subset of sample points (n = 201) for use in validation and assessing the accuracy of our classification. We mosaicked the north and south classifications and calculated the relative proportion of each vegetation class for each of the indigenous territories (MSA, MSB, MSBA/SIK, MITK, and KST), Saslaya national park, the mestizo region of BOSAWAS, and the buffer region that runs along the southern border of BOSAWAS. We also used a 2x2 chi-squared analysis to gauge whether the proportion of regions classified as intact primary forest was significantly different in indigenous vs. mestizo controlled regions of BOSAWAS in the same manner as discussed for the LCC analyses.

RESULTS

Hypothesis 1: **Areas under indigenous management have a better outcome in terms of net forest loss per capita than areas under colonist management**

Regions in the BOSAWAS reserve under indigenous management have shown great resiliency against net vegetation loss and primary forest fragmentation associated with agricultural/pastoral conversion, settlement, and logging when compared to the mestizo inhabited portion of the BOSAWAS reserve (Table 4). Over the 15 years covered by the satellite images, the indigenous people show 0.24 hectares/capita of deforestation in 1995 and 0.15 hectares/capita in 2002. In contrast, the mestizo per capita figure rose from 1.65 hectares/capita in 1995 to 2.50 hectares/capita as pastures have expanded, over 16 times the indigenous ratio. The chi-square goodness of fit analyses for the two later periods for both 1995/96 [$X^2(1, N=6358)=17.17$, $p < 0.0001$], and the 2001/02 [$X^2(1, N=5699)=399.51$, $p < 0.0001$] demonstrated significant increases in per capita deforestation in mestizo regions compared to the expected proportions of deforestation in the indigenous regions. Compared to the control/standard of the indigenous regions, the increased proportion of disturbed forest in mestizo regions was statistically significant. The results of the t-tests demonstrated significant increased mean NBR values in indigenous controlled regions of BOSAWAS compared to the mestizo regions of

BOSAWAS for both 1995/96 ($\alpha = 0.05$, $p < 0.0001$, mean difference = 0.073) and 2001/02 ($\alpha = 0.05$, $p < 0.0001$, mean difference = 0.0670).

Table 4

Deforestation in and around Bosawas reserve

by territory: 1987, 1995/96, and 2001/02

Territory	1987	1995/96		2001/02	
	Deforested (km2)	Deforested (km2)	Deforestation per capita (has)	Deforested (km2)	Deforestation per capita (has)
Mayangna Sauni As (MSA)	0.29	3.76	0.11	4.83	0.1
Mayangna Sauni Bu (MSB)	0.35	5.62	0.3	4.98	0.21
Mayangna Sauni Bas aka Sikilta (SIK)	0.21	2.7	0.8	3.03	0.7
Miskitu Indian Tasbaika Kum (MITK)	1.26	9.52	0.28	7.77	0.18
Kipla Sait Tasbaika (KST)	1.51	9.69	0.29	3.64	0.09
Total Mayangna	0.84	11.98	0.21	12.25	0.16
Total Miskitu	2.78	18.8	0.28	11.5	0.14
Total Indigenous	3.62	30.45	0.24	24.19	0.15
Mestizo area Bosawas	17.09	144.44	1.65	356.98	2.5
Total Bosawas	20.71	174.89		381.17	
Li Lamni Territory	2.85	13.66	0.167	20.88	0.2
External Mestizo 10km Buffer Region	97.22	183.77	n/a	357.19	n/a
2km Buffer - Indigenous	0.11	1.61	n/a	3.62	n/a
2km Buffer - Mestizo	0.08	3	n/a	10.18	n/a

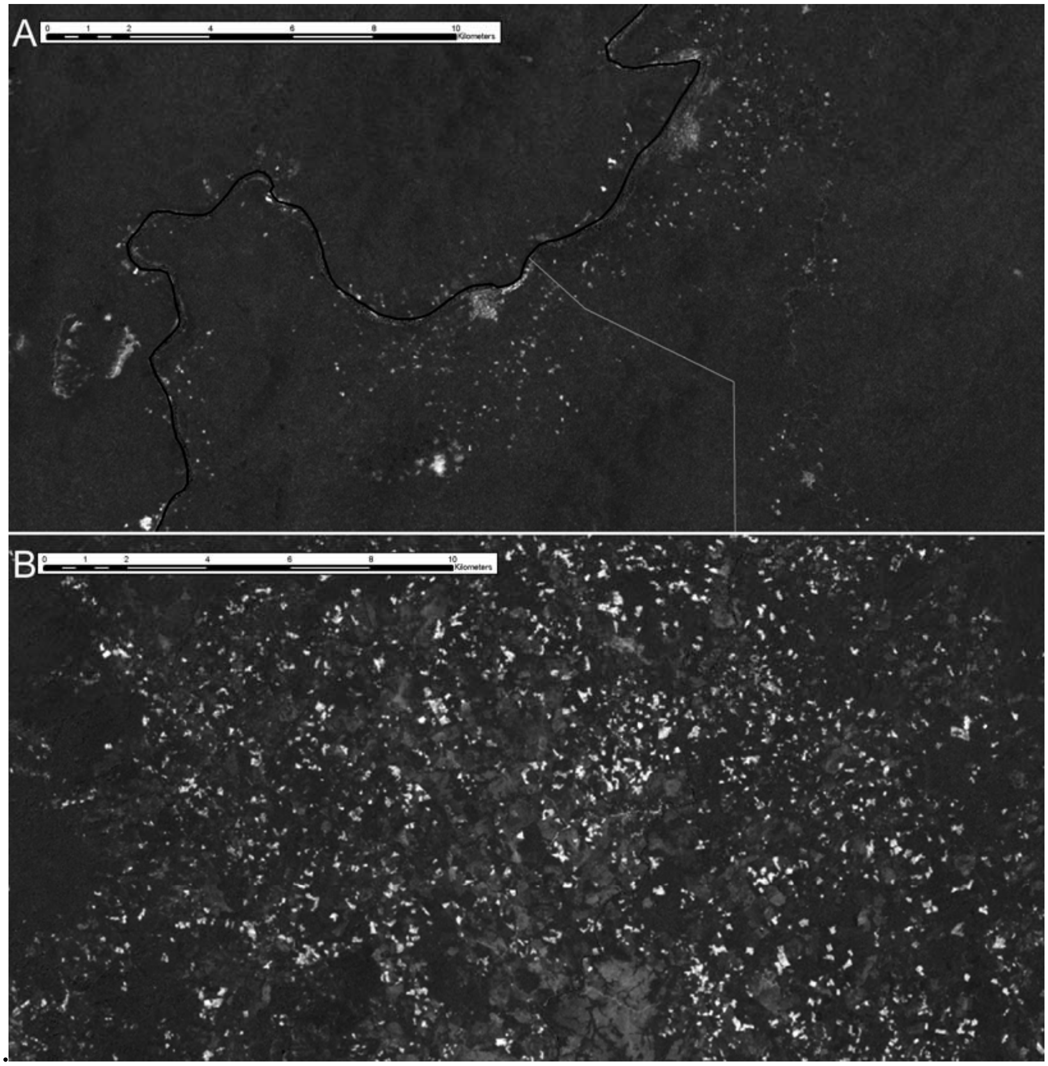
Hypothesis 2: Areas under indigenous management have a better outcome in terms of forest connectivity than areas under mestizo settler management

With regard to forest connectivity, the different settlement patterns and livelihood strategies result in very different patterns of disturbance. Figure 2a below shows the visual pattern of minor forest conversion and fragmentation in the indigenous region of BOSAWAS in the MITK and KIP territories, where the settlement-deforestation pattern appears to be confined to small community areas and severely limited in both its scope and intensity. There are well over 3,000 people living in the area of the image south of the Coco River. It includes the towns of Raití and Walakitán. Contrast this to figure 2b in the mestizo region in and south of BOSAWAS, where the parcel shaped polygons represent net vegetation loss, bright white being recent or substantial net vegetation loss ranging to the muted grey of older or less substantial net vegetation loss. There are fewer people in this image, but much larger parcel sizes. Parcels are spread over the landscape.

Quantitatively, the region under indigenous management had a mean intact forest patch size of 5.627 km^2 and a mean area: perimeter ratio of 146.2 while the sample region under mestizo settler management had a mean intact forest patch size of 0.045 km^2 and a mean area: perimeter ratio of 9.0. Results of the chi-square goodness of fit test further corroborated the significance of the difference between the area: perimeter ratios ($X^2(N=724)=12.86$, $p<0.001$). Visually these patterns are also quite apparent. The distribution of intact and undisturbed primary forest demonstrated by both the land cover change and vegetation classification analyses indicate the effect that the indigenous demarcation has had on stemming the losses of intact forest to agricultural conversion, settlement, and logging.

Figure 2

Indigenous (A) vs. mestizo (B) patterns of land conversion. Note larger patch size and widespread land conversion in the mestizo region compared to the relatively small scale and extent of land conversion in the indigenous area. Scale bar includes a total of 10 kilometers, with 2 kilometer division marks.



Hypothesis 3: Indigenous people are able to significantly halt or slow the advance of the agricultural frontier without violence through their own efforts if they are empowered to do so.

The analysis of a 2 km buffer zone within indigenous demarcation lines compared to a 2 km buffer south of the same lines in the mestizo area demonstrates significant differences in levels of disturbance of forest cover. The 2 km buffer region within the indigenous territories experienced proportionally less cumulative land cover change (0.09% in 1987, 1.0% in 1995/96, and 2.3% in 2001/02) than the 2 km buffer region within the mestizo occupied region (0.06% in 1987, 2.0% in 1995/96, and 6.7% in 2001/02), and the results of the t-test show the 2 km buffer region within the indigenous controlled area to have a significantly higher NBR value compared to the 2 km buffer region within the mestizo controlled region ($\alpha = 0.05$, $p < 0.0001$, mean difference = 0.0154).

Hypothesis 4: The Mayangna tend to deforest less per capita than Miskitu

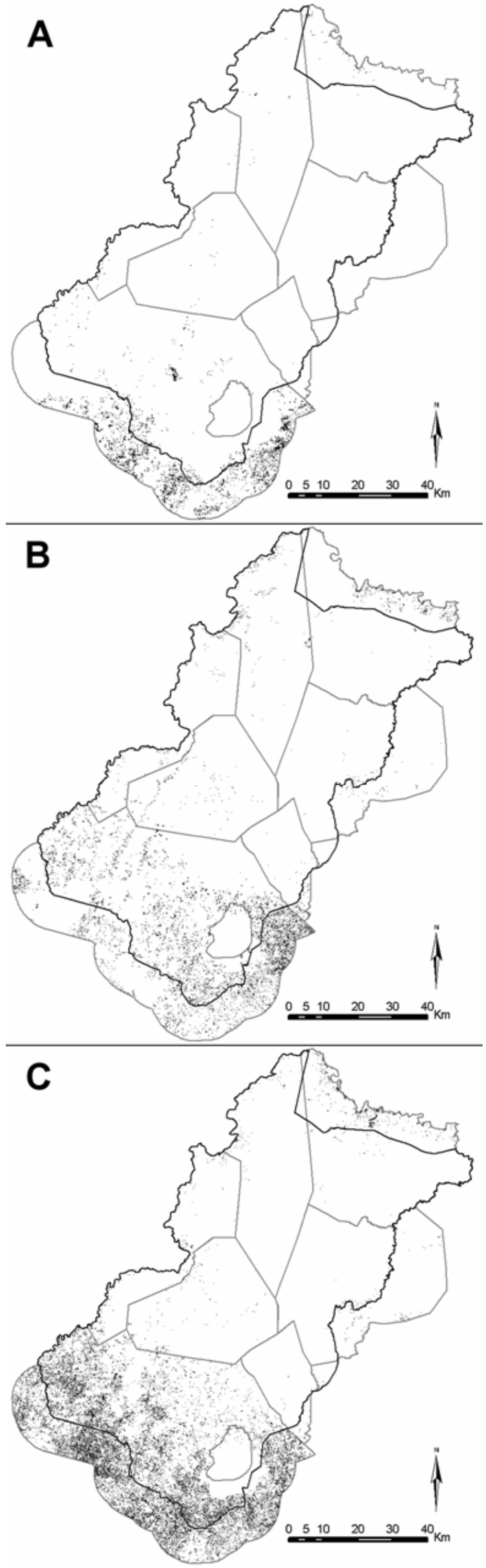
Taken only as a percentage of the territorial area deforested, the proportion of disturbed areas was higher in Miskitu controlled regions compared to the corresponding Mayangna controlled region, and the results of the ANOVA showed the Mayangna controlled regions had a slightly higher mean NBR value compared to the Miskitu controlled regions ($\alpha = 0.05$, $p < 0.005$, mean difference = 0.0087), and significantly higher mean NBR value compared to mestizo-controlled regions ($\alpha = 0.05$, $p < 0.0005$, mean difference = 0.0764) during the 1995/96 period. It should also be noted that the ANOVA showed the Miskitu controlled regions also had a mean NBR that was significantly higher than that of the mestizo controlled regions ($\alpha = 0.05$, $p < 0.0005$, mean difference = 0.0678). These patterns persist during the 2001/02 time period as the mean NBR value for Mayangna regions was significantly higher than both Miskitu ($\alpha = 0.05$, $p < 0.0001$, mean difference = 0.0083) and mestizo regions ($\alpha = 0.05$, $p < 0.0001$, mean difference = 0.0710). However, when deforestation amounts are converted to per capita to account for population differences, results of chi-square goodness of fit tests for both the 1995/96 [$X^2(1,N=6358)=0.28$, $p=0.591$] and 2002 [$X^2(1,N=5699)=0.01$, $p=0.929$] time periods do not indicate any significant differences. The hypothesis is not supported.

Hypothesis 5: The BOSAWAS boundary itself has halted or slowed the advance of the agricultural frontier.

The effect of the demarcation of the BOSAWAS boundary is demonstrated when we compare cultural disturbance in the in the first 10 kilometers of the mestizo-inhabited buffer region south of the BOSAWAS reserve, with proportions of disturbance increasing from 9.1% in 1987, 14.4% in 1995/96, and 28.0% in 2001/02 vs. the above-mentioned disturbances in the mestizo area of BOSAWAS of ~2.5%, ~6.6%, and ~16.4% in the same time periods. This area enjoys neither the protections of the indigenous populations or the boundary of the BOSAWAS reserve, and as such has the most dramatic increases in proportion of disturbed and fragmented forest areas (Figure 3).

An interesting aspect of the function served by the BOSAWAS border is demonstrated in the statistical analyses of the NBR values in the mestizo controlled region of BOSAWAS compared to the 10 km buffer region south of the southern BOSAWAS border, which is also mestizo-controlled. In the middle time period (1995/96), after mestizo settlers had a substantial amount of time following the contra war to establish themselves within and around the BOSAWAS region, there was a significant difference in the mean NBR value between the mestizo controlled region within BOSAWAS and the 10

Figure 3
Land cover change polygons in 1987 (A), 1995/96 (B), and 2001/02 (C)



kilometer buffer region south of BOSAWAS ($\alpha = 0.05$, $p = 0.005$, mean difference 0.0342). During the late period (2001/02), these two regions appear to have reached some degree of stasis, as the difference between the regions is not statistically significant, although it is close ($\alpha = 0.05$, $p = 0.056$, mean difference = 0.0153). The hypothesis that the boundary has been effective in halting or slowing the advance of the agricultural frontier is not supported, although it took over 5 years for the lands in the southern part of the reserve to begin to resemble the lands to the south of the boundary (see also Figure 2, Table 4).

Supervised Classification Results (Current Land Use or Vegetative Cover)

Initially, the supervised classifications were completed using the seven-class schema listed previously in the methods section. However, after consideration of the resolution of the imagery being used (25m^2 pixels) and the spectral similarity of two pairs of the classes (secondary forest/guamil and agriculture/pasture) we decided to aggregate the pairs of similar classes into single classes, resulting in the five following classes: primary forest, secondary forest/guamil, agriculture/pasture, rivers, and settlements. We feel that this simplified vegetation classification schema better represents the biological diversity of the region within the technological and operational limitations of the satellite platform and image analysis software. The resulting five-class maximum likelihood supervised classification had an overall accuracy of 86.07% with a kappa statistic of 0.823 (Table 5) (compared to 76.1%, kappa = 0.709 for the seven class schema).[4]

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[4] A note is justified on the accuracy and specificity of the maximum likelihood supervised classification. The model outputs of this algorithm (and indeed most classification methods) are highly dependent on the scale of the data (25m^2 pixels for our analyses), and the spectral/biological variability of the training data used to classify the imagery. The accuracy of the model outputs can thus be expected to mirror the spectral and

The proportions of the various vegetation classifications in the 2001/2002 image are shown in Table 6. These also corroborate some of the patterns described in the previous land cover change analyses. The percentage of the indigenous territories within BOSAWAS classified as primary forest was ~88%, and when the secondary forest/guamil class is included in this statistic, the proportion increases to nearly 96%. When compared to the mestizo-controlled regions of BOSAWAS, we see an overall coverage of ~85%, but only 59% of this region is classified as primary forest. When we look at the chi-square analysis of the differing proportions of intact primary forest in indigenous vs. mestizo controlled regions of BOSAWAS during the 2001/02 time period, we see a significant increase in the observed level of deforestation in the mestizo region compared to the indigenous region (expected level) [X^2=(1,N=6439)=756.2, $p < 0.0001$].

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spatial scale of the data used to create them, and in the case of moderately coarse scale multispectral satellite imagery, the patterns described by the model outputs can be interpreted as moderately coarse in their scale as well. This does not mean that the model outputs are inaccurate, rather that their accuracy is relative to the accuracy of the data used to create them. In this case, Landsat TM5 and ETM7+ can be expected to accurately describe the broad vegetative patterns of the region, and to a reasonable degree distinguish between the major vegetation types. In this sense, the proportions described by the model output should be understood as describing an estimated relative frequency of the vegetation classes rather than a strict description of the exact numerical/class values at a given spatial location.

Table 5

Error matrix* for maximum likelihood supervised classification

	Primary Forest	Rivers	Secondary Forest	Agriculture Pasture	Settlement
Unclassified	0.00%	0.00%	3.90%	10.80%	25.00%
Primary Forest	*98.40%*	0.00%	9.80%	0.00%	0.00%
Rivers	0.00%	*100.00%*	0.00%	0.00%	0.00%
Secondary Forest/Guamil	1.60%	0.00%	*78.40%*	10.80%	0.00%
Agriculture Pasture	0.00%	0.00%	7.80%	*78.40%*	0.00%
Settlement	0.00%	0.00%	0.00%	0.00%	*75.00%*

Overall Accuracy = (173/201) = 86.07%
Kappa Coefficient = 0.8217

*The columns in the error matrix represent the field data ground truth observations made in Nicaragua during the summer 2004 field season. The rows represent the predicted classes of the maximum likelihood classification model output.

Table 6

Percentage of each territory classified with supervised classification*

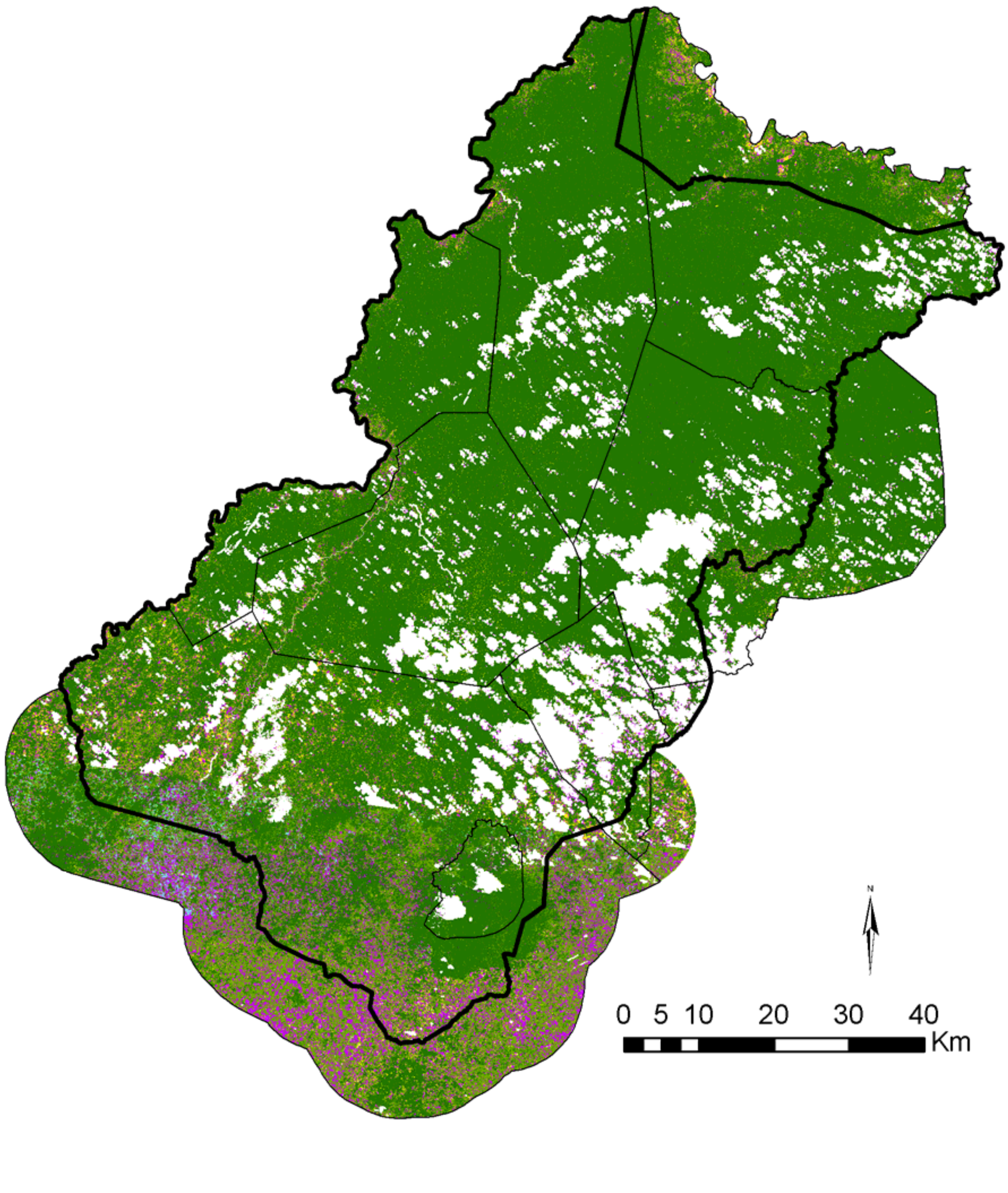
(overall accuracy = 86.07%, kappa = 0.8217, Table S5)

Territory	Primary Forest	Secondary Forest / Guamil	Agriculture / Pasture	Settlement
Mayangna Sauni As (MSA)	94.46%	4.37%	0.59%	0.59%
Mayangna Sauni Bu (MSB)	91.73%	5.97%	0.61%	1.69%
Mayangna Sauni Bas aka Sikilta (SIK)	84.41%	10.67%	2.04%	2.85%
Miskitu Indian Tasbaika Kum (MITK)	88.77%	8.49%	1.41%	1.33%
Kipla Sait Tasbaika (KST)	94.15%	4.74%	0.52%	0.60%
Total Mayangna	92.64%	5.46%	0.70%	1.18%
Total Miskitu	92.08%	6.18%	0.86%	0.88%
Total Indigenous	92.40%	5.77%	0.77%	1.06%
Saslaya National Park	87.36%	10.21%	1.93%	0.30%
Bosawas Mestizo Area	60.79%	26.20%	9.12%	2.94%
10 km Buffer Region	31.79%	43.27%	20.20%	2.65%

* The major rivers category was excluded from this table, as it accounted for a very small proportion of the area of all territories.

Figure 4

Current vegetation cover using five category supervised classification – dark green = intact primary forest, light green = secondary forest/guamil, purple = agriculture/pasture, light blue = major rivers, and yellow = settlements. Note: linear feature in lower quarter of the image is the point at which the two scenes overlap.



DISCUSSION

The results of the study clearly support three of five hypotheses tested by this method. Indigenous people have, with even sporadic assistance, been able to protect major portions of their part of the Bosawas Biosphere Reserve. However, the satellite data show troubling spots where colonist occupation seems to be building up. There is a disturbing area of new deforestation on the southern boundary of Mayangna Sauni As east of the PisPis River outside of the Bosawas boundary. This area is the point of the lance for the mestizo invasions around Cola Blanca and the upper Wawa River. This invasion threatens to deforest the upper Wawa River Basin which would have disastrous effects on the Miskito Keys fishery. The Amak River at the southern boundary of Mayangna Sauni Bu and the creeks along the southern boundary of Miskitu Indian Tasbaika Kum are also showing some “leakage” to colonists.

One of the more interesting results is that the indigenous residents of Bosawas have, over the first 12 years of their most recent residency, maintained a very low per person deforestation rate. The fact that this rate declined between 1995 and 2002 is interesting, but as yet unexplained. In terms of their relationship with forests, indigenous people maintained 95.34% of their forest cover in primary or advanced secondary forest. The category of primary forests alone amounts to 88.8%. These data, obtained by satellite analysis, confirm data taken from socioeconomic studies completed with the indigenous territories in the mid-1990s (The Nature Conservancy 1997a,b,c,d,e) in which the self-reporting on the size of farm plots and fallows of indigenous residents all over the Biosphere Reserve indicated that close to 95% of their areas remain in primary forests. At the time, there was no easy way to examine the truth of their claims, but the data from this study confirm that they are accurate reporters of their own activities.

While the indigenous residents have been protective of the primary forests, the mestizo colonists have rather steadily depleted the forests with an sharply increasing ratio of deforestation per capita as pastures are cleared and planted. In terms of vegetative cover, the mestizo polygon has only 59.1% of their area in primary forest with another 26.6 % in secondary forests and guamiles. The amount of secondary forest is somewhat surprising and remains unexplained until further fieldwork can be done. It may be that the policies of the Ministry of Environment and Natural Resources (MARENA) are working and that some mestizo colonists are actually leaving the reserve and allowing forests to take over again. MARENA, while unable to physically protect the reserve, has steadfastly refused to consider legalization of colonist tenure, to build new roads into the mestizo area, and has labored to prevent bank credit for farming or ranching from being applied in the reserve. Over the long run, these policies may prove to be effective.

The differences between indigenous residents and mestizo colonists are principally due to differences in the cultural patterns of landholding and in the longer term livelihood strategy. These differences are clearly reflected in the data from this study. The landholding pattern of private property with residence of each colonist on his or her farm combined with the livelihood strategy of land speculation results in a fragmented forest in which the raw scars of pasture spread out yearly from each farm center, eventually eliminating the forest or reducing it into small patches that cannot sustain wildlife. These patterns are clear from the steadily increasing ratio of deforested land per capita in the mestizo area and from the data on forest connectivity in mestizo and indigenous areas. On the other hand, indigenous communal land tenure with the community/work areas/ hinterland distinctions has maintained large areas of intact forest. Furthermore, this pattern is accompanied by raising cattle in communities, because they are too important to leave by themselves in work areas or in pastures away from communities.

On the basis of somewhat fragmentary evidence along the Wawa River, it was hypothesized that Miskitu farmers might be more commercially oriented than Mayangna farmers and thus tend to deforest more on a per capita basis than the Mayangna. The fact that this seems not to be true is interesting. The explanation may lie in the fact that the most valuable Miskitu cash crop is their bean crop and along the Coco River, they are very active in planting it. However, beans are planted principally in disturbed areas along the rivers that are created when the river rises during the rainy season and lowers during the dry season, leaving muddy banks on which beans are planted. The net effect probably does not show up on satellite images except as included in the category of Rivers. Additionally, some of the areas of settlement and activity in the MITK territory were obscured by clouds and were therefore excluded from(?) the analyses.

In the vegetative cover analysis, the territory of SIK (Sikilta), shows characteristics more like the mestizo area than like the other indigenous areas. This puzzling difference between Sikilta Mayangna and the other Mayangna may easily be explained when it is realized that there has been a colonist invasion for the past 20 years into Sikilta (which received an agrarian reform land title in 1986). Less than 50% of the deforestation and cropping observed can be attributed to indigenous practices.

Some may argue that the prevalence of intact forest cover in indigenous areas is not a proxy for ecological health. That the indigenous areas are able to sustain healthy animal populations is indicated by the data produced by the St. Louis Zoo study on Bosawas hunting patterns. Although the study has not concluded, personal communication with the principles over the past four years indicates that the indigenous areas of Bosawas house the complete range of Central American fauna and that the hunting patterns of indigenous residents have not created the “empty forest” syndrome (Gros et al. 2004; St. Louis Zoo 2004). Unlike the indigenous people reported on recently by Bennett and Robinson (2000), Mayangna and Miskitu people rely far more on domestic production of protein than they do on hunting and they spatially separate activities in way that preserves habitat. Most hunting in the territories studied by the Zoo goes on in the work areas where there is a higher density of white-tailed deer, collared peccary, and *Cuniculus paca* than in the areas formally designated as hunting sinks. Additionally, the indigenous territories of Bosawas took the extraordinary step of formalizing their own cultural mechanisms for insuring that game is plentiful in the areas of heavier hunting pressure. In their case, the core of the Isabelía mountain range that runs through the heart of Bosawas is believed to harbor dangerous mythical animals called Waulas and, because of the danger to humans, are traditionally tabooed and generally avoided except to pass through well-known trails. This entire area became designated by them as the Waula Conservation Zone in 1999 and is formally designated on indigenous maps of the reserve.

The finding that the boundary between indigenous residents and mestizo colonists has slowed deforestation to a trickle on the indigenous side is also slightly astounding. The disturbance that exists is nearly entirely due to “leakage” where mestizo farmers have indeed invaded indigenous space. Why have they not proceeded on north? Part of the explanation lies with the methods of demarcation of the indigenous territories. When the lines were demarcated, an agreement was forged by indigenous residents with each pre-existing colonist that produced a “social” line where the colonist agreed to limit their advance further north. Thus the straight lines shown on maps are actually quite messy and dodge around pastures, crops, etc. Another part of the answer is due to the vigilance of the indigenous forest rangers. As mentioned in the introduction, support for the training, maintenance, and field trips of these crews has been sporadic. Several institutions have supported the effort, but funding tends to be project-oriented while the threat goes on forever. However, even in hard times some patrolling and discussion with invaders and would-be invaders has taken place. In a visit by the P.I. of the present study to the most remote part of Mayangna Sauni As on the Wawa River in the summer of 2003, the side of the river claimed by Mayangna Sauni As was clear of colonists, while the side belonging to the community of Awas Tingni, also a major Mayangna community, had several colonists busily cutting down forest. The reason? When they had tried to settle on the other side of the river, a group of Mayangna men from the town of Musawas had paid them a visit and made it clear that the forest on their side was protected. Awas Tingni people, relying on attorneys to vindicate their historic land claims, had not felt empowered to ask them to leave. The incident dramatized the difference between the social capital generated by the documentation process in Mayanga Sauni As and the relative lack of it in Awas Tingni which had not gone through such a process.

On the other hand, from the data of this study, the Bosawas boundary has been much more permeable. The flood of people into the southern part of the reserve has been notable and over 40% of the primary forest and 16% of all categories of tree cover is now missing and unlikely to be recovered. The increasing similarity of mestizo area inside the reserve to the first 10 kilometers outside indicates that state controls have been ineffective in protecting the reserve. The indigenous efforts have been much more fruitful. Whereas the boundary that separates indigenous areas from mestizo areas has proved effective in halting the advance of the agricultural frontier[5], the Bosawas boundary itself seems only to have slowed the advance for a time. During the middle time period seen on the 1995 satellite image, there was still some degree of open land available for settlement outside of the Bosawas border. As available lands have become increasingly occupied, the pressure to cross the Bosawas boundary to settle and find arable land seems to have increased. The outcome by 2002 is that, even taking the entire mestizo polygon into account, the current deforestation is beginning to resemble the outer buffer zone polygon. The land cover change and vegetation classification data both indicate that the buffer region continues to experience disproportionate deforestation and fragmentation compared to within the Bosawas reserve, but the trend indicates that a similar degree of vegetation loss and fragmentation will develop within the Bosawas boundary within the next decade. Obviously if the forests of the 2170 km^2 mestizo area are to be saved, something will need to be done to remove colonists or prevent further deforestation.

The data regarding the original boundaries of the Saslaya National park are also interesting. The park during the Contra War appears to have been heavily invaded in its southern region, perhaps because of the war raging to the north. After the war, efforts by the government and by the emerging civil society to protect the park seem to have largely succeeded. There is much more forest in the park in 2002 than in 1987. Additionally, the

[5] There are two areas of significant mestizo invasion that affect this picture. One is where the Amak River meets the MSB territory and one is where the Pispis River (near Bonanza) encounters MSA. Both of these invasion areas have some time depth now, and, while it is unlikely that the mestizos will be expelled, it is also unlikely that they will proceed farther north.

Land Cover Change Analysis and the Vegetative Cover Analysis both reveal that the social demarcation of the park was more important in the end than the statutory demarcation. There is much land to the south of the park where the forests have been respected , despite the actual location of the line?

CONCLUSIONS

Mestizo and indigenous land uses exhibit marked difference in levels of cultural disturbance to the forests as well as the proportion of the region classified as primary forest, secondary forest, and agriculture. Additionally, all differences between indigenous and mestizo controlled regions are statistically significant. The distinction of Miskitu versus Mayangna is much less transparent, as while there may be more activity in Miskitu regions, similar proportions of change and forest cover persist. When corrected on a per capita basis, the two groups show approximately the same patterns of forest use.

Indigenous people are able to maintain the integrity of demarcated indigenous territories without violence if they are empowered to do so and receive even minimal levels of funding and training. This result is due to the social capital generated by a participatory process of documenting the territorial claims, forming stewardship organizations, and management planning.

From external studies in at least two of the territories, it appears that the impact of indigenous subsistence on the fauna within their territories is benign. Most hunting takes place in areas near communities and most protein is acquired from fishing and domestic animals.

It seems that the Bosawas southern boundary that faces the advance of an unconstrained agricultural frontier has not proved effective in halting the spread north of the frontier, but it may have allowed indigenous people some time to demarcate territorial claims and organize themselves to defend their own lines while the southern portion of Bosawas was filling. In any case, the ability of the state to defend the biosphere it created is shown to be extremely weak.

Forest connectivity is difficult to gauge and quantify, but based on our Area/Edge ratio as well as a visual analysis of disturbed regions and the obvious patterns of fragmentation they demonstrate, forests in indigenous regions, even with significant populations, are much less fragmented and represent a more continuous and therefore healthy forest ecosystem when compared to the mestizo regions within or outside the Bosawas reserve.

In the end, the question of whether indigenous people make good conservation partners will have to be answered on a case by case basis until the factors that lead to BOSAWAS-like results are analyzed in a number of cases. In this case, it seems that the conservation effort has been successful and that indigenous people have been much more protective of the flora and fauna than the government which created the reserve. The future of the indigenous areas, however, clearly depends on collaboration with the government and with NGOs who can provide scientific information to territorial authorities by which to make management decisions information. Also, as the primary conservation areas are co-managed with the government, the future will depend on the willingness of the government to work with its indigenous partners effectively.

Acknowledgments

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Literature Cited

Bennett, E. L., and J. G. Robinson. 2000. Hunting of Wildlife in Tropical Forests: Implications for Biodiversity and Forest Peoples. World Bank Environmental Department Papers, No. 76. The World Bank, Washington DC.

Chapin, Mac. 2004. Losing Touch: Conservationist NGOs and Traditional and Indigenous People. Worldwatch Magazine, Dec:17-31.

Chicchón, A. 2000. Conservation Theory Meets Practice. Conservation Biology **14**: 1368-1369.

Colchester, M. 2000. Self-Determination or Environmental Determinism for Indigenous Peoples in Tropical Forest Conservation. Conservation Biology **14**: 1365-1367.

Colchester, M., 1994. Salvaging Nature: Indigenous People, Protected Areas, and Biodiversity Conservation. The United Nations Research Institute for Social Development, Discussion Paper no. 55. The United Nations Research Institute for Social

Development, Geneva.

COICA (Coordinadora de Organizaciones Indígenas de la Cuenca Amazónica) 1990. Primer Encuentro Cumbre Amazónico entre Pueblos Indígenas y Ambientalistas: Declaración de Iquitos. Iquitos: COICA.

Dasmann, R. F. 1976. National Parks, Nature Conservation, and "Future Primitives." The Ecologist **6**(5):164-178.

Dassman, R.F. 1975. The Conservation Alternative. John Wiley and Sons, New York.

Diamond, J. 2005. Collapse: How Societies Choose to Fail or Succeed. Viking Books, New York.

Dowie, Mark. 2005. Conservation Refugees: When Protecting Nature Means Kicking People Out. Orion: **November/December**.

Groome, M. J., G. K. Meffe, and R. Carroll, eds. 2005. Principles of Conservation Biology, 3rd ed. Sinauer Associates, Sunderland, MA.

Gros, P., G. Camilo, and C. Asa. 2004. Effect of Indigenous Land Use on Mammal Populations in a Central American Rainforest. Paper presented to the annual meeting of the Society for Conservation Biology. New York City.

Kaimowitz, D., and A. Fauné. 2003. Contras and Comandantes: Armed Movements and Forest Conservation in Nicaragua's Boswas Biosphere Reserve. Pages 23-47 in S. Price, editor. War and Tropical Forests: Conservation in Areas of Armed Conflict. Haworth Press, New York City.

Katz, E.G. 2000. Social Capital and Natural Capital: A Comparative Analysis of Land Tenure and Natural Resource Management in Guatemala. Land Economics **76**:114-132.

Key, C. H., and N.C. Benson. 2004. Ground Measure of Severity, the Composite Burn

Index; and Remote Sensing of Severity, the Normalized Burn Ratio. FIREMON Landscape Assessment documents. National Park Service-U.S. Geological Survey National Burn Severity Mapping Project. Available at http://burnseverity.cr.usgs.gov/methodology.asp

Krech III, S. 1999. The Ecological Indian: Myth and Reality. New York: W.W. Norton and Co.

Lillesand, T. M., and R.W. Kiefer. 2000. Pates 592-594 in Remote Sensing and Image Interpretation, 4th ed. John Wiley & Sons, New York

McCay, B. J., and S. Jentoft. 1998. Market or Community Failure? Critical Perspectives on Common Property Research. Human Organization **57**: 21-29.

Portes, A. 1998. Social Capital: Its Origins and Applications in Modern Sociology. Annual Review of Sociology **24:1-24.**

Redford, K.H., 1991. The Ecologically Noble Savage. Cultural Survival Quarterly **15**(1): 46-48.

Redford, K.H. and S. E. Sanderson. 2000 Extracting Humans from Nature. Conservation Biology **14**: 1362-1364.

Redford, K. H., and A. M. Stearman. 1993 Forest-Dwelling Native Amazonians and the Conservation of Biodiversity: Interests in Common or in Collision? Conservation Biology **7:** 248-255.

Redford, K. H., P. Coppolillo, E. W. Sanderson, G. A.B. Da Fonseca, E. Dinerstein, C. Groves, G. Mace, S. Maginnis, R. A. Mittermeier, R. Noss, D., J. G. Robinson, A.Vedder, and M. Wright. 2003 Mapping the Conservation Landscape. Conservation Biology **17**: 116-131.

Saint Louis Zoo. 2004. Proyecto Biodiversidad y Sostenibilidad de la Caceria: Reporte por MAKALAHNA y de las comunidades de Mayanga Sauni Bu. (Xerox MS only) St. Louis Zoo, St. Louis, MO.

Schwartzman, S., A. Moreira and D. Nepstad. 2000. Rethinking Tropical Forest Conservation: Perils in Parks. Conservation Biology **14**.1351-1357.

Schwartzman. S., D. Nepstad and A. Moreiera. 2000. Arguing Tropical Forest Conservation: People versus Parks. Conservation Biology **14**: 1370-1374.

Smith, J., 1998. Land Cover Changes in the Bosawas Region of Nicaragua 1986-1995/96. MS in Xerox submitted under contract to The Nature Conservancy. Athens, Georgia, Center for Remote Sensing and Mapping Science, Department of Geography, University of Georgia, Athens.

Stevens, S., 1997. Conservation through Cultural Survival : Indigenous Peoples and Protected Areas. Island Press. Washington D.C.

Stocks, A. 1996. The BOSAWAS Natural Resource Reserve and the Mayangna of Nicaragua. Pages 1-31 in K. H. Redford and J.A. Mansour, editors. Traditional Peoples and Biodiversity Conservation in Large Tropical Landscapes. Island Press, Washington D.C.

Stocks, A. , J. Beauvais and L. Jarquín. 2000. El Activismo Ecologico Indigena en Nicaragua: Demarcacion y Legalizacion de Tierras Indigenas en Bosawas. Wani (Journal of the Nicaraguan Caribbean) **25**:6-21.

Stocks, A. 1998. Indigenous and Mestizo Settlements in Nicaragua’s Bosawas Reserve: The Prospects for Sustainability. Paper presented at the annual meeting of the Latin American Studies Association, Chicago, 24–28 September. Available in Xerox Copy.

Stocks, A. 2003. Mapping dreams in Nicaragu´as Bosawas biosphere reserve. Human Organization **62**(4):65–78.

Stocks, A. 2005. Too Much For Too Few: Problems of Indigenous Land Rights in Latin America. Annual Review of Anthropology **16**:85-105.

Terborgh, J. 2000. The Fate of Tropical Forests: a Matter of Stewarship. Conservation Biology **14**: 1358-1361.

Terborgh, J. 1999. Requiem for Nature. Island Press, Washington D.C.

The Nature Conservancy. 1997a. Mayangna Sauni As: Tradición Oral de la Historia y Estudio Socioeconómico de las Comunidades Mayangna de la Cuenca del Río Wapuk. Impresiones Modernas, Managua.

The Nature Conservancy. 1997b. Mayangna Sauni Bu: Documentación del Reclamo Historico de las Comunidades Mayangna de la Cuenca del Río Bocay. Impresiones Modernas, Managua.

The Nature Conservancy. 1997c Sikilta (Mayangna Sauni Bas): Historia y Situación Actual de los Mayangna Balna del Uliwas. Impresiones Modernas, Managua.

The Nature Conservancy. 1997d. Kipla Sait Tasbaika: Tradición Oral y Estudio Socioeconómico de las Comunidades Indígenas del Sector Raudales. Impresiones Modernas, Managua.

The Nature Conservancy. 1997e. Miskitu Indian Tasbaika Kum: Historia y Situación Actual de las Comunidades Miskitu del Alto Coco. Impresiones Modernas, Managua.

The Nature Conservancy. 1997f. Población Mestiza en el Suroeste de La Reserva Bosawas: Estudio Socioeconómico. MS (available in xerox only). The Nature Conservancy, Managua.

Wilcox, B. A., and K.N. Duin. 1995. Indigenous Cultural and Biological Diversity: Overlapping Values of Latin American Ecoregions. Cult. Surv. Quarterly **18**(4): 49-53.