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*Brief Comment*

# Land Cover Assessment of Indigenous Communities in the BOSAWAS Region of Nicaragua[1]

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## INTRODUCTION

In some regions of the world, indigenous peoples still retain control over the lands and resources they and their ancestors have utilized for centuries. However, such control is becoming increasingly rare, as these lands are often coveted by outsiders because of their rich biodiversity and valuable natural resources (Dasmann, 1991; Stevens, 1997). Conservationists are interested in establishing parks and reserves for conservation, timber interests want to harvest trees, and nonindigenous settlers seek to claim seemingly underutilized lands. In response to such pressures, the territories utilized by indigenous peoples have often been designated as national parks or other protected areas. The new management paradigm for these conservation areas calls for the incorporation of the indigenous peoples into the management process (Stevens, 1997). A critical component of such management systems are land cover data that reveal the land covers present and the processes incurring land cover change. Land cover changes reveal the environmental conditions and human actions that have shaped the landscape, including ecological succession, timber removal, and natural disturbances such as hurricanes.

This study utilizes remotely sensed images to conduct a land cover analysis of three indigenous communities in Nicaragua that are attempting

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to develop comprehensive land use management plans compatible with the goals of the government-created BOSAWAS Natural Resource Reserve (Fig. 1). Encompassing 7,300 sq km, the goals of the Reserve are to conserve a portion of the largest remaining stand of tropical rain forest north of the Amazon Basin, while promoting the sustainable use of its resources (Stocks, 1994). To facilitate the entry of the indigenous communities into the management process, the communities have been working with two nongovernmental organizations (NGO), The Nature Conservancy (TNC) and the Alistar Foundation. These NGOs have provided technical and legal assistance to the communities as well as training to the indigenous forest rangers to monitor the communities' territories. The goal of this study is to provide land cover data to the communities so that they will be able to work with the Nicaraguan Government on planning the sustainable use of the Reserve's resources.

Two of the three communities under study are made up of Mayangna (Sumu) peoples (Mayangna Sauni As and Mayangna Sauni Bas), while the other community is made up of Miskitu, Kipla Sait Tasbaika. The Mayangna inhabit the interior valleys of north-central Nicaragua, while the Miskitu are found along the Caribbean coast and the Coco River valley (Sollis, 1989). Approximate 1995 populations of the communities were 500 for Mayangna Sauni Bas and 3,400 for both Mayangna Sauni As and Kipla Sait Tasbaika (Stocks, 1998; Stocks *et al.*, 1998). The three communities are similar in that settlements occur along rivers that provide transportation to agricultural lands, as well as hunting and gathering areas. All three practice subsistence slash-and-burn (swidden) agriculture, clearing plots of primary and secondary forest along the river valleys. Each clearing is used for two or three cropping cycles and then abandoned for new areas. Major crops include maize, rice, beans, bananas, and yucca. As the lands lie fallow, fertility regenerates allowing them to be reused in the future. Meat is provided through hunting and fishing, as well as raising chickens, pigs, and in a few circumstances, cattle. All three communities are relatively isolated, with no roads. However both Mayangna communities are located near mestizo mining towns that serve as markets for indigenous goods as well as points of embarkation for settlers seeking land.

## METHODS

Information required to conduct a land cover analysis of the three indigenous communities includes their territorial claims, the current extent of land covers, and recent land cover changes. Such an analysis will allow the communities to work with Nicaragua's environmental ministry, the

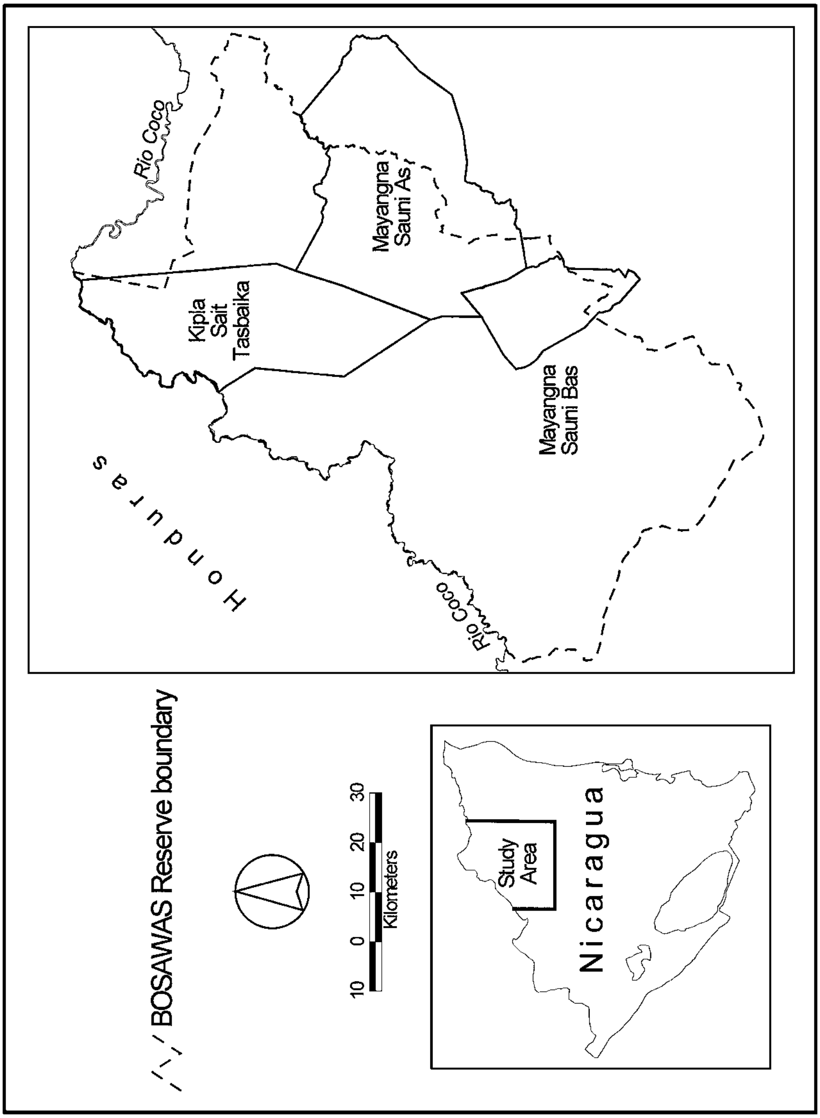


**Fig. 1.** Indigenous communities and the BOSAWAS Natural Resource Reserve, Nicaragua.

*Ministerio del Ambiente y los Recursos Naturales* (MARENA), on the Reserve's management plan. Land cover was identified using remotely sensed images, while existing maps provided community boundaries and the information required to register the images to a common coordinate system. Overlays of the geographic data sets were conducted to identify the land covers within individual communities and the land cover changes that had occurred between 1986 and 1995.

A number of images from a variety of sensors were required to provide land cover data for the three communities, including a Landsat multispectral scanner (MSS) image to identify 1986 land cover, and a single Landsat thematic mapper (TM) image, along with three SPOT high resolution visible (HRV) panchromatic images to identify 1995 land cover. The large number of images were required because of the prevalence of cloudy conditions throughout the year in the region, which made many images unusable.

Existing maps provided ground control for image rectification, as well as information to be incorporated into the spatial database. Specifically, these maps included 1:50,000-scale topographic maps produced in 1987 by the *Instituto Nicaragüense de Estudios Territoriales* (INETER) and 1:50,000-scale indigenous community maps produced by the Center for Environmental Anthropology (CEA) at Idaho State University. The 1:50,000 scale topographic maps were used to obtain ground control points for the rectification of the satellite images, while the indigenous community maps were used to delineate the boundaries of their claims. These indigenous community maps had been hand drawn, using the topographic maps as a template.

Source data were also collected during two site inspections. These inspections were conducted to gather ground truth information on the communities, acquire maps, and meet with researchers working in the communities. The first inspection occurred in July/August 1995, and lasted approximately 4 weeks. To facilitate the gathering of ground truth information on existing land use and land cover conditions, hardcopy color prints of portions of the satellite images were taken to the study area. Fieldwork included an aerial survey of the area and visits to both Mayangna and Miskitu villages. Handheld photographs were acquired during the aerial survey to obtain ground truth information in inaccessible portions of the Reserve.

The second site visit was conducted during January/February 1996 (lasting for 3 weeks) and involved collecting information on land cover sample areas to be used in the image classification process. The timing of this visit was critical, because it occurred during the dry season, the same time of the year as when the images were acquired. Thus, the environmental conditions recorded during this visit were very similar to those occurring during image acquisition. Locations of the sample areas were determined in Universal Transverse Mercator (UTM), North American Datum of 1927 (NAD 27) ground coordinates using a Trimble Geoexplorer$^{TM}$ global positioning system (GPS) receiver. The NAD 27 was chosen to make the database compatible with existing map products of the area. At each GPS sample point, a labeled diagram was sketched of the surrounding landscape and ground photographs acquired.

A land cover classification scheme was then developed for the study based on the capabilities of the images utilized and information gathered during the field surveys. The three classes delineated were advanced forest, scrub/early secondary forest, and agriculture/pasture. A more detailed classification scheme would have been beneficial, but the inclusion of the MSS and SPOT images necessitated a more generalized system. The advanced forest class was used to include both primary and older secondary forests, since the two were spectrally indistinguishable on all of the images. In the tropics, once an agricultural plot is abandoned, it quickly proceeds through the successional process, with only 15 years of regrowth required for a secondary forest to become spectrally inseparable, utilizing existing digital sensors, from mature forest (Moran, 1993). The creation of the aggregated scrub/early secondary forest and agriculture/pasture classes was necessitated by the limited number of spectral bands of both the MSS and panchromatic (black and white) SPOT sensors.

To facilitate the classification of the satellite images, ground truth information gathered from one-half of the GPS sample points were used to guide the classification process. These points were overlayed upon the 1995 TM and SPOT images to link ground information with image characteristics. Diagrams and photographs acquired at the GPS points were then compared with each of the images on-screen. This registration of GPS point locations to the images resulted in image characteristics such as color and relative texture (smooth versus rough) being linked with specific land cover types.

Once the GPS point registrations were complete, homogeneous sample training areas for each land cover class were identified on the 1995 TM image, and mean spectral reflectance curves were created. The resulting data were used to guide the classification of the 1995 TM image and to identify land cover sample areas on the 1986 images. Areas of specific land cover classes on the 1986 MSS images were identified by analyzing those areas where land cover changes were unlikely to occur, as well as by developing reflectance curves that exhibited similar values.

Thematic classification was conducted using both supervised classification and visual interpretation. Supervised classification involves an analyst using ancillary data sources to identify representative portions of an image for each desired feature class, with the spectral signatures derived from these training areas then used to classify the entire image using a clustering algorithm. Visual interpretation, on the other hand, involves an analyst delineating the various land cover patches on a photograph with a pen, or on a computer screen using a cursor. A patch was defined as a contiguous swath of a specific land cover. Visual interpretation was used on the MSS images since supervised classification was made impossible by severe striping in Bands 1 and 2 of the images.

Land cover for the second date of the analysis was derived from the three SPOT images and the 1995 TM image. The SPOT panchromatic images were classified through visual interpretation, while supervised classification was utilized to classify the TM image. After the TM image was classified, it was converted to a vector land cover dataset by digitizing the boundaries of the land covers on the raster classification image that resulted from the classification process. Overall classification accuracy for the three land cover classes was 92% (Smith, 1998).

Once the classification and vectorization was complete, all of the land cover files were converted to ARC/INFO format for editing and analysis. Two land cover datasets were created, one for each year, by combining the results of the image classifications. These datasets were then clipped with the boundaries of the three communities to isolate the land cover within each. This created a total of six land cover datasets, two for each community, one for 1986 and the other for 1995. Data sets from the individual communities were then overlayed to identify the land cover changes that occurred between 1986 and 1995.

## RESULTS AND CONCLUSIONS

The results of the 1986 classification reveal that advanced forest dominated all three communities, with only small amounts of scrub/early secondary forest and agriculture/pasture present (Table I). Agriculture/pasture was present in relatively small amounts, while the amount of fallow lands, represented by scrub/early secondary forest patches, was considerably greater. Between 1986 and 1995 the total area and the number of patches of agriculture/pasture increased dramatically in all three communities, with the amount of scrub/early secondary forest increasing in Kipla Sait Tasbaika and Mayangna Sauni As. In 1995, the scrub/early secondary forest patches represent those areas that were utilized by the inhabitants when they first returned to the region in 1991 and subsequently abandoned for more fertile plots. Advanced forest continued to dominate all three communities, even as its total amount decreased in both Kipla Sait Tasbaika and Mayangna

**Table I.** Land Cover Amounts

| Class | 1986 | | | 1995 | | |
|---|---|---|---|---|---|---|
| | Number of patches | Total area (sq km) | Average patch size (sq km) | Number of patches | Total area (sq km) | Average patch size (sq km) |
| Kipla Sait Tasbaika | | | | | | |
| Agriculture/pasture | 13 | 2.9 | 0.2 | 51 | 6.4 | 0.1 |
| Scrub/early secondary forest | 39 | 9.2 | 0.2 | 102 | 15.3 | 0.2 |
| Advanced forest | 2 | 1127.9 | 563.9 | 14 | 1118.1 | 79.9 |
| Mayangna Sauni As | | | | | | |
| Agriculture/pasture | 2 | 0.3 | 0.1 | 73 | 17.0 | 0.2 |
| Scrub/early secondary forest | 31 | 29.3 | 0.9 | 93 | 93.9 | 1.0 |
| Advanced forest | 8 | 1606.0 | 200.8 | 11 | 1524.4 | 138.6 |
| Mayangna Sauni Bas | | | | | | |
| Agriculture/pasture | 1 | 0.2 | 0.2 | 57 | 7.5 | 0.1 |
| Scrub/early secondary forest | 26 | 19.9 | 0.8 | 23 | 5.6 | 0.2 |
| Advanced forest | 2 | 385.5 | 192.8 | 1 | 392.6 | 392.6 |

**Table II.** Land Cover Changes (sq km)

| Change process | Kipla Sait Tasbaika | Mayangna Sauni As | Mayangna Sauni Bas | Total |
|---|---|---|---|---|
| Deforestation | 15.8 | 85.9 | 5.1 | 106.8 |
| Reconversion | 0.5 | 8.4 | 4.0 | 12.9 |
| Reforestation | 7.6 | 4.5 | 12.2 | 24.3 |
| Remained agriculture/pasture | 0.5 | 0.2 | 0.2 | 0.9 |
| Remained scrub/early secondary forest | 3.0 | 16.4 | 3.8 | 23.2 |
| Remained advanced forest | 1111.5 | 1520.0 | 380.4 | 3011.9 |

Sauni As. Analysis of the locations of the agriculture/pasture and scrub/early secondary forest patches reveal that some originate outside the boundaries of the two Mayangna communities. This would indicate that they have been caused by mestizo settlers who have infringed on the communities' territories.

By overlaying the two datasets for each community, land cover change processes were identified. Three processes were identified as occurring between 1986 and 1995: deforestation, reconversion, and reforestation (Table II). Deforestation involves the removal of tree cover from an area and is delineated by those areas that were advanced forest in 1986 and agriculture/pasture, or scrub/early secondary forest in 1995. Reconversion is the reutilization of fallow lands for agriculture. Areas undergoing reconversion were scrub/early secondary forest in 1986 and agriculture in 1995. Reforestation is the final change process and involves the continuation of ecological succession, that is, a maturing of the natural vegetation. These areas were agriculture or scrub/early secondary forest in 1986, and advanced forest in 1995. Deforestation impacted the greatest area, especially in Mayangna Sauni As, with reforestation affecting the second largest area. Over one-half of the reforestation occurred in a single community, Mayangna Sauni Bas. Reconversion affected relatively small amounts of area in all three communities.

Results of the analysis reveal that the land covers present reflect processes that were affecting the country as a whole. The small amount of agriculture/pasture present in 1986 is the result of land abandonment during Nicaragua's civil war. Indigenous populations were either forcibly moved away from the border region, or fled to Honduras, thus abandoning their lands (Stocks, 1998). At the conclusion of the war in 1990, the indigenous populations returned and reestablished their traditional agricultural practices. The large amounts of land affected by the deforestation and reconversion processes reflect this. In addition to the indigenous peoples, mestizo settlers seeking land also moved into the area, as shown by the clearings present along the southern borders of the two Mayangna communities. Indigenous forest rangers in Mayangna Sauni Bas patrolling this region identified 15 families inhabiting territory the community claims (Stocks *et al.*, 1998).

The land cover analysis of the three communities was conducted to enable the communities to be active players in the management of the BOSAWAS Reserve. Analysis of the locations of current agricultural lands, the amount of change that has occurred, along with a census being conducted by TNC and the Alistar Foundation, will enable the communities to develop comprehensive land use management plans that meet their needs and the goals of the Reserve. The land cover data will form a baseline for the continual monitoring of land cover, while allowing the indigenous forest rangers to work with the national government in repressing mestizo settler invasions.

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