Modeling the Population-Environment Interaction:
A Geo-demographic Analysis of North-central Costa Rica to Support Biological Corridor Designation, Conservation Policy and Practice

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Abstract

This study seeks to incorporate a rich and diverse collection of demographic and socioeconomic spatial datasets into an analysis of critical areas for conservation and in the designation of biological corridors between existing protected areas in Costa Rica. Located to the north of the greater San José metropolitan area, the largest urban population center in the country, the project area encompasses five national parks (PN's): PN Turrialba, PN Volcán Irazú, PN Braulio Carrillo, PN Volcán Poás, and PN Juan Castro Blanco, (approximately 6,500 km² total).

Focusing on datasets from the year 2000, we have joined together data about human populations, biophysical conditions, infrastructure, land tenure and other landscape factors as layers in a geographic information system and produced a priority areas model based on a simple, adjustable factor analysis. A selection of data variables were statistically evaluated using a weight or ranking system and new spatial layers developed, based on the results of the factor score of each variable. Areas on the landscape where the resulting ranks or weights of these variables are clustered, we classified as locations in the study area where human population / land-use pressure is most intense and demanding on the available natural resources. A similar model was developed using biophysical and other landscape variables to identify areas where the rate and intensity of natural resource depletion is most concentrated.

These two analyses were joined together in a single overlay model, and the result spatially represents what we define as priority areas, or critical areas. While factor analysis models are commonly used within a wide range of GIS applications and as decision-making tools in natural resource management, demographic variables have rarely been included in the analysis. Furthermore, when demographic data has been incorporated into these models, the coarseness of the spatial information (often only to the 'distrito' or district level) has imposed a limit on the potential analysis. With the assistance of public agencies in organizing their own data, it was possible to develop models, which are more spatially explicit and representative of the human presence on this landscape.

Our results present various models that differ based on adjustments made to the weighting of the human population or biophysical factors. We conclude by presenting a series of proposed biological corridors connecting the five protected areas. The comparison of this series of proposed biological corridors is accompanied by a critical examination of the evolution of the Mesoamerican Biological Corridor (MBC) and its lack of correlation with conservation targets defined in the study region. We observe that conservation efforts need to be directed towards the expansion of existing national parks in the study region in order to combat the increasing levels of forest fragmentation and biodiversity loss. We conclude generally that the demographic variables add to the integrity and specificity of the model and that adjustments made to the weighting of the factors affects results in consistent and expected ways. The complete research results are intended to be evaluated by conservation planners and managers, with the goal that the models can continue to be improved upon and used to help inform future conservation planning in the project area.

INTRODUCTION

The objective of this study is to identify areas within a set geographic region, which might be key targets for the implementation of conservation management and policy. In conservation GIS practice, this has developed into what is more commonly known as a critical areas analysis (Hopkins, 1984). However, these types of conservation targeting exercises can result in the development of policies which are potentially misguided and doomed to failure due to their inabilities to adequately model the factors of land-use activities, human population dynamics, and more locally-defined stakeholder presence.

Given the now dominant use of Geographic Information Systems (GIS) and related technologies as tools in natural resource research and planning, and the recognition of the capacity of GIS to inform and influence decision-making at a range of administrative levels, there is a clear impetus to test methods for the integration and analysis of human population factors which might be spatially enabled and modeled. The key assumption here is that the incorporation of these factors will function to more adequately and accurately inform the results of GIS analysis, and will therefore allow for more informed decision-making on the part of conservation policymakers and managers.

Furthermore, in the specific context of Costa Rica, limited financial and personnel resources within the principal natural resources administrative body, the Ministry of the Environment and Energy (MINAE), have increased the need and utility of using GIS to target conservation programs and practices.

Study Area

The focus of this study is the area surrounding, connecting, and including five national parks: PN Volcán Poás, PN Volcán Irazú, PN Braulio Carrillo, PN Turrialba, and PN Juan Castro Blanco. The total area of interest measures approximately 6,500 km^2 (Figure 1).

The parks of this study region were selected due in large part to the following characteristics:

1. Spatial proximity to the metropolitan area of San Jose, the population center of the country;
2. High level of biodiversity and endemism, particularly of plant species;
3. Relatively small area (only Braulio Carrillo is over 40,000 ha in size);
4. Abundance of geospatial information available from various institutions working in region.

(Figure 2)

The national parks, (with the exception of Juan Castro Blanco), are located within the Conservation Area of the Central Volcanic Cordillera (ACCVC). There are eleven Conservation Areas in Costa Rica administrated by the National System of Conservation Areas (SINAC), a main division within MINAE. In total, the ACCVC manages twenty-three separate protected areas, covering approximately 1,400 km^2. As of the year 2000, the entire protected area system of Costa Rica was comprised of 151 protected areas, classified into eight different management categories (Figure 3).

These eight management categories can essentially be grouped according to two levels of protection, outlined by Sterling Evans as the following:

> "Type I is 'strict' protection (national parks, biological reserves, national monuments, natural reserves, and wildlife refuges) with these objectives: 'to preserve species and to reduce human intervention in environments and ecological processes'…Type II includes forest reserves and protected zones whose objective 'partially to protect the biological diversity as they are open to exploitation of resources under certain conditions'" (Evans, 1999).

Several researchers/conservationists have pointed to the need to increase the size of the protected areas, especially those located within this study region. The argument has been that increasing pressure from human activities, (mainly through deforestation), have caused fragmented forests, as well as "conservation islands" (Sanchez-Azofeifa et al, 2003).

In national studies of biodiversity conservation, it has been recommended that the country implement efforts to increase the area and consolidate its network of strictly protected areas (INBIO, 2002). A report from the project GRUAS in 1996, recommended that the national parks and biological reserves in the system should be increased to cover approximately 19.5% of the national territory. Today, this percentage remains at 12.5% (CONARE, 2002).

The high level of plant endemism observed in this study region is a strong indicator of its overall significance to the biological richness of Costa Rica, (with a biodiversity level at ~ 5% of the global total). In fact, one of the four areas of endemism classified within the country is located within this study region: the high uplands of the central volcanic cordillera (INBio, 2002). These characteristics lend increased impetus to the need for stricter management and conservation of the region's forest and water resources. Furthermore, the proximity of this study region to the population center of the country points to a need for more research into the interaction between areas of high biodiversity significance and human population development and land-use activities.

Previously, this study region has been integrated into several GIS analyses primarily focused on deforestation rates, as well as on identifying the relationship between population growth and deforestation. As Sader and Joyce concluded in their national study of deforestation between 1940 and 1983, only 17% of the original natural forest cover remained in the mid-1980's (Sader & Joyce, 1988). It is the claim that in the 1970's alone; the rate of deforestation was at 1% of Costa Rican territory (or 511 km² per year – 1.4 km² daily) (Palloni and Rosero-Bixby, 1999). In their CDE working paper on "Population and Deforestation in Costa Rica", Palloni and Rosero-Bixby acknowledge the parallelism between population growth and increased deforestation rates when they state that, "The most commonly mentioned causal link between these two processes is the demographic pressure on land combined with public policies favoring settlement in public lands to avoid land reform and to take away population pressure" (Palloni and Rosero-Bixby, 1999). However, they also emphasize that the parallel, however strong and connected, is not the singular cause of deforestation, nor is it defined in any simple terms. Palloni further alludes to the concept that population growth ought not to be equated directly with deforestation levels when he states: "Population pressure is neither a necessary nor a sufficient condition for deforestation to occur; population growth only matters if it occurs in conjunction with land inequality. Instead, distorted titling legal codes and policies lead to deforestation even in the absence of population pressures of any sort" (Palloni, 1994). These conclusions support the overall concept of this study: that it is necessary to analyze the interaction of variables focusing on demographic and socioeconomic trends in a region as well as land-use activity and land-holdings in order to more adequately assess the relative impact of the human population presence on the forest resources of the area. By bringing this analysis into the toolbox of a geographic information system (GIS), we hope to provide a methodological framework which is both sound, adaptable, and malleable to incorporate other inputs and scales.

METHODS

As stated previously, the objective of this study is to identify key targets for the implementation of conservation programs and practices using GIS to model the biophysical, human population, and land-use factors interacting in the region. In order to do this, we divided the analysis into three separate phases.

First, we analyzed spatial data available primarily on biophysical and land-use factors in what is known as a spatial multicriteria decision-making assessment, or "weighting and ranking" schema. This enabled us to define areas of significance related to biodiversity, ecosystem representation, land cover change, and pressure associated with land-use activities. Although this method has become more widely implemented in this type of analysis, for its relative ease of use and ability to introduce a socioeconomic and/or human population presence into conservation GIS analysis, we questioned its potential in adequately representing the wealth of demographic variables available for human population analysis, as are readily available in the National Census.

Therefore, we introduced an intermediate phase into this study where factors assessed in the first phase are modeled relative to the finest scale of publicly available political/administrative divisions in Costa Rica, the district (distrito). We focused this part of the analysis on data available from the past two census years, 1984 and 2000. Land cover data from 1986 and 2000, permitted a comparable assessment of changes in the biophysical setting over time. This phase of the analysis sought to identify key groups of districts where conservation policy and implementation might be targeted at a more local administrative level.

Finally, given the results from the first part of the analysis, we compare the targeting of critical areas for conservation with the series of proposed biological corridors, as related to the larger regional project known as the Mesoamerican Biological Corridor (MBC). As the MBC has evolved in scope and objectives over the past several years, so has criticism of it from the conservation scientist community. We examine the changing spatial definition of the MBC corridor designations, and offer a comparison with the key target areas, as identified in the earlier stages of our analysis.

Geospatial Datasets used in GIS Analysis

It is important to note that an underlying objective in this study has been to develop an analysis with a methodology which would remain flexible as well as easily repeatable in future studies. For this reason, a vast majority of datasets used in this analysis were produced by Costa Rican national governmental and educational institutions, and were selected for their accessibility and wide availability, as well as for their relative precision and integrity. Acknowledgements to those institutions who contributed datasets are made at the end of this paper.

Additionally, we selected methods of GIS analysis that require a relatively minimum level of hardware and software sophistication. For our part, all analysis was performed on a Pentium III machine, with 512 MB RAM, and less than 20 GB of hard drive space. The software package we used was Environmental Systems Research Institute's (ESRI) ArcView 3.2, with Spatial Analyst v.1.1. We mention these hardware and software specifications because we feel that they are closely similar to those found in the offices of MINAE (as well as other governmental ministries), and our aim is to document a type of analysis that could easily be performed by the GIS analysts in these offices.

A list of geospatial datasets included in each phase of the analysis can be viewed in Appendix I.

Phase I – Spatial Multicriteria Decision-Making Assessment

As Jacek Malczewski notes in the introduction of a chapter entitled "Spatial Multicriteria Decision Analysis":

> "Decision analysis is a set of systematic procedures for analyzing complex decision problems. The basic strategy is to divide the decision problem into small, understandable parts; analyze each part; and integrate the parts in a logical manner to produce a meaningful solution" (Malczewski in Thill, 1999).

For the purposes of this phase of GIS analysis, we follow what Malczewski describes as spatial multiattribute decision-making, or MADM (Thill, 1999). In this case, each dataset can be defined as a decision variable, in relation to the decision of identifying conservation targets, or critical areas. Datasets are described by both their spatial location and their attribute data. These attribute data become redefined relative to their criterion in the decision analysis. Once each dataset, or layer, has been defined in terms of its criterion, both spatially and by attribute data, the resulting layers are overlaid to produce a combined result of multicriteria assessment.

To place this in the context of weighting and ranking, the attributes (and occasionally the spatial location) of each data layer are assigned values which define the relative connection to identifying whether a spatial location is to be targeted for conservation programs and practices. These values may vary within data layers, according to differing attributes. Once all the data layers have been assessed and valued individually, they are combined in an additive way to produce a resulting assessment, as informed by these multicriteria. When the individual data layers are combined, they may either be assigned equal importance in the resulting decision set, or they may be assigned various ranks. Thus the resulting decision set can be varied based on the values assigned to criteria within each data layer, as well as values assigned between data layers.

In our particular analysis, we used the datasets listed in Appendix I as our set of layers. These we divided into separate categories so as to create two composite layers for the ultimate decision set. These two categories could best be defined as: biophysical/biodiversity significance and adverse land-use (Figure 4). All layers were assigned values based on their attributes and then converted to grids. We chose a minimum grid cell size of two hectares, or approximately 141.42 m^2. According to the Costa Rican Forest Law passed in 1996, the minimum size of a forest patch is no less than two hectares, with seventy trees measuring > 30cm diameter at breast height (Ley Forestal, 1996). Since forest dominates as a key natural resource of this study region, and decreases in forest cover are so closely correlated with biodiversity loss, we found this to be an appropriate cell size for the dataset grids.

Initially, we generated binary grids for each data layer, with equal weighting for each attribute. This produced a series of grids which represent the presence or absence of a particular criterion on the landscape. For the biophysical/biodiversity composite layers were defined and combined to represent spatial locations of increased biodiversity significance. This decision subset could also be defined as areas in need of strict protection under the management of MINAE. A final adverse land-use composite was created as a representation of areas where land-use activities and impact are negatively affecting the potential for forest cover regeneration.

The intersections of these composite analyses enabled the identification of key areas for the targeting of conservation programs and practices. Analytical confidence is highest when examining the resulting decision set of simple binary overlays, where all criteria and datasets were weighed and ranked equally.

Through close reference to similar studies by Leclerc and Rodriguez (1998) and Maas (2002), we repeated the composite grid analysis through weighting the variables within each dataset, where applicable. The resulting decision set was then compared empirically with the un-biased result.

Phase I(b) – Integration of Datasets to District Level

The district, or distrito, administrative division in Costa Rica is the finest level to which the national census data is made publicly available. With just over sixty districts distributed entirely within the study region, we hypothesized that through normalizing the various datasets to the district level and setting that as the minimum level of analysis, the resulting observations would better inform the definition of conservation targets; or, more appropriately, associating key conservation target regions with administrative areas where there is a wealth of demographic variables available through the national census would provide the tools for decision-makers to effect more comprehensive conservation programs.

Here we will note that the Central American Population Center graciously offered their dataset of census segment center points for the study region. A Thiessen polygon map layer was generated from these census segment centroids and used in Phase I of this analysis, as a variable in the "Adverse Land-Use Composite" to represent estimated population density distribution. Thiessen polygons are calculated based on a method known as the Dirichlet tessellation, which subdivides a planar surface into areas based around proximate center points. This method has been frequently used in the analysis of fine-scale census data in many countries throughout the world, and is generally regarded as the most viable option for producing a polygon surface for this type of application in the absence of actual census segment delineations (Martin, 1996). It is our estimation that this layer more accurately represents the population distribution in this area than the populated areas point coverage more widely available for use and derived from the 1:50,000-scale topographic maps. The Thiessen polygon layer and density distribution can be viewed in Figure 5.

Phase II – Comparison with Mesoamerican Biological Corridor Proposed Designations

As the Mesoamerican Biological Corridor project has evolved in meaning and scope over time, as have the proposed designations of biological corridors in Costa Rica. These changes can be assessed both spatially and contextually. The most recent series of proposed biological corridors is managed and mapped by SINAC/MINAE, under the plan of each Conservation Area. In this final phase of the GIS analysis, we performed an overlay of three different sets of corridor designations, (Proyecto GRUAS, PROARCA, and current MBC), with our resulting analyses of conservation targets in the study region to assess their spatial correlation.

RESULTS / DISCUSSION

Phase I – Spatial Multicriteria Decision-Making Assessment

For this phase we produced decision sets based on the two composites of biodiversity and adverse effects. Within the first set of decision set results, our intent was to produce a multicriteria assessment which provided equal weighting to all variables, (within and between layers). A more elegant result was produced when weights were factored in the analysis, particularly where it was possible to rank such layers as the road types, population counts, and ecosystem representation.

We initially performed an assessment of land use, forest cover loss and fragmentation using Landsat TM images from both 1986 and 2000, which had originally been classified by FUNDECOR and CATIE. This allowed us to derive the spatial distribution of cultivated land for 2000 to be used in the adverse effect composite. We calculated the amount of natural forest area lost between 1986 and 2000 as well as the level of forest fragmentation within the area (Figure 7). In their analysis of deforestation in Costa Rica between 1986-1991, Sanchez-Azofeifa, Harriss, and Skole demonstrated that at a national level, both deforestation and fragmentation had increased over time (although it has been demonstrated that the rate of deforestation has slowed since the late 1980's) (Sanchez-Azofeifa et al, 2001). Using methods similar to theirs, we evaluated the relative change in the study region between 1986 and 2000.

The comparison was made only for areas which were classified as having natural forest cover in 1986. Therefore, we do not consider areas which may not have been classified as natural forest in 1986, but we classified as such in the image from 2000. Additionally, all forest areas which were less than two hectares, (the minimum mapping unit), were deleted as were areas classified as cloud cover in the 2000 image. It is extremely difficult to capture a cloud-free satellite image within the region and therefore there was no other option for this present study but to include this particular image classification. Therefore, it is possible that the total forest area for 2000, as calculated in the table in Figure 7, may be less than the actual forest cover. However, it was our assessment that this omission would not alter the overall conclusion in the table that deforestation and fragmentation trends continued to increase between 1986 and 2000. The deforestation rate of natural forest cover in the study region was calculated at approximately 40 km^2 per year.

Natural forest cover loss between 1986 and 2000 was then compared with the ecosystems identified in the region, as defined by the recently released Central American regional ecosystem map (Vreugdenhil et al, 2002). Figure 8 displays both a map of the natural forest cover change between 1986 and 2000 in the study region, as well as the natural forest cover loss during that time period overlaid with the ecosystems of the area. The ecosystem type which experienced the greatest amount of natural forest cover loss for this time period is classified as "Bosque denso latifoliado siempre verde nuboso montaño y altimontaño", according to the ecosystem map classification scheme. Only 37% of this ecosystem type is currently under strict protection within the greater study region.

The biodiversity composite was compiled and simplified by combining the natural forest cover as identified for the year 2000 with the sites of endemic plant species, as published by the National Biodiversity Institute (INBio). Other factors eventually integrated into the analysis included slope and aspect, as derived from a digital elevation model of the study region.

The adverse land-use composite contained the more complex array of factors and weights, as layers representing similar land-use were incorporated from various data sources. The most complicated of these was the representation of land under cultivation. The assumption was that any land under cultivation is posing a negative impact on biodiversity level in the area. In this analysis, the following geospatial datasets were considered to represent areas of cultivated land: coffee plantation locations, export plant plantations, Agrarian Development Institute (IDA) land settlements, and patches defined as cultivated land by the 2000 land cover/land-use classification. In order to avoid double counting these areas within the final composite, we eliminated all land cover/land-use classifications of cultivated areas which were located within IDA settlements. These combined layers were then weighted equally to represent cultivated regions within the study area.

The adverse land-use composite was assembled from the various layers using a simple additive method. It was then classified into three levels of pressure or threat: low, medium, and high. Low was defined as area where only one factor of adverse land-use is in place. Medium represents areas where at least two factors are at play, and high represents as many as three or more factors. Once these two composites were combined and assessed, the conservation target areas were identified as areas where medium-high levels of adverse land-use intersected with areas of biodiversity significance (Figure 9). The target areas identified in Figure 9 can be interpreted as regions which would require more in-depth surveys of land tenure, demographic, and socioeconomic characteristics in order to develop more sound conservation policy and practice. Such regions may present key opportunities for corridor designations, as currently defined under the Mesoamerican Biological Corridor. Regions outside of these target areas, where adverse land-use is not at a high level, which remain within a buffer distance of the national parks could be areas considered for the expansion of the existing national parks.

We also note that special attention should be made to the target areas defined within the existing national parks in the study region. While these areas are technically under the “strict protection” management category, there is evidence that land-use and deforestation still takes place within park boundaries, as supported by the fact that a percentage of the land designated as national park in this study region still remains in private hands. According to a 1999 study by MINAE, of all the protected areas, (all management categories), within the Central Volcanic Cordillera Conservation Area, less than 3% of that total protected area was in public landholding (SINAC-MINAE, 1999). The 2002 state of the nation report indicated that 11% of all national park land in Costa Rica remains as private property. Furthermore, the report noted that the government would require approximately $54.7 million USD to purchase that property (Estado de la Nación, 2002).

While we performed several iterations within this phase of the analysis, it became quite evident that the possibilities for adjustments in weights and ranking would not be exhausted within the scope of this study. Furthermore, the utility of the model clearly increases with the addition of each new dataset, provided the data are of a comparable scale and attribute quality. In terms of the specific datasets analyzed in this phase, it would be beneficial if all point data layers were to be integrated instead as polygon layers, should this information become available. Some may argue that the analysis should be limited to one vector data type, in the situation where similar variables, (such as land-use activity), are being assessed. Our analysis allowed for differing dataset types, (point and polygon), to be integrated into the same composite and representing the same category of land-use pressure. This was done in the interest of providing as many variables as possible given data availability.

Although we were able to test several iterations of weights and ranking for these composites and the resulting decision set, the weight/ranking schema were informed by an individual, (along with comparison with previous studies), rather than an expert or stakeholder group. A future study might focus on an expert/stakeholder team approach to assessing the criteria, and then provide a comparison with a study such as this which was individually-driven.

Phase I(b) - Integration of Datasets to District Level

While sixty-four districts are located entirely within this region of study, the conservation targets identified in Phase I intersect with twenty-four of them. A map series was generated within the detailed results set which represent various demographic and socioeconomic variables distributed by district within the study region, for both census years of 1984 and 2000. Although the results of this subset analysis of Phase I are not presented in detail within the context of this paper, the full results set may be consulted in the final thesis publication (Buck, 2004). Given the availability of variables at this district level, as well as the ability to target environmental services programs and incentives to administrative districts, we present the framework of the multicriteria decision-making and assessment model as a tool which can produced integrated results for both biodiversity and human population/sustainable development analysis that are scalable and can be generalized to spatial units more easily interpreted by decision-makers focused on development and resource allocation within their administrative regions.

Phase II – Comparison with Mesoamerican Biological Corridor Proposed Designations

Background of the MBC:

The original roots of the Mesoamerican Biological Corridor project were initiated with a project known as Paseo Pantera. In 1990, the Wildlife Conservation Society (WCS), in conjunction with the Caribbean Conservation Corporation (CCC), began working together to promote the concept of developing wildlife corridors throughout Central America, linking existing protected areas in order to allow for freer movement of keystone species, such as the Florida panther. The concept was first proposed by Archie (Chuck) F. Carr III of the WCS, who also coined the project name of Paseo Pantera – or – Path of the Panther. The theory behind Paseo Pantera was based primarily in ecological thought: that if it was possible to choose certain indicator species in a region (often large migrating mammals), and develop corridors for those species, taking into account their natural histories and movement patterns, then other species would also incorporate into the use of these corridors, and eventually a restoration of biodiversity levels might be accomplished. The US Agency for International Development (USAID) granted funding to both WCS and CCC in that same year, to place towards a five year pilot project of Paseo Pantera. The relative success in the efforts of those involved in Paseo Pantera, revealed itself in late 1994, when the governments of Central America signed a treaty for the creation of the biological corridor.

At the end of the project period in 1995, USAID put out a round of grants for bidding on the Paseo Pantera project, and in quite a shock to the Wildlife Conservation Society and the Caribbean Conservation Corporation, the grants were awarded instead to PROARCA (Programa Ambiental Regional para Centroamerica – Regional Environmental Program for Central America), in conjunction with the Nature Conservancy, the World Wildlife Fund, and the University of Rhode Island. The project name was then changed to its current name of the Mesoamerican Biological Corridor.

In an evaluation report, entitled "Defining Common Ground for the Mesoamerican Biological Corridor" and published in October of 2001, the World Resources Institute (WRI) defines the Mesoamerican Biological Corridor as having three specific aims:

- Protect key biodiversity sites
- Connect these sites with corridors managed in such a way as to enable the movement and dispersal of animals and plants
- Promote forms of social and economic development in and around these areas that conserve biodiversity while being socially equitable and culturally sensitive.

(WRI, 2001).

This final objective is what most clearly separates the MBC from the Paseo Pantera work. While the theory behind the Paseo Pantera project was based more strictly in ecological thinking, the objectives set out by the MBC have incorporated a development component that did not previously exist. WRI's report explains that the Mesoamerican Biological Corridor involves a social and economic development aspect due to prior concerns expressed by local groups over the perceived goals of Paseo Pantera:

> "The Paseo Pantera project proposal, which was defined mostly in terms of biological outcomes, worried many local residents, especially indigenous groups, who feared expropriation of their ancestral lands and the expansion of protected areas onto their territory. The broadening of the MBC's scope to incorporate socioeconomic goals was in part a response to these fears" (WRI, 2001).

Conservationists, however, are skeptical and critical that by drawing in socioeconomic development goals, the MBC programs are attempting to address problems which are beyond their capabilities to solve, and in turn, sacrificing progress what could be made for conservation in the name of political correctness.

The proponents of the Mesoamerican Biological Corridor program, however, say that it exemplifies what is known as the "bioregional" approach, where land-management plans are intended to develop strategies which "encompass entire ecosystems or bioregions, aiming to protect and restore them so they can simultaneously conserve biodiversity and sustain farming, forestry, fisheries, and other human uses" (WRI, 2001).

As noted in the background above, he Mesoamerican Biological Corridor concept and plan has evolved dramatically over the past decade, as is reflected to some extent in the spatial distribution of proposed corridor designations in various phases of the project. Three of these phases were outlined in Figure 6 of this paper, and are overlaid with the resulting weighted decision set of conservation targets in Figure 10.

Analysis Results:
The results of this simple overlay procedure reveal that the current proposed areas of the Mesoamerican Biological Corridor have minimal representation in the study region. Furthermore, there is significant change between the three phases, indicating changes in direction, administration, and definition of the biological corridor proposals.

While the other two maintain a regional Central American context, Proyecto GRUAS was a plan developed within Costa Rica, with the main objective of restructuring and expanding the existing protected areas system to ensure the preservation of at least 90% of the country's biodiversity (SINAC-MINAE, 1996). The proposed designations of Proyecto GRUAS, as observed in Figures 6 and 10, indicate the regions between the existing national parks where the proposal hoped to provide connectivity between and expansion of the existing system.

The second phase, as labeled "PROARCA/CAPAS" in both figures, has in fact been published by various sources, and is often accompanied by the disclaimer that it was merely a working version of the Mesoamerican Biological Corridor project, as envisioned in 2000. Within this conceptual map, we can observe that nearly the entire area outside of the national parks in this study region was considered as potential area for a corridor designation.

The current version of the Mesoamerican Biological Corridor proposed corridor areas was obtained from the offices of SINAC-MINAE, where each Conservation Area has taken on the responsibility of identifying corridor regions to be located within each area. As can be clearly observed in Figures 6 and 10, very little of the study region is assigned to a corridor designation, presenting a drastic difference from both the Proyecto GRUAS and PROARCA/CAPAS proposals.

CONCLUSION

While this study has presented only a subset of the potential complexity of a multicriteria decision-making assessment and analysis, we conclude that this analytical tool, while allowing for the integration of across-discipline variables, also creates a series of results which can be both adapted to the context of administrative/political boundaries, as well as compared with current conservation program target regions, such as the Mesoamerican Biological Corridor project.

Despite MINAE's identified objective of purchasing more private land holdings within existing protected areas in the study region, the Mesoamerican Biological Corridor continues to dominate the sources of international funding, making it very difficult for national conservation agencies and institutions to embark on conservation projects, without them being directly related to the MBC.

Although still in its early stages of development, it is hard to ignore the extent to which the Mesoamerican Biological Corridor has entered the vocabulary of conservationist and development-related entities throughout the region. The name itself is attached to so many environmental and sustainable development projects in each country that it is hard to say whether or not the name represents an institution or program, or whether it represents a concept for promoting conservation. However, the amount of money invested in the work since 1995 has been so significant that one wonders why the Mesoamerican Biological Corridor is so difficult to define.

Criticism continues to question whether the objectives of the MBC are too broad for its overall work to be effective in any one area, especially that of conservation. Jim Barborak, when asked recently to publicly comment on the MBC study published by the World Resources Institute, said the following regarding the broadened scope of the MBC:

> "We conservationists must certainly re-double our efforts to encourage increased national investment and donor community action in order to attack the problems of health, land tenure, credit, education, agricultural and forest production which afflict these marginal areas – but not with our own scarce resources and personnel. There are other institutions which have the responsibility and institutional capacity to attack these problems. To reorient a high percentage of the limited available funds for biodiversity conservation towards activities which aren't the most significant in the short term to accomplish this end will neither resolve the problems of poverty nor the problems of biodiversity conservation" (as translated from Barborak, 2001).

This sentiment was echoed in the recent Mesoamerican Protected Areas Congress held in Managua in March of 2003, (a precursor to the World Parks Congress held this past September). The debate took place primarily between a conservation scientist community and the proponents of the current Mesoamerican Biological Corridor. The conservationist community posed the question: "Where has the biology gone in the Mesoamerican Biological Corridor?". The MBC community response was that consideration of the human population constitutes an important part of the biology in the MBC.

While the purpose of our study has been neither to refute nor support either side of this debate, we do acknowledge that the changing geospatial definition of the Mesoamerican Biological Corridor has resulted in an apparent de-prioritization of this north-central region located within the study area. Current MBC literature indicates that the three priority regions for Costa Rica are located in the trans-boundary regions with Nicaragua and Panama (CCAD, 2002).

We also conclude that the establishment of biological corridors within this study region would not satisfy the conservation targets and needs as identified, especially given the current lack of a sound legal definition for the MBC within the context of Costa Rican law, (at this point in time the authors are only aware of the development of a property tax incentive program for areas formally placed in the MBC). Rather, there is strong indication that conservation in this study region needs to be focused on the expansion of existing protected areas under strict protection/management in order to combat the increasing level of forest cover fragmentation and related biodiversity loss.

However, given the financial and personnel resources of the Mesoamerican Biological Corridor program, as well as a strong presence within the programs of SINAC-MINAE and other conservation institutions in Costa Rica and internationally, the opportunity exists for further surveying and conservation targeting exercises to be implemented in regions throughout the country. Such targeting exercises would allow for MINAE to more appropriately direct its limited funds for the purchase of park in-holdings, increased management, and the eventual expansion of existing national parks and biological reserves.

To this end, in the creation of a program for the identification of conservation targets, we advocate the use of GIS and multicriteria decision-making and assessment models in the context of national, regional and local analyses. As presented within this study, the proposed model follows a simple and elegant framework, while complexity and quality generally increase with addition of variables as data layers, as well as with the informed decisions of groups as opposed to individuals. The current availability of new data sources, most notably of a national dataset of high-resolution aerial photography and MASTER imagery produced by the CARTA Mission in 2003, will allow for national institutions to produce analyses across a broad range of scales.

Finally, the capacity of these models to adequately represent the interaction of socioeconomic and demographic variables within the landscape is dependent upon the increased involvement of the social science community. While general population prosperity and sustainable development are a prominent consideration in the MBC and related programs, the actual modeling and surveying of these objectives as related to conservation objectives remains nebulous. Given the availability of scalable data, the malleable framework of the multicriteria decision-making assessment model as used within a GIS allows for the rapid integration of these variables. Without the collaboration of social scientists in the context of this analysis, the results will remain too limited in their ability to be adapted into conservation management in this landscape dominated by a web of human and natural resource interaction.

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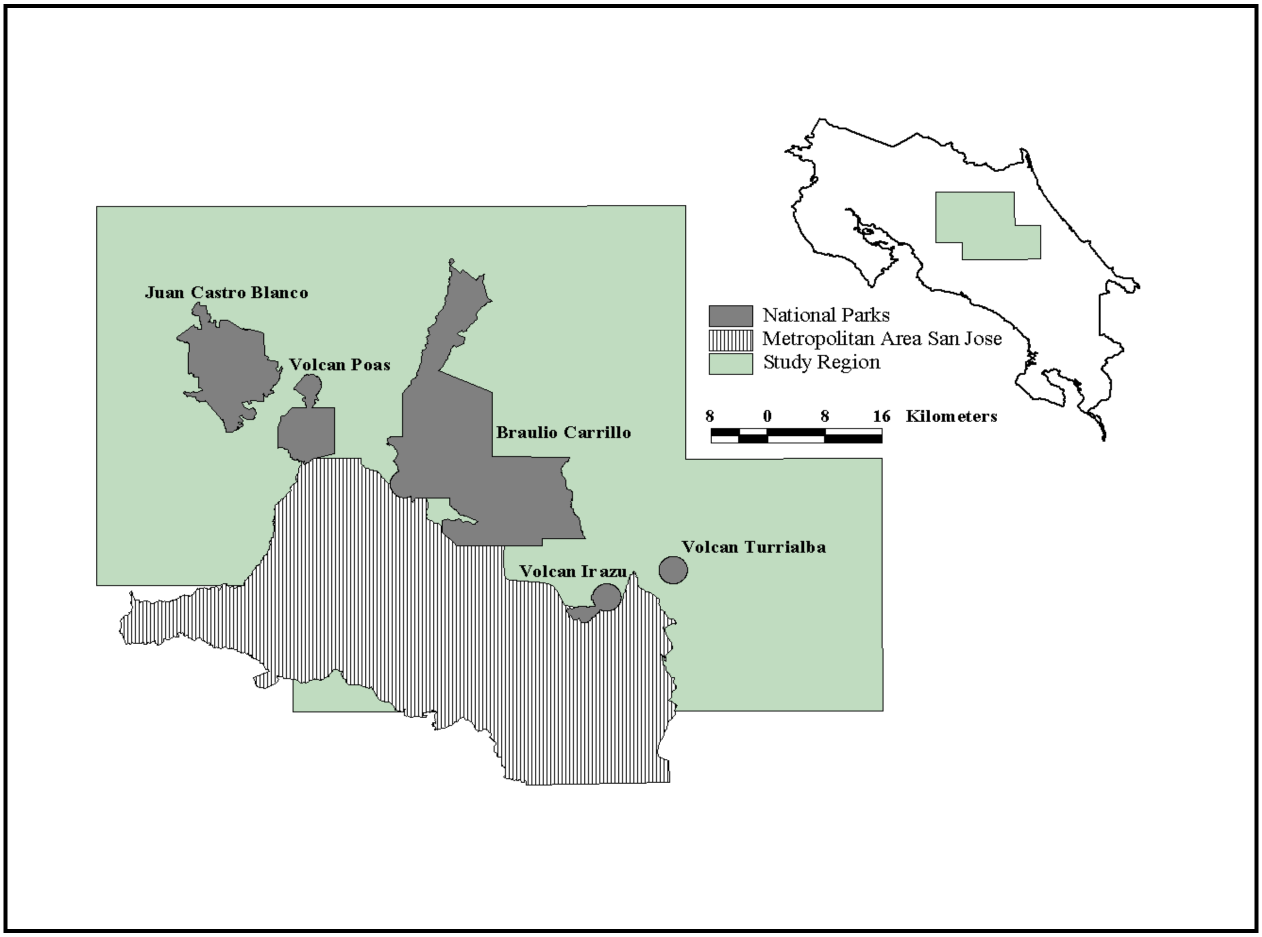


Figure 1. Study Region. Source: SINAC, INEC 2000.

Name	Area (hectares)	Year declared
Braulio Carrillo	47,583	1978
Volcán Poas	6,506	1971
Volcán Irazú	2,000	1955
Turrialba	1,256	1955
Juan Castro Blanco	14,453	1998

Figure 2. National Parks of Study Region, (SINAC 2000).

Management Category	**# Protected Areas**	**Total Area (hectares)**
National Parks	25	567,941
Biological Reserves	8	21,648
Natural Reserves	2	1,420
National Monuments	1	232
Protected Zones	31	157,094
Forest Reserves	11	282,660
National Wildlife Refuges	50	175,466
Wetlands	23	84,678
Total	**151**	**1,291,139**

Figure 3. Protected Areas of Costa Rica, (SINAC 2000).

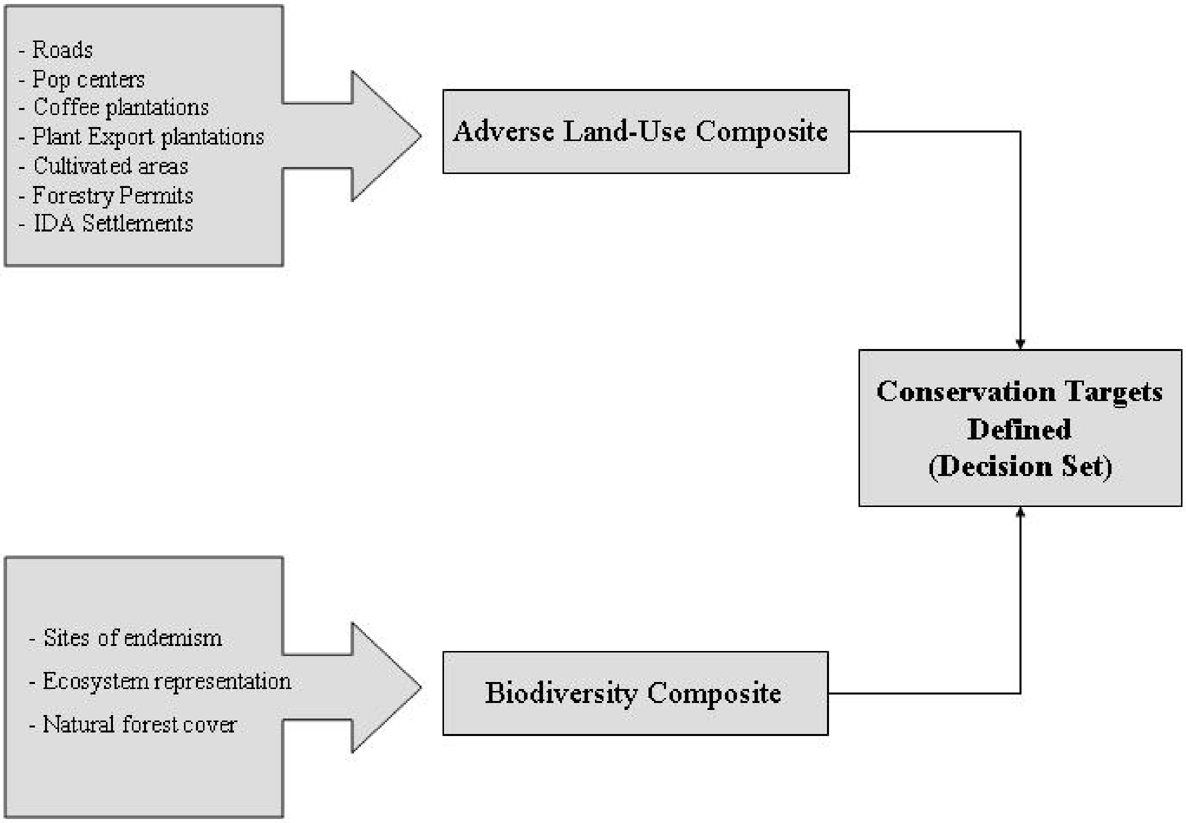


Figure 4. Phase I Analysis Decision Diagram

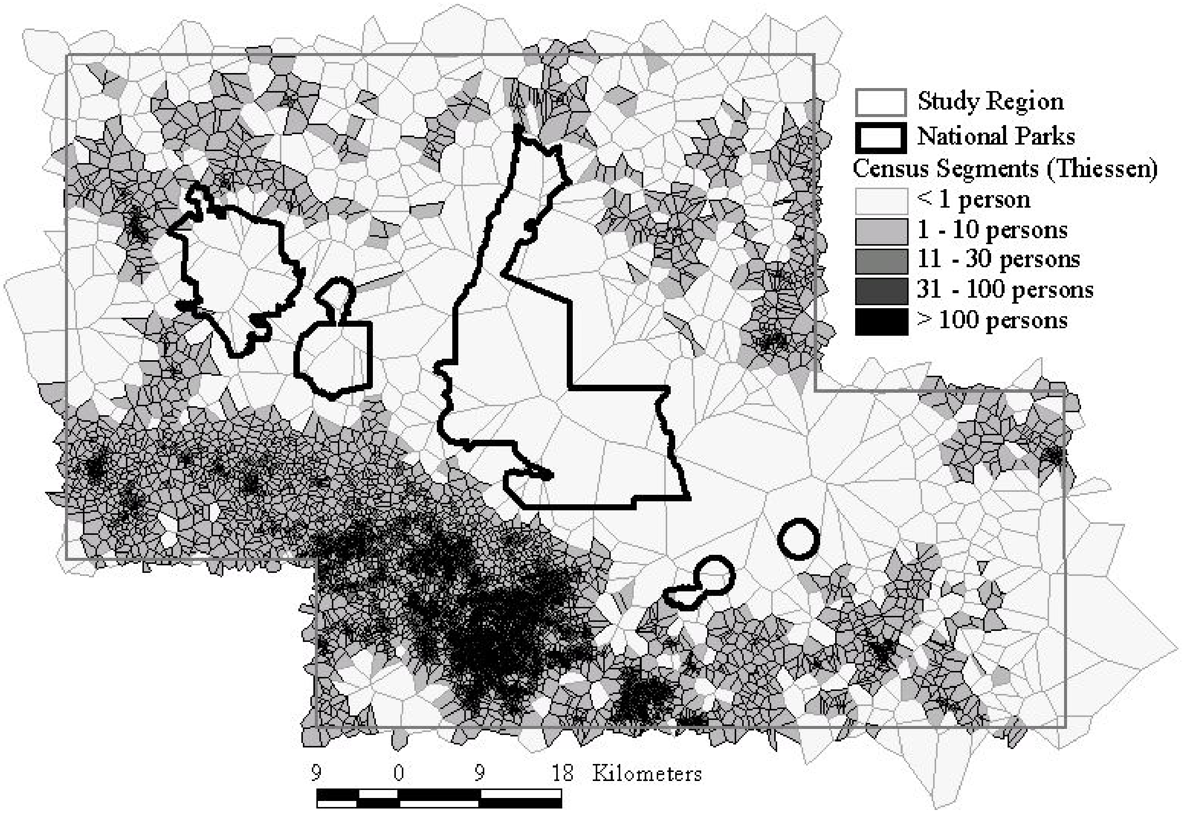
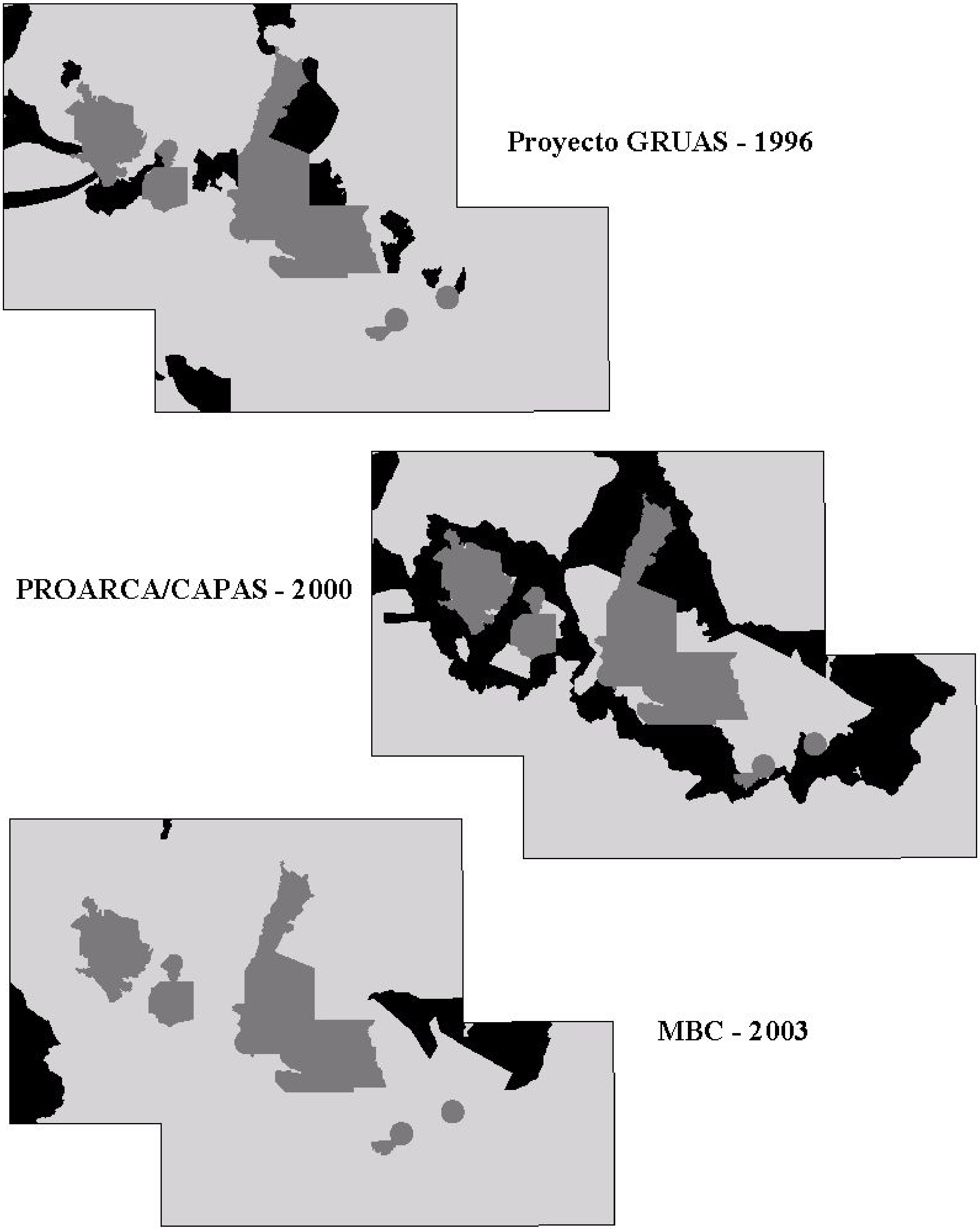


Figure 5. Population Density, Thiessen Polygon Distribution. Original Data Source: CCP, 2002.



Proyecto GRUAS - 1996

PROARCA/CAPAS - 2000

MBC - 2003

Figure 6. Evolution of MBC in Study Region. Sources as indicated: PROARCA (2000) and SINAC/MINAE (1996 and 2003).

Class range (km^2)	**# of fragments 1986**	**Total forest area 1986 (km^2)**	**# of fragments 2000**	**Total forest area 2000 (km^2)**	**Change in # of fragments (2000 - 1986)**	**Change in total forest area (km^2) (2000 – 1986)**
0.02 – 0.1	226	10.75	299	14.67	73	3.92
0.1 – 0.5	128	27.64	154	33.67	26	6.03
0.5 – 1.0	27	19.15	23	15.07	-4	-4.08
1.0 – 5.0	16	35.97	26	48.33	10	12.36
≥ 5.0	4	1,652.38	9	1,077.69	5	-574.69
Total	**401**	**1745.89**	**511**	**1189.43**	**110**	**-556.46**

Figure 7. Change in natural forest cover between 1986-2000 as function of fragment size. Source: Forest cover data: FUNDECOR, 2000.

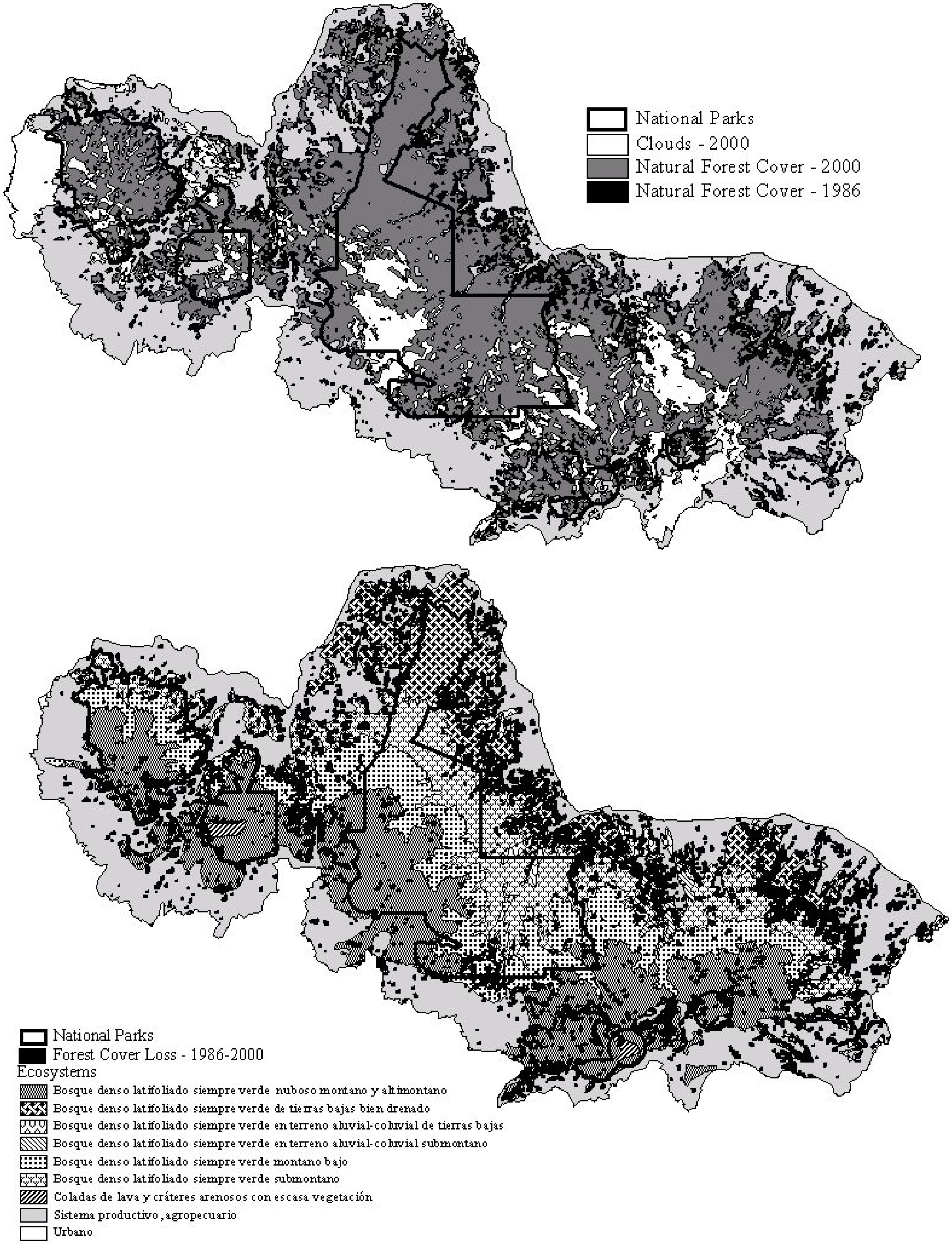


Figure 8. Forest Cover Change and Loss by Ecosystem.

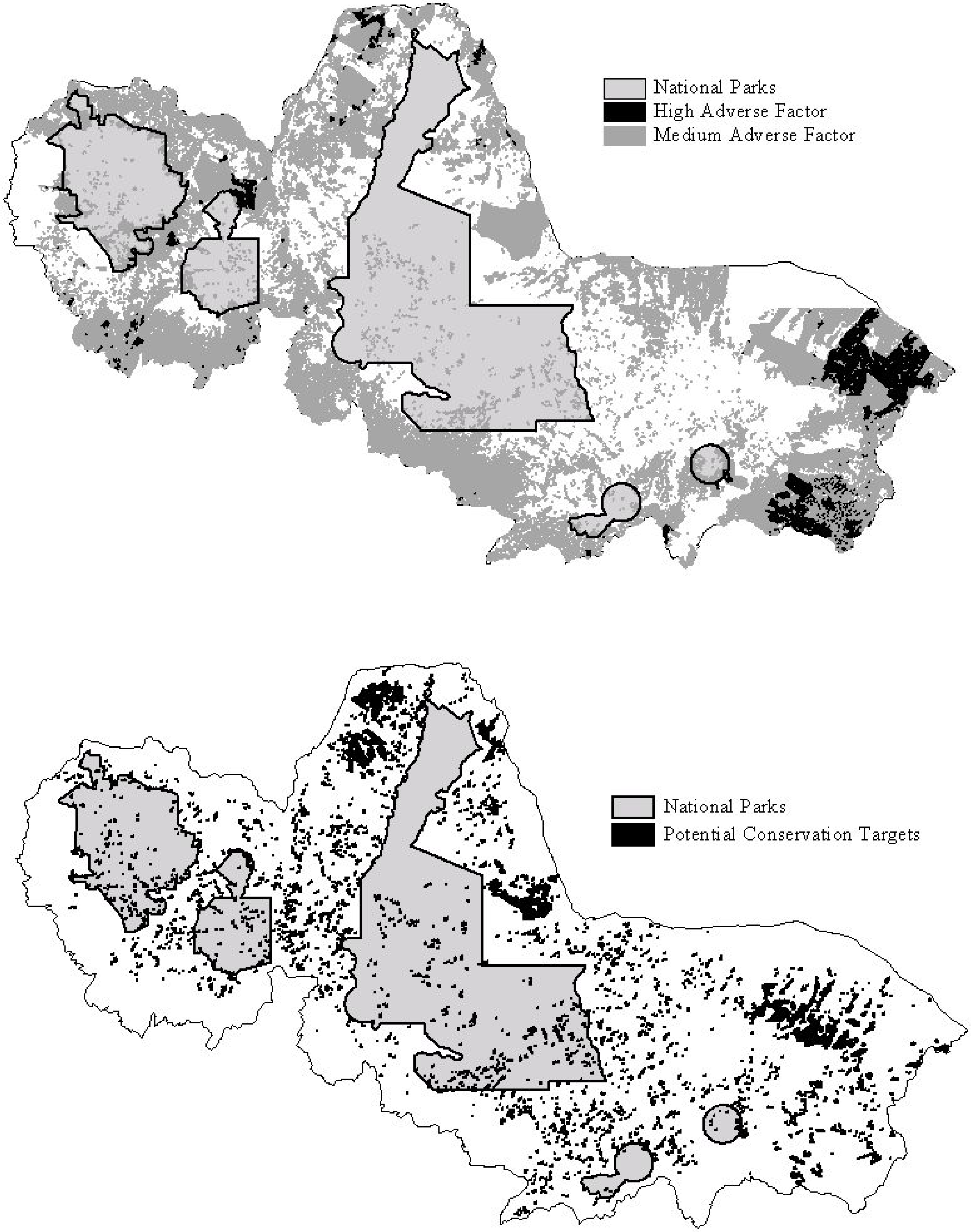


Figure 9. Medium/High Adverse Effect and Overlap of Medium/High Adverse Effect with High Biodiversity Significance

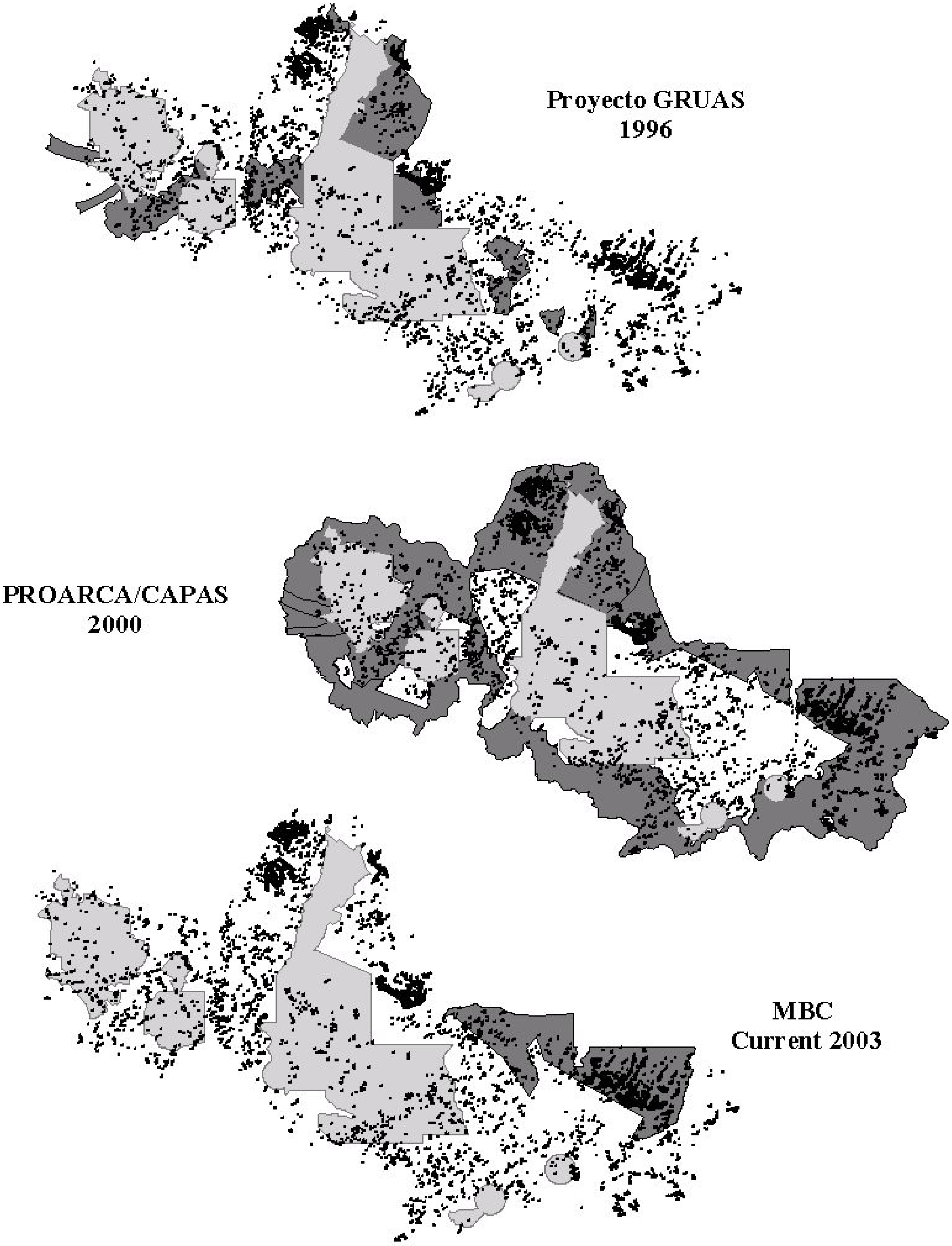


Figure 10. Series of Proposed Biological Corridors and Overlay with Conservation Targets.

Appendix I.

Geospatial Datasets Used in Analysis

Phase I – Spatial Multicriteria Decision-Making Assessment

Name	GIS Dataset Type	Institution
Land Cover, 1986/96, 2000	Raster Image	FUNDECOR
Census Segment Centroids	Vector Point	CCP (UCR)
Ecosystems	Vector Polygon	CCAD (multi-institution)
Protected Areas/Cons Areas	Vector Polygon	SINAC/MINAE
Environmental Service Projects (PSA)	Vector Polygon	FONAFIFO/MINAE
Roads	Vector Line	IGN
IDA settlements	Vector Polygon	IDA
Sites of Endemic Plants	Vector Point	INBIO
Digital Elevation Model	Raster Image	CATIE
Coffee Plantations	Vector Point	MAG / ICAFE
Export Plant Plantations	Vector Point	MAG
Forestry Permits	Vector Point	SINAC/MINAE
Private Conservation Reserves	Vector Point	Red Reservas Privadas

Phase I(b) – Integration with Districts and Census Information

This phase of the analysis included the above datasets, as well as:

Name	GIS Dataset Type	Institution
District boundaries	Vector Polygon	INEC
Canton boundaries	Vector Polygon	INEC

Phase III – Comparison of Target Conservation Areas with MBC Corridor Designations

The above datasets are referenced in this final phase of the analysis, as well as the following:

Name	GIS Dataset Type	Institution
Proyecto GRUAS	Vector Polygon	SINAC/MINAE
PROARCA Corridors	Vector Polygon	PROARCA-CAPAS (multiple)
Present MBC Designations	Vector Polygon	SINAC/MINAE