Selection of Protected Areas within the Savegre River Watershed in Costa Rica: Landscape Planning Implications for Transboundary Protection

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Abstract

This paper offers a landscape approach to site selection/expansion of existing protected areas that fall across non-traditional boundaries where a more holistic approach is necessary. In the case study of the Savegre River watershed in Costa Rica, a conservation suitability analysis was applied to examine the feasibility of establishing new protected areas in this watershed through the analyses of available biophysical and socio-economic data. Geographic Information Systems (GIS) was used to determine the suitability of land available for conservation. Three 'themes' were applied to the existing base information – heterogeneity of landforms, ecological integrity and conservation values – and analysed in ArcView 3.2a Spatial Analyst. Weights were applied to each of the landuse planning units to determine areas of highest conservation value. Socio-economic constraints were layered to determine constraints for protection and proposed new protected areas were finally identified using conservation planning principles and reserve design criteria.

Introduction

The conservation planning community recognizes that effectively conserving biodiversity depends on an ecosystems management approach integrating protected areas into wider land and water use planning (IUCN 1994). Natural areas do not adhere to political boundaries. To confine and divide natural ecosystems with arbitrary boundaries and apply different, isolated management styles only damages already fragile systems.

This paper briefly summarizes research within the Savegre River watershed, Costa Rica (Fernandes 2002) in coordination with the joint project between the National Biodiversity Institute (INBio) and the Spanish Development Agency. The results were eventually integrated in the overall land use management plan for the watershed.

The availability of a large amount of existing base information was essential to the research and was provided mainly as GIS data from INBio. The methodology took a landscape or coarse filter approach to conservation planning for the watershed. It was adapted from a WWF-Canada conservation suitability analysis developed for assessments in Canada. Due to time constraints, no new or raw data was developed for the study area.

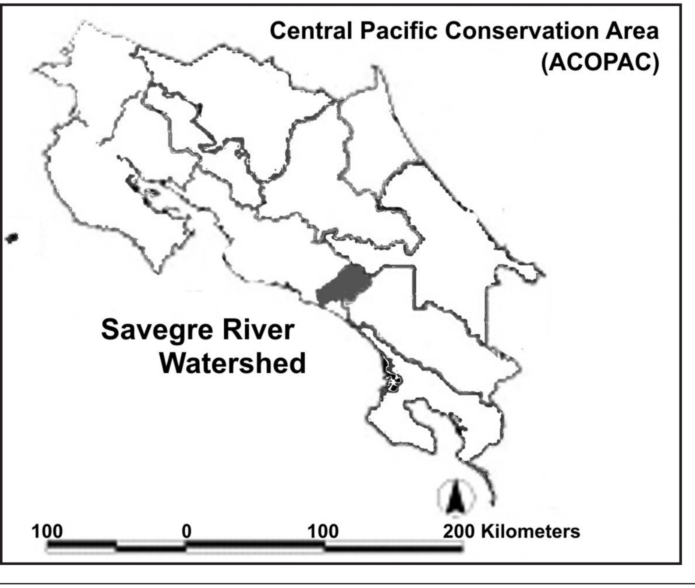
The primary research goal was to develop a methodology that could evaluate the feasibility of establishing viable and stricter protected areas within the Savegre River watershed above the existing Forest Reserve Management. The main objectives were to: 1) Evaluate the conservation value of public and private lands in the Savegre River watershed using available biophysical, social and economic data.; and, 2) Identify options for suitable areas to establish zones of protection and conservation in the watershed. Those interested in more detail on the methodology, analysis and application are referred to Fernandes (2002).

Costa Rica and the Savegre River Watershed

Costa Rica accounts for 0.42% of the world's landmass, but contains a 4% representation of all plants in the world. Approximately 250,000 species are found within its borders – with more continually being discovered. Costa Rica maintains its global status at the forefront of biodiversity conservation and management due to continued efforts to preserve its natural heritage and biodiversity by setting aside approximately 25% of its land cover to some form of conservation protection.

The research area falls within the ecological boundaries of the Savegre

Figure 1. Central Pacific Conservation Area (ACOPAC)



River watershed located in the Central Pacific Conservation Area (ACOPAC) on the west coast of Costa Rica (Figure 1). The 58,918 hectare watershed (590 km^2) travels through six different elevation ranges – from ocean level to an alpine elevation of 3,491 meters – and seven life zones (INBio *et al.* 2001). The Los Santos Forest Reserve, the Cerro Vueltas Biological Reserve and the Cerro Narra Protected Zone are the three main protected areas within the watershed (Figure 2).

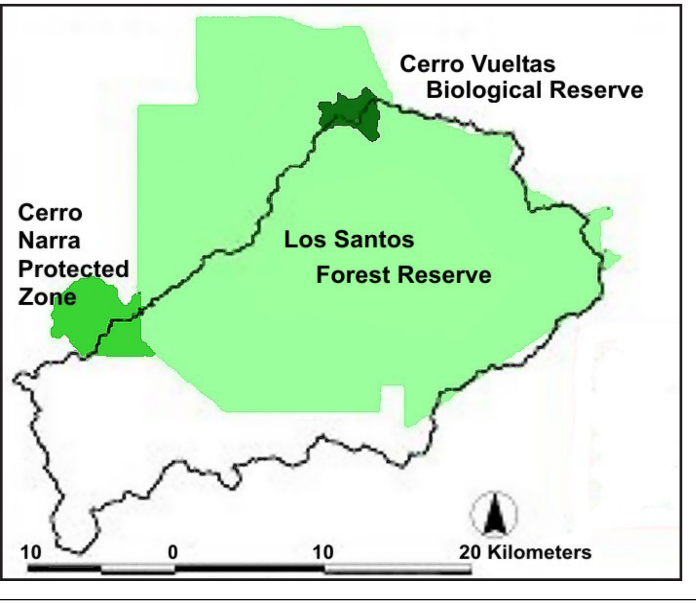
The unique landscape of the watershed – variations in topography, altitudinal gradients, solar exposure, humidity, precipitation and the presence of seven life zones – combine to create an area of high biodiversity and floristic wealth (INBio *et al.* 2001).

In the watershed, 63% of the total land surface is covered in natural ecosystems and of that, 62% is occupied by dense forest.

The Savegre River watershed and its biodiversity have been negatively affected by diverse development pressures, mainly at lower altitudes on the Pacific coast, adjacent to the Transamerican Highway at the watershed's highest reaches to the east, and along the periphery where secondary highways penetrate the watershed. Most of the resource rich interior is protected and contains large tracks of unfragmented landscape due mainly to the legal protection of the forest reserve and rugged landscape that make it difficult to access interior locations.

Within the river basin, 47 of Costa Rica's 88 ecosystems were identified, including 9 natural ecosystems, 15 semi-natural and 23 cultural ones (INBio

Figure 2. Existing Protected Areas in the Savegre River Watershed



et al. 2001). Due to the coarse scale of the research, these ecosystems were reclassified to group those with smaller areas into logical categories. The large number of ecosystems is in part a product of the altitudinal/elevation gradient, which provides a wide variety of natural conditions, and options for the development of human activities. Diverse economic activities in the low altitudinal level have created greater wealth of cultural ecosystems.

Natural ecosystems represent the largest surface area within the river basin occupying approximately 63% of the total area.

Methodology

Since biodiversity occurs at multiple scales and should be considered at the genetic, species, and ecosystems levels of organizations, the most appropriate scale of analysis for this study was taken to be a broad, coarse level. Planning focused on species habitat requirements rather than on specific species is not only economical, but also ensures longevity of habitat and species survival (Margules 1997). A lack of complete field data for fauna (and to an extent flora) excluded methodologies that used species as indicators for more suitable methodologies.

A review of methodologies led to selection of a conservation suitability analysis created by Quebec Lumber Manufacturers' Association AMBSQ-WWF Canada (2001) as most appropriate for this study. It was considered best suited to assess areas for higher conservation protection and assist in the design of the protected areas.

This method is extremely flexible – as more refined information is found, layers can be added to the framework. Additionally, it can be weighted to suit different conservation planning goals and objectives. This methodology also supports and complements a gap analysis and considers biophysical, social and economic variables.

Geographic Information Systems (GIS) have long been used as a mapping method for planning, decision-making and ecosystem monitoring related to ecosystem challenges (Parks Canada 2000). In this case, vector based data was available, but had to be converted to raster based data to perform spatial analysis. A suitability ranking was created using criteria for the map layers to create different outcomes based on the selection of a weighting scheme (Table 1).

Development of Themes and Theme Components

The conservation suitability analysis focused on the three themes: 1) heterogeneity of landforms; 2) ecological integrity; and 3) conservation values (Figure 3). Although the AMBSQ-WWF Canada report (2001) concentrated only on public lands, this research incorporated both public and private lands to assess conservation value. Three main changes were made to the AMBSQ-

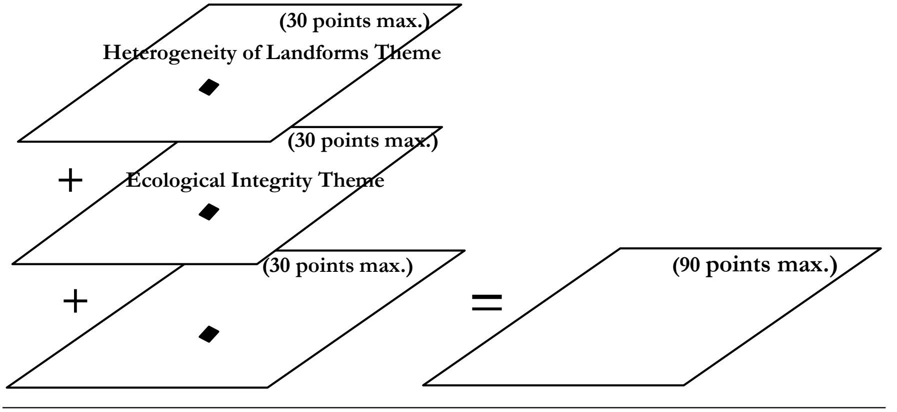
WWF Canada methodology to reflect the specific characteristics of tropical climates, watershed management goals and available GIS information for the region. A comparison of these changes is included in Table 1.

Buffers along rivers are a form of erosion control from adjacent land use sedimentation runoff and can improve the quality of water for both species and

Table 1: Comparison of Methodologies, Scenarios and Associated Weights

Themes	Original AMBSQ-WWF Canada Methodology (2001)	Changes to Methodology (Fernandes 2002)	Scenario 1 Weights	Scenario 2 Weights
heterogeneity of landforms	topography-relief, parent material texture (data unavailable), surficial deposits and slope position	soils composition, geology and slope and aspect of the watershed	30	50
ecological integrity	roads, primary logging roads, railways and hydro-electric transport lines, weighted the buffered zones and areas free of clearcuts	fragmented forest landscapes and road buffers	30	20
conservation value	headwaters, older forests and wetlands	land uses (ecosystems), vegetation coverage, erosion potential and ecological corridors (rivers)	30	20
Totals			**90**	**90**

Figure 3. Illustration of the Three Themes



human use. Rivers are also natural corridors for species movement and the protection of a river's riparian area provides extremely important habitats for species.

For each theme, components were grouped into categories that could be ranked and data was rasterized. Spatial analysis was performed to determine three conservation value ranges (high, medium and low) and two scenarios (Table 1) that weighted the themes differently. Results were converted back into vector data, overlaid and compared with existing protected areas and constraint maps that have been developed.

The analysis was initially tested using 1 ha^2 cell size. Results clearly showed that finer detail was necessary for three reasons: 1) slope and aspect themes were misrepresented; 2) buffers for secondary rivers were not captured; and 3) final map outputs provided greater detail for protected area boundary location, as well as the improved general aesthetics of the final maps.

Heterogeneity of Landforms Theme

Spatial heterogeneity is often linked as a factor that affects biotic diversity (Burnett *et al*. 1998). Other geomorphological elements such as aspect and slope have also been shown to influence vegetation. Burnett *et al*. (1998) found that plots with high geomorphological heterogeneity supported the highest plant diversities among all combinations of plant type and diversity.

A 'neighbourhood statistic' analysis using ArcView 3.2a, Spatial Analyst was performed to identify the most heterogeneous areas by counting the number of different enduring features that fell within a 400 m radius of each cell. Using the 'variety' statistic (ESRI 1996) the number of different heterogeneous landform values within each circle was determined, with the value assigned to the centre cell.

Kavanagh and Iacobelli (1995) suggest that for protected areas to be effective, disturbance regimes need to be considered in defining their size. A small protected area may be drastically impacted or eliminated by disasters such as fire, flood, or landslide. Designing for a larger site ensures that the protected area will have a greater opportunity to survive (Armesto and Pickett 1985; Reice 1994 as cited in Nichols *et al.* 1998).

The resulting map (Figure 4) indicates strong heterogeneity throughout the watershed. Almost the entire watershed was covered by high conservation values.

Ecological Integrity Theme

Ecological integrity was used as the second theme. Non-fragmented ecosystems are more likely to reflect the most attributes such as composition, structure and function. The size and configuration of individual protected areas will influence how well ecological processes and biological diversity are represented

(Kavanagh and Iacobelli 1995).

The two spatial units used to define the ecological integrity theme were island size of fragmented forest ecosystems and road fragmentation. Fragmented dense forest ecosystems were ranked according to island size using existing INBio categories (Table 2) for natural ecosystems – the smallest fragment (<3 hectares) the lowest rank and the largest fragment (>500 hectares) given the highest rank.

Figure 4. Heterogenity of Landforms Theme

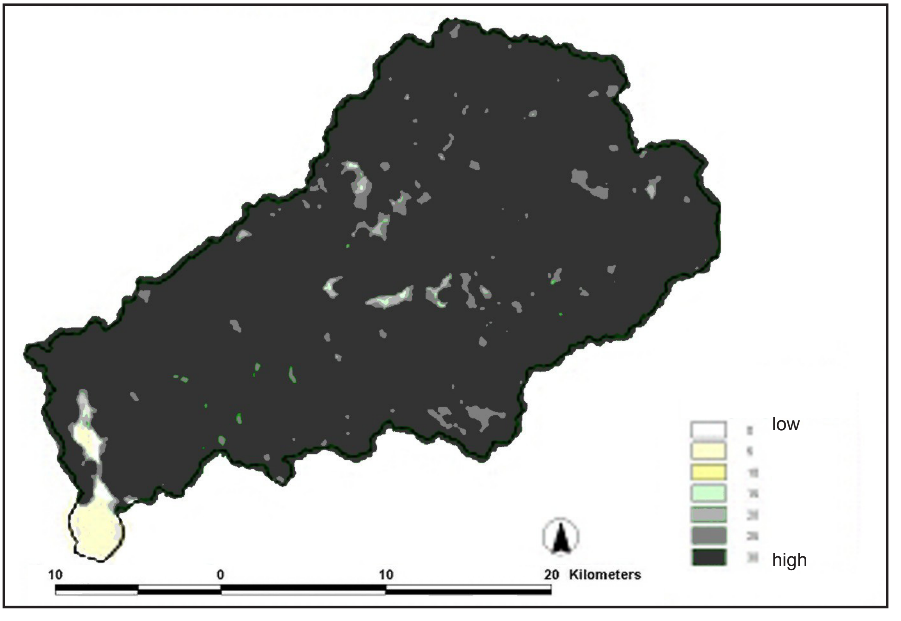


Table 2: Fragmentation of Natural Ecosystems & Associated Weights

Class	Number of Islands	Total Size (Hectares)	% of Total Watershed	Associated Weight
< 3 ha	20	28.08	0.07	5
3 – 50 ha	35	578.21	1.53	10
50 – 100 ha	2	140.79	0.37	15
100 – 150 ha	2	252.00	0.67	20
150 – 500 ha	1	155.73	0.41	25
> 500 ha	3	36,364.12	96.14	30
Total:	**64**	**37,823.08**	**100.00**	

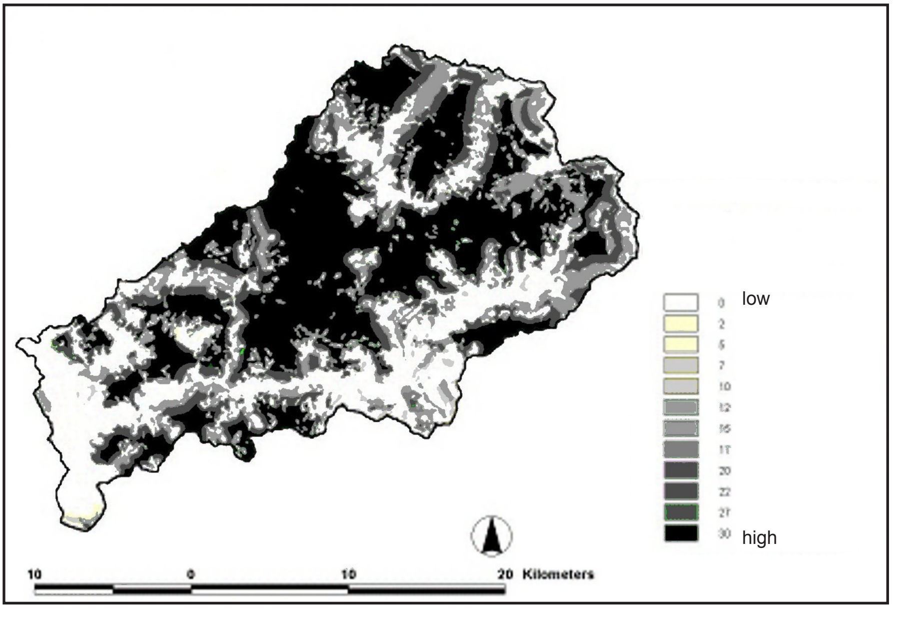
Source: ECOMAPAS (2001), excluding associated weight figures.
Vegetative island ranges do not exist for: 200-300 and 350-500 ha.

Roads have been shown to have devastating effects on ecosystems and wildlife movement, so they were identified and included in this research. Three levels were identified: the Inter-American Highway (fully paved); primary (partially paved); and secondary roads (unpaved, dirt roads). These roads were buffered with two zones and weighted to reflect a lowest to highest conservation value the farther away from the road one moved. The areas outside of the buffer zones were associated with the highest conservation value (Table 3).

Table 3: Road Systems Classification, Buffer Widths and Weight Values

Class	Associated Weight
Class 1: Inter American Highway (paved)	
Buffer 1 (1,000m)	0
Buffer 2 (1,000m)	10
Outside of buffers	30
Class 2: Primary Roads (partially paved)	
Buffer 1 (500m)	0
Buffer 2 (500m)	10
Outside of buffers	30
Class 3: Secondary Roads (not paved—dirt roads)	
Buffer 1 (250m)	0
Buffer 2 (250m)	10
Outside of buffers	30

Figure 5. Ecological Integrity Theme



It is important to note that volumes were not known for the road system in the watershed.

The ecological integrity theme map (Figure 5) indicates (not surprisingly) strong cores of conservation value within unfragmented landscapes and lower values within settlement areas and along road systems. The lower watershed floor also appears to have some of the lowest conservation values that are consistent with the dominant cultural ecosystems.

Conservation Values Theme

The spatial units used to define the conservation values theme consisted of: headwaters conservation; vegetation coverage; ecological connections; and

Table 4: Conservation Values and Associated Weights

Conservation Value Variables	Associated Weight
Headwaters (measured by elevation ranges)	
< 1,000m	0
1,000m to 1,500m	5
1,500m to 2,000m	10
2,000m to 2,500m	15
2,500m to 3,000m	20
3,000m to 3,500m	30
Vegetation Coverage	
Natural Ecosystems: Dense Forest, Dense Mangrove and Dense Chusquea Grassland	30
Semi-Natural Ecosystems: Thin Forest, Dense Wooded Scrub, Dense Scrub, Thin Scrub	20
Cultural Ecosystems: Dense Grassland, Wooded Grassland, Shrub Grassland, Aceite Palm Plantation, Coffee Cultivation, Teak Plantation, Melina Plantation, Rice Cultivation, Pejiballe Plantation and Mora Plantation	0
Ecological Connections	
Primary Rivers	
Buffer 1 (100m)	30
Buffer 2 (200m)	20
Outside of buffers	0
Secondary Rivers	
Buffer 1 (30m)	30
Outside of buffer	0
Erosion Potential	
Category 1: none (no values)	--
Category 2: slight (no values)	--
Category 3: moderate	10
Category 4: severe	20
Category 5: very severe	30

erosion potential (Table 4).

Headwaters are considered to provide important ecological functions and their protection is important for downstream water quality. The greatest number of headwaters are located in the 2,000m to 3,500m ranges and the greatest weight values were given to these elevation ranges.

In Mexico, traditional shaded coffee fields were confirmed to harbour high biodiversity and found to play an important conservation role (Moguel and Toledo 1999). Though it is recognized that some cultural landscapes such as the various tree plantations, the various cultural grasslands and the smaller shrub ecosystems do support biodiversity, these ecosystems were weighted '0' due to their non-permanent nature and management practices that see these areas cleared of vegetation on a rotational basis.

Ecological connections were added to the methodology due to the nature of the study area. Buffers along rivers and streams offer a number of advantages. They are not only an effective way of reducing the velocity of runoff from upland areas and provide natural filtration of runoff from sedimentation and crop fertilizers (Brooks *et al*. 1997), but they are natural corridors for flora and fauna. Slope was not taken into consideration when determining the buffer widths.

Erosion potential was identified as an important variable in tropical areas especially within watersheds with characteristically steep slopes. The vegetation cover that intervenes between the extremely high rainfall for tropical areas and the thin and sensitive soil layer beneath offer a critical control on erosivity (Newsom 1997). The Savegre River watershed is very susceptible to extreme flooding in the lowlands during the rainy season. As a surrogate, this is the weakest variable; however, protection of erosion prone areas is extremely important for environmental and socio-economic reasons.

Findings

The conservation values theme map (Figure 6) indicates the highest conservation values are found in the high elevation ranges in the alpine and sub-alpine floors and along the main river courses. The medium conservation values were concentrated in the mid-elevation ranges.

When the existing protected areas (Cerro Nara Protected Zone and Cerro Vueltas Biological Reserve) were added to the high conservation value layer, a natural extension to the Cerro Vueltas Biological Reserve was apparent. Expansion of the Cerro Nara Protected Zone is also possible, but with greater difficulty as more fragmentation has occurred with the natural vegetation coverage (Figure 7).

A comparison of identified protected areas and high conservation value

Figure 6. Conservation Values Theme

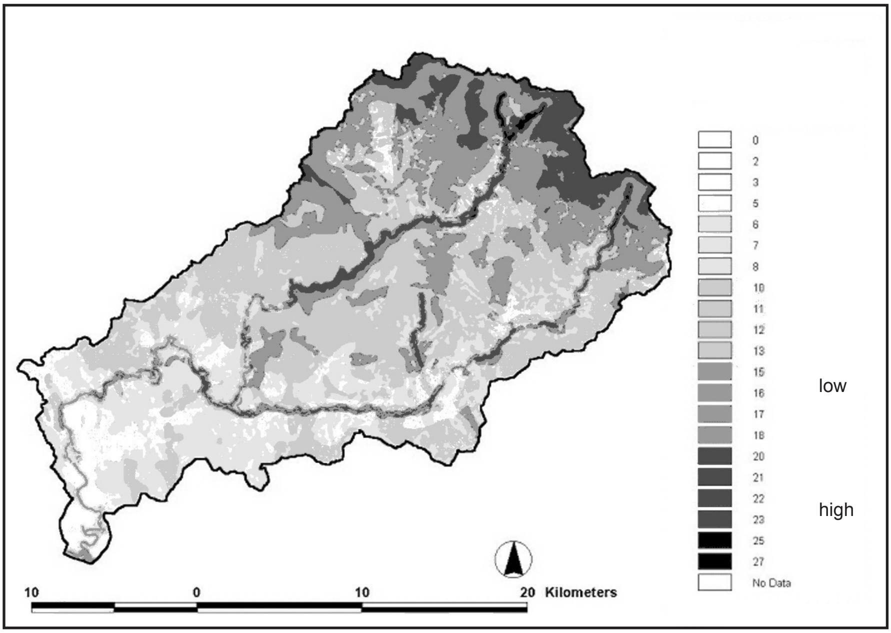
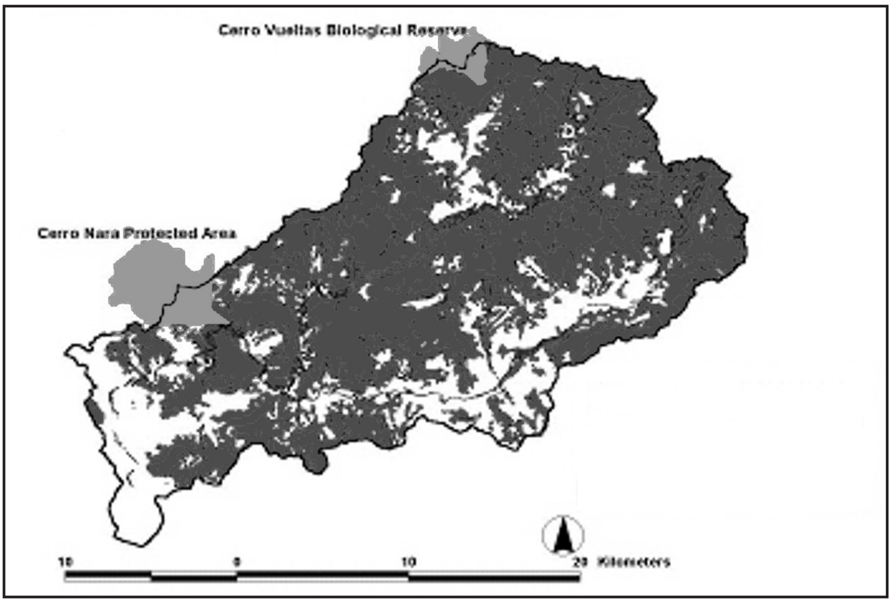


Figure 7. Scenario 2 and Existing Protected Areas Boundaries



layers found that the majority of lands owned by the State fell within high conservation value zones. In addition, these lands formed a natural extension to Cerro Nara and Cerro Vueltas. Conversion of government-owned land is extremely valuable to the existing protected areas.

The final map uses reserve design criteria applied to lands with high conservation value (Figure 8). It identified boundaries for a proposed national park, extensions to the existing Cerro Vueltas Biological Reserve and Cerro Nara Protected Zone, as well as proposed biological corridors. The total area proposed for all new protected areas is summarized as follows:

New National Park: 3,851 hectares

Biological Reserve Extension: 8,178 hectares

Biological Corridor: 5,567 hectares

Biological Runner: 13,543 hectares

TOTAL: 31,139 hectares

The total land proposed for protection is significant and constitutes approximately over half of the watershed's total area. The core proposed protected areas (new national park and biological reserve extension) constitute 12,029 hectares in total or approximately 20% of the watershed.

Conclusions and Implications of Research

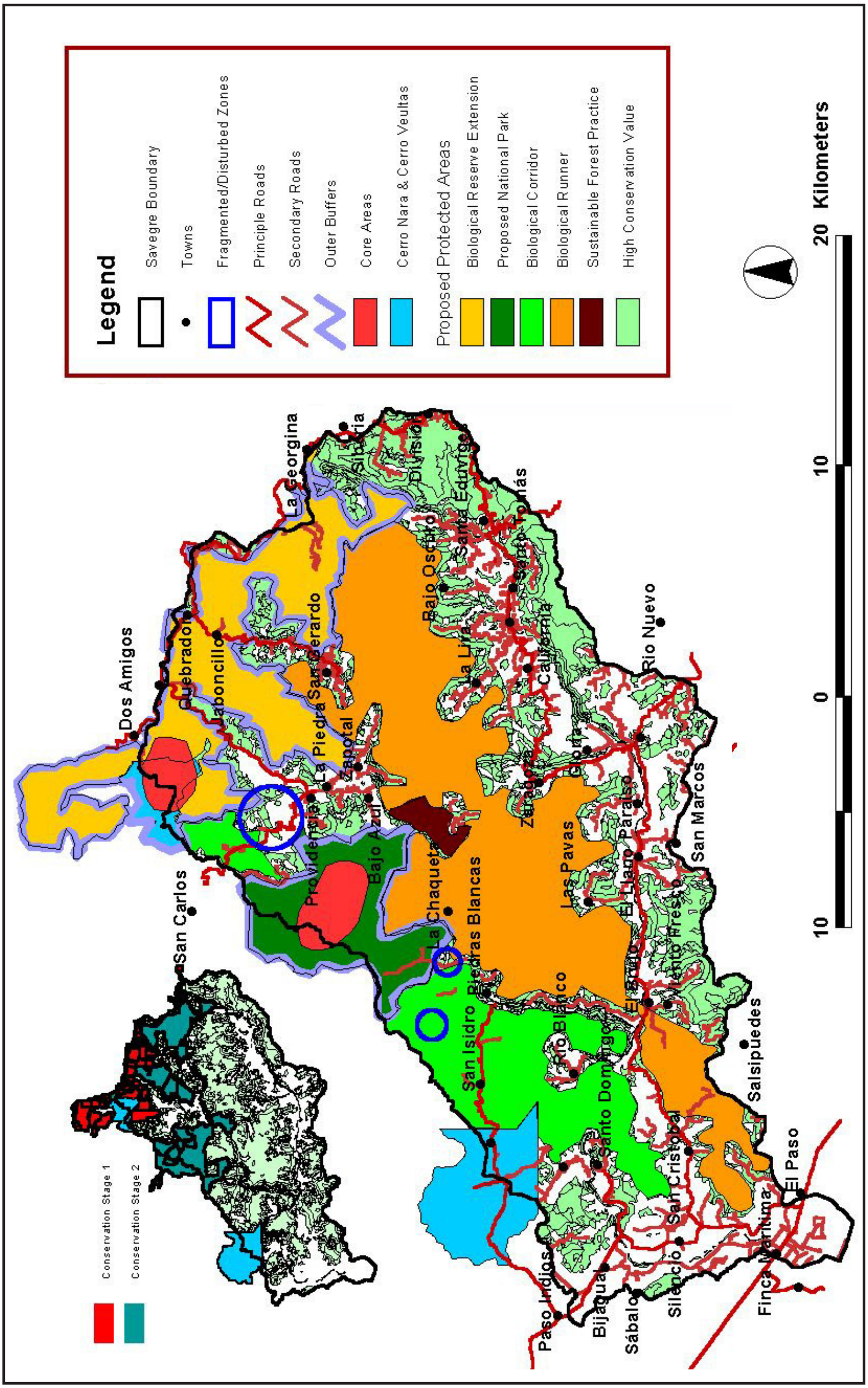
Areas of high conservation value were identified to determine if the watershed contained landscapes that warranted protection. Public lands were identified and found to contain high conservation value that required a protection designation.

Research concluded that it was feasible to establish new protected areas in the Savegre River watershed including extensions to the existing Cerro Vueltas Biological Reserve, the creation of a new national park, identification of protected cores, identification of inner buffers and outer buffers (or zones of transition) that could be used for community-based management projects, and the identification of biological corridors that could link protected zones and provide a biological runner through the important elevation ranges of the watershed.

Implications for Landscape Planning

This methodology offers a multi-disciplinary, landscape approach to site selection and/or expansion of existing protected areas that is flexible and can easily be applied to transboundary sites where the land in question straddles non-traditional boundaries. Landscape planning through the use of a conservation suitability analysis has strong implications for the conservation planning field and can assist protected area planners to plan more holistically, provides a tool to plan proactively and can incorporate vast arrays of data sources for analysis.

Figure 8. Reserve design applied to high conservation values



This is one step in the overall conservation planning process – i.e., the identification of the most suitable land with high conservation value. The establishment of human-nature relationships is essential to conservation planning and this is one of the main strengths of landscape planning that can be applied to transboundary protection. The natural extension to this coarse level analysis is a finer more detailed site-specific analysis at the community level.

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