A Multiscale Method for Assessing Vegetation Baseline of Environmental Impact Assessment (EIA) in Protected Areas of Chile

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Abstract—The exponential growth of recreation and tourism or ecotourism activities is affecting ecological processes in protected areas of Chile. In order to protect protected areas integrity, all projects inside their boundaries must pass through the Environmental Impact Assessment (EIA). The purpose of this research was to design a multiscale method to assess vegetation for the EIA baseline in protected areas of Chile and developing countries. The data obtained could be used to indicate patterns of biodiversity of the ecosystem at different scales, and at the same time monitor changes due to human activity. The method was applied in Conguillío National Park, in South Central Chile. Three scales of vegetation characterization were used. They are complementary and can be modified depending on the sensitivity of the ecosystem, the intensity of impacts and the human resources and technology available. Our method proved to be efficient in characterizing ecosystem diversity at different scales. We encourage the use of this multiscale method to assess vegetation baseline in protected areas.

The increasing world use of protected areas (PAs) for ecotourism (Ceballos-Lascurain 1996) can damage natural resource quality (Rivas 1994) and jeopardize the main role of protected areas in conserving biodiversity. This global trend is affecting the National Protected Areas System of Chile (SNASPE).

SNASPE covers 18.3% of the Chilean territory. Compared to an average of 8.2% of protected area worldwide (McNeely and others 1994), this percentage seems to be sufficient to achieve conservation goals, even though most of the Chilean protected areas are located in the climatic extremes of the country. Many important and diverse ecosystems in central Chile are scarcely represented or not at all in the system (Armesto and others 1992; Lara and others 1995; Villarroel 1992). SNASPE has four major environmental problems: 1) lack of representation of important ecosystems, 2) mining and extractive activities inside the PAs, 3) cross-boundary impacts like fragmentation, exotic weed invasions and pollution and 4) impacts produced by development and use of new infrastructure inside PAs.

Since 1996, the Chilean Forest Service has promoted a new system of tourism development in PAs (Lazo 1996). Now, private companies can apply for permits to develop tourist facilities and infrastructure inside PAs. Recreation development is necessary to satisfy the demand of the increasing number of tourist visitors to SNASPE.

Chilean environmental law demands that all projects in protected areas pass through an Environmental Impact Assessment procedure (EIA). The idea is to recognize, monitor and mitigate the impacts of development inside PAs. One of the key stages in the procedure is to develop a baseline or a description and study of initial conditions in the influenced area (Greene 1984; Stork and Samways 1995). The EIA baseline must describe and analyze biotic, abiotic and social components of the impacted system. Assessment, monitoring and mitigation of the impacts require accurate and useful baseline data (Conesa 1995).

Ecologists have used vegetation as an indicator of soil and climatic conditions for a long time (Grossman and others 1998). Recently, many authors have shown the potential of vegetation to indicate biodiversity of entire ecosystem (Krebs 1994). Vegetation controls most of the environmental conditions in ecosystems, including the energy and material flows. Furthermore, vegetation is the result of other animal-plant ecological interactions like herbivory, seed predation and frugivory. Vegetation characterization has proven to be one of the easiest ways to assess and classify the whole ecosystem. Vegetation is preferred because it can integrate a broader range of ecological processes in a site or landscape if some specific measuring criteria are used (Mueller-Dombois and Ellenberg 1974; Grossman and others 1998). At the same time, more information is available about vegetation than any other biotic component; probably because vegetation analysis demands less time and resources than the study of any other biotic component, but also because there has been a historically bias in focusing on vegetation for assessing natural systems.

In developing countries like Chile, there are not enough resources to assess all variables in biotic components for an EIA baseline, so some easily measured biodiversity indicator must be found (Stork and Samways 1995). With a multiscale approach, vegetation can be used to improve the characterization of ecosystem diversity. Scale-dependant patterns and processes in vegetation can be captured, and their interactions can be analyzed and understood. The

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correlation between temporal and spatial scale in ecological processes (O'Neill and King 1998) can be used, in this multiscale approach, to assess ecosystem function.

Objectives

In this study, we propose a multiscale method to use vegetation as an indicator for the biotic component of the EIA baseline for PAs. We define three levels for this approach, depending on the scale and the detail required for different development projects and the environmental characteristics of the affected area. Second, we apply the method to Conguillío National Park. The application tries to probe the advantages of our method compared to traditional one scale or plot based vegetation assessment methods.

The Method

We developed a multiscale method to analyze vegetation for the EIA baseline, using three stages. The stages correspond to successive approaches to vegetation from a broad to a fine scale. The cost of the successive stages increases with the detail required. The method for assessing an EIA vegetation baseline in PAs considers the three following stages: physiognomy, stand structure and composition. In this paper, we present a general description of each stage and the results of the application to our study area. We used Fosberg (1967) as a conceptualization to define the three stages.

Physiognomy

The vegetation physiognomy is defined by its overall physical appearance (Fosberg 1967). It combines structural features (height and spacing), growth form (morphology and aspect) and leaf attributes (seasonality and phenology) of dominant species (Grossman and others 1998). Even when physiognomy is the result of structure and composition of the vegetation, it is not necessary to directly measure these characteristics to identify vegetation physiognomy (Shimwell 1972). The spatial representation of plant communities is one key stage for assessing environmental impacts of development projects. The physiognomic categories for classification are broad (for example: forest, shrubland and grassland) and easy to assess even by non-specialists. We proposed using wide physiognomic categories to characterize and classify patches at landscape level. For this purpose, remote sensing technology must be used. Physiognomic types can be used to determine landscape structure (patches, matrix and landscape elements), to assess landscape diversity (Forman 1995) and to provide information about the impacts of the project in landscape elements. Spatial statistical models can be use to interpret the impacts on landscape (Turner and Gardner 1991).

We defined two steps for assessing physiognomic characteristics of vegetation:

<u>1. Physiognomic types identification and characterization.</u> This step integrates physiognomic and structural attributes for describing vegetation types after aerial photointerpretation. We proposed using the International category described by Fosberg (1967) and cited in Mueller-Dombois and Ellenberg (1974). Field recognition and confirmation of information collected with aerial photointerpretation are necessary to validate the results.

<u>2. Vegetation mapping using physiognomic types.</u> Physiognomic types should be represented in vegetation maps. Spatial distribution of the types, cover (absolute and relative) and possible impacted areas are easy to assess with vegetation maps. Geographic Information Systems (GIS) facilitate the management of data and the incorporation of more spatial variables. The spatial display of the information is crucial for management decisions. This is especially when a protected area still lacks a vegetation map, or the existing maps are in too broad scale to assess human impacts.

Stand Structure

Structure is defined as the spatial arrangement of the vegetation biomass (Fosberg 1967). Three elements define structure: 1) vertical structure, 2) horizontal structure and 3) abundance (Shimwell 1972). Therefore, any method to assess vegetation structure in the stand scale must consider these three variables in order to address the structural patterns of plant communities at the stand scale. We propose the two following basic steps for sample stand structural variables for EIA baseline in PA.

<u>1. Random stratified sampling of structural attributes.</u> In order to measure quantitative structural attributes like basal area, height, coarse woody debris, etc., we propose random permanent plot sampling, using physiognomic types as strata. Permanent plots will be useful for monitoring of the impacts after the execution of the project. This procedure includes structural profiles in horizontal and vertical dimension, using the same randomized points.

<u>2. Regeneration assessment.</u> Regeneration of dominant species must be addressed, using smaller plots inside the permanent plots. Seedling abundance and size distribution are useful indicators of stand dynamics.

Composition

Composition is the list of plant species that form vegetation (Fosberg 1967). Floristic classifications use species or groups of species to define vegetation types (Grossman and others 1998). Composition is crucial to determine plant diversity through the assessment of plant species richness and evenness. Functional attributes of vegetation, as life forms or deciduousness, can also be inferred using composition analysis.

We propose the following steps for assessing composition:

<u>1. Floristic Relevés.</u> The Braun-Blanquet method for classifying vegetation, using plant composition, has been shown to be consistent, easy to use and effective in describing plant communities and plant diversity. An adequate number of relevés must be sampled in order to cover plant community heterogeneity. Relevé plot size must be determined by species-area curves, depending on the vegetation type. This simple procedure optimizes the species richness assessment compared with standard size plot. Vegetation heterogeneity must be captured by stratifying the sample area, using physiognomic types or structural attributes. Vegetation in ecotones and riparian habitats, usually biodiversity hot-spots,

should be sampled with higher intensity to capture overall species diversity. Soil and disturbance features should also be recorded to understand general patterns of environmental gradients.

2. Community Classification. We propose the use of tabular comparison classification, using character species (Mueller-Dombois and Ellenberg, 1974). Multivariate pattern analysis could be used to confirm or to improve tabular classification. Communities should be named either inside or outside the phytosociological hierarchical system, depending on the information available for the study area. The use of phytosociological nomenclature allows ecosystem comparisons in a regional scale.

3. Floristic List. The floristic list should consider all vascular plant species found in relevés. Plants collected outside relevés must be included. Using both methods of plant collection, we ensure sampling of rare species or species with patchy. The species should be classified as native or exotic. Taxic diversity (Bisby 1995), expressed in families, genus and species number, should be calculated to assess biogeographical factors of plant diversity.

Case Study

In 1995, CONAF licensed the development of the Conguillío National Park recreation area. The project included the construction and management of 12 cabins and a restaurant. Old buildings and 100 campgrounds were already located in the area.

The area of study (38°38'S - 71°39'O), defined by direct impacts of the project, consists of 241 ha, where altitude ranges between 1,000 and 1,100 m. Climate is cool-moist-temperate with dry summer months. The average annual precipitation is around 2,000 mm. Forests and shrublands cover most of the area. *Araucaria araucana* (Monkey puzzle tree) and *Nothofagus* spp. (Southern beeches) dominate vegetation (Donoso 1993 and Gajardo 1994). Soils in this area have predominantly formed from recently deposited volcanic ejecta. Soil heterogeneity is greatly due to differences in the nature of the parental material (ashes, pumice, and lava) and time since its deposition (Casertano 1963; Peralta 1975; Pauchard 1998). Llaima Volcano activity and Conguillío Lake floods are the major natural disturbances affecting the area.

Results

Physiognomy

We found eight physiognomic types: four forests, three shrublands and one grassland. Physiognomic attributes in comparison with floristic attributes are shown in Table 1. Due to the small area affected by the project, we did not apply landscape analysis to the case study.

Stand Structure

Using stand structure attributes, we identified different successional stages related to the physiognomic types. Forests and shublands present an uneven aged structure. In older forests, *Nothofagus* spp. show an even aged stand structure, while *A. araucana* shows cycled recruitment. Heterogeneity within the stands is due to gap dynamics that create a fine mosaic of dominant tree cohorts. *Nothofagus dombeyi* (Coihue) forms old-growth forests with heights between 30-35 m and DBH around 80 cm, sharing the dominant story with *A. araucana* with DBH of 50 cm. On the other hand, *Nothofagus antarctica* (Nirre) only forms shrubland or short forest where *A. araucana* is the emergent story. In the understory, *Chusquea coleu* (Fam. Bambuceae) creates dense patches inside forests of *Nothofagus* spp. Most of the forest and shrubland has one sub-shrub story of *Pernettya* spp. (Fam. Ericaceae). Tree regeneration occurs in gaps where microclimate conditions are adequate for seedling growth. *A. araucana* seedlings prefer areas with herb or sub-shrub cover. *Nothofagus* spp. seedlings occupy bared areas with exposed mineral soil or coarse woody debris in advanced decay.

Composition

We classified 67 relevés in six plant communities, using tabular comparison. Four plant communities were forest, one shrubland and one grassland (Table 1). *N. dombeyi* communities are part of the subasociation Gaulherio Nothofagetum dombeyi araucarietosum Finck 1995 (Finckh 1996). *N. antarctica* communities belong to the sub-alianze Ribesi-Nothofagenion Eskuche 1969 (Eskuche 1973). The cluster analysis of the relevés by Euclidean distance showed similar patterns of clustering as the tabular comparison. This output helped to validate our tabular comparison results. We found 115 vascular plant species, of which 87 (83%) were natives and 18 (16%) exotic. The 115 species belong to 67 genera and 45 families. *A. araucana* is the only species within a conservation category (Benoit 1989).

Discussion

The advantage of our method is that it combines three different scale approaches to capture the whole diversity of plant communities. Most vegetation studies focus on only one of these criteria. In the last decade, literature has shown the importance of assessing ecological phenomena in different scales (Peterson and Parker 1998). Ecological processes are scale dependent, so a broader range of processes will be assessed if you look at different scales. In order to probe our method's advantages, we will analyze the case study results, discussing the implications for diversity assessment.

Physiognomy

Physiognomic classification allows us to display and to analyze vegetation types spatial patterns. Mapping and GIS management of the data give us a notion for assessing possible impacts of the project on vegetation. In the study case, the process of physiognomic classification clarifies the idea that we are dealing with complex vegetation mosaics where forest, shrubland and grassland are occupying different sites related more with soil and geomorphological attributes than with climatic gradients. Future research could check the effectiveness of physiognomic classifications at a landscape scale for assessing vegetation patterns

Table 1—Comparison between physiognomic and floristic classifications of vegetation. Physiognomic type, stratum, height, and area are attributes of structural sampling. Floristic plant communities, total number of species, average number of species per relevé and number of relevés sampled are attributes of composition stage. The stratum are: A: arboreus, I: Intermediate, ar: shrubs, h: forbs.

Physiognomic type	Dominant species	Height (m)	Stratum	Area (ha)	Floristic plant community	Total number of species	Average No. of spp. per relevé (range)	Number of relevés sampled
Tall closed evergreen forest	*Nothofagus dombeyi* - *Araucaria araucana*	35	A,I,ar,h	54,4	*Nothofagus dombeyi* - *Adenocaulon chilensis*	28	12 (9-15)	8
Medium tall closed evergreen forest	*N. dombeyi*	25	A,I,h	5,4	*Nothofagus dombeyi* - *Osmorrhiza chilensis*	8	5,3 (3-8)	3
Tall open evergreen forest	*A. araucana* - *Pernettya* spp.	30	A,ar,h	18,6	*Nothofagus antarctica* - *Pernettya pumila*	22	7,7 (4-12)	13*
Short closed deciduous forest	*Nothofagus antarctica* - *Pernettya myrtilloid*	13	A,I, h	16,5	*Nothofagus antarctica* - *Chusquea coleu*	36	8,9 (6-13)	21
					Nothofagus antarctica - *Embothrium coccineum*	31	12 (7-18)	8
Tall closed deciduous shrubland	*N. antarctica* - *A. araucana*	10	A,ar,h	17,8	*Nothofagus antarctica* - *Pernettya pumila*	22	7,7 (4-12)	13*
Tall open deciduous shrubland	*N. antarctica* - *A. araucana*	20	A,ar,h	71,0	*Nothofagus antarctica* - *Pernettya pumila*	22	7,7 (4-12)	13*
Short evergreen shrubland	*Berberis buxifolia* - *Ribes cucullatum*	1	ar,h	5,7	*Berberis buxifolia* - *Acaena pinnatifida*	28	9,7 (8-15)	10
Grassland	*Solidago chilensis* - *Phacelia secunda*	0,3	h	2,2	*Solidago chilensis* - *Phacelia secunda*	5	3,2 (5-1)	4
Volcanic ashes				13,8				
Lake border				35,0				
Total				240,7				

*Total number of relevés are in the three physignomic types.

and human impacts in PAs. For this purpose, the National Inventory of Native Vegetation of Chile would be an interesting example of state of the art in vegetation classification and PAs of developing countries.

Stand Structure

In the case study, the structural stage allows us not only to make predictions about vegetation dynamics, but also about wildlife habitat characteristics. Using stand structure, we can identify the relationship between physiognomic types and successional phase or disturbance regimes. In the study case, structural patterns of forests and shublands confirm Veblen (1982) and Veblen and others (1995) hypothesis of *A. araucana* - *Nothofagus* spp. dynamics. *A. araucana* seems to become dominant in absence of huge disturbance like lava. *A. araucana* uses the periods after low-intensity disturbances to grow. In these periods, *Nothofagus* spp. dies, liberating limited resources, especially light. Then *Nothofagus* spp. will establish again and due to their higher growth rate, they soon get into the upper canopy competing successfully for light and suppressing *A. araucana* growth. Structural complexity gets higher in old-growth forest of *N. dombeyi* and lower in shrubland and grassland (Table 1). Stands with lower rates of severe disturbances have a more diverse structure represented in the number of stories, coarse woody debris and snags. *N. dombeyi,* in absence of disturbances, suppresses *A. araucana* growth and dominates the canopy.

The structural stage of our method gives information about the habitat diversity and dynamic of the ecosystem. Parameters like coarse woody debris, story number and density allow predictions to be made about habitat and microhabitat diversity and characteristics. Regeneration and size distribution of dominant trees are indicators of successional patterns. In general terms, for some authors, structure is the most important variable to be assessed because it determines ecosystem function.

Composition

The study case results show that floristic plant communities are associated with structural patterns (Table 1), but in some cases different plant communities are present in the same physiognomic types. Cluster analysis helps to clarify plant communities and validate the results of tabular comparison. Species richness is similar in all communities, only secondary forests of *N. dombeyi* and grassland have lower values (Table 1). Even when species richness in the area seems low, taxic diversity presents an unusual number of families and genera, which could be products of higher endemism rates.

Our method for composition proved to be efficient in capturing species richness (alpha diversity) and patterns of distribution of floristic plant communities. Rare species, indicator species and relative abundance of species are captured. Further modification could improve sampling statistical performance without damaging the advantages of easy and quick sampling. Randomization and statistical stratification of the relevés by physiognomic types would help to make quantitative inferences about species diversity. Plant communities can be classified in phytosociological hierarchical systems, but this option is constrained by the availability of regional classification studies.

Application Considerations

The application showed that the method was feasible to apply to Chilean Protected Areas. Not major problems were found in using the sampling techniques. Remote sensing data is available for all Chilean territory, so physiognomic classification can be achieved. The National Vegetation Inventory has released new information already processed. Vegetation maps 1:50.000 represent PA. GIS must be used to process the data, so cost could arise.

Structural attributes are easy to sample even by rangers or people without technical background. With a good sampling design, a broad area can be covered with a minimum cost in instruments and work hours. Floristic stage involved a more time consuming sampling. Taxonomic classification requires expertise for field recognition, but national herbariums have a good collection of plants than can make easier to identify the specimens.

The main problem of our design is the qualitative approach in information collection. This may imply difficulties in measuring changes in vegetation with statistical rigor. Further work, using remote sensing technology and sampling design, must be done to achieve this goal.

External issues can also affect the applicability of the method. Political and economical restrictions of the public institutions involved in PAs management can weak this method performance in Chile or other developing countries.

Conclusions

1. Vegetation is a useful indicator of biodiversity for the EIA baseline in PAs. To assess vegetation baseline, we propose a multiscale method, using three stages: physiognomic, structure and composition.
2. The three stages are correlated with basic ecological parameters. Structural diversity, habitat diversity, ecotones, edge effect, vegetation dynamic and others can be assessed using the multiscale method.
3. The multiscale method proved to be more efficient to capture whole ecosystem diversity than the one-scale methods. It provides the information necessary to satisfy the requirements of biodiversity assessments.
4. The three stages give flexibility to the method. The detail level will depend on the objectives and the impacted area. The application of the method is feasible in Chilean PAs and other countries.

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