Versión impresa ISSN 0304-8799
Versión electrónica ISSN 0717-9200

BOSQUE

BOSQUE / VOLUMEN 33 - N° 3 - 2012

CONTENIDO

VOLUMEN 33 N° 3 / 2012

BOSQUE es publicada por la Facultad de Ciencias Forestales y Recursos Naturales de la Universidad Austral de Chile. Fundada en 1975 con una periodicidad anual, a partir de 1985 aumentó su periodicidad a semestral. A partir de 2003 tres números al año (abril, agosto y diciembre).

BOSQUE is published by the Faculty of Forest Sciences and Natural Resources, Austral University of Chile. It was first published as a yearly journal in 1975. Since 1985 it has been issued twice a year and since 2003 it is issued three times a year (April, August and December).

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Fono: 56 (63) 221998. Correo Electrónico: revistabosque@uach.cl
Página web: http://www.revistabosque.cl
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BOSQUE es financiada por la Universidad Austral de Chile.

Versión impresa ISSN 0304-8799
Versión electrónica ISSN 0717-9200

BOSQUE

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VOLUME 33 N° 3 / 2012

BOSQUE 33(3): 243-244, 2012 DOI: 10.4067/S0717-92002012000300001

EDITORIAL

Biennial IUFRO Landscape Ecology Conference

Conferencia bienal de Ecología de Paisaje de IUFRO

Cristian Echeverría

Chair, 2012 IUFRO Landscape Ecology Conference (www.iufrole2012.cl)
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The recent Biennial Conference of the IUFRO Landscape Ecology Working Party 8.01.02, entitled, "Sustaining humans and forests in changing landscapes: forest, society and global change" was held in Concepción, Chile from the 2nd to the 12th of November, 2012. This Working Party is coordinated by Jiquan Chen (University of Toledo, Ohio, USA) and seeks to promote and facilitate the application of landscape ecology concepts in the policies and practices of forested landscapes worldwide. It also encourages communication and interaction among scientists who have an interest in landscape ecology and forestry. For this purpose, the Working Party has gathered in seven places across the world: Slovenia, the United States, Canada, Japan, Italy, China and two years ago, Portugal. This year, it was the first time that the Working Party gathered further south in the southern hemisphere, and in particular, in Latin America. The region offers new challenges to forest landscape ecology due to its tremendous heterogeneity of ecosystems and diverse socioeconomic conditions. South American forests represent a large fraction of the world's biodiversity and, in turn, are characterized by progressive deforestation and degradation.

During the 2012 Conference, we received diverse types of scientific contributions such as keynote speakers' plenaries, symposia, oral presentations, posters and short manuscripts for publication in an 'ISI' journal. The contributing topics ranged from forest landscape management to studies on spatial patterns and ecological processes including the effects of climate change and landscape planning. These studies were conducted in diverse, contrasting landscapes, from the sub-Antarctic forests in Cape Horn, Chile to the Siberian forests, including landscapes from Brazil to Australia and Turkey.

It is our major interest to promptly divulgate these works through publication in an open-access scientific journal that is widely known in Latin America. With this goal, the Issue 33 (3) of the Bosque Journal is dedicated to the publication of the short manuscripts accepted by the conference's scientific committee. The scientific committee was formed by Louis Iverson (Chair, USDA Forest Service, USA), João Azevedo (Instituto Politécnico de Bragança, Portugal), Jean Paul Metzger (Universidade de Sao Paulo, Brazil), Sandra Luque (IRSTEA, France), Ajith Perera (Ontario Ministry of Natural Resources, Canada), Guillermo Martinez Pastur (Centro Austral de Investigaciones Científicas, Argentina), Damasa Magcale-Macandog (University of the Philippines Los Banos, Philippine) and Jan Boegart (Universite Libre de Bruxelles, Belgium). The process of publication was coordinated by Laura Nahuelhual (Universidad Austral de Chile), who is a member of the conference's organizing committee.

EDITORIAL

Conferencia bienal de Ecología de Paisaje de IUFRO

Biennial IUFRO Landscape Ecology Conference

Cristian Echeverría

Chair, 2012 IUFRO Landscape Ecology Conference (www.iufrole2012.cl)
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Entre el 2 y 12 de noviembre del presente año se celebró en Concepción, Chile, una nueva versión del congreso internacional IUFRO (International Union of Forest Organizations) del Grupo de Trabajo en Ecología de Paisaje 8.01.02, titulada *Sustaining humans and forests in changing landscapes, forest, society and global change*. Este grupo es coordinado por Jiquan Chen (Universidad de Toledo, Ohio, EE.UU.) y tiene como objetivo promover y facilitar la aplicación de los conceptos de la ecología de paisaje en políticas y prácticas de paisajes forestales a nivel mundial. También busca incentivar la comunicación e interacción entre científicos con interés en la ecología de paisaje y manejo forestal. Con este propósito, se han sostenido siete reuniones internacionales en diversos países, a saber, Eslovenia, Estados Unidos, Canadá, Japón, Italia, China y, hace dos años, en Portugal. En noviembre 2012, la reunión del Grupo de Trabajo se celebró por primera vez en el hemisferio austral y, en particular, en América Latina. Esta región ofrece enormes desafíos para la ecología de paisajes forestales, debido a su gran heterogeneidad de ecosistemas y diversas condiciones socioeconómicas. Los bosques de Sudamérica representan una parte importante de la biodiversidad del planeta y, a su vez, se caracterizan por sufrir una progresiva deforestación y degradación.

En el encuentro de Concepción, Chile, se recibieron diversos tipos de contribuciones científicas, tales como plenarias, simposios, comunicaciones orales, pósteres y manuscritos cortos para su publicación en una revista 'ISI'. Las temáticas variaron desde el manejo de paisajes forestales hasta el estudio de patrones espaciales y procesos ecológicos, pasando por los efectos del cambio climático y los cambios del paisaje. Estos trabajos fueron conducidos en áreas de estudio muy diferentes y contrastantes, desde los bosques sub-antárticos del Cabo de Hornos hasta los bosques del sur de Siberia, incluyendo los paisajes de Brasil, Australia y Turquía, entre otros.

Es nuestro interés dejar a disposición del público, lo antes posible, estos trabajos científicos, de texto completo y libre acceso, a través de una revista científica de dilatada trayectoria en América Latina. Por ello, el número 33(3) de la revista Bosque está dedicado a la publicación de los manuscritos aceptados por el comité científico del presente congreso. Este comité científico estuvo presidido por Louis Iverson (USDA Forest Service, EE.UU.) y conformado, además, por João Azevedo (Instituto Politécnico de Bragança, Portugal), Jean Paul Metzger (Universidade de Sao Paulo, Brasil), Sandra Luque (IRSTEA, Francia), Ajith Perera (Ontario Ministry of Natural Resources, Canadá), Guillermo Martínez Pastur (Centro Austral de Investigaciones Científicas, Argentina), Damasa Magcale-Macandog (University of the Philippines Los Banos, Filipinas) y Jan Boegart (Universite Libre de Bruxelles, Bélgica). El proceso de publicación estuvo coordinado por Laura Nahuelhual (Universidad Austral de Chile), quien fue miembro del comité organizador del presente congreso.

BOSQUE 33(3): 245-248, 2012 DOI: 10.4067/S0717-92002012000300002

ARTÍCULOS

Tree species richness, does it play a key role on a forest restoration plantation?

Riqueza de especies arbóreas ¿Juega un rol clave en la restauración forestal?

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SUMMARY

The Brazilian Atlantic forest is considered one of the world's biodiversity conservation hotspot. Today there is less than ten percent remaining. Therefore it is necessary to restore these ecosystems. There are many ways of achieving restoration's main goals, but there is a lack of ecological studies that analyzes tree species richness as a variable. Thus, this study's goal is to investigate if there is a difference between a forest restoration in a gradient of tree species richness that varies from 20, 60 to 120 species, by using the litterfall as an indicator. Every month, for one year the forest litter was collected from litter traps that were previously installed. Results revealed that stands produced litterfall by the increasing gradient of species was of 5,370, 5,909 and 6,432 kg ha^{-1} yr^{-1}. The statistical analyses revealed no significant difference among them. Therefore this six-year-old forest restoration plantation shows no difference on the litter production by the tree species richness.

Key words: Brazilian Atlantic rainforest, forest restoration, landscape ecology, tree biodiversity, forest litter production.

RESUMEN

El bosque atlántico brasileño es considerado un *hotspot* de la conservación mundial de la biodiversidad. Hoy hay menos de 10 % de su área original. Por lo tanto, es necesario restaurar estos ecosistemas. Hay diversas maneras de alcanzar las principales metas de la restauración de los bosques, pero hay una falta de estudios ecológicos que analice la riqueza de especies de árboles como variable. Por lo tanto, el objetivo de este estudio fue investigar si hay una diferencia entre las restauraciones forestales en un gradiente de riqueza de especies de árboles que varía de 20, 60 a 120, usando la hojarasca como indicador. A cada mes, durante un año, esta fue recogida de las trampas de hojarasca previamente instaladas. Los resultados revelaron que la producción de hojarasca del bosque, en orden creciente de especies, fue de 5.370, 5.909 y 6.432 kg ha^{-1} año^{-1}. Los análisis estadísticos no revelaron diferencia entre ellos. Consecuentemente, el bosque plantado de seis años de edad demostró que no hubo diferencia en la producción de hojarasca de la riqueza debido a la especies de árboles.

Palabras clave: selva atlántica brasileña, restauración forestal, ecología del paisaje, biodiversidad de árboles, producción de hojarasca.

INTRODUCTION

The Brazilian Atlantic rainforest is considered one of the world's conservation hotspot for its endemic species and biological diversity. Today there is only 8.10 % of its original area, or, 99,944 km², on patches that are disconnected and isolated from each other in the landscape, mostly by matrixes of agricultural plantations, such as, sugar cane and degraded grazing (Mittermeier *et al.* 1999).

Therefore it is necessary to restore the biome and to put into practice projects of ecological restoration of disturbed areas (Davis and Slobodkin 2004). The plantation of trees allows the reestablishment of ecological functional processes or environmental services (Hillebrand and Matthiessen 2009) such as of litter biomass production that protects soil from erosion, promotes biochemical and geochemical cycles (Golley *et al*. 1975, Pritchett 1979, Jordan 1985, Borders *et al.* 2006), also the forest stand planted by borders of rivers reconnects the isolated remaining fragmented forest by forming a corridor by the river (Hillebrand and Matthiessen 2009).

Forestry studies such as intensive management is discussed for reforestation projects of native ecosystems (Campoe *et al.* 2010), but there is a lack of ecological studies on restoration of rainforests considering different arrangements of species on tree stands. There is need to investigate if they play a role on achieving ecological restoration main goals more successfully (Davis and Slobodkin 2004, García and Martínez 2012). The species richness is the number of species in an area, and the evenness is how many individuals there is of each species (Hillebrand and Matthiessen 2009, García and Martínez 2012). Some studies reveals that the higher the diversity of species more biomass is produced by the forest stand and ecosystem (Golley *et al*. 1975, Wardle *et al*. 2006, Lorenzen *et al*. 2007).

The results of restoration efforts can be measured by the use ecological indicators, such as biomass production, basal area increment, or, volume per unit of area (Golley *et al*. 1975). Therefore, this work tries to answer if the tree species richness of plantations, under intensive forestry, plays an important role on reestablishing the environmental services of the forest, faster and closer to the aims of the ecological restoration, by using forest litter production as an indicator.

METHODS

This study was conducted in the Research Station of the Department of Forest Sciences (University of São Paulo) located at Anhembi, São Paulo, Brazil: 22° 47' S and 48° 09' W. The climate data was collected during the research period. The average temperature was 21.9 °C, and the annual precipitation was 1,313.5 mm. The trial area is located in the semideciduous atlantic forest (Cesar 1988). The plantation was done by September 2006, on a landscape of degraded grazing matrix of *Brachiaria decumbens* Stapf on a riparian area by the borders of Tiete River.

The experimental design has one factor of study is the tree species richness that had three levels of, 20, 60 and 120, native tree species. A total of 120 tree species are all native from the region were planted. Their proportion of ecological classes, suggested by (Budowski 1965, Denslow 1987) was even in all treatments on each plot, of 60 % of pioneer and 40 % of non-pioneer (secondary and climax).

The spacing used on the plantation was of 3.0 m x 1.5 m, and initial density was of 480 individuals per plot or 2,222 individuals ha^{-1}. The plot size was 45 m x 48 m, 2,160 m², or, 0.216 ha. Treatments were distributed totally randomly, and there were four plots per treatment. All trials had the same intensive forestry management. It consisted on the use of herbicide in doses of 7 L ha^{-1} in implantation, and 5 L ha^{-1} for the maintenance. Fertilization was done with 178 kg ha^{-1} of triple superphosphate and 2,000 kg ha^{-1} of dolomite lime, 178 kg ha^{-1} of fertilizer NPK 10:20:10 ratio in implantation and a dose for maintenance of 178 kg ha^{-1} of NPK 18:08:18. The control of ants was systematic and used baits.

The litter traps were installed on the useful plots, which consist of excluding the two borderlines on the perimeter of each plot. A total of three litter traps were installed randomly on each useful plot and placed at 0.5 m above the ground. The litter trap was a square of 0.5 m per 0.5 m, or, 0.25 m² areas. It was made of wooden frame with the bottom covered by a shading screen. Every month the litterfall was collected from the litter traps. All plant materials that would perhaps fall inside them were collected every month, from August 2011 until July 2012. It was then packed on brown paper bags, identified, and taken to the forced air oven, 65 ºC. They were weighed on electronic scale of 0.01 g precision. The Tukey's test was done on SAS 9.2 software, considering 95 % probability ($P < 0.05$).

RESULTS

All results of the litterfall were similar among treatments. The effect of seasonality was alike in all treatments, with higher deposition on dry months and lower on rainy months (figure 1, figure 2). It showed higher litterfall deposition on August 2011 and March 2012,

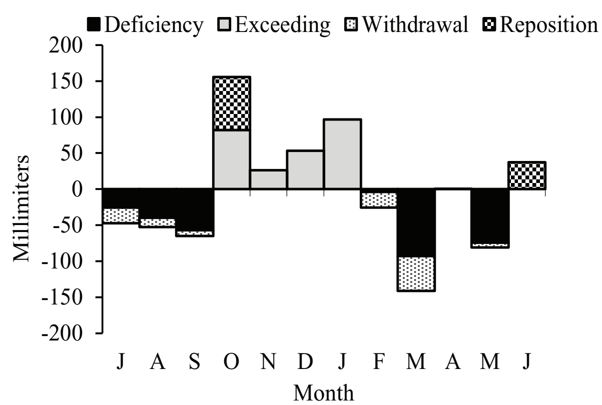

Figure 1. Pattern of the annual soil water balance (mm) for the period of the study. Calculations were done using a Thornthwaite-Mather Model (Thornthwaite 1948, Mather 1978).

Patrón del balance anual de agua del suelo (mm) para el periodo de estudio. Los cálculos fueron hechos usando el Modelo Thornthwaite-Matter (1948-1978).

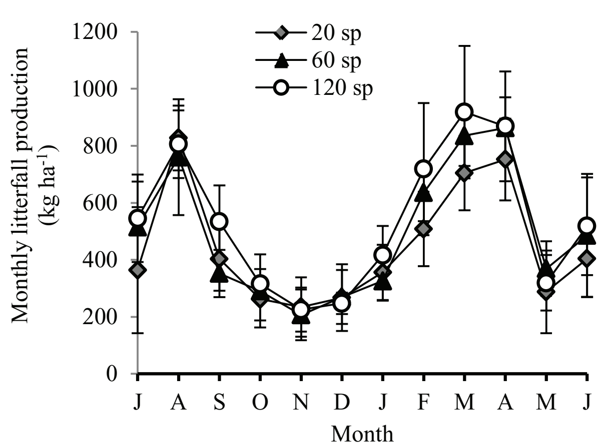

Figure 2. Monthly litterfall production. Bars represent the standard variation.

Producción mensual de hojarasca (kg ha^{-1}). Las barras representan la desviación estándar.

when precipitations were of 4 mm and 37.2 mm, respectively. It diminished, until reaching its minimum on November 2011, month of the highest precipitation, 249.3 mm.

The annual litterfall production was 5,370, 5,909 and 6,432 kg ha^{-1} yr^{-1} on treatments of 20, 60, 120 species, respectively (figure 3). The 120 species treatment obtained, on average, 8.13 % and 16.51 % more litter biomass than the trials of 60 species and 20 species, correspondingly. Comparing the results with tropical forests of Panamá, the results were close. Golley (1975), obtained for the river Sabana site, 6,200 kg ha^{-1} yr^{-1} of litterfall.

The month mean litter production (figure 4) was 447.54, 492.43 and 536.03 kg ha^{-1} month^{-1}. The results of the statistical analyses showed that there is no significant difference on the litterfall production between the trials. The statistical analyses show that there are no significant differences between them for a 95 % probability ($P < 0.05$).

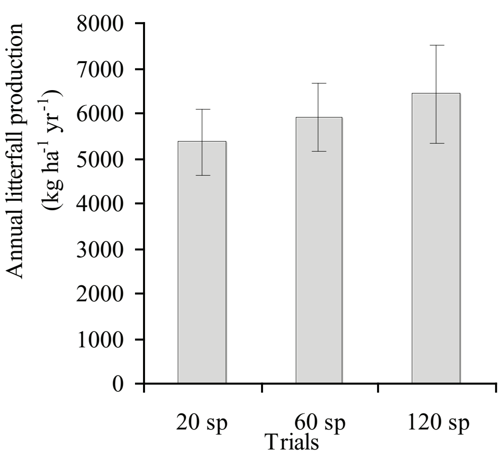

Figure 3. Annual litterfall production. Bars represent the standard variation.

Producción anual de hojarasca. Las barras representan la desviación estándar.

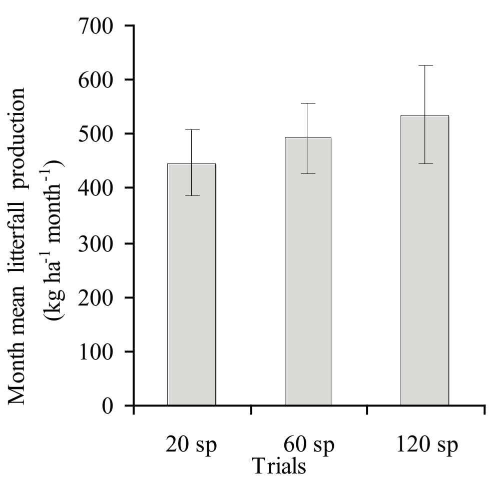

Figure 4. Month Mean litterfall production. Bars represent the standard variation.

Producción media mensual de hojarasca (kg ha^{-1} mes^{-1}). Las barras representan la desviación estándar.

DISCUSSION

Our results were similar to those found by Golley *et al*. (1975) in tropical forests in Panama obtained near the river Sabana site with 6,200 kg ha^{-1}yr^{-1} of litterfall. A Costa Rican study conducted with four tree species (two native and two commercial tree species) produced 6,290 ± 480 kg ha^{-1} yr^{-1} and showed no statistical difference ($P < 0.0001$) in the young secondary forest site (7 – 9 year old) 5,430 ± 390 kg ha^{-1} yr^{-1} (Celentano *et al*. 2011). The experiment of the United States Department of Agriculture (USDA) arboretum, established on 1960 in Puerto Rico shows that the litterfall of older forests are higher than younger forests plantations. In ten commercial tree species, the litterfall ranged from 14,300 down to 8,100 kg ha^{-1} yr^{-1}, for *Pinus caribea* var *hondurensis* Barr y Golf. and *Anthocephalus chinensis* (Lam) A. Rich, respectively (Cuevas and Luego 1998).

CONCLUSIONS

The study reveals that this six-year rainforest restoration experiment does not have a relation between production of forest litter and tree species richness at this stage of the experiment. It may represent that further when the forest restoration gets older there are more chances to obtain a difference in annual litterfall among treatments. Probably, the tree species richness will play an effective role on litterfall production, when forest becomes more mature.

ACKNOWLEDGMENTS

Acknowledgments to, Grupo Florestal Monte Olimpo, professors Fernando Seixas, Fábio Poggiani, Paulo C. Sentelhas, forest engineer João Carlos T. Mendes, employees of EECFA and for the scholarship granted by Santander/USP.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 249-252, 2012 DOI: 10.4067/S0717-92002012000300003

Climatically induced trends of change of floristic composition in forest communities in Northern Baikal region (Southern Siberia)

Cambio en la composición florística de las comunidades boscosas inducidas por el clima en el norte de la región Baikal (sur de Siberia)

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SUMMARY

Calculations of the activity indices and species richness of belt-zonal elements of the flora of Baikal region forests have been done in order to reveal the presence of climatogenic changes. The results provided evidence for the weakening status of xerophilic species in the floristic composition of hemiboreal light coniferous forests (with dominance of *Pinus sylvestris*). On the contrary, no significant change has been observed in the floristic composition of mountain light coniferous boreal forests (with dominance of *Larix gmelinii*). Besides, it was found that there was an increase in activity of the species of the dark-coniferous belt-zonal group peculiar to dark-coniferous boreal forests (with dominance *Abies sibirica* and *Pinus sibirica*).

Key words: flora, forests, climate warming, Baikal region, Siberia.

RESUMEN

Se calcularon los índices de actividad y riqueza de especies de los elementos zonales de la flora de los bosques de la región Baikal, con el fin de revelar la presencia de cambios climatogénicos. Los resultados entregan evidencia del estado de debilitamiento de las especies xerofílicas en la composición florística de los bosques de coníferas de luz hemiboreales (con dominancia de *Pinus sylvestris*). Por el contrario, no se observaron cambios significativos en la composición florística de los bosques boreales montañosos de coníferas de luz (with dominance of *Larix gmelinii*). Además, se encontró un aumento en la actividad de especies del grupo zonal de coníferas oscuras, peculiar de los bosques boreales de coníferas oscuras (con dominancia de *Abies sibirica* y *Pinus sibirica*).

Palabras clave: flora, bosques, calentamiento climático, región Baikal, Siberia.

INTRODUCTION

In most regions across the globe, the currently recorded climate warming leads to changes in composition, structure and functioning of plant ecosystems (Gitay *et al.* 2002). Some of previously made predictions as to the magnitude of temperature rise (Budyko and Izrael 1987) and, accordingly, displacement of the boundaries of natural zones by the year 2000 (Kobak and Kondrashova 1992) have lacked support from any known factual evidence. Nevertheless, there are sufficiently dramatic changes in ecosystems which are associated with climate warming, such as displacement of phenological phenomena (Menzel and Estrella 2001), and expansion of thermophilic plant species (Walther 2000, Sobrino Vesperinas *et al.* 2001). On the other hand, many changes have a latent character which manifests itself only through a detailed analysis of the parameters of ecosystems.

The aim of this study is to estimate probable climatic changes on the northern part of Baikal region happened at the recent time. This is supported by analysis of composition and structure of cenoflora of classes of forest vegetation. According to this data the prognosis of future potential climatogenic trends in vegetation dynamics has been discussed.

METHODS

This research was performed on the western macroslope of Ikatskii Ridge (light-coniferous hemiboreal and boreal forests), on Upper-Angara depression, on the western and eastern macroslopes of the southern part of Barguzinsky Range, and on the northeastern macroslope of the Svyatoi Nos Peninsula (dark-coniferous boreal forests) in the northern Baikal region.

The study areas (500 to 1,500 m a.s.l.) were situated in the region where permafrost rocks may have a continuous, discontinuous, or insular distribution. The annual average temperature was varying up 0 ºC to -6.7 ºC, and the annual amount of precipitation varied from 300 to 1,000 mm (Federal Service of Geodesy and Cartography of Russia 1993).

Analysis of floristic composition performed on basis of about 500 geobotanical descriptions of forest phytocenosis (releves), where full floristic composition and cover-abundance of individual plant species was estimated. Releves were performed on the 200 m^2 plots along the altitudinal transects from summit to foothill of mountain macroslopes. Classification of vegetation was generated through the use of the TURBO (VEG) software package (Hennekens 1996) within the framework of the ecologo-floristic approach (the Braun-Blanquet approach) according to which dark-coniferous and boreal light-coniferous forests refer to the class *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl., Siss. *et* Vlieger 1939, and hemiboreal light-coniferous forests refer to the class *Rhytidio rugosi-Laricetea sibiricae* K. Korotkov *et* Ermakov 1999.

The floristic composition of dark-coniferous forests, light-coniferous boreal forests and light-coniferous hemiboreal forests were taken in our study as the cenoflora, which is consistent with contemporary tenets of comparative floristics (Yurtsev 1987, Bulokhov 1993).

The ecologo-geographical groups of species were determined according to (Malyshev and Peshkova 1984). Species of the forest floristic complex were classified into dark coniferous (DC), light coniferous (LC), and preboreal (PB) groups. In addition, the cenofloras included species of the steppe floristic complex with forest–steppe (FS), mountain steppe (MS), and true steppe (TS) groups; the highmountain and mountain zonal complexes combined into the montane group (MM), and the azonal complex classified as the meadow group (MG), separately was singled out aquatichelad group (AH).

The analysis of the relationships of activity ranks and species richness for the ecologo-geographical groups of the cenoflora was carried out following the scheme reported in (Telyatnikov 2001). For the species of the cenoflora the activity indices were determined according to (Yurtsev 1968), and class intervals were calculated for the species richness of the ecologo-geographical groups of species. Accordingly, the activity was calculated as, $R=\sqrt{AB/N}$ [1], where R was a species activity, A was a sum of coverages of the species of the belt-zonal group in a given syntaxon, B was the occurrence frequency of these species, and N was the number of descriptions.

To calculate the class intervals, the following equation was used, $C=(X_{max}-X_{min})/K$ [2], where C was a class interval, X_{max} was the maximum value of partial activity or of the number of species, X_{min} was the minimum value of partial activity or of the number of species, and k was the number of belt-zonal groups.

RESULTS

In light-coniferous hemiboreal forests of class Rhytidio-Laricetea the ranks of activity and species richness coincided with each other in the dark coniferous, preboreal, light coniferous, and forest–steppe groups, but in the mountain steppe and true steppe groups, the ranks of species diversity were higher than the ranks of activity (table 1).

In the cenoflora of light-coniferous boreal forests of class Vaccinio-Piceetea the ranks of activity and species diversity coincided in all constituent zonal elements (table 2). This may be regarded as evidence that this cenoflora had existed for a long time under relatively stable climatic conditions.

Analysis of the activity and species richness of dark-coniferous forests pointed to a consistency of the rank indices both in activity and in species richness for almost all ecologo-geographical groups of species (table 3). The sole exception was provided only by the dark-coniferous group where the activity class of species was more than the class of species richness. Such an exceeding may be a sign the onset of the more favorable conditions for the species of this group in the recent past.

DISCUSSION

Tendencies in the dynamics of climate in certain areas depend on their geographic location (Kislov 2001). For example, recent warming is well manifested in continental regions, Asia in particular, and tendencies characteristic of the Asian continent as a whole can also be observed in central Transbaikalia. Climatic trends in the warm and cold seasons are opposite in this region, with winters becoming warmer and summers becoming colder: over 51 years, the average temperature of the cold season increased by 0.37 ºC and that of the warm season decreased by 0.31 ºC (Kulikov *et al*. 1997). It is apparent that the general climate warming is accounted for by the increase in winter temperatures. In the Baikal region as a whole, the annual average air temperature also increased by 3.5 ºC over 100 years (Gruza and Ran'kova 2004).

Hemisphere predict a 10–20 % increase in the amount of precipitation (Budyko *et al.* 1991, Izrael *et al.* 1999). A trend toward an increase in the annual amount of precipitation (by 33 mm over 50 years) has already manifested itself in central Transbaikalia (Kulikov *et al.* 1997). Similar climatic trends in this region are also described by Bazhenova and Martyanova (2003).

There is a well known concept that the number of species colonizing a certain area is initially small, but they exhibit a high landscape activity; thereafter, along with differentiation of niches, the total species diversity increases, whereas the activity of most species proves to be low. When florocenogenetic changes take place, this is first manifested in a decreasing activity of some species (which will be displaced), and then the total number of species begins to decrease.

There is evidence that dark coniferous, preboreal, light coniferous, and forest–steppe groups exist under relatively stable climatic conditions in light-coniferous hemiboreal forests. Therefore, we may consider that climate warming over the past 50 years has not yet affected the species richness and activity of these groups. Apparently, certain conditions unfavorable for mountain steppe and true steppe groups developed in the ecotopes of this cenoflora in the

Table 1. Species richness and activity indices ecologo-geographical groups of light-coniferous hemiboreal forests.
Riqueza de especies e índices de actividad de grupos ecológico-geográficos de bosques hemiboreales de coníferas.

Index	Belt-zonal group					
	DC	PB	LC	FS	MS	TS
Total coverage of species %	17	64	1496	1074	651.5	195.5
Frequency of species occurrence	9	27	577	621	467	140
Species richness	4	3	35	40	40	21
Activity, points	0.18	0.59	13.27	11.67	7.88	2.36
Species richness class	6	6	1	1	1	3
Activity class	6	6	1	1	3	5
Difference	0	0	0	0	-2	-2

Table 2. Species richness and activity indices of ecologo-geographical groups of light-coniferous boreal forests.
Riqueza de especies e índices de actividad de grupos ecológico-geográficos de bosques boreales de coníferas de luz.

Index	Belt-zonal group						
	MM	MG	MS	FS	PB	DC	LC
Total coverage of species, %	256.5	59.5	29	175.5	95.5	1,004	3,425
Frequency of species occurrence	54	20	17	92	33	150	791
Species richness	6	3	2	9	3	13	52
Activity, points	1.81	0.53	0.34	1.95	0.86	5.97	25.32
Species richness class	7	7	7	7	7	6	1
Activity class	7	7	7	7	7	6	1
Difference	0	0	0	0	0	0	0

Table 3. Species richness and activity indices of ecologo-geographical groups of dark-coniferous forests.
Riqueza de especies e índices de actividad de grupos ecológico-geográficos de bosques boreales de coníferas oscuras.

Index	Belt-zonal groups					
	MM	LC	DC	PB	MG	AH
Total coverage of species, %	81.0	1,344.0	1,169.5	197.5	98.0	51.5
Frequency of species occurrence	18	323	275	16	38	15
Species richness	5	60	41	9	6	7
Activity, points	0.85	14.64	12.60	1.25	1.36	0.62
Species richness class	6	1	3	6	6	6
Activity class	6	1	1	6	6	6
Difference	0	0	+2	0	0	0

near past. As true steppe species belong to arids in climatological terms, such unfavorable conditions can be created by more abundant moisture supply resulting from increasing precipitation and permafrost thawing. Conversely, more mesophilic groups represented by species of the forest floristic complex improve their competitiveness under such conditions. As the observed trends of temperature and humidity are consistent, the activity of the steppe species complex in the cenoflora of class Rhytidio-Laricetea will probably further decrease. Thus, differentiation of the floristic composition with a tendency toward its mesophytization will take place in this cenoflora.

The cenoflora of the dark-coniferous forests includes an extensive variety of shade-loving moderately thermophilic mesophytes and mesohygrophytes. Such species are the most numerous and constitute the core of the dark-coniferous ecologo-geographical group. As regards the other groups forming part of the cenoflora of dark-coniferous forests, high indices of activity and species richness correspond to the light-coniferous ecologo-geographical group. Ecologically, its species are more heliophilic and somewhat more cryophilic. The species of these two belt-zonal groups predominate in the cenoflora of dark-coniferous forests both in the quantity and in the phytocenotic role. The species of the other belt-zonal groups in the cenoflora of dark-coniferous forests are few in number and show low activity.

The territories under study are part of drainage basin of Lake Baikal, which have been designated by UNESCO as

World Heritage Site. Therefore active anthropogenic impact on forest ecosystems was limited in the XX century. The fire and selective logging are basic destabilizing factors for forest ecosystems, but these factors don't brining to irreversible changes of vegetation, soil degradation and soil erosion.

The main assignment of Baikal region forests is the realization of water and soil protective functions, as well as biodiversity conservation. Anthropogenic fire is the particularly strong risk for forest ecosystems of Baikal region. The authors consider that significant purpose in recent time is the maximal decrease of anthropogenic fire, especially in the light-coniferous hemiboreal forests and the strict control for the recreation activity in the Baikal region forests.

CONCLUSIONS

Based on the data received we can conclude that due to climate warming, ecological differentiation takes place in the cenoflora of hemiboreal light-coniferous forests of class Rhytidio-Laricetea. In this class the status of xerophilic species represented by plants of the mountain steppe and true steppe groups weaken due to an increase in moisture supply in habitats on mountain slopes in the lower part of the forest belt.

The observed tendencies of changes in the composition of cenofloras indicate that habitats in the lower band of mountain slopes of ultra continental climatic sectors become wetter due to increasing of precipitation and degradation (thawing) of permafrost.

Current climatic changes have not yet affected the composition of plant species and parameters of their activity in the upper part of the forest belt of ultra continental climatic sectors, which is reflected in the equilibrium between the ranks of activity and species richness in zonal groups of species in the cenoflora of boreal light-coniferous forests of class Vaccinio-Piceetea.

Contemporary climate change is favorable for dark-coniferous species that can be evidence of mitigation of climate continentality in dark-coniferous habitat.

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Recibido: 24.05.12
Aceptado:10.10.12

BOSQUE 33(3): 253-259, 2012 DOI: 10.4067/S0717-92002012000300004

The 21st century climate change effects on the forests and primary conifers in central Siberia

Efectos del cambio climático del siglo 21 en los bosques y coníferas primarias en Siberia central

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SUMMARY

Regional studies have shown that winters warmed 2-3 °C while summers warmed 1-2 °C during the1960-2010 period in central Siberia. Increased warming predicted from general circulation models (GCMs) by the end of the century is expected to impact Siberian vegetation. Our goal is to evaluate the consequences of climate warming on vegetation, forests, and forest-forming tree species in central Siberia. We use our envelope-type bioclimatic models of the Siberian forests and major tree conifer species based on three climatic indices which characterise their warmth and moisture requirements and cold resistance, and on one soil factor that charactrises their tolerance to permafrost. Coupling our bioclimatic models with the climatic indices and the permafrost distributions, we predict the potential habitats of forests and forest-forming tree species in current climate conditions and also in the 2080 projected climate. In the 2080 drier climate conditions, Siberian forests are simulated to decrease significantly and shift northwards while forest-steppe and steppe would come to dominate 50 % of central Siberia. Permafrost is not predicted to thaw deep enough to sustain dark (*Pinus sibirica*, *Abies sibirica*, and *Picea obovata*) taiga. Dahurian larch (*L. gmelinii+cajanderi*), which is able to withstand permafrost, would remain the dominant tree species. Light conifers (*Larix spp*. and *Pinus sylvestris*) may gain an advantage over dark conifers in a predicted dry climate due to their resistance to water stress and wildfire. Habitats for new temperate broadleaf forests, non-existent in Siberia at present, are predicted by 2080.

Key words: climate warming, bioclimatic models, major conifer ranges, Central Siberia.

RESUMEN

Estudios regionales muestran que los inviernos se han calentado de 2 a 3 ºC mientras que en los veranos se reportan alzas de 1 a 2 ºC entre 1960 y 2010 en Siberia Central. El aumento del calentamiento predicho por modelos de circulación general (GCMs) para el fin de este siglo impactaría la vegetación en Siberia. El objetivo del estudio fue evaluar las consecuencias del calentamiento climático sobre la vegetación, los bosques y las especies arbóreas de Siberia central. Se usaron los modelos bioclimáticos de tipo envolvente de los bosques siberianos y las especies de coníferas más importantes, basados en tres índices climáticos que caracterizan sus requerimientos de calor y humedad y resistencia al frio, y en un factor de suelo que caracteriza su tolerancia al permacongelamiento. Acoplando los modelos bioclimáticos con los índices climáticos y la distribución del permacongelamiento, se pudo predecir los hábitats potenciales de bosques y las especies arbóreas bajo las condiciones climáticas actuales y para las condiciones climáticas al año 2080. Bajo las condiciones climáticas más secas del año 2080, se predice que los bosques siberianos decrecerán significativamente y se desplazarán hacia el norte mientras que los bosques esteparios y la estepa dominarán el 50 % de la superficie de Siberia Central. Se predice que el permacongelamiento no se derretirá a niveles tan profundos suficientes para sostener la taiga oscura (*Pinus sibirica*, *Abies sibirica* y *Picea obovata*). El alerce dahuriano (*L. gmelinii+cajanderi*) que es capaz de soportar permacongelamiento, permanecerá como la especie dominante. Las coníferas de luz (*Larix spp*. y *Pinus sylvestris*) pueden ganar ventaja sobre las coníferas oscuras en un clima más seco debido a su resistencia al estrés hídrico y los incendios. Para el 2080 se predice el surgimiento de hábitats para los nuevos bosques templados latifoliados, no existentes actualmente en Siberia.

Palabras clave: calentamiento climático, modelos bioclimáticos, rangos mayores de coníferas, Siberia central.

INTRODUCTION

Regional studies in Siberia have already registered a change in climate at the end of the 20th century (Soja *et al*. 2007, Tchebakova *et al*. 2011ab). A mounting body of evidence of the changes in Siberian vegetation and in the forests in particular related to climate warming is available in the literature and summarized in the reviews of Soja *et al.*(2007) and Tchebakova *et al.* (2011a). At the northern treeline, the forest has shifted into tundra and open forests have become more stocked. Within the permafrost zone, which is dominated by only *Larix dahurica* P. Lawson*,* an undergrowth of dark conifers like Siberian cedar (*Pinus sibirica* Du Tour), fir (*Abies sibirica* Ledeb.), and spruce

(*Picea obovata* Ledeb.) up to 40-years-old is found because of an active layer depth recently increased in a warming climate. Upper treeline shifts of 40-100 m upslope is registered in the mountains in the south: Altai, Kuznetsky Alatau, West Sayan, and even in the north in the Putorana Plateau. At the lower treeline in the West Sayan, the *Pinus sibirica* seed production is significantly decreased for 1990-1999, the warmest decade of the last century, which may cause changes in the forest structure. Foresters presumably explain this fact by an increased probability of the cone damage done by the moth *Dioryctria abietella* (Denis *et* Schiffermüller) (Lepidoptera: Pyralidae (Phycitinae)). This moth is recently found to produce two generations within a single longer growing season observed under climate warming.

In this study, using IPCC (Intergovernmental Panel on Climate Change) climate change projections, we hypothesize what large-scale potential effects of climate change we may expect on vegetation, forests, and forest-forming conifers by the end of the 21st century within the Krasnoyarsk territory in central Siberia. To reach this goal, we couple our bioclimatic models of the Siberian forests and major tree conifer species with these IPCC projections to predict their potential distribution in 1960-1990, from historical climate data, and in a changed climate by 2080, from GCM (General Circulation Models)-predicted data.

Figure 1. Study area in central Siberia (black) with locations of 80 weather stations used in the study on the background of the former Soviet Union.

Área de estudio en Siberia central (negro) con la ubicación de 80 estaciones climáticas sobre el mapa de la anterior Unión Soviética.

METHODS

The study area is the vast Krasnoyarsk territory and adjacent Republic of Khakassia to its south (figure 1). The territory stretches from the Arctic seas to the Mongolian border for about 2,500 km and is 10 -fold larger than Great Britain, 4.5-fold larger than France, and 3-fold larger than Chile (Ushakova 2006). The territory crosses different vegetation zones from Arctic tundras in the north southwards to taiga (northern, middle and southern), subtaiga, forest-steppes, and steppes, respectively. The change in climate across the study area at the turn of the 21st century was calculated from the data from 80 weather stations within the study area (figure 1). Climate change was considered for three climatic variables: winter and summer thermal conditions (January and July temperatures) and annual precipitation. Change for all three variables was calculated from differences (departures) between the means of the 30-year baseline period 1961-1990, the means of the historic period 1990-2010, and the GCM-modeled period 1990-2080 (figure 2). Departures of both temperatures and precipitation for 1990-2010 from the basic period 1960-1990, as evaluated by the Student criteria, were statistically significant at the level of 0.02. Then, July and January temperatures and annual precipitation were used to calculate climatic indices ecologically important for vegetation: growing degree-days, base above 5 ºC, GDD_5, and negative degree-days below 0 ºC, NDD_0, characterizing warmth requirements and cold resistance, and an annual moisture index, AMI, the ratio of GDD_5 to annual precipitation characterizing resistance to water stress.

We used our SiBCliM (Siberian bioclimatic model) (Tchebakova *et al.* 2009), a static envelope-type large-scale bioclimatic model based on the vegetation classification of Shumilova (1962) in our calculations. SiBCliM simulate Siberian zonal vegetation and forests from three bioclimatic indices: GDD_5, NDD_0, and AMI, uniqely limiting each vegetation class. The bioclimatic limits within the model were derived from the ordination of 150 weather stations each of which was characterised with a given vegetation class in axes of the GDD_5, NDD_0, and AMI indices (Tchebakova *et al.* 2003). SiBCliM separated vegetation and forests by GDD_5 into latitudinal subzones from north to south: tundra; forest-tundra; northern, middle and southern taiga; and forest-steppe. The AMI separates vegetation into two large types**,** forest and steppe, and further subdivides the forest into dark (shade-tolerant and water-loving *Pinus sibirica*, *Abies sibirica*, and *Picea obovata*) and light (shade-intolerant and water-stress resistant *Pinus syvestris* L. and *Larix spp.*) according to Russian geobotany classifications. NDD_0, equal to -3,500-4,000 °C, corresponded well to the permafrost border and also tended to separate dark and light-needled conifers. Four temperate vegetation classes (broadleaf forest, forest-steppe, steppe, and semi-desert/desert) that do not exist in the current Siberian climates were included in SiBCliM because of their potential importance in future climates. Therefore, in total, the current version of SiBCliM included 14 vegetation classes: ten boreal and four temperate vegetation classes.

The forests across Siberia consist largely of eight conifers (Pozdnyakov 1993): about 50 % *Larix spp.* (four species), 13 % *Pinus sylvestris*, 7 % *Picea obovata*, 6 % *Pinus sibirica*, and 2 % *Abies sibirica*. Climate envelopes of GDD_5, NDD_0, and AMI for each conifer were found using gene-ecological studies (data of about 250 provenances

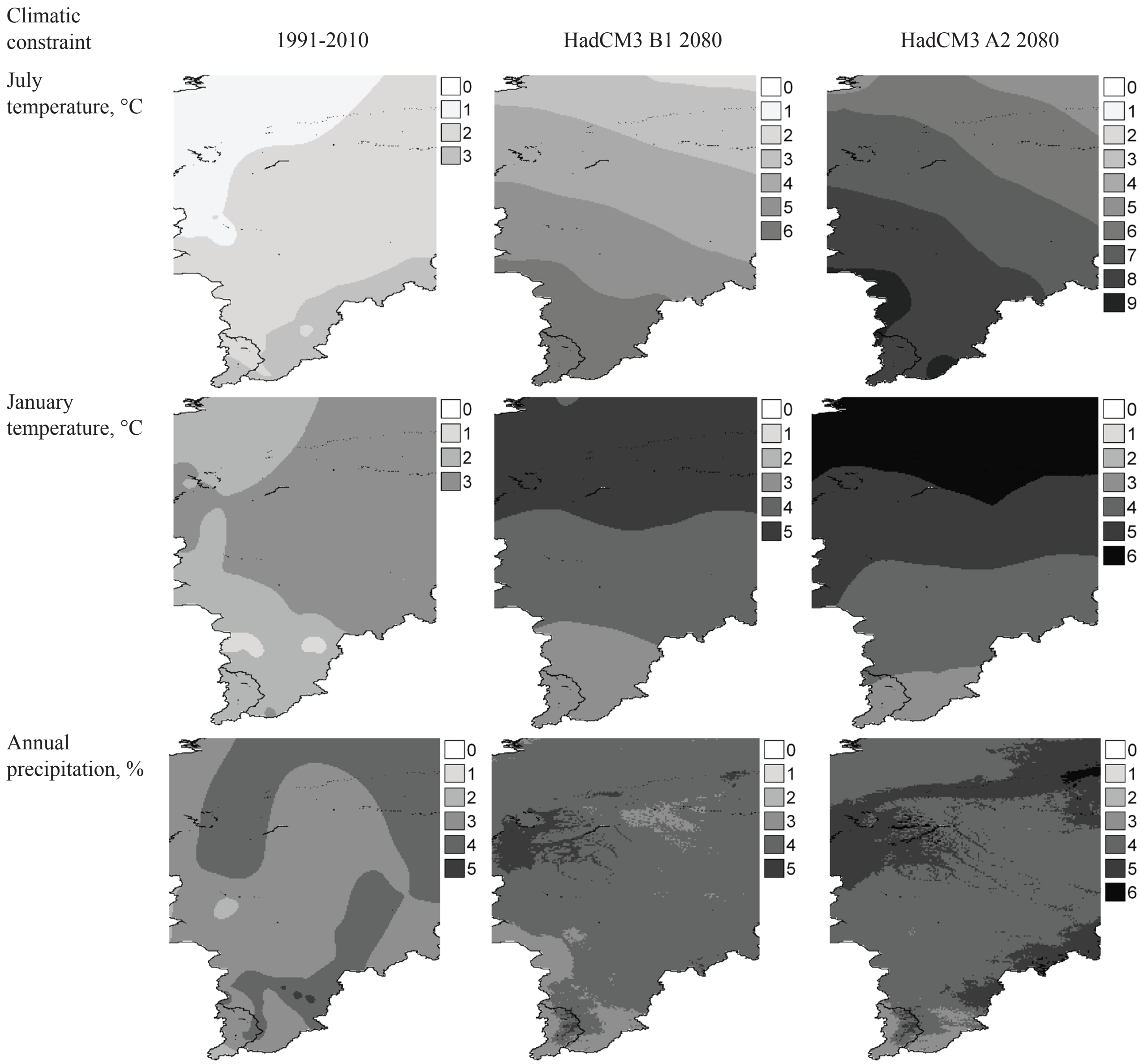

Figure 2. Departures of July and January temperatures and precipitation across central Siberia in 1991-2010 relative to the baseline period, 1961-1990, calculated from historic data (left) and those derived from the HadCM3 B1 (center) and A2 (right) 2080 climate change projections. Scale: 0 – beyond the study area; 1 – 1 °C, 2 – 2 °C, 3 – 3 °C, 4- 4 °C, 5 – 5 °C, 6 – 6 °C, 7 - °C, 8 – 8 °C, 9 – 9 °C.

Temperaturas y precipitaciones de julio y enero a lo largo de Siberia central para el periodo 1991-2010 en relación al periodo base 1961-1990, calculadas a partir de datos históricos (izquierda) y aquellos derivados de las proyecciones de cambio climático bajo HadCM3 B1 (centro) y A2 (derecha). Escala: 0 – fuera del área de estudio; 1 – 1 °C, 2 – 2 °C, 3 – 3 °C, 4- 4 °C, 5 – 5 °C, 6 – 6 °C, 7 -7 °C, 8 – 8 °C, 9 – 9 °C.

for *Pinus sylvestris* and 150 for *Larix spp*., Rehfeldt *et al.* 1999, 2002), the climate estimated for extreme locations on range maps, and various publications (Tchebakova *et al.* 2003, 2006).

No soil conditions except presence/absence of permafrost were taken into account in SiBCliM. Permafrost, occurring on 80 % of Siberia, is an important ecological factor controlling the contemporary vegetation distribution across Siberia (Shumilova 1962, Pozdnyakov 1993). The active layer depth (ALD), a portion of thawed permafrost, equal to 2 m, calculated from the above climatic indices GDD_5, NDD_0 and AMI ($R^2 = 0.7$), was substituted for the permafrost border in SiBCliM. ALD > 2 m explicitly allowed all conifers to thrive, and ALD < 2 m allowed only one conifer *Larix dahurica* Turcz. (*L. gmelinii* (Rupr.) Rupr. + *L. cajanderi* Mayr.) that could withstand lower ALD to grow (Pozdnyakov 1993).

Kappa (K) statistics (Monserud and Leemans 1992) were used to compare both the modeled vegetation and the conifer distributions in Siberia in the contemporary climate to the actual map of Isachenko *et al.* (1988) and the "Forests of the USSR" map of Isaev *et al.* (1990).

Each forest type and conifer distribution from 1960-1990 to 2080 was mapped by coupling our bioclimatic models with bioclimatic indices and the permafrost distribution for the basic period and 2080 simulation. Climatic departures for the 2080 climate were derived from two climate change scenarios, the HadCM3 A2 and B1 (IPCC 2007), reflecting the largest and the smallest temperature increases: up to 9 °C and to 4-5 °C in summer and > 9 °C and 6-7 °C in winter.

RESULTS

Tchebakova *et al*. (2011ab) demonstrated climate warming over the last half century from 1961 to 2010 in central Siberia. Our analysis proved that for 1991-2010, when compared to the basic 1961-1990 time period, winters became 2–3 °C warmer in the north and 1–2 °C warmer in the south by 2010. Summer temperatures increased by 1 °C in the north and by 1–2 °C in the south. Change in precipitation was more complicated, increasing on average by 10% in middle latitudes and decreasing 10–20 % in the south, promoting local drying in already dry landscapes (figure 2).

The comparison between our modeled and the real (Isachenko 1988) vegetation maps showed that the overall agreement was "fair" (K = 0.53) and agreements by separate vegetation classes showed from "exellent" (K > 0.7) to poor (K < 0.4) matches across Siberia (Tchebakova *et al.* 2009). Thus, K-statistics proved that SiBCliM accomplished a fair work in modeling Siberian vegetation. Simulations indicated that vegetation would be severely altered by 2080: a moderate change in vegetation was predicted from the B1 scenario, but dramatic changes were predicted from the A2 scenario (Tchebakova *et al.* 2009). The forest zones could shift northwards as far as 600-1,000 km by substitution or complete replacement of the northern ecosystems (tundra, forest-tundra). Siberian forests would decrease and forest-steppe, steppe ecosystems, and even semidesert/desert were predicted to dominate 50 % of central Siberia due to the 2080 drier climate. Despite the predicted large increases in warming, permafrost was not predicted to thaw deep enough to sustain dark (*Pinus sibirica*, *Abies sibirica*, and *Picea obovata*) and light (*Larix sibirica* and *Pinus sylvestris)* taiga. *Larix dahurica* taiga was predicted to continue to be the dominant zonobiome because of its ability to withstand continuous permafrost. SiBCliM also predicted temperate broadleaf forest (with *Tilia sibirica* Bayer) and forest-steppe habitats in the south, which are non-existent today.

The tree species distribution across central Siberia is shown in figure 3. Comparison of conifer distributions on real and modeled (figure 3) maps showed a fair agreement. Any climate-modeled tree range is a potential one because it does not consider soil or phytosocial (competition) and disturbance factors, so a potential range is always larger than a real range. Thus, 73 % of the real *Pinus sibirica* range (figure 3: 1A), 34 % of the *Abies sibirica* range (figure 3: 2A), 64 % of the *Pinus sylvestris* range (figure 3: 3A), and 46 % of the *Larix sibirica* and *L. gmelini* range (figure 3: 4A) were within their climatic potential ranges (figure 3: 1-4B). Those matches might be higher because historically part of the primary conifer forests were replaced by secondary birch and aspen forests after large disturbances (clearcuts and wildfire).

During the 21st century, with the warming and drying climate, habitats should become increasingly more suitable for drought-resistant light conifers: two times larger for *Pinus sylvestris* (figure 3: 3C) and 10 % larger for the *Larix* genera as a whole (figure 3: 4C). However, permafrost will not thaw deep enough to support Siberian conifers requiring 1-2 m of ALD. *Larix dahurica*, which can withstand the shallow ALD, would still dominate most Siberian taiga. Habitats for dark conifers, *Pinus sibirica* and *Abies sibiric*a (figure 3: 1C and 2C), would shrink about 1.5-2-fold and shift north- and northeastward as far as 600 km by 2080. Their distribution will be limited by the permafrost border in the north and the drying climate in the south.

DISCUSSION AND CONCLUSIONS

Natural climate-change-caused disturbances (weather, wildfire, infestations) and antropogenic disturbances (legal/illegal cuttings) have increased their impacts on the boreal forest in Siberia for the last three decades (Pleshikov 2002, Soja *et al.* 2007). Permafrost melting initiates thermokarst and solifluction processes across broad expanses of Siberia thereby disturbing forest landscapes (Abaimov *et al.* 2002). With the retreat of permafrost, forests would decline in extent due to lack of moisture in interior Siberia and be replaced by steppe in well-drained areas or by bogs in poorly drained areas (Tchebakova *et al.* 2009). Based on the analyses of the transient effects of climate change on the circumboreal biosphere, Soja *et al*. (2007) suggest a potential non-linear, rapid response of the boreal ecosystem to changes in climate vs the expected slow linear response.

Fire and permafrost are considered to be the principal mechanisms affecting the forest's range and structure (Polikarpov *et al.* 1998). Predicted warm and dry climates enhance the risks of high fire danger and thawing permafrost, both of which challenge contemporary ecosystems. The northern treeline shift is dependent on tree migration rates, permafrost retreat rates, and soil suitability for the future forests. Current estimates, however, suggest that due to low natural migration rates, forest zones and tree species shifts will require long periods to adjust to the great amount of predicted climate change. However, developing management strategies for seed transfer to locations that are best ecologically suited to these genotypes in future climates could be man's contribution toward assisting

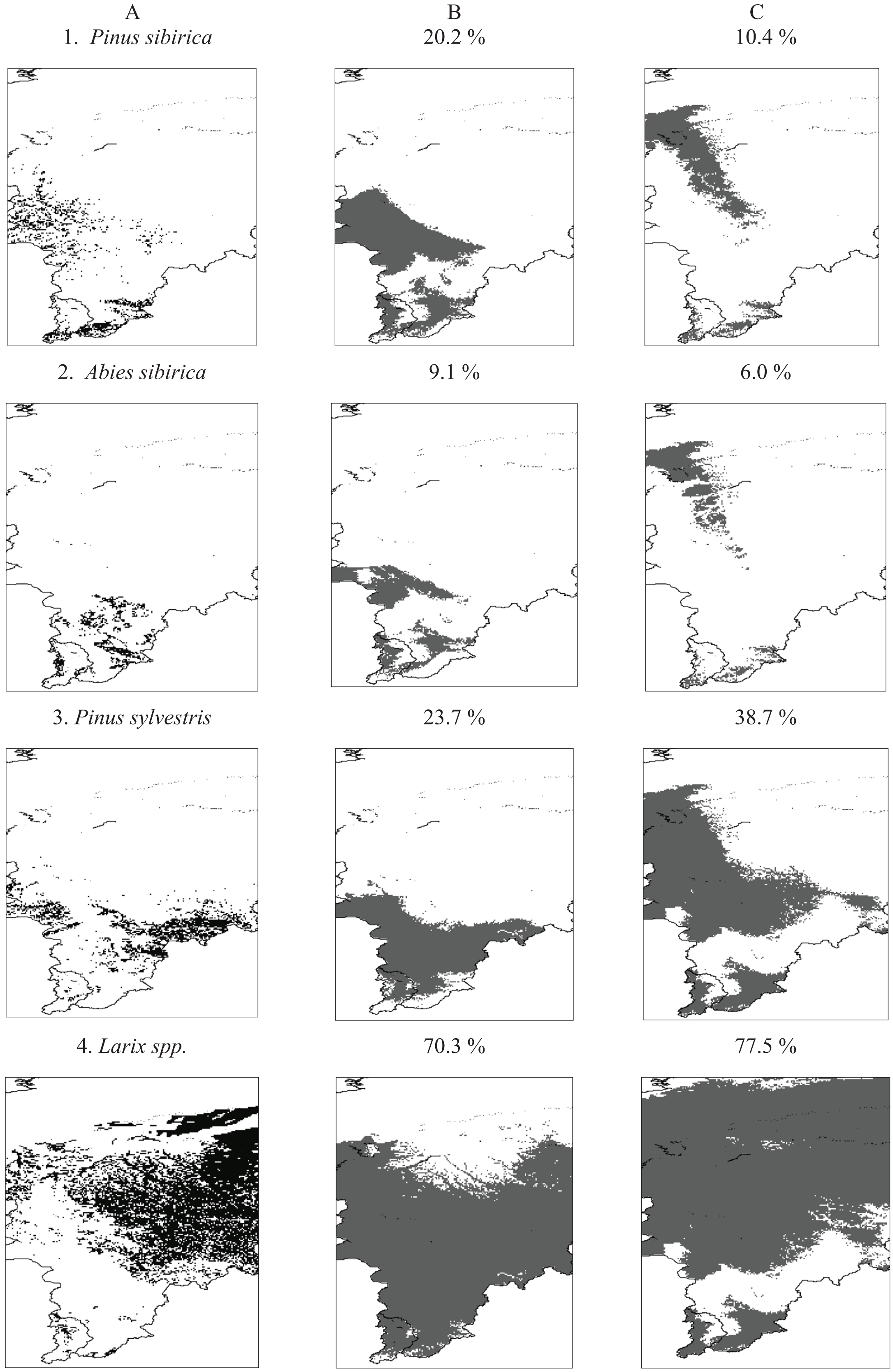

Figure 3. Major conifer conifer distributions: in Isaev et al. (1990) map (1-4 A), modeled (% of the total area) in current climae (1-4 B) and in the 2080 HadCM3 A2 climate (1-4 C).

Distribución de las principales coníferas: en el mapa de Isaev et al. (1990) (1-4 A), modelado (porcentaje del área total) para el clima actual (1-4 B) y para el clima de 2080 HadCM3 A2 (1-4 C).

trees and forests to be harmonized with a changing climate (Rehfeldt *et al*. 1999, 2002).

The southern treeline shift is controled by fire. In the last two decades extreme fire seasons have significantly increased in Siberia (Soja *et al.* 2007), and catastrophic fire frequency has increased to once in 10 years (Shvidenko *et al.* 2011). Due to an increased forest fire frequency and shorter fire return intervals, forest regeneration may not be possible in a hotter and drier climate or if possible, may not survive the forest establishment stage. Frequent fires may also change the forest structure. The fire return interval in the light conifer (*Larix spp*. and *Pinus sylvestris*) middle taiga in central Siberia is currently 20-30 years (Furyaev *et al.* 2001) compared to 200-300 years in the dark conifer (*Pinus sibirica* and *Abies sibirica*) southern and mountain taiga in southern Siberia (Polikarpov *et al*. 1998). After fire events, slowly growing dark conifers, not adapted to frequent fires, typically die; both larch and pine, evolutionarily adapted to fire, successfully regenerate after fire events. While adaptation of the forests and tree species to climate change at the range boundaries would occur by means of migration (Kirilenko and Solomon 1998), within the forest ranges the genetic means are considered the principal means of adaptation (Rehfeldt *et al*. 2002).

Our envelope-type vegetation and forest models are based on climate-vegetation classifications. This approach is best-known and simplest to predict the equilibrium response of vegetation to climate change. However, the major disadvantage of this type of models is that vegetation/forest types will not change and shift as a whole under climate change in the future. The vegetation/forests are made up of a number of species which will individually respond to a changing climate and may compose not only known but also unknown vegetation/forest types (Peng 2000).

Our simulations of the forests and forest-forming conifers in central Siberia demonstrate the profound effects of the GCM-predicted climate change on the ecological distribution of future forests. Forest analogs (tree species composition) to the future forests of Siberia exist contemporarily, thus, we can assume that the forests are capable of adjusting to the predicted environmental change. Light conifers may have an advantage over dark conifers in a predicted dry climate and may cover a larger area in the near future due to their stronger resistance to water stress and wildfire. SiBCliM also predicted new habitats suited to temperate vegetation (broadleaf forest and forest-steppe) in the south by 2080.

Evidence of changes in the Siberian taiga structure and shifts in treeline in central Siberia are available in the literature. Kharuk *et al.* (2005) show that in Evenkia (Central Siberian Tableland) undergrowth of *Pinus sibirica, Picea obovata,* and *Abies sibirica,* which are not currently found on cold permafrost soils are now emerging in the *Larix gmelinii* taiga, possibly due to the increased depth of ALD that allows for the survival of dark-needled seedlings. Strong evidence treeline shifts of 50-120 m during a 50-year span in the mid-20th century is derived *in situ* in the southern mountains in central Siberia (for more details see Soja *et al.* (2007) and Tchebakova *et al.* (2011a).

Principal forest ecosystem services would be altered under climate change impacts. The ecosystem services in mountain forests in the southern Siberia are predicted as follows: both demand and supply of provisioning of timber and firewood would remain the same; both demand and supply of carbon sequestration would increase; demand for prevention of wildfires would increase while the supply of service would worsen; demand for maintaining natural habitats for biodiversity would increase while the supply would worsen; both demand and supply for the provisioning of fresh water would increase; both demand and supply of the provisioning of land and conditions for farming would improve (Gerasimchuk 2011).

The establishment of agricultural lands may appear in new forest-steppe and steppe habitats because the forests would retreat northwards. Currently, food, forage, and biofuel crops primarily reside in the steppe and forest-steppe zones which are known to have favorable climatic and soil resources. During this century, traditional Siberian crops could be gradually shifted northwards and new crops, which are currently non-existent but potentially important in a warmer climate, could be introduced in the extreme south (Tchebakova *et al.* 2011b). Desertification is expected in some extreme southern Siberian areas as a result of decreased precipitation and dramatically increased temperatures.

ACKNOWLEDGMENTS

We ackowledge the support of the RFFI project 10-05-00941, the NASA LCLUC NEESPI project and NASA Interdisciplinary Science NNH09ZDA001N-IDS.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 261-265, 2012 DOI: 10.4067/S0717-92002012000300005

Carbon budget recovery and role of coarse woody debris in post-logging forest ecosystems of Southern Siberia

Recuperación del balance de carbono y el rol de los residuos leñosos de gran tamaño en ecosistemas forestales post-cosecha del sur de Siberia

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SUMMARY

Forest harvesting is a major human-caused disturbance affecting carbon budgets in forest ecosystems. This study was concerned with post-logging carbon pool changes in Scots pine (*Pinus sylvestris*) and Siberian fir (*Abies sibirica*) stands. To understand carbon budget recovery trends following logging, carbon stock and fluxes were measured in stands differing in time since logging. In both Scots pine and fir stands disturbed by logging, the tree phytomass contribution to the carbon budget decreased drastically, whereas the coarse woody debris (CWD) carbon pool exhibited a marked increase. Sixty years following logging, the Scots pine stand carbon storage was almost 70 % of that prior to logging and the ratio between the phytomass and soil organic matter was the same as before the disturbance. While the phytomass carbon showed a similar trend in the fir stand of the same age, it was less than on the control stand. In a 50-55-year-old fir stand, 26 years since harvesting, the phytomass carbon recovered only by 15 %. Siberian fir and Scots pine logging sites differed in CWD loading and decomposition rate. The phytomass dynamics and CWD loading values obtained suggest that Scots pine stands which have experienced logging are most likely carbon sinks, as was clear from the phytomass production exceeding organic matter decomposition-caused fluxes. Conversely, logged fir ecosystems are likely to be sources of carbon to the atmosphere due to a large CWD loading, faster rate of its decomposition, and slow phytomass increment.

Key words: carbon budget, logging, phytomass, coarse woody debris, decomposition.

RESUMEN

La explotación forestal es un importante disturbio de origen humano que afecta el balance de carbono en ecosistemas forestales. Este estudio se concentró en los cambios de las reservas de carbono post-cosecha de rodales de pino silvestre (*Pinus sylvestris)* y abeto siberiano (*Abies sibirica*). Para entender la recuperación del balance de carbono después de la cosecha, se midió el stock y flujo de carbono en diferentes momentos posterior a la cosecha. En ambos rodales explotados, la contribución de la fitomasa forestal al balance de carbono disminuyó drásticamente, mientras que la reserva de carbono en los residuos leñosos de gran tamaño (CWD) exhibió un marcado incremento. Sesenta años después de la cosecha, el almacenamiento de carbono en rodales de pino silvestre fue casi del 70 % respecto a lo de antes de cosecha. El radio entre la fitomasa y la materia orgánica del suelo fue el mismo al de antes de la perturbación. Si bien la fitomasa de carbono mostró una tendencia similar en el rodal de abeto, éste fue menor que el rodal control. En un rodal de abeto de 50-55 años de edad, 26 años desde la explotación, el carbono de la fitomasa se recuperó en sólo un 15 %. Rodales explotados de abetos de Siberia y de pino silvestre difirieron en la carga de CWD y en la tasa de descomposición. La dinámica de la fitomasa y los valores de carga de CWD sugieren que los rodales explotados de pino silvestre son probablemente sumideros de carbono, como se desprende de la producción de fitomasa que excede los flujos de materia orgánica causados por descomposición. A la inversa, rodales de abeto explotados son probablemente fuentes de carbono a la atmósfera debido a la gran carga de CWD, la tasa más rápida de descomposición y el lento incremento de fitomasa.

Palabras clave: balance de carbono, explotación forestal, fitomasa, restos leñosos, descomposición.

INTRODUCTION

Different types of disturbances of forest ecosystems, which are recognized to be globally important carbon sinks, often alter the ratio between the rates of phytomass productivity and organic matter decomposition and, as a result, induce carbon budget changes.

Forest harvesting is a major anthropogenic disturbance having profound and prolonged impacts on forest ecosystems (Bergstedt and Milberg 2001). Cutting of trees alters the forest structure and functional attributes of forest ecosystems (De Grandpre *et al*. 2000). The resulting carbon budget changes are sometimes as far as conversion of such ecosystems from carbon sinks to carbon sources.

This study focused on estimating a long term dynamics of carbon pools in *Pinus sylvestris* L. (Scots pine) and *Abies sibirica* Ledeb. (Siberian fir) stands fragmented by logging in the east of Baikal region.

METHODS

A total of six sites differing in time since logging were sampled; three in *Pinus sylvestris* and the other three in *Abies sibirica* stands. Each logged site consisted of several logging compartments with skidding trails in between (table 1).

The organic matter pools on the logged sites were measured in the sample plots representative of the logging compartments, and on the skidding trails. The skidding trails and the logging compartments of the plots were 5-6 m and 30 m wide, respectively. The stand phytomass was calculated based on the stem wood volume, the wood density, and conversion ratios available for tree crowns and roots (Stakanov *et al*. 1994). We calculated ground vegetation and forest litter biomass using the layer weight data obtained from 20 x 20 cm sample plots (n = 10). To calculate that of fine roots and detritus, 20-cm deep 20 x 20 cm soil pits were made. Soil humus contents were measured using Walkley-Black wet oxidation technique.

To obtain coarse woody debris biomass, including down deadwood, tree stumps, and coarse roots, we recorded the diameters, at both ends, and length of each log, as well as each tree stump diameter and length. Additionally, the decomposition class of each log and each tree stump was determined through the applications of methodology described by Klimchenko (2005). Dead coarse root biomass was calculated based on the stump numbers and size and on the volume of the logs of similar diameter using conversion ratios (Stakanov *et al*.1994). Each coarse woody debris element was assigned to one out of three decay classes based on visual estimation of its physical condition. Wood density in each decay class was measured and used to determine coarse woody debris loading and decomposition rate.

RESULTS

The 180-year-old undisturbed *Pinus sylvestris* stand found on the podzol soil contained 116.5 Mg ha^{-1} of carbon (figure 1A), with the above- and bellow-ground phytomass accounting for up to 56.6 % of the total carbon storage (figure 1B). Plant detritus contributed 29.7 %, and about 14.0 % of the total carbon was allocated in the soil humus. In the recently logged *Pinus sylvestris* sites, the carbon allocated in the live phytomass ranged 7.6 % to 14.6 % of the total carbon, whereas the phytodetritus and humus contribution was twice to triple that in the control. These changes were a result of wood extraction from these stands. The total carbon storage in these disturbed sites was up to 60.8 Mg ha^{-1}, half as much as in the undisturbed site. However, in the 60-year-old logging site of *Pinus sylvestris*, the total carbon storage increased by half to twice and the contribution of living phytomass, phytodetritus, and soil humus almost reached the level in the undisturbed stand (58 %, 23 %, and 19 %, respectively).

Quite different dynamics of the organic matter pools was observed for *Abies sibirica* stands growing on podbur soil, which is more fertile than Podzol (figure 2A). Although the total carbon storage in the undisturbed 220-year-old *Abies sibirica* site was about the same as in the undisturbed *Pinus sylvestris* stand, 129.8 Mg ha^{-1}, the storage structure was different (figure 2B). Like in the *Pinus sylvestris* sites, the live phytomass accounted for half of the total carbon here, but the plant detritus contained much less (17.5 %) and soil humus considerably more (32 %) carbon. After logging, in the three-year-old *Abies sibirica* logged site, the phytomass contribution decreased by more than an order of magnitude (down to 3.6 %) and the relative humus contribution increased to 44.8 %. The total carbon on this site even increased due to a five-fold increase in coarse woody debris stock induced by logging. In the 26-year-old *Abies sibirica* logged site, which supported a 50-55- year-old stand, the carbon storage ratio between the main organic matter pools did not reach that obtained for the undisturbed *Abies sibirica* stand. The contribution of the live phytomass was twice that in the three-year-old logging site. The coarse woody debris pool

Table 1. Sample stand characteristics.
Características de los rodales muestreados.

Sites	Time since logging (years)	Major woody species	Stand age (years)	Average stand height (m)	Average tree diameter (cm)	Standing volume (m^3 ha^{-1})
		Pinus sylvestris forests, Ulan-Burgasy Mt. Ridge				
Control	-	*Pinus sylvestris*	180 ± 20	19.5 ± 1.1	22.0 ± 2.2	180
Clear-cut	60	*Pinus sylvestris*	60 ± 4	10.3 ± 0.7	9.8 ± 1.3	122
Recently logged site	2	*Pinus sylvestris*	-	-	-	20
		Abies sibirica forests, Khamar-Daban Mt. Ridge				
Control	-	*Abies sibirica*	220 ± 35	12.4 ± 1.8	16 ± 2.6	199.4
Logged site	26	*Abies sibirica*	55 ± 5	4.7 ± 0.5	6.1 ± 1.2	17.5
Recently logged site	3	*Abies sibirica*	-	-	-	-

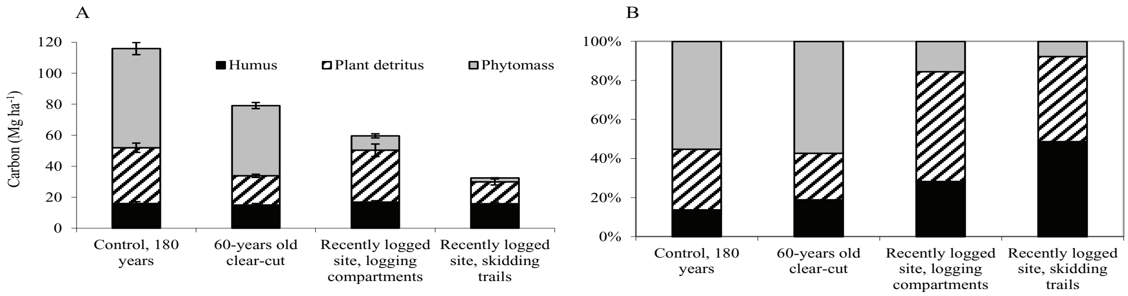

Figure 1. Carbon storage (A) and contributions of the main pools (B) in the logged Scots pine sites.
Almacenamiento de carbono (A) y contribuciones de las principales reservas (B) en rodales explotados de pino silvestre.

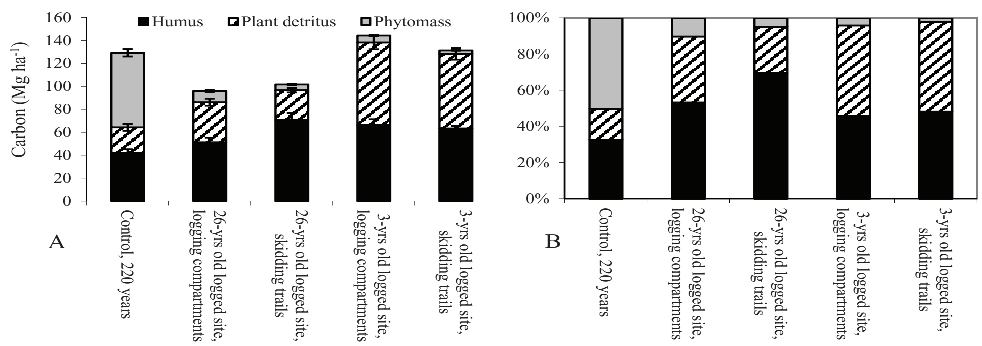

Figure 2. Carbon storage (A) and contributions of the main pools (B) in the logged Siberian fir sites.
Almacenamiento de carbono (A) y contribuciones de las principales reservas (B) en rodales explotados de abeto siberiano.

contributed more than triple less (35.7 %) to total carbon stock, whereas soil humus contribution was still relatively high (54.2 %)

The total loading of coarse woody debris was about 13.3 Mg ha^{-1} of carbon in the undisturbed *Pinus sylvestris* site, which amount was about equal to that in the logging compartments of the recently logged site (12.9 Mg ha^{-1} of carbon) vs. at most 1.2 Mg ha^{-1} of carbon on the skidding trails. In the 60-year-old clearcut site, the total coarse woody debris stock was only 6.2 Mg ha^{-1} of carbon. Coarse woody debris loading in the compartments of the recently logged *Pinus sylvestris* site was almost twice that of live tree biomass. In the 60-yr-old clear-cut an on the control site with a 180-yr-od *Pinus sylvestris* stand, the coarse woody debris contribution to the total carbon decreased to become 13-18 % of that of the live phytomass (figure 3).

The skidding trails on the recently logged *Abies sibirica* site stood out for the highest coarse woody debris load, 61.6 Mg ha^{-1} of carbon (figure 3), which amount accounted for about 63.8 % and 80.5 % of the total plant organic matter in the logging compartments and skidding trails, respectively.

The undisturbed *Pinus sylvestris* and *Abies sibirica* sites were similar in coarse woody debris contribution to the total organic matter, about 10.3 % and 12.5 %, respectively, *i.e.* about 34-38 % of the total phytodetritus pool of these site.

DISCUSSION

Carbon is accumulated in forests in three main pools: living phytomass, dead plant residues, and soil humus. These pools are the major forest carbon budget controls. Living phytomass is the main sink of the atmospheric carbon, plant residues are its main source, and soil humus is one of the largest carbon reservoirs, because of a very low rate of turnover of its components. The changes of the ratio between these three pools often result in changing of the carbon-flux pattern in an ecosystem. Increasing plant detritus enhances carbon efflux, whereas phytomass losses lead to decreases in the amount of fixed carbon and in stand production.

On the logging sites the plant detritus increase most prominently due to the presence of high amounts of logging slash. The rate of coarse woody debris decomposition calculated based on the log wood density in the chronosequences appear to differ between the logged *Abies sibirica* and *Pinus sylvestris* sites. The decomposition rate constant calculated using a single exponential model (Olson 1963) is 0.025 per year for the *Abies sibirica* logs and 0.0069 per year for *Pinus sylvestris* logs. These values are comparable to those reported for these woody species in literature (Harmon *et al*. 2000, Yatskov *et al*. 2003, Trefilova *et al*. 2009).

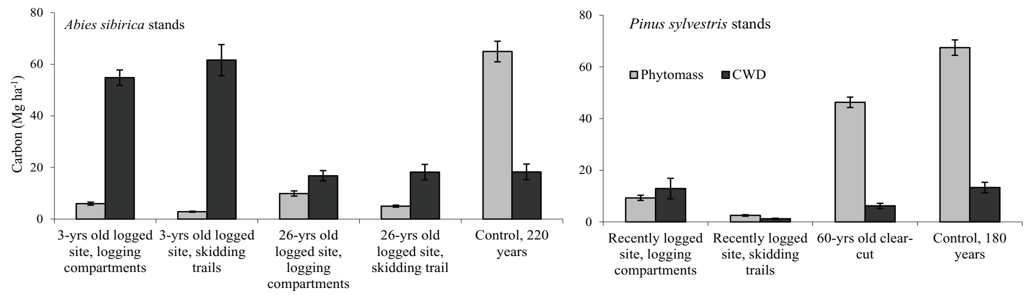

Figure 3. Dynamics of phytomass and CWD stock in recovery lines of fir and pine forests.
Dinámica de fitomasa y stock de CWD en líneas de recuperación de bosques de abeto y pino.

Based on the coarse woody debris loading and decomposition rate values obtained, the coarse woody debris pool at the recently logged *Abies sibirica* site is likely to decrease averagely by 41 % (*i.e.* by about 25 Mg ha^{-1} of carbon) in next 26 years. This carbon will most likely return to the atmosphere, because no soil humus carbon increment was observed in the *Abies sibirica* chronosequence. Such huge an efflux will obviously not be compensated by future phytomass, as its increment measured on the 26-year-old logged *Abies sibirica* site was only 2-4 Mg ha^{-1} of carbon and generally did not exceed 10 Mg ha^{-1} (figure 3).

The efflux from the decomposing coarse woody debris found on the recently logged *Pinus sylvestris* site is presumed to be substantially lower due to a lower coarse woody debris amount and rate of decomposition as compared to the *Abies sibirica* sites. The organic carbon efflux from decomposing *Pinus sylvestris* coarse woody debris is, thus, predicted to reach only 2 Mg ha^{-1} of carbon during the next 60 years, which amount is much less than the phytomass increment obtained for this site for the same time period (figure 3)

Coarse woody debris buildups and increases in the net carbon efflux have been reported by other researchers (Plaut 2002, Howard *et al*. 2004, Liu *et al*. 2006). A comparison between the post-logging succession series of the two woody species show that logged *Abies sibirica* stands remain a carbon source to the age of 55-60, whereas logged *Pinus sylvestris* sites become carbon sinks by this age due to high phytomass production, low logging slash amount and rate of decomposition.

CONCLUSIONS

Logging in *Pinus sylvestris* and *Abies sibirica* stands is found to alter the ratio between the main organic carbon pools and to reduce drastically tree phytomass contribution to logged site carbon budgets.

In the recently logged *Pinus sylvestris* and *Abies sibirica* sites, the carbon-related significance of soil organic matter pools (phytodetritus and humus) increase considerably. These two woody species appear to differ in the time needed for the ratio to recover back to pre-logging. In the 60-year-old logged *Pinus sylvestris* sites, the stored carbon is as high as almost 70 % of that on the control site. The ratio between phytomass and soil organic matter recover back to pre-logging by this age. The phytomass carbon also increase in the disturbed *Abies sibirica* stand of the same age, though it does not reach the level on the control stand. In the 50-55-year-old stand, carbon recover only by 15 % of its pre-logging pool.

The decomposition rate of *Pinus sylvestris* logs is significantly lower as compared with *Abies sibirica* logs and coarse woody debris. Slow post-logging phytomass recovery and rapid decomposition of a huge amount of logging slash make the disturbed *Abies sibirica* sites potential sources of carbon to the atmosphere. Conversely, the logged *Pinus sylvestris* sites become carbon sinks due to the high stand growth rate, low logging slash load and decomposition rate.

ACKNOWLEDGEMENTS

This research was supported by the Russian Foundation for Basic Research (RFBR) (Grants 10-04-00337 and 11-04-01884) and by joint grants of RFBR and Krasnoyarsk Regional Foundation for Science and Technical Development (Projects 11-04-98008 and 11-04-98089).

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 267-270, 2012 DOI: 10.4067/S0717-92002012000300006

Changes in height growth patterns in the upper tree-line forests of Tierra del Fuego in relation to climate change

Cambios en los patrones de crecimiento de los bosques del límite superior altitudinal de Tierra del Fuego en relación al cambio climático

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SUMMARY

Nothofagus pumilio occupy the mountain slopes reaching to the upper altitudinal limit of the forests. This extremely stressful environment represents the optimum conditions to study changes in growth patterns due to climate variations. Our goal was to analyze recent changes in stem height growth in forests located in the upper altitudinal tree-line along Tierra del Fuego (Argentina), and establish possible linkages to changes observed in surface temperature during the last decades. Nine locations were sampled, and four plots were measured in each location. Forest structure was characterized, and stem analyses were performed to assess height growth patterns. ANOVAs and classification analyses were conducted using location and time as main variables. Tree-growth height increased with time, e.g. 1.0 cm.year^{-1} during 1870-1959, 2.7 cm year^{-1} during 1960-1979, and 5.0 cm year^{-1} during 1980-2010. These differences were significant between periods and locations, and can be related to its geographical situation. Increment in stem height growth seems to be related with the worldwide surface air temperature. A decline in stem height growth registered during the last two decades can also be related with the regional decrease in the mean air temperature. The analysis of stem height growth is a useful tool to evaluate the incidence of climate change over trees growing under extreme environmental conditions.

Key words: tree-line, *Nothofagus,* height growth, climate change, forest structure.

RESUMEN

Los bosques de *Nothofagus pumilio* ocupan las laderas de montaña hasta alcanzar el limite altitudinal del bosque. Estos ambientes extremos, donde los bosques están bajo condiciones de estrés ambiental, son óptimos para estudiar patrones de cambio debidos a variaciones climáticas. El objetivo fue analizar cambios recientes en el crecimiento en altura en bosques localizados en el tree-line altitudinal en Tierra del Fuego (Argentina) y establecer posibles vinculaciones con cambios en la temperatura observados durante las últimas décadas. Se muestrearon nueve sitios, y se midieron cuatro parcelas en cada sitio. Se determinó la estructura forestal y se realizaron análisis fustales para evaluar los patrones de crecimiento en altura. Se realizaron ANOVA y análisis de clasificación usando como factores principales al sitio y al tiempo. El crecimiento en altura aumentó a lo largo del tiempo, *e.g.* 1,0 cm año^{-1} durante 1870-1959, 2,7 cm año^{-1} durante 1960-1979 y 5,0 cm año^{-1} durante 1980-2010. Esas diferencias fueron significativas entre períodos de tiempo y sitios, pudiendo estar relacionadas con la localización geográfica. El incremento en el crecimiento en altura observado está relacionado con los cambios en la temperatura de superficie experimentada en todo el mundo. Una declinación en el crecimiento en altura durante las últimas dos décadas, también puede estar relacionada con una disminución regional de la temperatura de aire. El análisis del crecimiento en altura es una herramienta de utilidad para evaluar la incidencia que tiene el cambio climático sobre el crecimiento de los árboles que crecen en ambientes extremos.

Palabras clave: bosque altitudinal, *Nothofagus,* crecimiento en altura, cambio climático, estructura forestal.

INTRODUCTION

Lenga (*Nothofagus pumilio* (Poepp. *et* Endl.) Krasser) is an endemic species of Patagonian forests with a wide geographical distribution (35° 35' to 55° 31' S). These forests live from the sea level (up to 30 m height) to the upper altitudinal tree-line, where forming forests with a stunted morphology of 1-2 m high. Sometimes, it is possible to find ñirre (*Nothofagus antarctica* (Forster) Oersted) and guindo (*Nothofagus betuloides* Bidr. Egefam) in the tree-line. Similar to that occurs in these forests, in mountain regions of Northern Hemisphere and Australasia, morphological changes induced by thermal variations in altitudinal gradients were observed (Kullman 1979, Holtmeier 2000).

In these environmental conditions, the forests growth under the extreme stress conditions, mainly influenced by thermal variations (Tuhkanen 1992). In Tierra del Fuego, the correlation between growth and temperature increase with altitude, evidencing the greater influence of climate close to the tree-line (Massaccesi *et al*. 2008). Therefore, it is expected that these thermal changes should influence over growth rates, stem morphology and regeneration at the tree-line (Fajardo and McIntire 2012), being these environments the best places to study climate change processes (Cuevas 2000, Daniels 2000).

The goal of this study was analyze recent changes in height growth patterns in the upper tree-line *N. pumilio* forests along Tierra del Fuego (Argentina), and establish possible linkages to changes observed in surface temperature.

METHODS

Nine locations were selected in the central-south sector of Tierra del Fuego (Argentina), covering ranges of latitude, longitude and aspects of tree-line forests (table 1). In each location, a tree-line area without evident recent disturbances was chosen for samplings. Four plots of 50 m^2 each were established, and basal diameter was measured in all trees. In each plot, a dominant tree was chosen and cross sections cuts were obtained every 25 cm from the base to the total height. Cross sections were used for stem analysis to reconstruct the history of height growth in each tree. Height growth increments were compared with worldwide surface air temperature (Jones *et al.* 1999) for the period 1900-1999, and local air temperature of weather stations for the period 2000-2010.

A factorial ANOVA was performed to analyze height growth patterns using location and time (1870-1959, 1960-1979 and 1980-2010) as main factors. Comparisons of means were performed using Tukey test at $P > 0.05$. Furthermore, a cluster analyses was conducted using the Ward's method linkage with Euclidean distance matrix to find similarities among the different locations and height growth increments of each decade for the period 1910 to 2010.

RESULTS

Sampling locations covered a north-south gradient from 54º 52' 29" to 54º 31' 42" S, and east-west gradient from 66º 40' 32" to 68º 18' 03" W, with different aspects, and reaching altitudes from 518 to 662 m a.s.l. (table 1). Sampled forests have ages from 67 to 140 years, with basal diameters between 6.6 and 16.7 cm, dominant heights between 1.7 and 3.0 m, densities between 3,850 and 6,250 trees ha^{-1}, and basal area at stem base between 26.3 and 86.3 m^2 ha^{-1} (table 1).

In the factorial ANOVA, height growth increment significantly varied among locations, as well as the time period (table 2). Fagnano location presented the lowest height growth increment (1.6 cm year^{-1}), and was significantly different from Escondido, Malvinera, Observación and Tristen locations (2.7 to 3.8 cm year^{-1}). The remaining locations showed intermediate values between these groups. Significant differences were found among time periods. Height growth increments gradually increased along the time, reaching to 1.0 cm year^{-1} during 1870-1959, 2.7 cm year^{-1} during 1960-1979, and 5.0 cm year^{-1} during 1980-2010. Significant interactions were detected due to the height growth increments differed in magnitudes among period for the different locations (figure 1). A similar pattern of height growth increment was observed for all sites, related to the time period. Increments of height growth were higher during 1980-2010 period compared to 1960-1979, and were higher during 1960-1979 compared to 1870-1959 period.

In the cluster analysis, it was observed two groups at Euclidean linkage distance of 8 defined by the distance to major water bodies (Fagnano Lake, Beagle Channel or Argentinean sea). One group composed of three locations (Malvinera, Tristen and Observación) presented distances

Table 1. Geographic situation of sampling sites and mean values of forest structure variables registered in each site.
Situación geográfica de los sitios de muestreo y valores medios de las variables de estructura forestal registradas en cada sitio.

Location	Latitude	Longitude	Aspect	Altitude (m a.s.l.)	Age (years)	D (cm)	H (m)	N (trees ha^{-1})	BA (m^2 ha^{-1})
A: Andorra	54º44'23"	68º18'03"	E	662	67	9.2	2.1	6,000	46.3
B: Bronzovich	54º37'16"	67º48'08"	E	581	110	11.6	2.3	6,050	76.0
E: Escondido	54º39'57"	67º47'00"	W	599	115	12.4	2.9	4,950	73.2
F: Fagnano	54º31'42"	67º56'33"	S	581	109	6.6	1.7	6,250	23.3
J: Jeujepen	54º35'06"	67º14'29"	N	621	80	16.7	2.1	3,850	86.3
M: Malvinera	54º37'23"	66º40'32"	N	545	114	11.1	3.0	5,400	54.3
N: Nontop	54º52'29"	67º09'41"	S	518	140	10.4	2.3	8,050	85.5
O: Observación	54º36'56"	67º05'44"	W	606	79	9.5	3.0	4,088	29.9
T: Tristen	54º42'44"	67º56'47"	W	610	85	8.1	2.8	5,250	36.0

D: basal diameter; H: dominant height; N: density; BA: basal area at stem base.

Table 2. Analysis of variance of height growth increment (HGI) considering location and time period as main factors.
Análisis de varianza del incremento del crecimiento en altura (HGI) considerando la localización y período de tiempo como factores.

Factor	Level	HGI (cm year^{-1})
Location	Fagnano	1.61 a
	Nontop	1.65 ab
	Bronzovich	2.24 ab
	Jeujepen	2.61 ab
	Escondido	2.73 b
	Malvinera	2.75 b
	Tristen	3.13 b
	Andorra	3.15 b
	Observación	3.55 b
	F	4.52
	P	< 0.001
Period	1870-1859	1.00 a
	1960-1979	2.67 b
	1980-2010	5.01 c
	F	208.19
	P	<0.001
Interactions	F	6.37
	P	<0.001

F: Fisher test; *P*: probability level. Different letters denote significant differences between treatments by Tukey test ($P < 0.05$).

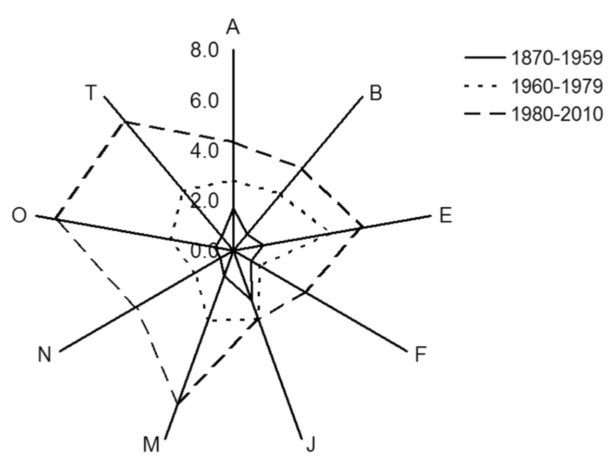

Figure 1. Height growth increments of each location at three period times used in table 2. See location names in table 1.
Incrementos del crecimiento en altura de cada localización en tres períodos de tiempo usados en el cuadro 2. Ver nombres de las localidades en el cuadro 1.

between 13.9 and 21.7 km with N and W aspects, while the second groups presented lower distances (1.3 to 9.4 km). This last group presented two subgroups at euclidean linkage distance of five, one defined by S aspects (Fagnano and Nontop) and the second one by E (Andorra and Bronzovich), W (Escondido) and N (Jeujepen) aspects (figure 2).

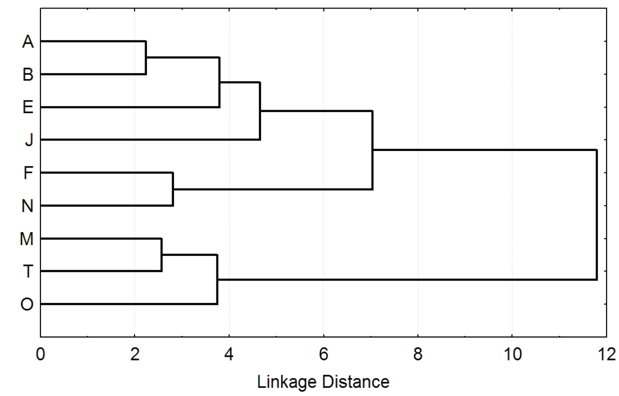

Figure 2. Cluster analysis of height growth increments of each decade (1910 to 2010) among locations. See location names in table 1.
Análisis de agrupamiento de los incrementos del crecimiento en altura de cada década (1910 a 2010) entre localizaciones. Ver nombres de la localizaciones en el cuadro 1.

When average height growth increment for all location were compared with surface air temperature (figure 3), a correlation was observed: (a) a steady-state for the period before to 50's, (b) an increase in temperature and height growth increments between 60's and 80's, and (c) an slight decrease in temperature and height growth increments since the 90´s to the present (figure 3).

DISCUSSION

Forest structure variables registered in this work are comparable to those measured in other studies, *e.g.* Barrera *et al.* (2000) register in Tierra del Fuego values of 7,520 trees ha^{-1}, basal area of 56 m^2 ha^{-1}, 10 cm diameter, 2 m height and ages of 137 years. Aspects and geographic locations (distance to major water bodies) influence more than forest structure and tree growth, *e.g.* south aspects produce lower increments, while greater distances to water bodies produce higher increment values.

The differences in height growth increments between 1960-1979 and 1870-1959, and between 1980-2010 and 1960-1979, are consistent with variations observed in the worldwide surface air temperature of the second half twentieth century (Jones *et al.* 2001). These changes are registered at different magnitudes along the worldwide forest ecosystems, but are more evident in forests growing at extreme environmental conditions (*e.g.* high latitudes or high elevations) (Massaccesi *et al.* 2008).

Height growth of the trees follow a typical sigmoid curve (Ivancich *et al.* 2011), defined by genetics of the species and the site quality of the stands (Klepac 1983). In our study, the changes in height growth pattern are not related to tree age. It was expected that greatest increments of growth occurred during the first years of development, and then decline gradually, reaching to values close to zero at

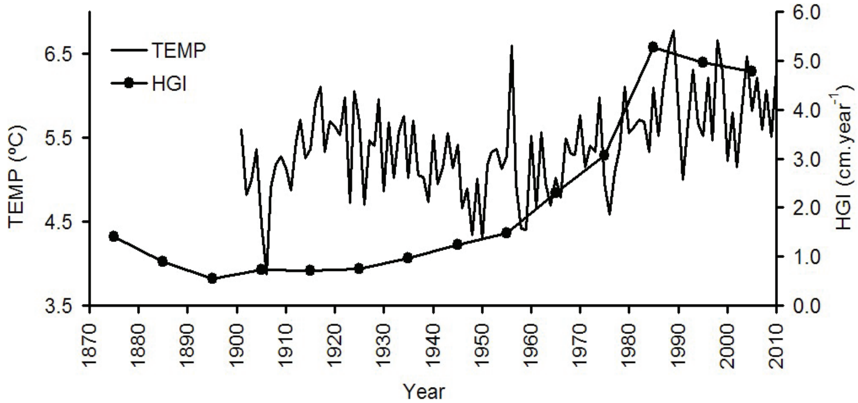

Figure 3. Surface air temperature (TEMP) in the studied area (1900-1999 were obtained from Jones *et al.* 1999, and 2000-2010 from local weather stations), and average height growth increment (HGI) for the nine studied locations.

Temperatura del aire superficial (TEMP) en el área de estudio (datos de 1900-1999 fueron obtenidos de Jones *et al.* 1999, y 2000-2010 de las estaciones climáticas locales) y el incremento promedio del crecimiento en altura (HGI) para las nueve localizaciones estudiadas.

the senescence stage (Martínez Pastur *et al.* 1997). However, the changes in height growth increments of this study are related to climate changes, with a trend to increase (*e.g.* 60's to 80's) or to decrease (90's to the present). This decrease in tree growth since the 80's is in agreement with other authors (*e.g.* Masiokas and Villalba 2004).

CONCLUSIONS

Stem analysis is a useful tool to evaluate the effects of climate change on trees growing under extreme environmental conditions. Forest structure and growth change according to aspects and geographic locations (distance to major water bodies), but increments in stem height growth seem to be correlated with worldwide surface air temperature. Tierra del Fuego forests growing at the altitudinal tree-line clearly increase height growth increments during the last 50 years, but also detect a decline during the last two decades correlated with the regional decrease in the average air temperature.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 271-274, 2012 DOI: 10.4067/S0717-92002012000300007

Do beavers improve the habitat quality for Magellanic Woodpeckers?

¿Los castores mejoran la calidad del hábitat para el pájaro carpintero magallánico?

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SUMMARY

The effect of the disturbances caused by the American beaver (*Castor canadensis*), introduced to the Cape Horn Biosphere Reserve, on species of birds that are forest habitat specialists is poorly understood. Using telemetry data, we determined which attributes of abandoned beaver meadows have a strong impact on habitat selection by the Magellanic woodpecker (*Campephilus magellanicus*). We detected a positive relationship between the woodpecker habitat use and the fraction of old-growth forest located near these meadows. These results suggest that favorable habitat conditions are generated around small meadows with old-growth forest, because they might increase availability of wood-boring larvae.

Key words: American beaver, *Campephilus*, habitat selection.

RESUMEN

El efecto que tienen las perturbaciones causadas por el castor norteamericano (*Castor canadensis*) -introducido en la Reserva de Biosfera Cabo de Hornos- sobre especies de aves especialistas de hábitat forestales es poco conocido. Utilizando datos de telemetría determinamos qué atributos de las castoreras abandonadas tienen una mayor influencia en la selección del hábitat por los carpinteros negros (*Campephilus magellanicus*). Existe una asociación negativa entre el uso del hábitat por carpinteros y el tamaño de las castoreras, mientras que los carpinteros muestran preferencias por el bosque antiguo ubicado cerca de estas castoreras. Estos resultados sugieren condiciones de hábitat favorables cerca de las castoreras pequeñas y rodeadas de bosque antiguo, probablemente debido a un aumento en la disponibilidad de larvas taladradoras de madera.

Palabras clave: Castor norteamericano, *Campephilus*, selección de hábitat.

INTRODUCTION

Woodpeckers are highly sensitive to anthropogenic forest disturbances that cause the loss of their foraging and breeding structures at different spatial scales (*e.g.*, snags or large decaying trees; Lammertink 2004, Bull *et al*. 2007). Humans can indirectly contribute to the degradation of bird habitats by introducing mammal species that feed on trees and alter forest ecosystems, including feral goats, rabbits, feral cattle, hogs, and beavers (Hahn *et al*. 2011).

The American beaver (*Castor canadensis* Kuhl.), introduced to the sub-Antarctic forests of southern South America in the 1940s, is likely to represent one of the most dramatic cases of forest degradation by an invasive species worldwide (Skewes *et al*. 2006, Anderson *et al*. 2009). Beaver ponds flood adjacent forest areas, thus transforming the forest into meadows once the beavers abandon their dams (Anderson *et al*. 2009). Beaver ponds and meadows have diverse effects on wildlife in sub-Antarctic forests, decreasing the diversity of aquatic organisms and understory plants (Anderson and Rosemond 2007, Anderson *et al*. 2009). However, the effect of beavers on forest specialist species, such as the endemic Magellanic woodpecker (*Campephilus magellanicus* King.) is poorly understood. Vergara and Schlatter (2004) reported more intense foraging by woodpeckers within old-growth forest as distance to beaver meadows decreased. Recently, it was determined[1] that although woodpeckers only occupy

[1] Gerardo E Soto *et al*., unpublished data.

marginally standing dead trees within abandoned beaver meadows, they exhibit a strong preference for forest areas near to these meadows. In the beaver's native range, several woodpecker species have been reported using beaver meadows and their forest boundaries (Lochmiller 1979, Edwards and Otis 1999). These findings suggest that the disturbance generated by beavers may positively influence the quality of adjacent foraging habitat for woodpeckers. The goal of this study is to evaluate the influence that landscape-scale attributes of beaver mea-dows, and their adjacent boundary areas, might have on the habitat selection patterns of Magellanic woodpeckers.

METHODS

This study was conducted on Navarino Island in the Cape Horn Biosphere Reserve, southern Chile. The study area encompasses a surface of 924 ha, from sea level to an altitude *ca.* 400 m a.s.l., centered on the Omora Ethnobotanical Park (54° 57' S, 67° 39' W). Vegetation occurs as a mosaic of *Nothofagus spp.* forest stands, scrubland patches, beaver meadows, natural wetlands, and peat bogs in the lower areas. Forest stands vary in their composition (including *Nothofagus betuloides* (Mirb.) Oerst., *Nothofagus antarctica* Bidr. Egefam, and *Drimys winteri* J. R. *et* Forster in moist and flooded areas, as well as *N. pumilio* in drier and upland areas), age (*i.e.*, old-growth and second-growth), and level of human disturbance, including logging, fires, and livestock impacts. American beavers were first discovered on Navarino Island in the 1960s (Sielfeld and Venegas 1980), being currently widespread in almost all watersheds across the island. In the study site, all beaver meadows were areas once covered by ponds (probably for over 10 years), where the ground is partially flooded with scattered standing dead trees and herbaceous species in less humid sites (Anderson *et al*. 2009) (figure 1).

We used a GPS database of telemetry locations for modeling within home-range habitat selection pattern of Magellanic woodpeckers[2]. Woodpecker locations were determined daily through radio-telemetry by homing-in (unpublished data). Between January and March 2012, we tracked six male woodpeckers from different adjacent families (2-5 individuals per family). We identified and mapped 19 beaver meadows within the study site using high-resolution QuickBird imagery (resolution = 2.4 m) and geo-referenced field data (figure 1). As woodpeckers actively use habitats near abandoned beaver meadows (unpublished data), we delimited a buffer of 100 m around the boundary of each beaver meadow. This buffer area was considered to be ecologically important for woodpeckers given that more than 70 % of kernel utilization values were distributed within such buffers. Using a vegetation cover map and the 95 % kernel home ranges of each individual, we quantified variables characterizing each beaver meadow and their adjacent areas. We estimated the area of each meadow and the proportion of the buffer occupied by old-growth forest, second-growth forest, and open vegetation (*i.e.*, peat- and scrublands).

We used binomial generalized linear models to assess the selection of buffer areas around beaver meadows by woodpeckers. In these models, each combination of beaver meadow and individual was considered as an independent data record. Thus, habitat use probability was specified as the frequency of telemetry fixes within the buffer in relation to the total fixes recorded within the home range. We did not include fixes within the meadows because only four times (< 1.5 % of data) were woodpeckers recorded in meadows. The relative area of each buffer within the home range was specified as an offset variable in order to control for the availability of these boundary areas. Beaver meadows and individuals were included as random effect factors. Akaike's information criterion (AIC) and weights were used to evaluate the support for competing a priori models.

RESULTS

We identified three best supported models (ΔAIC < 2), which comprised the 69 % of Akaike weights (table 1). According to the model-averaged coefficients, the proportion of old-growth and secondary forest had a positive effect on the probability of a woodpecker selecting a buffer area, whereas for the proportion of open areas and size of beaver meadows, this effect was negative (table 2). However, only the effects of old-growth forest and meadow area were significant, having importance coefficient values higher than 0.8 (table 2).

DISCUSSION

Our results suggest that a positive effect of the proximity of beaver meadows on woodpecker preferences is conditioned by the attributes of the habitat adjacent to these meadows. Old-growth forest is disproportionally more used by woodpeckers as its availability increased around beaver meadows. Old-growth forests function as a primary habitat for woodpeckers, and hence the increased foraging activity near the meadows suggests an improvement in habitat quality. Probably, proximity to flooded areas results in microclimatic gradients in soil moisture conditions that under the canopy may favor infestation of individual trees by woodboring insects (Vergara and Schlatter 2004), the main prey of woodpeckers (Short 1970, Ojeda and Chazarreta 2006). Thus, beavers indirectly could improve, at least in the short or medium term, the quality of habitat for woodpeckers. The preference of woodpeckers for areas near small-sized meadows may be a response to better habitat conditions in these sites. Moreover, small-sized meadows represent small discontinuities (gaps) within the old-growth forest, and hence woodpeckers do not need to move large distances to cross these forest gaps. Further, small meadow areas

[2] Jaime E Jiménez *et al.*, unpublished data.

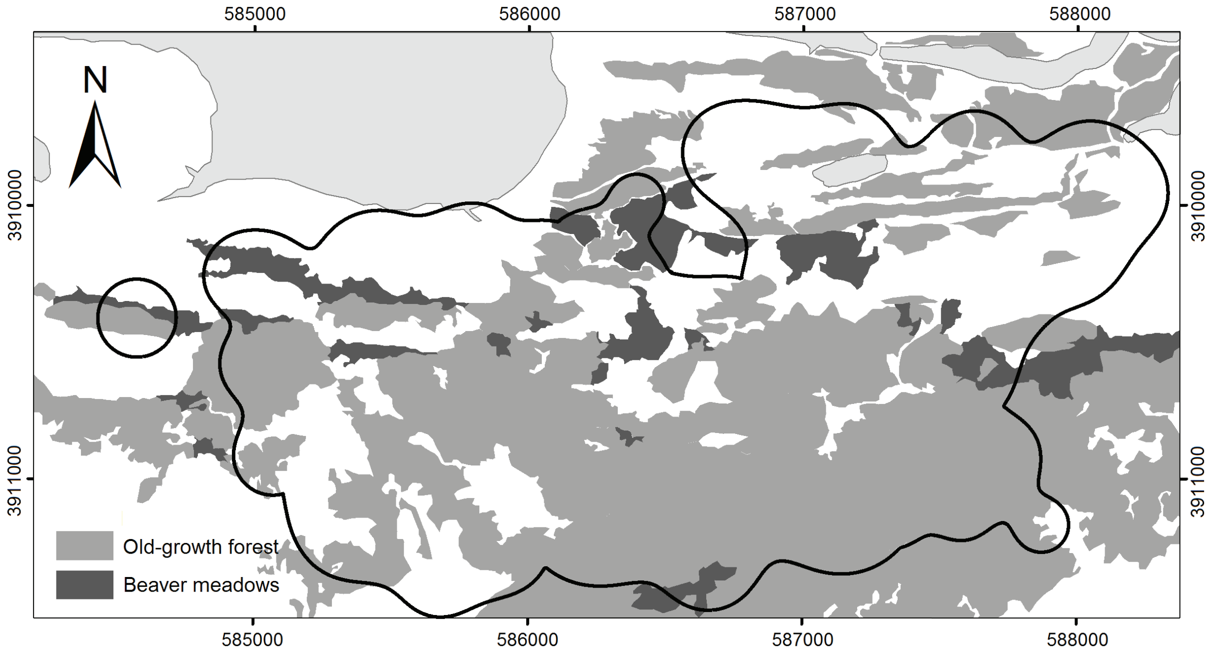

Figure 1. Map of the study area showing the spatial distribution of old-growth forest and beaver meadows in Cape Horn Biosphere Reserve, Navarino Island, Chile. Light grey coloring refers to lakes and sea water. White areas correspond to other cover types (see text). Thick line represents the pooled 95 % kernel home ranges of the six woodpeckers studied.

Mapa del área de estudio que muestra la distribución espacial de los bosques de crecimiento antiguo y las praderas sobre castoreras en la Reserva de Biosfera Cabo de Hornos, Isla Navarino, Chile. El color gris claro representa los lagos y el agua del mar. Las áreas blancas corresponden a otros tipos de cobertura (ver texto). La línea gruesa representa los límites espaciales de los kernels agrupados del 95 % de los ámbitos de hogar de los seis pájaros carpinteros estudiados.

Table 1. *A priori* candidate models explaining the selection of buffer areas around beaver meadows by woodpeckers in Navarino Island. Only candidate models with ΔAIC < 4 are shown.

Modelos candidatos a priori que explican la selección de las zonas de amortiguamiento alrededor de castoreras por pájaros carpinteros en la Isla Navarino. Sólo se muestran los modelos candidatos con ΔAIC < 4.

Model	k	AIC	ΔAIC	Weight
Old-growth forest + Meadow area	3	386.77	0.00	0.29
Old-growth forest + Secondary forest + Meadow area	4	387.07	0.30	0.25
Old-growth forest + Open vegetation + Meadow area	4	388.08	1.31	0.15
Old-growth forest + Secondary forest + Open vegetation + Meadow area	5	389.04	2.27	0.09
Old-growth forest + Open area	3	389.50	2.73	0.07
Meadow area	2	390.01	3.24	0.06
Old-growth forest	2	390.43	3.66	0.05
Old-growth forest + Secondary forest	3	390.76	3.99	0.04

Table 2. Model-averaged coefficients, adjusted standard errors, p values and importance values from models explaining the selection of buffer areas around beaver meadows by woodpeckers in Navarino Island (see table 1).

Coeficientes promediados, errores estándares, valores de probabilidad y valores de importancia de los modelos que explican la selección de las zonas de amortiguamiento alrededor de castoreras por pájaros carpinteros en la Isla Navarino (ver cuadro 1).

Variable	Coefficient	Adjusted SE	*P*	Importance
Old-growth forest	0.689	0.338	0.041	0.94
Meadow area	-0.010*	0.005*	0.036	0.84
Secondary forest	0.265	0.206	0.199	0.38
Open vegetation	-0.150	0.168	0.372	0.32

*Multiplied by 1,000.

have larger perimeter/area ratios than large meadows and hence, microclimatic conditions suitable for wood-boring insects would increase relatively in buffer areas.

CONCLUSIONS

Although beavers cause the extensive loss of old-growth forest, the primary habitat for Magellanic woodpeckers, they indirectly improve the habitat quality for woodpeckers in Navarino Island. Such an increase in habitat quality could occur due to small beaver meadows provide favorable environmental conditions for the infection by wood-boring insects in *Nothofagus spp.* trees located near beaver-created habitats.

ACKNOWLEGMENTS

We thank the Scientific Committee of the 2012 IUFRO Landscape Ecology Conference and the valuable comments by anonymous reviewers. This research has been partially supported by the Sub-Antarctic Biocultural Conservation Program of the University of North Texas (UNT) and the Institute of Ecology and Biodiversity (IEB, P05-002 ICM-MIDEPLAN, and PFB-23 Basal-CONICYT). Special thanks to Mario Nazar who supported equipment and travel costs. Jorge Tomasevic provided technical advice, and SAG has provided permits to capture birds. This publication is a contribution to the long-term ecological research program of the Omora Ethnobotanical Park (IEB, UNT, and Universidad de Magallanes) in the Cape Horn Biosphere Reserve.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 275-279, 2012 DOI: 10.4067/S0717-92002012000300008

The role of land-use visions for protection of forest landscapes: the Białowieża Forest (Poland)

El rol de las visiones del uso del suelo en la protección de los paisajes forestales: el bosque de Bialowieza (Polonia)

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SUMMARY

The work concentrated on relations between the issues of use and protection that developed in the Polish part of the Białowieża Forest last century, particularly during the post-war decades. Owing to extraordinary natural values, the area deserves very careful protection, however, negative impacts on the landscape have been widely observed. The changes involving perforation and fragmentation of forest cover caused by continuous logging are accompanied by spatial disorder in built areas and their vicinities resulting from tourism development. The aim of the research was to identify the underlying forces of negative tendencies and simultaneously, obstacles to progress in nature conservation of the area. Comparison of views and visions of land-use and management of the Forest showed that great differences in attitudes, applied perspectives and expectations to the Białowieża Forest exist. The study revealed the importance of a socio-cultural dimension for a current stage of landscape evolution. This influence is connected with a steady pressure on wood exploitation and results, at least partially, from a strong position of forest administration in this area and from specific land-use visions emphasizing economic services of the forest. Noteworthy, actions undertaken across the country and numerous efforts to extend protection of the area have not succeeded so far. It is argued that underestimation of natural values expressed by local communities in addition to weaknesses of the state's environmental law may bring serious hazards to the analysed landscape and affect the whole system of nature conservation in Poland.

Key words: landscape, change, values, Białowieża Forest, Poland.

RESUMEN

Esta investigación estudió las relaciones entre el uso y protección del bosque Białowieża, Polonia, durante el último siglo, particularmente en las décadas de la post-guerra. Debido a los extraordinarios valores naturales, esta área necesita una protección muy especial. Sin embargo, se han observado diversos impactos negativos sobre el paisaje. Los cambios implicaron perforación y fragmentación del bosque causados por la continua tala de árboles, debido a la expansión urbana asociada al desarrollo turístico. El objetivo de esta investigación fue identificar los forzantes subyacentes de tendencia negativa y los obstáculos para el progreso de la conservación de la naturaleza en la zona. Comparación de puntos de vista, visiones de uso del suelo y manejo del bosque, evidenciaron importantes diferencias en actitudes, perspectivas y expectativas aplicadas al bosque de Białowieża. El estudio reveló la importancia de la dimensión socio-cultural en el estado actual de evolución del paisaje. Esta influencia está relacionada con una presión constante sobre la explotación maderera, por lo menos parcialmente, desde una fuerte posición de la administración forestal en esta área y desde visiones específicas de uso de suelo que enfatizan los servicios económicos de los bosques. Cabe destacar, que acciones realizadas en todo el país y los numerosos esfuerzos para ampliar las áreas de protección no han tenido éxito hasta el momento. Se argumenta que la subestimación de los valores naturales expresada por las comunidades locales, además de las debilidades de la legislación ambiental del Estado, pueden traer serias amenazas para el paisaje analizado y afectar a todo el sistema de conservación de la naturaleza en Polonia.

Palabras clave: paisaje, cambio, valores, bosque Białowieża, Polonia.

INTRODUCTION

The Białowieża Forest is a remnant of vast European lowland woodlands and it still exhibits several features indicating a rich primeval forest. Possessing outstanding natural values, the area was enlisted to Unesco World Heritage in 1979. However, recent centuries (Mitchell and Cole 1998) and particularly, the 20th century has been connected with acceleration of disturbance processes (Conservation of the Białowieża Forest 2003, Wesołowski 2005). A current study regards processes that affected the Polish part of the Forest during last decades.

The work consists of three parts. The first part is focused on landscape change and identifies main tendencies characteristic of the post-war period. The second aims to distinguish the underlying forces of change. The third part is concentrated on current visions of the Białowieża Forest and its land-use, and consequently, on conceptions of its management and preservation. Trying to recognize the logic of the forest's management the study exposes different attitudes to the Forest as well as levels and agents of social interactions.

METHODS

The Białowieża Forest (Puszcza Białowieska) is situated in the north- eastern part of Poland, near the present Polish- Byelorussian border (figure 1). The Forest stretches over 150,000 ha (62,500 ha in Poland) and is a constituent of a unique landscape formed by the most extensive stands of old-growth woodlands in Europe. It lies in the transition between the boreal and temperate zones, is composed of diverse plant communities, *e.g.* oak-lime hornbeam (*Tilio-Carpinetum* Oberd*)* and pine-spruce-oak (*Pino-Quercetum* Ilicis, Faliński 1986, 1988, Kwiatkowski 1994) and comprises extensive marshy land. This is a refuge for numerous protected and endangered species, for instance the European bison (*Bison bonasus* Linnaeus)*,* wolf (*Canis lupus* Linneo)*,* lynx (*Lynx lynx* Schreber), golden eagle (*Aquila chrysaetos* Linnaeus), snake eagle

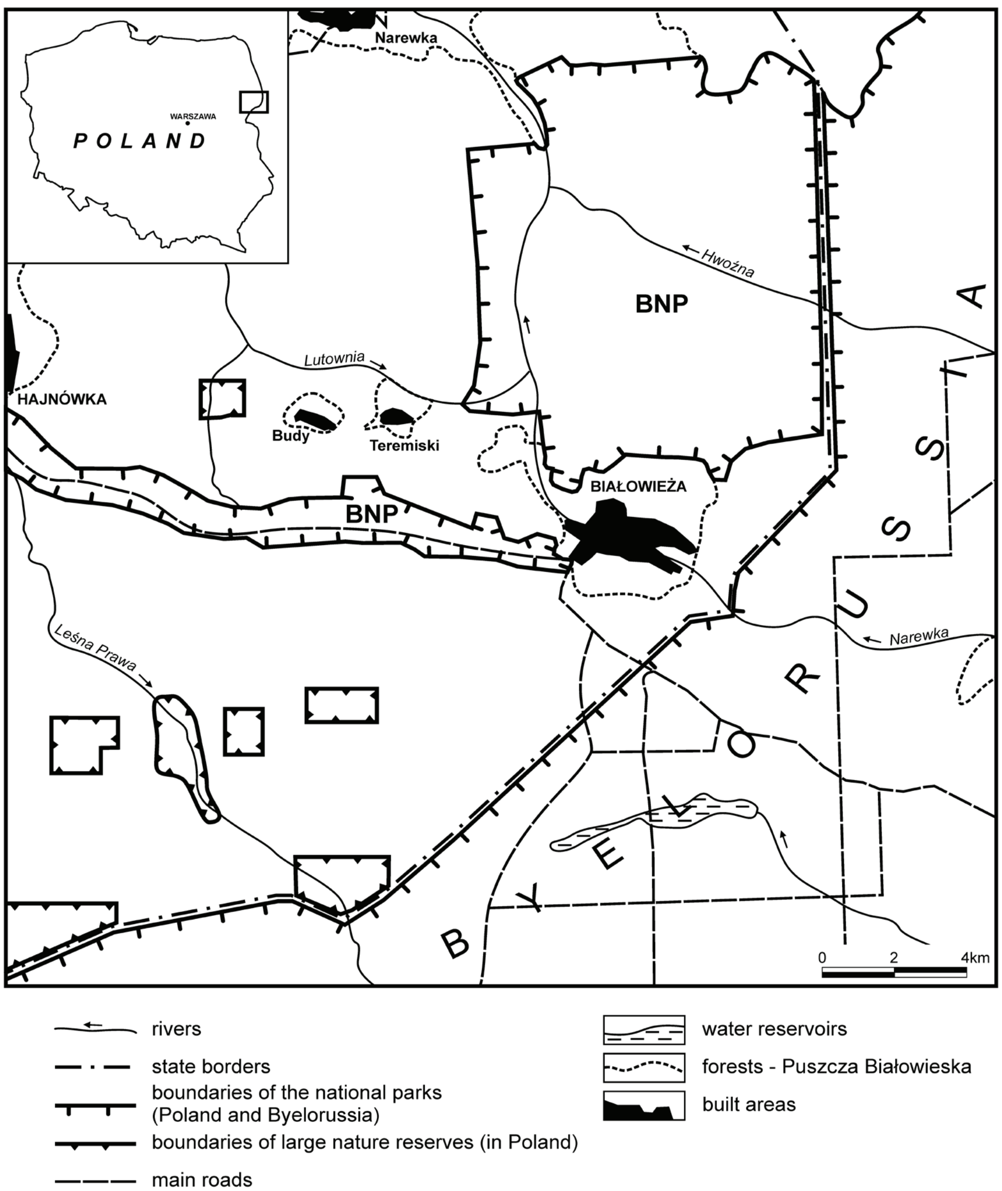

Figure 1. The Białowieża Forest- a central part (on the basis of 1:200,000 Topographic maps N-34-XXX, N-34-XXXVI, 1992, Wojskowe Zakłady Topograficzne, Warsaw).

Parte central del bosque de Bialowieza (Con base en mapas topográficos N-34 XXX, N-34-XXXVI, 1992, escala 1: 200.000, Wojskowe Zakłady Topograficzne, Varsovia).

(*Circaetus gallicus* Gmelin), great grey owl (*Strix nebulosa* Forster). Remarkably, socio-cultural elements of the landscape have always been strongly dependent on forest amenities. The region is highly ranked in conservation system; several forms of protection can be found here, including National Park, a Biosphere Reserve, and an Important Bird Area. However, it is widely reported that existing protection is insufficient (Conservation of the Białowieża Forest 2003, Wesołowski 2005). While a part of the forest is managed as a strict reserve (Białowieski National Park), the rest has been facing a steady human impact.

A preliminary stage of the study was focused on a broad-scale landscape analysis and comprised an extensive research of literature with contribution of comparative studies of geobotanic and topographic maps, satellite photos and statistical data. The second phase comprised the synthesis of the results and aimed to distinguish main processes of landscape change. The subsequent conclusions revealed significance of anthropogenic factors for the present state of the landscape. Therefore the third stage put stress on socio-cultural determinants of identified processes and emphasized concerns connected with attitudes to the forest, views and visions of landscape use and values exhibited by different social groups. Observation and a wide analysis of relevant literature including not only scientific reports, but also additional materials such as interviews and press articles were all important for this stage of the study. Furthermore, the research incorporated examination of state and regional environmental policy, management plans (Forest Management and Inventory Plans[1]), adequate planning procedures (including spatial plans and policies of local communities), and an array of other official documents (formal letters among interested groups and administrative decisions).

RESULTS

An analysis of landscape change showed that a considerable human impact on the Polish part of Forest began during the 1st World War (1915) and consisted in large-scale logging operations. In 1990s exploitation rates, though not performing as the highest in history, tended to increase above a level of 130,000 m^3 yr^{-1} (Wesołowski 2005, Forest Management and Inventory Plans 2001-2011[1]). In consequence, significant changes of landscape structure appeared, which are connected with the process of borealisation, appearance of new habitats, rejuvenation, reduction of an amount of dead wood, and unification of spatial structure (Bobiec *et al.* 2000, Fuller 2000, Conservation of the Białowieża Forest 2003, Wesołowski 2005). It is proved that many key bird species are much scarcer in logged fragments than in protected zones (Czeszczewik and Walankiewicz 2006, Wesołowski *et al.* 2005). Cutting has been continuing until now, exceeding the amount of 1,100,000 m^3 in the period 2002-2011 (Forest Management and Inventory Plans 2012-2021: Białowieża, Browsk, Hajnówka; Management and Protection Program 2011[1]) and became a cardinal, but not a single factor leading to deterioration in landscape structure. Regarding general spatial processes in land transformation (Forman 2006) the role of perforation and fragmentation of a forest cover should be highlighted. Additionally, investigation of spatial documents of the local communities[2] revealed that settlement sprawl, which frequently accompanies tourism and leisure, induces spatial disorder in major villages and their vicinities and considerably adds to degradation caused by wood exploitation.

The undertaken research showed that two predominant, contrasting land-use visions of the Białowieża Forest play a significant role in discussion on and establishment of management plans and environmental policy of the area. Forest authorities supported by local societies and local authorities insist on the necessity of wood production, and on the other hand, bodies engaged in nature conservation in Poland, *e.g.* non-government organisation highly promote strengthening of ecological functions. Additionally, an option linking wood extraction with new forms of landscape protection has developed as an antagonistic idea towards the park's extension. Noteworthy, a crucial issue consists in reasoning of the models of development. The analysis showed that two of the possibilities go along with steady socioeconomic pressure on intensification of logging. Thus, it can be argued that a simplistic, well-established vision of forest and its management can be seen as a prominent driver of landscape change.

The research revealed significant differences in patterns of perception of the Białowieża Forest. This is interesting that characteristic stress put on exploitation, which is expressed by local communities (Giergiczny 2009) does not find appreciation in the country (Czajkowski *et al.* 2008). Disturbing changes and their consequences provoked a lengthy debate on management and protection of the Białowieża Forest (Kozieł 2010). Moreover, an important difficulty faced by the Forest is caused by weaknesses of the state's environmental legacy- a decisive role of local communities in the process of establishing and changing national parks made enlargement of the Białowieża National Park impossible. Therefore a question on values attached to the landscape and attitudes both to the Forest and to nature conservation carries a lot of weight. Numerous press articles, leaflets, as well as formal decisions[3]

[1] Forest Management and Inventory Plans 2001-2011: Białowieża, Browsk, Hajnówka. Regionalna Dyrekcja Lasów Państwowych w Białymstoku. Białystok. 2003.
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[2] Study of the spatial plan of the Białowieża community. 1999, with changes. Białowieża.
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[3] Conservation of the Białowieża Forest (Poland), Document for information for the Bureau. 2003.

and specialist publications (Wesołowski 2005) examined in this work signal a considerable influence of forest authorities, responsible for management of areas outside the National Park, on the social awareness. As a result, public opinion on a local level underestimates importance of natural values contrary to economic services provided by the Forest. Against numerous country and international attempts to change the paradigm of forest management, an emphasis is still laid on elementary benefits and on a need to retain control over the natural processes (Management and Protection Program[4]). Employment of these visions in landscape management, though may meet expectations of certain groups of interest, will result in serious decline in ecological values and in landscape depreciation. A further loss of oldest tree stands is one of the consequences (Wesołowski 2005). It should also be stressed that deterioration in landscape structure is connected with a problem of low respect for aesthetic values encapsulated in the ancient forest (Korbel 2012).

DISCUSSION AND CONCLUSIONS

An analysis of contemporary factors and processes of change taking place in the area of the Białowieża Forest has demonstrated that the region has been threatened by a decline in its intrinsic natural qualities (see *e.g.* Mitchell and Cole 1998, Bobiec *et al*. 2000, Conservation of the Białowieża Forest 2003, Wesołowski 2005, Kozieł 2010). One of the most important forms of deterioration in landscape structure consists in habitat fragmentation and is caused mainly by exploitation of the area for commercial forestry (Mitchell and Cole 1998, Bobiec *et al*. 2000, Fuller 2000, Wesołowski *et al.* 2005, Czeszczewik and Walankiewicz 2006). As outlined before, land-use visions deserve special attention, since they can become an essential factor of landscape change. Results of the research lead to two general conclusions: 1. Relations between human and natural are essential as far as effective conservation of the forest is regarded, 2. Maintenance of extraordinary values of the area requires the change of social attitude to the Forest (especially at a local level).

Nowadays the Białowieża Forest is at its turning point; the parliament is working on the change of the State's Nature Protection Law (Ustawa o ochronie przyrody 2004). A direction of landscape evolution depends on decisions being taken with consideration to ecological and socioeconomic conditions and on hierarchy of values attached to forest and more, to nature amenities. Noteworthy, it can be argued that a specific attitude of local communities and local authorities highlighting productive functions of the primeval forest and tending to dismiss concerns of conservation and national heritage (Conservation of the Białowieża Forest 2003, Wesołowski 2005, Korbel 2012) constituted not only a strong driving force of landscape change at a regional level, but also one of narratives of nature conservation in Poland.

It seems to be important that an analysis of processes instigating a post-war degradation of the Białowieża Forest must be followed by a discussion on social perception of natural values and services forest ecosystems provide. They constitute a basis for land-use visions and become a hidden factor highly influencing nature conservation and landscape change.

[4] Management and Protection Program for LKP 'Białowieża Forest' 2012-2021. Regionalna Dyrekcja Lasów Państwowych w Białymstoku. Białystok, 2011.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 281-285, 2012 DOI: 10.4067/S0717-92002012000300009

The influence of land use on edge effect in an Atlantic forest fragment in north-east Brazil

Influencia del uso del suelo sobre el efecto de borde en un fragmento de bosque atlántico en el noreste de Brasil

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SUMMARY

Although the edge effect is a phenomenon much studied in tropical forests, the effects of edge creation in open ombrophilous forests of the Atlantic Forest of northeastern Brazil are little discussed. Plant communities with large canopy openness, including periods with partial loss of leaves may respond differently to the impacts of edge formation because species may be more light-tolerant. The matrix can have a direct influence on the edge effect. Most studies available examine the consequences of the interface between forest and agricultural areas or pasturelands. However, the effects of the creation of a water body have been little studied, despite being frequent in the last century. In this study, we analyze the edge effect in two faces of a fragment, the first edge in contact with sugarcane crop, and the second with a lake formed by a dam. To neutralize the effect of selective logging and avoid counting species established before the edge formation, we analyzed the composition and density of the juvenile layer (≤ 1m). The results pointed out that the construction of a dam (water body) has caused an edge effect in the forest fragment, which seems to be not relevant in the area adjacent to sugarcane cultivation.

Key words: rain forest, fragmentation, edge effect, Atlantic forest, Brazil.

RESUMEN

Si bien el efecto de borde es un fenómeno ampliamente estudiado en bosques tropicales, los efectos de la creación de bordes en bosques abiertos ombrófilos del bosque atlántico del noreste de Brasil han sido poco discutido. Comunidades vegetales con una gran apertura de copa, incluyendo periodos con pérdida parcial de hojas pueden responder de manera diferenciada a los impactos de la formación de bordes ya que las especies pueden ser más tolerantes a la luz. La matriz puede tener una influencia directa sobre el efecto de borde. La mayoría de los estudios disponibles examinan las consecuencias de la interface entre el bosque y las áreas agrícolas o praderas. Sin embargo, los efectos de la creación de un cuerpo de agua han sido poco estudiados a pesar de ser frecuentes en el último siglo. En este estudio se analiza el efecto de borde en dos lados de un fragmento, el primer borde en contacto con un cultivo de caña y el segundo con un lago formado por una represa. Para neutralizar el efecto de madereo selectivo y evitar el conteo de especies establecidas antes de la formación del borde, se analiza la composición y densidad de la capa juvenil (≤ 1m). Los resultados indican que la construcción de una represa (cuerpo de agua) ha causado un efecto de borde en el fragmento de bosque, que parece no ser relevante en el área adyacente al cultivo de caña.

Palabras clave: bosque lluvioso, fragmentación, efecto de borde, bosque atlántico, Brasil.

INTRODUCTION

Distribution patterns of species near forest edges have been one of the most studied phenomena in ecology in recent decades (Laurance 1990, Mathias *et al*. 2007, Numata *et al*. 2009, Ribeiro *et al*. 2009). In Brazil, most studies have been accomplished in closed canopy Amazon forests where the formation of an edge drastically changes the community. For communities with a more open canopy, such as the Atlantic Forest of northeastern Brazil that has periods with partial loss of leaves, little is known. Perhaps these communities respond differently to the impacts of an edge formation, since their species are more adapted to the presence of light.

The Atlantic Forest of northeastern Brazil is the biogeographical unit of Atlantic forest with higher probability to lose species at the regional scale due to fragmentation (Silva and Tabarelli 2000). In Alagoas State, the forest cover was fragmented into 4,429 patches totaling a forest area of 1,926 km^2 (Menezes 2010) most fragments are small and with high edge/interior ratio. The present study analyzed the edge effect in a fragment of an open rain forest in two different interfaces – the first oriented toward a sugarcane crop, and the second, to a lake formed by a dam. This paper aims at identifying differences in density and/or species richness between these two interfaces and how both variables respond to an edge-interior gradient.

METHODS

The studied fragment (09° 25’ and 09° 26’ S and 35° 42’ e 35° 41’ W) had a total area of 283 hectares of open rain forest, in the Alagoas State (Assis 2000). The fragment of vegetal cover, was limited by sugarcane crops and by the lake of a dam used for agricultural irrigation. The 86.6 ha dam was built in 2001, whereas the sugarcane field was established in the 1970s (figure 1).

Thirty transects (5x50 m) were marked, oriented from the edge towards the interior, 15 transects were established in the interface of the fragment oriented towards sugarcane crops, and 15 to the water body. Each transect was subdivided into 10 contiguous plots (5x5 m) in an edge-interior gradient (figure 2). In order to establish a model that could indicate the effects on the future flora, from the recruitment analysis, the survey was based on the sample of juvenile individuals, with height ≥ 1 m and diameter at breast height (DBH) < 5 cm. The distribution of the most abundant species (those with overall total density greater than 30 individuals) was also examined.

The species classification, considering the successional category, was made based on available literature (Lorenzi 1998, Silva and Tabarelli 2000). Species richness and density at the 5x5 m plots were both analyzed with generalized linear models (GLM) presuming normal distribution. Each model started with three explanatory variables and all possible interactions between them: distance from the plot to the edge (measured in meters), sampled transect (the 30 transects are paired, as can be seen in figure 2) and surrounding environment (either sugarcane field or the water body). Next, each model was simplified following a backwise procedure: non-significant interactions were removed, starting from highest level interactions and highest *P* values. Finally, the simplified models assumptions were verified using Levene tests for variance homogeneity and Shapiro-Wilk tests for normality of models residuals.

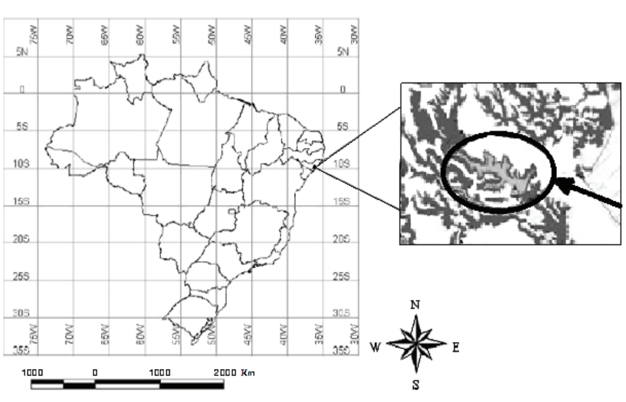

Figure 1. Location of the study area. Study area: fragment of open rain forest, isolated by the sugarcane cultivation, and the lake formed by a dam.
Ubicación del área de estudio. Área de estudio: fragmento de un bosque lluvioso abierto, aislado por un cultivo de caña y por un lago formado por una represa.

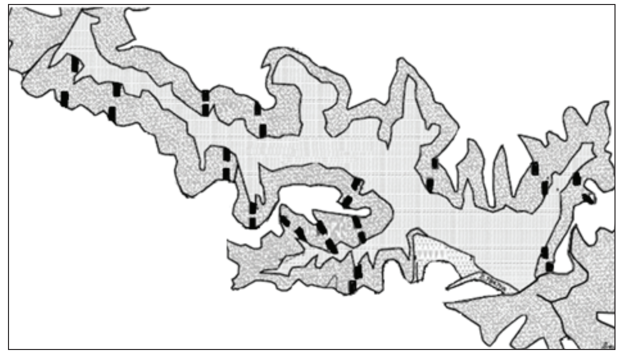

Figure 2. Illustration of the transects distribution along the fragment.
Ilustración de la distribución de transectos a lo largo del fragmento.

RESULTS

At the juvenile layer, 168 species were recorded. The diversity in the adjacencies to the water body was similar to those found at the edge adjacent to the sugarcane with Simpson index values of 0.020 and 0.018, respectively. The density of both fragment faces was also similar, 3,851 individuals ha^{-1} and 3,429 individuals ha^{-1}, respectively. For both faces, the family Myrtaceae featured higher species richness (28), followed by Fabaceae (20) and Rubiaceae (18). The two faces were also similar regarding floristic composition (Sorensen = 0.76). All species with more than 30 individuals sampled occurred in both studied faces.

Both statistical models violated the residuals normality assumption verified with the Shapiro-Wilk test (richness W = 0.982, $P \leq 0.001$; density W = 0.973, $P \leq 0.001$), and the species richness model also violated the assumption of variance homogeneity verified by the Levene’s test (F = 1.847, $P = 0.007$). These models, therefore, cannot be used as reliable sources to explain the variation in the collected data. In order to carry on with data analysis, we then decided to simplify our approach by using simple linear regression, which is known to be robust to assumptions violations. To avoid potential noise from the interactions, we independently analyzed data from each surrounding environments, then performing four independent regressions (two for each response variable).

The simple linear regression analyses showed that at the edge surrounded by the lake, both species richness

(r^2 = 0.034; *P* = 0.024; y = 5.64 – 0.15x) and density (r^2 = 0.082; *P* ≤ 0.001; y = 10.91 – 0.50x) were reduced while the distance from the edge increases, albeit the correlation coefficients were very low. The same relationships were not statically significant at the edge surrounded by sugarcane field, neither for species richness (*P* = 0.30) nor for density (*P* = 0.20). Since the variation on both variables in both surrounding environments was very high, the data was not displayed in scatterplots, as can be seen in figures 3A and 3B.

To *Henrietia sucosa* (Aubl.) DC. and *Myrcia lasiopus* DC., the pattern of greater density in relation to the proximity to the edge was significant only in the face oriented toward the dam. *Cecropia pachystachya* Mart. ex Miq. and *Solanum paniculatum* L. presented significant variation in both faces, with higher density in the plots of the edge.

Five climax species were recorded: *Sorocea bonplandii* (Baill.) Burger, *Xylopia ochrantha* (Mart.) Kuntze, *Discophora guianenses* Miers., *Manilkara rufula* (Miq.) H.J. Lam and *Pouteria bangii* (Rusby) T.D. Penn. Of these species (figure 4), only *X. ochrantha* and *D. guianenses* had significant distribution pattern as a function of edge-interior gradient. Due to the low number of individuals found (< 30), common to climax species, an analysis of distribution patterns of these species was not undertaken, comparing the two faces of the fragment. Nevertheless, all five species occurred in the two faces of the forest.

DISCUSSION

The analyses along the edge-interior gradient shows that richness and density decrease as distance from the

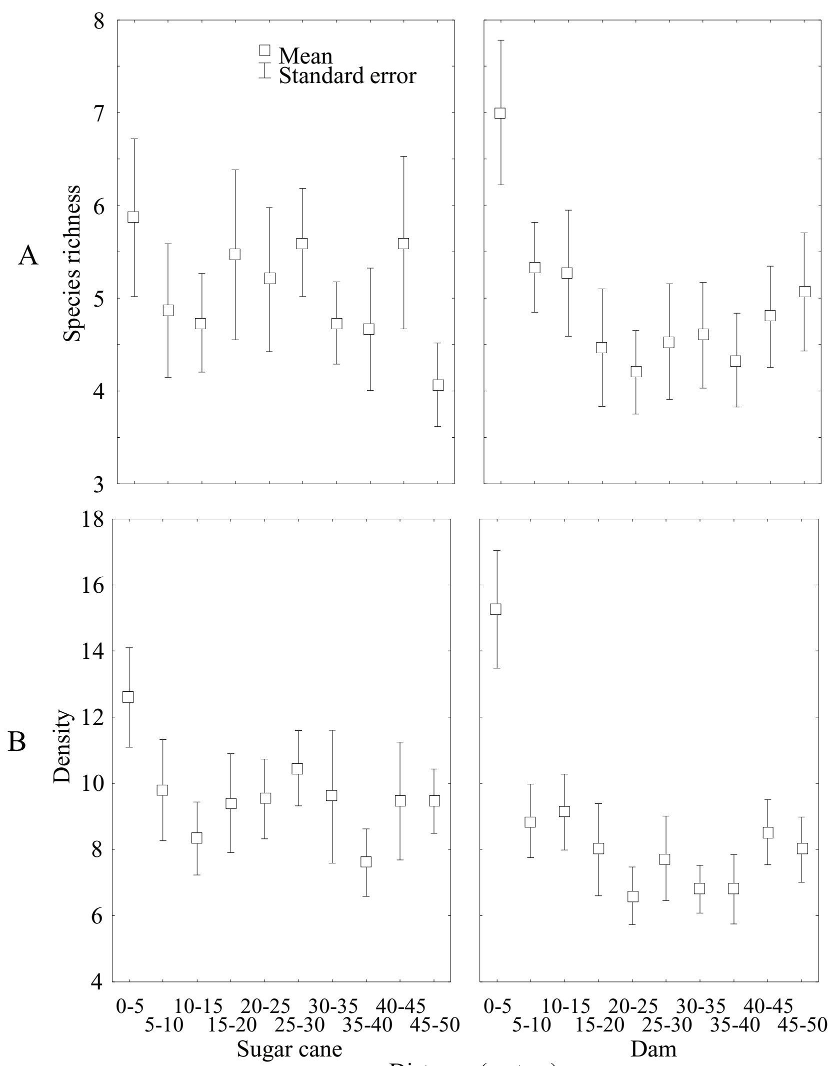

Figure 3. Mean values (and standard error) of the number of species, in plots distributed over edge-interior gradient, plots situated in the face oriented toward the sugarcane crops, and plots situated in the face oriented toward the lake of the dam.

Valores medios (y error estándar) del número de especies en parcelas distribuidas a lo largo del gradiente borde-interior, parcelas situadas en la cara orientada hacia el cultivo de caña, y parcelas situadas en la cara orientada hacia el lago de la represa.

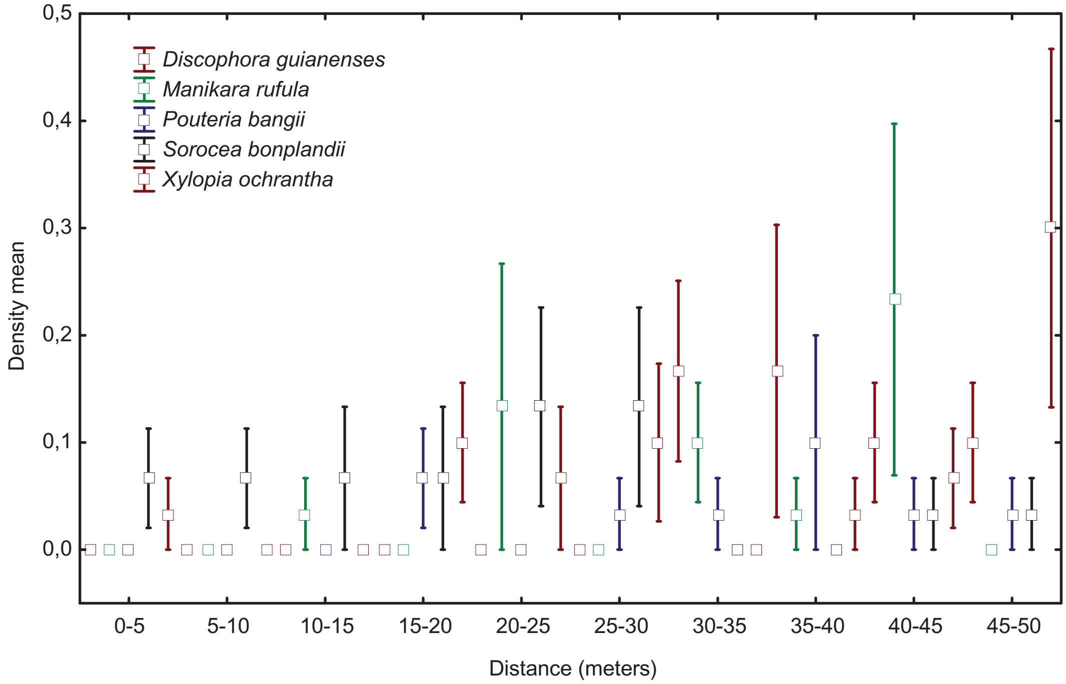

Figure 4. Mean values (and standard error) of the density of individuals, in plots distributed over edge-interior gradient, plots situated in the face oriented toward the sugarcane crops, and plots situated in the face oriented toward the lake of the dam.

Valores medios (y error estándar) de la densidad de individuos, en parcelas distribuidas sobre el gradiente borde-interior, parcelas situadas en la cara orientada hacia el cultivo de caña, y parcelas situadas en la cara orientada hacia el lago de la represa.

edge increases only for the face oriented toward the water body. A similar pattern of distribution with higher richness and heterogeneity in the plots closer to the edge is also observed by Fox *et al.* (1997), in the rainforests of Australia. Oosterhoorn and Kappelle (2000) also present similar results in a forest in Costa Rica. Besides this, Gehlhausen *et al.* (2000) show, in different locations, that species richness is correlated with environmental variables, like canopy openness and soil moisture, two variables that usually vary as a function of the edge-interior gradient (Cadenasso *et al.* 1997). Meanwhile, for tropical forests, little is known about the edge effects in fragments oriented toward the water body of human origin.

At the face oriented toward the dam, the species *H. sucosa* and *M. lasiopus*, considered pioneers in the successional stage, present a pattern of higher density in relation to the proximity to the edge. The species *S. paniculatum* present higher density at the face oriented toward the sugarcane than toward the dam (32 and 04 individuals, respectively), which can be ascribed to the fact that they are invasive species that are more likely to reach the forest through the face oriented towards the sugarcane.

In the analysis of the climax species, only *X. ochrantha* and *D. guianenses* show a significant pattern of distribution as a function of the edge-interior gradient, with prominence of *D. guianenses*, found in the plots located 30 m from the edge. Although considered as climax species, *S. bonplandii, M. rufula* and *P. bangii* do not present a significant pattern of distribution over the edge-interior gradient. This pattern, added to the fact that only one of these climax species was not sampled in plots near the forest edge, may result from the fact that the region's rain forest is relatively open, so the above-mentioned species might be used to some degree of light exposure. Probably, species or populations of species that evolve in the presence of larger natural openness of the canopy suffer less the impacts of the edge formation than those species from dense rain forest. The absence of edge effects in open tropical formations has also been reported by Queiroga and Rodrigues (2005) and Santos and Santos (2008), for areas of Caatinga and Cerrado, in Brazil. The opposite has been verified in dense forests, such as the Amazon (Laurance *et al.* 1998). It is possible that the effect of the formation of an edge is inversely proportional to the natural openness of the canopy.

CONCLUSIONS

The difference in the distribution of species richness and density of individuals over the edge-interior gradient, that is present only in the face of the fragment oriented toward the lake of the dam, is an important indicative that the creation of the dam has a greater edge effect on the forest fragment than the cultivation of sugarcane as both species richness and density decrease while the distance from the edge increases. However, these results should not be generalized, since little is known about the edge effects caused by a water body. Many species appear to be indifferent to the edge effect. Possibly, these species or populations that live in the open ombrophilous forest are more adapted to the presence of light. It is important to point out that two climax species - *X. ochrantha* and *D. guianenses*- show a significant pattern of distribution as a function of the edge-interior gradient. These species may demand greater conservation efforts.

ACKNOWLEDGEMENTS

The authors are grateful to the Curator of the MAC Herbarium, Dr. Rosângela Pereira de Lyra Lemos, and to her team, especially to Maria Noêmia Rodrigues and Flávia Cavalcante, for the support on plants identification. A Ana C M Malhado, Everando VSB Sampaio e Elcida L Araújo for their comments on early drafts of this paper. We are also grateful to three anonymous referees for valuable comments on the submitted manuscript.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 287-292, 2012 DOI: 10.4067/S0717-92002012000300010

A visual perception study in landscapes subject to fires in South East Australia

Estudio de percepción visual en paisajes sujetos a quemas en el sureste de Australia

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SUMMARY

Results of a visual perception study of landscapes subjected to prescribed burning regimes in South East Australia provided insight for improving fire management policies by considering the aesthetic dimension of landscapes. Preference and similarity data were collected during a series of photo-sorting interviews using photos as stimuli. Data were analyzed using a mix-method approach finding 10 landscape clusters. These were different in terms of the visual effect of different fire intensities over time and people's knowledge about fire management practices.

Key words: prescribed burns, landscape aesthetic, landscape management.

RESUMEN

Resultados de un estudio de percepción visual de paisajes sometidos a regímenes de quemas controladas en el sudeste australiano, sugieren como mejorar políticas de manejo del fuego al considerar la dimensión estética del paisaje. Datos de preferencia y similitud entre paisajes se recolectaron durante una serie de entrevistas (N = 40) utilizando métodos de sorteo en los cuales se usaron fotografías como estímulos (N = 56). Los datos se analizaron con métodos mixtos encontrando un total de 10 grupos de paisajes. Estos se diferenciaron por el efecto visual que provocan distintas intensidades de quemas en el paisaje a través del tiempo y por el conocimiento sobre las prácticas de fuego que tenían los entrevistados.

Palabras clave: quemas prescritas, estética del paisaje, ordenación del paisaje.

INTRODUCTION

Landscape aesthetic is one use of forests that is usually obscure for land managers; however, it has a great influence on the extent the community accepts and supports management practices (Gobster 1999, Ryan 2007). People can visualize the effect of management practices as part of a natural process or as a decline of landscape quality and such perceptions influence public response to management practices. This information is relevant to develop forest management policies.

In the USA, it is well known that the successful implementation of fire management programs in areas that people use for living and recreational purposes, rely on considering public response to fire effects on the landscape (Daniel *et al.* 2007). The outcomes of perception studies about the effects of fire on the landscape influence the development of planning and management programs of those areas. This is achieved by studying people's perception of the visual effects of management practices. Here, people discriminate between the aesthetics of landscapes. The outcomes of these studies can provide a set of landscape categories, with associated preference values and verbal descriptions, which suggest the extent that people appreciate the landscape from a scenic, ecological and/or utilitarian point of view, among others (Wilson 1984, Kaplan *et al.* 1998). Such types of results are influenced by the knowledge of management practices, familiarity with the study site and by the visual aspects of the landscape that change (Ryan 2005).

People's response to landscape change is explored here in the Australian context, where little research has been conducted on this topic. The site includes 300 hectares of Australian ecosystems at The Royal Botanic Gardens Cranbourne which are periodically subjected to prescribed burning regimes. Patches between 8 to 20 hectares are burnt in random locations within the site, twice a year to facilitate seed germination and plant growth.

METHODS

A mix-method approach (Villagra and Vergara 2012) was used to study people's perception of landscape change at The Royal Botanic Gardens Cranbourne. Participant groups were selected by convenience to assure that experts (N = 19) and lay respondents (N = 21) were interviewed. Within each group, respondents were selected randomly among visitors to the Royal Botanic Gardens Melbourne and staff members of the Department of Sustainability and Environment, Victoria, Australia (table 1). Both groups were different with respect to their knowledge of fire management practices, providing a good scenario to evaluate the extent that education influences perception. Experts were involved in fire management practices; in contrast, the lay respondents had other professions unrelated to fire management.

A detailed description of the methodology can be found elsewhere (Villagra and Vergara 2012). In short, fifty six photographs were taken at 14 different sites of the Royal Botanic Gardens Cranbourne which were burnt during 2007 and were used as stimuli to interview the two sample groups. Photos were taken from each site to the four cardinal directions and at four different times before and after fires during 2007 and 2008 (figure 1). Photographs were taken in April before the burns, three days after the burns, six months and one year after. The 56 photographs were shuffled and used to interview the participants to collect preference and similarity data. During the interview, peo-

Table 1. Description of participants.
Descripción de participantes.

Category	Sub-category	Expert group (EG) %	Lay group (LG) %
Gender	Male	63	35
	Female	37	65
Age group	18-25	5	5
	26-65	95	75
	65+	0	20
Place of childhood development	Urban area	74	70
	Rural area	26	30
Visits to the study site	Never	73	80
	First time	0	0
	Al least once a week or more	0	0
	Al least once a month	0	0
	A few times a year or less	27	20
Educationlevel	Elementary school	0	0
	Secondary highschool	10	5
	Tafe/trade education	10	20
	University/postgraduate degree	80	75

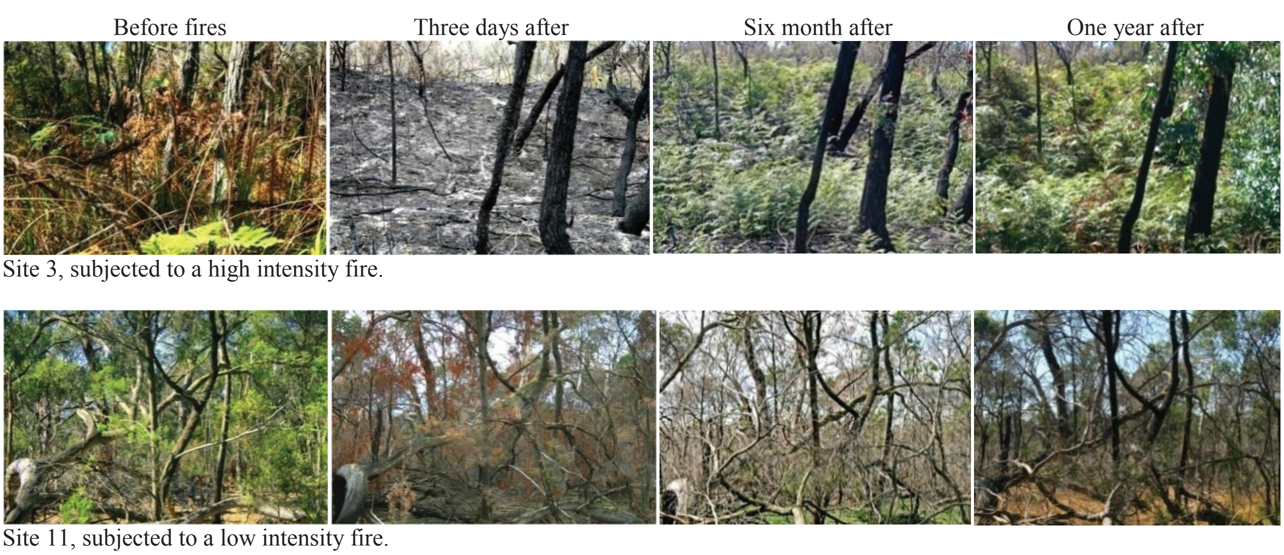

Figure 1. Examples of the set of photographs taken from each of the 14 sites.
Ejemplos del conjunto de fotografías tomadas en cada uno de los 14 sitios.

ple were asked to sort photos by preference using a scale 1 to 7, where 1 represents the lowest and 7 the highest value. Then, they were asked to sort the same photos by similarities in as many piles as they desired and provide verbal descriptions to characterize each pile they formed in their own words.

Descriptive statistics were used to analyze preference data. Aggregated mean and standard deviation preference values for each photo were used to graph variations of landscape preference for the 14 sites over time. This approach provided a preliminary overview of the grouping of the data in terms of landscape preferences (figure 2). Verbal responses were analyzed using content analysis to explore the most frequent landscape descriptors that people utilized to describe most and least preferred images. Hierarchical cluster analysis with between-group linkage method was performed, using the SPSS software V.15, to explore similarity data and the natural groupings of photographs and descriptors for each sample group. A Chi-square measure was used to determine distances between data points and values were neither transformed nor standardized.

RESULTS

Landscape preferences and descriptors. In most of the cases, preferences for landscapes decreased immediately after fires and then increased over time (figure 2). Most preferred landscapes were usually scenes photographed one year after the fires. 44 % of the experts described these landscapes as 'healthy' and 'diverse' and 26 % described them as formed by 'mixed species', finding the 'green' colours and 'the shape of the tree' appealing. Same images were most preferred for the respondents, however, for different reasons. 33 % of the respondents suggested they liked these images the most because they are 'colourful', 'vibrant' and 'beautiful'.

Least preferred images were the scenes photographed right after fire 21 % of the experts suggested that some of the least preferred scenes looked 'dry' and 'scrubby', because they had been subjected to a 'low intensity burn', or fire intensity not enough to have an effect on plant regeneration. Experts thought these landscapes provided 'bad accessibility', look 'damaged' and 'need fire' to regenerate the ecology. Instead, the respondents preferred landscapes that were recently burnt and illustrated in black and white the least. They suggested that these landscapes appeared 'dead' and 'ugly' in appearance. 24 % of the respondents suggested that they looked 'dense' and 'messy' and does not present a means of exit ('lack of exit') for the public.

Landscape classification. Results of the hierarchical cluster analysis suggested a set of 10 landscape clusters, five for the experts (C1 to C5) and five for the respondents (C6 to C10). These categories are illustrated in figure 3 and 4, where clusters are named according to the verbal descriptors that respondents used the most to qualify photos in each cluster. In addition, the aggregated mean preference value (agg.M), standard deviation value (SD), the photo that represent the cluster the most (Rep.Photo) and the time when photos of each cluster were taken (Time) are indicated.

DISCUSSION

Visual images of landscape change over time (due to the effect of different fire intensities) clearly influence preferences (Gobster 1999). The post-fire regrowth of vegetation and changes in colour are the factors that affect landscape preferences over time with both groups. These results support the idea that people value the scenic aesthetic of landscapes in a similar way, regardless of their background (Kaplan 1998). Clusters C1 and C6 are the least preferred by both groups. These clusters include landscape images

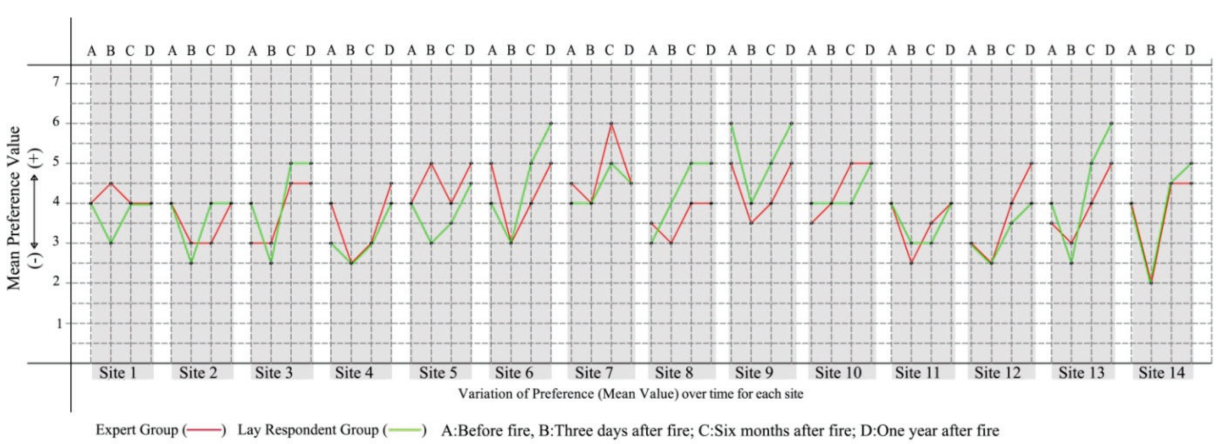

Figure 2. Variation of landscape preferences over a year.
Variación de las preferencias del paisaje a lo largo de un año.

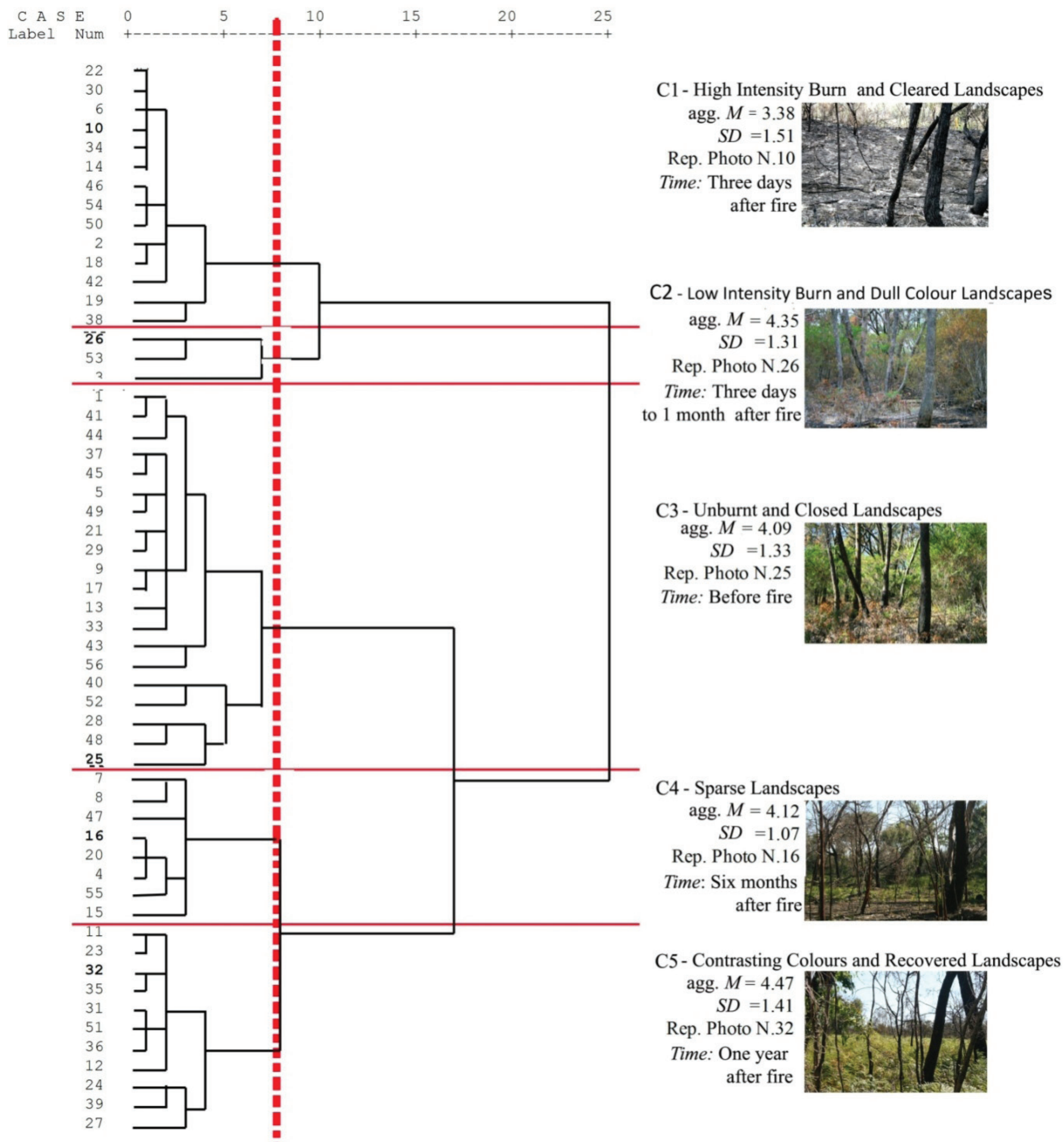

Figure 3. Dendogram of the expert group. Integrated results of the hierarchical clustering analysis, aggregated mean preference values and landscape descriptors. The between-group linkage method was used. Note: dull landscapes refer to landscapes that lack of bright and intense colours, and are opposed to landscapes with contrasting colours, that illustrate colours which are opposite to one another.

Dendrograma del grupo de expertos. Resultados integrados del análisis jerárquico de agrupamiento, de los valores de preferencia agregados promedio y descriptores del paisaje. Se utilizó el método de relación entre grupos.

photographed three days after the burns, depict evidence of a large amount of burnt material and lack of green colour. According to the experts, these landscapes were subjected to a 'high intensity burn', or a very strong fire that cannot assure the regrowth of vegetation.

Instead, Clusters C4, C5, C9 and C10 are the highest preferred of all and include landscape scenes photographed a year and six months after the burn. Photos in these clusters depict ferns in bright-green and strong yellow colour and a few black trees that are sparsely distributed in the foreground area. Both study groups are clearly influenced by the colour and the sparse distribution of features in these scenes. However, only the experts see a hint of recovery after fire (C5) while the lay respondents may think some of these scenes are not even burnt (C10). Clearly, people's knowledge about management practices influence the

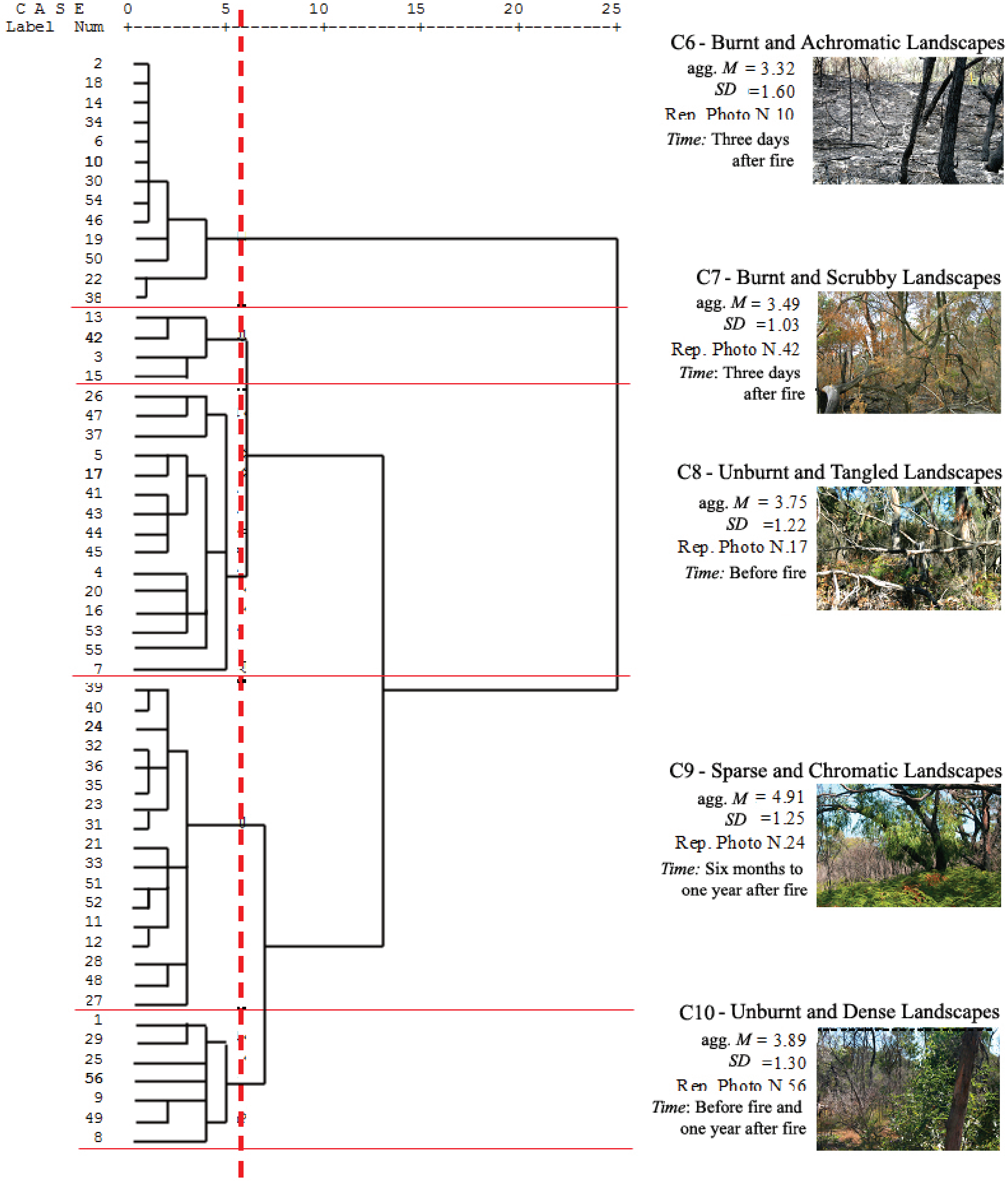

Figure 4. Dendogram of the lay respondent groups. Integrated results of the hierarchical clustering analysis, aggregated mean preference values and landscape descriptors. The between-group linkage method was used.

Dendrograma de los grupos no expertos. Resultados integrados del análisis jerárquico de agrupamiento, de los valores de preferencia agregados promedio y descriptores del paisaje. Se utilizó el método de relación entre grupos.

meaning people assign to landscapes as found in previous studies (Ryan 2005). Clusters C2 and C7 comprise images taken within days after fires and depict flammable material (yet unburnt) on the ground, such as old and dry vegetation. According to the experts, these scenes are subjected to a 'low intensity burn'. This means that the fire is neither enough to destroy the vegetation completely nor sufficient to stimulate the regrowth of new plant species. Instead, for the respondents these images are described only as 'burnt' and 'scrubby'.

People's discrimination of landscapes was found to be a useful approach to study similarities and differences in people's responses (Kaplan *et al.* 1998). It is clear that these cluster types evoke different landscape meanings for both groups. While experts evaluate landscapes in relation to both ecological and aesthetic values, responses from the respondents are mostly based on aesthetic values. Differences between landscape clusters illustrated in the dendograms suggest that the experts discriminate among landscapes mostly in relation to the effects of fire management practices.

CONCLUSIONS

Preference for landscapes subjected to prescribed burning regimes over time are similar between experts and the lay public, but the meanings both groups assign to these landscapes is different due to their degree of knowledge about fire management practices. This plays a key role in the discrimination of landscapes, as well as in the extent to which the communities' value landscape aesthetics subjected to controlled burning programs, that are aimed at both, conserving biodiversity and preventing devastating fires - as it is the case in Australia. Therefore, fire management policies should focus on enhancing the community knowledge about the process of prescribed fire and their beneficial effects in the long term.

Outcomes which are good for the ecology of landscapes as well as for the community can be assured by taking awareness of these types of results. In light of this, considerations such as increasing people's knowledge about the effects –aesthetic and ecological- of fire management practices over time can be taken. For example, strategies such as community visits to controlled burn sites and community involvement in designing conservation efforts should be encouraged. Such activities can increase the confidence and understanding of the community in the effects of prescribed burn programs.

ACKNOWLEDGMENTS

The author would like to thank the University of Melbourne in Australia, and the staff members of the Royal Botanic Gardens Cranbourne for their continuous support during the development of this study.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 293-297, 2012 DOI: 10.4067/S0717-92002012000300011

GIS-based classification and mapping of forest site conditions and vegetation

Clasificación y mapeo en SIG de la condición y vegetación forestal

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SUMMARY

A method of automated classification and mapping based on a spatial analysis of a digital elevation model (Shuttle Radar Topography Mission (SRTM 90m), Landsat 5-TM imagery, and ground data was applied to classify and map forest site conditions and vegetation on a test site. The vector maps obtained reflected the test site potential environmental conditions, forest types, and regenerating vegetation age stages.

Key words: Central Siberia, site conditions and forest type mapping, geographical information system (GIS), digital elevation model (DEM), remote sensing data.

RESUMEN

Se aplicó un método de clasificación y mapeo automatizado basado en el análisis espacial de un modelo de elevación digital (*Shuttle Radar Topography Mission* (SRTM) 90m), imágenes satelitales Landsat 5-TM y datos de campo con el fin de clasificar y mapear la condición y vegetación forestal en sitios de prueba. Los mapas vectoriales obtenidos reflejan las condiciones ambientales potenciales del sitio de prueba, los tipos de bosque y los estados sucesionales de la regeneración de la vegetación.

Palabras clave: Siberia Central, mapeo de condiciones de sitio y del tipo de bosque, sistema de información geográfica (SIG), modelo de elevación digital (DEM), datos de sensores remotos.

INTRODUCTION

Mapping is a key tool in studying vegetation cover, particularly its spatial inventory, dynamics, and biodiversity. Nowadays, vegetation maps are successfully built and effectively updated using GIS methodologies and remote sensing data (Wondie *et al*. 2010, Hill *et al*. 2010, Bargiel and Herrmann 2011, Ohmann *et al*. 2011).

Our efforts have for quite a time been focused on developing GIS-based approaches to classification and mapping of forest site conditions and forest ecosystem regeneration.

The first and crucially important step to accomplishing such tasks is to choose appropriate classification principles to base map legends upon. A topogenetic (from Greek *genesis* – origin, *i.e.* based on origin in similar topographic site condition) approach developed for mountain forests of the Russian Far East (Kolesnikov 1956, Ivashkevich 1933) allows to build forest classifications that reflect regeneration dynamics of vegetation communities in different site conditions. According to the topogenetic principle, the entire diversity of vegetation communities is classified not by continuously changing outward characteristics (*e.g.*, species composition), but by similarity of site conditions. In a given area, sites similar in topographic location and in combination of mesorelief are segregated. These are, in fact, sites similar in ecological regime.

Applying remote sensing data requires the development of methods of forest type recognition in satellite images. However, few of the characteristics behind the Russian traditional concept of forest type (Sukachev 1972) are recognizable in space imagery. For this reason, indirect characteristics, such as relief elements indicative of different site conditions are used (Bock *et al.* 2005, Landmann *et al.* 2010, Ryzhkova *et al.* 2011, Clerici *et al*. 2012).

Application of geographic information system technologies enables a minimum-human-involvement method to map forest site conditions within areas similar in a number of pre-set characteristics (*e.g.*, climatic, orographic, edaphic, and biotic parameters) and to build a map of potential site conditions, which will serve as the basis for classifying forest communities.

METHODS

The southern part of near-Yenisei Siberia was chosen to be our test site (56º - 58º N, 92º - 96º E). Topographically, this area consists of two distinct parts: West Siberiam Plain and Central Siberian Tableland. The forests of the area are markedly diverse in composition, structure and regeneration dynamics of vegetation communities comprising them. They are heavily disturbed by both natural and human factors. The major vegetation age stages occur in big areas covering a range of forest site conditions (Lapshina *et al.* 1971).

The test site forest cover was classified using the principles of the topogenetic classification (Ivashkevich 1933, Kolesnikov 1956). The main genetic unit of this classification is forest type, which is interpreted as a series of genetically linked and sequentially replaced communities developing within a certain type of site conditions. Site conditions type, which is identified based on the geological and geomorphological parameters of a given area, presents a key element of the forest type concept. The types of the major and secondary forest communities found within a given type of site conditions are grouped to constitute a vegetation regeneration series, or, in other words, a forest type (Kolesnikov 1956). The site type units and the relatively corresponding forest vegetation units are shown in table 1.

To carry out automatized classification of a DEM-composite (elevation a.s.l., slope, and curvature) and satellite images, we used standard methodologies, such as ISODATA and MAXLIKE (Tou and Gonzalez 1974, Richards and Xiuping 2005), as well as ERDAS IMAGINE 9.2 and ESRI ArcMap 9.3 products.

Using the above principles and methods, a classification of the forest site conditions and the associated vegetation types was developed for the study area typical of plain and low-mountain southern taiga forests found along Yenisei River. To do this, we used digital elevation model (SRTM-3-DEM 2010) data to build topological transects that crossed the study area and analyzed these transects using the thematic and general geographic maps contained in the GIS database, literature information, and ground observation data.

RESULTS

An automated classification and mapping of forest site conditions and vegetation based on a spatial analysis of a DEM, satellite imagery, and ground data was developed and applied to the test site. The topographic profiles we built and landscape maps (Sochava 1977, Gudilin 1987) were used to analyze the test site geomorphological conditions and to identify sites relatively similar in topography (ratio between mesorelief forms, range of elevations a.s.l., and surface roughness) and corresponding to certain landscape types and their combinations. A preliminary number of classes for an unsupervised DEM classification was determined.

To establish the boundaries of these classes, a two-layer (elevation and slope) image was classified using ISODATA. This enabled to identify terrain roughness classes relatively similar in morphometric relief parameters (table 2) and interpret them thematically with respect to geomorphology, zonal soil types, and vegetation. Forest site conditions types were identified for each geomorphological complex (GMC) based on the ranges of slope and elevation above sea level (m a.s.l.).

As a result, a map of potential site conditions was built, which shows sites similar in topographic location, soil, and hydrological conditions, *i.e.* in ecological regime, the main vegetation cover control.

The most common vegetation regeneration series were determined for a range of site conditions found in each of geomorphological complexes of the test site with the help of ground data, archived and literature evidence. The vegetation regeneration series were formed from age stages grouped within each age class.

A Landsat 5-TM image was analyzed to identify land cover classes based on spectral characteristics and to interpret them as the following age or regeneration stages of forest vegetation: a) initial regeneration stages (burned and logged sites); b) young (up to 40 years old) deciduous stands; c) deciduous stands aging 40-80; (d) conifer stands 80- 120 years old approaching cutting age; and (e) mature and old conifer stand over 120 years of age.

The results of the imagery analysis were superposed on the geographic information system layer of potential forest site conditions. The information classes were analyzed and identified according to the expert classification developed by the authors. This allowed us to build vector polygonal layers reflecting the distribution of vegetation regeneration series (forest types) and stages in a range of site conditions found in the test site (figure 1).

Table 1. Relatively correspondent vegetation and site condition units.
Vegetación correspondiente relativa y unidades de condición de sitio.

Topogenetic vegetation classification units	Forest site conditions classification units
Stand type (age stage)	Elementary ecotope
Forest type (short vegetation regeneration series, a part of long-term natural succession)	Forest site condition type, *i.e.* sites similar in slope, aspect, and hydrological regime
Group of forest types (a long-term regeneration series, or a natural succession series)	Group of forest site condition types - sites similar in mesorelief elements (watersheds, slopes, river valleys, depressions, etc.) and moisture regime
Geomorphological complex of forest types	Geomorphological complex of forest site condition types - sites similar in mesorelief form proportions, elevation range, and roughness

Table 2. Geomorphological complex (GMC) morphometric parameters.
Parámetros morfométricos de GMC.

Class parameters						
GMC class number	Elevation m a.s.l.	Mean elevation m a.s.l.	Elevation m a.s.l. STD	Slope		
				Slope interval, deg.	Mean slope, deg.	Slope STD, deg.
I	184-225	204.8	20.74	0.08-2.66	1.37	1.29
II	241-273	257.15	16.25	0.46-2.12	1.29	0.83
III	203-268	235.83	32.45	0.00-6.29	3.13	3.16
IV	296-337	316.4	20.9	0.57-2.95	1.76	1.19
V	320-409	364.27	44.51	1.30-7.42	4.36	3.06
VI	158-269	213.6	55.72	0.00-4.70	2.19	2.51
VII	293-377	335.1	41.83	0.75-4.97	2.87	2.11
VIII	106-162	134.1	28.11	0.15-3.23	1.69	1.54
IX	473-561	516.63	43.96	1.66-6.80	4.23	2.57
X	208-269	238.45	30.8	1.06-3.27	2.16	1.11

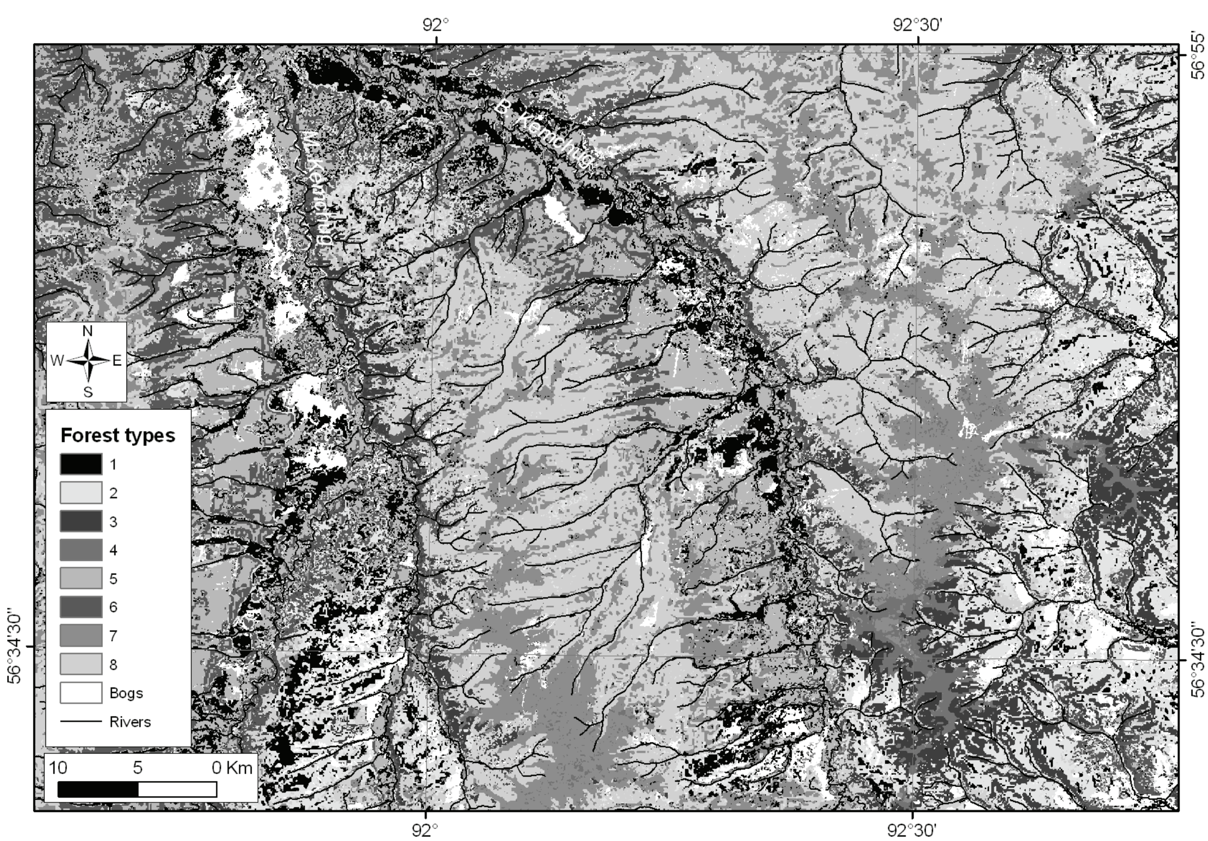

Figure 1. Fragment of the study area forest dynamics map (layer of forest types). See text for forest type description.
Fragmento del área de estudio y dinámica forestal (capas de tipos de bosque). Ver texto para descripción de tipos de bosque.

Forest types in a range of site conditions: 1. Scots pine/tall grass/forb stands supported by dark-colored sod forest soils and dark-grey loamy forest soils occur in watersheds and on the adjacent very soft slopes. 2. Scots pine/forb stands on sod-slightly podzolic, sod acidic forest, and grey loamy forest soils are limited to soft (1-3º) slopes. 3. Scots pine/forb/whortleberry (*Vaccinium vitis-idaea*) stands on sod-podzolic soils and light-grey forest loamy sand on moderately steep (3-5º) slopes. 4. Mixed Scots pine/dark conifer/feather moss/grass stands on lightly loamy podzolic soils in convex watersheds. 5. Fir/spruce/tall grass/forb stands supported by dark-colored sod forest, dark-grey, and double-humus-horizon moderately loamy sod-podzolic soils on flat-topped elevations and the adjacent soft slopes of an accumulative high plain. 6. Mixed fir/spruce/grass stands on sod-podzolic and grey forest soils on an accumulative high plain slopes. 7. Mixed fir/spruce/feather moss/short grass stands on sod-podzolic loamy soils on flat watersheds and soft slopes in the low-elevated part of the mountain range (1-3º). 8. Mixed fir/spruce/feather moss/forb stands on sod-podzolic loamy soils on various slopes in the low-elevation part of the mountain range.

DISCUSSION AND CONCLUSIONS

The genetic classification is highly promising regarding GIS-based mapping of vegetation cover dynamics. This classification covers characteristics of natural and human-caused changes in the temporal and spatial patterns of the main structural forest cover units, *i.e.* forest types, considers forest site conditions and all forest development stages (Kolesnikov 1956). These advantages of the classification, when taken together, are an excellent tool for predicting vegetation succession directions and rates (Ryzhkova *et al.* 2011).

The characteristics of two geomorphological complexes of forest site conditions with an account of geomorphology, zonal soil types, and vegetation summarizes in table 3.

GIS technologies are very useful to compare and analyze various information layers and thus to ensure more objective identification of the links between vegetation and eco-geographic factors (Hill *et al*. 2010, Bargiel and Herrmann 2011, Ohmann *et al*. 2011).

A methodology of automated mapping of potential site conditions and forest regeneration dynamics involving a spatial analysis of multi-band satellite data, a digital elevation model, and ground measurements were developed and applied to south central Siberia. The combined use of automated methods and expert interpretation of the classes obtained allowed us to identify certain characteristics, such as forest site conditions types, forest types, and age stages of regenerating vegetation, unrecognizable in space images, but important regarding thematic mapping.

The application of the proposed approach enables to obtain vector maps showing the test site potential forest site conditions, forest types, and the regenerating vegetation age stages based on DEM (SRTM 90m) and Landsat ETM+ imagery.

ACKNOWLEGMENTS

This study was supported by Russian Foundation for Basic Research project 10-05-0094, project ZAPAS (Assessment and Monitoring of Forest Resources in the Framework of the EU-Russia Space Dialogue), project 27.32 (Basic Research Program of Presidium RAS) and Interdisciplinary project 14.

Table 3. Forest site conditions and the corresponding forest types (forest vegetation regeneration series).
Condiciones del sitio forestal y los tipos forestales correspondientes (*i.e.* series de regeneración de la vegetación forestal).

GMC class number	Geomorphological complex (GMC) description	Forest site conditions types based on slope range	Forest type (Kolesnikov 1956)
III	Elongate-elevated or rolling, elevated and ridged (riverside), denudation, and denudation-erosional plains (203-268 m a.s.l.) made up by light-brown and yellow-brown loessed deluvial-eluvial mid-weight and light pulverescent- limous clays, and, on high-to-middle river terraces, by light loams and loamy sands. The soils are of the dark-gray and grey forest type, leached chrnozems, in places, grass sod-podzilic and podzolic.	0-1	Scots pine/herb/tall grass
		1-3	Scots pine/herb
		3-5	Scots pine/red whortleberry/herb
		>5	Scots pine/herb/feather moss
V	Hilly-ridged, ridged-bold-hilled dissected plateaus with different slopes (320-409 m a.s.l.) made up by proluvial and eluvial-deluvial brown and red-brown, crush-stoned, heavy loams and loamy sands. The soils are grass sod-podzolis (grass sod-deep podzolic), forest grey, gleic.	0-1	Fir/spruce/grassy bog
		1-3	Spruce/fir/small grass/feather moss
		3-5	Spruce/fir/grass/feather moss
		>5	Spruce/fir/feather moss

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 299-302, 2012 DOI: 10.4067/S0717-92002012000300012

Selecting ecotonal landscape units on Meridional Plateau, Southern Brazil

Selección de unidades ecotonales de paisaje en Plató Meridional, Sur de Brasil

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SUMMARY

The Escarpa Devoniana environmental protection area, located in the Meridional Plateau of South Brazil, supports a high diversity mosaic of native araucaria (*Araucaria angustifolia*) forests and grasslands patches. In order to conduct studies of its dynamics, the biodiversity of grassland-forest ecotones in South Brazil Project team has been developing a methodological approach for sorting ecotonal areas for sampling. This essay validates this methodology to the major grasslands occurrence area in the Brazilian Atlantic Forest Biome, the Campos Gerais region. The entire area was divided into a 1 x 1 km grid that was overlayed with vegetation typology files. The criteria for quadrat selecting were: (a) 25 % or more of forest remnants; (b) 25 % or more of grasslands remnants; (c) at least 20 % of contact between them. The non-supervisioned classification potential ecotonal areas were validated through visual checking in a high resolution qualitative way, always by the same operator. The quadrats could be achieved by the researchers in a *.kmz file, which allows someone selecting them in the Google Earth platform.

Key words: landscape ecology, Campos Gerais, GIS, sampling methods.

RESUMEN

El área de preservación ambiental de la Escarpa Devoniana, situado en la meseta meridional del Brasil, presenta un mosaico de gran diversidad de bosques de araucaria (*Araucaria angustifolia*) y pastizales nativos. Para llevar a cabo estudios de su dinámica, el equipo del proyecto de biodiversidad de ecotonos de bosques y pastizales en el sur de Brasil ha desarrollado un enfoque metodológico para ordenar áreas ecotonales de muestreo. Este ensayo valida la metodología para la zona de ocurrencia de grandes pastizales en el bioma de bosque atlántico, la región de Campos Gerais. Toda el área fue dividida en cuadrículas de 1 x 1 km cubiertas con archivos de tipología de vegetación. Los criterios para la selección de cuadrículas fueron: (a) 25 % o más de los restos de bosque; (b) 25 % o más de los restos de pastizales; (c) al menos el 20 % de contacto entre ellos. La clasificación no supervisada de áreas potencialmente ecotonales fue validada a través de comprobación cualitativa visual de alta resolución, siempre por lo mismo operador. Los investigadores podrían obtener las cuadrículas en un archivo con formato *.kmz el cual permite su selección en la plataforma de Google Earth.

Palabras clave: ecología de paisajes, Campos Gerais, SIG, métodos de muestreo.

INTRODUCTION

Grasslands in southern Brazil are natural ecosystems present in this region prior to the forest expansion in the Late Quaternary (Behling and Lichte 1997, Behling and Pillar 2007). Grasslands form ecotones with araucaria (*Araucaria angustifolia* (Bertol.) Kuntze.) forest isolated rounded patches, linear riparian forests, or larger forests over slopes (Moro and Carmo 2007).

The natural grasslands dynamic are associated with water and soil conditions (Curcio 2006) and with disturbances such as fire and pasture (Overbeck *et al.* 2007). Investigations on the araucaria forest expansion over the grasslands in the Campos Gerais region, in the Paraná State, are being conducted with a proposed, not published yet, methodology for sorting areas developed to the Pampas Biome, in Rio Grande do Sul[1]. In that region, forests spread mainly from their edge over the open areas (Oliveira and Pillar 2004), or from little woody nucleous not far from the forest (Duarte *et al.* 2007).

This essay validates this geographic information system methodology to select and sort ecotonal areas on the major grasslands occurrence in the Brazilian Atlantic Forest Biome, the Campos Gerais region.

METHODS

The systematic and standardized approach to select suitable sampling units combined stratification and ran-

[1] Hasenack H, E Weber, E Vélez, R Cardoso. 2011. Procedimento para seleção de unidades amostrais de paisagem (UAPs) em campos e em ecótonos campo/floresta no Rio Grande do Sul – Projeto SISBIOTA.

domization from knowledge about the current distribution and spatialization of grasslands and forests ecotones. For this, we used the database related to the Escarpa Devoniana environmental protection area ('APA' in Portuguese), a conservation unit of extensive use with 392,363 ha (SEMA/IAP 2004). Images from 2004 were a fusion of Landsat 7 satellite bands. Analyses were performed by the software ArcGIS 9.x using the vector-based landscape analysis tools extension (ESRI 2006).

We adopted in the first step, as reference, a standardized spatial grid of 10x10 km recommended by the Brazilian Government (Serviço Florestal Brasileiro/ Ministério do Meio Ambiente) for sampling to the National Forestry Inventory. According to them, this resolution allowed ecotone delimitations in several different regional landscapes no matter the predominant matrix. Thiessen polygons resulted from the equidistant lines interacting between points and the environmental protection area limits were overlayed with vegetation typology files of the environmental protection area. The attribute table contained patches information, as patch identification number, grid code, use class (araucaria forest, grasslands, silviculture, agriculture, and water bodies), total area (m^2 and hectares), and perimeter.

Using the class attribute, the criteria for quadrat selection were: (a) 25 % or more of forest remnants; (b) 25 % or more of grasslands remnants. These arbitrary criteria were considered enough to provide a good probability of grasslands and forests were in contact. As the quadrats selected this way could not be real ecotonal areas, once they could be apart, validation of the non-supervisioned classification was conducted in a qualitative way, always by the same operator, through visual checking of the contact between grasslands and forests patches. Every quadrat was analyzed by means of the more recent images of Google Earth and only the contact of at least 20 % of the two vegetation were considered ecotones for our purposes. This criterion was arbitrary too, considering the finest scale of the mapping interpretations and the field necessities for replica plotting settlement.

RESULTS

The 85 10 x10 km polygons have covered 850,000 ha, so we perceived that this grid size covered much more than the environmental protection area (figure 1A). Besides, the initial proposed resolution, of 30 meters, was unable to discriminate some small ecotones in this region and, in spite of the Brazilian government technical recommendations, a new delimitation was necessary. So each polygon was divided again, this time in a 1x1 km grid with 4,647

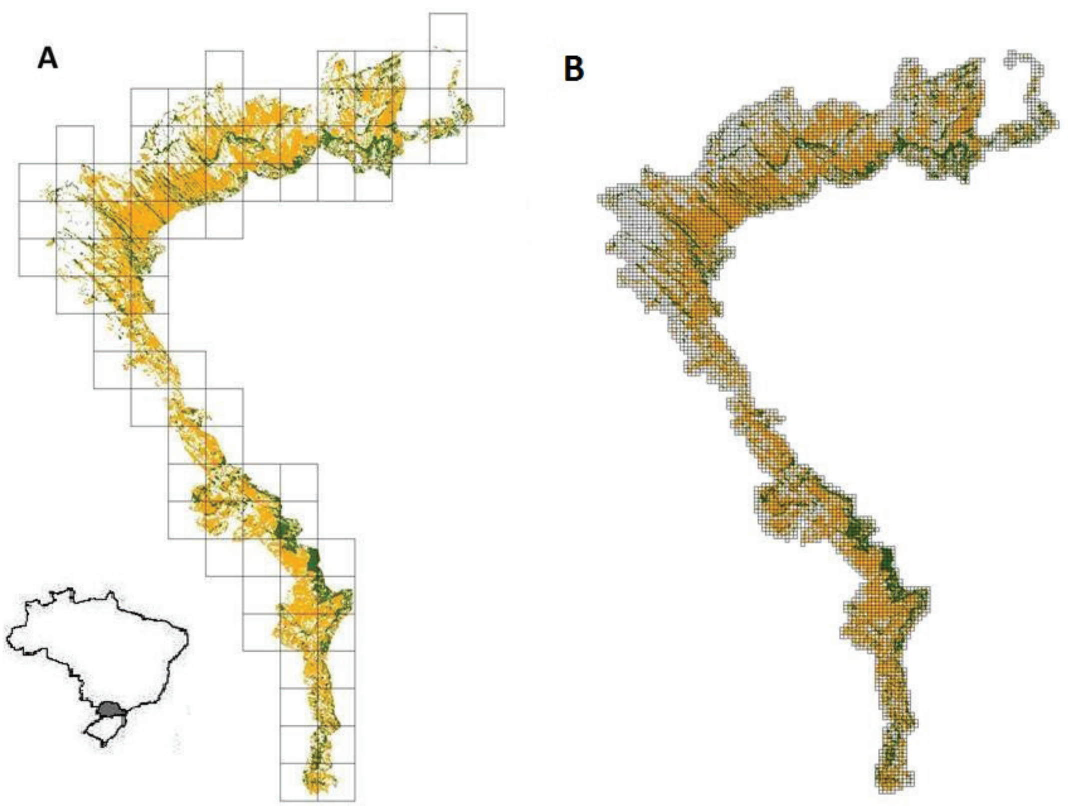

Figure 1. Natural vegetation on Escarpa Devoniana APA under 85 10 x10 km. A) Thiessen polygons and B) under 4,647 1x1 km grid.
Vegetación natural en la Escarpa Devoniana APA bajo 85 polígonos de 10 x10 km. A) Polígonos de Thiessen de 10 x 10 km. B) Bajo una grilla de 1x1 km (B).

polygons covering almost 465,000 ha (figure 1B), including just 15 % of marginal areas outside the environmental protection area.

This environmental protection area grid generated one attribute table containing 77,003 vegetation patches, where 42,083 were classified as agriculture and 8,956 as silviculture. So, almost 66 % of the vegetation patches were anthropogenic. There were 12,528 araucaria forest patches, and 14,930 patches identified as grasslands and/or savannas, and/or wetlands. After this screening, circa 1,950 quadrats (195,000 ha) potentially could have ecotones, *i.e.*, quadrats that presented grasslands and araucaria forests, corresponding to 22.9 % of the total area.

It was necessary a visual checking on the higher resolution images of Google Earth to discriminate the grasslands areas from savanna and wetlands. In this procedure, we have found also several araucaria forest classification errors related to actual silviculture areas. Forests deeply located into canyons were desconsidered as well, due to their hypothetical difficulty to contact grasslands above. After the visual validation, only 1,544 quadrats (18.2 % of the total area) achieved the third proposed criterion for real ecotone presence in the studied scale - at least 20 % of contact between grasslands and araucaria forests patches (figure 2).

The quadrats were then transposed by the research team into a *.kmz file for the project site, which allowed someone selecting them in the Google Earth platform. In the site https://sites.google.com/site/sisbiotaparana, accessing the *.kmz files, one could see a georeferenced index file with a 1 x 1 km grid. Sorting any one, the noted UTM coordinates allowed to access shape files of the systematic mapping where one could see the grid sequential numbers and its related attribute tables.

DISCUSSION AND CONCLUSIONS

This is a reliable method for assessing cartographic representative areas for sampling. The previous quadrats selection helps the research team on randomly sorting ecotonal areas before their field works, especially for those that do not have much local vegetation knowledge. The former 10 x 10 km proposed grid is not suitable for ecotones identification in Campos Gerais region due to the finer scale required (Wu and Qi 2000). Also, the extension and convex shape of the environmental protection area lead to the selection of larger areas without interest outside the environmental protection area limits. To divide the area in a smaller grid, as 1 x 1 km, is an option, but now we have to achieve another resolution patch. If finer images were not available, one could use the Google Earth platform (Taylor and Lovell 2012). In that case, one could be aware that, before mapping, quadrat images must be georeferenced by means of at least 10 GPS field points every sampling (Lang and Blachke 2009).

Nevertheless, even bearing ecotones, some of the quadrats may not be suitable for sampling. Each sorted quadrat should be then evaluated according to its distance and access conditions, relief, special permission entrance needs, and so on. Following Metzger (2006), a landscape

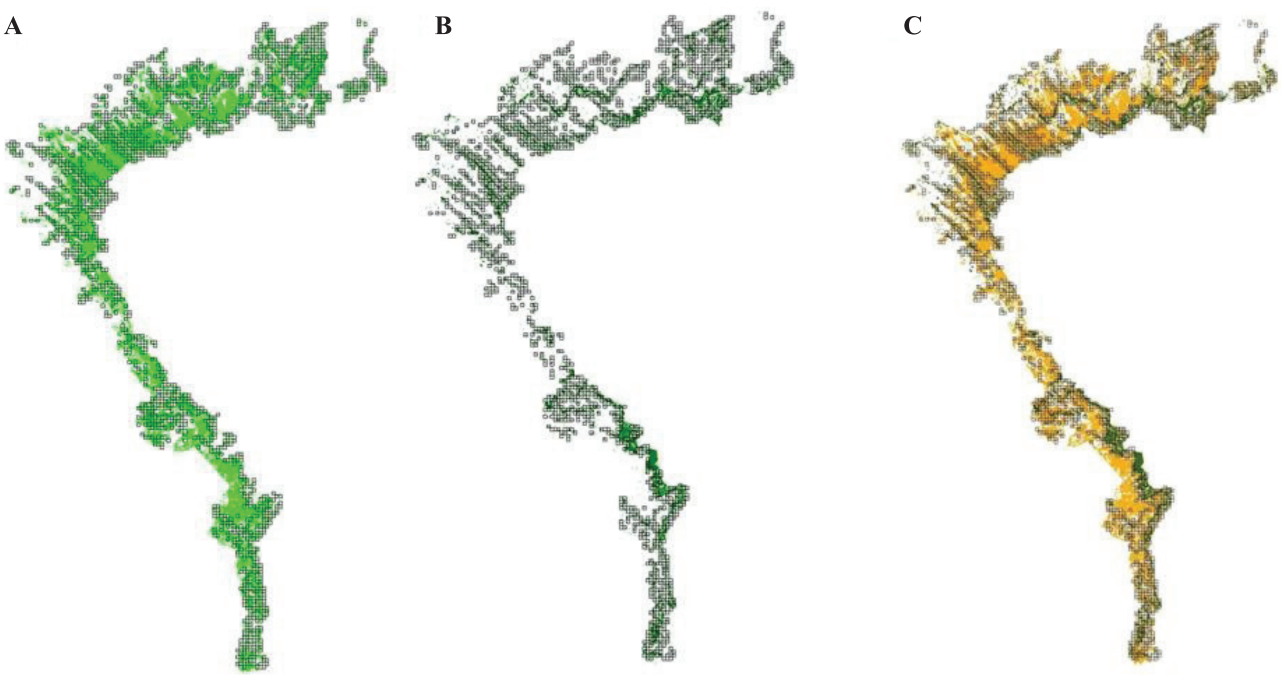

Figure 2. Vegetation remnants on a 1 x 1 km grid on the Escarpa Devoniana APA: A) grasslands, B) araucaria forests, and C) ecotonal areas.

Remanentes de vegetación en una grilla de 1 x 1 km en la Escarpa Devoniana APA. A) Pastizales. B) Bosques de araucaria. C) Áreas ecotonales.

context analysis should be performed as well, particularly according to spatial redundancy, connectivity or contiguity with another ecotonal area, barriers existence, or any other parameter that could possibly influence the quality of the ecotone at each focused biocoenosis.

ACKNOWLEDGMENTS

We are grateful to our colleague Atila Santana of the project *Biodiversidade dos campos e dos ecótonos campo-floresta no sul do Brasil: bases ecológicas para sua conservação e uso sustentável*, supported by the MCT/CNPq/MEC/CAPES/FNDCT Nº 47/2010 – SISBIOTA BRASIL.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 303-308, 2012 DOI: 10.4067/S0717-92002012000300013

Boundaries and mosaics: an approach to evaluate changes and to profit landscape planning, São Sebastião Island, SP/Brazil

Fronteras y mosaicos: una aproximación para evaluar cambios y apoyar la planificación del paisaje, São Sebastião Island- SP/Brazil

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SUMMARY

This study assumed that the spatial identification of mosaics obtained by the analysis of interactions between frontiers over time would be a great strategy to obtain planning units, since the boundaries reveal the changes, heterogeneity and fluxes in a landscape. For this purpose, we selected 16 watersheds in São Sebastião Island (São Paulo, BR), mapped the land use and cover (1962 and 2009) and built matrices of patches by boundaries. The analysis of these matrices using multivariate ordination and clustering allowed us to identify mosaics. The mosaics showed very well the temporal diversity of interactions across frontiers and the landscape conservation status, but had limitations to indicate management practices.

Key words: environmental planning, forest conservation, landscape ecology.

RESUMEN

Este estudio asume que la identificación espacial de mosaicos obtenida a través del análisis de interacciones entre fronteras en el tiempo sería una buena estrategia para obtener unidades de planificación, ya que los límites revelan los cambios, heterogeneidad y flujos en un paisaje. Para este propósito, se seleccionaron 16 cuencas en São Sebastião Island (São Paulo, BR), se mapeó el uso y cobertura de suelo (1962 y 2009) y construyeron matrices de parches por fronteras. El análisis de estas matrices usando ordenación y agrupamiento multivariado permitió identificar los mosaicos. Los mosaicos mostraron bien la diversidad temporal de interacciones a través de las fronteras y el estado de conservación del paisaje, pero tuvieron limitaciones en indicar prácticas de manejo.

Palabras clave: planificación ambiental, conservación de bosque, ecología de paisaje.

INTRODUCTION

The Brazilian landscapes have been showing the multiplicity of accumulated uses over time, often resulting in very heterogeneous landscapes and generating major conflicts among social actors (Brito 2003). This territories are relevant to environmental planning (Polette and Silva 2003) because they are complex landscapes extremely fragile, which should be strongly conserved, but have numerous interests of human uses (Santos and Caldeyro 2007).

The heterogeneity, rarely discrete in a territory and derived from a wide range of habitats (Lovett *et al.* 2005); can be analyzed through the diversity of types and configuration of elements that compose the landscape, the intensity of interaction between these elements and the nature of the relationship between the elements (Mimra 1993). It can also be observed by different kinds of pressure over natural fragments (Gergel and Turner 2002), the porosity of the matrix (Coulson *et al.* 1999) or by connectivity between elements (Li and Reynolds 1995, McGarigal and Marks 1995). It is important to note that one can not directly relate landscape complexity to presence of impacts. De Pablo (2000) has shown that certain landscapes structures may or may not cause negative impacts, depending on the types and quantities of interactions among their elements.

Several authors have interpreted the heterogeneity using the patch-corridor-matrix model (Forman 1995, Dramstad *et al.* 1996). Another way is to evaluate mosaics that reproduce specific sets of elements and their interactions (Forman 1995, Roldán-Martin *et al*. 2003). This method identifies the mosaics as a set of patches with the same frequency of boundaries, that is, the same pattern of ecological interactions. Thus, they are part of a network of similar interactions (Cadenasso *et al.* 2003, Valverde *et al.* 2008). This conception assumes that boundaries or transition zones between patches are the areas where ecological flows take place, which can be altered by changes in the patterns of spatial arrangement (Roldán-Martin *et al*. 2006, Turner and Cardille 2007).

If each mosaic represents one aspect of heterogeneity and conservation status, it can be assumed that also it could have specific management actions. This is the premise evaluated in this study. This study aims to evaluate the possibility of identifying management units through mosaics defined by the interactions between frontiers.

METHODS

This study selected 16 watersheds of São Sebastião Island (municipality of Ilhabela, São Paulo, BR) facing the São Sebastião Channel (figure 1), since this area is the one that has suffered the most human influence over the last 500 years over the atlantic forest. Nevertheless, human actions on this island are heavily concentrated in its shoreline, retaining about 92 % of forest conserved, being the Brazilian city with the greatest area/Atlantic Forest of the country (Bertolo *et al*. 2012).

The land use and land cover maps of the watersheds from 1962 and 2009 were made in ArcGIS9.2 from aerial photographs, scale 1:35.000 and SPOT 5 satellite images with a resolution of 10 meters. Based on those maps, matrices of patches by boundaries were prepared (figure 2A). The matrices were subjected to DECORANA ordination (DCA, figure 2B). The three axes of DCA were subjected to a hierarchical cluster analysis (euclidean distance) (figure 2C). The groups composed of this step represent the mosaics, showing similar patterns of frontiers based on their frequencies (Roldán-Martín *et al*. 2006, Valverde *et al*. 2008, Hardt 2010). The mosaics are specific clusters for each date, which has particular associations among their elements.

In order to compare changes between landscape mosaics over 47 years it is necessary to form mosaics with similar patterns. Thus, the mosaics of each year were regrouped and organized into a single matrix of mosaics by boundaries (figure 2D), subject to further analysis of ordination and variance. The mosaics have been characterized by ANOVA, with a cut off level of dendrogram determined on the 2-2 comparison of the frontiers frequencies observed in each bifurcation branch (figure 2E).

RESULTS

We identified five mosaics in 1962 and 2009. Figure 3 shows the results of DCA of the mosaics identified in both years and the clustering made from their coordinates in the ordination axis. This information, together with the ANOVA and t-test, allowed the verification of just how different are the groups between themselves, and which boundaries contributed to the identification of the groups. Figure 4

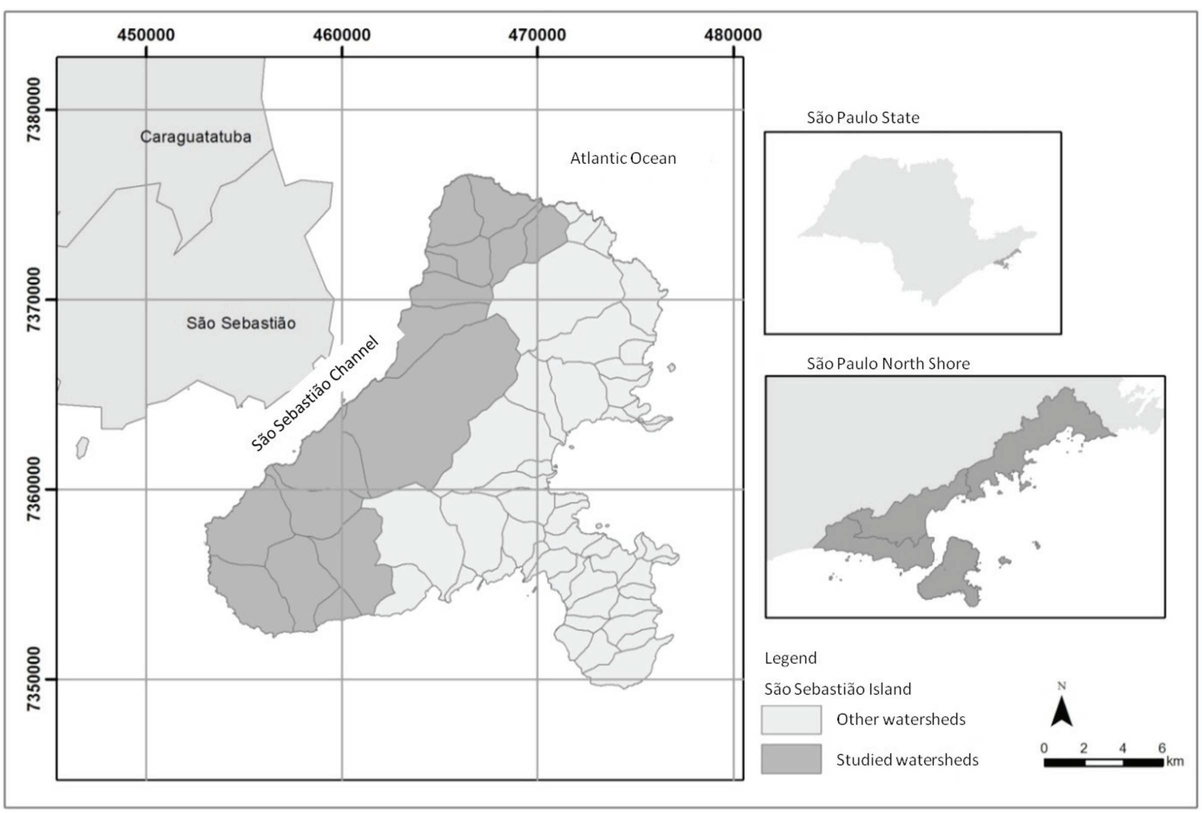

Figure 1. Location of São Sebastião Island.
Ubicación de la Isla São Sebastião.

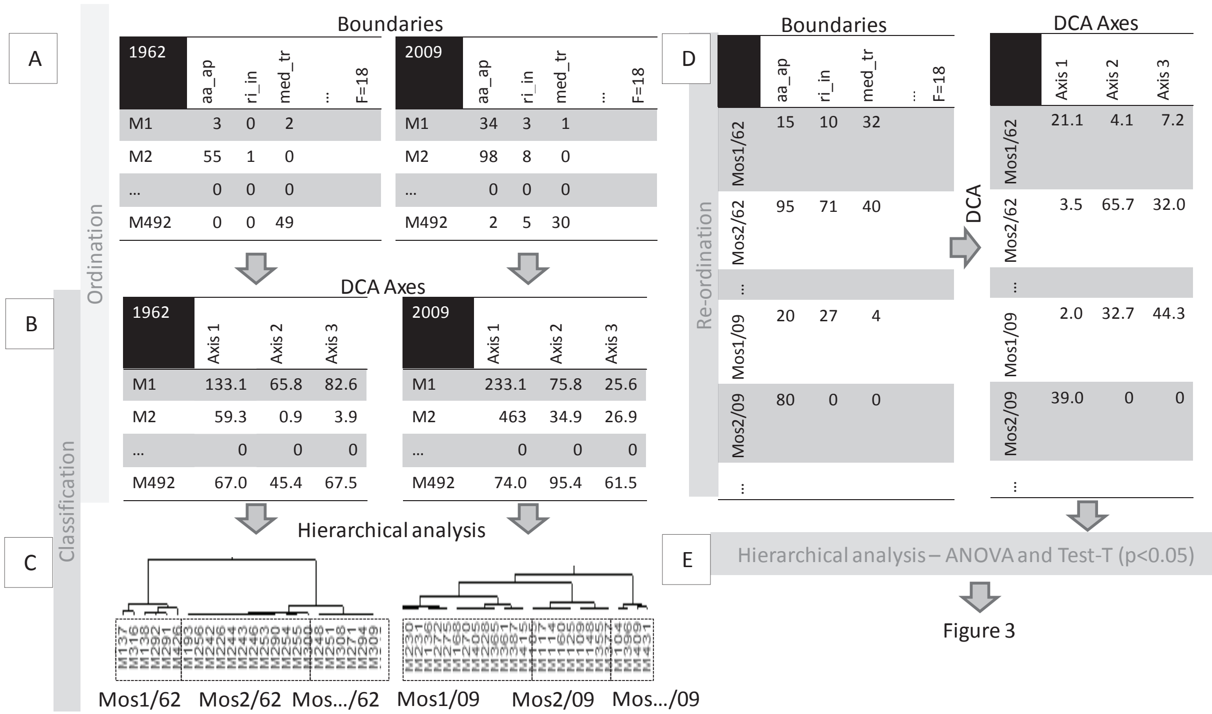

Figure 2. Methodological schema (adapted from Hardt 2010).
Esquema metodológico (adaptado de Hardt 2010).

shows the spatial distribution of mosaics and their description in terms of area, boundaries and uses.

DISCUSSION

The results show that over 40 years of landscape study, there were no major changes in the dominant uses or even in relation to areas occupied by forest, inclusive pointing to an increase of forest amount (figure 4D). However, the mosaics denote that the network of interactions through boundaries has substantially changed (figure 4C). Mosaic five, for example, with the landscape higher conservation status, has an increase in patches number and frontiers (figure 4B), which may have affected the quality of forest, although it maintained the same land uses in 1962 and 2009. We also highlight mosaic 3, which has always been occupied predominantly by forest in initial succession stage (figure 4D). Despite this condition, the mosaic presents a large number of land uses boundaries that has been expanded over time (figure 4BC).

We defend the idea that, despite the same conditions of land uses, different situations of boundaries can affect the forests and their territories in a quite distinct way. Some researchers show that structural arrangements of boundaries provide evidence of change in ecological condition, indicate ecological complexity and influence on flows between patches (Fortin *et al*. 1996, With 2005, Teixido *et al*. 2010). It suggests that mosaics based on boundaries can denote changes and conservation status that are not visible by land use areas. One can infer that some territories with high percentage of forests also need management, due the influence of boundary number and richness that have been established over time.

These findings strengthen the observations of other authors that indicate the mosaic as a functional space, which reflects the interaction between landscape elements and highlights the relationships between major patches, providing good support to understand the environmental supply and territory management decisions (Zeng and Wu 2005, Valverde *et al*. 2008). However, it is important to remember that mosaics are the manifestation of the ecological interactions at different levels of detail. There are certain scales that have reasonable descriptive capacity, but do not have an adequate performance from the management viewpoint. This study is an example, because the adopted scale does not consider all the uses relations that are important for the management. Depending on the scale, mosaics could be more useful for describing landscape or defining management guidelines.

CONCLUSIONS

The mosaics assess over time allow to show the temporal diversity of interactions across boundaries, indicating changes and conservation status that are not visible by land use areas. We infer that some mosaics with high percentage of forests also need management, despite of the conservation condition. However the mosaics are not effi-

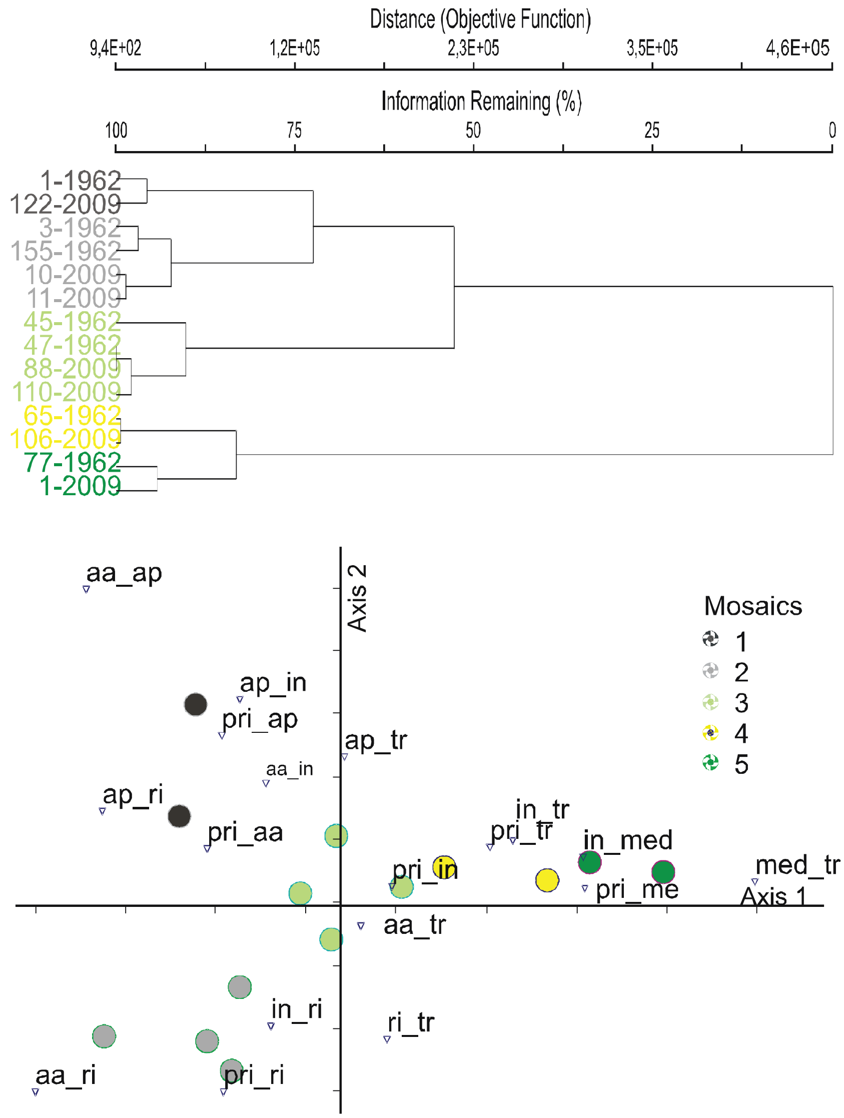

Figure 3. Mosaics obtained from DCA and cluster analysis (land uses: aa-stepping stones; ap-urban concentration; in-forest (initial stage); med-forest (intermediate/late stage); pri-forest (pioneer stage); ri-isolated residences; tr-trails).

Mosaicos obtenidos a partir del análisis DCA y de cluster. Usos de suelo: aa-escalones; ap-concentración urbana; in-bosque (en estado inicial); med-bosque (en estado medio/tardío); pri-bosque (en estado pionero); ri-residencias aisladas; tr-senderos.

cient as effective planning units in function of the adopted scale. Mosaics are more adequate to description than management. It is important to study how articulate both the description and management.

ACKNOWLEDGMENTS

This research was funded by CAPES and Fundação Carolina. We would also like to thank for the Foundation Forest, the administration of Ilhabela State Park.

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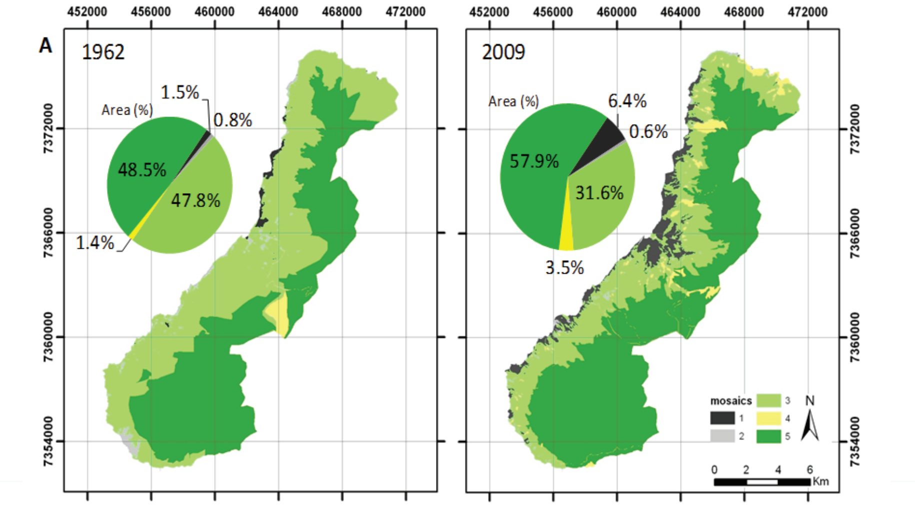
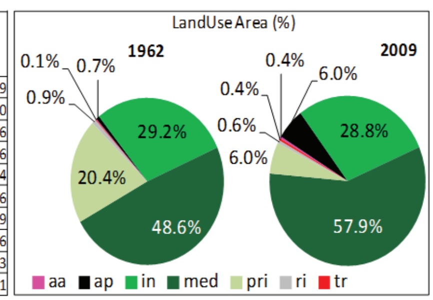


B

		Patch No.	Boundarie No.	Boundarie Richness	Use richness	Area (ha)
mosaic 1	1962	113	160	8	3	243.9
	2009	82	107	8	3	101.0
mosaic 2	1962	19	29	8	4	131.6
	2009	51	141	9	4	1016.6
mosaic 3	1962	5	256	11	2	7608.4
	2009	33	164	14	4	5026.6
mosaic 4	1962	1	6	4	3	214.9
	2009	79	144	13	3	553.6
mosaic5	1962	3	7	4	2	7714.3
	2009	29	30	3	2	9214.1



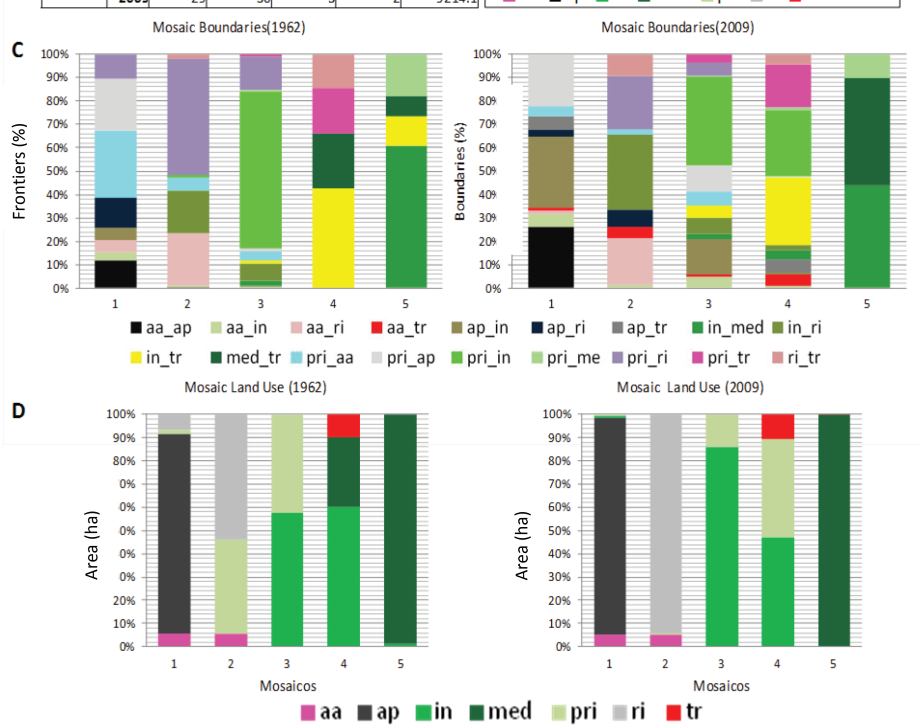


Figure 4. Mosaics, boundaries and land uses of 1962 and 2009 (A) types of mosaics; (B) characteristics and percentage of each mosaic; (C) relative frequency of boundaries; (D) land use relative area.

Mosaicos, fronteras y usos de suelo en 1962 y 2009 (A) tipos de mosaicos; (B) características y porcentaje de cada mosaico; (C) frecuencia relativa de fronteras; (D) área relativa de usos de suelo.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 309-312, 2012 DOI: 10.4067/S0717-92002012000300014

Frost ring distribution in *Araucaria araucana* trees from the xeric forests of Patagonia, Argentina

Distribución de anillos de heladas en árboles de *Araucaria araucana* en bosques xéricos de la Patagonia argentina

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SUMMARY

Frost rings are defined as anatomically abnormal and ecophysiologically pathological structures. We studied frost injuries in tree-rings of *Araucaria araucana* trees growing at the northern limit of its natural distribution. We recorded 121 frost injuries at two sites in the northern xeric distribution of *A. Araucana* forests. Frost rings at both sites were primarily restricted to the middle frost ring section of the rings. These results represent the first attempt to report and describe the occurrence of these events for this species and region. These proxy records represent important indicators of extreme temperature conditions.

Key words: tree-rings, injuries, earlywood, latewood, extreme events.

RESUMEN

Las lesiones de heladas en los anillos de crecimiento de árboles son definidas como estructuras anatómicamente anómalas y ecofisiológicamente patológicas. En este trabajo se estudiaron estos anillos de heladas en árboles de *Araucaria araucana* creciendo al límite norte de su distribución natural. Se registraron 121 marcas de heladas para los dos sitios estudiados. En ambos sitios el mayor porcentaje de heladas se ubicaron en la mitad del anillo. Estos resultados representan un primer intento de informar y describir la ocurrencia de marcas de heladas en anillos de crecimiento para esta especie y la región. Registros de esta naturaleza representan importantes indicadores de eventos extremos en la temperatura.

Palabras clave: anillos de crecimiento, lesiones, leño temprano, leño tardío, eventos extremos.

INTRODUCTION

Extreme climatic events could have strong effects on forest ecosystems altering the state, functioning, and stability. At high latitudes, these events include frosts and long-term air temperature drops during the growing season (Hantemirov *et al.* 2000). Frost records can be recorded in the annual rings of tree species and are defined by Schweingruber (2007) as anatomically abnormal and ecophysiologically pathological structures resulting from frost injuries to the cambium in the xylem, with local difficulties in sap flow dynamics and normal continuity of radial and axial tracheid morphology. In general, frost rings consist of underlignified, crumpled (deformed) tracheids, collapsed cells, traumatic parenchyma cells, and abnormal tracheids (Glerum and Farrar 1966). The position of the tissue damaged by the frost within the ring is determined by the season in which the frost event occurrs, resulting in damaged rings caused by late and/or early frosts (Stöckli and Schweingruber 1996). Even when the impact of frosts on trees can be rapid or unnoticeable, frost rings have been used as markers of extreme temperature events occurring during the growing season and the construction of frost-ring chronologies could be used as proxies of climate variability in the forest environment (Payette *et al*. 2010).

Araucaria araucana (Molina) K. Koch (pehuén), an endemic species to the northern extremes of the South American temperate Subantarctic forests of Argentina and Chile (Roig and Villalba 2008), have been demonstrated to be a useful tree species for spatial and temporal reconstructions of growth variability (Mundo *et al*. 2012). In this work, we described the first attempt in reporting frost injuries in different positions of the *Araucaria arucana* tree-rings in the Argentine northwestern Patagonia.

METHODS

The study was conducted at two *A. araucana* stands of open forests growing in rocky outcrops at the forest-steppe boundary in the northwestern Patagonian foothills in the province of Neuquén, Argentina. At each stand, two increment cores per tree were taken at breast height (1.3 m) on a variable number of trees (table 1). Wood samples were air dried, mounted on wooden supports and sanded with pro-

Table 1. Characteristics of the two *Araucaria araucana* sites in Neuquén, Argentina.

Características de los dos sitios de *Araucaria araucana* en Neuquén, Argentina.

Characteristics	Sites	
	Chenque-Pehuen	Carriel Malal
Number of sampled trees/Number of trees with frost rings	65/52	54/20
Chronology time span	1391-2007	1421-2011
Latitude S	38º 05´ 59,9”	38º 55´ 36,8”
Longitude W	70º 52´ 36,3”	70º 32´ 59,8”
Altitude (m)	1,653	1,510
Total rings analysed	12,216	11,799

gressive finer sand papers in the laboratory to highlight the tree-ring annual boundary structure. Samples were visually cross-dated and ring-width series were measured on a Velmex measuring system with a precision of 0.001 mm. The quality control of the measured tree-ring series was checked according to standard cross-comparison methods proposed by Stokes and Smiley (1968) and by statistical cross-dating procedures performed by the COFECHA computer program (Holmes 1983). Frost rings were revealed visually on the carefully smoothed surface of the samples. Frost rings were identified and the position in the ring was recorded as: early frost ring (EFR), middle frost ring (MFR) and late frost ring (LFR). The relative frequency of the frost ring ocurrence was determined. In addition, we built contingency table with the different frost positions in the two sites.

RESULTS

We recorded 121 frost injuries at the two sites, 99 in Chenque-Pehuen and 22 in Carriel Malal, representing 0.81 % and 0.18 % of the total number of rings analyzed at each site, respectively. Of the 65 trees sampled at Chenque-Pehuen, 52 (81.5 %) recorded at least one frost ring. Alternatively, 20 of the 54 trees sampled (37.0 %) at Carrier Malal exhibited at least one frost ring (table 1).

Frost ring dates ranged between 1401 and 1975 and only a few years showed frost injuries at both sites, such as 1916, 1941 and 1948 (table 2). There were some years

Table 2. Years of frost ring formation (*) in early frost ring (EFR), middle frost ring (MFR) and late frost ring (LFR). Double (**) represents two frost rings in the same years.

Años de formación de lesiones por heladas (*) en el leño temprano, mitad del leño y leño tardío del anillo. Doble (**) representa dos lesiones de heladas en el mismo año.

Carrier Malal				Chenque-Pehuen							
Year	EFR	MFR	LFR	Year	EFR	MFR	LFR	Year	EFR	MFR	LFR
1703	*	-	-	1401	*	-	-	1863	-	*	-
1707	*	-	-	1409	-	*	-	1864	-	*	-
1763	*	-	-	1424	-	*	-	1869	-	*	-
1797	-	*	-	1548	-	*	-	1871	*	*	-
1846	*	-	-	1551	-	*	-	1875	-	*	-
1916	-	*	-	1589	-	*	-	1886	-	*	-
1931	*	-	-	1624	-	-	*	1889	-	*	-
1941	*	-	-	1626	*	-	-	1901	-	*	-
1948	*	-	-	1627	-	**	**	1902	-	*	-
				1628	*	-	-	1908	-	*	-
				1635	-	**	-	1909	-	*	-
				1675	-	-	*	1916	*	*	-
				1754	-	*	-	1933	-	*	-
				1756	-	*	-	1937	*	-	-
				1757	-	*	-	1940	*	-	-
				1766	-	*	-	1941	*	-	-
				1777	-	*	-	1942	-	*	-
				1842	-	*	*	1945	*	*	-
				1849	-	*	-	1948	-	-	*
				1851	-	*	-	1975	*	-	-
				1853	-	*	-				

(1842, 1871, 1916 and 1945) for which we found tree ring frost injuries in two different positions at the same site. Furthermore, we observed the formation of two xylem frost injuries within the same annual ring for the years 1627 and 1635 in Chenque-Pehuen.

Within the annual ring, frost injuries ocurred more often in the middle frost rings at both sites (table 2). For Chenque-Pehuen, 78.8 % of the frost injuries occurred in the middle frost rings, 14.1 % in the early frost rings and 7.1 % in the late frost rings. For Carriel Malal, the proportions were 63.6 % and 36.4 % in the middle frost rings and early frost rings, respectively, while no injuries were found in the late frost rings. The position of the frost injury was significantly independent of the site (X^2 P = 0.0037, Cramer contingency coefficient = 0.32) (table 3). The mean interval of frost events was 13.7 and 30.6 years for Chenque-Pehuen and Carriel Malal, respectively. The minimum interval of frost occurrence was 1 year for Chenque-Pehuen and 4 years in Carriel Malal, while the maximum interval was 124 and 70 years, respectively (table 4).

Table 3. Table Contingency indicating the frost positions within the ring and sites.
Tabla de contingencia indicando los sitios y la posición de las heladas en el anillo.

Position in the ring	Sites	
	Chenque-Pehuen	Carriel Malal
Early frost ring	10	7
Middle frost ring	31	2
Late frost ring	5	0
X^2 Pearson	0.0037	
Cramer contingency coefficient	0.32	

Table 4. Mean, minimum and maximum intervals of frost events at the study sites.
Media, mínimo y máximo de los eventos de heladas en los sitios estudiados.

Sites	Mean	Minimum	Maximum
Chenque-Pehuen	13.7	1	124
Carriel Malal	30.6	4	70

DISCUSSION

Reconstruction of growing-season frost activity may be used as an dendroecological tool of climate variability and may provide insights for future risks of frost damage in a warming climate and forest ecosystem (LaMarche Jr and Hirschboeck 1984, Hantemirov *et al*. 2004, Payette *et al*. 2010). In *A. araucana* xeric forests, frost rings occurr more often in the middle frost ring position than in other positions at both study sites. This provides evidence that early summer frosts are more frequent events at the two sites than early spring events. Similar results were found for *Pinus obovata* Ledeb. and *Larix sibirica* Ledeb. where frost injuries occurred more often in the earlywood than in the latewood (Gurskaya and Shiyatov 2006). The occurrence of frost injuries in different positions within the rings of trees for a single year (1842, 1871, 1916 and 1945), implies that frost ring damage is present in the earlywood of a tree and in the latewood of another. This could be explained on the degree of the tree ring development among individuals and the individual cold hardiness (Gurskaya and Shiyatov 2006). In addition, we observe the presence of two frost injuries in the same ring of trees during some years in Chenque-Pehuen (1627 and 1635). According to Gurskaya and Shiyatov (2002), the presence of two frost injuries provides evidence that the growing season in the corresponding years was extremely severe. Although few rings, the presence of frost records in the same years at both sites (1916, 1941 and 1948 years) suggests the presence of regional events that may affect a large forest area.

CONCLUSIONS

These results represent the first report and description of occurrence of frost events for this species and region. The differences between sites in the frequency of frost rings and frost ring positions may be related to a landscape effect: slope and geomorphology may play and important role in the frequency of frost rings. The frost ring chronologies from *A. araucana* developed in this study represent a reliable record for the interpretation of past extreme climatic events. Furthermore, the presence of frost rings in the same years recorded in the two chronologies indicate the capability of *A. araucana* to record large-scale extreme climatic events in northern Patagonia.

ACKNOWLEDGMENTS

This research was supported by the Inter-American Institute for Global Change Research (IAI-CRN2005), the Agencia Nacional de Promoción Científica y Tecnológica of Argentina (PICT-Bicentenario 2679), and the National Council for Scientific and Technical Research of Argentina (CONICET) through a doctoral fellowship granted to Martín Ariel Hadad.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 313-319, 2012 DOI: 10.4067/S0717-92002012000300015

Mapping tree genera using discrete LiDAR and geometric tree metrics

Mapeo del género de árboles usando LiDAR y métricas geométricas para árboles

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SUMMARY

Maps of tree genera are useful in applications including forest inventory, urban planning, and the maintenance of utility transmission line infrastructure. We present a case study of using high density airborne LiDAR data for tree genera mapping along the right of way (ROW) of a utility transmission line corridor. Our goal was to identify single trees that showed or posed potential threats to transmission line infrastructure. Using the three dimensional mapping capability of LiDAR, we derived tree metrics that are related to the geometry of the trees (tree forms). For example, the dominant growth direction of trees is useful in identifying trees that are leaning towards transmission lines. We also derived other geometric indices that are useful in determining tree genera; these metrics included their height, crown shape, size, and branching structures. Our pilot study was situated north of Thessalon, Ontario, Canada along a major utility corridor ROW and surrounding woodlots. The geometric features used for general classification could be categorized into five broad categories related to: 1) lines, 2) clusters, 3) volumes, 4) 3D buffers of points, and 5) overall tree shape that provide parameters as an input for the Random Forest classifier.

Key words: Airborne LiDAR, tree genera mapping, tree geometry, Random Forest Classification.

RESUMEN

Los mapas de géneros de árboles son útiles para el inventario forestal, planificación urbana y el mantenimiento de la infraestructura de líneas de transmisión. Se presenta un estudio de caso de uso de datos LiDAR de alta densidad para el mapeo de géneros de árboles a lo largo del derecho de paso (ROW) de un corredor de línea de transmisión. El objetivo de la investigación fue identificar árboles individuales que mostraban o poseían una amenaza potencial a la infraestructura de la línea de transmisión. Mediante el uso de mapas tridimensionales de LiDAR se derivaron métricas de árboles que están relacionadas con la geometría de éstos (formas del árbol). Por ejemplo, la dirección del crecimiento dominante de los árboles es útil para identificar árboles que crecen inclinados hacia las líneas de transmisión. También se derivaron otras métricas geométricas que son útiles para determinar los géneros de los árboles, tales como altura, forma de la copa, tamaño y estructura de ramas. El área de estudio se ubicó al norte de Thessalon, Ontario, Canadá, a lo largo de los principales corredores de ROW y en los bosques aledaños. Los atributos geométricos usados para la clasificación de los géneros fueron categorizados en cinco amplias clases: 1) líneas, 2) agrupamiento, 3) volúmenes, 4) amortiguamiento en 3D de puntos, y 5) forma general del árbol que provee parámetros como una entrada para el clasificador forestal aleatorio.

Palabras clave: LiDAR aéreo, mapeo de género de árboles, geometría de árbol, clasificación forestal aleatoria.

INTRODUCTION

Airborne light detection and ranging (LiDAR) has become a useful way of retrieving biophysical variables and for updating forest inventory maps. Tree genera or species information at an individual tree level is particularly useful in growth and yield estimates and have been studied primarily for forest applications such as updating forest inventories. In Holmgren and Persson (2004), the authors classified Norway spruce (*Picea abies* (L.) H. Karst.) and Scots pine (*Pinus sylvestris* L.) in Remningstorp Sweden. Ørka *et al*. (2007) classified spruce (*Picea sp.*), birch (*Betula sp.*) and aspen (*Populus* sp.) at Ostmarka natural forest in southern Norway and Suratno *et al*. (2009) classified ponderosa pine (*Pinus ponderosa* Douglas ex C. Lawson), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western larch (*Larix occidentalis* Nutt.) and lodgepole pine (*Pinus contorta* Douglas) at the University of Montana's Lubrecht Experimental Forest near Missoula, Montana. Korpela *et al*. (2010) classified Scots pine, Norway spruce and birch by using intensity variables at Hyytiälä forest station in southern Finland. All these studies demonstrate the capability of using LiDAR for producing maps of tree species. When forested landscapes intersect with anthropogenic infrastructure, often complex monitoring and analysis are required; therefore, in addition to purely forestry applications, we would like to provide another use of tree genera mapping. We focus on electric transmission line ROW management and the identification of trees with the potential to cause power delivery disruptions by interfering with these transmission lines.

The management of right of ways remain a challenge that utility company face, in particular, interruptions that are related to grow-in or fall-in vegetation that contribute to over 20 % of total outages (Eckert 2004). The conventional right of way vegetation management in Ontario is based on a six or eight year cycle assessment involving crew visits or aerial inspections to determine if the utility transmission infrastructure has enough clearance from the vegetation. The inspection process is labour intensive, time consuming, and thus expensive. As a result, the use of LiDAR to map and manage right of way vegetation is becoming attractive because it can mitigate the inspection process (Ituen and Sohn 2010). In order to predict effective clearance zones and revisit periods, the identification of tree species growing in or near the right of way is important due to the different growth rates of different species. With proper genera (or species) data together with stem growth direction and tree-height data, growth and yield tables can be implemented to better estimate and predict the potential growth of the vegetation in or near a right of way. This is beneficial for determining the amount of cutting, trimming, or pruning that would yield a safe clearance zone around transmission lines and towers.

METHODS

LiDAR data was collected on 7 August 2009 north of Thessalon, Ontario, Canada, using a Riegl LMS-Q560 at an altitude of 140 m above ground level. The point density was approximately 40 pulses per m^2. We surveyed 186 tree samples in the field, at eight different field sites measuring tree stem location, species, and diameter at breast height (DBH). Species collected include white birch (*Betula papyrifera* Marsh.), sugar maple (*Acer saccharum* Marsh.), red oak (*Quercus rubra* L.), jack pine (*Pinus banksiana* Lamb.), poplar (*Populus* tremuloides Michx.), white pine (*Pinus strobus* L.), white spruce (*Picea glauca* Moench Voss), and larch (*Larix laricina* (Du Roi) K. Koch). Of the trees surveyed, 34 were maple, 67 pine, and 59 poplar, comprising the majority (160) of the 186 surveyed trees; we focus this work on these three genera.

The process of geometric feature extraction involves quantifying the geometric differences among the three genera of interest (figure 1).

The geometric features were classified into five categories and a qualitative description of each category is given in table 1 (equations and descriptions: appendix 1). For each tree, we isolated the tree crown from the rest of the tree by locating the height of the tree crown base and applied a height threshold.

These 24 features were used as input to the random forest classifier for genera classification; to validate the classification stability, we randomly split our sample trees into 30 % for training and 70 % for validation and repeated the classification 20 times. In addition to the 24 geometric features that we derived, for the purpose of right of way

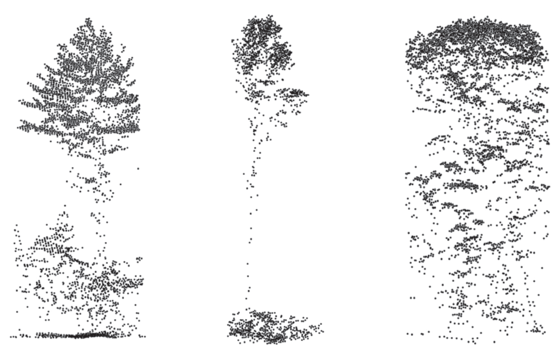

Figure 1. Sample trees from the genera *Pinus* (a), *Populus* (b), and *Acer* (c) respectively.
Árboles muestra del género *Pinus* (a), *Populus* (b) y *Acer* (c), respectivamente.

Table 1. Descriptive* summary for each geometric category.
Breve descripción* de cada categoría geométrica.

Linear (Internal): Feature # 1 – 5	Characteristics of lines (lengths with respect to tree height, tree crown height, and orientation angles) derived by grouping LiDAR points within the crown.
Clusters (Internal): Feature # 6 – 10	Characteristics of clusters (number of points, distances from each LiDAR point to the best fit lines and planes, volume of each cluster) within the crown.
Hulls (External): Feature # 11 – 17	Describe the form of the crown in terms of hulls (volume and the surface area of the convex hull or alpha shape for each crown, distance attributes calculated from each point to the closest facet of the convex hull).
Buffers (Internal): Feature # 18 – 21	Point distribution properties of the internal structure (proximal behaviors), each point is buffered outward in three dimensional space, volume and count of overlapping spheres are calculated.
Forms (External): Feature # 22 – 24	Describe the overall shapes (ratio between radius of the crown to crown and tree heights, ratio between crown height and tree height).

* Equations and descriptions: appendix 1.

mapping, we also computed the major growth direction of each tree to determine whether the tree is leaning towards or away from the utility transmission lines using a vertically sliding voxel to identify and connected point centroids within each trees' LiDAR point cloud to determine the approximate stem location and orientation.

RESULTS

For illustration, we included the results from using one example field site that involved the utility transmission line application. In this example, we demonstrated the capability of using LiDAR for mapping trees that showed potential threat. Figure 2A shows the LiDAR scene of the field site and the value (tone) of the points represented height above ground level (m) and figure 2B shows the location of the trees that we sampled in the area along the utility right of way, we surveyed 50 trees at this field site.

The utility transmission line at this site carries 230 kV, and according to the North American Electric Reliability Corporation (NERC) FAC-003-2 standard, this section of the transmission line would require a 50' (approximately 15.24 m) minimum vegetation clearance distance (MVCD) zone. Therefore, a buffer zone of 15.42 m is extended from each side of the transmission line and we selected trees that intersect with the buffer zone. The polygons on figure 3 represent the maximal perimeter of each tree crown projected to the ground level. Within the set of trees that intersect with the buffer zone, we further selected the trees that are taller than 15.42 m, indicating that if they fall, these trees may have the potential of contacting the utility infrastructure. Figure 3 shows the results of the tree boundaries that are mapped into three categories: 1) original tree boundaries 2) trees growing within MVCD, and 3) trees within MVCD and taller than 15.42 m.

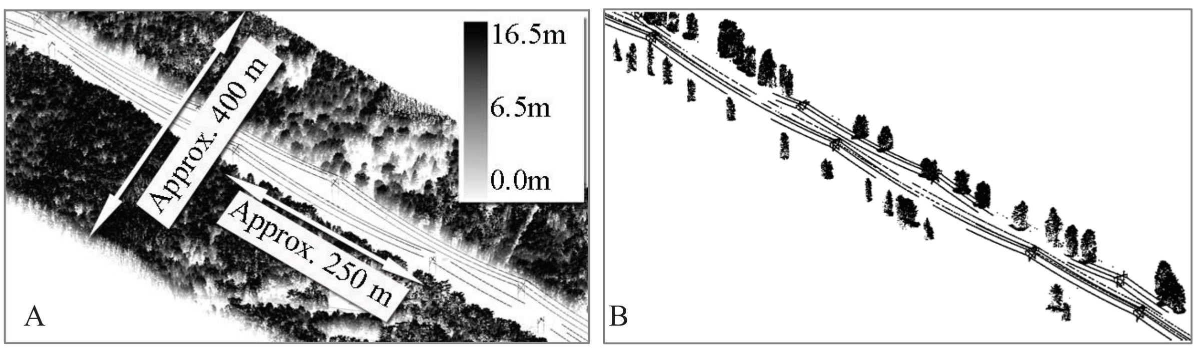

Figure 2. An oblique view of our LiDAR scene, height above ground level (A) and the locations of trees surveyed (B).
Vista oblicua de la escena LiDAR para la altura sobre el suelo (A) y las ubicaciones de los árboles estudiados (B).

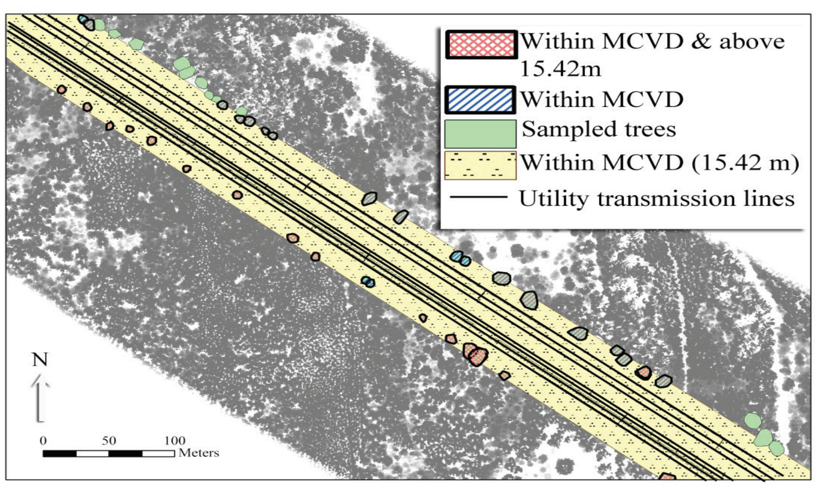

Figure 3. Map of tree crowns sampled along the ROW. Identified are the subset of trees that grow within the MVCD buffer zone, and further, those trees within the MVCD that are taller than 15.42 m. Light grey represents LiDAR point cloud with trees of interest shown in colour.
Mapa de copas de árboles muestrados a lo largo de ROW. Se identificaron los subgrupos de árboles que crecen dentro de la zona de amortiguamiento de MVCD, y luego, los árboles dentro de MVCD que son más altos que 15,42 m. El gris claro representa nubes de puntos LiDAR con árboles de interés mostrado en color.

The dominant growth direction of the tree can inform of the vertical angle of the tree, specifically toward a transmission line. Figure 4 shows the major growth direction of several example trees by connecting the centroids of a vertically moving voxel. The top centroid and the bottom centroid are connected to form a straight line as shown. The perpendicular distance from each tree top and tree bottom to the infrastructure is calculated, if the distance from the tree top to the infrastructure was smaller than the distance from the tree bottom to the infrastructure, then we defined the tree is leaning towards the infrastructure and these trees were flagged.

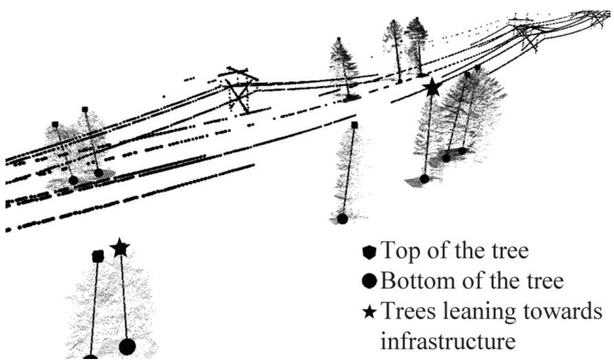

Figure 4. Example results showing the major growth direction of the sub-sampled trees. Straight lines are drawn by connecting the highest point within the tree to the lowest point within the tree.

Ejemplo de resultados que muestran la principal dirección de crecimiento de los árboles sub-muestreados. Las líneas derechas conectan el punto más alto del árbol con el punto más bajo de éste.

The genera classification results were added to the scene in the end; this additional information was useful to determine growth rate and time allowed utility companies to revisit the site for clearing the clearance zones. Figure 5 shows a map of tree boundaries with genera information, trees sampled in this field site only contain pines and poplar and therefore has no maples.

DISCUSSION AND CONCLUSION

In this paper we have presented a case study where LiDAR data can assist the mapping of vegetation along the utility ROW, we identify trees that are growing within the MVCD, and further recognize trees that are taller than the buffer distance meaning if the trees fall, it may potentially come in contact with the infrastructure. We then extend our knowledge by selecting trees that are leaning towards the infrastructure and include the genera information for better growth prediction. Although we have place an emphasis on tree genera classification, the information provided by the LiDAR can also yield additional attributes such as tree height, crown size and crown base height. The features input for Random Forest classification are related to the internal (clusters, lines and planes derived within the tree crown) and external geometry (overall shape of the tree crown) of the tree which makes our project unique from other studies that perform species or genera classification by using vertical profiling approach where features are derived from vertical point distribution attributes. The benefits of deriving features from geometric perspective are the close relationship between these features to tree forms which can be related to the biophysical interpreta-

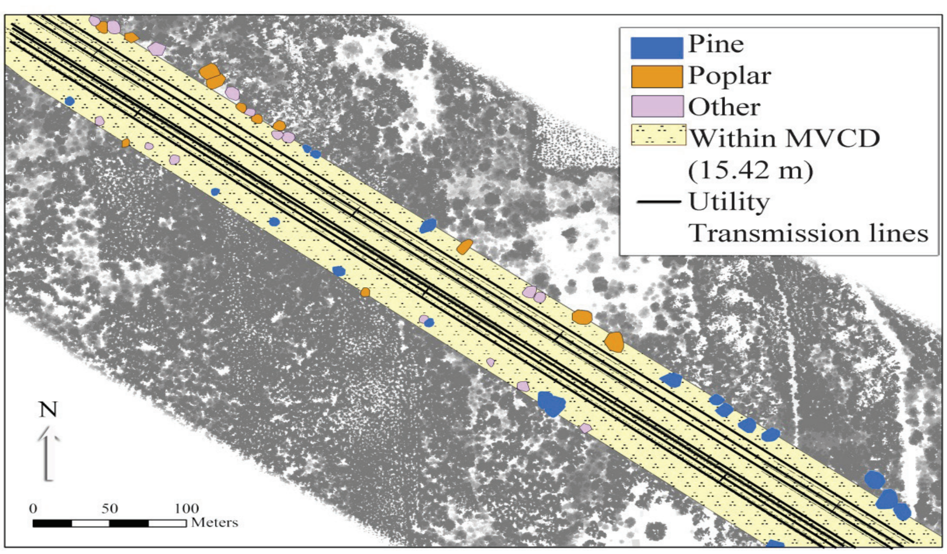

Figure 5. Map of tree boundaries with genera information. Light grey represents LiDAR point cloud with tree of interest showing in colour. Potential hazardous trees circled in red.

Mapa de límites de árboles con información de género. Gris claro representa nube de puntos de LiDAR y en color los árboles de interés. Árboles potencialmente peligrosos se muestran en círculos rojos.

tion; it also yields better visual representations. The two approaches have its advantage and limitations and our current study suggest that they could be combined and provide supplementary information to form a stronger classifier, delivering a better accuracy (Ko *et al.* 2012).

ACKNOWLEDGMENTS

This research was funded by GeoDigital International Inc., Ontario Centres for Excellence, and a Discovery Grant from the Natural Sciences and Engineering Research Council of Canada.

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Recibido: 24.05.12
Aceptado: 10.10.12

Appendix 1.

No.	Equation	Description
F1	$\frac{\sum_{n=1}^{k} L_n}{k \times H_t}$	Average line segment lengths divided by tree height
F2	$\frac{\sum_{n=1}^{k} L_n}{k \times H_c}$	Average line segment lengths divided by crown height
F3	$\frac{\sum_{n=1}^{k} L_n}{k} \times \frac{H_c}{H_t}$	Average line segment lengths multiplied by the ratio between tree and crown heights
F4	$\frac{\sum_{n=1}^{k} a_{xyn}}{k}$	Average line segment angles (rad) measured from the x-y plane to the line
F5	$\frac{\sum_{n=1}^{k} b_{xyn}}{k}$	Average line segment angles (rad) measured from the y axis to the line projected onto the x-y plane

Where, k = number of clusters at the end of the clustering algorithm, N_c = number of points in the crown, L_n = length of the line in the cluster, H_t = tree height, H_c = tree crown height, a_{xy}= angle between each line segment to xy plane, b_{xy} = angle between the projected line to y-axis.

No.	Equation	Description
F6	$(\sum_{n=1}^{k} \frac{N_n}{N_c}) \div k$	Average number of points in each cluster divided by the number of points in the crown
F7	$(\sum_{n=1}^{k} \frac{\sum_{l=1}^{N_n} d_l}{N_n}) \div k$	Average of the average orthogonal distance from each point to the line in the crown
F8	$(\sum_{n=1}^{k} \frac{\sum_{p=1}^{N_n} d_p}{N_n}) \div k$	Average of the average orthogonal distance from each point to the plane in the crown
F9	$(\mathbf{F7} \div H_c) \times (\mathbf{F8} \div H_c)$	F7 divided by the crown height multiplied by F8 divided by the crown height
F10	$(\sum_{n=1}^{k} \frac{V_n}{N_n}) \div k$	Average volume of the convex hull for each cluster divided by the number of points in the cluster

Where N_c = number of points in the crown, N_n = number of points in the cluster, d_l = orthogonal distance from each point to the line, d_p = orthogonal distance from each point to the plane, V_n = convex hull volume for cluster n, N_c = number of points in the crown.

No.	Equation	Description
F11	$\frac{V_h - V_a}{V_h}$	Difference between the convex hull and alpha shape volumes compared to the convex hull volume
F12	$\frac{A_h - A_a}{A_h}$	Difference between the convex hull and alpha shape areas compared to the convex hull area
F13	$\frac{V_h}{N_c}$	Volume of the crown convex hull divided by the number of points within the crown
F14	$\frac{V_a}{N_c}$	Volume of the tree crown alpha shape divided by the number of points within the crown
F15	$\frac{\sum_{n=1}^{N_c} d_h}{N_c}$	Average distance from each point to the closest facet of the convex hull
F16	$\sqrt{\frac{\sum_{n=1}^{N_c}(d_h - \mathbf{F15})^2}{N_c}}$	Standard deviation of orthogonal distances from each point to the convex hull
F17	$\mathbf{F15 \div F16}$	Coefficient of variation

Where V_a = volume of the alpha shape of the tree crown, V_h= volume of the convex hull of the tree crown, A_a = area of the alpha shape of the tree crown, A_h = area of the convex hull of the tree crown, d_h = orthogonal distance form each point to the closest convex hull facet, N_c = number of points in the crown.

No.	Equation	Description
F18	$\sum_{i=N_1}^{N_c}\sum_{j=N_1}^{N_c} V_{ij}$	Where i≠j; sum of overlapped volume between i^{th} and j^{th} spheres
F19	N_{ij}	Overlapped count of points captured by i^{th} and j^{th} spheres
F20	$\mathbf{F18} \div N_c$	Overlapped volume divided by the number of points within the crown
F21	$\mathbf{F19} \div N_c{}^2$	Count divided by the square of the number of points in the crown

Where Vij = overlapped volume between i^{th} and j^{th} speheres, N_{ij} = count of points captured by i^{th} and j^{th} spheres, N_c = number of points in the crown.

No.	Equation	Description
F22	$H_t \div \sqrt{\frac{A_{xy}}{\pi}}$	Tree height divided by the radius of the crown is circular when projected to x-y plane
F23	$H_c \div \sqrt{\frac{A_{xy}}{\pi}}$	Crown height divided by the radius of the crown is circular when projected to x-y plane
F24	$\frac{H_c}{H_t}$	Crown height divided by tree height

Where A_{xy} = area of tree crown projected to x-y plane

BOSQUE 33(3): 321-328, 2012 DOI: 10.4067/S0717-92002012000300016

Spatio-temporal effects of human drivers on fire danger in Mediterranean Chile

Efectos espacio-temporales de los factores humanos en el peligro de incendio en Chile mediterráneo

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SUMMARY

The aim of this study was to analyze how human factors, specifically land use and cover change (LUCC), influence wildfire danger in a mediterranean region of central Chile. Main drivers of LUCC were associated with changes in socio-economic conditions, which had strong effects on the structure of the landscape and on the danger of wildfires. Ignition and flammability were evaluated as key components of fire danger. Ignition probability was modeled for 1999 and 2009 using an autologistic regression, based on fire records from Corporación Nacional Forestal (CONAF) and geographic, biophysical, and socioeconomic databases. Flammability was assessed by combining the National Vegetation Cadastre of 1999 and its update of 2009, and the fuel model developed by Julio (1995). Spatiotemporal analysis of flammability was performed and related with primary LUCC processes, namely, plantation expansion, forest regrowth, and agricultural abandonment. We combined the ignition probability and flammability analysis to produce wildfire danger maps. Results show that fire danger is a dynamic indicator that depends largely on human factors. By 1999, the area under high fire danger comprised 31,399 ha, whereas by 2009 this area had increased by 54,705 ha. For both periods, wildfire danger had a similar spatial distribution, concentrating near main roads, cities, and larger towns (26.3 % of the high fire danger area). Also high fire danger areas concentrated over zones covered by exotic forest plantations (33.2 %). These results provide a basis for a more effective design of fire control strategies.

Key words: fire danger, probabilities of ignition, flammability, landscape.

RESUMEN

El objetivo de este estudio fue analizar la influencia de factores humanos, en específico del cambio de cobertura y uso de suelo (CCUS), en el peligro de incendios forestales en una región mediterránea de Chile. Para ello, se evaluó la probabilidad de ignición y la inflamabilidad del paisaje como componentes clave del peligro de incendio. La probabilidad de ignición fue determinada a través de una de regresión autologística para los años 1999 y 2009, utilizando como base los registros de la Corporación Nacional Forestal y variables generadas a partir de bases de datos geográficas. La inflamabilidad se evaluó mediante la combinación de las categorías de vegetación presentes en el Catastro y evaluación de recursos vegetacionales de Chile de 1999 y su actualización de 2009, y el modelo de combustible desarrollado por Julio (1995). Se llevó a cabo un análisis espacio-temporal de inflamabilidad el que se relacionó con los principales procesos CCUS (expansión de plantaciones, regeneración forestal y abandono de tierras agrícolas). Se combinó la probabilidad de ignición y el análisis de inflamabilidad para producir mapas de peligro de incendios. Los resultados mostraron que el peligro de incendio es un indicador dinámico que depende en gran medida de factores humanos. En 1999, las áreas de alto peligro concentraron 31.399 hectáreas, mientras que para el año 2009 esta área aumentó en 54.705 ha. En ambos períodos el peligro tuvo una distribución espacial similar, concentrándose cerca de las carreteras, principales ciudades (26,3 % de la zona de peligro) y en áreas cubiertas por plantaciones forestales (33,2 % de la superficie bajo peligro alto de incendio).

Palabras clave: peligro de incendio, probabilidad de ignición, inflamabilidad, paisaje.

INTRODUCTION

Wildfire is one of the most important factors driving environmental transformations in a wide variety of ecosystems (FAO 2007). While physical processes involved in combustion are theoretically simple, understanding the relative influence of human factors in determining wildfire is an ongoing task (Guettouche *et al*. 2011). Human influence on wildfire has been classified into three categories: institutional, human-environment interaction, and human values placed on land use (Cardille *et al*. 2001). Institutional and social policies facilitate or constrain certain management alternatives that model landscape. Such drivers have mostly a temporal dimension, longer than the appearance of change, reason why often an historical perspective is needed. Moreover, human-environment interaction involves the evolution of the landscape (e.g. land tenure, land use patterns, and infrastructure) along with changes in population behavior and preferences that can increase the probability of ignition (Chuvieco 2010). Also, there is clear evidence that the role of humans on shifting land use and cover, and therefore on landscape structure and function, has increased wildfire danger, particularly in Mediterranean regions (Moreira *et al*. 2001). These changes have been associated with particular processes of abandonment of agricultural lands and post afforestation resulting in a higher fuel load that is generated in the process (Viedma *et al*. 2006).

The present study analyses how human factors, particularly land use and cover change, influence wildfire danger taking as a case study the Maule Region in south-central Chile. We follow the framework proposed by Chuvieco *et al*. (2010), which considers fire danger as the potential that a fire ignites or propagates. We focus on two main components of fire danger which are ignition and flammability. Due to the nature of the region and principal causes of fire, we focus on understanding the human causes of ignition. In turn, flammability as a component of the fire spread potential was related to fuel load and continuity.

METHODS

In past decades, the Maule Region (35° 25′ 36″ S, 71° 39′ 78″ O) has undergone a widespread and fast land use and cover change mainly driven by socio-economic conditions, which in turn, have had strong effects on the structure of the landscape and on wildfire danger. Two key components of fire danger were evaluated, namely human-set ignition probabilities and flammability. We determined ignition probabilities for years 1999 and 2009 using autologistic regressions estimated based on fire records from Corporación Nacional Forestal (CONAF), and geographic, biophysical and socioeconomic databases. Integrated wildfire danger maps were constructed by the combination of higher probabilities estimated from ignition maps (probabilities over 0.7) and higher flammability determined from the fuel load maps for each period (over 3,000 kg m^{-2}).

Also, landscape flammability maps were constructed combining the land cover classes from the National Vegetation Cadastre (1999) (henceforth Catastro) and its update (2009) developed by CONAF and the fuel model generated by Julio (1995). The matching between land covers used by Julio (1995) and those from Catastro is presented in appendix 1. In addition we conducted a spatio-temporal (1999-2009) analysis of main land use and cover change using the Land Change Modeler extension (Argis 9.3). Since the focus of the study was the assessment of the influence of land use and cover change processes on wildfire danger, changes in land cover were regrouped accordingly as follows: a) plantation expansion included changes of use on any land class (excluding forest exotic plantation) to forest exotic plantation, differentiating between those caused by afforestation (plantation on agricultural land and shrublands) and those caused by substitution (plantations established on arboreous shrublands and native forest areas); b) forest regrowth included changes from shrublands of any nature to secondary native forests; c) agricultural abandonment included changes from agricultural land to any category excluding forest exotic plantations. Using map algebra we assessed areas of change in fuel properties and related these areas to particular land use and cover change processes.

RESULTS

Land use and cover change and fire danger. Between 1999 and 2009, 27.4 % of the Maule Region's area (2,188 km^2) registered land use and cover change, while the rest of the landscape persisted with the same coverage. In 1999 the landscape was dominated by agricultural land (27.8 %), followed by shrubs (20.5 %), forest plantations almost exclusively of *Pinus radiata* D. Don (18.4 %), secondary native forests (14 %) and arboreous shrublands (9.2 %).

Adult plantation expansion occurred at annual rates of 2.55 % and 1.23 % for the processes of afforestation and substitution, respectively, increasing the total area of plantations from 493,959 ha in 1999 to 588,580 ha in 2009 (197,322 ha from afforestation and 39,617 ha from substitution). Plantation expansion increased fuel load and fuel availability, having different impacts on other parameters of flammability, as the rate of linear spread and resistance to control. Increases in fuel load ranged between 3 and 40 Mg ha^{-1} (figure 1). The largest increase on fuel load was associated to the change from agricultural land to exotic plantations.

Forest regrowth occurred at an annual rate of 1.08 %. On one hand, this process increased fuel load where initial coverage was dense and semidense shrubland, with presence of dominant species like *Nothofagus obliqua* Mirb., *Acacia caven* Mol. and *Chusquea spp.*, but decreased fuel load in areas where the land use and cover change transition led to a final cover of open forest of *Nothofagus antarctica* (G. Forster) and *Nothofagus pumilio* (Poepp *et* Endl.). Increases in fuel load and fuel availability were associated with a decrease on propagation speed and resistant to the first control line.

The loss of agricultural land occurred at an annual rate of 0.51 %, and affected 49,337 ha. This implied an increase in fuel load that ranged between 6 Mg ha^{-1} to 45 Mg ha^{-1}, which led to an increase of available fuel varying from 1,902 kg m^{-2} to 3,533 kg m^{-2}. This process was also associated with a decrease in the speed of propagation and resistant to control. The largest increase in fuel load was associated with the change from annual pastures to secondary forest, while the lowest increase was observed as a result of the change from agricultural land to open shrubland (figure 2).

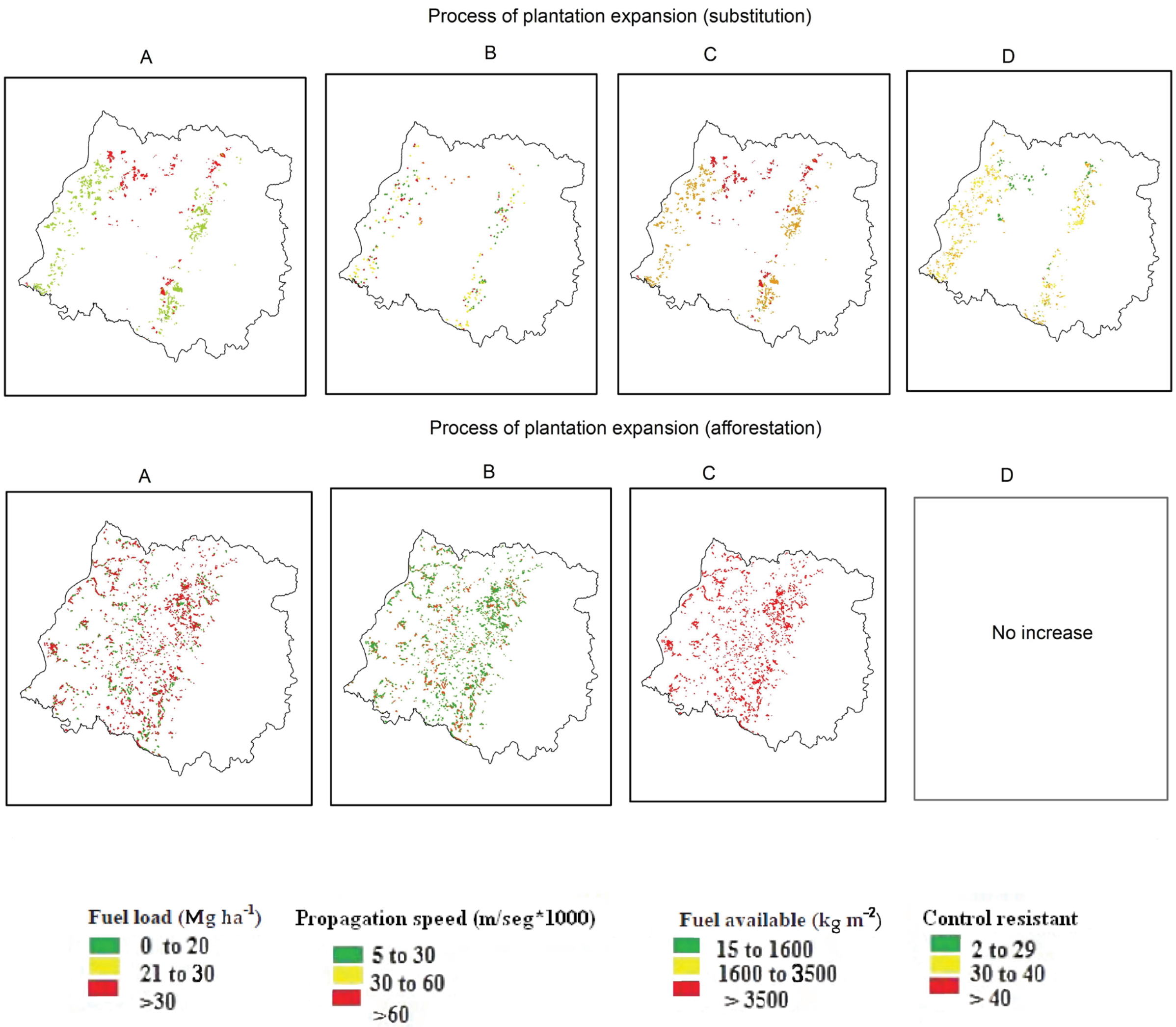

Figure 1. Spatial distribution of increase in fuel parameters, resulting from plantation expansion by substitution and afforestation.
Distribución espacial del incremento en los parámetros de combustible, resultante de la expansión de plantaciones por sustitución y reforestación.

Ignition probabilities. Autologistic regressions for both years presented[1] an overall accuracy above 70 %. For both periods, explanatory variables were distance to towns and cities, and also distance to streams and water bodies. This means that probabilities of ignition increased as distances from these covers decreased (table 1).

Fuel load was a significant explanatory variable for the period 2009 indicating an increase in ignition probabilities in areas with higher fuel load, corroborating that landscape changes during this period have increased fuel load and flammability.

Fire danger. Wildfire danger assessment analyzed two key components of wildfire: the likelihood of an area to ignite and the potential of fire propagation and duration, which relate to the properties of the fuel. Results show that fire danger is a dynamic indicator that depends in great measure of human factors. By 1999 danger area comprised 12,056 ha whereas in 2009 this area had increased by 42,649 ha. For both periods fire danger had a similar spatial distribution, concentrating near principal roads, cities and larger towns (26.3 % of the area), and also on areas covered by exotic forest plantations (33.2 %) and agricultural land (18 %). In the second year a large danger area was located in the central valley of the Maule Region in zones covered by shrublands (59.7 %) (figure 3).

DISCUSSION

According to historical statistics from CONAF, in the Maule Region 99 % of fire ignitions are associated with

[1] Jorge Silva *et al.*, unpublished data.

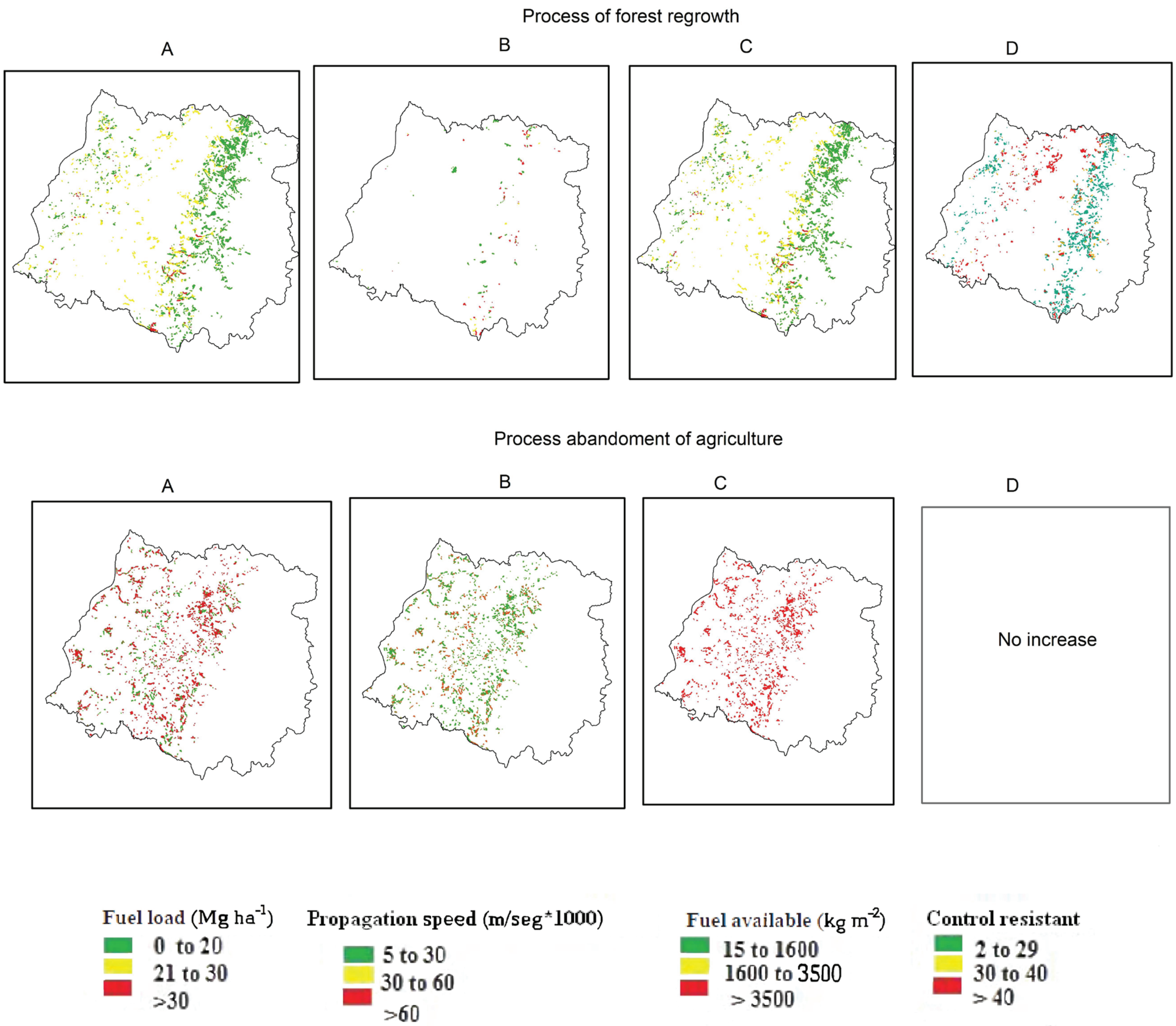

Figure 2. Spatial distribution of increase in fuel parameters, resulting from for forest regrowth and agricultural abandonment processes.
Distribución especial del incremento de los parámetros de incendio, resultante del recrecimiento forestal y el abandono agrícola.

human causes. In this sense, the results generated in this study are consistent with these records, showing flammability and ignition probabilities were determined by variables related to human activity. Other studies have showed a positive relationship between population density and number of wildfires in different Mediterranean zones (Cardille *et al*. 2001). Also a positive relationship has been found between increase in urban population and wildfire (Cardille *et al*. 2001). Demographic statistics of Maule Region show an increase in population between both periods of analyses for almost the whole Region, however the highest rates of increase correspond to the municipalities of Talca and Maule, where an increase in fire danger was found.

The most relevant land use and cover change in the period 1999-2009, namely plantation expansion and agricultural abandonment, have contributed to increase the wildfire danger area, as indicated by ignition probabilities and fuel load. Plantations began to expand in the early 1970´s and grew rapidly, mainly on the Coastal Range, but recently they have also reached the central zone of the region and the Andes range. A recent study reveals that plantations in the coastal area of the Maule Region increased nearly ten-fold between 1975 and 2007 at an average annual rate of 6.4 %, with important implications for the landscape (Nahuelhual *et al*. 2012).

In the case of agricultural abandonment, while forest industrial development has created dynamic labor mar-

Table 1. Results from the autologistic regressions for years 1999 and 2009.
Resultados de las regresiones autologísticas para los años 1999 y 2009.

Variable	Year			
	1999		2009	
	Coefficient	*P* value	Coefficient	*P* value
Constant	-16.622	< 0.001***	-16.616	< 0.001***
Distance to towns (km)	-16.622	< 0.001***	-16.616	< 0.001***
Distance to rivers and streams (km)	-16.622	< 0.001***	-16.616	< 0.001***
Distance to water bodies (km)	-16.622	< 0.001***	-16.616	< 0.001***
Distance to protected areas (km)	-16.622	< 0.001***	-16.616	< 0.001***
Average temperature of warmest month of the previous season (degree Celcious)	-16.622	< 0.001***	-16.616	< 0.001***
Total precipitation of the previous season (mm)	-16.622	< 0.001***	-16.616	< 0.001***
Southern exposure (binary variable equal to 1 if pixel shows southern exposure and 0 otherwise)	-16.622	< 0.001***	-16.616	< 0.001***
Fuel load (Mg ha^{-1})	-16.622	< 0.001***	-16.616	< 0.001***
yW	-16.622	< 0.001***	-16.616	< 0.001***
Total precision	0.702		0.708	
Sensibility	0.667		0.698	
Specificity	0.737		0.719	

Source: Jorge Silva *et al*., unpublished data.

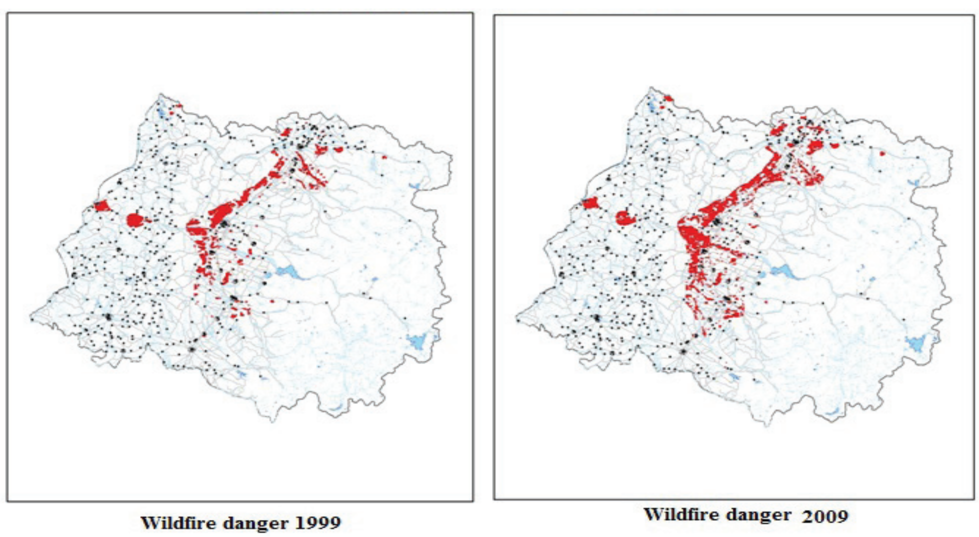

Figure 3. Wildfire danger maps for years 1999 and 2009.
Mapas de peligro de incendios para los años 1999 y 2009.

kets, it has also endangered both traditional agricultural patterns and local development strategies (Moreira *et al.* 2001), driving abandonment of agricultural lands.

Wildfire danger is a dynamic phenomenon that changes its spatial representation by both climate variability and human factors. Among the many human factors that affect wildfire danger is land use and cover change. The combination of this type of analysis with fuel properties and probability of ignition provides valuable information for prevention and fire management (Cardille *et al*. 2001), especially when both can serve as predictive models.

CONCLUSIONS

This study has been able to identify key human factors that affect wildfire danger in a Mediterranean Region of

Chile. The processes of plantation expansion and agricultural abandonment together with the expansion of human activity near cities and on the urban-rural interface are key factors in increasing wildfire danger.

While this work focuses on past trends, future research should improve the analysis by creating future scenarios of land use and social development so they can be used in a predictive way.

ACKNOWLEDGMENTS

This research has received funding from the Seventh Framework Programme of the European Union (FP7/2007- 2013) under Project No. 243888. We also wish to thank Dr. Antonio Lara for his valuable help in homologating land covers from Catastro and the land categories of the Combustibility Models of Julio (1995).

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Recibido: 24.05.12
Aceptado: 10.10.12

Appendix 1

Combustibility modeling by Julio *et al.* (1995) shows five groups that comprise 31 combustibility models, including a sixth group comprised by three different situations associated to non-combustible areas. Groups' descriptions and their respective models are showed in the Appendix. These groups were linked to Catastro land use categories.

Group	General description	Symbol	Specific description	Catastro land use categories
I	Meadows, pastures, and agricultural crops	PCH		
		PCH1	Hygromorphic dense	----
		PCH2	Hygromorphic sparse	----
		PCH3	Mesomorphic dense	----
		PCH4	Mesomorphic sparse	Perennial grasslands Annual grasslands
		PCH5	Vineyards and orchards	Agricultural land Rotation crop, pasture
II	Shrublands and secondary forest	MT		
		MT01	Dense mesomorphic shurblands and secondary forest	Dense esclerofic secondary forest and shrubland and open and semidense Ciprés de la cordillera forest
		MT02	Medium density and sparse density mesomorphic shurblands and secondary forest	Open and semidense esclerofic secondary forest and shrubland and open and semidense cipres de la cordillera forest
		MT03	Dense hygromorphic shurblands and secondary forest	Dense secondary forest of Roble-Raulí-Coihue, Lenga, and Roble-Hualo forests
		MT04	Medium density and sparse density hygromorphic shurblands and secondary forest	Open, and semidense secondary forest of Roble-Raulí-Coihue, formation, Lenga formation, and Roble-Hualo
		MT05	Formations with predominance of *Chusquea sp*	
		MT06	Formations with predominance of *Ulex sp*	
		MT07	Secondary forest with formations different from evergreen forest	Open, semi-dense and dense secondary forest of Roble-Raulí-Coihue, Lenga, and Roble-Hualo
		MT08	Secondary forest that correspond to evergreen forest.	Open evergreen secondary forest
III	Native tree formations	BN		
		BN01	Alerzales	
		BN02	Araucarias	
		BN03	Dense *Nothofagus* formations	Dense native forest of Roble-Raulí-Coihue, Lenga, and Roble-Hualo
		BN04	*Nothofagus and evergreen* medium density formations	Semi-dense native forest of Roble-Raulí-Coihue, Lenga and Roble-Hualo
		BN05	*Nothofagus and evergreen* sparse density formations	Open native forest of Roble-Raulí-Coihue, Lenga, and Roble-Hualo
IV	Plantation	PL		
		PL01	New plantations of conifers without management from 0 to 3 years	Young plantation or recently harvest
		PL02	Young plantations of conifers without management from 4 to 11 years	
		PL03	Adult plantations of conifers without management from 12 a 17 years	

		PL04	Mayor plantations of conifers without management 17 years	
		PL05	Young plantations of conifers with management 4 a 11 years	
		PL06	Adults plantations of conifers with management 12 to 17 years	*Pinus radiata* plantation
		PL07	Larger plantations of conifers with management over 17 years	
		PL08	New *Eucalyptus* plantations from 0 to 3 years	
		PL09	Young *Eucalyptus* plantations from 4 to 10 years	*Eucalyptus spp.* plantation
		PL10	Larger *Eucalyptus* plantations over 10 years	
		PL11	Broadleaf and mixed plantations	
V	Waste from clearcutting forestry exploitation	DX		
		DX01	Waste from clearcutting of conifers and eucalyptus	
		DX02	Waste from forest exploitation (trapping) of thickets and native forest	
VI	Land without vegetation	SV		
		SV01	Body water	River, lakes, reservoirs, beaches
		SV02	Urban areas	Town and cities
		SV03	Bare soil	Fallow soil

Document available at: http://ftp.forestaluchile.cl/LINFOR/articulos/Modelaci%C3%B3n%20de%20Combustibles.pdf and CONAF *et al.* (1999).

BOSQUE 33(3): 329-332, 2012 DOI: 10.4067/S0717-92002012000300017

Non-wood forest products for livelihoods

Productos forestales no maderables como medios de vida

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SUMMARY

Forests provide a diversity of non-wood forest products as a resource base for regional and rural development. The role of non-wood forest products differs in time and space. The aim of the study was to analyze the role of non-wood forest products in livelihoods, especially forest-dependent communities, in Ukraine and Sweden. 114 interviews with local stakeholders in two countries were done for this study. The results showed that (1) non-wood forest products have potential for economic rural development, (2) traditional practices of non-wood forest products utilization were retained and revived in Ukraine, (3) and were no longer economically but rather socially important for local people in Sweden. Non-wood forest products have great potential for sustainable rural development, as resources for economic development.

Key words: sustainable forest management, sustainable rural development, sustainable livelihoods, Ukraine, Sweden

RESUMEN

Los bosques proveen una diversidad de productos forestales no maderables (PFNM) como recursos base para el desarrollo regional y rural. El rol de los productos forestales no maderables difiere en el tiempo y el espacio. El objetivo del estudio fue analizar el rol de los productos forestales no maderables como medio de vida, especialmente en las comunidades dependientes del bosque, en Ucrania y Suecia. Se llevaron a cabo 114 entrevistas con actores sociales locales. Los resultados muestran que (1) productos forestales no maderables tienen un potencial en el desarrollo económico de las comunidades rurales, (2) los patrones tradicionales de uso de los productos forestales no maderables han sido retenidos y revividos en Ucrania, (3) los productos forestales no maderables ya no son económicamente relevantes en Suecia pero sí tienen una importancia social. Los productos forestales no maderables tienen un gran potencial para un desarrollo rural sustentable, como recursos para el desarrollo económico.

Palabras clave: manejo forestal sustentable, desarrollo rural sustentable, medios de vida sustentables, Ucrania, Suecia.

INTRODUCTION

Globally, forest resources and products are fundamental for the livelihoods of a large part of the world's population (FAO 1999). Forests provide a diversity of non-wood forest products (NWFPs) as a resource base for regional and rural development. NWFPs are defined as goods of biological origin other than wood, derived from forests, wooded lands and trees outside forests (FAO 1999). Presently, estimates indicate that 80 % of the population in developing countries uses NWFPs to meet some of their nutritional needs and provide herbal medicine (FAO 1999). Additionally, NWFPs have potential to contribute to local livelihoods, providing resources for value-added products such as jams, extracts for medicines, vitamins, and antioxidants. Also in developed countries, where locals were dependent on NWFPs in the past, and actually continue to provide important social and cultural values for local households (Kardell 1980, Janse and Ottitsch 2005, Forest Europe 2011, Stryamets *et al.* 2012).

In this study, we analyze the role of NWFPs in livelihoods, especially forest-dependent communities. The sustainable livelihoods approach seeks to improve rural development policy and practice by recognizing the seasonal and cyclical complexity of livelihood strategies (Allison and Ellis 2001). The aim of this study was to analyze the role of NWFPs for different groups of forest stakeholders in rural landscapes in Ukraine and Sweden in order to define the contribution of these forest resources to local livelihoods in countries with different economic and social-cultural conditions.

METHODS

We conducted qualitative semi-structured interviews (Kvale 2007) with local forest stakeholders. In total, 54 interviews were taken in 26 settlements and towns in Ukrainian Roztochya and 60 interviews in 36 settlements and towns in Swedish Småland. The interviews were taken with different groups of stakeholders including villagers in settlements with different population size located at different distances to the forest and managers of forest enterprises.

Roztochya, the Ukrainian case study, is located in the western part of Ukraine and eastern Poland, and forms the watershed between the Baltic and Black Sea catchments (Stryamets *et al.* 2012). The Ukrainian part of Roztochya is situated in the temperate lowland forest eco-region, and covers 992 km^2. It is an important green infrastructure that forms a corridor for biodiversity and cultural heritage. Forests cover *ca.* 44 % of the total area and the rest is made up by agricultural land, cultural woodlands and villages. The population density is about 80 persons km^{-2} (Stryamets *et al.* 2012).

Småland, the Swedish case study, is located in the central part of the region with the same name, an upland area in southern Sweden, the core of which forms the southernmost larger island of boreal forest in the country. Non-industrial private forest owners own 80-85 % of the forests in the study area. The study area encompassed 22 parishes with a total area of 1792 km^2, and an average population density of 53 persons km^{-2}. The population trend is negative, especially in rural areas which host 26 % of the population (Stryamets *et al.* 2012).

RESULTS

Roztochya (Ukraine). All interviewees collected wild berries. Around 60 % of local people collected at least four different species of berries, namely wild strawberries [*Fragaria vesca* L.] (on average two liters), blueberries [*Vaccinium myrtillus* L.] (on average 10 liters), blackberries [*Rubus caesius* L.] (on average 10 liters) and raspberries [*Rubus idaeus* L.] (on average 6 liters). The maximum number of collected species was eight, *i.e.*, including also lingonberries [*Vaccinium vitis-idaea* L.], guelder rose [*Viburnum opulus* L.], common hawthorn [*Crataegus monogyna* Jacq.] and rowan [*Sorbus aucuparia* L.]. The berries collected for sale were wild strawberries, blueberries, blackberries and raspberries. Collection of medical herbs was popular. On average, five species of medical herbs in forests were collected by each household. Almost 96 % of the respondents also collected mushrooms for own consumption and for sale such as penny bun or cep [*Boletus edulis* Bull. ex Fr.], red-capped scaber stalk [*Leccinum aurantiacum* (Bull. ex Fr.) S. F. Gray)], honey fungus [*Armillaria mellea* (Vahl. ex Fr.) Kumm.] and birch bolete (*Leccinum scabrum* Bull. Gray]. The respondents stated that not more then 10 % of local people in the region hunted regularly. Most hunters came from the larger towns and cities near Roztochya. These hunter typically hunted ducks [*Anas platyrhynchos* L.], hare [*Lepus europeus* L.], fox [*Vulpes vulpes* L.], roe deer [*Capreolus capreolus* L.] and wild boar [*Sus scrofa* L.]. Some interviewees reported that they earned more than 3,000 UAH[1] (approximately 300 EUR, equivalent to two monthly salaries in rural areas) per season from selling berries. The price for one litre of blueberries was on average 10-15 UAH, which means that people collected and sold approximately 200 litres of berries. The price for one litre of wild strawberries was around 50 UAH (approximately 5 EUR), one kilogram of penny bun was 60 UAH (approximately 6 EUR). The respondents did not like to talk about the amount of money that they could earn from selling mushrooms and berries, but they pointed out that they could live on that money for several months. Local people sold berries and mushrooms on the markets in the nearest cities and towns, and along the main roads in the region. Interviewees mentioned that one could earn 100 UAH (approximately 10 EUR) per day, which was more than the mean daily labour payment in rural areas. The distance to markets was 2 to 60 km. In villages located close to the border with Poland, local people sold berries (mostly blueberries) to foreign companies, which transported berries to Poland to produce value-added products. Respondents mentioned that it was easy to sell to the Polish companies, because they bought all collected berries. The average price for one litre of blueberries was 10 UAH (approximately 1 EUR). Local people also collected NWFPs for their own needs. All respondents mentioned that it was a tradition to cook dishes including NWFPs for religious holidays, Christmas. Observation of this tradition was important even for respondents for whom collection of mushrooms was not an economic or subsistence activity. People collected berries for their kids because it was a clean and healthy product. The respondents that hunted mentioned that they used meat for food. Some people stated that picking berries and mushrooms was like a hobby. Nearly 90 % of the respondents said that their parents had taught them to pick berries and mushrooms; however, some stated that nowadays kids would rather spend time with computers instead of going to the forest. A majority of the respondents mentioned that the collection of NWFPs had became more intensive compared to 20-25 years ago. One of the reasons was that, during the Soviet period, people had jobs and there was no time and need to collect NWFPs to earn money. However at present, unemployment was high and the forest provided an opportunity to support often scarce livelihoods.

Småland (Sweden). In the Swedish case study, local people harvested NWFPs only for personal use. Almost 80 % of interviewed local people collected berries mainly for making pies for immediate use (blueberry pie). The amount of collected berries varied from 0.5 to 90 litres, and on average it was 2-5 litres of blueberries per family. Several respondents also made preserves for their own consumption during winter. *Chanterel cantharellus* (L.) Murrill and *Craterellus tubaeformis* (Fr.) Quel were collected once or twice per season for immediate cooking. Local people did not collect any medical herbs in this region. The tradition

[1] UAH = Ukrainian Hryvnia (1 UAH = 0.09 EUR = 0.123 USD, approximately).

to hunt and use meat for traditional food like game meat with wild mushrooms was popular in the study area. More than 40 % of respondents stated that at least one member of their family was an active hunter. The most popular species to hunt were moose [*Alces alces* L.], roe deer, wild boar, hare [*Lepus timidus* L.] and ducks. The hunters mentioned that they got good ecological meat for free. The meat was used for domestic consumption; only one respondent mentioned selling small amounts of meat. Many respondents stated that collection of berries and mushrooms for food and to sell was important for livelihoods in the region 60-70 years ago. Even 20 years ago, it was more common to pick different berries and mushrooms for food. The respondents pointed out that, nowadays, one could buy everything in the stores. Among the respondents, people of middle age and older were most interested in harvesting NWFPs, especially if the practice was a tradition in their families and they have lived permanently in the countryside. Respondents claimed that as a result, the berry and mushroom yields had become reduced during recent years. Intensive forest management was mentioned by the respondents as a reason for decreasing quantities of berries and mushrooms in forests.

DISCUSSION

This study shows that local populations in forested regions have used NWFPs for domestic and economic purposes for centuries, and continue to do so. The traditional knowledge about different NWFPs, collection methods, processing, storage, and use, which have been passed through generations, was deeper among local people in Ukraine than in Sweden. By contrast, hunting was more popular, accepted, relied on old traditions and better organized in Sweden, while in Ukraine it was of minor importance to local people. At present, however, the role of NWFPs for local livelihoods is clearly different in Ukraine and Sweden, and this is mainly linked to differences in economic development. In Ukraine selling NWFPs for economic benefit and the recreational and cultural aspect of collecting NWFPs in Sweden were important.

To understand a role of NWFPs in sustainable rural development, economic valuation of forest resources need to be done. First, we need to classify the forest products concerning rivalry and excludability. Forest products are divided by level of rivalry and chance to exclude potential users of forest resources (Sandström *et al.* 2011). As a result, forest products could be classified as: (i) private goods (could belong only to one individual), (ii) public goods (could be use by general public and are not limited in quantity), (iii) club goods (limited by special fee or restriction), and (iv) common pool goods (could be used by everyone, but are limited in quantity). For resources which are rival and excludable, they are marketable and it is easy to put the price. For public goods, which are open for public and every one could benefit from them; for example, a nice view of coniferous forest in winter, it is impossible or very difficult to estimate its monetary value. Free riders, in this case, are companies which collect berries in Sweden using the immigrants working potential. This problem already causes a discussion about the free access to berries picking with commercial aim (Sandell and Fredman 2010). But as soon as it would be restrictions and fees towards the collection of berries, it would move to the club goods or even to private goods. Hunting is well organized in the Swedish case study (Boman *et al.* 2011), because it is private goods and it is rival and excludable. Other NWFPs, like berries, mushrooms and medical herbs are rivals, because if one would pick all berries other could not. But they are non-excludable because everyone in both case studies could collect them. The club goods are non-rival, but they are excludable, *e.g.* entrance fee in national park, horse riding club membership, or BR territory, to become a part of you have to apply.

CONCLUSIONS

Traditional knowledge and traditional ways of using the NWFPs are present in both countries, but there is a risk to loose such knowledge, because of the depopulation of rural areas, increased welfare, and development of other interests than nature, and people's disconnection from nature. NWFPs have great potential for sustainable rural development, as resources for economic development e.g. tourism development, traditional food and healthy products. Knowledge about the importance and benefits from the NWFPs should be maintained and developed. To promote sustainable use of NWFPs, forest management should include the interests of the local rural population.

ACKNOWLEDGMENTS

We thank local people for sharing their knowledge in Roztochya and Småland. The Swedish Institute and Marcus and Amalia Wallenberg foundation provided economic support for this study.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 333-337, 2012 DOI: 10.4067/S0717-92002012000300018

Recognizing the nature of traditional identity through the study of changes in the landscape (Juréia- Itatins, São Paulo, Brazil)

Reconocimiento de la naturaleza de la identidad tradicional por medio del estudio de cambios en el paisaje (Juréia- Itatins, São Paulo, Brasil)

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SUMMARY

This study analyzed spatial variability with regard to natural resources of interest to traditional communities within an important protected area in the São Paulo State - the Juréia-Itatins Ecological Station. The historical occupation of the area was interpreted with a focus on the traditional practices related to the use of land, exploitation of the natural resources and topographic features. A historical line was drawn showing a clear relation between the expansion of the occupation and the development of new practices, giving rise to different outcomes in different ways of living with nature. We suggest that the decisions made about Juréia Forest conservation recognize the historical and territorial variations of traditional practices.

Key words: cultural identity, traditional community, changing landscape.

RESUMEN

Este estudio analizó la variabilidad espacial de intereses de comunidades tradicionales sobre los recursos naturales dentro de una importante área protegida en el Estado de São Paulo, la Estación Ecológica Juréia-Itatins. La historia de la ocupación fue interpretada con un enfoque en las prácticas tradicionales relacionadas con el uso de la tierra, la explotación de los recursos naturales y las características topográficas. Una línea histórica fue construida mostrando una clara relación entre la expansión de la ocupación y el desarrollo de identidades tradicionales, dando lugar a diferentes formas de convivir con la naturaleza.

Palabras clave: identidad cultural, comunidad tradicional, cambio del paisaje.

INTRODUCTION

We increasingly recognize the value of traditional culture and its relationship to landscape. However, we need to increase our knowledge, consolidate concepts and develop methods to integrate various aspects of ecological and human interest. In many countries, mapping of traditional cultural landscapes is a common strategy which brings together nature and community (Antrop 1997, Eetvellde and Antrop 2004, Moreira *et al.* 2006, Stephenson 2007, Angoletti 2007, Cullota and Barbera 2011). Other studies also try to map the human interest variability regarding the features of the landscape (Garibaldi and Turner 2004, Farina and Belgrano 2006, Garibaldi 2009). However, this is not an easy task. People do not have a uniform perception of the landscape but rather build a vision of areas through their specific interests (Farina and Belgrano 2006).

The Brazilian Atlantic Forest shows a great diversity of environments where we can often find traditional identities that have different strategies and interests regarding the preserved forest (Diegues 1998, Adams 2000, Sanches 2001). They are distributed in family units around or inside the forest fragments, often within protected areas. These areas have been fairly steady for centuries and conceived as territories for cultural reproduction and social development of traditional identities. These territories have a well-known history and maps associated with the natural environment, but this knowledge does not link land use with historical aspects, forest conservation, human interests or new forms of territorial occupation.

To contribute to this knowledge gap, we suggest verifying if there is any relationship between cultural identities established in the Atlantic forest and its forms of land use throughout history, assuming that this information may reveal interests and ways of living with nature.

METHODS

The study area was Juréia-Itatins – an Ecological Station located in one of the most important areas of the Atlantic Forest in São Paulo State (Ribeiro *et al.* 2011). It covers an area of 110,904 hectares (figure 1), with a great diversity of environments that exhibit high connectivity between biological systems and traditional communities distributed in 133 family units.

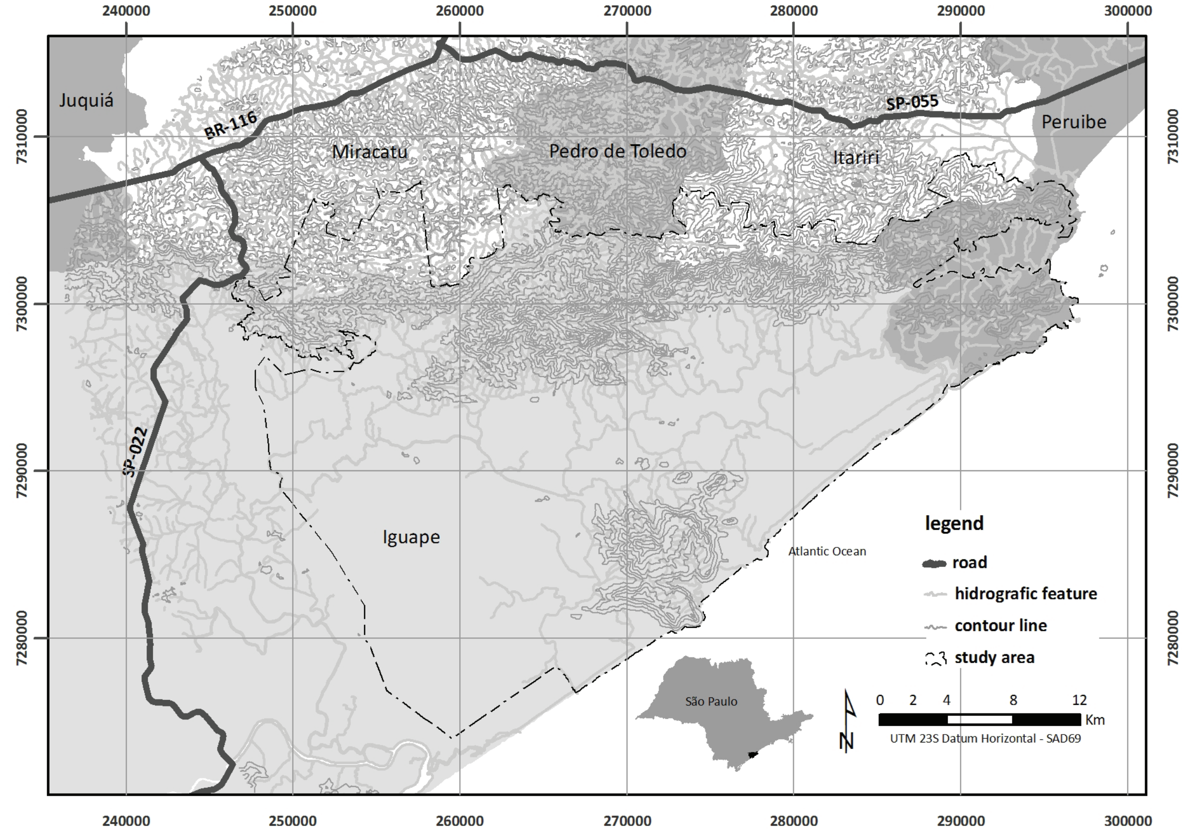

Figure 1. Study area: Juréia-Itatins Ecological Station (EEJI).
Área de studio: Estación Ecológica Juréia-Itatins (EEJI).

First we analyzed the historical process from the beginning of its colonization process (17th century) until 2009, focusing on the evolution of traditional practices related to land use and exploitation of natural resources, as suggested by Cullota and Barbera (2011). Historical periods have been defined according to highly significant changes in the landscape, based on two criteria: (a) expansion of land use in new topographic areas and (b) transformation of traditional practices related to natural resources in the landscape.

The second step was to map the traditional territories. The thematic maps of land cover, land use, homes, routes and heritage were used on a base map with hydrographic charts and isolines at 1:50,000 scale. Further information was obtained from ALOS satellite images, with 10 meter resolution.

We interpreted this information based on the potential existence of natural resources of interest to traditional communities. The conditions of access to these resources were also analyzed. The geographic information system (GIS) ArcGis 9.2 was used for data handling and the interpretations were overlaid.

The third step was intended to understand the expansion process of land use and transformation of land use practices, revealing cultural identities and their natures.

RESULTS

This study shows that there was a chronological relationship between traditional practices used for over four centuries in the Juréia Forest and topographic characteristics of each portion of the landscape (table 1, figure 2). This relationship allowed the identification of three types of traditional identity: (a) the *caiçaras,* who are closely linked to the history of occupation of the coast soon after the discovery of Brazil, commonly described as artisanal fishermen of mixed European and Native ancestry; (b) the *ribeirinhos* of mixed European, Native and African ancestry who established themselves during the 2nd period (early 19th century) on river plains, due to the suitability of the land for rice cultivation and easy river transportation; and (c) the *extrativistas*, descendants of *caiçaras* and *ribeirinhos*, who have occupied the 200- to 800-meter high hillsides since the 1950´s with the purpose of extracting timber for commercial purposes.

DISCUSSION

The differences between the historical and more recent contexts reveal a significant change in the pace of transformation. For example, the *caiçara* and *ribeirinho*

Table 1. Land use in different historical periods.
Uso de suelo en distintos periodos históricos.

	1st Period	2nd Period	3rd Period
Beginning of occupation	End of XVI century	Beginning of XIX century	Middle of XX century
Topographical characteristics of the occupied areas	Coastal buffer from 150 to 800 meters from the shoreline, lowlands with maximum elevation of 10 meters	Range of river plains of approximately 800 meters with maximum elevation of 20 meters	Mountains between 200-800 meters
Traditional practices	Subsistence activities, predominantly fishing. Also included: use of resources from forests, shifting cultivation and hunting	Subsistence activities and shifting cultivation. Also included: hunting, use of resources from forests and commercial activities, predominantly rice cultivation	Commercial activities of resources from forests: palm (*Euterpeedulis*) and caxeta (*Tabebuiacassinoides*)
Traditional identity	*Caiçara*	*Ribeirinho*	*Extrativista*
Number of family units	74	29	30

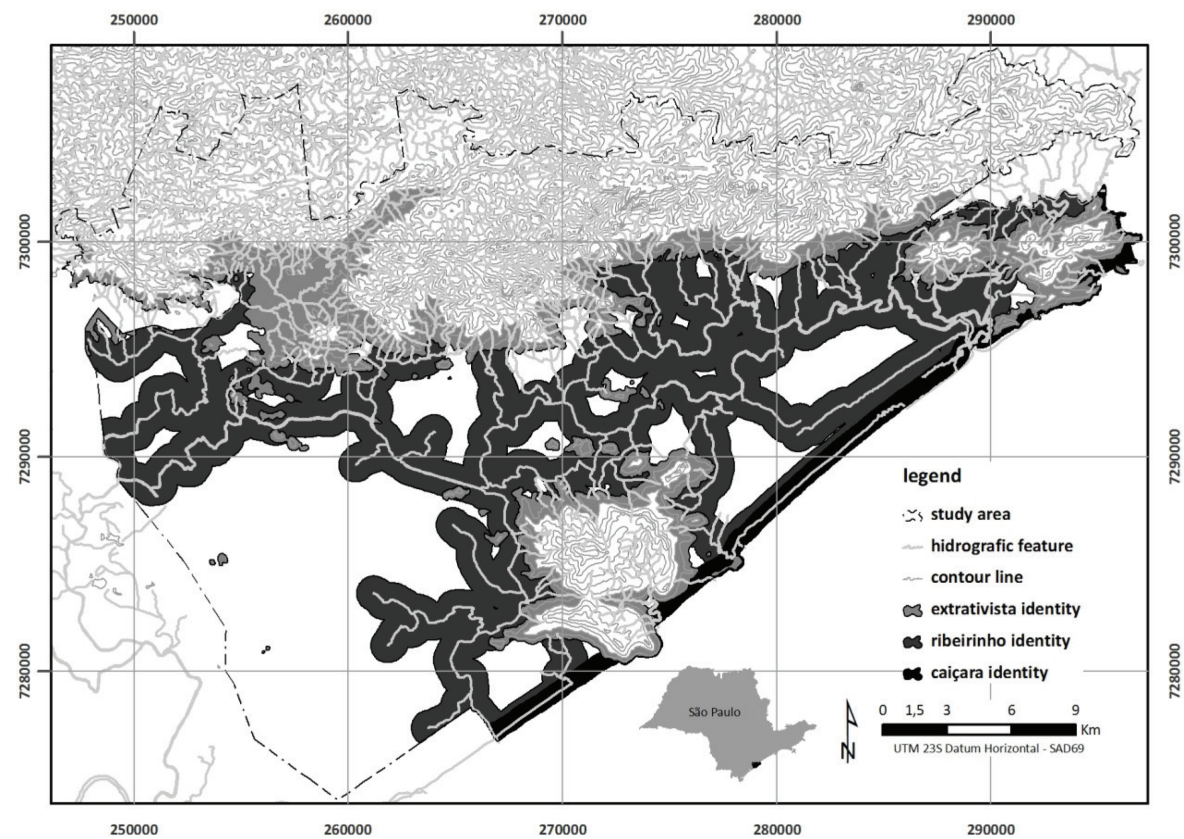

Figure 2. Traditional territories of Juréia.
Territorios tradicionales de Juréia.

identities have merged after two centuries, evolving into an *extrativista* identity between the decades of 1950-1970. The historical evolution in Juréia had been slow until the past half century. The transformation of practices has been intense ever since and two new areas of economic development, banana plantations and tourism, have developed simultaneously (figures 3 and 4), affecting the landscape and degrading the forest.

Until the 20th century, the procedures and frequency of use of natural resources were based on local knowledge. In

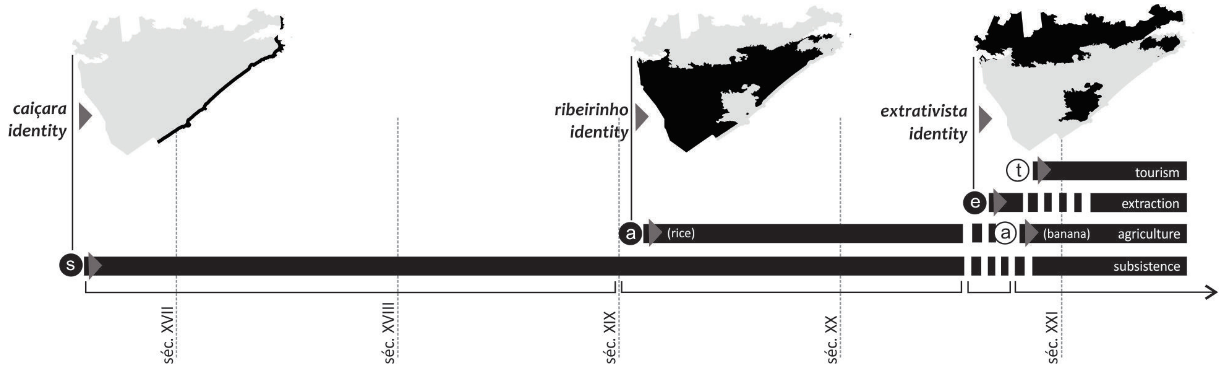

Figure 3. Historical timeline of the Juréia occupation.
Línea de tiempo histórica de la ocupación de Juréia.

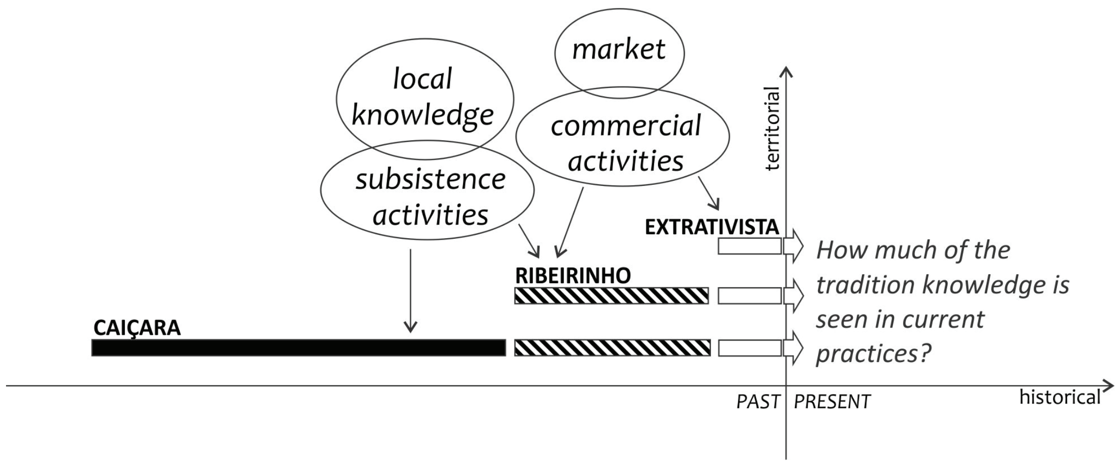

Figure 4. Conceptual model of the evolution of identities and territories in Juréia.
Modelo conceptual de la evolución de identidades y territorios en Juréia.

the 21st century, "local knowledge" was abandoned because of the criteria defined by the economic market. Such detachment from the traditional "know-how" constitutes the major drawback in contemporary life. Nowadays we can find three identities that coexist in Juréia, but communities show different interests and uses of the land that have different degrees of impact on the Forest. However, the Brazilian law treats them equally and provides the same rights to all of them. This situation causes serious conflicts among environmental NGOs, governmental offices, traditional communities and members of the academia.

New opportunities for land use and exploitation of natural resources have replaced traditional practices, creating disruptions of historical patterns of all sorts. One can assume that there was loss of knowledge regarding traditional procedures and, consequently, a loss of the community's ability to be sustainable. But this loss is unequally distributed on the landscape and has caused greater degradation in mountains, despite the fact that there is more than 90 % of forest cover in those areas. This process cannot be ignored as it has been so far.

Many other studies also showed changes of historical patterns of traditional communities (Adams 2000, Sanches 2001, Peroni and Hanazaki 2002), but those studies considered that all communities had the *caiçara* identity. This study shows a map of the occupied land that accounts for different degrees of historical representation and environmental interests. This result suggests that the decisions about conservation and culture value in this landscape should be made considering environmental losses in both historical and territorial domains. Thus, the traditional community located on the coastal area, which maintains the practices of the first period of occupation, is the best reference of ancestry and environmental sustainability.

CONCLUSIONS

This study identifies three cultural identities considering the period of occupation by the traditional communities and geographic characteristics of occupied territories in the Atlantic Forest landscape. Each identity has specific interests, resulting in different ways of living with nature, despite the fact that communities are inserted into a single protected unit and abide by the same environmental legal rules. We suggest that the decisions made about Juréia Forest conservation recognize the historical and territorial variations of traditional practices.

ACKNOWLEDGMENTS

We would like to acknowledge CAPES for its financial support to this research and Fundação Florestal for providing the maps and allowing us to carry out this study.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 339-344, 2012 DOI: 10.4067/S0717-92002012000300019

Landscape changes in Serra do Japi: legal protection or scientific expectation?

Cambios del paisaje en Serra do Japi: ¿protección legal o expectativa científica?

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SUMMARY

The creation of new legally protected areas brings many conflicts that distance the real landscape from the expected according to environmental law or conservation researchers. In this study, we mapped and compared the changes in Serra da Japi (São Paulo State, Brazil) throughout 40 years with scenarios of legal protection and scientific expectation on forest conservation, to evaluate the distance between them. This may allow us to infer the direction of historical changes and assist in the debate among decision makers. The results showed that most legal requirements on forest protection in the current landscape have been met. The 1960s was the period when the forest cover was closest to the desirable conservation stage. Although the Serra do Japi has maintained large areas of forests during the entire study period, human interference increased with the expansion of reforestation and urban areas, and access roads were identified as a primary potential driving forces of change. In addition, habitat loss was observed in the landscape, which can represent the first phase of a sequence of modifications detrimental to the environmental conservation of this protected area, including decision changes to land use. In conclusion, the changes evolved toward conservation expectations, but not toward the forest configuration of scientific expectation.

Key words: landscape ecology, environmental law, scenario, LUCC, Atlantic Forest.

RESUMEN

La creación de nuevas áreas legalmente protegidas trae muchos conflictos que alejan el paisaje real del que se espera por la legislación ambiental o por los investigadores en conservación. En este estudio se cartografiaron y compararon los cambios ocurridos en Serra do Japi (Estado de São Paulo, Brasil) a lo largo de 40 años con escenarios de protección legal y de expectativa científica sobre la conservación de bosques, buscando evaluar la distancia entre ellos. Este estudio nos permite inferir acerca de la dirección de cambios históricos y contribuye al debate entre tomadores de decisión. Los resultados mostraron que la mayoría de las exigencias legales de protección forestal fueron cumplidas en el paisaje. La década de 1960 fue el periodo con cobertura forestal más próxima a la deseada para la conservación. Aunque Serra do Japi ha mantenido grandes áreas de bosques en todo el periodo estudiado, la influencia humana se incrementó con la expansión de plantaciones forestales, de áreas urbanas y principalmente de las carreteras de acceso, identificadas como potenciales fuerzas conductoras de cambio. Además, se observó pérdida de hábitat en el paisaje que puede representar una primera fase de una secuencia de cambios perjudiciales para la conservación ambiental de esa área protegida. Esto incluye cambios en la decisión del uso del suelo. En conclusión, los cambios evolucionaron en dirección a las expectativas de la conservación, pero no hacia la configuración de bosques bajo una expectativa científica.

Palabras clave: ecología de paisaje, legislación ambiental, escenario, CUCS, bosque atlántico.

INTRODUCTION

In the last decades, Brazil has received much attention around the world due to the creation of new legally protected areas (Jenkins and Joppa 2009), preserving singular ecosystems threatened by the advance of human activities. However, this initiative also brought many conflicts with the population, mainly regarding different interests on land use (Abakerli 2001), such as the conflict between state government and residents in the creation of protected areas of restrictive uses that prohibits the territorial occupation (Payés *et al*. 2013), principally in regions of urban expansion. During this time, these conflicts created pressures that have changed the protected landscapes, distancing the real landscape from the expected legal scenario. The understanding of the distance between these scenarios may aid in the interpretation of the consequences of the consensus of social negotiations. In addition, the scenarios of public consensus in the Brazilian territory, supported or not by legal documents, are usually distant from those aimed by most conservation researchers (Terra and Santos 2011), but few studies have examined this issue. Knowing how close or far a landscape is from the legal requirements or the ideal condition requires studies that examine the expected scenarios in face of land use changes observed throughout time. This is considered by many authors a good way to obtain information on conservation policies (Frapolli 2007, Petrosillo *et al.* 2009). In this context, the present study evaluates the changes in land use in the last 40 years of a protected Atlantic Forest, hierarchizing the distances in relation to two scenarios of conservation: enforcement of the legal protection and technically ideal scenarios. This strategy may allow us to infer if the historical changes evolved toward expectations of conservation, legal requirements or interests on land use.

METHODS

The study area comprised 14,060 ha of the "Serra do Japi", a mountainous region in Jundiaì, southeastern Sao Paulo State, Brazil. This area encompasses 8,000 ha of conserved Atlantic Forest, of which 2,000 ha are protected as a Biological Reserve (SJBR). In spite of the increasing urban pressure, this region is protected at all administrative levels: municipal, state, and federal.

The last 40 years of changes in the study area were evaluated using three land use maps based on aerial orthophotos from 1962, 1994 and 2005, scale of 1:25,000, in ArcGis®.

We designed two important scenarios of expectations to the forest conservation of Serra do Japi from different criteria for the maintenance of native forests. The first scenario represents the set of legal acts of forest protection (legal scenario) and the second scenario was a scientific technically ideal proposal for the forest conservation (ideal scenario). The legal scenario was represented in a map that illustrates all areas that according to forest laws must be forests (table 1). In areas without legal protection, the land uses recorded in 2005 were maintained. The ideal scenario proposed the maintenance of natural forests in different forms of relief, with special attention to local connectivity and its role in the regional landscape (table 2).

Table1. Protection measures for the forest cover of Serra do Japi and its corresponding legal acts.
Medidas de protección para la cobertura forestal de Serra do Japi y sus correspondientes acciones legales.

Legal act	Mapped forests and materials used
Forest code. Law 4.771/65 - CONAMA 302 and 303/02	Areas of Permanent Preservation (APP): Forests around streams, springs, lakes, dams and wetlands: land use map of 2005 + urban boundary + drainage ® function "buffer wizard" of ArcGis; Upper-third of hillsides; and slope greater than 45°: MDT ® function "Slope" of ArcGis ® slope map.
Forest as a natural asset CONDEPHAAT 11/83	Forests found in 1983 within the boundaries of the heritage protected area: land use map of 1994 (nearest year).
Area of environmental protection (AEP). Laws 4.023 and 4.095/84	Forests protected by the Forest Code; existing forests in 1984 within the boundaries of AEP: map of 1994.
Protection of the Atlantic Forest. Decree 750/93 and Law 11.428/06	Atlantic Forest in advanced and intermediary stages of regeneration in 1993: map of 1994.
Creation of the biological reserve. Law 3.672/91 and Law SNUC 9.985/00	Existing forests within the boundaries of the protected area SJBR, and its categorization in advanced stages of regeneration: map of 1994.

Table 2. Criteria of the construction of the ideal scenario for Serra do Japi.
Criterios para la construcción del escenario ideal para Serra do Japi.

Objectives	Criteria of forest conservation
Moratorium	Maintain the existing fragments in intermediary and advanced stages of regeneration.
Biodiversity conservation	Maintain or recover forests in a range of relief gradient: fluvial lowlands, convex hills, mountains, and hilltops.
Protection of water resources and erosion prevention, mudslides and soil loss	Maintain forests along springs, lakes, dams, high slope areas, top of hills and mountains, according to the Forest Code.
Protection of potentially floodable areas	Maintain or recover fluvial lowland forests.
Improvement of local connectivity	Broaden the strip of gallery forest of 30 m, required by the Forest Code, to 70 m, based on a study on border effect for the area (Hardt 2010).

RESULTS

The historical mapping and the interpretation of the legal protection measures for the area allowed the characterization and spatial configuration of the land use and cover of the Serra do Japi throughout the years and its legal expectation (figures 1 and 2).

In the construction of the legal scenario, we created maps of forest cover for each one of the legal protection measures (figure 3A-E), which mostly overlapped each

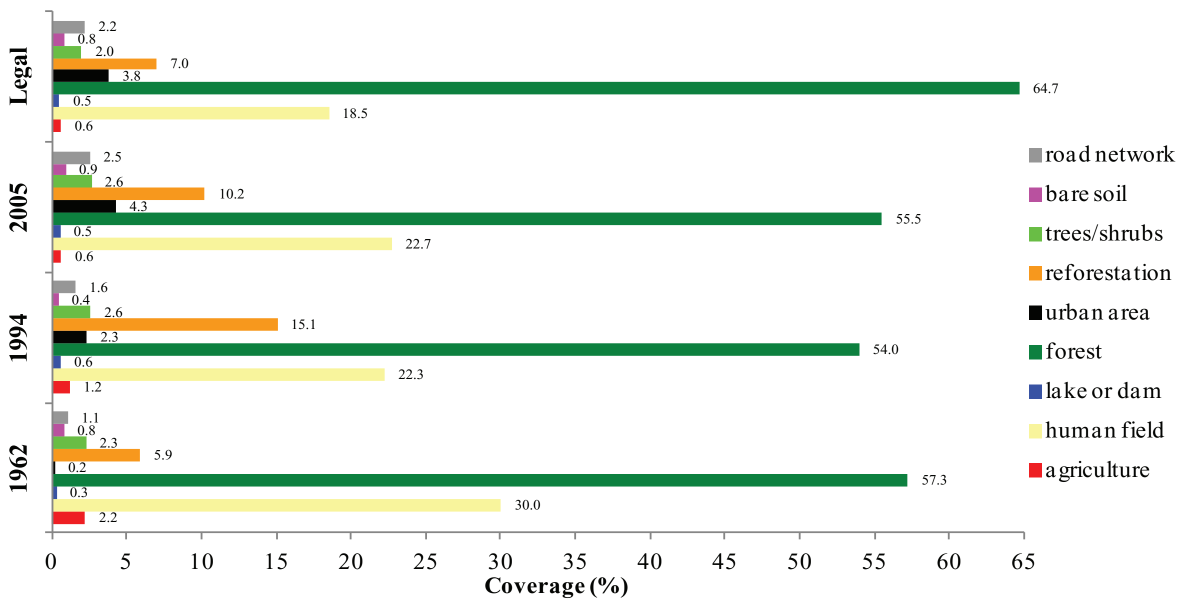

Figure 1. Characterization of the land use and cover of the Serra do Japi (Jundiaí/Brazil) in 1962, 1994, 2005 and legal scenario.
Caracterización del uso y cobertura de la tierra de Serra do Japi (Jundiaí/Brazil) en 1962, 1994, 2005 y escenario legal.

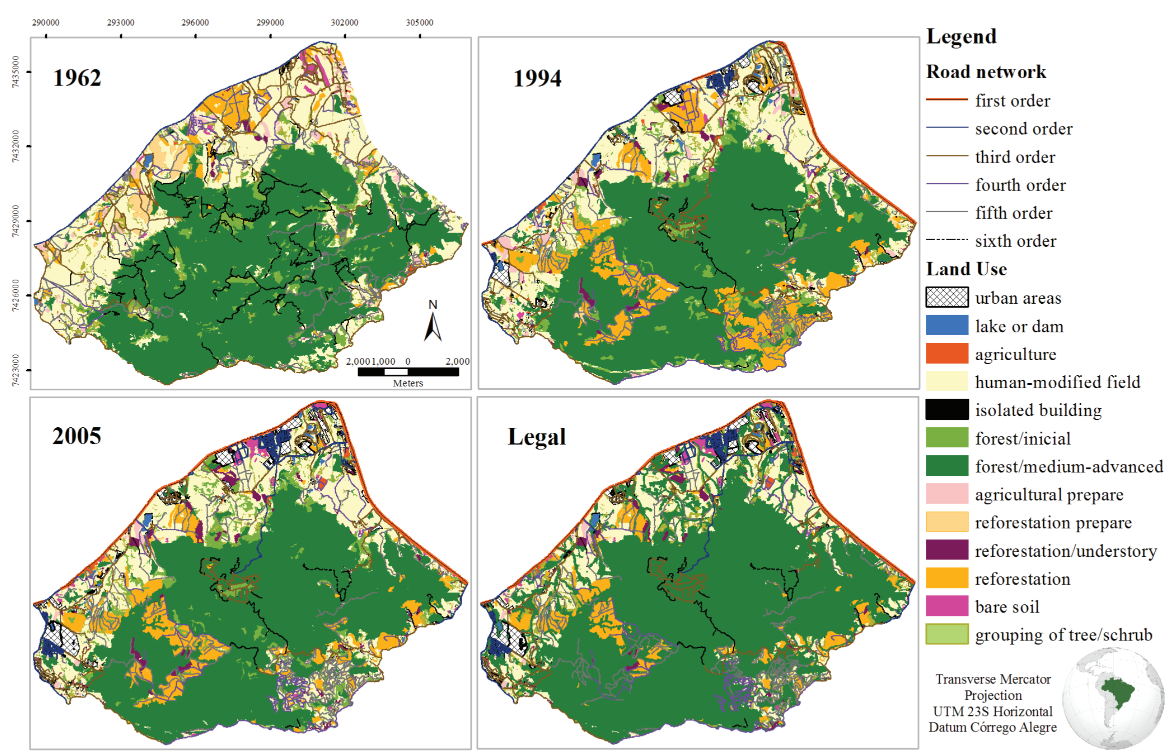

Figure 2. Land use map of Serra do Japi (Jundiaí/Brazil) in 1962, 1994, 2005 and legal scenario.
Mapa del uso de la tierra en Serra do Japi (Jundiaí/Brazil) en 1962, 1994, 2005 y escenario legal.

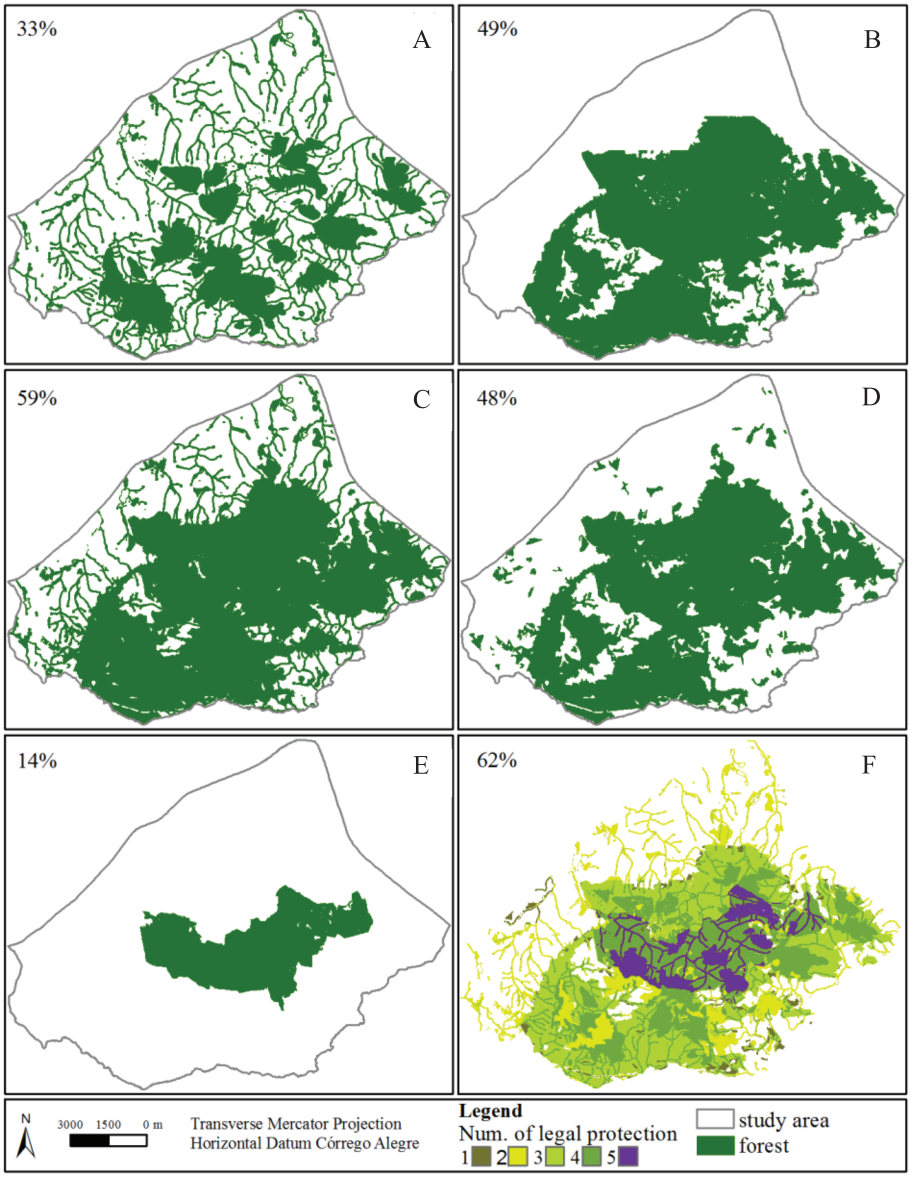

Figure 3. Forest cover (%) of Serra do Japi legally protected: (A) Forest Code-APP, (B) protected heritage, (C) environmental protection-AEP,(D) Atlantic Forest, (E) protected area and (F) total legal protection.

Cobertura de bosque (%) del área legalmente protegida en Sierra do Japi (A) Código Forestal, (B) patrimonio protegido, (C) protección ambiental-AEP, (D) bosque Atlántico, (E) área protegida y (F) protección legal total.

other (figure 3F). For the ideal scenario, we also created maps of forest cover with the spatial configuration of each one of the technical-scientific conservation criteria (figure 4A-C), with a final proposal for the ideal forest cover of Serra do Japi (figure 4D).

DISCUSSION

The legal measures seek to protect 62 % of the Serra do Japi as forest, while from a technical-academic view the ideal conservation scenario aims to protect 83 % of the forest cover in advanced-intermediary stages (figures 3 and 4). In the ideal scenario, a large forest portion should be concentrated in mountainous areas and land use should be restricted to the historically urban territory. Even the areas of human interference would be connected to the forest core by corridors of gallery forests and small fragments (figure 4). Under the premise of conservation, what would be the distance between these scenarios and the landscape observed in recent years?

Based on the legal requirements of forest protection, the current landscape fulfills 90 % of the expected. This percentage could be even higher if the legal protection of the gallery forests and hills (forest code) was more effective (71 %). On the other hand, the comparison of the scientific expectation scenario with land-use and land-cover

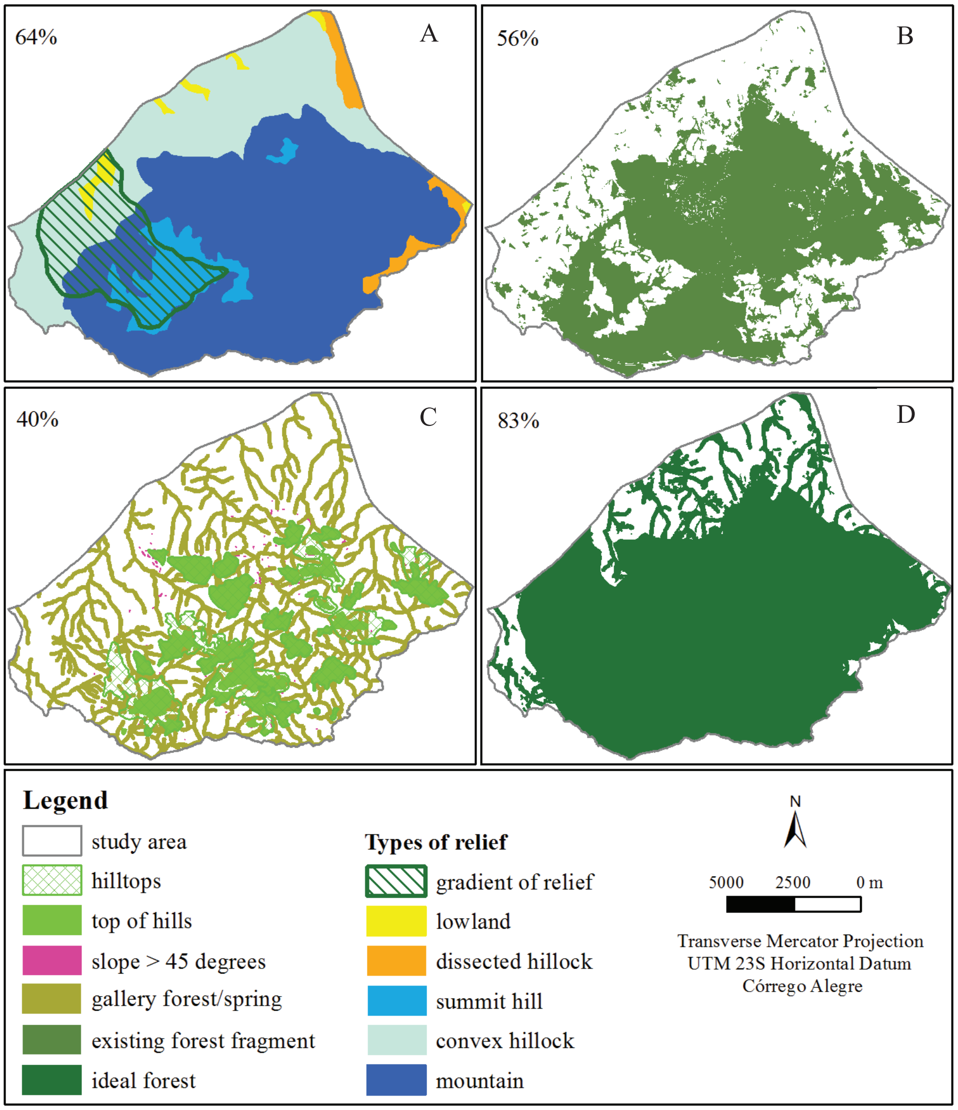

Figure 4. Criteria used in the construction of the ideal conservation scenario of the Japi forest cover (%): (A) relief types, (B) current forests, (C) expansion of Forest Code-APP and (D) ideal forest cover.

Criterios utilizados en la construcción del escenario ideal para la conservación de la cobertura forestal (%) de Japi: (A) tipos de relieve, (B) bosques actuales, (C) expansión del Código Forestal-APP y (D) cobertura forestal ideal.

change (LUCC) revealed that they were very distant from this proposal. In terms of forest area, 1962 was the period closest to the expected, with 31% less from the desired. The legal and scientific expectation scenarios have distinct configurations, probably because the environmental laws are not focused only on biodiversity conservation.

Despite these differences, the historical predominance of the percentage of forests over other types of land use demonstrates the local concern with the conservation of Serra do Japi. Since the 1960s, Serra do Japi had more than 60 % of its area composed of trees, such as reforestation areas, tree clusters, and mainly forests (figure 1). In addition, the successional evaluation of the forest suggests that human interference did not prevent the evolution of the natural development process. In thirty years (1962-1994), 60 % of the forest in early secondary stages became intermediary and advanced and in the following ten years (1994-2005), additional 32 % evolved to advanced stages.

Contrary to this conservation history, especially between 1962 and 1994, urban areas, artificial dams and reforestation areas expanded (figure 1). Despite changes in exploitation trends between 1994 and 2005, with reduction in the investments in new areas of reforestation in regions that should be legally covered by forests (figure 2C-D). The most expressive and concerning change was the widening of access roads, not in extension but in area (figure 1). This expansion was a consequence of the widening of old trails of 1962 and new connecting roads between neighboring municipalities, access to new human settlements and economic activities, such as the complex road system of reforestation areas, responsible for the fragmentation of forests that should be protected (figure 2). Although in the decades following 1960 the road circuitry decreased (Dramstad *et al.* 1996), widening roads had new connective roles that increased their potential of interference on forests. Along with urbanization, the increase in access is a driving force of high potential of change (Antrop 2005) and should not be the reality of a protected area. In addition, although the forest cover was always over 50 %, with some additions by dilation due to the natural regeneration or recovery of gallery forests, some habitat losses occurred. These losses occurred in different patterns of change: by perforation (mainly 1962), dissection (land developments in 1994), fragmentation (mainly 1994), and shrinkage (south and southwest areas). Are alarming losses resulting from economic activities, such as the selective exploitation of timber in 1962, silviculture in 1994, and urban clusters in 2005. There is a probable sequence of habitats changes under human influence that starts with patches of land use perforating the matrix, undergoes fragmentation, and can cause the extinction of habitats due to the attrition effect (Formam 1995, Dramstad *et al.* 1996, Farina 2008). It should be pointed out that a growing human interference usually alters the management decisions based on the changes in people's perception about the landscape (Antrop 2005). Therefore, we believe that the view of social groups may be changing, increasing the risks on protected areas or on those of great importance for forest conservation.

The results allowed us understanding that exist a distance between the scenarios of legal and ideal and showed that historical changes have been more engaged with the expectations of conservation than with the interests on land use. This strategy of analysis may be useful in the evaluation of conservation policies regarding their effectiveness, consequence and distance from the academic opinion.

CONCLUSIONS

The changes occurred in Serra do Japi evolved toward the expectation of conservation, but not toward the configuration of forests expected by the environmental legal protection or the scientific expectation. The historical evaluation of the changes in land use alerts for the expansion of urbanization and mainly the increase in accessibility, as important driving forces of change in the Japi landscape.

ACKNOWLEDGMENTS

The authors acknowledge the support received from FAPESP (São Paulo State Foundation for Science Funding) through concession the PhD scholarship (process number 06/55385-0) and the financial support (process number 08/01505-0).

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 345-352, 2012 DOI: 10.4067/S0717-92002012000300020

Stream corridors as indicators of watershed land use: A case study in Istanbul

Corredores ribereños como indicadores de uso de suelo de una cuenca: un caso de estudio en Estambul

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SUMMARY

Riparian ecosystems as components of stream corridors provide a range of regulating ecosystem services including water production. Water quality, a component of water production is a major concern in urbanized watersheds. Water quality monitoring has been a very common method of investigating watershed impairment particularly in case of human impacts but it is now clear that hydrologic and ecological parameters may support and improve monitoring studies substantially. In three major watersheds of the Istanbul city (Alibeyköy, Sazlıdere, and Kağıthane) we initiated a large-scale study with the objective of evaluating integration, health, and functionality levels of riparian ecosystems. We combined a thorough field survey study with a GIS assessment to reach this objective. A total of 66 sub-watersheds have been selected in the main study watersheds and survey points have been determined at their outlets. All perennial streams in the study have been surveyed for 5 main categories; ecological water quality, water quality for use, riparian integrity, riparian functionality, and riparian habitat potential. We found that a substantial amount of the streams in or close to urban areas had lost their functionality. Furthermore, around 10 percent of all streams in the peri-urban areas had been channelled. Water quality has also been deteriorated in many streams. For example, average NO_3^{-1} concentration at the urban streams was 76.63 mg L^{-1} while it was 2.67 mg L^{-1} at the forested part of the same watershed.

Key words: urban planning, land use, sprawl, watersheds, stream corridors.

RESUMEN

Los ecosistemas ribereños como componentes de los corredores fluviales proveen un rango de servicios ecosistémicos incluyendo la producción de agua. La calidad de agua, un componente de la producción de agua, es una preocupación relevante en las cuencas urbanizadas. El monitoreo de la calidad de agua ha sido un método comunmente aplicado para investigar el debilitamiento de las cuencas, particularmente a causa de los impactos humanos. Sin embargo, es claro que los parámetros hidrológicos y ecológicos pueden sustentar y mejorar sustancialmente los estudios de monitoreo. En tres grandes cuencas de la ciudad de Estambúl (Alibeyköy, Sazlıdere, and Kağıthane) se iniciaron estudios de gran escala con el objetivo de evaluar los niveles de integración, salud y funcionalidad de los ecosistemas ribereños. Se combinó un trabajo de campo exhaustivo con una evaluación usando SIG para alcanzar tal objetivo. Se seleccionaron 66 sub-cuencas en las principales cuencas de estudio y se determinaron puntos de muestreo en sus salidas. Todos los esteros permanentes fueron evaluados para cinco categorías principales; calidad ecológica del agua, calidad de agua para uso, integridad ribereña, funcionalidad ribereña y potencial de hábitat ribereño. Se encontró que una cantidad sustancial de los esteros en o cerca de áreas urbanas han perdido su funcionalidad. Además, cerca de un 10 % de todos los esteros en las áreas periurbanas han sido canalizados. La calidad del agua también se ha deteriorado en muchos de estos esteros. Por ejemplo, la concentración promedio de NO_3^{-1} en los esteros urbanos fue 76.63 mg L^{-1} mientras que en las áreas forestadas de las mismas cuencas alcanzó solo 2.67 mg L^{-1}.

Palabras clave: planificación urbana, uso de suelo, expansión, cuencas, corredores ribereños.

INTRODUCTION

Stream corridors are living components of the landscape and a major concern from hydroecological point of view. A complex biotic component of stream corridors is riparian ecosystems which provide a wide range of regulating ecosystem services especially around populated regions. Both water quality and quantity may become a concern in urbanized watersheds. Management of urban and peri-urban watersheds becomes more challenging with respect to water production in such cases. It is now widely understood that functional riparian ecosystems can remove large amounts of nitrate and phosphate from the water that flows through them (Gorniak 1993, Hill 1996, Casey *et al.* 2001, Hunter *et al.* 2006). Riparian ecosystems are also capable of trapping sediment runoff from land, enabling bank stability and thus minimising soil loss into watercourses (Tubman and Price 2001, McKergow *et al.* 2004, Kreutzweiser *et al.* 2009). Another benefit of the riparian vegetation is the shading of water surface and thus regulating the temperature of aquatic ecosystems (Pusey and Arthington 2003). Biodiversity and habitat provision as well as energy and nutrient benefits of riparian ecosystems have also been quite well documented. With all these mentioned capabilities, the state of a stream corridor can be characterized by three aspects: i) habitat potential, ii) ecosystem integrity and iii) ecosystem functionality.

Habitat potential is determined for single species of a region in particular. However, a broader assessment can be done for groups of species sharing a common habitat. Aquatic habitat is often used in studies of stream habitats based on physical, chemical and biological characteristics. Physical habitat includes parameters such as channel dimension, stream flow and riparian vegetation; chemical variables include water pH and nitrate levels; and biological components serve as indicators of the ecological community that utilize the river, *e.g.* fish and macroinvertebrate species composition and diversity. Whitacre (2004) has identified 11 stream attributes that are included in six stream habitat assessment protocols used by USDA (United States Department of Agriculture) which are: reach length, gradient, sinuosity, percent pools, residual pool depth, bankfull width, bankfull width/depth, D_{50}, fine particle percent, pool tail fine particle percent, and large woody debris in 100 meters.

The term ecosystem integrity is used by Jordan and Vaas (2000) as a defining term of a combination of many components of the system, *e.g.*, the quality of water and physical habitats, the abundance, health, and diversity of aquatic plants and animals, and balance among trophic guilds and functional groups of biota. Karr's (1992) definition of ecological integrity is "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region". As a simple approach ecological integrity defines the distance of an ecosystem from natural conditions or the human impact level in an ecosystem.

Ecosystem functionality is a well-known and studied aspect of ecosystems compared to integrity. In this study it covers the role of riparian components of streams to provide water-related ecosystem services (*i.e.* sediment and nutrient immobilization, flood control).

The above mentioned aspects of stream corridor state can be determined with field surveys combined with water quality monitoring studies. Field surveys that are supported with hydroecologic water monitoring studies -that includes biologic parameters like macroinvertebrates- provide information on many attributes of stream condition. One question that may arise in this context may be "can stream corridor conditions that include riparian areas be handled and evaluated from certain aspects to link with watersheds that they drain?" This linkage can diminish the work load of municipalities and other related public agencies that are responsible for stream corridor maintenance.

The reason for performing this study particularly in Istanbul was the fast urbanization trend of the city that caused deterioration of fluvial systems. More than 10 reservoirs are providing water to Istanbul city with a population of more than 12 million. Watersheds of most reservoirs are under pressure of urbanization and sprawl.

We worked in three important watersheds (Alibeyköy, Sazlıdere, and Kağıthane) of the city towards the objective of linking stream corridors with their watersheds quantitatively. To reach this objective, we combined field surveys, water quality monitoring and GIS assessments.

METHODS

Study area. Study watersheds cover a large area on Istanbul's European side peninsula (figure 1). Alibeykoy and Sazlidere watersheds are draining into reservoirs while Kağıthane creek drains into a well-known estuary called Golden Horn. Croplands constitute a large part of Sazlidere watershed while forestlands at the upper elevations and urban areas at the lower elevations characterize the Alibeykoy and Kağıthane watersheds. The streams draining Kağıthane and Alibeykoy are receiving pollutants that are generated by settlements and industrial activities along the creeks. Flooding is also a major problem at downstream of Alibeykoy and Kağıthane streams because riparian ecosystems are replaced by settlements in many places. The areas of watersheds and their basic properties are given in table 1.

The annual precipitation ranges between 650 and 1,100 mm decreasing southwards. The Black Sea shore receives the highest amount of precipitation. Neogen and Carboniferous formations characterize the geology of the region. Limestone and clay schists exist in Carboniferous zone locally. Andesites and alluvial zones also exist in the region.

Field methods. A total of 66 sub-watersheds were selected in the three main watersheds and survey points for stream corridors were determined at their outlets. Thirty eight of the sub-watersheds were used for model construction and the rest for model performance test. All perennial streams in the study were surveyed for three main categories: i) ecosystem integrity, ii) ecosystem functionality y

Table 1. Study watersheds and some basic information.
Cuencas bajo estudio e información básica.

Watershed	Watershed area	Reservoir area	Type of use
Sazlidere	194	9.87	Water supply
Alibeykoy	158	4.66	Water supply
Kağıthane	388	NE	NE

NE: not exist.

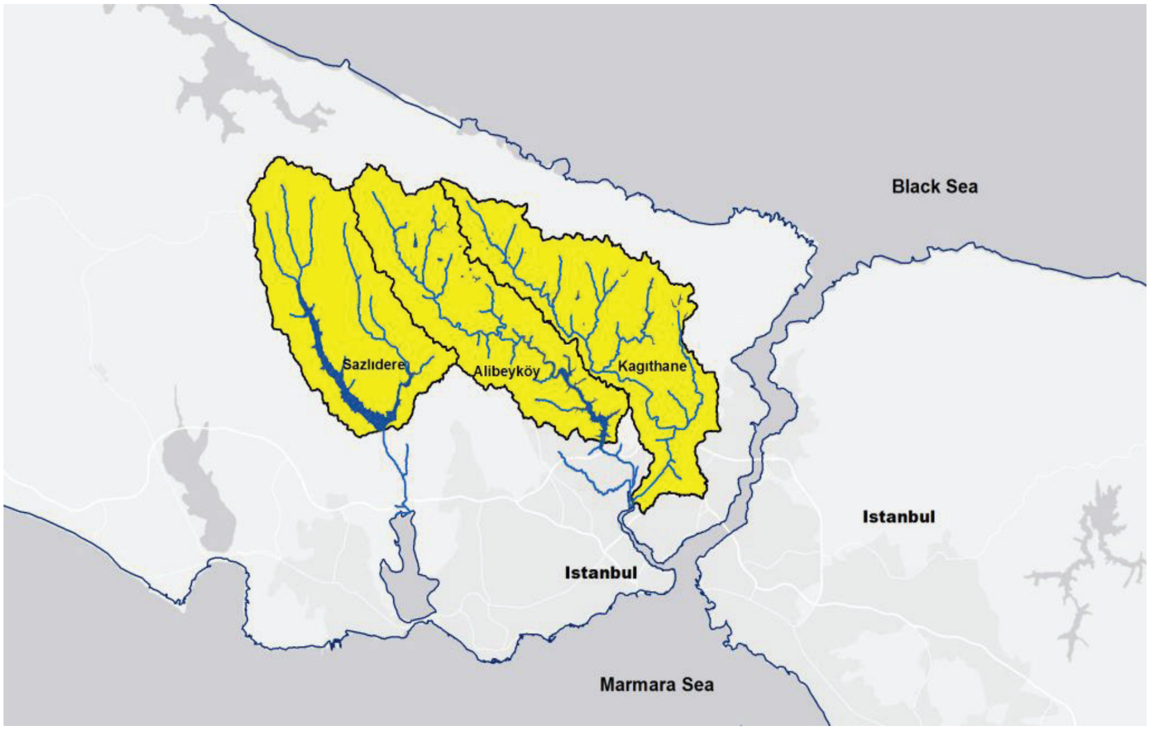

Figure 1. Sazlıdere, Alibeyköy and Kağıthane watersheds from west to east direction.
Cuencas Sazlıdere, Alibeyköy y Kağıthane desde el Oeste al Este.

iii) aquatic habitat potential. Each category was quantified, statistically analyzed and linked with watershed attributes.

The procedures were as follows: field surveys at stream corridors. Field surveys were implemented using a stream channel survey protocol developed for this purpose. It included ecologic and hydrologic attributes. Relevant survey parameters were selected for the three categories (table 2).

Water quality monitoring. The water quality parameters that have been determined on each stream survey section were: Total suspended sediments (TSS), nitrate (N-NO_3), ammonium (N-NH_4), colour, phosphate (PO_4), hardness, calcium hardness, calcium (Ca), magnesium (Mg), HCO_3, alkalinity (A).

Other than these, electrical conductance, pH, oxygen concentration, temperature, and turbidity were analyzed in the field. The Kağıthane watershed included large amounts of forestland and water quality attributes of this watershed were calculated as forested and total area to see the difference.

The water quality monitoring did not have a temporal dimension as the objective was not to evaluate the stream water quality over time. The water quality monitoring part of the study was performed towards two objectives to reveal the water quality condition of the streams and to use water quality as a verification tool. Chemical, physical and ecological (macroinvertebrate population numbers and diversity) parameters were determined to reach the first objective. Two new parameters called ecologic water quality (WQeco) and water quality for various uses (WQuse) were computed for the second objective. This was to link water quality with stream and watershed attributes. The parameters to compute WQeco were: alkalinity, dissolved oxygen, nitrate, ammonium, phosphate, pH, suspended sediments, turbidity.

The parameters to compute WQuse were: electrical conductance, pH, turbidity, total and calcium hardness, calcium and magnesium ion concentrations. The computation method was to determine the range of a parameter and divide it into a certain number of score ranges. As an example, electrical conductance was split into five ranges and scored as: 0-250 $\mu S\ cm^{-1}$ = 0; 250-750 $\mu S\ cm^{-1}$ = 1; 750-2,000 $\mu S\ cm^{-1}$ = 2; 2,000-3,000 = 3; 3,000-4,000 $\mu S\ cm^{-1}$ = 4. The polluted streams got higher WQ scores in this approach. The watershed attributes that have been determined and evaluated were: forest intensity (forint), settlement intensity (settlint), farmland intensity (farmint), road intensity (roadint), area, mean elevation, mean slope, stream density, stream frequency. We used ArcGIS 9.3 for spatial analyses.

Data processing and transformation. The stream survey parameters included both objective (D50, erodibility, etc.) and subjective (shade effects of vegetation, visible human impacts etc.) data. The data was combined to calculate a score for each category. The scoring was done in three steps; frequency analysis was done for each measured or estimated parameter unless well-known classifications

Table 2. Survey parameters used for estimating stream state categories.
Parámetros del estudio usados para la estimación de las categorías de los esteros.

AHP (aquatic habitat potential) score	EF (ecosystem functionality) score parameters	EI (ecosystem integrity) score parameters
Shade effect of riparian ecosystem	Land use on both sides of the corridor	Visible human impacts around the channel (bridge, road, recreation, grazing, etc.)
Channel modification	Riparian vegetation composition and density	Intensity of riparian vegetation
Biologic activity in water	Shade level of the riparian vegetation	Direct impacts to natural stream channel (channelization, digged, restoration measures, widening, etc.)
Number of pools in 50 meters up and downstream	Width of Riparian zone	Distance to road and settlements
Number of riffles in 50 meters up and downstream	Frequency of herbaceous plants	Macroinvertebrate and fish population
Number of woody debris deposition in 50 meters up and downstream	Leaf area cover of herbaceous plants	Herbaceous cover diversity
Embeddedness	Herbaceous biodiversity (Shannon index)	
D_{50} (Medium sediment particle size)	Soil permeability	
Bankfull width	Soil erodibility	
Bankfull width/depth ratio	Soil compaction and bulk density	
LWD (Large woody debris) size and deposition		
Sinuosity		
Gradient		

exist like EC, each frequency class (five classes) was given a score, aquatic habitat potential, ecosystem functionality, and ecosystem integrity scores were calculated for 66 stream cross sections (38 model construction, 28 for model test).

Then the categories were transformed into values that are statistically useable (table 3). Transformations were as follows:

SSR transformation is suggested by Zar (1996) and preferred to square root transformation in case of zero values. It is implemented as;

$$p' = \sqrt{p + 3/8} \qquad [1]$$

Where,
p = number to be transformed.

Linking stream properties with watershed properties. Significant land use properties for the 66 sub-watersheds (38 model construction, 28 for model test) were determined as intensity values (land use/watershed area) in the three major watersheds. Correlations between forest intensity (forint), settlement intensity (settlint), farmland intensity (farmint), and road intensity (roadint) and stream corridor categories were investigated and significant correlations were determined. Forest, settlement, farmland, and road intensities are easily available data for many public authorities especially for municipalities.

Simple and multiple regression models were developed and compared with two artificial neural networks models. NeuroXL predictor software was used to develop artificial neural networks models. The artificial neural networks1 was a predicting model based on one independent variable while two independent variables were used in artificial neural networks2. Zero based log sigmoid function was used as the activation function. The 0.365 r^2 value became 0.433 after the learning phase for artificial neural networks1 while r^2 value of 0.232 became 0.704 for artificial neural networks2.

These four statistical models were developed by using data from 38 sub-watersheds. The models were tested on data from the other 28 sub-watersheds. The least square errors of models were calculated to find out best model to predict aquatic habitat potential, ecological integrity, and ecological functionality from watershed land use intensities data and vice versa.

RESULTS

Water quality. The upper portion of Kağıthane watershed is covered mainly with forestlands (figure 2). Therefore the water quality of headwater streams was in good condition as expected. The mean values of water quality parameters also showed that the streams draining forested headwaters were receiving large amount of pollutants while passing through urban areas as expected (table 4). The mean total suspended sediment concentrations of steam waters at forested areas were almost one fifth of the remaining part of the watershed. Nitrate and ammonium concentrations were much higher at Kağıthane and Sazlıdere watersheds compared to forested part of Kağıthane and Sazlıdere. Alibeyköy watershed had highest total suspended sediments, ammonium, phosphate, hardness, calcium hardness, calcium, and magnesium values.

Table 3. The statistical transformations used for aquatic habitat potential (AHP), ecosystem integrity (EI), ecosystem functionality (EF), water quality for various uses (WQuse), and ecologic water quality (WQeco scores).
Transformaciones estadísticas usadas para AHP, EI, EF, WQuse y valores de WQeco.

	N	Mean	Std. dev.	Kolmogorov-Smirnov Z	Asimp. Sig. (2-way)	Type of data and transformation
AHP	38	4.158	4.918	1.701	0.006	NN SSR
EI	38	6.868	5.576	0.672	0.757	NN SSR
EF	38	10.579	5.976	1.060	0.211	NN SSR
WQuse	38	4.944	2.484	0.610	0.851	NN SSR
WQeco	38	4.389	3.425	1.111	0.169	NN SSR

NN: not normally distributed, SSR: special square root.

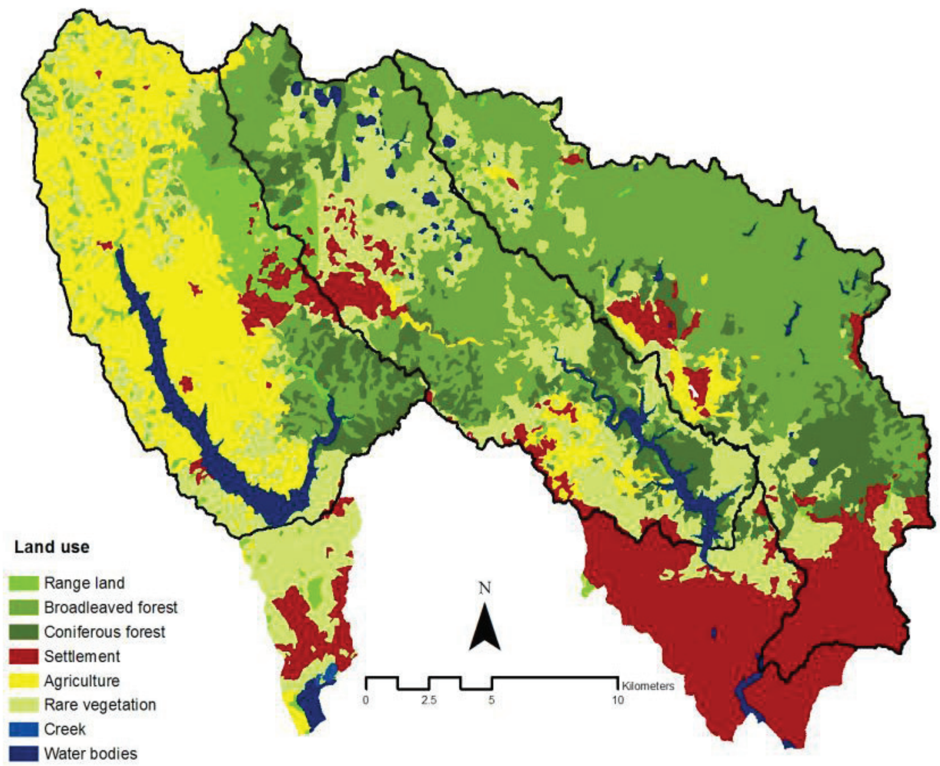

Figure 2. Land use in study watersheds.
Uso de suelo en las cuencas bajo estudio.

Table 4. Water quality of streams in study watersheds.
Calidad de agua de los cursos de agua en las cuencas de estudio.

Watershed	TSS mg L^{-1}	N-NO_3 mg L^{-1}	N-NH_4 mg L^{-1}	Colour cpu	PO_4-P mg L^{-1}	H mg L^{-1} $CaCO_3$	CaH mg L^{-1} $CaCO_3$	Ca mg L^{-1}	Mg mg L^{-1}	A mg L^{-1} $CaCO_3$	HCO_3 mg L^{-1}
Kağıthane Forested	0.21	2.67	0.26	12.00	4.29	160.00	77.42	31.03	20.15	62.78	76.59
Kağıthane	1.01	76.63	5.08	26.92	5.44	357.00	219.86	88.12	33.46	170.30	207.76
Alibeyköy	1.32	39.16	12.50	16.25	8.17	691.06	440.34	176.49	61.18	228.01	278.17
Sazlıdere	0.57	16.14	0.43	7.50	4.73	548.40	310.40	124.41	58.07	251.85	307.26

TSS: total suspended sediments, H: hardness, CaH: calcium hardness, A: alkalinity.

Stream properties - watershed properties linkage. The linear relationships between stream corridor categories (habitat, integrity, functionality) and land use properties are given below (table 5). Significant correlations were determined among the categorized stream corridor categories, water quality scores (WQuse, WQeco) and selected watershed attributes. Farmlands correlated with macroinvertebrate diversity, herbaceous cover, and diversity of surveyed stream sections but no significant correlation was determined for water quality and categorized stream corridor properties (aquatic habitat potential, ecosystem integrity, and ecosystem functionality). Forest intensity and settlement intensity were generally the dominating land use attributes to affect stream conditions but on the opposite directions.

Simple and multiple regression models were determined based on significant correlations. The aquatic habitat potential, ecosystem integrity, and ecosystem functionality were estimated with these regression models and two other artificial neural networks models for the test sub-watersheds. Performances of the models were compared with least squares error method (table 6). The Reg1 in the table represents simple regression, MReg represents multiple regression. Artificial neural networks1 is the one independent and artificial neural networks2 is the two independent variable. Artificial neural network model as explained above.

The simple and multiple regressions had better performance results compared to artificial neural networks models for ecosystem integrity and ecosystem functionality estimations. Aquatic habitat potential estimation was better done with Artificial neural networks2 model.

As the final stage of model application we conducted visual model estimations for the 28 verification sub-watersheds. The ecosystem functionality estimation done by a simple regression equation has been given below (figure 3) with forest intensity as the independent variable.

Forest intensity increases as the colour gets darker while ecosystem functionality decreases as the yellow circles gets larger. The yellow circles becoming larger at settlement (*i.e.* Kağıthane low regions) and agriculture-intensive regions (*i.e.* Sazlıdere watershed) is an indication of diminished stream ecosystem functionality in comparison to forest-intensive watersheds. The ecosystem functionali-

Table 5. Correlations among stream corridor attributes and some watershed land use properties.
Correlaciones entre los atributos de los corredores ribereños y las propiedades del uso de suelo en la cuenca.

Attibutes	Statistics	Forint	Settlint	Farmint	Roadint
Aquatic habitat potential (AHP)	Pearson correlation	-0.343	0.377*	-0.176	0.304
	P (2-tailed)	0.059	0.037	0.343	0.097
	N	38	38	38	38
Ecosystem integrity (EI)	Pearson correlation	-0.568**	0.408*	-0.125	0.347
	P (2-tailed)	0.001	0.023	0.504	0.055
	N	38	38	38	38
Ecosystem functionality (EF)	Pearson correlation	-0.564**	0.417*	-0.055	0.380*
	P (2-tailed)	0.001	0.020	0.769	0.035
	N	38	38	38	38
Water quality for various uses (WQuse)	Pearson correlation	-0.415*	0.461*	-0.202	0.470**
	P (2-tailed)	0.023	0.010	0.283	0.009
	N	38	38	38	38
Ecologic water quality (WQeco)	Pearson correlation	-0.337*	0.530**	-0.190	0.449*
	Sign. (2-tailed)	0.069	0.003	0.316	0.013
	N	38	38	38	38

*0.05 significance level. **0.01 significance level.

Table 6. Comparison of simple regression, and multiple regression with two artificial neural networks (ANN) models. # represent the lowest errors.
Comparación entre regresiones simples y múltiples con dos modelos de redes neuronales artificiales (ANN). # representan los errores más bajos.

Attributes	lseReg1	lseMReg	lseANN1	lseANN2
Aquatic habitat potential (AHP)	13.71	49.72	42,63	10,02#
Ecosystem integrity (EI)	32.52	11.90#	29,71	114,70
Ecosystem functionality (EF)	16.68#	60.36	20,50	28,28

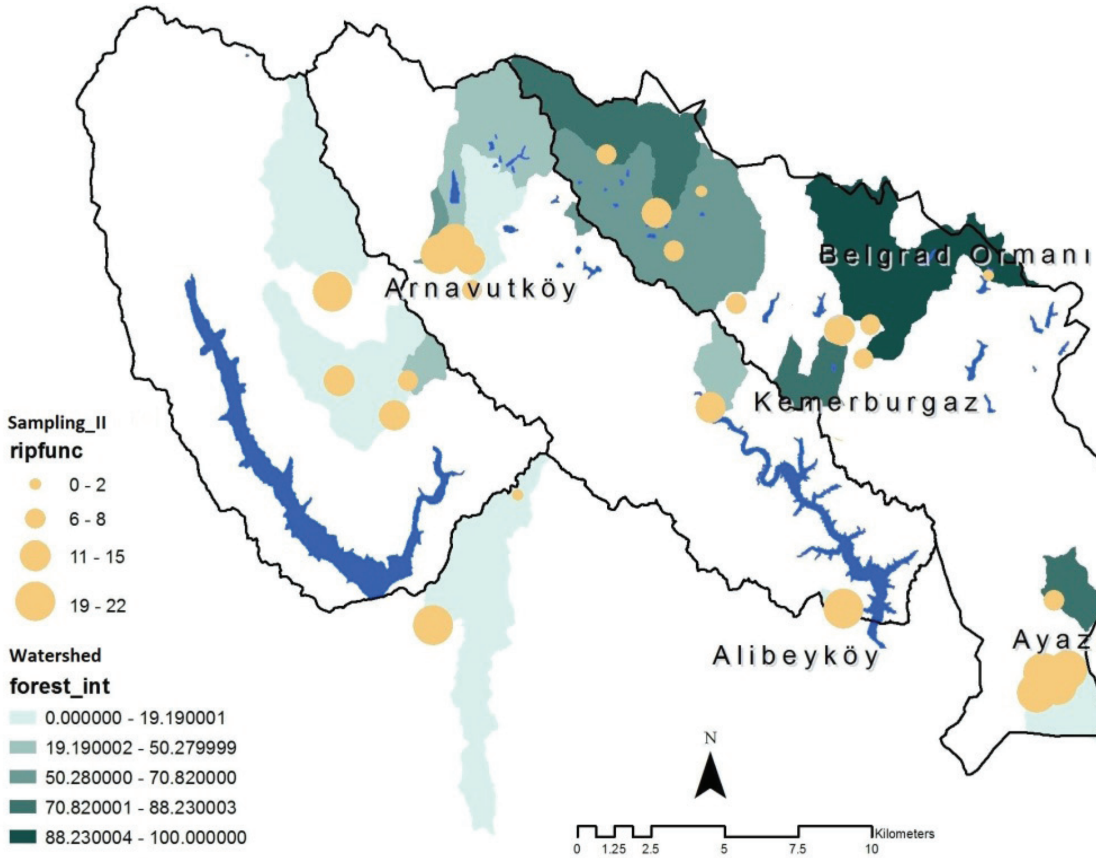

Figure 3. EF estimation at the verification watersheds.
Estimación de EF en las cuencas de verificación.

ty is higher in forested watersheds (smaller circles) but in some cases sparse vegetation (brushlands, meadows, etc.) or villages in or around the forest are causing variability in ecosystem functionality.

DISCUSSION AND CONCLUSIONS

Conventional approach to evaluate watershed deterioration bases on water quality monitoring. This is a very effective approach if ecological parameters (*i.e.* macroinvertebrates) are also taken into consideration. However, water quality monitoring can be linked with watershed attributes but not stream corridor attributes especially to assess riparian ecosystems. This study offers a new direction to address this topic with simple and low data demanding models. Basic approach is to evaluate watersheds and their stream corridor properties together. The integrity, functionality, and habitat potential have been taken into account in this study as defining elements of stream corridors. This is an ecological approach because even a channelization can be considered as a stream restoration objective in many cases as it is in Istanbul.

The results of the study were generally in line with recent studies with respect to land use impacts on stream conditions. Positive impacts of forests on suspended sediment concentration have been documented with numerous studies (*i.e.* Bartley *et al.* 2012, Somura *et al.* 2012). In general, suspended sediment concentration was found to be inversely proportional with forest cover percentage in a watershed (Mouri *et al.* 2011). This increase in macro invertebrate diversity in farmlands (Victor and Ogbeibu 1985) is generally attributed to increase in fine sediment supply to the streams (Scarsbrook and Halliday 1999, Niyogi *et al.* 2007). Forest intensity and settlement intensity had also significant impacts on stream conditions.

The study had also practical outputs like simple regression equations. Public authorities responsible of stream restoration work can determine stream channel functionality level estimations without much field work with this approach. The restoration requirements of the streams can be ranked with certain accuracy as ecosystem functionality together with ecosystem integrity, and aquatic habitat potential represents ecological levels of stream corridors.

A large amount of parameters were measured in the field and many of them have been used to combine parameters like ecosystem integrity and WQeco. A wide range of watershed attributes has also been determined to find out the most convenient and practical statistical linkages. With the support of these data, simple and statistically applicable relationships were determined to be used by relevant public authorities. Most municipalities have a certain level of digital maps that may enable them use this approach.

ACKNOWLEDGMENTS

The study was supported by TUBITAK with the Project number 107Y149.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 353-358, 2012 DOI: 10.4067/S0717-92002012000300021

Forest conservation index and historical evolution in a coastal region: The São Sebastião Island, São Paulo, Brazil

Índice de conservación de bosques y evolución histórica en una región costera: Isla São Sebastião, São Paulo, Brasil

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SUMMARY

The aim of this study is to identify the current conservation status of five forested watersheds which have been under different human pressures throughout history of São Sebastião Island to assess relations between pressures which have occurred in the past and the current environmental quality. Through maps of land use, landscape metrics, and the development of a forest conservation index, it was possible to identify in watersheds the greater landscape fragmentation, implications on quantity and quality of available habitat, and effects of boundaries.

Key words: landscape change, landscape metrics, indexes.

RESUMEN

El objetivo de este estudio es identificar el estado de conservación de cinco cuencas en diferentes fases evolutivas en la isla de São Sebastião (SP) de manera que se pueda evaluar las relaciones entre las presiones pretéritas y la calidad del medio ambiente actual. A través de mapas de uso del suelo, las medidas del paisaje y el desarrollo de un índice de conservación de bosques fue posible identificar en las cuencas la mayor fragmentación del paisaje, las implicaciones sobre cantidad y calidad del hábitat disponible, y los efectos de las fronteras.

Palabras clave: cambios del paisaje, métricas del paisaje, índices.

INTRODUCTION

Many habitats have been fragmented by human activities, in order to use natural resources (Botequilha-Leitão *et al*. 2006); creating mosaics that result in losses of large continuous forest areas (Lang and Blascheke 2009). The extent of forest loss is highly dependent on human pressures throughout the landscape's history, and it varies with different territories (Bertolo *et al.* 2010). The specific changes in each segment of the territory create a structural heterogeneity in the landscape, which can be evaluated by composition and configuration metrics and forest conservation indexes. The information provided by metric and index are related to ecosystem structure's complexity (Peng *et al.* 2010), function, and composition of the ecological system, features including conservation state of forests and human interference in landscape (Bertolo *et al.* 2012). In this context, the aim of this study is to identify the current conservation status of five forested watersheds which have been under different human pressures throughout history of St. Sebastian Island (evolution phases).

METHODS

The mapping of São Sebastião Island (SP), the selection of watersheds, and their segmentation into two zones are shown in figure 1.

Five watersheds were selected representing different evolution phases described by Bertolo *et al.* (2010): preservation, conservation, regeneration, exploitation, and urbanization. Because of the occurrence of different historical land uses (Lima 2011), the watersheds were segmented in two zones both above and below (A and B) 100 m altitude.

Several authors (Botequilha-Leitão *et al.* 2006, Lang and Blascheke 2009) suggest that one way to understand the condition of the landscape is through of indexes and metrics that summarize mathematically maximum information. In this direction, we proposed an index involving different successional stages of forest as a good indicator of the conservation state. The forest conservation index (IC) was developed for zones A and B of the watersheds and their standard values (equation 1) from the amount of dense ombrophilous forest (i) at advanced succession stages

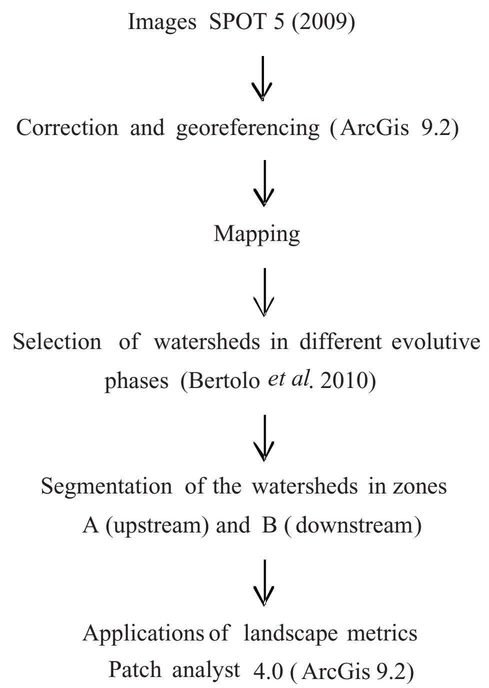

Figure 1. Flowchart of the materials and methods used.
Diagrama de flujo de los materiales y métodos utilizados.

(FODm/a) (ii) at intermediate succession stages and remnants (FODi,r) and (iii) at initial (FODp). The quantities of forest were weighted in favour of the best succession stage and summed using equation 2. The equations 1 and 2 were developed for this investigation and the weights were based on Tabarelli and Mantovani (1999).

$$\mathrm{VP}i = \frac{\mathrm{V}ij}{\mathrm{V}imax} \quad [1]$$

Where,
VP*i*: standard value of metric *i*.
V*ij*: metric's value *i* for watershed *j*.
V*imax*: highest metric's value *i* in all watersheds.

$$\mathrm{IC}j = (\mathrm{FODma}j \times 1) + (\mathrm{FODIr}j \times 0.6) + (\mathrm{FODp}i \times 0.3) \quad [2]$$

Where,
IC*j:* forest conservation index of watershed *j*.
FODma*j*: FODm/a of watershed *j*.
FODIr*j*: FODi,r of watershed *j*.
FODp*j*: FODp of watershed *j*.

Four metrics widely used in academic researches (Geri *et al.* 2010) to investigate landscape fragmentation by composition and configuration were selected: mean patch size (MPS), mean patch edges (MPE), number of patches (NumP); class area proportion (CAP).

To verify reasonable relationship between fragmentation effects and quality of forest was used regression analyses performed between: (a) between forest conservation index of watershed and standardized metric's results; and (b) mapped class area proportion for dominant class (CAP) in each evolutive phase and zones A and B. R^2 values ≥ 0.95 were considered for zone A.

RESULTS

In the five watersheds studied, we have been identified 34 types of land uses and natural vegetation cover, with 60 % area of Dense Ombrophilous Forest associated with different stages of regeneration and different types of land use (figure 2).

The values of R^2 metrics relative to forest conservation index of watershed, the zones A and B for all watersheds showed that there was a tendency of second order of polynomial regression in both zones, but most significant to zone A (table 1). The exception was number of patches in zone B, which showed an exponential relationship with the forest conservation index of watershed.

The results showed that: (1) number of patches had a distinct behavior between zones A and B (figure 3), indicating that for B there were high values of number of patches and low values of forest conservation index of watershed without inflection point; (2) mean patch size showed that the greater number of patches and a larger number of small patches, decreasing the quality of the landscape due to the increase of fragmentation (figure 3); (3) mean patch edges the better state phases (preservation and conservation) showed the largest mean patch size of forest for both zones (figure 3).

The class area proportion confirmed what was expected for watersheds in opposite evolutive phases (figure 4), larger tracts of forest at the advanced succession stage for both zones in preservation phase and higher values of human interference for both zones in urbanization phase.

Table 1. Results of R^2 for metrics in relation of forest conservation index.
Resultados de R^2 para las métricas relativas al índice de conservación de bosques.

Metrics	R^2	
	A zone	B zone
MPS	0.99 (p)	0.72 (p)
MPE	0.99 (p)	0.75 (p)
NumP	0.98 (p)	0.74 (e)
CAPd	0.95 (p)	0.46 (p)

MPS: mean patch size; MPE: mean patch edge; NumP: number of patches; CAPd: class area proportion dominant. (p): polynomial; (e): exponential.

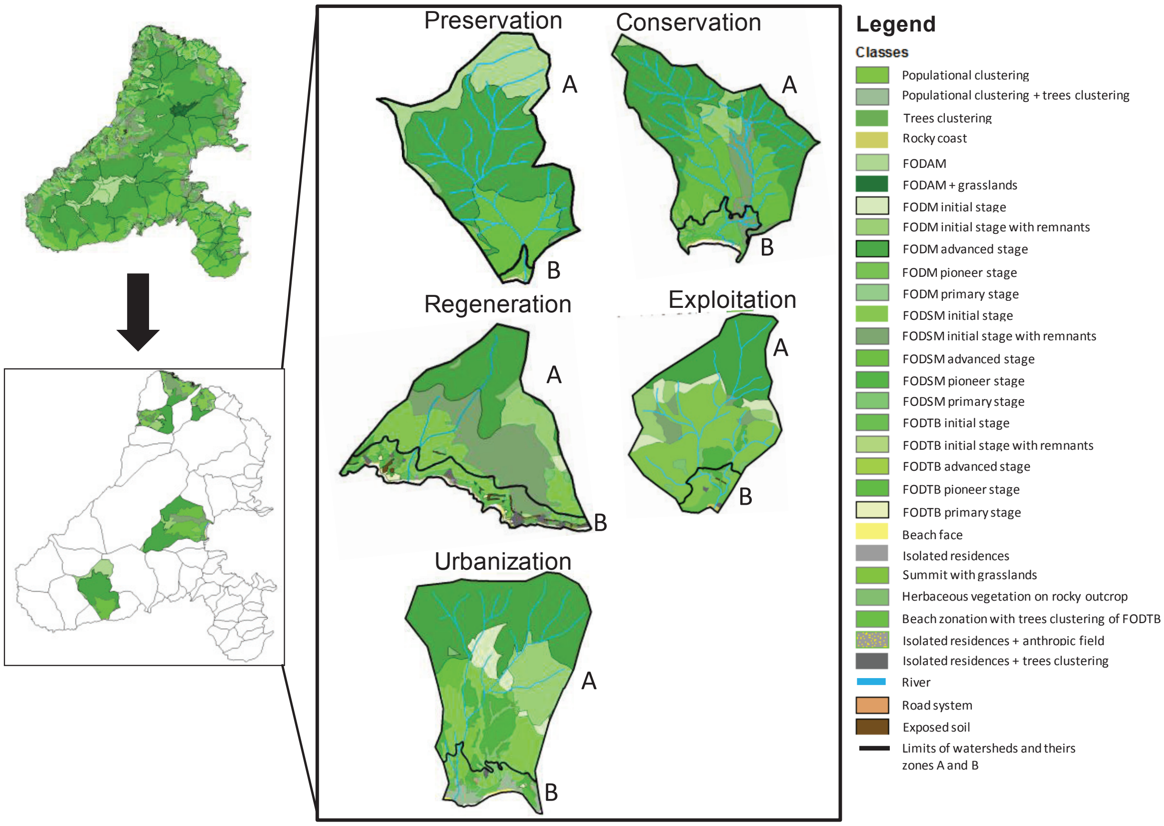

Figure 2. Types of uses and natural vegetation cover of watersheds of Ilhabela (Fundação Florestal, in press).
Tipos de usos y cobertura de vegetación natural de las cuencas de Ilhabela (Fundação Florestal, in press).

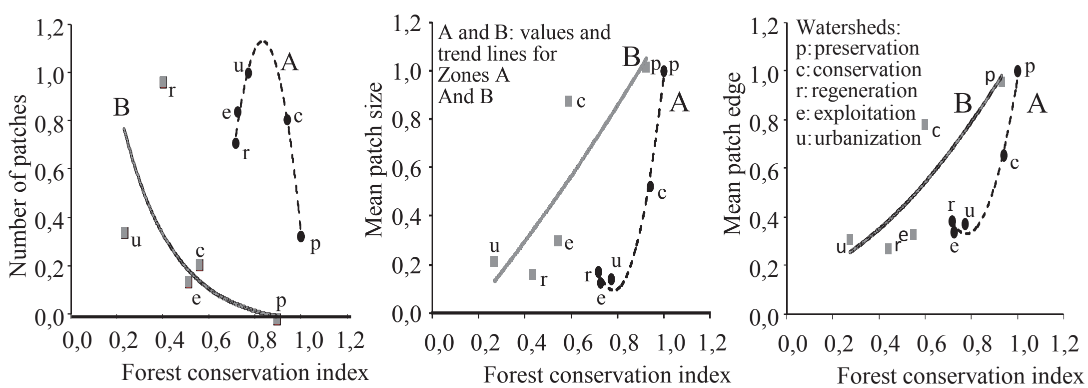

Figure 3. Relationship between forest conservation index and landscape metrics for watersheds in five evolutive phases.
Relación entre el índice de conservación de bosque y las métricas de paisaje para cuencas en cinco fases evolutivas.

The forest conservation index (CI) showed a high correlation ($R^2 = 0.95$) with the dominant classes in the A zones. For B zone, the IC exhibited a low value of R^2 probably caused by high landscape fragmentation. Except for preservation's phase, the CAPD for B zone to conservation, regeneration and exploitation phases were represented by vegetation in early stages. For urbanization's phase the human interference was the dominant class (figure 5).

DISCUSSION

The mapping shows that the presence of the Ilhabela State Park (PEIB) is fundamental to keep the more advanced stages of forest succession in larger areas (figure 2), corroborating the information described by Bertolo *et al.* (2010).

The second order polynomial regression between most of the metrics and forest conservation index of watershed

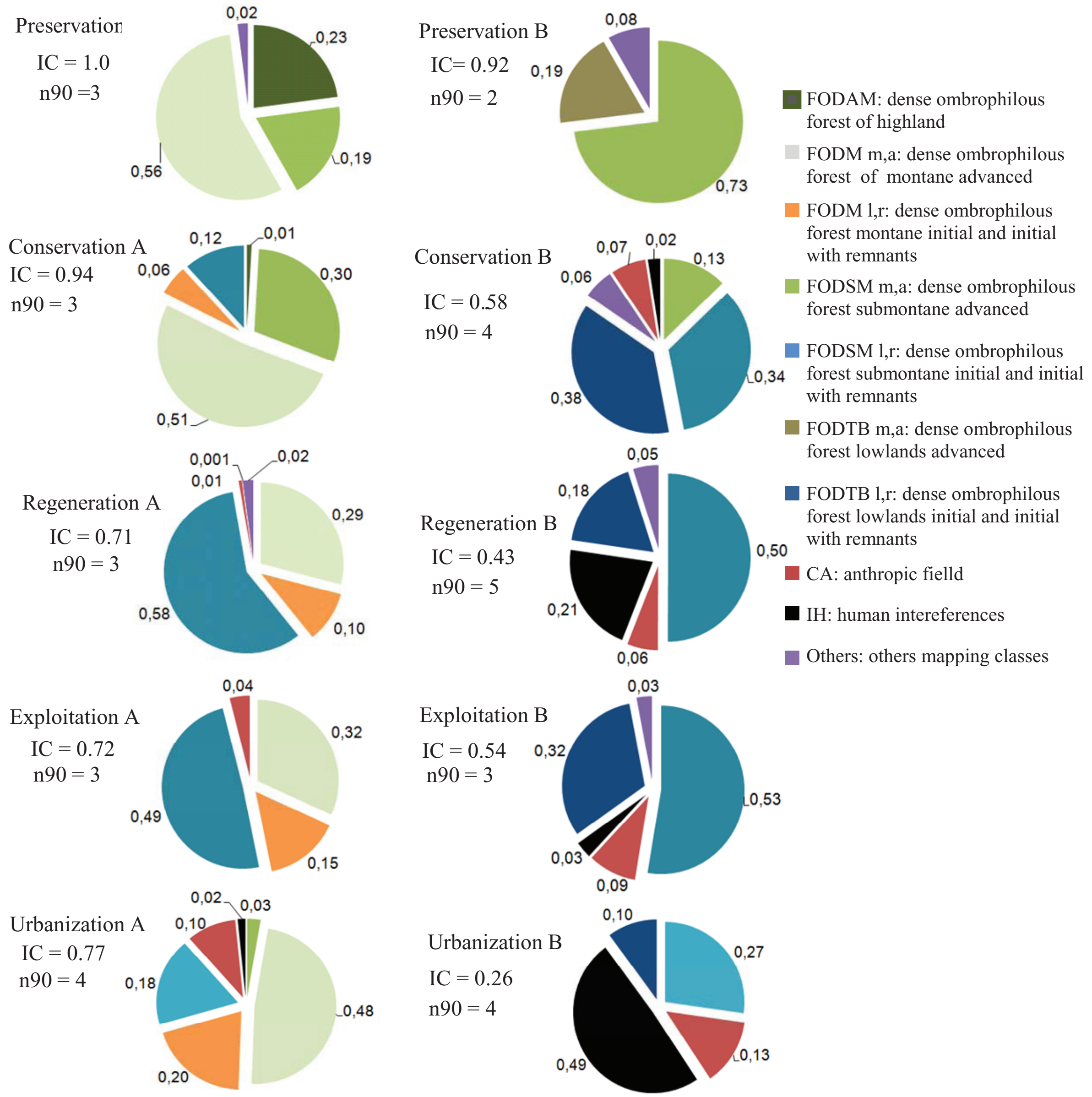

Figure 4. Class area proportion for zones A and B of watersheds. IC: forest conservation index; n90: number of mapped classes to cover 90 % of the landscape.

Proporción de clases de áreas para las zonas A y B de las cuencas. IC: Índice de conservación de bosque; n_{90}: número de clases mapeadas para cubrir el 90 % del paisaje.

indicates the existence of an inflection point, from which the increased quality of the forest can cause significant changes in metrics. This could indicate the existence of a critical amount of forest, on the São Sebastião Island, necessary for proper maintenance of ecological processes. This value for A and B area is in the range 618-704 ha and 63-72 respectively, about 70-80 % of forest cover.

The regression between forest conservation index of watershed and metrics shows that there is a significant degree of fragmentation in B zones of the watersheds, and most representative in the regeneration phase, resulting in major changes in biological processes and the existence of a strong relationship between the boundaries and the general state of forest conservation.

The class area proportion - for reporting the abundance of each type of land use - is one of the simplest metrics to analyze the landscape (Botequilha-Leitão *et al.* 2006) when different landscapes are compared. Thus, it is observed that in relation to watersheds in phases of urbanization and regeneration, the great diversity of types of land uses is indicative of high landscape fragmentation, resulting in a wide variety of environments. This could cause losses of habitat, decreases in environmental quality, and consequent reduction in resources available for the species

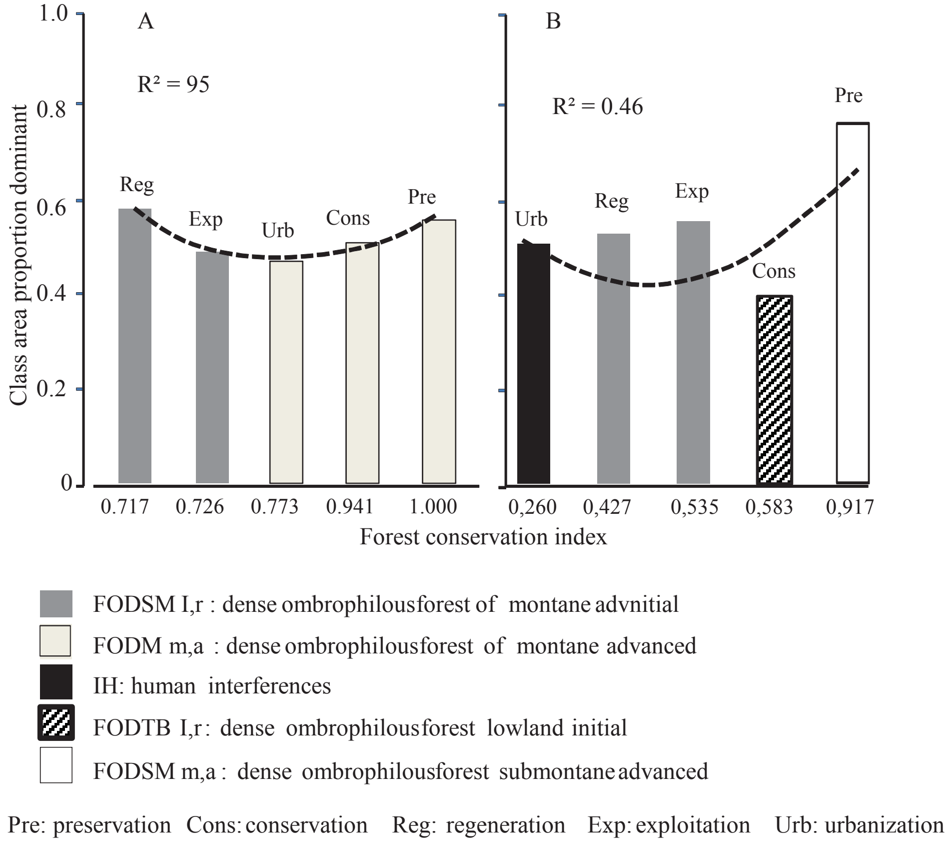

Figure 5. Relationship between forest conservation index and the dominant class (CAP) for zones A and B of watersheds.
Relaciones entre el índice de conservación de bosque y las clases dominantes (CAP) para las zonas A y B de las cuencas.

(Botequilha-Leitão *et al.* 2006). For the regeneration phase, the class area proportion as well as metrics reflecting a conflict with historical classification, indicating that the classification made by Bertolo *et al.* (2010) in this watershed should be reviewed in relation to 2009.

Despite the visible loss of watershed quality in the regeneration phase, it can be assumed that in current times, there is sufficient environmental quality for the maintenance of biodiversity, especially because of the dominance of herbaceous/shrub species. Those species are few and are fast growing between ten and thirty years (Veloso *et al.* 1991). Thus, although "FODSMI,r" represents the largest area in watershed, this vegetation could not reach its succession climax, making it more vulnerable to human activities and natural processes of weathering.

The forest conservation index of watershed shows a high correlation with the dominant classes determined by the class area proportion in zone A (figure 5), represented by the forest in advanced stages of succession, especially in the urbanization phase. This phase presents a greater amount of vegetation with a better quality when compared with the regeneration and exploitation phases, despite being more fragmented in zone A than the other two watersheds.

For zone B (figure 5B), the low value of R^2 for the forest conservation index of watershed could be due to high fragmentation of the landscape and a high variety of mapped classes. In this zone, the class area proportion for conservation, regeneration, and exploitation phases are represented by the vegetation in the early stages while for the urbanization phase, the human interference is the dominant class.

CONCLUSIONS

The sum of information between the mean patch edges, mean patch size, class area proportion and number of patches metrics identifies the increase of fragmentation caused by human actions between watersheds at different stages of human influences throughout history. This can be observed mainly below 100 m altitude, with an emphasis on the regeneration phase.

The data indicates that there is a forest critical amount for São Sebastião Island that may vary from 618-704 ha and 63-72 ha (around 70-80 %), respectively, A and B zones. This amount is necessary for proper maintenance of ecological processes and ecosystem services.

ACKNOWLEDGMENTS

This research was funded by CAPES (Coordination for the Improvement of Higher Level -or Education-

Personnel) and CNPq (National Council for Scientific and Technological Development). We would also like to thank for the Foundation Forest-Brazil, the administration of Ilhabela State Park.

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Aceptado: 24.05.12
Recibido: 10.10.12

BOSQUE 33(3): 359-362, 2012 DOI: 10.4067/S0717-92002012000300022

Recognizing vegetation chronosequence in Landsat imagery

Reconocimiento de la secuencia cronológica de la vegetación en imágenes Landsat

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SUMMARY

This paper presents a description of an algorithm of automated identification of forest regeneration stages using a spatial analysis of Landsat-5 TM imagery and field data. Based on this algorithm, several raster maps were built to show the vegetation regeneration stages in a range of habitat types found in southern Yenisey Siberia.

Key words: remote sensing data, GIS, forest regeneration dynamics map.

RESUMEN

Este trabajo presenta la descripción de un algoritmo que permite identificar automáticamente los estados de la regeneración del bosque usando un análisis espacial de imágenes *Landsat*-5 TM y datos de campo. Basándose en este algoritmo, varios mapas raster fueron creados para mostrar los estados de la regeneración de la vegetación en un rango de tipos de hábitat encontrados en el sur de Yenisey, Siberia.

Palabras clave: datos de sensores remotos, SIG, mapa de dinámica de regeneración forestal.

INTRODUCTION

Siberian boreal forests have been drastically altered over the past sixty years by increasing logging activity, industrial projects, areas burned by wildfires, and devastated by pest outbreaks. These alterations have resulted in a deep disturbance of forest ecosystem equilibrium and have induced forest biodiversity and ecological function reduction. This necessitates the development of new methodologies of forest resource recovery estimation and prediction (Pontus 2005).

Maps created using traditional methods become out of date very soon. At present, creating new or updating old maps involves the use of satellite images and GIS (geographic information system) technologies in combination with traditional mapping methods. We have developed a methodology of automated recognition of forest regeneration stages based on a spatial analysis of remote sensing and ground data. Recognition accuracy mainly depends on the spectral characteristics of a given surface provided by the same space-borne instrument and the image classification algorithms applied; different woody species are recognized with different confidence levels. The major problem here is that spectral characteristics of many vegetation types overlap making hampering their differentiation. While deciduous species are easy to segregate from dark conifers, the segregation becomes problematic where light conifers come in. In this case the differentiation between species close in their spectral characteristics, as for example, between *Picea obovata* (Ledeb.) (spruce) and *Abies sibirica* (Ledeb.) (fir), *Pinus sylvestris* L. (pine) and *Larix sibirica* (Ledeb.) (larch), *Betula pendula* Roth (birch) and *Populus tremula* L. (aspen), is usually not possible (Napryushkin 2002). To recognize woody species composition, it is reasonable to use diverse moderate-resolution images received from the same instrument and to involve various data from other sources for image detailing (Maslov 2005).

Automated recognition requires the identification of elementary forest vegetation sites similar in woody species composition and age, which are referred to as community type. Each elementary site (or elementary unit) represents a certain vegetation age stage and is used to build a vegetation chronosequence (Kolesnikov 1956, Ryzhkova 2007).

METHODS

We selected the southern part of Yenisei Siberia as the test site. This extremely topographically non-uniform area encompasses a plain part of West Siberian Lowland west of and the low mountains of Yenisei Mountain Ridge and Usol Hollow east of Yenisei. The test site vegetation cover is composed of subtaiga forests broken in places by forest-steppe sites and croplands. The forest communities are diverse regarding woody species composition, structure, and regeneration characteristics. These forests have been heavily disturbed by human activities and all stages of the major woody species regeneration are, therefore, found across vast areas in a wide range of habitats.

We analyzed satellite images in a stepwise way, with GIS technologies and the standard procedures of ERDAS IMAGINE 9.2 and ESRI ArcMap 9.3 being applied at each step.

Satellite data processing involved several stages. The first stage was preliminary data processing that included image geometrical correction and transformation to a desirable map projection, georeference, as well as topographic normalization. The images were converted into the basic map projection (UTM zone 46) to be then superposed on the forest fund data layer for a spatial analysis. To artificially equalize the extents of slope insolation, the images were topographically normalized using SRTM-3-DEM. The images were then combined to obtain multitemporal image.

At the second stage, reference samples for the supervised image classification were formed, based on the results of a joint analysis of the images and vector maps of elementary forest inventory sites (Korets *et al.* 2007). In effort to create reference samples, the main statistical indicators were calculated for each elementary forest inventory site using the set of the pixels of the image raster layers that occurred within a given elementary forest inventory site. Prior to this operation, elementary forest inventory site marginal pixels were discarded to reduce the effect of the map superposition-caused error.

The similarity of elementary forest inventory sites was judged from the standard deviation of remotely-based attribute values of elementary forest inventory sites. The final ranking of elementary forest inventory sites by similarity was done by crossing the sets of elementary forest inventory sites, which appeared to be relatively similar in most attributes. The elementary forest inventory sites most similar in spatial structure were included into the model sample.

The selected set of the relatively similar elementary forest inventory sites was based upon to form information class samples for the following image classification by major woody species and ages. Each information class had several corresponding elementary forest inventory sites, the contours of which were used to identify training sample boundaries. These samples were then based upon to calculate information class parametric signatures for the following image classification through training.

At the third stage, the satellite images were classified by the method of maximum likelihood and generalized using a fuzzy composition approach considering the contextual information on pixel interlocation (ERDAS 1999). Finally, the classes obtained were interpreted by an expert as forest vegetation age or regeneration stages with the help of forest inventory data.

To correctly classify and understand the position of any one vegetation type in a vegetation chronosequence and to assess its current state, one needs to know the habitat characteristics controlling the probability of occurrence of any vegetation community type. To build a forest vegetation chronosequence layer, an expert classification based on the Knowledge Engineering Module (ERDAS 1999) was developed. The results of the analyses of the satellite images and habitat raster layer (Ryzhkova *et al.* 2011) were used as the input data for building the expert classification.

RESULTS

Using the above methods, we developed a classification of forest vegetation. To do this, we used four summer (June-July) and four autumn (September-October) cloud-free Landsat 5 (TM) scenes (1989-1990 years) received as close as possible to the periods of field studies and ground forest inventory.

The selected images were converted into the basic map projection and topographically normalized. The normalized images were then combined to obtain four 12-band multitemporal images, each consisting of six bands of a summer image and six bands of an autumn image. We excluded the thermal band from each set of initial seven bands of Landsat 5 (TM) images.

To classify multitemporal images, the training samples for major woody species and age were made. Moreover the training samples were made so that minor woody species be also considered. Secondary (*i.e.*, disturbance-induced deciduous) stands were analyzed based on the major woody vegetation spread trends. The deciduous stands containing a minor component of dark conifers were concluded to be secondary stands characteristic of dark conifers, whereas the stands containing Scots pine were concluded to replace light conifer forest where it had been disturbed. The information classes were formed through the elementary forest inventory site inventory database query. As a result, the information classes most common in a given part of the test site and the associated image were developed.

Then parametric signatures were calculated for each information class and a supervised classification of the images was done based upon these signatures. A generalized raster layer of surface spectrum-based elementary land cover classes was obtained using a fuzzy composition approach. The classes obtained were then visually assigned to the different forest regeneration stages by expert judgment with the help of all the available reference data (table 1).

A single classified image did not cover the entire test site and the overlapping images from either adjacent satellite pass were, therefore, used. Training samples for the overlap zone were developed automatically within the corresponding base image classes. Each image was classified separately to reduce effects of pixel spectral brightness variation among the images caused by certain vegetation phenophases and all kinds of atmospheric interferences.

To obtain a uniform class mosaic, all the classified ima-

Table 1. Forest vegetation classes interpretation.
Interpretación de las clases de vegetación boscosa.

Forest vegetation chronosequence	Forest regeneration stages	Information class (major woody species and age)
1. Scots pine/ tall grass/forb stands supported by dark-colored sod forest soils and dark-grey loamy forest soils occur in watersheds and on the adjacent very soft slopes	initial regeneration stages of light conifers	birch_aspen_initial_stage
	young and middle-aged deciduous stands, which replaced light conifers	birch_aspen_5_20 (pine) birch_aspen_20_40 (pine)
	40-80-yr-old mixed light conifer/ deciduous stands	pine_40_90_birch_60-80 birch_aspen_ (40-80)_pine >120
	80-120-yr-old light conifer stands	pine_80_100 pine_80_120_birch_>50
	over 120-yr-old light conifer stands	pine_ larix _>120
2. Fir/spruce/tall grass/forb stands supported by dark-colored sod forest, dark-grey, and double-humus-horizon moderately loamy sod-podzolic soils on flat-topped elevations and the adjacent soft slopes of an accumulative high plain 3. Mixed fir/spruce/grass stands on sod-podzolic and grey forest soils on an accumulative high plain slopes	initial regeneration stages of dark conifers	birch_aspen_initial_stage
	young and middle-aged deciduous stands, which replaced dark conifers	birch_fir_10_20 birch_aspen_10_40 (fir) aspen_birch_20_40 (fir)
	40-80-yr-old mixed light conifer/ deciduous stands	fir_spruce_60-80_birch_60_90 birch_aspen_ 40-60 (fir) birch_aspen_60_80 (fir)
	80-120-yr-old dark conifer stands	fir_spruce_80_120_birch_70_100
	over 120-yr-old dark conifer stands	spruce_fir_>120

ges were assembled in a certain sequence to ensure the best possible spatial superposition of overlapping classes.

To build a forest vegetation chronosequence layer in a stepwise manner we made the expert classification using the Knowledge Engineering Module. The elementary land cover classes obtained from remote sensing data classification were distributed among chronosequences (table 1) using a classification of habitat types and the associated forest vegetation (Ryzhkova *et al.* 2007).

Combined use of ground and remote sensing data, thematic maps, and DEM provided an overall picture of the forest communities found in southern Yenisei Siberia and made it possible to develop GIS layers of the vegetation age stages and chronosequence for this area (figure 1). Multitemporal images enabled to determine not only the major woody species and its age, but also secondary stand confinement to either dark or light conifer forest.

DISCUSION AND CONCLUSIONS

There exists neither uniform vegetation classification, nor satellite imagery-based vegetation cover map for Krasnoyarsk Region. The only forest vegetation maps in use nowadays are a 1:7 500 000 map in the Atlas of Krasnoyarsk Region and the Republic of Khakasia (Doykhon 1994) and a 1:1 500 000 USSR Forest Map (1973) containing out-of-date information. The forest regeneration dynamics map we developed through application of ground and satellite data for the southern part of Yenisei Siberia, which occurs within Krasnoyarsk Region, is of a scale of 1: 100 000. This map based on the dynamic forest type classification shows the vegetation by altitudinal vegetation belt, topography, and soil moisture regime, combines the major-species and secondary stands into genetic forest types, enables to assess current state of forest vegetation, and to predict its future recovery rate for as long as 200 years, which is the full logging rotation period in southern taiga forests.

As is clear from Kappa statistic = 0.74, the satellite imagery classification quality corresponds to the excellent object recognition accuracy (Monserud and Leemans 1992). Therefore, the methodology proposed enables to achieve a relatively high accuracy of recognition of forest communities found in a range of environmental conditions. The automated satellite image classification combined with spatial analysis procedures, allow us to minimize human involvement in the process of thematic map development.

Scientific interest to classifications reflecting vegetation cover trends has increased over the past several decades due to ever-increasing forest transformations (Ivanova 2011). Russian scientists also participate in this research area. However, no such type of work is underway in Krasnoyarsk Region. For this reason, the characteristics of forest regeneration dynamics determined in this study for plain and low-mountain southern taiga forests are unique as to the level of detail and can be extrapolated to the same landscape types found within central Siberia to model forest succession in a similar range of environmental conditions.

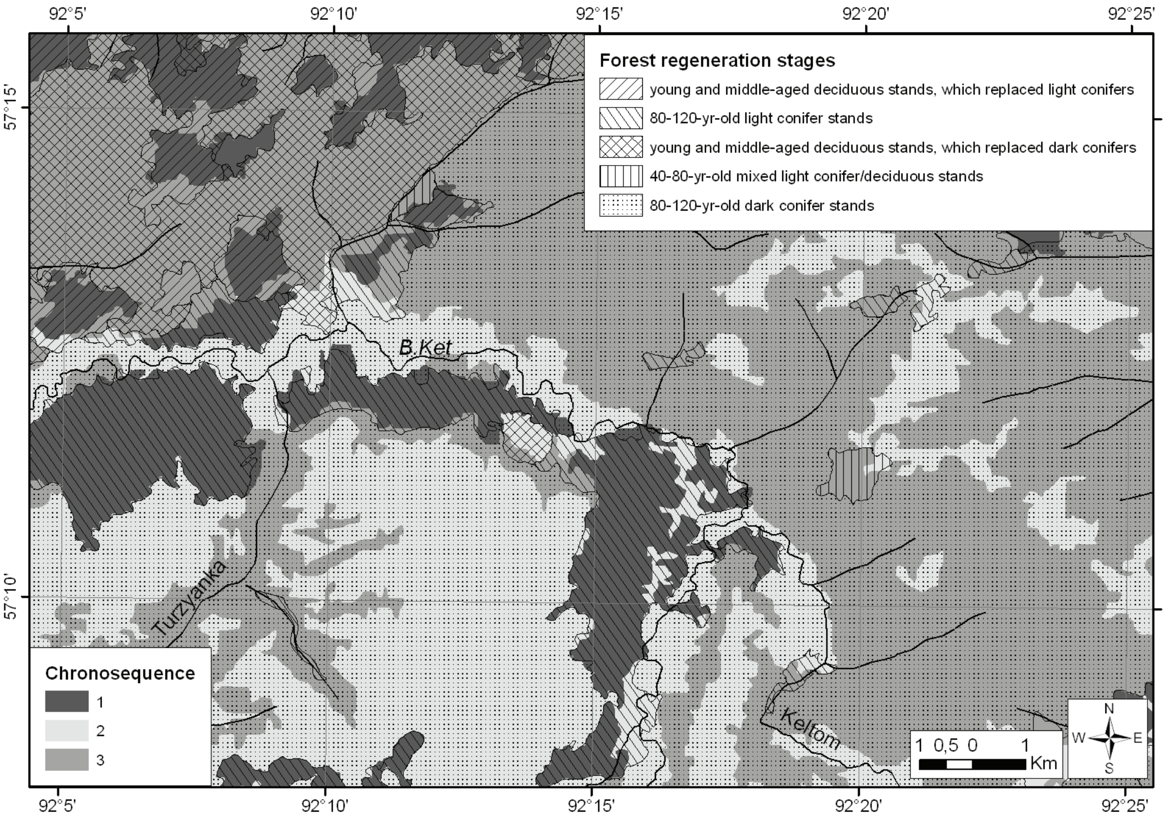

Figure 1. Fragment of two layers of the study area forest dynamics map.
Fragmento de dos capas del mapa que muestra la dinámica de bosques del área de estudio.

ACKNOWLEDGEMENT

This work was supported by Russian Fundamental Research Foundation Grants 10-05-00941-a, 11-04-98008-P_Siberia_a, Project ZAPAS (Assessment and Monitoring of Forest Resources in the Framework of the EU-Russia Space Dialogue) and project N° 27.32 program of the Presidium RAS.

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Recibido: 24.05.12
Aceptado: 10.10.12

BOSQUE 33(3): 363-366, 2012 DOI: 10.4067/S0717-92002012000300023

Spatial-functional pattern of ecotonal riparian landscapes on Meridional Plateau, Southern Brazil

Patrones espacio-funcionales de paisajes ribereños ecotonales en el Plató Meridional, en el sur de Brasil

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SUMMARY

This study analyzes the Pitangui and Jotuba riparian zonesinthe Meridional Plateau, to create a landscape model of forest/field riparian ecotones. The areas were delineated from 2001 orthophotos (1:10,000), including all native vegetation in flooding limits of the lotic channels. The landscape units (UP) were represented by the Alluvial Ombrophilous Mixed Forest metacommunity (FOMA) including as phytocoenosis both the riparian woody forest (FR) and hydrophilous vegetation (VH). Landscape metrics and statistical treatment were used to characterize landscapes and patches. To evaluate the FR patches we presumed a 30 m edge. The Pitangui River (1,072 ha) has double the riparian area of Jotuba River (539 ha), although proportionally both were UPs equivalent (40 % of FR and 60 % of VH). Both rivers have a large number of small rounded patches and relatively few large areas that trend to more complex and irregular shapes as the area increases. Also smaller patches are more spatially heterogeneous than the larger ones, and more aggregated along the river channel. 60 % of FR area on both rivers is under an edge effect: Pitangui has 91 core areas linked by 69 corridors and the Jotuba River has 53 core areas with 47 corridors. In the riparian zones, VH areas occupy the flood plains showing higher variability in size and spatial distribution. This summarizes the natural fragmentation of the riparian vegetation of regional rivers in Southern Brazil.

Key words: landscape ecology, Campos Gerais, landscape metrics, natural fragmentation.

RESUMEN

Este estudio analizó las zonas ribereñas de Pitangui y Jotuba en el Plató Meridional con el fin de crear un modelo de paisaje para ecotonos ribereños de bosques/pradera. Las zonas fueron delimitadas con ortofotos de 2001 (1:10.000), incluyendo toda vegetación nativa en los límites de inundaciones de los canales lóticos de los ríos Pitangui y Jotuba. Las unidades de paisaje (UP) estuvieron representadas por la meta comunidad de bosques mixtos aluviales ombrófilos (FOMA) con fitocenosis del bosque ribereño (FR) y vegetación hidrófila (VH). Se utilizaron métricas de paisaje y herramientas estadísticas para caracterizar los paisajes y los fragmentos. Para la evaluación de FR se asumió un borde de 30 metros. El río Pitangui (1.072 ha) presentó el doble de la zona ribereña que el río Jotuba (539 ha), aunque proporcionalmente ambos eran equivalentes UP (40 % de FR y 60 % de VH). Ambos ríos tienen gran número de pequeños fragmentos redondeados y relativamente pocas áreas grandes tendiendo a formas más complejas e irregulares al aumentar el área. Los fragmentos más pequeños fueron espacialmente más heterogéneos que los mayores y más agregados a lo largo del canal de río; 60 % del área de FR en ambos ríos está bajo el efecto de borde. Pitangui tiene 91 áreas centrales vinculadas por 69 corredores y el río Jotuba tiene 53 áreas centrales con 47 corredores. En las zonas ribereñas, las áreas de VH ocuparon las llanuras de inundación y mostraron la mayor variabilidad en tamaño y distribución espacial. Estos resultados resumen los patrones de fragmentación natural de la vegetación ribereña de los ríos regionales en el sur de Brasil.

Palabras clave: ecología de paisaje, Campos Gerais, métricas de paisaje, fragmentación natural.

INTRODUCTION

The detection of patterns in the arrangement and structure of the mosaic helps to understand the functional movements and flows through the landscape (Forman 1995). Creating models start with patterns identification and, among the Brazilian landscapes, riparian zones are often the focus on conservation. For Turner (2005) and Landeiro and Magnusson (2011), one of the main methodological problems in Landscape Ecology is the lack of replicated sites that share a pattern of spatial distribution, which provide a statistical basis of the properties and behavior of the patterns identified. This study analyzes the riparian zones in Pitangui and Jotuba rivers in the Meridional Plateau in Paraná State, in an attempt to build a landscape model in forest/field riparian ecotones by an internal data evaluation of its structural and functional integrity throughout connectivity.

METHODS

The study area was located in the Devonian Cuesta in Paraná State. This region is recognized by Probio (MMA 2002) as high and extremely high conservation importance. The river channels of Pitangui and Jotuba cross large floodplain areas. The riparian zones were delineated from orthophotos of 2001 (1:10,000), including native vegetation in flooding limits of the lotic channels (Attanasio *et al.* 2006, Arizpe *et al.* 2008). The anthropogenic areas were not considered in these riparian zones. The landscape units were represented by the alluvial ombrophilous mixed forest metacommunity (Veloso *et al.* 1991) including as phytocoenosis the riparian woody forest along the marginal deposits, and hydrophilous vegetation in the flooding surfaces.

This investigation was conducted at the landscape level, analyzing their composition gradient, number of patches, use diversity, aggregation, and structural connectivity. The patches were analyzed parametrically by media and standard deviation, including vegetation type, size of patches, shape, core area, and spatial disposition.

Riparian landscapes and patches were characterized by landscape metrics and statistical method, using the softwares FRAGSTATS v. 3.3 (McGarigal and Marks 1995) and PAST (Hammer 1999).

The riparian woody forest patches were classified in landscape elements (core areas, edges, bridges, branches and islets) using Morphologic Spatial Patterns Analysis (MPSA) method by software GUIDOS 1.3© Peter Vogt, EC-JRC (Vogt 2010) adopting a 30 m criteria as edge depth.

RESULTS

The Pitangui River had a 1,072 ha riparian area distributed in 95 riparian woody forest and hydrophilous vegetation patches, almost double that of the Jotuba riparian area, with 539 ha and 65 patches, although proportionally both were landscape units equivalent ($P < 0.05$). In the Pitangui we found 34 fragments of riparian woody forest (41 % of the riparian zone) and 61 fragments of hydrophilous vegetation (59 %). In the Jotuba River, we delineated 19 fragments of riparian woody forest (40 %) and 46 fragments of hydrophilous vegetation (60 %).

Both rivers had a large number of small patches and relatively few large areas. The Spearman's correlation between area and shape index (AREA/SHAPE), and area and fractal dimension (AREA/FRACT), for riparian woody forest (Pitangui r_s = 0.85 and 0.80; Jotuba r_s = 0.90 and 0.87), and for hydrophilous vegetation (Pitangui r_s = 0.75 and 0.62; Jotuba r_s = 0.78 and 0.61), shows that trend to more complex and irregular shapes as the area increased.

There were 91 core areas (177 ha) in riparian woody forest of the Pitangui, linked by 69 bridges, 93 branches, and 19 islets (figure 1). In the riparian woody forest of Jotuba, there were 53 core areas (86.2 ha), 47 bridges, 296 branches, and 11 islets (figure 2). 40 % of the riparian woody forest area is under edge effect of both rivers.

In the riparian zones, riparian woody forest was along the active river channel while hydrophilous vegetation areas occupy the flood plains with high variability of size and spatial distribution. The longitudinal flows had higher importance for functional integrity of riparian forests, although lateral flows appeared to be more important for hy-

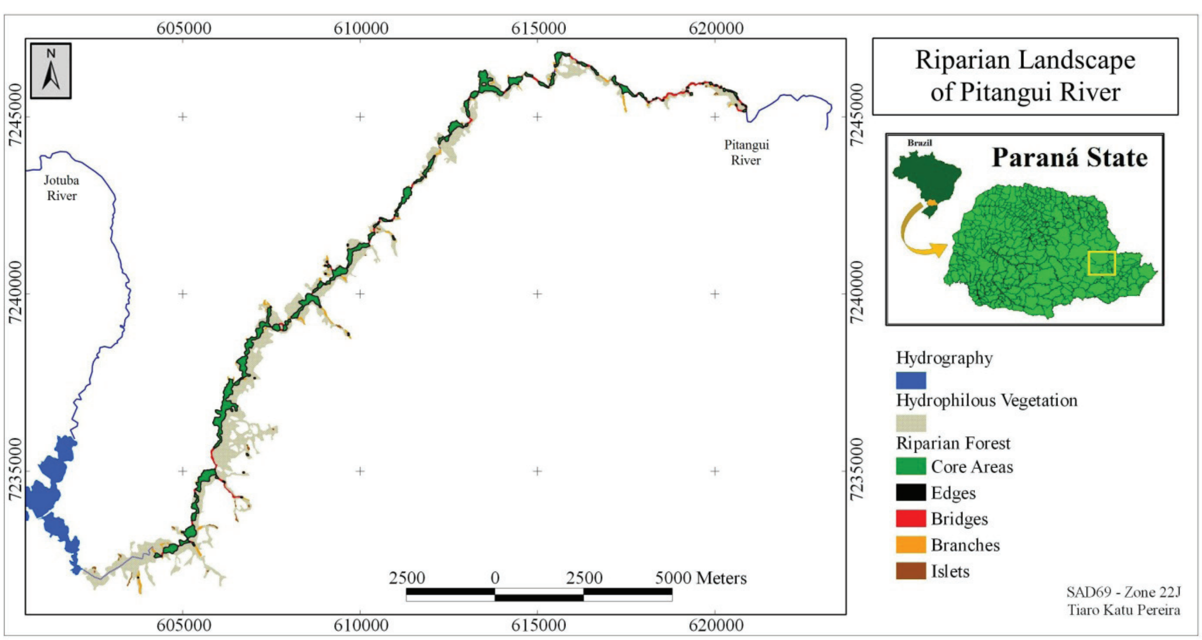

Figure 1. Landscape elements of Pitangui River, Paraná State, Southern Brazil.
Elementos del paisaje del río Pitangui, Estado de Paraná, sur de Brasil.

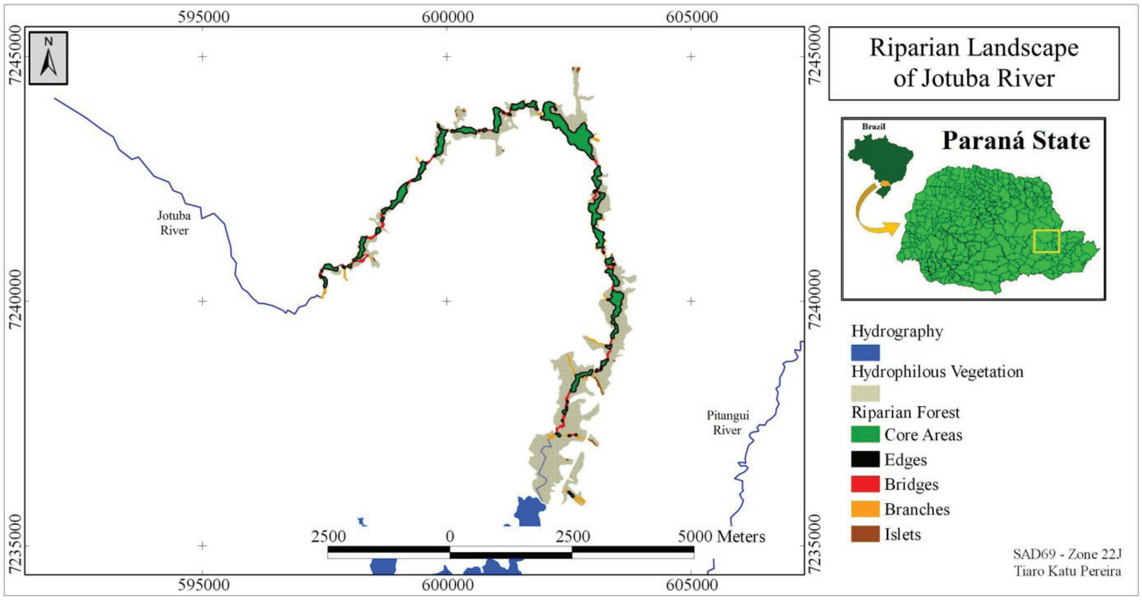

Figure 2. Landscape elements of Jotuba River, Paraná State, Southern Brazil.
Elementos del paisaje del río Jotuba, Estado de Paraná, sur de Brasil.

drophilous vegetation. Smaller patches are more spatially heterogeneous than the larger ones, and more aggregated along the river channels (tables 1 and 2).

DISCUSSION AND CONCLUSIONS

There are different patterns in the landscape related to relief, but the landscape elements are similar in both rivers (c^2 $P < 0.0001$). In both, 60 percent of riparian areas is hydrophilous vegetation. The analysis pointed at the importance of including wetlands in riparian analysis in Pitangui and Jotuba rivers. The federal law protects only 30 meters of both sides no matter their declivity or flood extension, and is insufficient to protect all wetlands of those rivers (Attanasio *et al*. 2006).

The fragmentation processes, as shown by the spatial distribution of the evaluated areas, were mainly natural. Connectivity indices were low due to the linear riparian

Table 1. Connectivity indices of Pitangui River, Paraná State, Southern Brazil. Indices: size class (ha), NP: number of patches, PROX: proximity index, ENN: euclidean nearest-neighbor distance (m), SD: standard deviation.
Índices de conectividad del Rio Pitangui, Estado de Paraná, sur de Brasil. Índices: clases de tamaño (ha), NP: número de fragmentos, PROX: índice de proximidad, ENN: distancia euclidiana al vecino más cercano (m), SD: desviación estándar.

Class	Riparian forest					Hydrophilous vegetation				
	NP	PROX	SD	ENN	SD	NP	PROX	SD	ENN	SD
< 1.0	23	765.6	1,769.8	134.1	186.6	17	146.8	318.3	57.3	37.3
1.0-9,9	5	2,763.6	6,177.6	87.6	56.0	33	317.6	633.7	62.8	45.7
10.0-49,9	3	1,886.7	2,494.3	22.6	9.2	8	286.8	341.9	89.0	160.3
> 50.0	3	14,720.9	13,849.8	9.3	2.3	3	74.6	86.9	38.9	17.1

Table 2. Connectivity indices of Jotuba River, Paraná State, Southern Brazil.
Índices de conectividad del rio Jotuba, Estado de Paraná, sur de Brasil.

	Riparian forest					Hydrophilous vegetation				
Classes	NP	PROX	SD	ENN	SD	NP	PROX	SD	ENN	SD
< 1.0	10	660.0	1,761.7	124.9	147.1	19	65.8	152.8	70.4	71.0
1.0-9.9	4	2,284.6	4,042.1	162.6	279.0	21	196.6	260.9	59.6	57.3
100-49.9	3	12,490.1	10,353.2	9.1	3.8	5	473.5	827.8	71.7	101.9
> 500	2	5,733.2	7,646.0	5.2	1.1	1	518.0	0.0	25.5	0.0

disposition of patches. The analysis revealed patterns of fragmentation and distribution of landscape elements, but to establish riparian landscape models for FOMA is important to extend the analysis to other rivers or segments (Turner 2005).

ACKNOWLEDGMENTS

We sincerely thank Dr. Milton Cesar Ribeiro for discussions in this work; the State University of Ponta Grossa (UEPG) and the Brazilian Ministry of Education (CAPES) for financial support.

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Recibido: 24.05.12
Aceptado: 10.10.12

Instrucciones para los autores de la revista Bosque, proceso de publicación y políticas para los árbitros

Actualización de fecha: agosto 2011

Instrucciones para los autores

Bosque es una revista científica que publica trabajos originales relacionados con el manejo y producción de recursos forestales, ciencias y tecnología de la madera, silvicultura, ecología forestal, conservación de recursos naturales y desarrollo rural asociados con los ecosistemas forestales. Las fechas de publicación son en abril, agosto y diciembre de cada año. Las contribuciones podrán ser en las modalidades de artículos, revisiones, notas u opiniones, en castellano o inglés.

- *Artículos.* Informan acerca de investigaciones inéditas de carácter científico que proyectan el conocimiento actualizado en un campo particular contemplado en los ámbitos de la revista y están sustentados en datos procedimentales propios o generados a partir de otros estudios publicados. La extensión máxima de los manuscritos será de 8.000 palabras, considerando todo su contenido (incluye todos los archivos del manuscrito con sus contenidos completos).
- *Revisiones.* Síntesis y discusión de la información científica más actual con respecto a un tema relevante en el ámbito de la revista. La extensión máxima de los manuscritos será de 8.000 palabras, considerando todo su contenido.
- *Opiniones.* Analizan, desde un punto de vista personal o con apoyo bibliográfico, un tema de actualidad relacionado con el carácter de la revista. La extensión máxima de los manuscritos será de 3.000 palabras, considerando todo su contenido.
- *Notas.* Describen metodologías o técnicas nuevas en el ámbito de la revista, o bien informan acerca de investigaciones en desarrollo, con resultados preliminares. La extensión máxima de los manuscritos será de 3.000 palabras, considerando todo su contenido.

Estructura de los manuscritos

La organización de artículos y notas debe seguir la siguiente estructura:

- *Título*. El título debe ser preciso y conciso. Elegir con mucho cuidado todas las palabras del título; su asociación con otras palabras debería ser cuidadosamente revisada. Debido al acceso internacional de la revista, se recomienda incluir en el título información relevante sobre la localización geográfica del estudio cuando corresponda.
- *Autores*. Indicar el nombre y apellido de todos los autores con letras minúsculas, con las letras iniciales en mayúscula. Separar los autores con coma. Ordene cada dirección mencionando los datos necesarios, primero la institución matriz (por ejemplo, la universidad) y luego las dependencias dentro de aquella en orden decreciente (por ejemplo, facultad, departamento, laboratorio); a continuación indique la ciudad y el país de residencia del autor. Aplique el formato del siguiente ejemplo:

Nombre1 Apellido1 [a], Nombre2 Apellido2 [b]*, Nombre3 Apellido3 [a,b]

[a] Universidad Uuu, Facultad Ffff, Departamento de Dddd, Ciudad, País.

*Autor de correspondencia: [b] Instituto de Iiiii, Departamento de Ddddd, Nombre de calle y número, Ciudad, País, tel.: 56-63-221056, correo@electronico.cl

- *Resumen*. Debe contener el planteamiento del problema, el objetivo, fundamentos metodológicos, resultados y conclusiones más relevantes, con un máximo de 250 palabras. Evite descripciones largas de métodos y no incluya citas bibliográficas ni los niveles de significancia estadística.
- *Palabras clave*. Como máximo cinco palabras (puede incluir una o dos frases breves de un máximo de tres palabras) que identifiquen claramente el tema del trabajo. Se sugiere usar nuevas palabras no incluidas en el título del manuscrito.
- *Introducción.* Comprende planteamiento del problema, importancia del tema, hipótesis si compete, objetivos, alcances del trabajo y limitaciones para su desarrollo, si es que las hubo. En este capítulo se realizará una síntesis e interpretación de la literatura relacionada directamente con el título y objetivos del trabajo.
- *Métodos.* Proveerá información suficiente y concisa de manera que el problema o experimento pueda ser reproducido o fácilmente entendido por especialistas en la materia. Deberán señalarse claramente las especificaciones técnicas y procedencia de los materiales usados, sin describir materiales triviales. Los organismos bióticos deberán ser convenientemente identificados de acuerdo con las normas internacionales que correspondan. En los métodos empleados se deberá señalar claramente el procedimiento experimental o de captación de datos y los métodos estadísticos, así

como los programas computacionales. Si el método no fuese original, se indicará bibliográficamente; si fuera original o modificado se describirá convenientemente. En cualquier caso, la presentación de varios métodos será cronológica.

- *Resultados.* Incluye la presentación sintética, ordenada y elaborada de la información obtenida. Entrega resultados en forma de texto escrito con apoyo de cuadros y figuras, si corresponde, conjuntamente con análisis e interpretación de los datos. Se deberá evitar tanto la repetición de detalles dados en otros capítulos como la descripción de aquello que sea evidente al examinar los cuadros o figuras que se presenten.
- *Discusión.* Incluye la interpretación integrada de los resultados y, cuando corresponda, la comparación de ellos con los de publicaciones previas. Es un análisis crítico de los resultados de acuerdo con los objetivos y la hipótesis, si fuera el caso. Debe comentarse el significado y la validez de los resultados, de acuerdo con los alcances definidos para el trabajo y los métodos aplicados. En este capítulo no deberán repetirse los resultados obtenidos.
- *Conclusiones.* Podrán ser incluidas en un capítulo único de conclusiones o bien integradas en la discusión. En caso de presentarlas como un capítulo, se incluirán allí en forma precisa y concisa aquellas ideas más relevantes que se deriven directamente de lo aportado por el trabajo. Deben dar respuesta a las hipótesis o a los objetivos planteados en la introducción. Deben redactarse en forma clara y objetiva sin incluir citas bibliográficas. Pueden incluir recomendaciones para trabajos futuros.
- *Agradecimientos.* En este acápite se deberán mencionar brevemente a personas e instituciones que contribuyeron con financiamiento u otro tipo de colaboración para la realización del trabajo.
- *Referencias.* Se indicarán las referencias de todas las citas bibliográficas señaladas en el texto, ordenadas alfabéticamente. La precisión y la veracidad de los datos entregados en las referencias bibliográficas son responsabilidad del o los autores de las contribuciones y deben corresponder a publicaciones originales. El número máximo de referencias será de 25 para artículos, notas y opiniones, y de 40 para revisiones. Utilice literatura moderna, relevante y directamente relacionada con su trabajo. Por lo menos 2/3 de las referencias deberán corresponder a revistas científicas de corriente principal.

Para las modalidades de revisión y opinión no se exige seguir la estructura indicada anteriormente. En todo caso, deben contener las secciones de título, autores, resumen, palabras clave, introducción, el desarrollo del trabajo adecuadamente dividido en capítulos, agradecimientos y referencias.

Estilo y formato

En general, el resumen, métodos y resultados del manuscrito deberán estar redactados en tiempo pasado, y la introducción, discusión y conclusiones en tiempo presente. Use tiempo presente cuando se refiera a resultados publicados previamente, esto ayuda a diferenciar entre los hallazgos de su estudio (tiempo pasado) y los hallazgos de otros estudios. En el texto no utilice acrónimos ni abreviaturas, escriba el nombre completo de las cosas; las excepciones que se pueden utilizar son aquellas de dominio global como, por ejemplo, ADN, pH, CO_2 y muy pocas otras. Tampoco utilice en el texto los símbolos de los elementos químicos. Acate las reglas gramaticales en todo el manuscrito, incluidos cuadros y figuras.

El trabajo debe estar escrito en hojas tamaño carta (279 x 216 mm), con márgenes de 2 cm por lado, interlineado a espacio y medio, letra Times New Roman, tamaño 12 puntos, con numeración de página en el extremo inferior derecho y número de línea correlativo para todo el trabajo, a la izquierda. Separar los párrafos a renglón seguido y con sangría de ocho caracteres a la izquierda de la primera línea. Debe presentarse en archivos electrónicos con procesador de texto Word o formato RTF.

El título principal se escribirá con letras minúsculas y negritas, centrado. En él deberá omitirse la mención de los autores de nombres científicos, los que, sin embargo, se presentarán la primera vez que se mencionen en el texto a partir de la introducción. En el encabezado superior derecho de cada página debe incluirse un título abreviado con un máximo de 60 caracteres y espacios.

Las ecuaciones se numerarán en el margen derecho con paréntesis cuadrados "[ ]"; en el texto se mencionarán de acuerdo con esta numeración.

Las unidades de medidas deberán circunscribirse al Sistema Internacional de unidades (SI). En la notación numérica, los decimales deberán ser separados por coma (,) y las unidades de miles por punto (.). En los textos en inglés, los decimales separados por punto y las unidades de miles por coma. Usar cero al comienzo de números menores a una unidad, incluyendo valores de probabilidad (por ejemplo, $P < 0{,}001$).

La descripción de los resultados de cada prueba estadística en el texto debe incluir el valor exacto de probabilidad asociado P. Para valores de P menores que 0,001, indique como P <0,001. En cuadros y figuras usar asteriscos para señalar el nivel de significancia de las pruebas estadísticas: * = $P < 0{,}05$; ** =$P < 0{,}01$; *** = $P < 0{,}001$; ns = no significativo.

Debe indicarse el nombre científico de todos los organismos biológicos que aparezcan en el texto, de acuerdo con la nomenclatura internacional respectiva. Si un nombre común es usado para una especie, la primera vez que cite en el texto, a partir de la introducción, se debe dar a continuación su nombre científico en cursiva entre paréntesis, por ejemplo, coihue (*Nothofagus dombeyi* (Mirb.)

Oerst.). Citas posteriores pueden aparecer con el nombre del género abreviado seguido del adjetivo del nombre científico (por ejemplo, *N. dombeyi*), siempre y cuando no produzca confusiones con otras especies citadas en el manuscrito. Al iniciar una oración con el nombre de una especie, escriba su género completo y no lo abrevie con su inicial. En el resumen y en el título no mencione los autores de nombres científicos.

En los cuadros se deben incluir los datos alfanuméricos ordenados en filas y columnas, escritos con fuente Times New Roman de 12 puntos (mínimo 9 puntos de tamaño), sin negritas. Sólo los encabezamientos de las columnas y los títulos generales se separan con líneas horizontales; las columnas de datos deben separarse por espacios y no por líneas verticales. En las figuras se incluyen otras formas de presentación de datos o información, como gráficos, dibujos, fotografías y mapas. En cuadros y figuras se deben incluir los títulos auto explicativos en castellano e inglés numerados en forma consecutiva (cuadro 1., cuadro 2., …; figura 1., figura 2., …). Las figuras llevan el título en el margen inferior y los cuadros en el margen superior. Los cuadros y figuras deben tener una resolución tal que permitan ser reducidos sin perder legibilidad. Sólo se trabaja en blanco, negro y tonos de grises. Sin embargo, podrán usarse colores en las figuras si ello es imprescindible para su comprensión. La inclusión de figuras con colores deberá acordarse previamente con el editor. El espacio que ocupen cuadros y figuras en el trabajo deberá ser menor al 50 % del total del impreso. Incluya en el archivo de texto principal los cuadros con sus respectivos títulos, ubicándolos lo más próximo posible después de haberlos citado por primera vez en el texto. Los cuadros deben estar en el formato de tablas (editables, no como imágenes). Las figuras deben ser entregadas en un archivo aparte, con un formato editable; su ubicación en el texto principal debe ser informada, incluyendo su título, al igual que los cuadros.

En las figuras todos los rótulos y leyendas deben estar escritos con letra Times New Roman de tamaño 9 a 12 puntos, sin negrita y respetando la gramática y normas de escritura de la revista. Las figuras pequeñas deberán estar diseñadas con un ancho máximo de 8 cm (una columna en la revista) y las grandes con un máximo de 16 cm de ancho (dos columnas en la revista). Excepcionalmente, una figura podrá tener 23 cm de ancho (y máximo 14 cm de alto) para presentarla en formato apaisado. Organice las figuras reuniendo en una sola aquellos objetos afines (por ejemplo, gráficos de un mismo tipo de información) e identifíquelos con una letra mayúscula (A, B, C…), la que se explicará en el título de la figura.

Los manuscritos en castellano deben incluir en un archivo separado las respectivas traducciones al inglés de:

- Título del manuscrito.
- Summary: debe ser equivalente en contenido al resumen en castellano.
- Key words: equivalentes a las palabras clave en castellano.
- Títulos de cuadros y de figuras.

En el caso de manuscritos en inglés, se debe incluir el respectivo texto en castellano.

Citas y referencias

Las citas bibliográficas se indicarán en el texto por el apellido del o los autores, seguido del año de publicación. Algunos ejemplos de citas bibliográficas más frecuentes son:

- Citas bibliográficas de uno y dos autores:

Santamaría (2010) constata que el crecimiento...
... están influidos por el sitio en cuestión (Santamaría 2010, López y Castro 2011).

- Citas bibliográficas de más de dos autores:

Barría *et al*. (2009) señalan como factor más importante...
... entre otros, el diámetro y la altura (Barría *et al.* 2009, Morán *et al.* 2010).

- Citas bibliográficas de un mismo autor, publicadas en un mismo año:

Rodríguez (2009abd) observa que en cada unidad de muestreo...
... lo que es coincidente con estudios anteriores (Rodríguez 2009ab, Morán *et al.* 2010acd).

- Citas de más de una publicación a la vez, se ordenan cronológicamente:

Cerón (2007), García y Villanueva (2009) y Suárez *et al.* (2010) analizan los componentes edafoclimáticos...

En el capítulo de referencias, las referencias bibliográficas deben incluir apellido paterno e inicial del o los nombres de todos los autores, el año de publicación, el título y la información complementaria que permita localizar la fuente del documento en cuestión; si cuentan con DOI, debe agregarlo al final de la respectiva referencia. Algunos ejemplos de los formatos de las referencias bibliográficas más frecuentes son:

- Referencias de artículos en revistas periódicas (escriba con cursiva los nombres completos de las revistas, sin abreviar):

Guddants S. 2008. Replicating sawmill sawing with topsaw using CT images of a full-length hardwood log. *Forest Products Journal* 48(1): 72-75.

Kogan M, C Alister. 2010. Glyphosate use in forest plantations. *Chilean Journal of Agricultural Research* 70(4):652-666. DOI: 10.4067/S0718-58392010000400017.
Karzulovic JT, MI Dinator, J Morales, V Gaete, A Barrios. 2009. Determinación del diámetro del cilindro central defectuoso en trozas podadas de pino radiata (*Pinus radiata*) mediante atenuación de radiación gamma. *Bosque* 26(1):109-122.

- Referencias de libros como un todo:

Morales EH. 2005. Diseño experimental a través del análisis de varianza y modelo de regresión lineal. Santiago, Chile. Andros. 248 p.
CONAF (Corporación Nacional Forestal, CL). 2007. Estadísticas de visitantes e ingresos propios de áreas silvestres protegidas de la Décima Región de Los Lagos. 52 p. (InformeEstadístico Nº 47).

- Referencias a partes o capítulos de libros:

Gutiérrez B, R Ipinza. 2010. Evaluación de parámetros genéticos en *Nothofagus*. *In* Ipinza R, B Gutiérrez, V Emhart eds. Domesticación y mejora genética de raulí y roble. Valdivia, Chile. Exion. p. 371-390.

- Referencias a memorias, tesis, seminarios de titulación o trabajos de titulación:

Emhart V. 2006. Diseño y establecimiento de un huerto semillero clonal de *Eucalyptus nitens* (Deane *et* Maiden) con fines de producción, investigación y docencia. Tesis Ingeniero Forestal. Valdivia, Chile. Facultad de Ciencias Forestales, Universidad Austral de Chile. 79 p.
Aparicio J. 2008. Rendimiento y biomasa de *Eucalyptus nitens* con alternativas nutricionales para una silvicultura sustentable en suelo rojo arcilloso. Tesis Magíster en Ciencias. Valdivia, Chile. Facultad de Ciencias Forestales, Universidad Austral de Chile. 234 p.

- Referencias a documentos en internet:

De Angelis JD. 2009. European pine shoot moth. Oregon State University Extension (Urban Entomology Notes). Consultado 10 jul. 2009. Disponible en http://www.ent.orst.edu/urban/home.html.

Para mayor información respecto de otros casos específicos relacionados con las citas bibliográficas y referencias bibliográficas, se pueden consultar los documentos que a continuación se señalan. No obstante, el orden y la tipografía de los elementos constituyentes de las citas y referencias bibliográficas deberán ajustarse a la reglamentación de la revista Bosque.

Biblioteca Conmemorativa Orton (IICA/CATIE). 2011. Normas para citar referencias bibliográficas en artículos científicos 4 ed. Consultado13 abr.2011. Disponible en http://biblioteca.catie.ac.cr/index.php?option=com_content&task=view&id=18&Itemid=50
The Council of Biology Editors (CBE). 1994. Scientific style and format: The CBE manual for authors, editors, and publishers. 6 ed. Cambridge, New York. Cambridge University Press. 704 p.

Carta de envío

Los autores deberán acompañar su manuscrito con una carta de envío que indique que el trabajo es original, no ha sido publicado previamente y no está siendo considerado para publicación en otro medio de difusión. También deberán declarar cualquier posible conflicto de intereses que pudiesen tener. Se deberá señalar el tipo de contribución del manuscrito (artículo, revisión, opinión, nota). La carta deberá ser firmada al menos por el autor líder del manuscrito.

Envío de documentos

Los archivos deberán ser nombrados según el tipo de información contenida en el archivo. Por ejemplo, los archivos digitales del manuscrito se etiquetarán de la siguiente forma:

Texto.doc: texto principal del trabajo (incluye cuadros).
Figuras.doc: figuras con sus títulos en castellano.
Ingles.doc: textos en inglés con el siguiente orden: título del trabajo, summary, key words, títulos de cuadros y de figuras.
Carta: carta de presentación y envío del manuscrito.

Los archivos digitales del manuscrito deben ser ingresados en la plataforma de edición *on line* de eQuipu (http://www.equipu.cl/): http://www.revistabosque.equipu.cl/index.php/revistabosque. Si presenta dificultades para el envío, puede remitirlo por correo electrónico a revistabosque@uach.cl. El autor de correspondencia recibirá una carta de acuse de recibo del Editor.

Proceso de publicación

El cabal cumplimiento de las instrucciones para los autores se refleja en menores tiempos del proceso editorial. El comité editor revisa el manuscrito para verificar la pertenencia al ámbito de la revista y el cumplimiento de las instrucciones para los autores. Cuando no se cumplen tales condiciones, el manuscrito es devuelto al autor de correspondencia, informándole su situación. Cuando se ha verificado el cumplimiento de dichas condiciones, se registra esa fecha como recepción del manuscrito y el comité editor envía el manuscrito a un mínimo de dos árbitros o revisores externos, en un sistema de doble ciego.

A los árbitros se les solicita declinar la revisión de un manuscrito cuando sientan que presentan conflictos de interés o que no podrán realizar una revisión justa y objetiva. Los árbitros evalúan el manuscrito de acuerdo con la pauta que proporciona la revista. Si los árbitros o el comité editor lo estiman pertinente, podrán solicitar a los autores, a través del editor, información adicional sobre el manuscrito (datos, procedimientos, etc.) para su mejor evaluación. La respuesta de los árbitros puede ser: publicar con modificaciones menores, publicar con modificaciones mayores o no publicar. Las observaciones de los árbitros son evaluadas por el comité editor, el cual informa por escrito al autor de correspondencia la decisión de continuar o no en el proceso de publicación y si su manuscrito deberá ser nuevamente evaluado por árbitros. Cuando el manuscrito es aceptado, el comité editor envía al autor de correspondencia una carta de aceptación de su manuscrito, indicando el tipo de modificación necesaria. En no más de ocho semanas el autor de correspondencia debe devolver una versión modificada a la revista, para que el comité editor analice el manuscrito corregido. El comité editor decide el orden en que aparecerán los trabajos publicados en cada número. Una contribución puede ser rechazada por el comité editor en cualquiera de las instancias del proceso de publicación, ya sea por cuestiones de fondo o de forma que no cumplan con las instrucciones para los autores. Ante sospecha de conducta poco ética o deshonesta por parte de los autores que han sometido su manuscrito al proceso de edición, el editor se reserva el derecho de informar a las instituciones patrocinadoras u otras autoridades pertinentes para que realicen la investigación que corresponda.

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Ante cualquier duda se sugiere contactarse con el editor (revistabosque@uach.cl) o revisar la información adicional de nuestra página web www.revistabosque.cl

La versión electrónica de libre acceso de los trabajos completos publicados por Bosque se encuentran en: http://mingaonline.uach.cl/scielo.php, http://www.scielo.cl, www.equipu.cl y http://redalyc.uaemex.mx/.

Políticas para los árbitros

Los árbitros o revisores de los manuscritos son integrantes clave del proceso editorial de la revista. Tienen la misión de contribuir a que la ciencia avance a través de su aporte en garantizar la alta calidad de los trabajos antes que éstos se publiquen. Su trabajo es altruista y anónimo con respecto a los autores de los manuscritos.

El editor envía cada manuscrito a por lo menos dos árbitros que considera idóneos para el tema y así el comité editor puede considerar diversas opiniones de especialistas para decidir sobre el proceso editorial.

La responsabilidad de los árbitros es la de evaluar rigurosamente los manuscritos dentro del plazo propuesto por la revista.

Los árbitros deberán declinar la revisión del manuscrito cuando sientan que presentan conflictos de interés o que no podrán realizar una revisión justa y objetiva, los árbitros deberán declinar la revisión del manuscrito. Un arbitraje apropiado incluye virtudes y debilidades del manuscrito, sugerencias para su mejoramiento, preguntas precisas para que los autores puedan responderlas y orientaciones para que el trabajo sea de mejor calidad y mayor aceptación por los futuros lectores. Los árbitros deben mantener la confidencialidad de los manuscritos que reciben para revisión y nunca utilizar o difundir datos o información de ellos; el hacerlo es una conducta reñida con la ética. Los árbitros deberán abstenerse de solicitar la inclusión de aspectos que el manuscrito no busca responder, como también de insinuar que sean citados sus propios trabajos.

Frente a la revista, los árbitros deberán velar por la calidad y rapidez de sus revisiones y evitar los conflictos de intereses. Los árbitros deben cumplir los plazos y formatos solicitados por la revista. Cuando ello no sea posible, deberán declinar oportunamente el arbitraje. Cuando requieran de un tiempo adicional para la revisión de un manuscrito, deberán informar al editor. Si un árbitro presenta conflicto de intereses con respecto a un manuscrito, deberá abstenerse de realizar la revisión, informando al editor. Cuando un árbitro propone no publicar un manuscrito o hacerlo sólo después de cambios mayores, podrá recibir una nueva versión corregida por los autores que haya acogido las sugerencias de mejoramiento. El arbitraje es una herramienta eficaz para mejorar la calidad de los trabajos.

El editor podrá difundir informes de arbitrajes entre los revisores (conservando el anonimato) para promover el buen desempeño, resolver controversias y mejorar el proceso de edición.

Los árbitros serán informados del destino del manuscrito que revisaron. Como una forma de retribuir sus valiosos aportes, el editor les enviará una carta de agradecimiento por cada arbitraje y publicará sus nombres a inicios del año siguiente a su colaboración.

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