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What about biological corridors? A review on some problems of concepts and their management

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Abstract

Natural ecosystems are increasingly being affected by climate change and fragmentation, which have a strong impact on biodiversity thus affecting habitats and species diversity of flora and fauna at all levels. As a response to this situation the idea of biological corridors was developed.

This review relates the problems associated with the main concepts and definitions of the biological corridors, seeking to highlight the advantages of this tool and describing its potential applicability, and showing the importance of the biological corridors as a solution to improve the conservation of species and so as to support sustainable development in areas of high biodiversity. Examples of biological corridors in several countries are cited and its application guidelines and conservation benefits are described.

In conclusion, the need to improve information on habitat and its association with wild species is highlighted through adaptive forestry that is part of a comprehensive management of forest ecosystems. In addition, it is important to monitor the effects of corridors implemented in a feedback process that allows a greater analysis and evaluation of the overall positive effects of their implementation. Finally, some management actions are proposed to improve the conservation of ecosystems.

Keywords

Ecosystem management, biodiversity conservation, biological corridor, sustainability

Introduction

Human development has been changing, destroying and simplifying the coverage of the planet, splits and reducing the area of natural habitat and, consequently, transforming the landscape into a mosaic of human settlements, agricultural land, or isolated

fragments of remaining forests (Bennett 1998, Morera et al. 2007, San Vicente and Lozano 2008).

Another factor in the degradation of natural ecosystems is climate change, which will cause a change in the distribution of ecosystems and species (Locatelli and Imbach 2010), especially forests, which play an important role to mitigate climate change by acting as 'sinks' that absorb carbon from the atmosphere, by storing it in biomass and soils: However, when they are cleared or degraded, they are also a major source of emissions of greenhouse gases (FAO 2013, Romijn et al. 2015).

All mentioned above leads deforestation to be considered as a serious environmental problem worldwide. Data are clear: while in 1990, the world had 4128 million hectares (ha) of forest, in 2015 that area had decreased to 3999 million ha. This means a change from 31.6% of the global area being forest land in 1990 to 30.6% in 2015. Africa and South America experienced the highest net annual loss of forests between 2010 and 2015, however the loss compared with the previous 5 years has been mitigated (FAO 2015).

Besides the loss of forest area, the remaining forests have been intensely fragmented. It is known as forest fragmentation interruption of continuous forest area into smaller fragments with varying degrees of isolation, due to anthropogenic, natural factors and especially forest fires (Bustamante and Grez 1995, Wilson et al. 2005, San Vicente and Lozano Valencia 2006, Cagnolo and Valladares 2011, Herrera et al. 2011) affecting the habitat of wildlife species which depend on these ecosystems (distribution, abundance). All this implies a decrease in natural habitat (Hobbs 1993, Bennett 1998, García 2002, Uezu et al. 2005).

When the area of natural habitat decreases, both richness and abundance of wildlife species are reduced consequently, and the rate of local extinctions increases (Bennett 1998, Steiner and Köhler 2003, Bustamante et al. 2005) as it is the case of temperate forests´ fragmentation affecting diversity and abundance of birds living in those ecosystems (Willson et al. 1994, Sieving et al. 2000). Similarly, the isolation can reduce exchange of individuals between populations from different fragments (San Vicente and Lozano 2008) of species that require continuous forests at different altitudes (Primack et al. 2001).

In the management of forests, adjacent or nearby protected wild areas are rarely under a common management plan that makes their protection more effective. (De Graaf et al. 1998, Puth and Wilson 2001, Graf et al. 2005). For these reasons, maintenance of land as reserves of natural resources and biodiversity is a key management objective and a prerequisite for sustainable forestry, since it is necessary to understand the dynamics and heterogeneity of natural forests to provide management guidelines (Lindenmayer et al. 2000, Franklin et al. 2002), like those included in several treaties that promote the implementation of activities to ensure the conservation of biodiversity, such as the Montreal Process and the Seminar of Experts on Sustainable Development of Temperate and Boreal Forests, which mention Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests.

In order to contribute to the solution, or at least to prevent large losses of biodiversity conservation, an alternative called "biological corridors" was proposed by Wilson

and Willis in 1975. Biological corridors have since then become an interesting option to face the problem of degradation and detriment of global biodiversity. The creation of biological corridors is so intended to be the basis to meet multiple objectives such as biodiversity conservation and use of all ecosystems´ environmental services, allowing the natural resources management to be integrated with such conservation (Gilbert et al. 1998, Pardini et al. 2005, Schmiegelow 2008, Moreno et al. 2011, Cushman et al. 2013). However, the concept has been used interchangeably with the use of land and its management. The objective of this review is to propose the different approaches of biological corridor that are found in scientific literature and contribute to improve research in forest conservation and management.

Main concepts and definitions

Within the concepts of biological corridor, three definitions stand out:

1. Territorial extension of different sizes and shapes, whose main function is to connect protected areas to allow both migration and dispersal of species of wild flora and fauna (García 2002).
2. Geographical space that provides connectivity between landscapes, ecosystems and natural or modified habitats, ensuring the maintenance of biodiversity and the ecological and evolutionary processes (CCAD-PNUD/GEF 2002), whose presence is essential in mitigating fragmentation effects (Bogaert 2001).
3. It is a territory (priority area) composed of farms (private property) and protected areas and state (public properties) that aims to improve the quality of life of communities both inside and outside the biological corridors, through the education of society in conservation and sustainable management of biodiversity (CCAD-PNUD/GEF 2002).

Concepts of biological corridors are related to the sustainable management of natural resources of public or private territories, however, the biological corridors have the aim of preventing populations of vulnerable species from living in confined and inadequate spaces through of integrated management that avoids the loss of biodiversity including the framework of economic, sustainable and social development (García 2002, De Camino et al. 2008).

The main design of the biological corridors was based on the assumption that fragmented territories, when they are united by a corridor, decrease the rate of extinction of the species that inhabit it, because it reduces the levels of inbreeding, supports gene flow of animals and vegetal species, and reduces the landscape vulnerability (Beier and Noss 1998, Bennett 1998, Groom 2001, Primack et al. 2001, García 2002, Tewksbury et al. 2002, Noss 2003, Canet-Desanti 2007, Boraschi 2009, Gilbert-Norton et al. 2010, LaPoint et al. 2013, Rolle 2017)

Managing Forest

In several countries it has been assumed that the only strategy for the conservation of ecosystems and their biodiversity is the delimitation of protected areas. Taking into account the fragmentation of habitats and their adjacent critical connectivity, the objective of a biological corridor is (should be) the preservation and increase of forest cover of an area. Managements plans implemented in this area would allow planning the sustainable use of the soil, providing new knowledge about the resources, creating more stable environmental conditions, improving the resilience of the ecosystems to the disturbances, promoting the diversification of the ecosystem services, and including the practice of an adequate silviculture for woodlands. (Bennett 1998, Beauvais and Matagne 1999, Toledo 2005, Moreno 2006, Moreno 2012)

Characterization of habitats for different group of fauna species, particularly regarding endemic ones, is a primary task. Biological corridors should be designed and evaluated considering the sustainable management of the land for the conservation of biodiversity; this requires a long-term monitoring action with the combination of the economic development of human populations and the preservation of nature. Biological corridors have began to be implemented progressively in recent decades, being Costa Rica one of the countries with most biological corridors approved: Cusingos-Las Nubes (also known as Alexander Skutch corridor), Amistosa, El Quetzal Tres Colinas, Fuente de la Vida La Amistad, Río Cañas, Fila Anguciana, as well as the Mesoamericano Corridor along with Mexico and other Central American countries.

However, the policies of some countries consist principally (if not only) in interconnecting protected wild areas to safeguard the conservation of groups of endemic and / or vulnerable species, thus facing fragmentation. Examples of these cases are the Monteverde corridor in Costa Rica (Beauvais and Matagne 1999), the Guadiamar Corridor in Doñana (Spain) (Toribio Feria and Prados Velasco 2004), the Geneva Biological Corridor (Switzerland), the Noé Corridor (Australia), and the mountain ecological corridor in the Metropolitan Region (Chile). Otherwise, some studies in several countries design the biological corridor associating vegetation and wildlife habitat (Mabry and Barrett 2002, Micheli and Peterson 1999, Moreno 2012, Rodríguez-Soto et al. 2013). In these cases, the analysis of the composition, structures and different environmental factors of the habitat, together with the potential conditions of the habitat, are used to better define the design of a biological corridor, since the requirements and effects of connectivity depend to a great extent on the behavior of each species, with respect to the use of different types of landscape. The underlying idea is that only large protected areas, properly interconnected, maintain genetic exchange and, therefore, conserve biodiversity in the long term (Beier and Noss 1998).

Monitoring biological corridors

Definitions above mentioned involve of biological corridors involve designing an adequate habitat that ensures the minimum requirements of a group of fauna or flora species (CCAD-PNUD / GEF 2002, García 2002, García 2005, Moreno-García et al.

2011). The corridors established have been designed so far for a simple connectivity of ecosystems, without identifying the characteristics of the habitat that allows to define a management plan according to the requirements of the species. In summary, there are two types of biological corridors: i) corridors whose objectives are to preserve the richness of fauna and flora, together with the development of local human populations and ii) corridors whose objectives are to preserve, restore or connect as much as possible fragments of original ecosystems that limit the effects of human activities highly developed. For both groups of corridors, environmental education is highly recommended.

In addition to environmental education, it is necessary to have indicators that help monitoring the level of achievement of the objectives for which the biological corridor was designed. Several investigations have been carried out, proposing a framework for the use of the principles, criteria, and indicators in the evaluation of the implementation of the corridors, such as, actual and potential habitat use (Acosta-Jamett and Simonetti 2004, Moreno et al. 2017, Rodríguez-Soto et al. 2011, Zúñiga et al. 2009), the biodiversity index (Campos and De Finegan 2002, Duelli and Obrist 2003, Milasowszky et al. 2009), growing rate of fauna and flora populations, however the systematization of results and data for the appropriate management of the ecosystems included in the corridors is low. We believe that it is important to delimit the scale of items to be evaluated, which ensures the effectiveness of the corridors (Hernández et al. 2004).

With respect to forest management, through an adequate zoning of the areas that involve the design of a biological corridor, the management of forests and the production of goods and services, flexible forestry practices can be carried out to achieve different conditions of soil cover according to the habitats and species of flora and fauna that they inhabit, particularly those that are in a degree of vulnerability. It is important that these activities should not alter the reproductive cycles of the species. The lack of conjunction between uses and / or activities is a subject that must be improved in forest management (Moreno 2012).

Conclusions

The review presented here shows the positive value of biological corridors as a tool for sustainable land management that seeks to ensure the conservation of biodiversity in forest ecosystems.

The main conclusions of this study were: (i) Though *biological corridor* is a relatively modern concept, many definitions were found, depending on their objectives, scale, and contextualization, (ii) the achievement of the biological corridors goals should imply to make a correct diagnosis of the current situation of the factors involved in the territory to preserve, (iii) the mere protection of areas, within the frame of any biological corridor´s design, will not solve, by itself, the problem if the corridor ultimately does not fulfill its functions, including the sustainable use of its resources, (iv) the effectiveness of a biological corridor is not only due to its design, but mainly to its proper functioning, framed in plans and programs of different scope and scale on a wide territorial basis, (v) it is necessary, with the aid of adequate indicators, the monitoring of the results so that the strategy of biodiversity conservation is continuously fed-back.

Regarding the main gaps in the literature, we have noticed lack of forest management through an adaptive silviculture as an option to meet conservation and development since in protected areas like those interconnected by biological corridors, forest management can help to accomplish both ecological and social economic development through the implementation of flexible silvicultural programs adapted to legal and biophysical conditions.

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