Available online at www.sciencedirect.com
ScienceDirect
Landscape and Urban Planning 81 (2007) 328–340
LANDSCAPE AND URBAN PLANNING
This article is also available online at:
www.elsevier.com/locate/landurbplan

Edge effects of roads on temperature, light, canopy cover, and canopy height in laurel and pine forests (Tenerife, Canary Islands)

Juan D. Delgado [a,*], Natalia L. Arroyo [b], José R. Arévalo [a], José M. Fernández-Palacios [a]

[a] *Departamento de Ecología, Facultad de Biología, E-38206, Universidad de La Laguna, Tenerife, Canary Islands, Spain*
[b] *Escuela Superior de Ingeniería Civil e Industrial, Facultad de Matemáticas, E-38206, Universidad de La Laguna, Tenerife, Canary Islands, Spain*

Received 26 June 2006; received in revised form 17 November 2006; accepted 7 January 2007
Available online 8 March 2007

Abstract

The estimation of the road edge effect is useful to understand changes induced by the road network on ecosystems. Road networks on islands may break ecosystem integrity through microclimate edge effects, which are known to be associated with disturbances to animal and plant communities. Road edge effects have been scarcely studied on oceanic islands. In this paper we studied road edge effects on microclimate and canopy structure in laurel and pine forests in Tenerife (Canary Islands). We assessed depth of road edge effect for temperature at four vertical layers (soil, litter and air at 5 cm and 1.3 m above ground), light intensity, canopy cover and height, in transects running from narrow (6–7 m width) asphalt roads and dust trails to 100 m to the interior of both forests. We used an ANOVA procedure with Helmert difference contrasts to identify the distances along transects over which edge effects were significant. We detected significant gradients for most parameters but they were consistently narrow both within and between forests. In the laurel forest, we detected highly significant gradients for soil temperature, light, and canopy cover and height in both asphalt and unpaved roads. In the pine forest, we detected a highly significant gradient for soil temperature at asphalt roads, and a significant light gradient for both asphalt and unpaved roads. From the road edge to the forest interior, significant temperature changes persisted for only 3 m, light variation persisted for 6 m, and canopy cover and height changed significantly within the first 10 m. Asphalt roads and dust trails revealed different patterns of variation for temperature between edge and interior. No differences were found between the two types of roads in edge-interior trends for light or canopy structure. The abruptness of microclimate and canopy gradients was slightly higher in the laurel forest than in the pine forest, caused by a higher edge contrast in the former. The depth of the road edge effect found in laurel and pine forests was small, but it could have cumulative effects on forest microclimate and forest associated biota at the island scale. Such changes deserve attention by local road managers for planning and design purposes.

Keywords: Canary Islands; Canopy height; Canopy cover; Edge; Forest; Light; Road; Temperature; Tenerife

1. Introduction

Undoubtedly, roads play a key role in urban and suburban development, facilitate movements of human population over the land, and connect societies and economies (Havlick, 2002). However, at the same time, roads generate many collateral problems for the conservation of ecosystems (Spellerberg, 1998; Trombulak and Frissell, 2000; Forman et al., 2002; Song et al., 2005) and landscape integrity (Jaarsma and Willems, 2002, Serrano et al., 2002). Roads create micro and mesoclimatic changes and probably contribute to global macroclimate change, through variation of the received sun radiation, wind regimes, moisture and temperature (Forman et al., 2002). Depending on the traversed ecosystem, road impacts on microclimate, vegetation and fauna can vary widely. For example, forest roads create linear gaps that remove forest area, divide the ecosystem and create structural edges where abiotic and biotic conditions change more abruptly than in open bushland (Forman and Alexander, 1998; Spellerberg, 1998; Trombulak and Frissell, 2000). In forested areas, the forest matrix dominates the landscape, but roads remove or disturb large areas through indirect effects that accumulate and interact at higher scales (Theobald

* Corresponding author. Permanent address: Departamento de Física Básica, Facultad de Física, E-38206, Universidad de La Laguna, Tenerife, Canary Islands, Spain. Tel.: +34 922 318363; fax: +34 922 318311.
E-mail address: jddelgar@ull.es (J.D. Delgado).

0169-2046/$ – see front matter
doi:10.1016/j.landurbplan.2007.01.005

et al., 1997; Forman, 1998; Heilman et al., 2002; Saunders et al., 2002; Riitters and Wickman, 2003). Disturbances on abiotic variables can extend variable distances beyond the road gap (Williams-Linera, 1990; Young and Mitchell, 1994; Laurance et al., 1997), and microclimate edge effects have been shown to extend to the surrounding habitats from only a few meters up to hundreds of meters (see examples in Forman et al., 2002). Therefore, the estimation of the road edge effect for abiotic variables is a useful tool to assess the amount of territory that is functionally affected by the road network (Forman and Deblinger, 2000). Concretely, the identification of underlying abiotic gradients that percolate the fragmented ecosystem is a necessary step to understand road influence upon ecosystem structure and dynamics (Forman and Alexander, 1998).

Oceanic islands worldwide are being heavily changed and constrained by urbanization and transportation pressures (Whittaker, 1998; Fernández-Palacios et al., 2004; Song et al., 2005). The Canary Islands have the highest road density of all the European islands, 6 km km^{-2} (Martín and Fernández-Palacios, 2001). In Tenerife, the road network occupies 3% of the island area, but this is a conservative figure based only on paved roads mainly on non-protected territory. The Canarian laurel and pine forests are traversed by a dense network of corridors including paved and unpaved roads, fire-breaks and powerline clearings, which have received little attention as ecological and landscape elements (Martín and Fernández-Palacios, 2001).

Previous studies have evaluated microclimatic differences between laurel forest natural gaps and interior revealing large differences in global radiation, photosynthetically active radiation (PAR), temperature, wind speed, and relative humidity (Aschan et al., 1994; González-Rodríguez et al., 2001). No study was available for the Canarian pine forest. Apparently, no previous work has been devoted to differences between road gaps and forest interior in both laurel and pine forests in the Canary Islands.

An evaluation of the ecological edge effects of the transportation infrastructure is urgent for the Canarian archipelago and for many other oceanic islands. Roads and associated structures are transforming amounts of territory probably far larger than expected by local environmental authorities. Local managers rely on mostly subjective and partial environmental impact assessments that do not consider road edge effects, the fragmentation process implied, and the specific damages to habitats and the biota (Byron et al., 2000).

Microclimate gradients across road edges influence many ecological processes and patterns. Abiotic gradients reaching the forest interior from the road may transform a large amount of forest into suitable habitat for exotic plants (Fraver, 1994; Goosem and Turton, 2000) and animals (Didham et al., 1998). Floristic composition changes more or less suddenly along such gradients (e.g. Landenberger and Ostergren, 2002; Hansen and Clevenger, 2005).

In the laurel forest, forest destruction by roads and other structures causes progressive vegetation degradation, with the new open spaces being concealed by shrubs, bracken ferns and numerous introduced Mediterranean elements (Höllermann, 1981). Numerous exotic plants are increasingly colonizing forest road edges in the Canary Islands (González and González, 2001; Arévalo et al., 2005). However, most exotic plants and many sun-loving native ones are apparently limited to narrow (1–5 m) open roadsides. Probably, microclimatic changes produced in the zone of road edge effect are favoring the spreading of exotics outward the road surface in the Canarian forests and other habitats (Arévalo et al., 2005).

Forest road edges in the Canaries also shelter high plant diversity and an important degree of endemism, especially regarding native edge-species and light-demanding ones. At the regional scale, roads would promote native sun-loving elements, since natural treefall gaps occur at very low frequencies in the Canarian laurel forest (Arévalo and Fernández-Palacios, 1998).

Regarding non-native animals, introduced ship rats use more frequently laurel and pine forest road edges than the forest interior when foraging (Delgado et al., 2001), and are also strong nest predators along and near roads (Delgado et al., 2005). Endemic lizards (*Gallotia galloti*) were more abundant along road edges than at the interior of both forests (Delgado et al., in press). Roads were thought to play a probable role as corridors through inhospitable forest matrix for these lizards, changing natural patterns of abundance, distribution and population genetic variation at the island scale. In some laurel forest patches, these heliothermic lizards are found only in a narrow stretch of forest outward the road surface where microclimatic requirements are met (Delgado et al., in press). If important ecological components (i.e. decomposers, top predators, pollinators) change relative abundances due to microclimate changes caused by roads, changes in key ecological processes can be expected to start alongside roads (i.e. changes in decomposition rates of necromass, predator–prey relationships, or plant–animal mutualisms) (Giller, 1996; Hansson, 2000). The interpretation of such biotic disturbances initiated at road gaps would benefit from knowing the underlying abiotic gradients.

In this paper, we evaluate microclimatic and structural gradients from roads to forest interiors. Along transects perpendicular to roads in both laurel and pine forests, we measured: (a) temperature at ground level, leaf-litter level, and two heights above ground; (b) light intensity; (c) canopy cover and height. Our goal was to determine if gradients in these variables differed for paved and unpaved roads, and between laurel and pine forests.

2. Study area

The field work was conducted on the laurel and pine forests of Tenerife (Canary Islands, 27–29°N, 13–18°W). Laurel forest sites are located on the Anaga mountains within the limits of the Parque Rural de Anaga, in the Anaga massif, NE Tenerife (700–1000 m asl) (Fig. 1). The pine forest sites are included in the Parque Natural Corona Forestal and Paisaje Protegido Las Lagunetas, along the dorsal road between La Esperanza and the Parque Nacional del Teide (∼1000–2000 m). The asphalt road segments studied have average daily traffic densities (mainly tourism particular cars and buses) of 253–1317 vehicles (laurel forest) and 1536–2460 vehicles (pine forest) (Anon, 2004).