Fire Risk in the Road Landscape Patterns of the State of Paraná, Brazil – Planning Grants for the Wildland-Urban Interface[1]

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Abstract

Urban growth worldwide has generated great concern in the planning of the different environments belonging to the wildland-urban interface. One of the problems that arise is the landscape treatment given to roads, which must not only comply with aesthetic and ecological principles, but also be functional, adding functions relating to forest fire prevention and control. The components for proper road functioning, such as slopes, right of ways, medians, signs, bridges and service stations, need appropriate landscape treatments to not only improve and conserve the site, but also to provide both comfort and safety to drivers and passengers. The relationship of these structures with the environment and road users requires incorporating fire-resistance characteristics into the layout, composition and selection of the plant species used.

The Highways Department of the state of Paraná, Brazil recommends 22 standards that define the function of the sites and the characteristics of the vegetation to be established. In none of these standards is forest fire risk taken into account. To contribute to road landscaping, the aim of this study was to analyze the fire risks of these landscape patterns so as to enrich them with less flammable species to inhibit and / or impede the spread of fire. In a detailed analysis of the recommended standards, it was found that in 50% of these standards, fire risk is one of the basic factors for the selection of species used. According to this research, road landscape standards that present the highest fire risks are: bus stops, service stations, property boundaries, industrial zones, native vegetation, degraded areas, green barriers (shelterbelts), slopes and central medians. We conclude that forest fire

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risk assessment in road landscape planning should be an essential tool to reduce damage caused by fire in the wildland-urban interface areas of Paraná, Brazil.

Keywords: road landscaping, landscape, fire prevention.

Introduction

The destruction of homes and loss of life due to fires in wildland-urban interface (WUI) areas are capturing headlines in various parts of the world (Gill and Stephens 2009). Wildland-urban interface areas are defined as physical spaces where vegetation and buildings coexist in an environment conducive to fires (Ribeiro and others 2010). Radeloff and others (2005) complement the concept of WUI by saying it is an area of conflict between humans and the environment, exemplified by, among other things, the destruction of homes by wildfires, habitat fragmentation, introduction of exotic species and the loss of biodiversity.

Ribeiro and others (2010), in diagnosing fires in WUI areas of Portugal, found that forest fires in these areas are a growing problem not only in Portugal, but around the world, where the increase in the frequency and danger of fires tends to coexist with the presence of human settlements.

WUI areas are of great concern in terms of fire management and risk assessment (Lampin-Maillet and others 2011).

The term fire risk refers to the potential for a fire to start and spread in an area (Soares and Batista 2007). According to Jappiot and others (2009), fire risk is the result of a combination of risk due to the probability of ignition (i), the probability of fire spread across the landscape (ii) and vulnerability expressed as the potential damage to vegetation, houses and other buildings, mainly because of the intensity of the fire.

Most studies of southern Europe indicate that the fire ignition sources are located around the interface between human activities and forested areas. Approximately 50% of fire ignition sources are located on the sides of roads (including all road categories). These ignition sources are varied: cigarettes, car accidents, cars without spark arrestors and power lines. They can produce different forms of ignition: cigarette butts, flames (fires, accidents) or sparking (power lines, motors, automobiles), which emit variable energy and thus display differential ability to ignite vegetation (Curt and Delcros 2007).

The vegetation along roads is usually divided into zones that are organized as a series of lines located on the sides of the road until reaching the adjacent natural vegetation or wildlife area. This organization depends on local environmental conditions and the structural components of the road corridor (hard shoulder,

travelled surface, declivity). The spatial patterning of these structural components and the vegetation play an important role in fire ignition and spread (Curt and Delcros 2010).

Related to the above, one of the issues that arises is the road landscaping treatment, which should not only comply with aesthetic and ecological principles, but also functional principles, including functions for the control of forest fires. Road landscaping refers to all activities carried out on the sides of roads or highways, promoting their integration into the landscape and combining the principles of ecological, cultural and aesthetic conservation (Biondi 2002).

In a practical and applied vision, Goetze (2000) lists the following goals for road landscaping: integrate the landscape to the environment, at the same time mitigating the effects of its implementation; reduce maintenance costs through the use of appropriate vegetation; contribute to road safety; create rest areas for road users; assist in road maintenance and enrich roadsides with native vegetation;contribute to the development of tourism in the region and generate savings in road maintenance by using vegetation that preserves its structure.

In Brazil, road landscaping is still in its early stages. Although the country has 8,514,876,599 km ², over 60% of freight transport is via national highways. In addition, 17.9 million cars circulate on Brazil's roads and highways, plus3.087 million light commercial vehicles, 1.17 million trucks and approximately 258,000 buses. According to the National Department of Transport Infrastructure, the country has just over 1.7 million kilometers of roads, of which only 10% are paved, or approximately 172,897 km, of which 57,211 km are federal roads (33%), 94,753 km are state roads (55%) and 20,914 km are local roads (12%). Regarding road maintenance, 80% of the paving is over ten years old (Brazil 2012).

In order to contribute to road landscaping, this work aims to analyze the fire risk of road landscape patterns and look for measures and techniques to implement that hinder fire ignition and spread in wildland-urban interface areas in Paraná, Brazil.

Methods

This research on fire risk in road landscaping was carried out for the roads of Paraná, Brazil (Figure 1).

The Department of Highways of Paraná, Brazil recommends 22 road landscaping patterns or standards (Goetzke 2000). They are:

1. Narrow Roadside Pattern (< 25 m) – linearly arranged vegetation, varying the species in groups of 5 individuals
2. Wide Roadside Pattern (> 25 m) – arranged as islands;
3. Fuel Station Pattern – creeping and shrub vegetation with lush flowering

or attractive foliage to mark the entry landscape;

4. Terraces Pattern – light vegetation able to survive the lack of water and soil fertility, and that covers most of the ground surface;
5. Fill Pattern – vegetation that contributes to drainage and ensures its stability, and can be shrubs (next to parking), grass (base of the fill) and trees (at the end);
6. Return Pattern – low-lying vegetation that indicates the returns;
7. Pattern for Industrial Areas – lush flowering vegetation to highlight these areas;
8. Pattern for Existing Tree Vegetation: floriferous herbaceous vegetation that complements the local tree vegetation;
9. Pattern for Commercial Stores on Side Streets: annual vegetation planted in flowerpots to visually set off these stores;
10. Road Sign Pattern – vegetation that serves as a backdrop for road signs;
11. Bridge Pattern – vegetation to indicate bridges;
12. Degraded Areas Pattern: rustic vegetation, able to survive in arid environments, with interesting landscaping;
13. Green Barrier Pattern: big trees to hide degraded areas;
14. Conduit (gutter) Pattern - vegetation that serves as a filter for slope runoff;
15. Intersection Pattern: vegetation (trees and shrubs) that serves as a stimulus to reduce speed;
16. Horizontal Curve Pattern / Living defenses – vegetation (trees and shrubs) used for long-distance signaling;
17. Cut Slope Stability Pattern – vegetation (grass, scandent bushes and creepers) to protect the slope against erosion;
18. Crosswalk Pattern – small bushes that provide stimulus lines to reduce speed and mark off the crosswalk;
19. Central Median Pattern with Light Barrier – easy-maintenance bush and grass cover that serves as a barrier against light;
20. Central Median Pattern without Light Barrier: low-maintenance creeping vegetation (low grasses);
21. Bus Stop Pattern – arboreal vegetation able to offer shade and wind shelter;
22. Anti-erosion Pattern – erosion-resistant vegetation, to ensure the stability of drain outlet (Figure 2a and 2b).

The relationship of road landscape patterns to fire risk is based on factors associated with fire ignition and spread, such as vegetation (lifestyles, flammability, seasonality), relief, microclimate, design and layout of vertical and horizontal road

structure, vehicular traffic intensity, type of neighborhood or land use, and human presence.

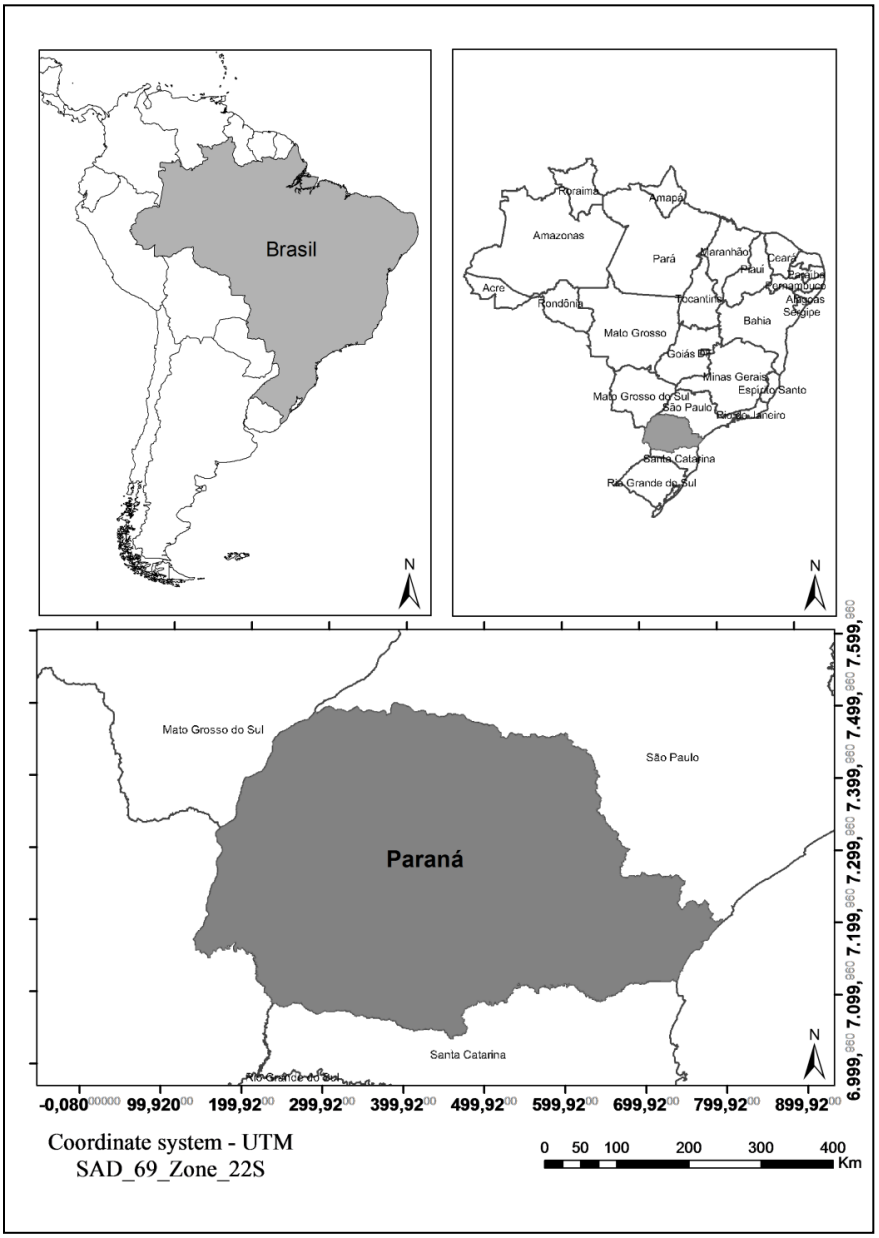

Figure 1—*Study area location.*

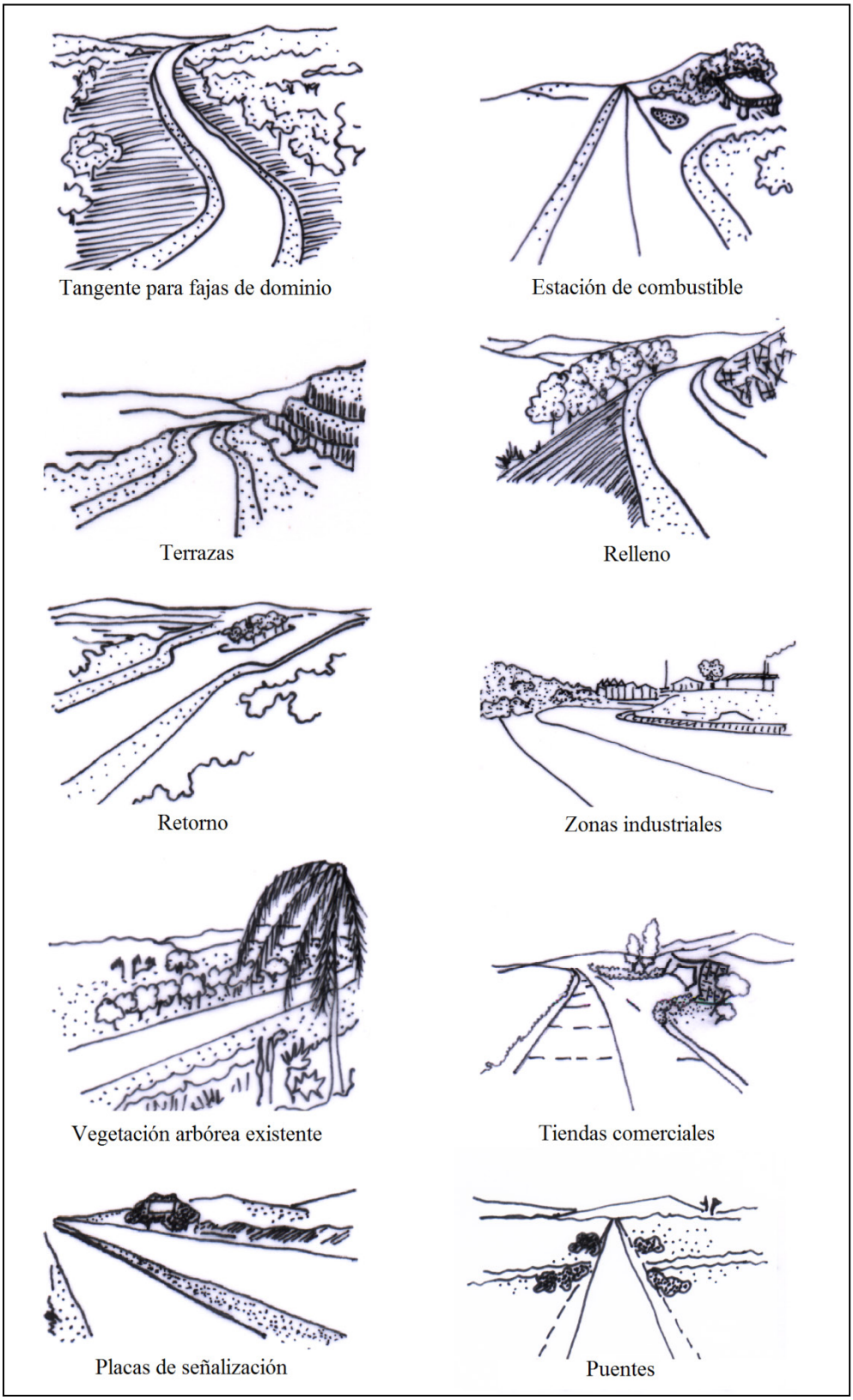

Figure 2a—*Road landscape patterns (based on Dória, 1973 and Göetzke, 2000).*

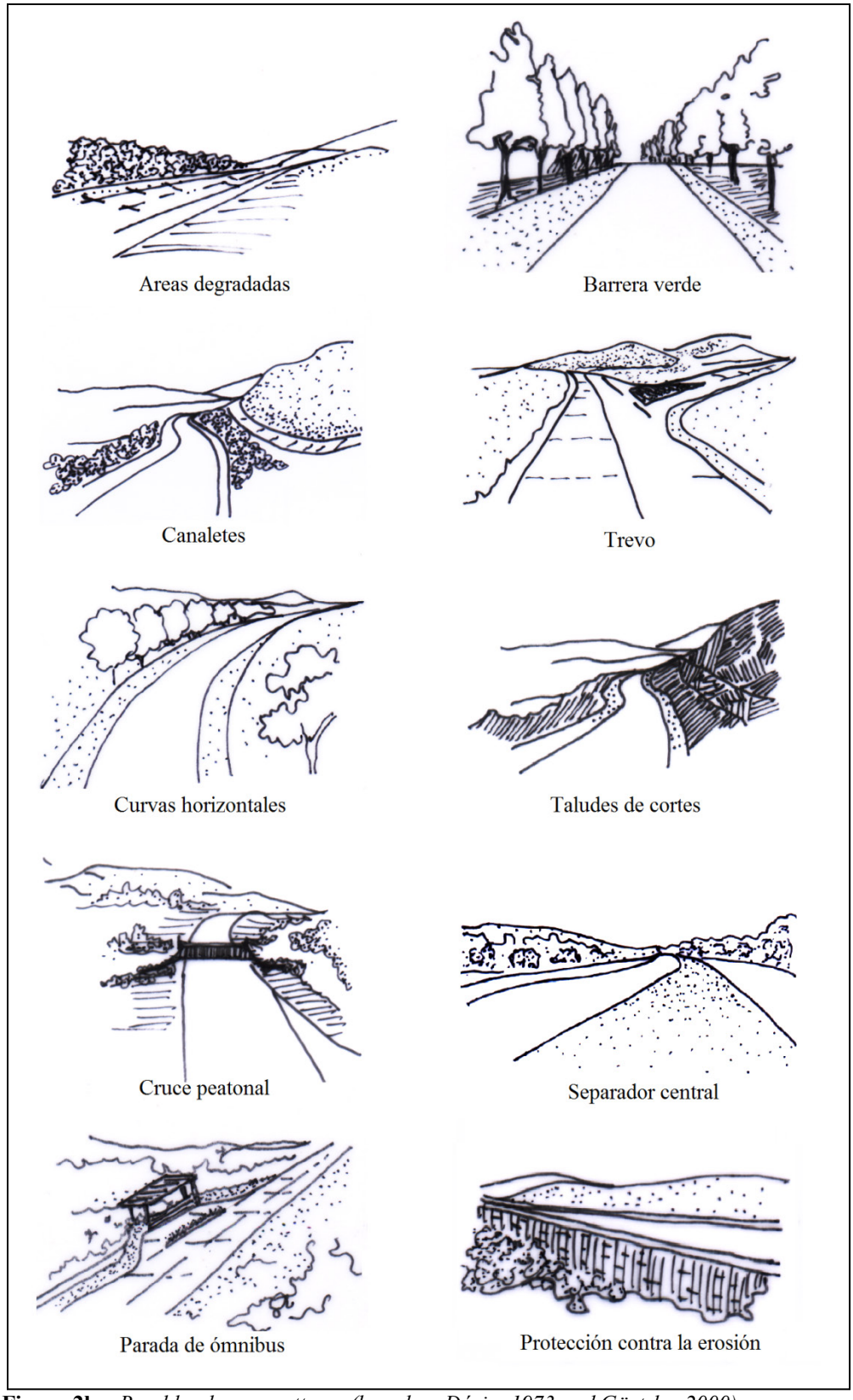

Figura 2b—*Road landscape patterns (based on Dória, 1973 and Göetzke, 2000).*

Results

The results of the fire risk analysis of 22 road landscape patterns are shown in Table 1. As can be seen, 54.5% (12) have a high risk of forest fires, 27.3% (6) have a low risk and 18.2% (4) have a medium risk.

Table 1-*Analysis of fire risk in 22 road landscape patterns.*

Road landscape pattern	Risk		
	H	M	L
Wide roadside pattern (<25 m)	x		
Narrow roadside pattern (>25 m)	x		
Fuel station	x		
Terraces		x	
Fill		x	
Return			X
Industrial areas	x		
Existing arboreal vegetation	x		
Commercial stores on side streets	x		
Road signs			X
Bridges			X
Degraded areas	x		
Green barrier	x		
Conduits (gutters)		x	
Intersections			X
Horizontal curves / living defenses		x	
Cut slope stability	x		
Crosswalk			X
Central meridian with light barrier	x		
Central meridian without light barrier	x		
Bus stop	x		
Anti-erosion			X

LEGEND: H = high; M = medium; L = low.

Discussion

Characterization of high fire risk

Road landscape patterns considered to have a high fire risk presented on their boundaries a type of neighborhood that provides a constant threat due to the presence

of ignition sources in land management activities on farm, livestock and forestry properties, as in the case of areas tangent to wide or narrow road right-of-ways.

The “Fuel Station,” “Stores on Side Streets” and “Bus Stop” patterns are considered highway service facilities. According to Biondi (2002), service facilities include all the necessary services for the comfort and safety of road users, such as checkpoints, fuel stations, restaurants, stores and others. These structures should be framed by the accompanying landscape. The high fire risk for these patterns is not associated with the landscaping of the facilities, but with the constant presence of man (anthropism), vehicular traffic intensity, flammable materials such as fuel (gasoline, diesel and ethanol), electrical appliances and equipment (refrigerators, air conditioners, fans, stoves, etc.) subject to accidents that can start fires, and the generation of waste or garbage (cigarette butts, paper, plastic, cardboard and wood) that can increase the amount of combustible material.

In the "Industrial Areas" pattern, regardless of the type of production, this site and its surroundings add many factors that increase susceptibility to fires, such as human activities, vehicular traffic intensity and flammable materials.

The risk of fire in the "Existing Arboreal Vegetation" and "Green Barrier" patterns depends on the characteristics of their constituent species. The degree of risk is associated with the species (flammability), composition (mix of species) and design (spacing or grouping form).

In the "Degraded Areas" pattern, the risk is higher because normally in these places, because of the various previous uses of the land (mining, agriculture use or forestry), there are residues which may contribute to both fire ignition and spread.

The "Cut Slope Stability” pattern poses a high fire risk not only for the use of flammable species, but mainly because of the relief that can favor the spread of fire.

As for the “Central Meridian with or without a Light Barrier” pattern, the fire risk is linked to the flammability of the species used and especially the design, which usually consists of a single species arranged in a continuous horizontal and vertical manner. Thus, the site presents easily-ignited combustible material, depending on the season, along with its continuous distribution favors the spread of fire.

Characterization of medium fire risk

The "Terraces" pattern refers to structures linked to the continuous ramps on the slopes that serve to prevent surface water runoff to the road platform (CATI, 2012). For this pattern in Paraná, light vegetation able to survive the severe lack of water and soil fertility, and which covers most of the ground surface, is recommended. The medium fire risk of this pattern is mainly due to the fact that the structure is vertically

interrupted and to the use of creeping vegetation (little combustible material) in the horizontal area.

The "fill" pattern is defined as road sections which, in order to be constructed, require the accumulation of materials obtained from cuts or elsewhere (CATI, 2012), giving the area extreme soil moisture conditions. For this reason the landscape treatment usually recommended is vegetation that contributes to drainage and ensures stability, and it can be shrubs (beside the road), grass (base of the fill) and trees (at the end). Due to the mixture of vegetation (herbaceous, shrub and tree), this pattern has a medium forest fire risk.

The “Horizontal Curves / Living Defenses” pattern presents a medium fire risk because the landscaping (tree and shrub insertion) cannot occupy both sides of the road so as not to impair driver visibility.

The medium fire risk for the “Conduit (gutter)” pattern can be associated with both the flammability of the vegetation that serves as a filter for the water that runs off the slopes and the continuous arrangement of vegetation that accompanies the conduit.

Characterization of low fire risk

The low fire risk of the "Return," "Intersection" and "Crosswalk" patterns is due to the greater amount of permeable area surrounding these patterns, isolating the vegetation or combustible material.

For the “Road Signs,” “Bridges” and “Anti-erosion” patterns, although the vegetation characteristic is important, the discontinuous landscaping arrangement reduces fire risk.

Conclusions

We conclude that the risk analysis performed made it possible to discriminate between road landscape patterns based on factors associated with fire ignition and spread.

It is also concluded that forest fire risk assessment in road landscape planning should be an essential tool to reduce fire damage in the wildland-urban interface areas of Paraná, Brazil.

From the characterization of the level of fire risk, it is possible to plan the selection and composition of less flammable species since it is not possible to change the essential structure of the road pattern.

Given the impossibility of changing road patterns, due to their functionality, from the characterization of the level of fire risk it is possible to plan the selection

and composition of less flammable species and impede the spread of fire.

Summary

This study analyzed forest fire risk in the road landscape patterns used in the state of Paraná, located in southern Brazil. Analyses were based on factors associated with fire ignition and spread, such as vegetation, relief, microclimate, structure design and layout of vertical and horizontal road structure, vehicular traffic intensity, type of neighborhood or land use and human presence. The results indicated that 54.5% (12) of the landscape patterns have a high forest fire risk, 27.3% (6) a low risk and 18.2% (4) a medium risk.

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