Optimizing the landscape patterning of fuel treatment of road corridors to reduce fire hazard

Curt, T. (1); Delcros, P. (2)

(1) Cemagref, UR EMAX Ecosystèmes méditerranéens et risques, 3275 route Cézanne - CS 40061, 13182 Aix-en-Provence cedex 5, France, thomas.curt@cemagref.fr

(2) Cemagref, UR EMGR Ecosystèmes montagnards, 2 rue de la Papeterie – BP 76, 39042 Saint Martin d'Hères cedex

Abstract: Many points of fire ignition are aggregated at the vicinity of roads in French Mediterranean Provence area. High car traffic and public attendance entail high fire hazard on neighbouring forests and wildland areas. Fire mitigation strategies at these interfaces may include the management of herbaceous and shrubby vegetation, and the spatial organization of vegetation facies. As such techniques are costly and the cumulated interface length is very high, managers are interested in optimised strategies. In a previous study (Curt & Delcros, 2009) we built a cellular automaton to simulate fire ignition and initial propagation in road-forest interfaces, using data from experimental burnings. This model was used to assess the relative importance of vegetation type, fuel treatment and spatial patterning of vegetation on the fire hazard. In this study, we used statistical optimisation techniques to minimize fire hazard for different (real and theoretical) interface sceneries. Results indicate that managing about 20% of the area can strongly reduce fire hazard in interfaces dominated by highly flammable vegetation. As the location of the initial point of ignition affects strongly fire ignition and propagation, it is recommended to manage intensively areas located at the immediate vicinity of roads, and areas submitted to high public attendance. Optimization techniques seem efficient to help building firewise management practices at road-forest interfaces.

Keywords: Cellular automaton; landscape pattern; fire propagation; fire risk; fuel management

Introduction

A large part of the points of ignition of wildfires are aggregated at the vicinity of roads in French Mediterranean areas. High car traffic and public attendance in road corridors entail high fire hazard on the neighbouring forests and wildland areas. As a consequence, managing the road corridors (defined here as the interfaces between roads and wildlands) is critical to limit fire hazard and the vulnerability of ecosystems located near road networks.

Fire mitigation strategies at road corridors traditionally focus on the management of herbaceous and shrubby vegetation in order to limit fire ignition and propagation. As the network of road corridors is very extensive, such management techniques are costly and time-consuming. Managers are therefore interested in optimised strategies of fuel treatment at the landscape-scale.

Road corridors (RC's) are defined here as linear interfaces between road and the neighbouring forest or wildland area that is likely to burn. RC's of southern France exhibit some specific features that may control fire ignition and spread towards wildland. First, the vegetation types of roadsides are specific (Forman et al., 2003) with a predominance of herbaceous species and shrubs. They mix live fuels (e.g. live herbaceous species) and dead fuels (e.g. tree litter). In addition, some species are sown or planted vegetation for recreational or management purpose. These vegetation types are poorly known in terms of composition, annual growth cycle and moisture content, and thus in terms of flammability (Guijarro et al., 2002; Manzello et al., 2006). We made specific flammability experiments on these vegetation types to assess the probability of fire ignition and spread (Curt et al., 2007). Second, RC'S show specific structural components whose spatial patterning is hypothesized to affect fire ignition and propagation: embankments, ditches, slopes and forest edges. Fire behaviour and level of fire risk for adjacent forest are likely to vary according to the spatial patterning, dimensions, vegetation and fuel treatment of these components.

In general, fuel management for the reduction of fire hazard includes three complementary aspects: fuel reduction, fuel conversion and fuel isolation (Pyne et al., 1996). In the context of RC'S, fuel reduction corresponds to grass mowing and shrub clearing, while fuel conversion is the replacement of highly flammable fuel by less flammable ones, and fuel isolation corresponds to techniques for fuel patterning to isolate flammable vegetation. Fuel reduction aims at reducing fuel biomass to prevent a site from becoming a source of serious fire, while fuel isolation aims at preventing fire from entering or leaving the site, and fuel conversion aims at substituting fuel at risk by fuel of lower flammability (Pyne et al., 1996).

Although fuel treatments do not always stop wildfires, they can alter fire behaviour and reduce the potential fire intensity levels across a landscape (Stratton, 2004; Finney et al., 2007). The spatial location of fuel treatment in a landscape can increase the likelihood of fire suppression to be effective (Finney, 2001; Jones et al., 2003; Stratton, 2004). It has been proved that greenstripping (i.e. the use of species having low flammability to create fuel breaks) is efficient to limit fire hazard at wildland-urban interfaces (e.g. Loehle 2004; Bevers et al. 2004). Experiments have proved that large fuel breaks managed by grass mowing and shrub clearing can reduce fire speed and intensity (Rigolot, 2002; Dupuy and Morvan, 2005).

1. Materials and Methods

In a first study (Curt & Delcros 2009) we used a cellular automaton (CA) to simulate fire ignition and initial propagation in road-forest interfaces. This CA had been implemented with data from experimental burnings. This helped us to simulate as accurately as possible the ignition and propagation of fire in vegetation communities typical of road corridors. This model has been used the test the importance of vegetation type and vegetation management on the fire hazard.

In this study, we hypothesized that: (i) local fuel treatment at strategic places in the road corridors would limit efficiently fire hazard; (ii) as road corridors are linear landscape features, the most efficient fuel treatments would be linear fuelbreaks or greenbelts (i.e. greenstrips). We thus proposed to test the efficiency of different scenarios of fuel treatment within road corridors to limit fire ignition then propagation. These scenarios have been built with the help of road managers to ensure that they were realistic. We thus tested:

- the percent of fuel treatment among the interface: fire hazard should decrease with the percent of fuels treated by shrub-clearing or grass mowing, but not necessarily in a linear way. Some studies indicate that an optimum percentage of fuel treatment helps to reduce strongly fire hazard;
- the location, size and pattern of the patches of fuel treated: for example, one predominant practice at RC's is to mow grass on a linear strip along the road to limit fire ignition and the intensity of fire. The width of this strip may vary according to the local regulation, a maximal width of 30 feet (9 meters) being believed to be highly effective in most cases (Cohen 2000; Gettle and Rice 2002). Likewise, areas with highly flammable fuels may be isolated from the others to prevent fire propagation.

To test the efficiency of these fuel treatments, we used statistical optimisation techniques (Nelder and Mead, 1965; Hooke and Jeeves, 1980; Bazaraa and Goode, 1981). These techniques have been used for predicting hazards in forests (Potts et al., 1985; Bevers et al., 2004), reducing crown fire hazard (Graetz et al., 2007), or planning the landscape location of fuelbeaks and fuels treatments in forests (Loureiro et al., 2002; Fernandes et al., 2004; Schmidt et al., 2008; Wei et al., 2008).

Here, our objective was to minimize fire hazard and the area of fuel treatment. The final aim is to help managers to optimize their efforts of fuel treatment to obtain a limitation of fire hazard or an acceptable level of risk.

2. Results

The spatial patterning of fuels and of the fuel treatments (i.e. the mowing of grass and shrub-clearing) clearly affected the probability of fire ignition and propagation at RC's.

Fire hazard can be minimized using low-flammable dicot grasses and regularly mowing the very flammable graminoids at strategic places. The high fire hazard level of mixed vegetation (graminae + pine litter + shrubs) can be lowered by a selective fuel treatment.

The lowest probabilities of fire propagation correspond to decreasing gradients of vegetation flammability at the vicinity of forest, especially for air-dried vegetation (i.e. at medium moisture content). The figure 1 shows that establishing flammable vegetation far from the forest edge limits the fire hazard. Managing about 20% of road corridor can strongly reduce fire hazard in interfaces dominated by highly flammable vegetation.

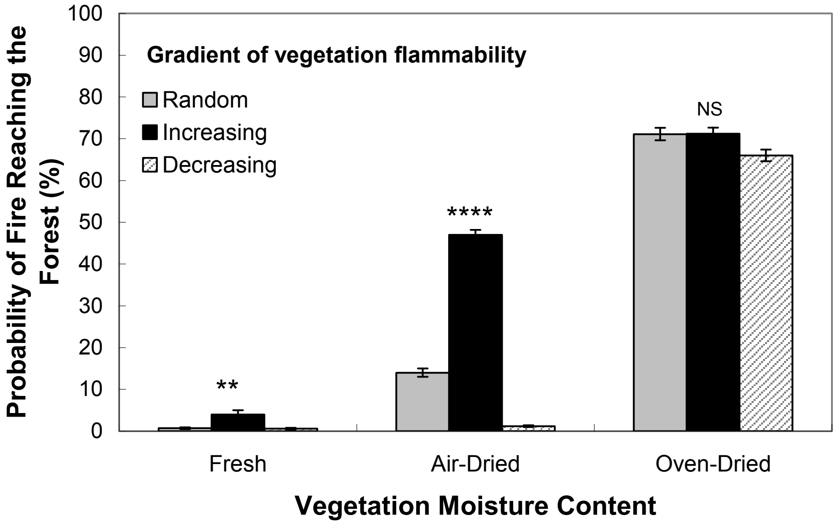

Figure 1. Probability of a fire ignited in the road corridor to reach the forest according to the gradient of vegetation flammability and the vegetation moisture content. 'Increasing' is for flammable vegetation located near the forest edge, while 'decreasing' is for flammable vegetation located far the forest edge (i.e. near the road). In the 'random' modality the flammable vegetation is located randomly within the road corridor. Fresh vegetation is at high moisture content, air-dried vegetation at medium moisture content, and oven-dried vegetation at very low moisture content.

As the location of the initial point of ignition affects strongly fire ignition and propagation, it is recommended to manage intensively areas located at the immediate vicinity of roads, and areas submitted to high public attendance (figure 2). If the location of the points of ignition can be predicted accurately, fuel treatments can be strictly delimited but very effective. If this location is random or unknown, fuel treatments should be operated on a large scale and directed towards the most flammable vegetation communities.

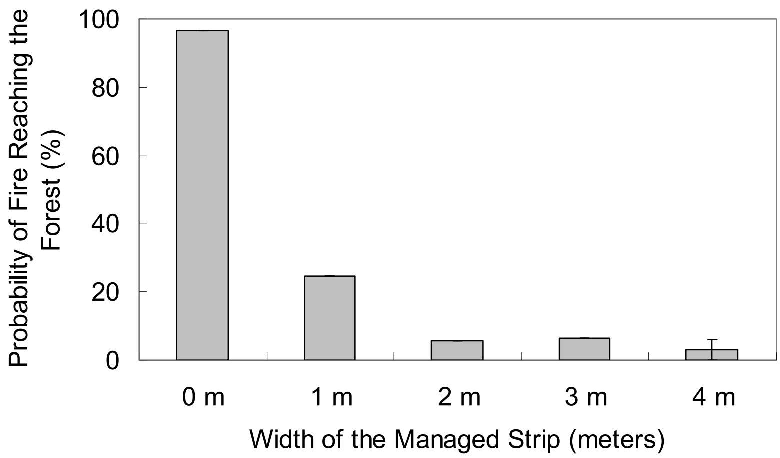

Figure 2. Probability of a fire ignited in the road corridor to reach the forest according to the width of the managed strip near the road

Heterogeneous patterns of fuel treatments (e.g. intersecting strips) are generally efficient because they are likely to limit fire propagation in the landscape. However, homogeneous patterns are generally preferred by managers as they are easier to achieve in the field. Effective homogeneous patterns are those that focus on the road verge or those that focus on the forest edge, which is often composed of very flammable fuels (figure 3).

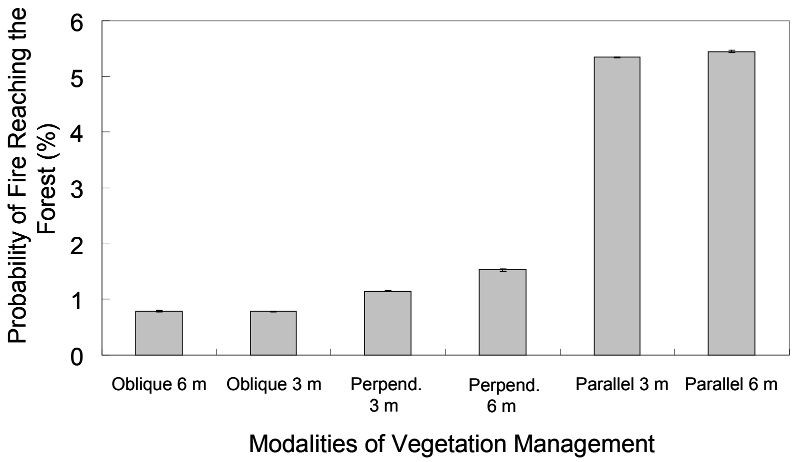

Figure 3. Probability of a fire ignited in the road corridor to reach the forest according to the pattern of fuel treatment. 'Oblique' is for strips of fuel treatment oblique to the road, 'perpend.' is for strips perpendicular to the road, and 'parallel' is for lines parallel to the road. The length of the strip (3 m and 6 m) is indicated

Conclusion

The optimal location of fuel treatments across a road corridor is a central challenge for fire management. Optimization techniques seemed efficient for testing firewise management practices. Landscape simulation of management practices is critical to limit the vulnerability of ecosystems in a context of expanding road network and increasing car traffic.

Fuel ignition then fire spread at RC'S is strongly influenced by the type of vegetation (i.e. community composition), its moisture content and the quality and timing of management. Fuel moisture content is controlled by meteorological conditions and to a lesser degree by site quality. The efficiency and adequacy of fuel treatment according to the rapid (daily, seasonal) fluctuation of fuel moisture content and biomass is likely to be site- and community-specific. Further research is still needed to assess ignitability and fire spread potential according to these variables.

References

Bevers M., P.N. Omi and J. Hof, 2004. Random location of fuel treatments in wildland community interfaces: a percolation approach, *Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere*, 34, p. 164-173.

Curt T., Ganteaume A., Alleaume S., Borgniet L., Chandioux O., Jappiot M., Lampin C. and Martin W., 2007. *Vegetation ignition hazard at road-forest interface (southern France)*. 4th International Wildland Fire Conference, Sevilla (Spain) 13-17 May 2007: 1-11.

Curt T., Delcros P., 2009. Managing road corridors to limit fire hazard. A simulation approach in southern France, *Ecological Engineering*, 36, p. 457-465.

Dupuy J.L. and Morvan D., 2005. Numerical study of a crown fire spreading toward a fuel break using a multiphase physical model, *International Journal of Wildland Fire*, 14, p. 141-151.

Fernandes P.A.M., Loureiro C.A. and Botelho H.N.S., 2004. Fire behaviour and severity in a maritime pine stand under differing fuel conditions, *Annals of Forest Science*, 61, p. 537-544.

Finney M.A., 2001. Design of regular landscape fuel treatment patterns for modifying fire growth and behaviour, *Forest Science*, 47, p. 219-228.

Finney M.A., Selia R.C., McHugh C.W., Ager A.A., Bahro B. and Agee J.K., 2007. Simulation of long-term landscape-level fuel treatment effects on large wildfires, *International Journal of Wildland Fire*, 16, p. 712-727.

Forman R.T.T., Sperling D., Bissonette J.A., Clevenger A.P., Cutshall C.D., Dale V.H., Fahrig L., France R., Goldman C.R., Heanue K., Jones J.A., Swanson F.J., Turrentine T. and Winter T.C., 2003. *Road ecology: science and solutions*. Island Press, Washington, D.C., USA, 481 p.

Graetz D.H., Sessions J. and Garman S.L., 2007. Using stand-level optimization to reduce crown fire hazard, *Landscape and Urban Planning*, 80, p. 312-319.

Guijarro M., Hernando C., Diez C., Martinez E., Madrigal J., Cabaret C.L., Blanc L., Colin P.Y., Perez-Gorostiaga P., Vega J.A. and Fonturbel M.T., 2002. *Flammability of some fuel beds common in the South-European ecosystems*. Forest fire research and wildland fire safety: Proceedings of IV

International Conference on Forest Fire Research 2002 Wildland Fire Safety Summit, Luso, Coimbra, Portugal, 18-23 November 2002, p. 152.

Hooke R. and Jeeves T.A., 1980. Citation Classic - Direct Search Solution of Numerical and Statistical Problems, *Current Contents/Engineering Technology & Applied Science*, p. 14.

Jones G., Chew J., Silverstein R., Stalling C., Sullivan J., Troutwine J., Weise D. and Garwood D., 2003. *Spatial Analysis of Fuel Treatment Options for Chaparral on the Angeles National Forest*. USDA For. Serv., Gen. Technical Report PSW-GTR, 15 p.

Loureiro C., Fernandes P. and Botelho H., 2002. *Optimizing prescribed burning to reduce wildfire propagation at the landscape scale*. Forest fire research and wildland fire safety: Proceedings of IV International Conference on Forest Fire Research 2002 Wildland Fire Safety Summit, Luso, Coimbra, Portugal, 18-23 November 2002, p. 74.

Manzello S.L., Cleary T.G., Shields J.R. and Yang J.C., 2006. Ignition of mulch and grasses by firebrands in wildland-urban interface fires, *International Journal of Wildland Fire*, 15, p. 427-431.

Nelder J.A. and Mead R., 1965. A simplex method for function minimization, *Computers Journal*, 7, p. 308-313.

Potts D.F., Peterson D.L. and Zuuring H.R., 1985. *Watershed modeling for fire management planning in the Northern Rocky Mountains*. Research Paper, Pacific Southwest Forest and Range Experiment Station, USDA Forest Service: ii + 11 pp.

Pyne S.J., Andrews P.L. and Laven R.D., 1996. *Introduction to wildland fire*. 2nd ed. New York, NY, John Wiley & Sons, 808 p.

Rigolot E., 2002. *Fuel-break assessment with an expert appraisement approach.* Forest fire research and wildland fire safety: Proceedings of IV International Conference on Forest Fire Research 2002 Wildland Fire Safety Summit, Luso, Coimbra, Portugal, 18-23 November 2002, p. 32.

Schmidt D.A., Taylor A.H. and Skinner C.N., 2008. The influence of fuels treatment and landscape arrangement on simulated fire behaviour, Southern Cascade range, California, *Forest Ecology and Management*, 255, p. 3170-3184.

Stratton R.D., 2004. Assessing the effectiveness of landscape fuel treatments on fire growth and behavior, *Journal of Forestry*, 102, p. 32-40.

Wei, Y., Rideout D. and Kirsch A., 2008. An optimization model for locating fuel treatments across a landscape to reduce expected fire losses, *Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere*, 38, p. 868-877.