

REMOTE SENSING AND VEGETATION RECOVERY MAPPING AFTER A FOREST FIRE

Study of a Mediterranean Basin

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ABSTRACT

In August 1990 some of the subwatersheds of the Real Collobrier research and experimental basin (Var-France) were totally or partially burnt by a forest fire. The catchments concerned provide an interesting case study of the hydrological consequences of a fire. Thus, since 1990, a research programme has been developed to better understand the effect of vegetation on runoff genesis during the post-fire years. This programme combines yearly vegetation surveys on experimental plots, remote sensing images (SPOT images from 1990 to 1994) and hydrological information. The methodology developed is based on a comparative analysis of post-fire hydrological behaviours of subcatchments, and yearly mapping of post-fire vegetation recovery by using remotely sensed data. The methodology and some results concerning vegetation recovery mapping are presented. The hydrological facet is not developed here.

1. INTRODUCTION

In August 1990, six of the eleven subwatersheds (Figure 1) of the Real Collobrier research and experimental basin (Var-France) were totally or partially burnt by a forest fire (Puech et al., 1991) (Table 1). The catchment surfaces vary from 1 to 70 km². They are situated in a mountainous area (slopes up to 40 %) and are covered by Mediterranean forests for 90 % of their surface.

comparing, year by year, the evolution of vegetation recovery with the evolution of hydrological response. Thus, since 1990, a research program has been developed to better understand the effect of vegetation on runoff. This program combines yearly vegetation surveys on experimental plots, remote sensing images (SPOT images), and hydrological information.

Table 1 - Some characteristics of Real Collobrier catchments

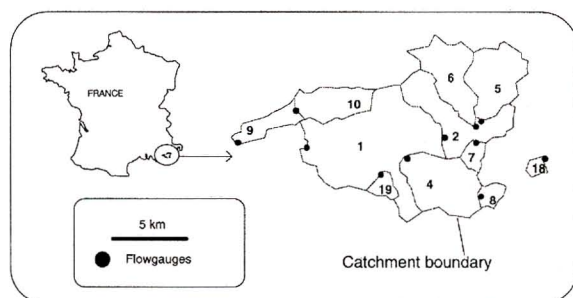


Figure 1 - Real Collobrier Catchments

The impact of the fire provides an interesting case study of the effect of vegetation on runoff, by

| | Basins | Surface (km ²) | Burnt surface (km ²) | % of burnt area for each catchment |
|----|--------------|----------------------------|----------------------------------|------------------------------------|
| 1 | Pont de Fer | 70.6 | 12.9 | 18 |
| 2 | Collobrières | 39.5 | 0 | 0 |
| 4 | Malière | 12.3 | 4.6 | 37 |
| 5 | Valescure | 9.4 | 0 | 0 |
| 6 | Maurets | 8.4 | 0 | 0 |
| 7 | Vaubarnier | 1.5 | 0 | 0 |
| 8 | Rimbaud | 1.4 | 1.3 | 82 |
| 9 | Dauids | 9.7 | 3 | 32 |
| 10 | Cogolins | 5.5 | 1.3 | 20 |
| 18 | Boussicaut | 0.7 | 0 | 0 |
| 19 | Meffrey | 1.5 | 1.4 | 89 |

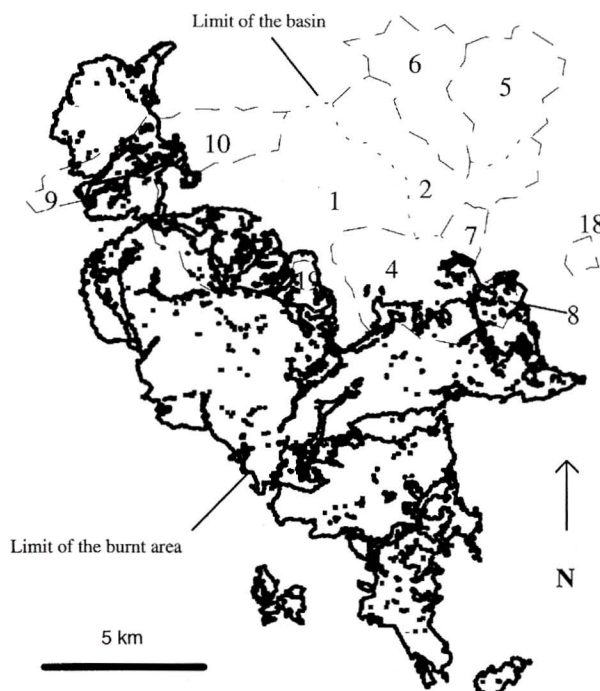


Figure 2 - Real Collobrier basin and the burnt areas (identified from a SPOT image of 09/1990) (Puech, 1993)

The evolution of the vegetation cover appears to be the fundamental phenomenon explaining the evolution of the hydrological response, so we have based our study on the following three points :

- 1 - mapping of post-fire vegetation recovery by remote sensing
- 2 - characterisation of the evolution of the post-fire hydrological response
- 3 - comparative analysis of the evolution of both vegetation recovery and hydrological responses.

In this paper, we present the first step concerning vegetation recovery after fire. The two other steps are discussed later.

2. GROUND DATA OBSERVATIONS

In order to perform a significant image-based study, we have localized 36 parcels of land (20 by 20 meters) on which we have observed, year after year at the same period, the vegetation recovery. In particular, the percentage of the surface covered by bare soils, rocks and different types of vegetation have been described.

These parcels have been chosen based on their homogeneity and representative nature (Viné and Puech, 1994). Figure 3 indicates the position of the observation plots.

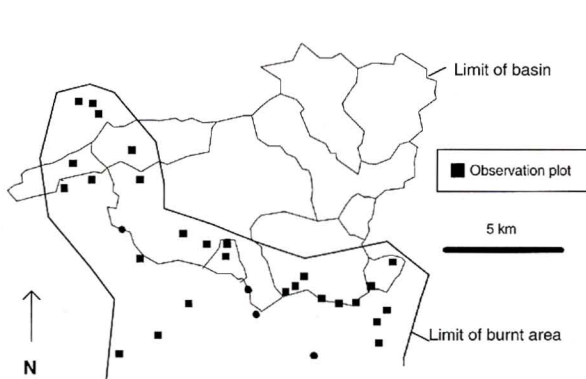


Figure 3 - Observation plots on Real Collobrier Basin

The analysis of the evolution of the 36 representative plots permitted the deduction of average behaviour for vegetation recovery on the Real Collobrier basin, since 1990. This behaviour is summarised in Figure 4.

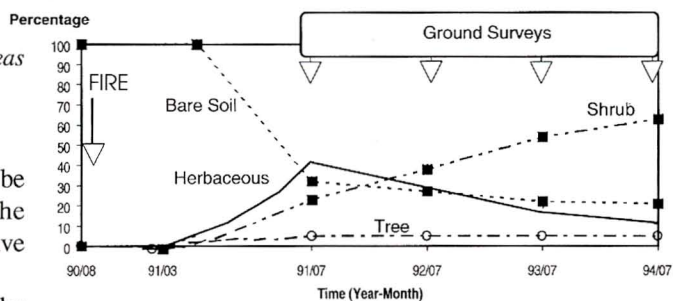


Figure 4 - Mean temporal evolution of principal cover types on burnt areas (Clément, 1995)

This figure 4 shows that :

- tree stratum has been almost completely destroyed by fire (from 90% of the surface covered before the fire to 10% during the 4 following years) ;
- bare soil decreased from 90% just after the fire to 25% four years later ;
- evolution of herbaceous plant communities and shrubs are linked, and their surface development is established as soon as 1991 (i.e., six months after fire). After this year, the surface covered by herbaceous plants and shrubs is quite invariant. The proportions of each of them vary through time : herbaceous plants being progressively replaced by shrubs. Two years after the fire, the herbaceous plants and shrubs have reached 0.5 to 2 meters in height. Then, these strata continued growing, but more in height than in surface area. Bare soil fraction appears quite constant after July 1997. These results are consistent with those obtained by (Trabaud, 1987).

3. REMOTE SENSING APPROACHES

Our hydrological aim is to characterise the effect of vegetation destruction (from vegetation to bare soil) and recovery (from bare soil to vegetation) on runoff. Therefore, the nomenclature for mapping vegetation recovery will concern bare soil and different vegetation strata which can have an impact on runoff : herbaceous plants, shrubs and trees. Our goal is not to describe the spatial variation in species composition and structure of the burnt area.

3.1. Pixel analysis

Before fire, high resolution remote sensing data, such as SPOT XS (20 m pixel), were well adapted to map vegetation. The pixels appeared homogeneous, because they were covered by only one strata (trees). After the fire, the analysis was more difficult, as the pixels became heterogeneous for the chosen nomenclature (figure 5). We therefore took a sub-pixel approach, in order to calculate the percentage of each layer (i.e. trees, shrubs, herbaceous plants, bare soil). However, in July, the herbaceous vegetation is no longer green. We therefore contracted the nomenclature into three groups : bare soils, dry vegetation and green vegetation (trees and shrubs).

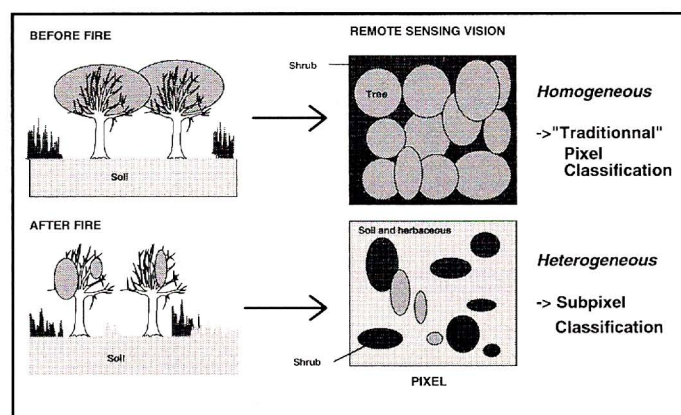


Figure 5 - homogeneous pixels (before fire) and heterogeneous pixels (after fire)

3.2. Remote sensing data

Data used were SPOT images from September 1990 (a few days after the fire), July 1991 and 1992, and June 1993 and 1994. These data have been transformed to make them geometrically and radiometrically compatible. For this last process, we have implemented a specific methodology, using a DEM (digital elevation model), for the correction of radiometric effects due to relief (Puech, 1993).

3.3. Methodology and results

The study has been focused on the burnt area that lies inside the hydrological catchments (1600 ha, Tab 1). Thus, according to the previous considerations, we mapped the vegetation recovery using two sub-pixel approaches :

- *the first one is qualitative* and uses the five images together. The goal is to create an unequivocal relationship between temporal evolution of the spectral signature of pixels and a vegetation recovery typology in four classes (Puech *et al.*, 1994). The

methodology uses an unsupervised classification based on temporal evolution of the red and near-infrared bands. This approach gives a representation cartographic of forest regeneration, but no quantitative information.

This map gives information much more complete than those obtained from data collected on the ground. In particular, it is possible to see that the two small burnt catchments of about 1 km², with 90% of burnt surface, are classified into two separate categories of vegetation recovery :

Meffrey catchment (1.5 km²) is classified as class A (*i.e.*, a significant vegetation recovery in 1991)

Rimbaud catchment (1 km²) is classified as class C (*i.e.*, a weak vegetation recovery in 1991)

These results are consistent with the hydrological analysis done at monthly step. This analysis has been performed by using a 2-parameter monthly conceptual model (GR2M) developed by Cemagref (Michel, 1991). These two parameters have been

estimated with hydrological data before fire, and used after fire. The comparison between calculated and observed runoffs indicates an increase of runoff just after the fire for only the totally burnt catchments. This increase is more than one year for Rimbaud, six months for Meffrey (the one with the most important vegetation recovery). After this period of increasing, observed runoffs are weaker than calculated ones (Viné et Puech, 1994).

- *the second one is quantitative* and uses a sub-pixel technique developed by (Raffy, 1993). The images are analysed one by one (*i.e.* year by year) on the basis of the bidimensional histogram red versus near-infrared. The method estimates the percentage (and its accuracy) of each class identified on the histogram for each pixel of the image. These classes are supposed to be « homogeneous ». In our case, the classes are the following : trees, bare soils and shadow. This nomenclature is quite different from the one used for our hydrological aim. The study of the link between these two nomenclatures is in process.

The first results obtained for bare soil are of great interest (for example, in 1993, means of 43 % and 38 % of surface covered by bare soil and herbaceous plants have been calculated, respectively, for the Rimbaud and Meffrey burnt catchments), and are consistent with ground observations (Table 2).

Table 2 - Percentages of Bare soil + Herbaceous plants : Ground observations (on two parcels)

| Catchments | Bare soils and herbs (%) | | | |
|------------|--------------------------|------|------|------|
| | 1990 | 1991 | 1992 | 1993 |
| Rimbaud | 90 | 80 | 65 | 50 |
| Meffrey | 90 | 70 | 50 | 40 |

4. LINK BETWEEN VEGETATION RECOVERY AND POST-FIRE HYDROLOGICAL BEHAVIOUR

The next part of this study will be the analysis of the linkage between vegetation recovery and hydrological evolution. The most important point, for us, is that the methodology used for remote sensing classification gives quantitative maps. This is new and very fundamental, we can now link in a quantitative way both the evolution of vegetation and the hydrological response.

5. CONCLUSION

Remote sensing appears to be a very useful tool to characterise the spatial evolution of land cover after a fire. It offers the possibility of making vegetation recovery maps over large areas, which is very difficult to do with ground observations. For a hydrological approach, remote sensing can provide precise maps concerning the evolution of land cover from different catchments. Thus, a quantitative approach of the link between hydrology and land cover is now possible.

6. ACKNOWLEDGMENTS

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