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Topographic and Vegetation Controls on Wildfires in South-East France, 1970-2019

C. Bountzouklis¹, D.M. Fox¹, E. Di Bernardino²

¹University of Côte d'Azur, UMR CNRS 7300 ESPACE, Nice, 06204, France; ²University of Côte d'Azur, UMR CNRS 7351 LJAD, Nice, 06108, France

1. Introduction:

Forest fires in the Euro-Mediterranean zone burn close to 500,000 ha per year. Many of these fires occur in the Wildland Urban Interface (WUI) (Fig. 1) where wildfires pose a serious threat to people and houses. The objective of this study was to quantify temporal changes in environmental factors influencing the spatial distribution of burned area in 3 departments (06, 13, 83) of the SUD-PACA region since 1970.



Fig. 1: Example of Wildland Urban Interface (WUI).

2. Methods:

A burned area polygon database accounting for 3,382 fires and a total burned area of 296,820 ha was obtained from the National Forestry Service (ONF) for fires between 1970 and 2019. Fire contour precision improved with time as satellite imagery became available (Fig. 2).

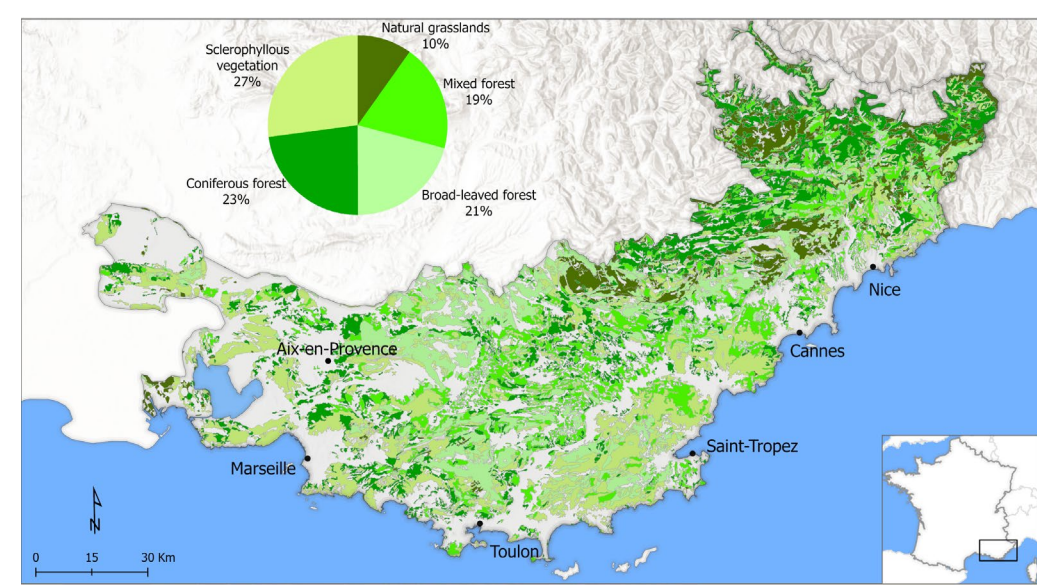


Fig. 3: Corine Land Cover (CLC) database for vegetation mapping.



Fig. 4: 5 m Digital Elevation Model (DEM) for slope inclination and aspect.

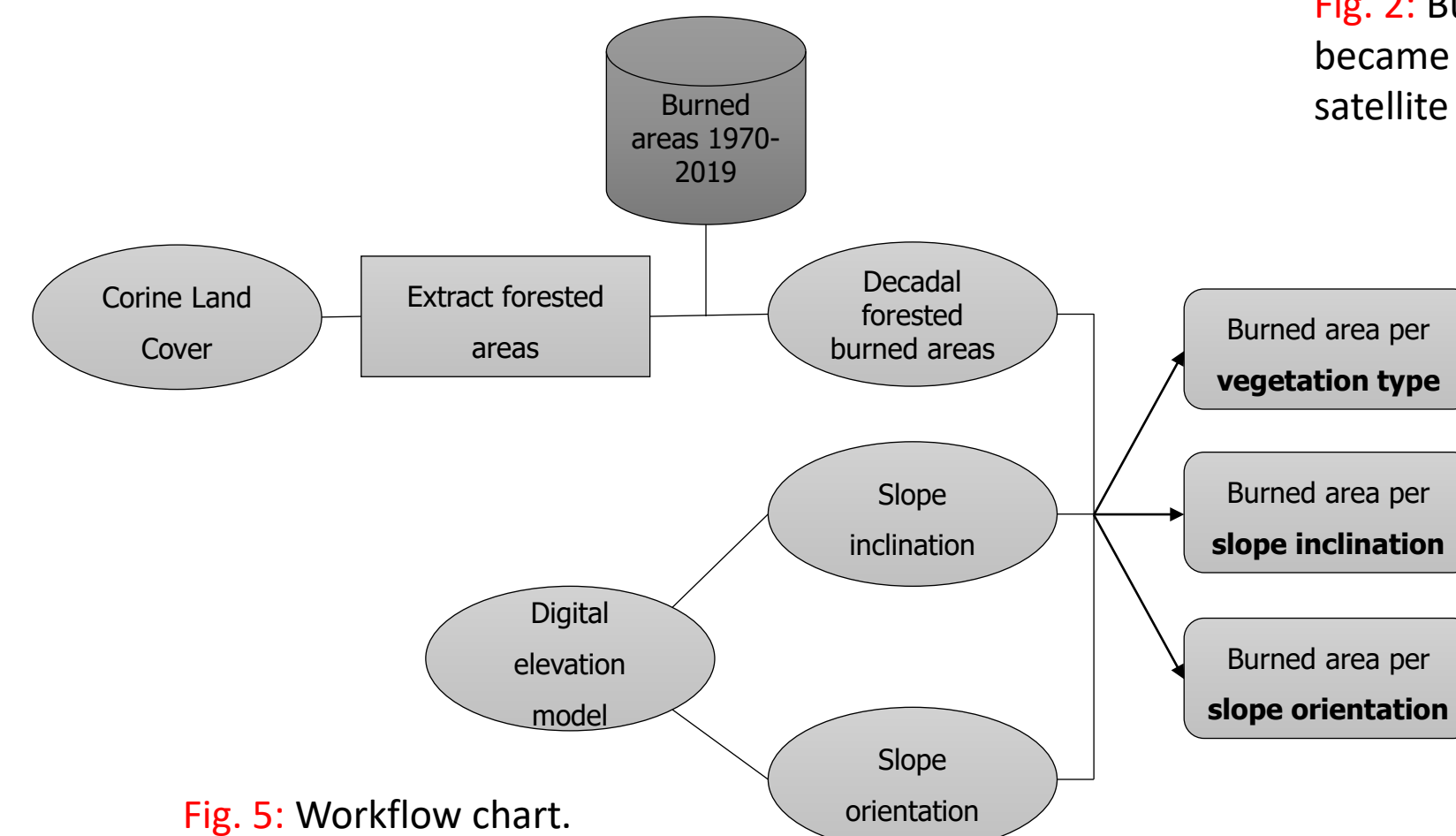


Fig. 5: Workflow chart.

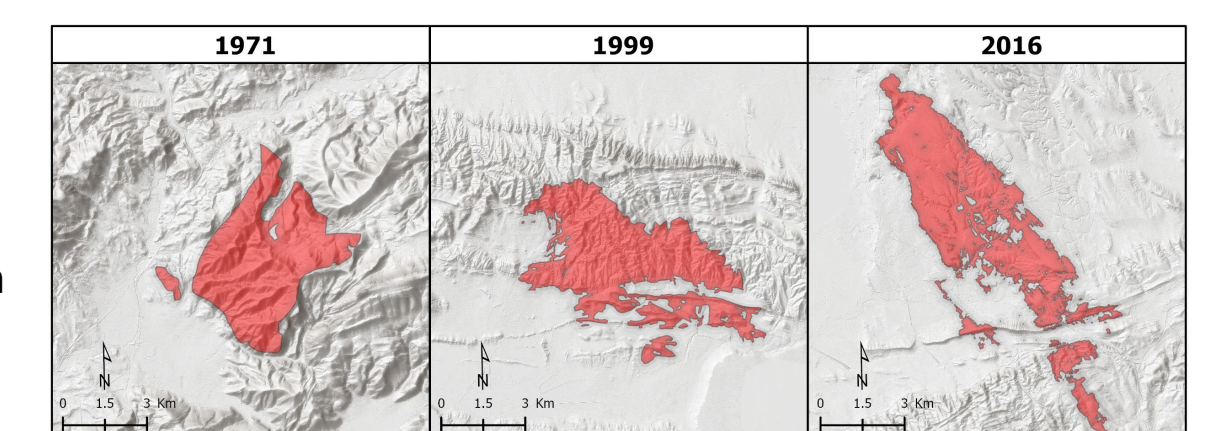


Fig. 2: Burn scar contours became more refined with satellite imagery.

As shown in Fig. 5, burn scar polygons were overlain on slope inclination and aspect to extract percentage burned area per slope and aspect categories. Burned forested area by vegetation type was also extracted in this way.

Data were calculated according to 25-year (1970-1994, 1995-2019) and decadal time intervals.

3. Results and Discussion:

Burned area is highly variable from one year to another, but big fire years tend to disappear after an improvement in fire prevention and suppression starting in the early 1990's; only 2003, the hottest/driest year on record stands out in the 1994-2019 time interval (Fig. 6).

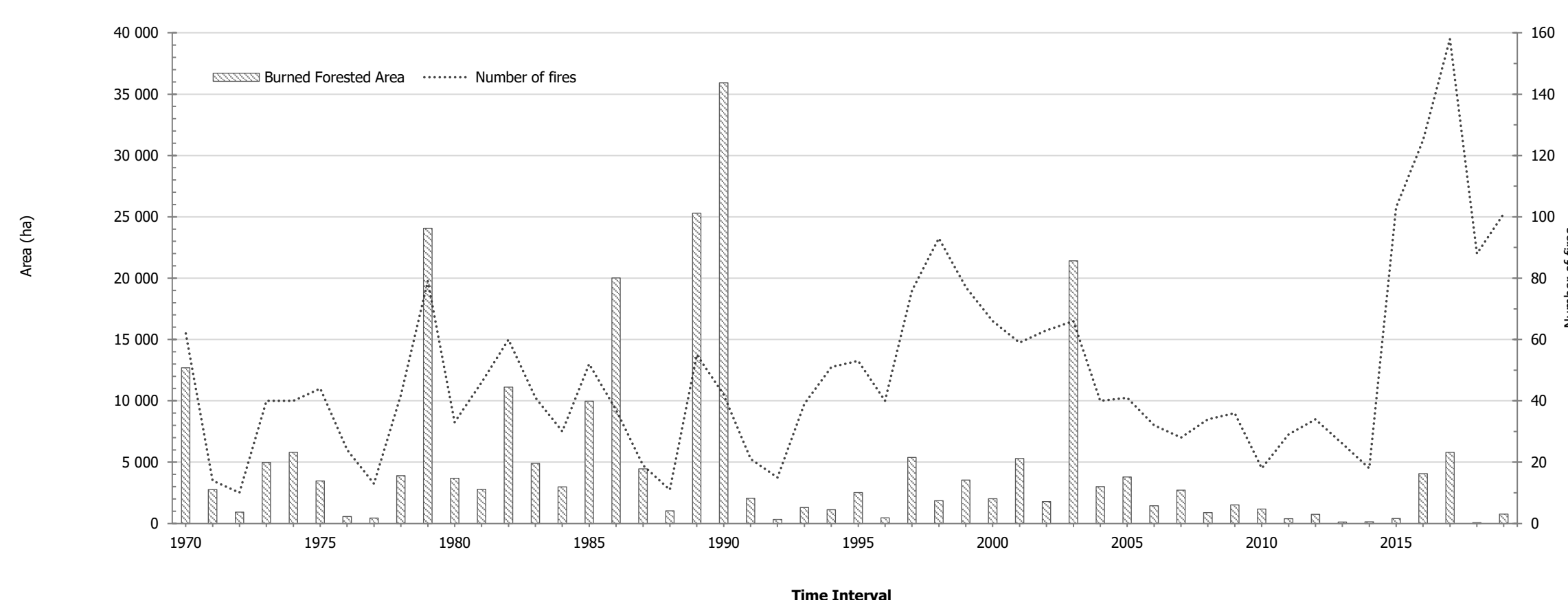


Fig. 6: Annual burned area and number of fires, 1970-2019.

Burned patch sizes shrunk in the second time interval (1995-2019) compared to the first (1970-1994) (Fig. 7). Some persistent hotspots persevere through time in both the Bouches-du-Rhône and Var departments, though both their size and fire frequency diminished.

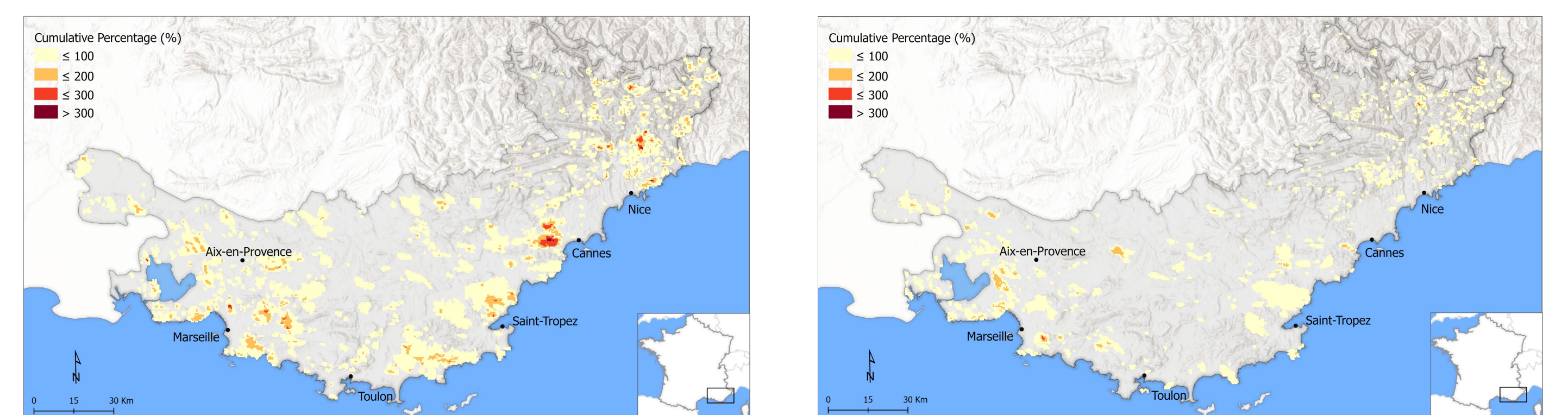


Fig. 7: Burned area frequency for the 1970-1994 (left) and 1995-2019 (right) time intervals.

Topographic and vegetation results are plotted as the distribution of total burned area according to category (sum of all bars in a decade=100%) in top row of figures and as a percentage of the category found in the field (i.e.. Percentage of north-facing slopes burned, for example) in bottom row figures. These values are sensitive to total burned area, so bar height decreases after the big fire decades of 1970-1979 & 1980-1989.

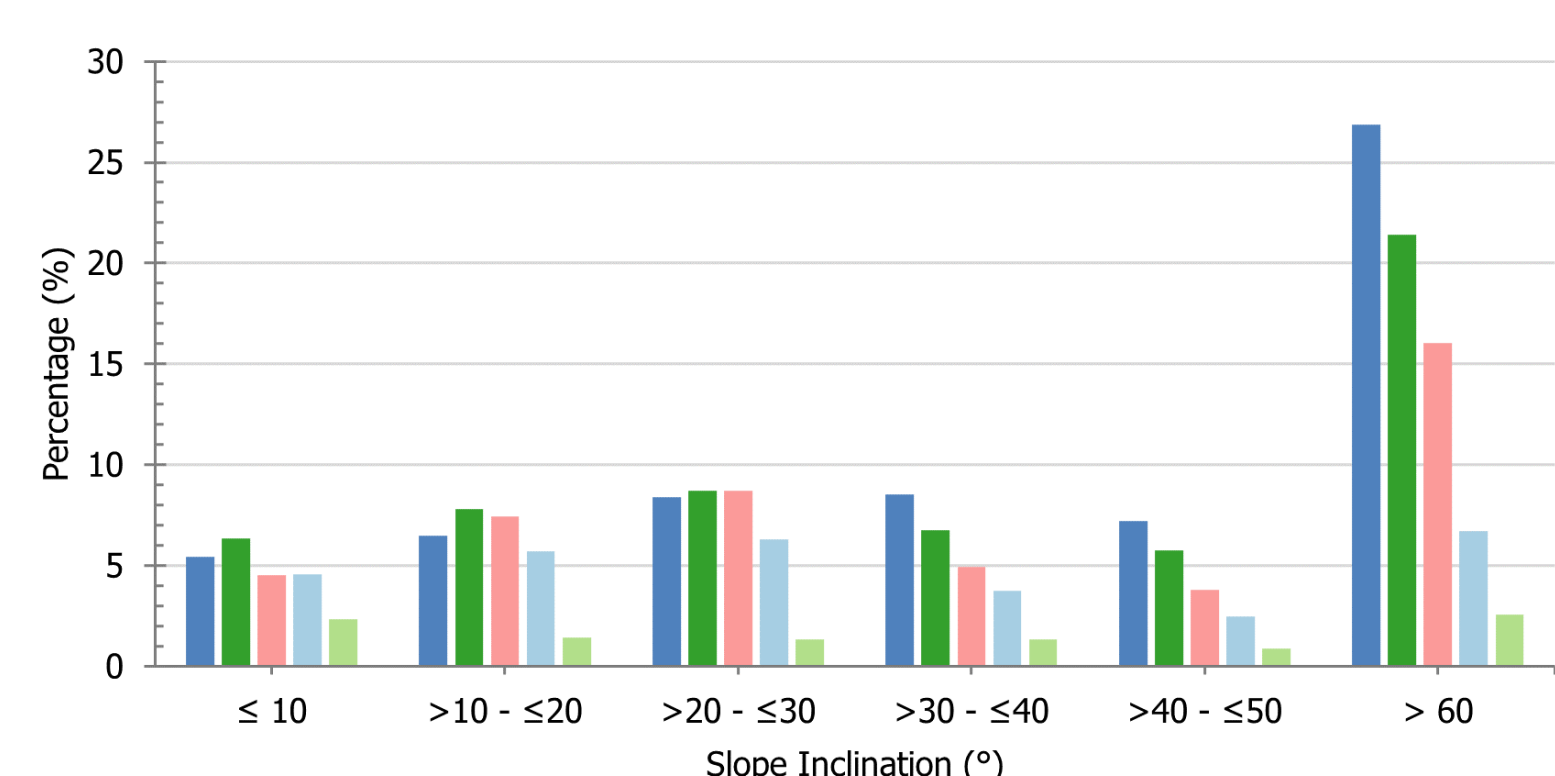
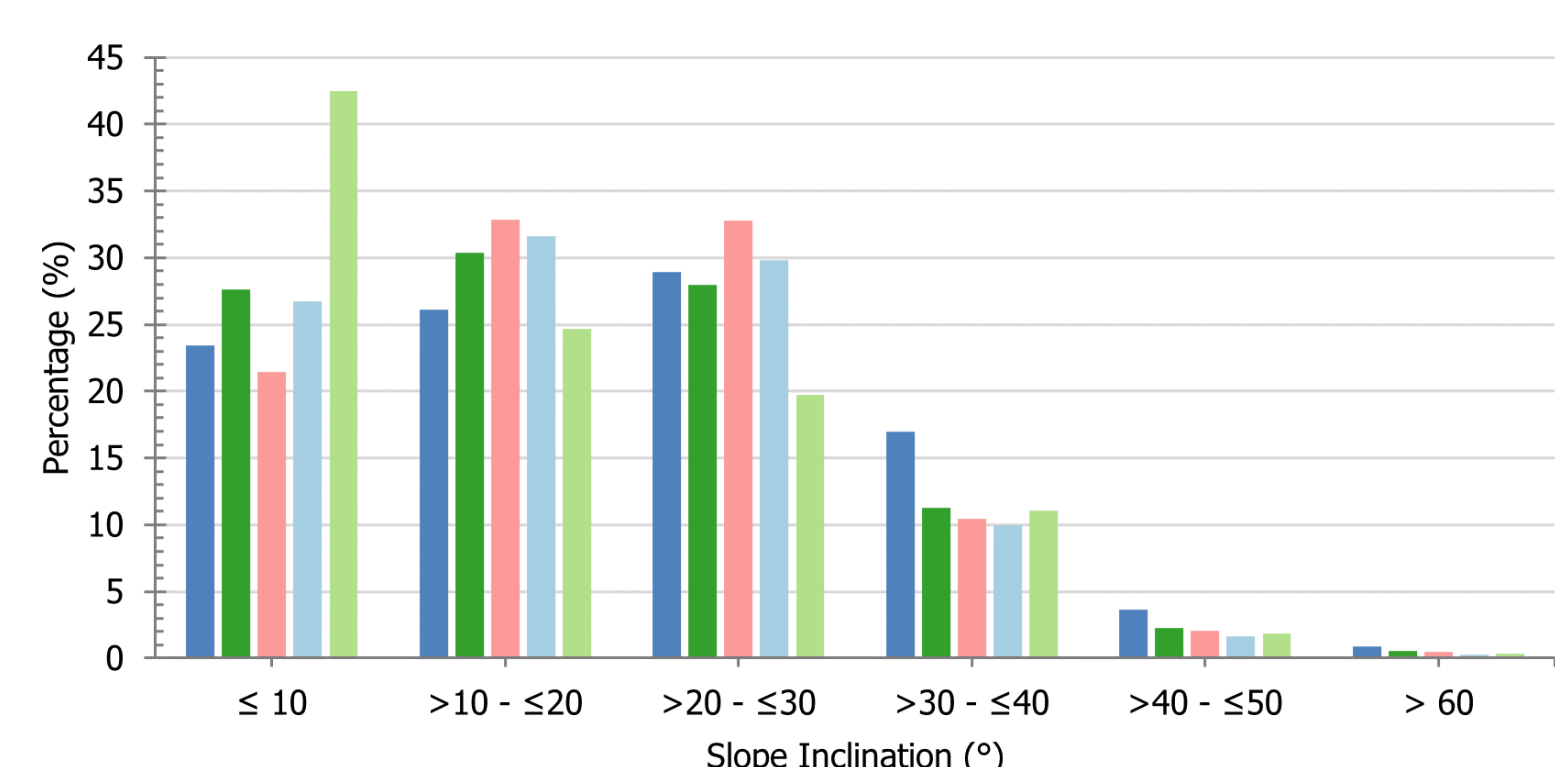


Fig. 8: Burned area per decade expressed as a percentage of total burned area per slope inclination category (sum of bars per decade=100%) (top) and as a percentage of slope category burned (bottom).

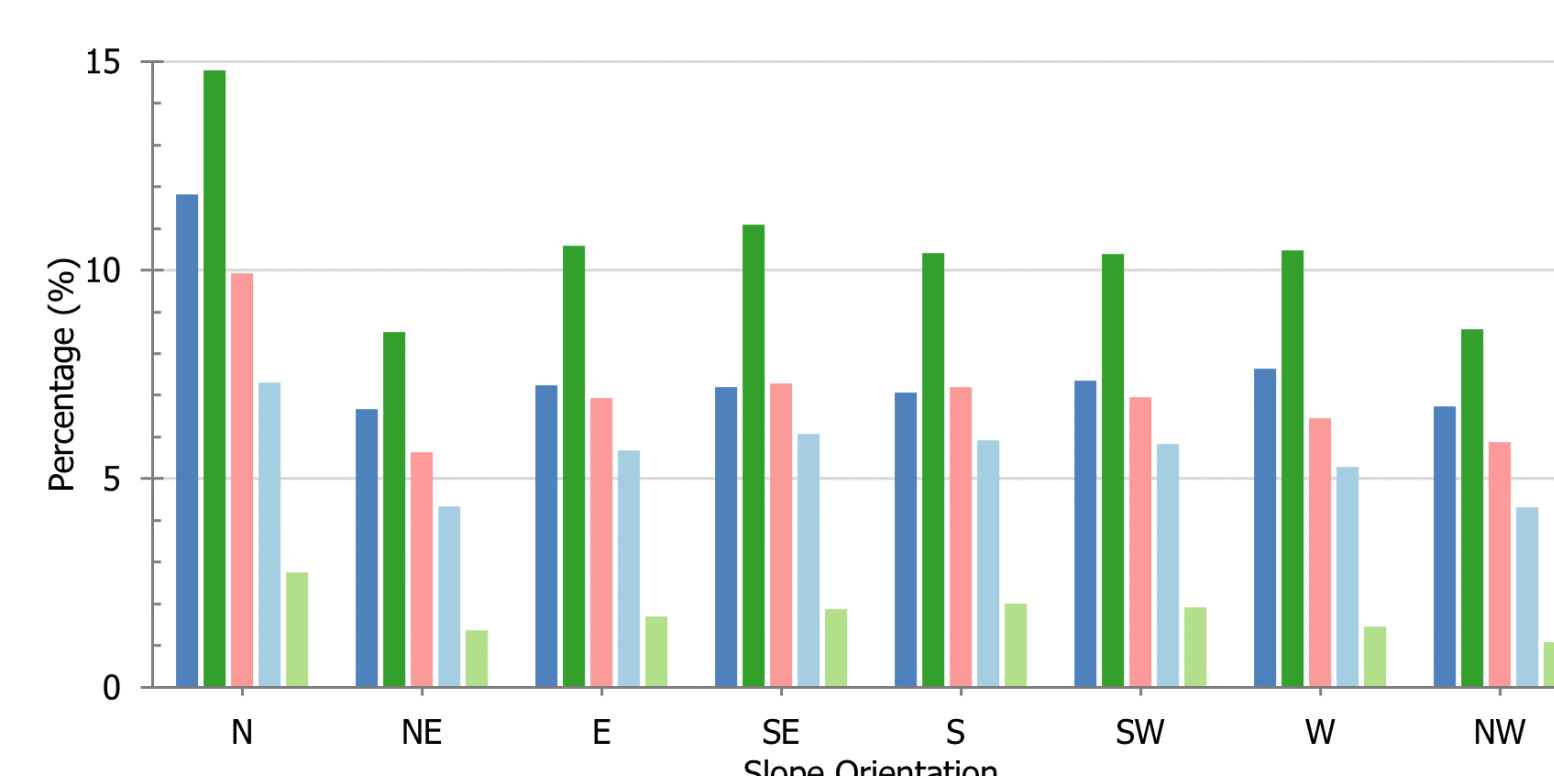
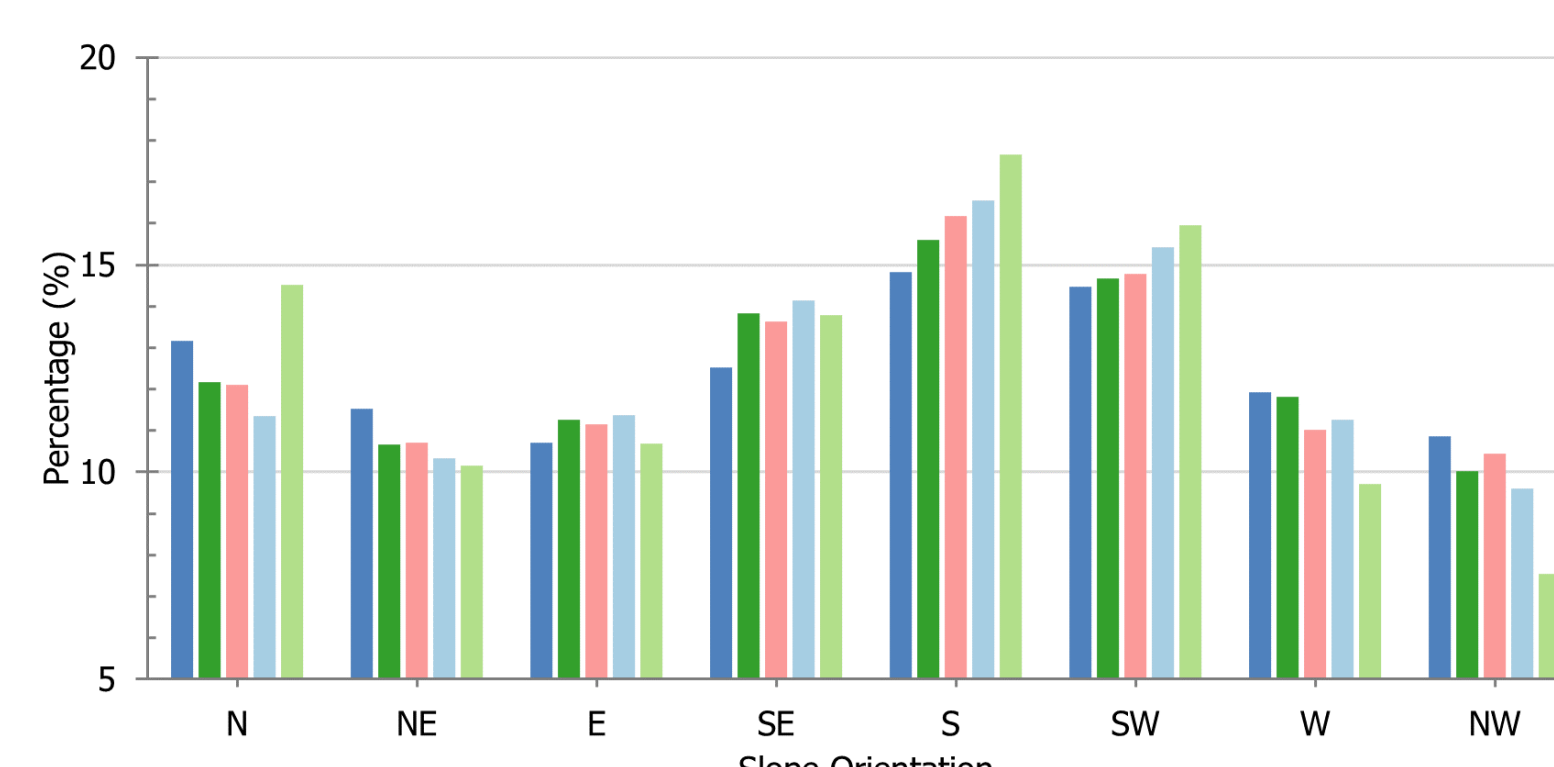


Fig. 9: Burned area per decade expressed as a percentage of total burned area per slope aspect category (sum of bars per decade=100%) (top) and as a percentage of slope aspect burned (bottom).

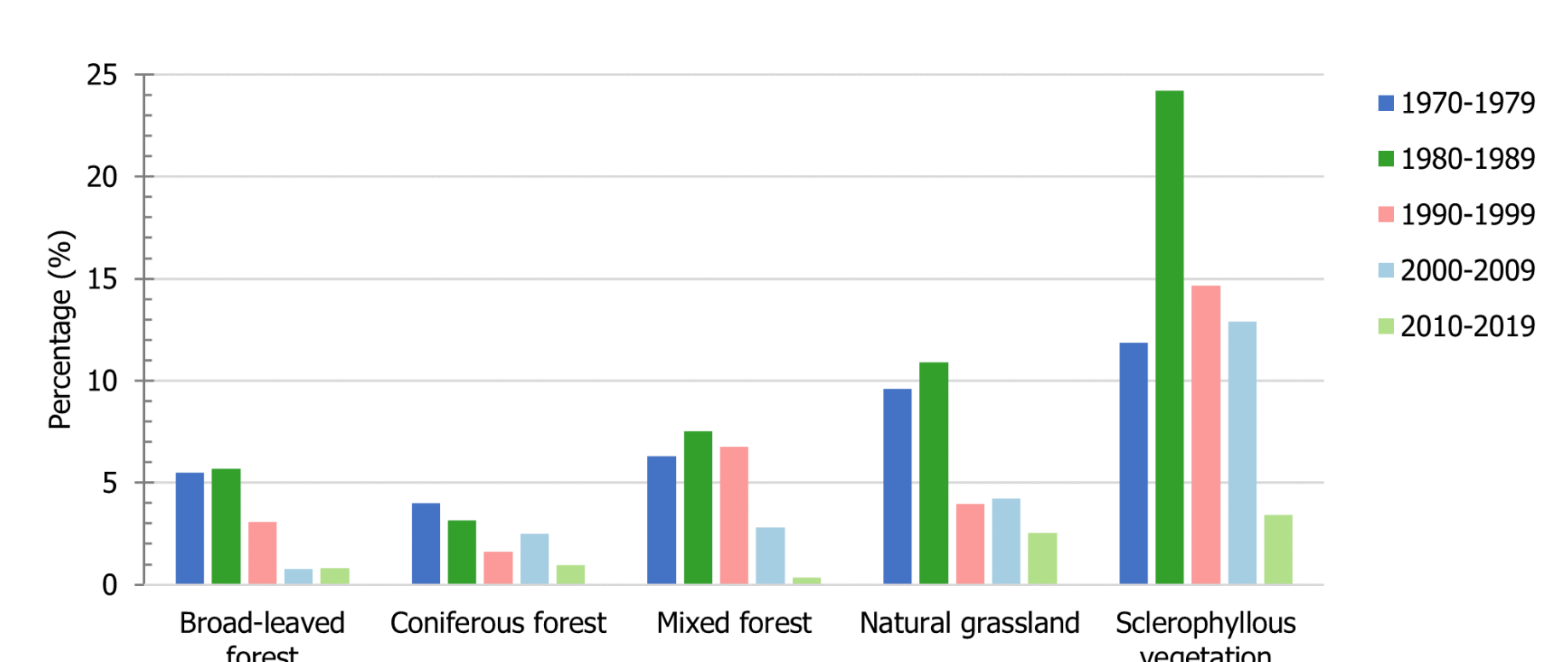
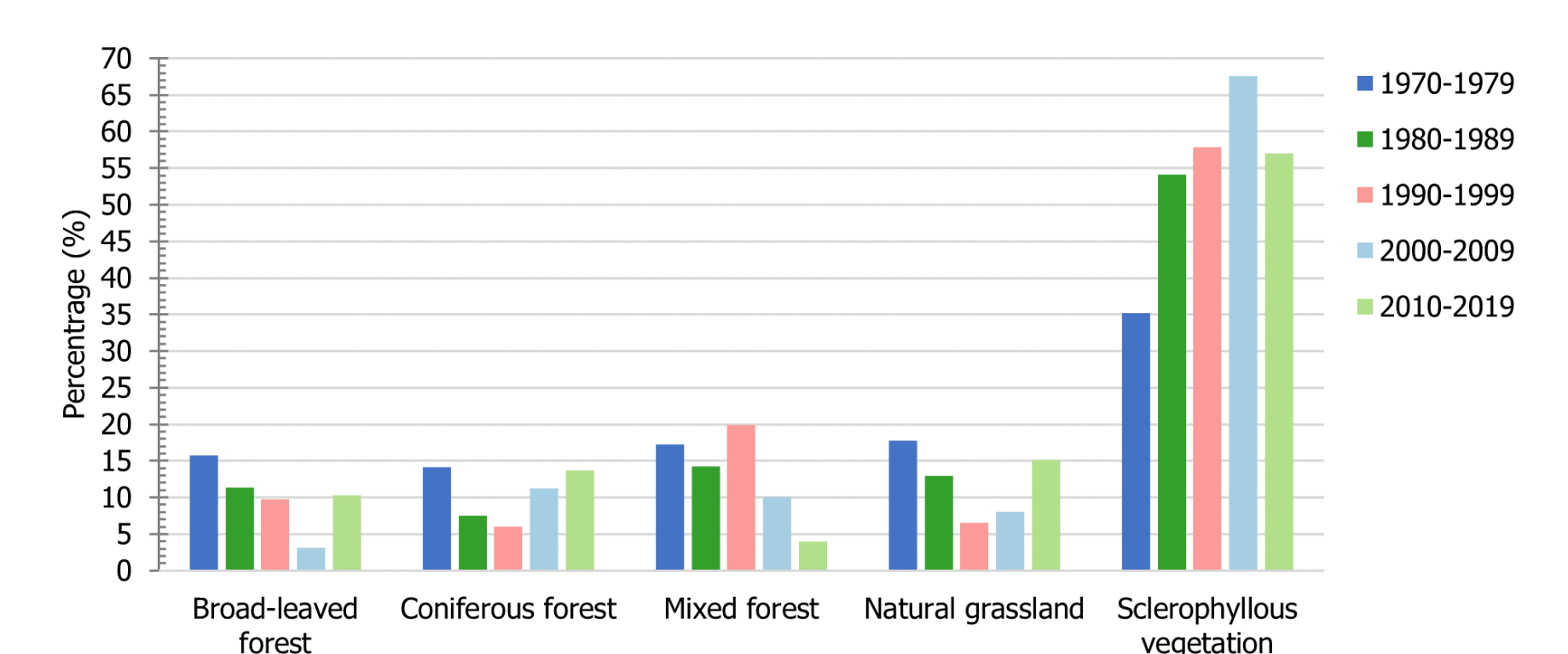


Fig. 10: Burned area per decade expressed as a percentage of total burned area per vegetation category (sum of bars per decade=100%) (top) and as a percentage of vegetation category burned (bottom).

Slope Inclination

Absolute burned area is generally greater on intermediate slopes (Fig. 8 top), and there's a tendency for burned areas to shift towards gentler slopes inclinations after 1990-1999; this coincides with the shift to more effective fire repression and suppression strategies.

The relative burned area (percentage of slopes burned) is greatest for steeper slopes (>60%) as shown in Fig. 8, bottom; this, however, concerns very little burned area. Slope inclinations most susceptible to burning remain the intermediate categories of about 10-40%.

Slope Aspect

Absolute burned area is greater on South-facing slopes (Fig. 9 top). South-facing slopes are drier and have more houses/roads with greater fire ignition risk. In addition, the Sud-PACA region has greater South-facing slope area than North-facing slopes.

Surprisingly, a greater percentage of North-facing slopes is burned than for South-facing slopes (Fig. 9 bottom). This unexpected can be linked to the direction of maximum wind speed, which is frequently from the North (Mistral winds).

Vegetation Type

Sclerophyllous vegetation (i.e.. Shrubland) has the greatest absolute burned area (Fig. 10 top). Shrublands are drier and allow greater wind speeds so fires propagate more quickly. This finding is confirmed when burned area is expressed as a percentage of vegetation category area (Fig. 10 bottom).

4. Conclusion

Burned area decreased sharply in the early 1990s when the SDIS firefighting service developed more efficient fire repression and suppression strategies after the catastrophic fires of the 1980s. Frequently burned patches diminished in both areal extent and fire frequency afterwards. Intermediate slopes are the most susceptible to burn, but the study reveals a shift to lower slope inclinations, and this may be due to the rapid suppression in the initial stages of the fire which thereby limits propagation to steeper slopes. Although fires are frequently found on South-facing slopes due to drier conditions and a greater potential for fire ignition, North-facing slopes have greater wind speeds and a greater proportion of these slopes are burned compared to South-facing slopes. Finally, shrublands are the most susceptible to wildfires. The next step is to use machine learning algorithms in conjunction with weather and land cover data to better predict forest fire risk in the future.

5. Acknowledgements

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