European Commission

Terrestrial Ecosystem Research in Europe: successes, challenges and policy

Final conference of the
terrestrial ecosystem research initiative — concerted action
(Terica) Project ENV4 – CT95 – 0051
Egmond aan Zee, the Netherlands, 20 to 23 June 1999

Edited by
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Directorate-General for Research

2000

EUR 19375 EN

LUCIFER: Land use change interactions with fire in Mediterranean landscapes

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INTRODUCTION

The Mediterranean landscapes have been considered a model of fine-grain, most diverse, natural and cultural landscapes caused by the ancestral human use of the land. However, in the last decades, improved socioeconomic conditions in EU-countries have altered the use of the land, eventually resulting in a change of landscape features. Parallel to this, fire occurrence has increased manifold. Fires dominate now in many areas in an unprecedented way, and may be altering the ecosystems in unknown ways. How the changes in the landscape have affected fire occurrence is little known. Similarly, little is also known about the impacts on key ecosystem structure and processes produced by the changes in the landscape caused by fire. Understanding these interactions is needed to properly manage these areas. This knowledge could also serve as a model to anticipate the impacts of land-use change in other fire-prone areas of the world.

In LUCIFER we attempt to:

a. Determine how the structure of the landscape has changed in the last 2-4 decades in fire-prone areas of all the Mediterranean countries of the EU, how fires themselves have contributed to such change, and what role have landscape changes played in promoting fire.

b. Asses whether fires induce a further homogenization of the burned area, hence increasing fire hazard.

c. Evaluate the relationship between land-use and patch heterogeneity and the post-fire flows of soil, water and nutrients from the burned area.

d. Establish the role of burned area on the post-fire species dynamics, asses the basis for species change between burns, in particular for rare/endemic species, as well as the potential colonization of burned areas by new species.

Models have been, and are being, developed that could serve to evaluate fire hazard and other threats to the ecosystem in fire-prone areas resulting from landscape changes.

ACTIVITIES AND EARLY RESULTS

1. Landscape changes and fire

Land-use/land-cover changes during the last 3-4 decades are being determined by means of aerial photography and remote sensing in all Mediterranean-type countries of the EU. First conclusions from three of the sites analyzed (Gredos, Cuenca and Alicante sites) indicate that the rate of change of the areas studied has been rather large (over 50% of the territory changed in the land-cover it sustained during the past 3-4 decades). In general, there has been a tendency for a reduction in cultivated areas and an increase in pine-woodlands. Two different tendencies have been observed: at the sites were fires started to become frequent in the early

1970's (Gredos, Alicante) there was an initial tendency towards landscapes becoming more homogeneous but this tendency was stopped with the onset of fires. At sites like Cuenca, the landscape became first more heterogeneous, as a likely result of sustained management, and later it turned more homogeneously. In 1994 this place sustained one of the very large fires in record in Spain. Fires are also being mapped in each of the landscapes studied. The analysis of the relationship between fire occurrence and features of the landscape is still preliminary but it appears that fires are very clumpy, do not occur evenly across a given area, tending to occur at preferred locations and topographies. Based on the analysis of two of the sites (Spain, Portugal), it appears that once-burned areas tended to sustain additional fires more frequently than expected, hence apparently conducing to an acceleration of the fire cycle. Analysis in all the areas being studied will confirm whether this is a general tendency of Mediterranean landscapes. The sensibility to fire of the various landscapes under study is being evaluated by analyzing the relationship between the structure of burned surfaces and fire conditions. Additionally, fractal analysis of burned area and number of fires is being conducted at all sites. Results from one of the Italian sites indicate that this approach could give indications of the limits of a given landscape to sustain certain types of fires.

2. Role of fire on altering landscapes

The role of fire in altering landscape structure is being established by detecting changes in the landscape after fire in relation to pre-fire land-use history or variations in fire-severity by combining remote sensing and field work, in this case focussing on plants and animals. After fire, landscapes are very dynamic and no clear relationship with the pre-fire structure has been found. Changes in land-uses through abandonment in one of the PT sties determined changes in vegetation composition and structure, which played a strong influence on the composition of animal (birds) species. The dynamics in relation to fire do not revert to those of previous land-uses. As for plants, based on one of the sites (E) persistence of a given land-use affected plant species richness after fire differently, depending on the substrate: greater permanence in land-use produced greater richness in basic substrates but lower richness in acidic substrates.

3. Soil, water and nutrient flows and fire interactions with the landscape

Sediments accumulated at erosion-dams in 12 catchments have been collected and are being analyzed to determine erosion losses through time in relation to fire and to land-use/land cover. Catchment post-fire sediment yield (0.13-10 Mg ha^{-1} yr^{-1}) was significantly higher than the pre-fire one (0.33-1.76 Mg ha^{-1} yr^{-1}). Sediment yield was positively correlated with the amount of area with steep slopes, fragile substrata and abandoned crop terraces. Soil erodibility decreases with increased plant cover following abandonment of cultivation. Fire, however, tends to homogenize all areas by increasing erodibility irrespective of their land-use type. Preliminary analysis of the spatial variability of soil properties within a given land-use type indicates that there exists a greater homogeneity of organic matter, organic carbon, and total nitrogen content in burned than in unburned soils, irrespective of land-use type. These results seem to confirm the hypothesis that the passage of the fire is able to homogenize some soil differences determined by initially different land uses.

4. Landscape, fire and species dynamics

The evaluation of how the size of burned areas (or patches within burned areas) affect species (plant and some animal groups) maintenance in the system, with particular attention to rare and endemic species or to species with an invading potential, is being investigated at sites of the East and West Mediterranean. The basic approach consists in selecting a large fire, whose land-use/land-cover history has been reconstructed, and sample selected plant and animal in relation to the edge of the burn. Particular attention is being devoted to rare/endemic species. Early results from one the large fires studied indicates that most plant species are rare, either in the burn or unburned area (less than 10% of the species are present in more than 50% of the sampled plots). Plant species richness increases in the burned area (157 vs. 233 and 195 vs.

264 for acidic and basic substrates, respectively). This increment is due mainly to cosmopolitan species and rarity increases for those species present in the unburned area. Although clearly distinct patterns of species richness were observed in the landscape, this were related to substrate. No clear fire-size effect was observed, as total species richness did not vary with the distance to the edge of the fire. Further fieldwork is still in progress, in particular to elucidate the causes (dispersal, herbivory) of the patterns being observed. Particular attention is being devoted to rare or endemic plant species. Lists of endemics of fire prone areas have been produced for the Eastern (HE) and western (E) Mediterranean. Hemicryptophytes and chaemophytes dominate the spectrum of life forms of endemics. The hypothesis that Mediterranean-endemic species would be more affected by fire than cosmopolitan ones has so far not been confirmed: the number of plants of different distributional range (cosmopolitan, endemics of restricted distribution) whose frequency changed as a result of fire was not different. Ecophysiological studies of the germination of 22 taxa of the genus *Centarea*, varying from broadly cosmopolitan to endemic did not find any relationship whatsoever to fire-related cues. Further work is in progress with additional groups of species from the East and West Mediterranean being investigated.

5. Modelling

Completed modelling efforts within LUCIFER comprise the development of a spatially explicit, generic vegetation model, which combines a dynamical simulator for each landscape unit, with a map that describes the spatial distribution of landscape features. A vertical representation of the vegetation structure (herbaceous, shrubby and tree components) and a weekly water budget of three soil layers are also simulated. The model takes into account the particular case of Mediterranean vegetation, with multiple species, and varied regeneration abilities after fire. The model takes a functional approach towards carbon and water to drive growth, competition and to simulate plant water status from which fire danger can be inferred. Spatial processes for water and seed dispersal are simulated and it can be easily linkable to fire ignition and fire spread routines. Initial results indicate that this a good tool to evaluate the change of fire hazard in the landscape through time and the interaction with additional fire as it may affect vegetation composition and structure. Changes in fire regime can also easily produce an evaluation of its likely impacts on the landscape. Additional modeling efforts within the project comprise cellular-automata approaches for the spreading of disturbances taking into account spatial interactions. Validation efforts are now underway to the various sites whose landscapes and fire incidence has been evaluated.