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Fire disturbance regimes: spatio-temporal effects on soil-vegetation interactions, soil properties and erosion processes

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Forest fires have been recognized to be an inherent component of Mediterranean ecosystems. It has been suggested that fires have been human induced for millennia as a management practice in the Mediterranean Basin. In recent decades, however, the number of fires and their areal extent in these ecosystems markedly increased. Landscape structure has dramatically changed during the past century in the nowadays region of Israel, from denuded of vegetation at the beginning of the 20^{th} century, to extensive afforestation by the 1960's. Currently natural maquis and homogeneous, even-aged stands, of *P. helepensis and P. brutia* stands dominate the landscape. Such stands are characterized by increased susceptibility to fire and facilitate the spread of the large fires occurring in the last decades.

The main, and well documented, effects of fire on soils include changes in the physicochemical properties and increased risk of erosion after burning. The latter is also related to the patterns of vegetation regeneration and forest architecture. Soil properties may experience short-term, long-term or permanent fire-induced changes, depending on disturbance regime, timing and magnitude of the event, affecting in turn vegetation regeneration and erosion processes. Moreover, wildfires are now driving desertification in some of the forest lands in the western United States.

Given the devastating effects of fire to the ecosystem we aimed at analyzing the multiple effects of increasing disturbance frequencies on soil-vegetation interactions in different spatio-temporal scales, ranging from days after the fire to a 30 year time pe-

riod and from a single soil pit to 10 m^2 plots up to entire basins. Additionally, our research addresses the effects of repeated burns, in sites that have burned as many as three times during this period.

Various filed and laboratory methods were used. First, we assembled and mapped all documented fires that occurred in Mt. Carmel region during the last 30 years. Detailed soil survey, including repellency measurements and chemical analyses were conducted at all fire sites. Following the 1989 and 2005 fires experimental plots were delineated in various treatments (slope, fire severity, slope aspect) to assess runoff and erosion. The 2005 plots were photographed monthly to evaluate vegetation recovery rates at small scales. Satellite image analysis was used to monitor vegetation changes at the basin scales. An extended vegetation field survey and satellite images from 1990 (following a 1989 fire), 1995, 2000 (following 1998, 1999 fires) and 2006 (following a 2005 fire) were used to classify the different vegetation categories, and analyze its dynamics.

Annual sediment yields were well correlated with vegetation cover (or lack of). A threshold of 40% coverage is sufficient for significantly reducing soil erosion from burnt plots, whilst over 60% coverage soil loss was totally prevented. It is apparent that under bare conditions most of the erosion processes may occur during a single intense rainstorm, whilst the presence of vegetation moderates this process. Considering runoff yields, however, it is evident that also the type of the emerging vegetation plays a key role in regulating surface flows; for example, herbaceous regeneration was found to increase runoff during the second year following fire in contrast to a parallel decline in soil loss.

Vegetation regeneration under recurrent fire regime exhibit not only slower rates of recovery but also gradual changes in vegetation communities' structure. The pine stands may be replaced by a mixed maquis-shrub community while this community, in turn, may be replaced with herbaceous vegetation. Laboratory analysis of soil chemical properties following severe fires supports the assumption of gradual degradation of the system, indicating a long-term (of several decades) rehabilitation period of most necessary soil nutrients.

It is proposed that following a fire event the rehabilitation of different ecosystem properties and processes, such as soil characteristics, erosion and vegetation structure, occur at different temporal rates and spatial scales. A mosaic of patches at different scales is formed in the landscape, and the interaction among them dictates ecosystem response. Recurrent fires impose a cascading disturbance process which can be viewed through time and space as a shifting mosaic of disturbance patches, and may ultimately alter ecosystem structure and processes in cases where fire regimes are al-

tered.