Ecological resilience after fire in mountain forests of the Central Alps

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Abstract: The ongoing climate warming may result in more frequent and more intensive fire events in the Central Alps. Because studies on the long-term fire history of the Central Alps suggest that forest fires were naturally more frequent, questions on the ecological resilience of these mountain forests after fires arise. On an 300 ha forest fire patch along an altitudinal gradient the re-colonisation has been observed annually after the fire event in August 2003. Re-vegetation has been assessed on a systematic sample (n=154) and on a stratified sample (n=40). On the latter sample, the original forest vegetation was assessed in 1996. Invertebrates were sampled weekly during the summer seasons 2004 and 2005 (1 and 2 years after the fire) on 18 trap sites along three transects at different altitudes. Trap sites were grouped into the three habitat types 'intact forest', 'burnt forest' and 'transition zone'.
Two years after the fire, following results are at hand: For a wide area, the vegetation was literally missing in 2004, though returned successively in 2005. Correspondingly the trees regenerated only locally in 2004. The speed of re-colonisation in terms of numbers of plant species strongly depended on the scale in consideration. On plots of 200 m^2 average species richness of the pre-fire vegetation and the post-fire vegetation in 2005 were equal, whereas at the scale of 500 m^2, the post-fire vegetation was significantly richer. Fire severity, as indicated by the thickness of the ash layer in 2004, correlated negatively with both vegetation cover and number of plant species in 2004. About 50 % of the collected invertebrate individuals were pollinators and 29 % were predators. Highest individual numbers were counted in the transition zone. The started studies will be continued in the next years in order to monitor the post-fire recovery and to seek for altitude-related differences in the fire adaptability of these forest-ecosystems.

Keywords: biodiversity, forest vegetation, regeneration, scale

1. Introduction

The ongoing climate warming is exceptional in the Central Alps (Rebetez and Dobbertin, 2004), and it may result in more frequent and more intensive fire events in this region. A recent evidence of this trend was given during the very hot and dry summer of 2003, when a high number of lightning- and partially also man-induced wildfires were registered in the Alpine valleys (Tinner *et al.*, 2006). Because studies on the long-term fire history of the Central Alps suggest that forest fires were naturally more frequent as at present (Gobet *et al.*, 2003; Carcaillet and Muller, 2005; Tinner *et al.*, 2005), questions on the ecological resilience of these mountain forests after fires arise in the context of past and future climates.

A great opportunity to study the ecological resilience was offered by a major wildfire in the central-alpine region of the valley of Valais, Switzerland, which was started by arson on August, 13th 2003. Due to the exceptionally dry conditions, the fire rapidly developed uphill towards the timberline. It burned 300 ha of forest in a band of about 800 m width along a vegetation gradient that ranges from mixed oak-pine (*Quercus pubescens*, *Pinus sylvestris*) at 800 m a.s.l. to spruce (*Picea abies*) and to open larch (*Larix decidua*) forests at timberline at 2100 m a.s.l. (Fig. 1; Wohlgemuth *et al.*, 2005). In 2004 we started a study case on the resilience and the recovery pattern of the damaged forest types and on the forest dwelling invertebrates. Relevées of the pre-fire vegetation serve as extraordinary reference to be compared with the actual succession. We measure the ecological resilience by vegetation cover and by number of species of different taxa and functional groups. The following questions are addressed: A) how fast does the re-colonisation proceed? B) Is the ecological resilience different with respect to elevation?

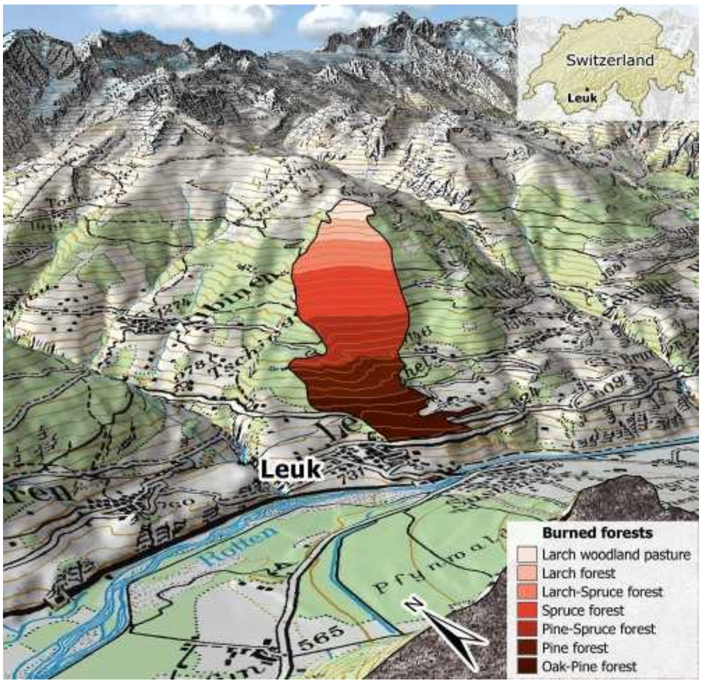

Fig. 1. Location of the forest fire patch in the central-alpine valley of Valais, Switzerland, 46°20'N, 7°39'E (2006 Swisstopo BA067917; image calculation with RaVis ©, Geoinformationsysteme ETH Zürich, elaboration: P. Krebs, WSL).

2. Methods

In and along the forest fire area patch several samples have been either installed in 2004 or revisited in 2004 (Fig. 2). The resilience after fire has been studied on both the vegetation and the invertebrates. On quadratic, 200 m^2 plots along a systematic grid of 125 m mesh size the re-colonisation of plant and moss species has been monitored in the whole burnt area since 2004. On sub-plots of 50 m^2 inside these plots, regenerating tree species have been counted. Ash layer was measured in 8 locations around the quadrats. Concentric plots of 30, 200 and 500 m^2 were assessed as part of a stratified sample in a PhD study before the fire (Gödickemeier, 1998). In 2004 and 2005, the plots were re-assessed in order to compare the vegetation of the pre-fire forests with the vegetation after the fire. Invertebrates were sampled weekly during the summer seasons 2004 and 2005 (1 and 2 years after the fire) on 18 trap sites along three transects at different altitudes by means of pitfall traps and window traps for soil-dwelling and flying active species, respectively (Fig. 3). Trap sites were grouped into the three habitat types 'intact forest', 'burnt forest' and 'transition zone'.

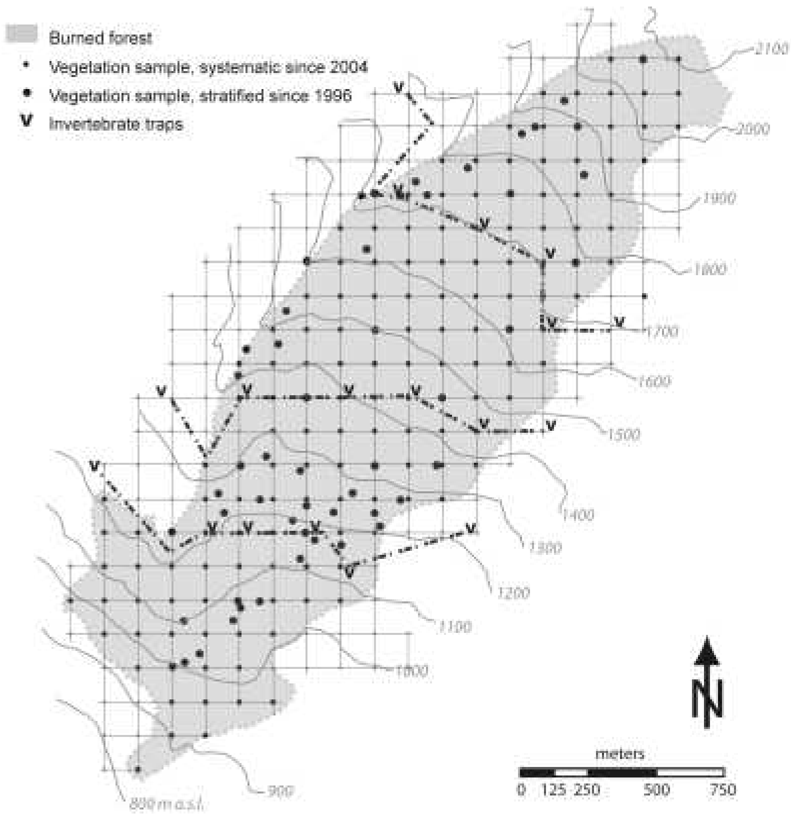

Fig. 2. Samples in and along the forest fire patch (shaded area) of Leuk.

Fig. 3. Invertebrate traps in the burnt forest above Leuk (Valais) one year after the fire: A window trap (left) and a pitfall trap with a roof protecting against rain (right; Foto:M. Moretti).

3. Results

Two years after the fire, following results are at hand: For a wide area, the vegetation was literally missing one year after the fire in 2004, though returned successively in 2005 (Fig. 4). Correspondingly, the trees regenerated only locally in 2004. Ash layers were not evenly distributed in the burnt area. Between 1400 and 1800 m a.s.l., ash layers were generally thicker than at the timberline or at lower elevations. As an indicator of fire intensity, the ash layer was significantly and negatively correlated with both vegetation cover and plant species richness in 2004. The speed of re-colonisation in terms of numbers of plant species strongly depended on the scale in consideration. On 30 m^2, two years after the fire, the average number of plant species was significantly smaller than in the intact forests in 1996 (Fig. 5A). On the 200 m^2-plots, there was no significant difference in average species richness between 1996 and 2005, and on the 500 m^2-plots, the average species richness in 2005 exceeded the one in 1996 significantly. In accordance with these results, the pooled species richness also shows a depression one year after the fire and a distinct increase after two years (Fig. 5B).

Invertebrate abundance was high one year after the forest fire. Regarding early post-fire succession of the invertebrates, the most frequent groups were beetles, two-winged flies, bees, and parasitic wasps. About 50 % of the collected individuals were pollinators and 29 % were predators; herbivores, decomposers, and wood-eating arthropods represented the rest (21 %). Highest individual numbers were counted in the transition and partially in the burnt zones, except for the ground-dwelling predators and decomposers, which were more abundant in the intact forests (Fig. 6).

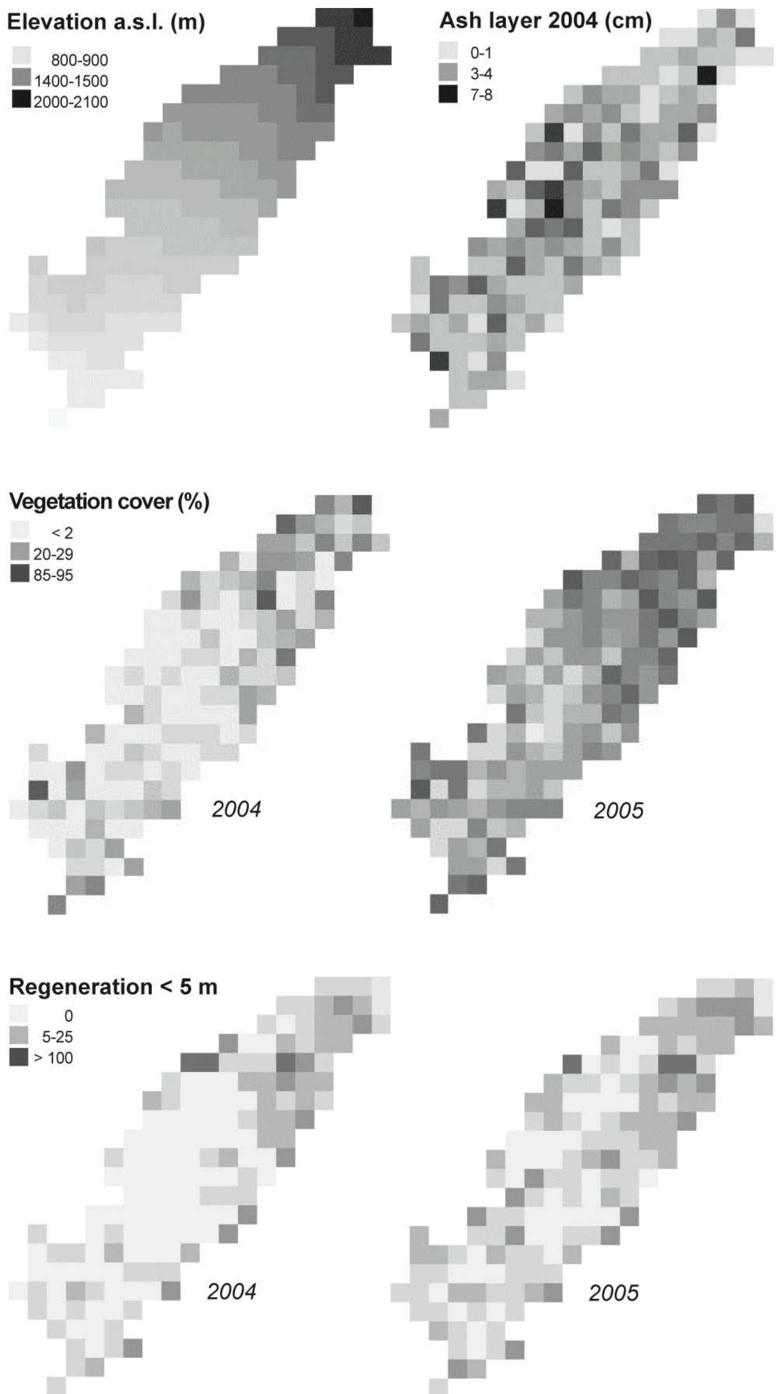

Fig. 4. Ash layer in 2004, vegetation cover and regeneration of tree species in year 1 and 2 after the forest fire. Results of the sample plots are displayed as oversized pixels.

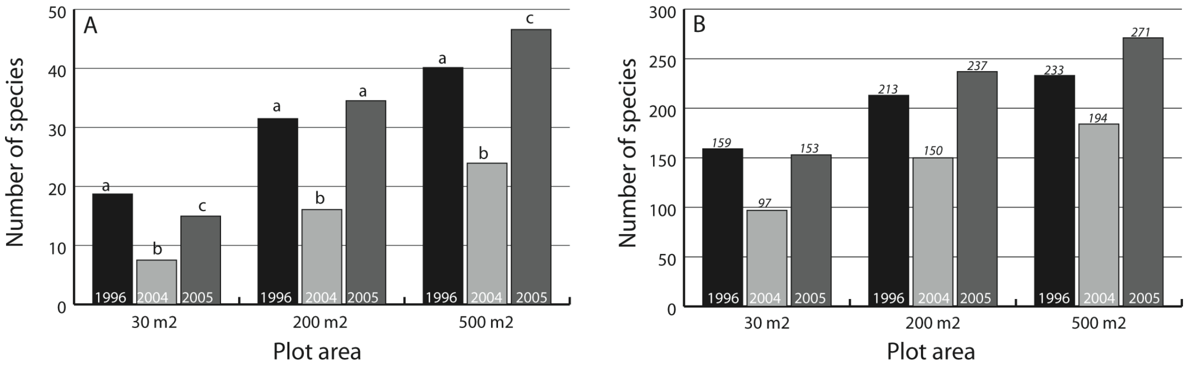

Fig. 5. A: Average number of species in concentric plots (n=40) before the fire (1996) and after the fire (2004, 2005). Characters indicate significant differences (paired t-test) between values of same plot size classes. B: Pooled number of species of 40 plots before and after the fire.

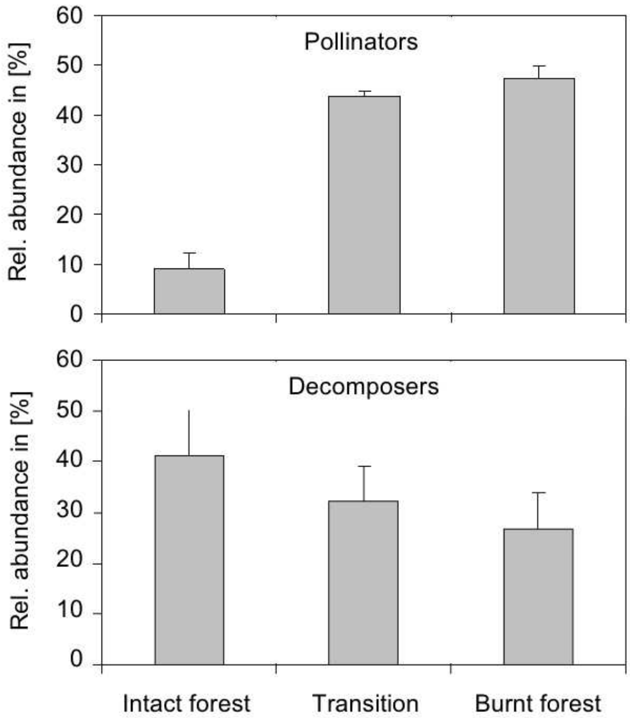

Fig. 6. Relative abundance of insect individuals along the transect on 1200 m a.s.l. (6 trap sites), grouped by zones and functional groups on the example of pollinators and decomposers.

4. Discussion

Re-colonisation by plants one year after the forest fire was most pronounced in transition between burnt areas and the intact forest as well as at higher altitudes towards the timberline. Wide areas were virtually without vegetation. But two years after the fire, the plants spread more rapidly: species abundances and number of species increased and partly exploded. Already two years after the fire, numbers of plant species exceeded the pre-fire vegetation on the scale of 500 m^2 and was equal to the former richness on the scale of 200 m^2, i.e. the process of boosting species richness was first detectible on larger scales and will be observable on smaller scales in the next years. Competition-free conditions in combination with increased incidence of light (Hofmann *et al.*, 1998; Wang and Kemball, 2005) account for the increased richness short after fires (Grubb, 1977; Safford and Harrison, 2004; Keeley *et al.*, 2005). Our observation of slower re-vegetation on intensively burnt locations corresponds with those of other studies (Schimmel and Granstrom, 1996; Rydgren *et al.*, 2004; Safford and Harrison, 2004). On places where the fire burnt the topsoil layer, vegetation was totally absent one year afterwards. In contrast, on places where the fire was less severe (and hence the ash layer small) plants with rhizomes such as *Calamagrostis varia* could resprout rapidly after the fire. This effect was reported for other plants such as *Rubus idaeus* or *Pteridium aquilinum* (Flinn and Wein, 1977).

The regeneration of tree species proceeds only slowly. For early colonizing conifers such as Scotch pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and European larch (*Larix decidua*), conditions for seed germination degrade successively with increasing spread of herbs. In contrast, fast growing Mountain willow (*Salix appendiculata*) and Aspen (*Populus tremula*), which altogether amount to 75 % of all shoots, seem to be well adapted to post-fire conditions.

One year after the fire, the invertebrate activity was large especially in the transitions between burnt areas and the intact forest, where the fire was less intensive. Forest edges as such are important for invertebrates as: 1) corridors for re-colonisation of new habitats, 2) as transition zones between burnt and unburned habitats, 3) as transition zones between open and closed habitats. These three components result in a high number of individuals and presumably also in high numbers of species at the forest edges. Edge zones are also important for species that need wood for their larval development, as well as open land with many flowers as adults (Wermelinger *et al.*, 2002; Moretti and Barbalat, 2004). Open burnt areas offer resources for both pioneer and ruderal species as well as for wood-eating species. Similar results were reported from burnt *Castanea sativa*-forests in the South of the Alps (Moretti *et al.*, 2004; Moretti *et al.,* in press).

Continued monitoring activities in the study site in Leuk will contribute to answer the question in which way the forest ecosystems are already adapted to fire as an episodic or periodic disturbance event and whether differences in fire adaptability are related to altitude.

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