ed that they will allow the reconstruction of global-scale spatial and temporal patterns of temperature and precipitation along this transect over the last several hundred years and to encourage the training of scientist and the application of dendrochronology and paleoenvironmental science within Latin America (Luckman and Boninsegna, 2002).

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Post-fire Vegetation Dynamics in Southern Switzerland

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Introduction

Because forest fires in central Europe are rare compared to North America, knowledge about the post-fire behavior of native European species is scanty. The expected climate change for the next century could influence fire regimes in central Europe thereby leading to more frequent forest fires. Thus, knowledge about post-fire behaviour and fire-sensitivities of central-European plant species may become more important for understanding and managing forest ecosystems.

In Switzerland most fires occur in the region south of the Alps during the early spring season (March to April). During this period the deciduous forest belt is threatened by fast spreading surface fires that, in certain cases, represent a very important disturbance factor (Conedera et al. 1996). It is well known that the vegetation shows different reaction patterns to fire depending on the life strategy of the species and the fire regime (Bond and van Wilgen 1996, Hofmann et al. 1998), but because fire affects species composition at timescales of years to centuries, direct observation of the full range of post-fire vegetational change is not possible. To overcome this difficulty, we combine paleoecological, dendroecological and phytosociological methods in order to (1) determine vegetation response patterns during different historical periods and fire regimes and (2) provide information on related long-term ecosystem dynamics.

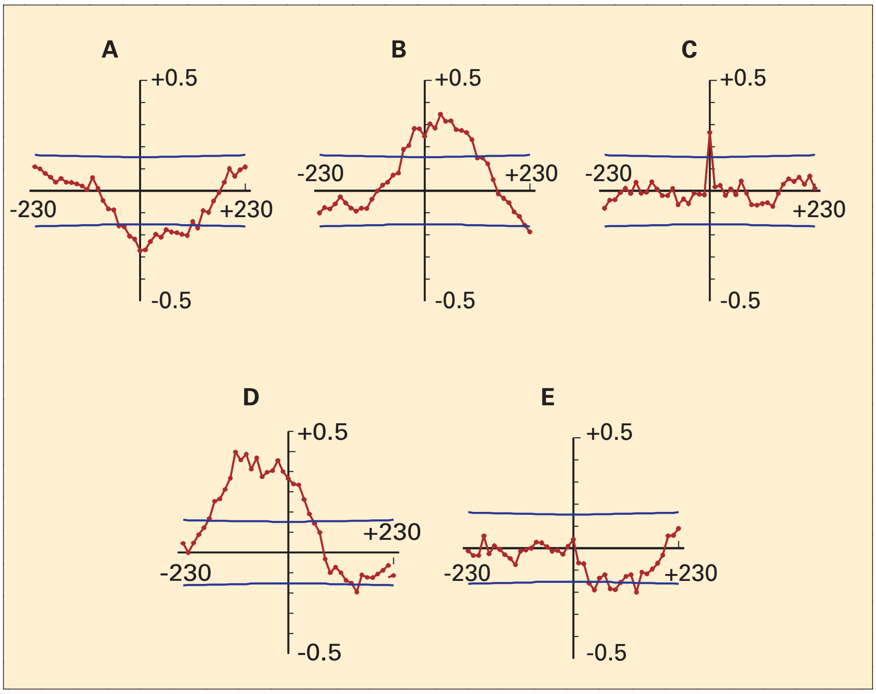

*Fig. 1: Correlograms of charcoal influx, pollen percentages and diversity from Lago di Origlio (5,100-3,100 BC cal.). Horizontal axis shows lag in years (one lag = 11.6 years). Vertical axis shows correlation coefficient – those outside the lines are significant at p = 0.05. **A**: decreasing taxa (charcoal vs. Ulmus spp.); **B**: increasing taxa (charcoal vs. Alnus glutinosa t.); **C**: opportunists (charcoal vs. Cichorioideae); **D**: fire precursors (charcoal vs. Pteridium aquilinum); **E**: plant diversity (charcoal vs. pollen diversity).*

Paleoecology

Sediment analyses of two small lakes (Lago di Origlio and Lago di Muzzano) were used to reconstruct vegetation history and fire ecology of the last 15,000 years (Tinner et al. 1999). A comparison of the recent sedimentary record with the wildfire database of southern Switzerland indicates that charcoal concentration and influx estimated from pollen slides correlate well with the number of forest fires occurring within a distance of 20 to 50 km from the coring site (Tinner et al. 1998). In order to determine post-fire vegetation responses, we computed cross-correlations for pairs of pollen types and charcoal concen-

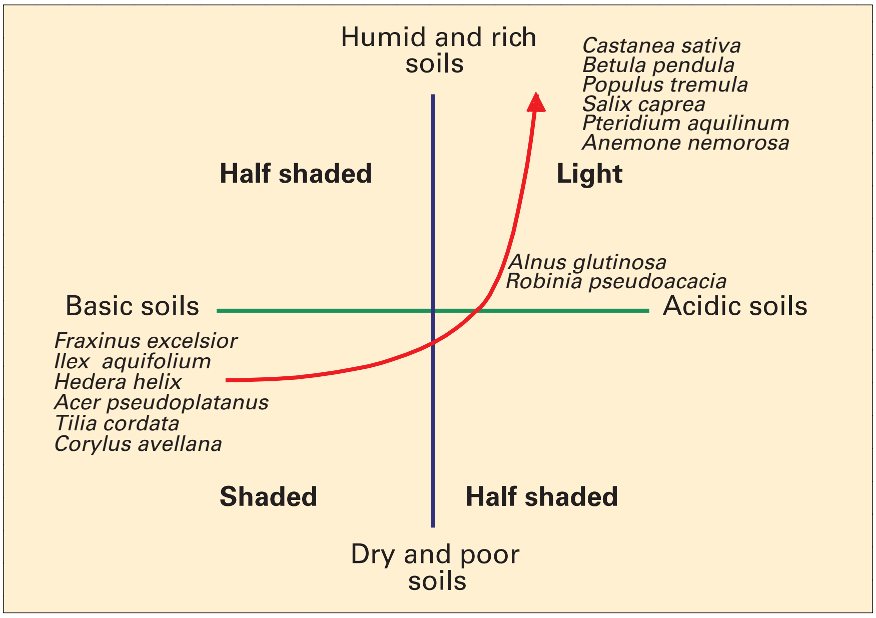

Fig. 2: Effect of fire on vegetation and soil types. The arrow indicates the directional change following fire. Communities change from shade-tolerant species on basic soils to shade-intolerant species on acidific soils.

trations during the period 5100-3100 BC, using a sample interval of approximately 10 years.

Dendroecology and Vegetation-Ecology

To study the effects of modern forest fires on the vegetation physiognomy we used a methodology consisting of community sampling in quadrats of 100 m^2, in order to analyse post-fire reactions of the vegetation as a function of forest type, fire frequency over the last 30 years and time elapsed since the last fire (Delarze et al. 1992, Hofmann et al. 1998). Dendroecological data were recorded for each plot to verify the reliability of the wildfire database of southern Switzerland and to reconstruct the fire history on the basis of fire scars where fire history was lacking (Hofmann et al. 1998). Ecological indices according to Landolt (1977) were used to evaluate the site conditions.

Results

Cross-correlations prove to be a very useful technique for detecting post-fire behavior of various taxa (Fig. 1). During the first part of the Neolithic (5,100-3,100 BC) four different reaction patterns could be distinguished (see also Tinner et al. 1999):

- decreasing type (i.e. *Abies*, *Fraxinus excelsior*, *Tilia*, *Hedera*, *Vitis*, *Ulmus* – see Fig. 1A): a significant negative correlation between fire occurrence and taxa abundances, marked at lag 0, reflecta a supposed fire sensitivity of the concerned taxa;
- increasing type (i.e. *Corylus*, *Salix*, *Sambucus nigra*, *Humulus t.*, *Alnus* – see Fig. 1B): the fact that the highest significant positive correlation between fire occurrence and taxa abundances occurs 10-30 years after the charcoal peak, reflects the recovering capacity of the concerned taxa;
- short term opportunist type (i.e. *Anemone*, *Trifolium repens*, *Mentha*, *Rosaceae*, *Cichorioideae* – see Fig. 1C): positive correlation between fire occurrence and species abundance

Table 1: Life strategies of selected fire favoured and unfavoured species in chestnut forests on siliceous soils on north facing slopes (source: Hofmann et al. 1998).
P = summer-green phanerophytes, E = evergreen phanerophytes, N = summer-green nanophanerophytes, J = evergreen nanophanerophytes, C = herbaceous chamaephytes, G = hemicryptophytes, G = geophytes; M = dissemination by mammals, U = dissemination by man, V = dissemination by wind, I = dissemination by insects (ants), O = dissemination by birds.

Chestnut forests < 1000m, north facing		**Biological form** (Landolt, 1977)	**Resprouting capacitiy** (very good: 5, very bad: 1)	**Colonisation capacity** (pioneers: 5, climax sp.: 1)	**Dissemination vector** (according to Oberdorfer, 1983)
Favoured	*Pteridium aquilinum*	G	5	4	V
	Betula pendula	P	3	5	V
	Robinia pseudoaccacia	P	5	4	U/V
	Populus tremula	P	5	5	V
	Salix caprea	P	5	5	V
Relative frequency of discriminating factors		H: 59%	E: 0% V: 62%	O: 6%	
Disfavoured Species	*Corylus avellana*	N	5	4	M/O
	Fraxinus excelsior	P	2-3	4	V
	Acer pseudoplatanus	P	4	4	V
	Tilia cordata	P	2-3	2	V
	Hedera helix	E	1	2	O
	Ilex aquifolium	E	2-3	2	O
Relative frequency of discriminating factors		H: 14%	E: 29% V: 50%	O: 36%	

is restricted to a very short time period (< 10 years). These taxa seem to take advantage of open-land conditions in the first years after fire;

- fire precursor type (i.e. *Plantago lanceolata*, *Quercus* (deciduous), *Pteridium*, *Caryophyllaceae*, *Poaceae*, *Pteridium aquilinum* – see Fig. 1D): A positive correlation exists but precedes charcoal peaks. Thus, these taxa seem to be responding to anthropogenic activities.

These findings are congruent with results of dendroecological and plant-community studies (Hofmann et al. 1998). Vegetational development after repeated forest fires is characterized by a decrease of the tree cover and by an increase of light-demanding shrub and herb species. Characteristics such as re-sprouting capacity, dissemination capacity and dissemination vectors are thought to play the basic role in the fire survival of species (Table 1). Favoured or disfavoured tree and shrub taxa under the present fire regime conditions widely correspond to those indicated by paleoecological studies. The ecological and dendroecological studies show that fire changes the composition of forest communities from a high abundance of shade tolerant species on basic soils to a high abundance of shade intolerant species on acidic soils (Fig. 2). This directional change can also be affected by various types of fire frequencies (Fig. 3). Increases in fire frequency lead to the dominance of fire-enhanced and fire adapted species (e.g. *Castanea sativa*). In some cases, fire can lead to local extinction of fire-intolerant and fire-damaged species (E.g. *Abies alba*). The resulting decrease in plant diversity is documented both for paleovegetation (Fig. 1D, for details see Tinner et al. 1999) and modern plant communities (Delarze et al 1992).

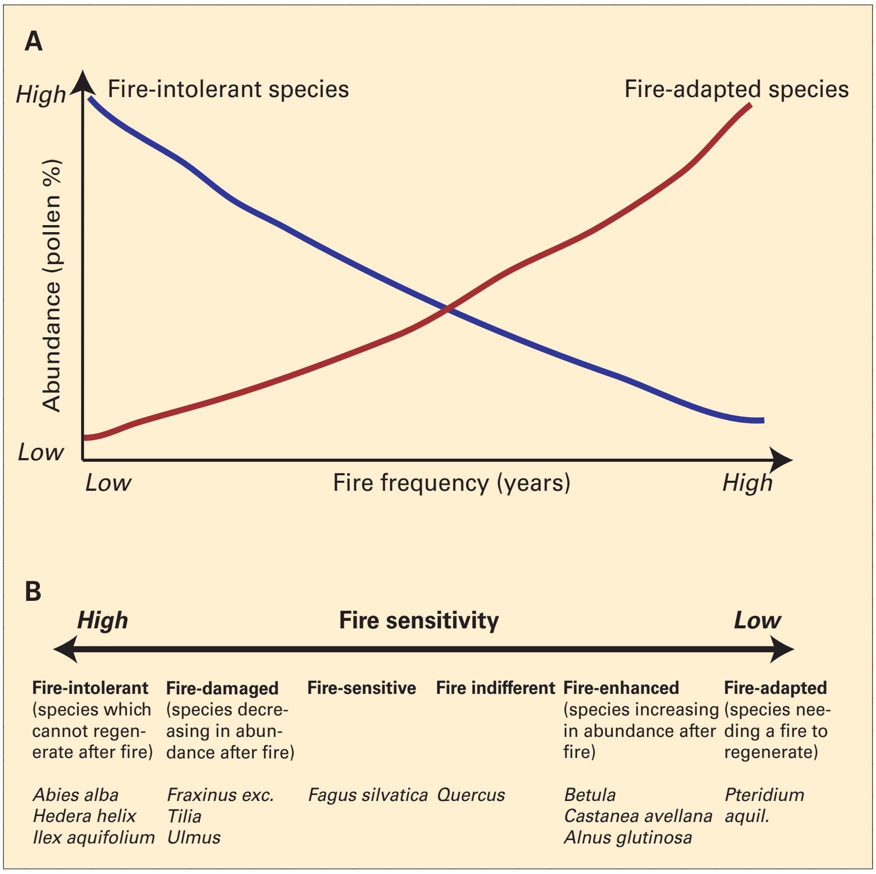

*Fig. 3: **A**: Effect of increased fire frequency on the abundance of fire-intolerant and fire-adapted species. With increased fire frequency, fire adapted species increase while fire-intolerant species decrease. **B**: Fire sensitivity classification for selected European plant taxa.*

Conclusions

A combined approach using both dendroecology and paleoecology provides important information about the sensitivity and the annual to century scale reaction patterns of woodland ecosystems after fires. This integrated approach has lead to initial classification of fire sensitivity of European tree species. Fire sensitivity of European species is similar that of related North-American species (e.g. very fire sensitive: *Abies amabilis*, *A. lasiocarpa*, *Ilex opaca*; fire-sensitive: *Fraxinus grandifolia*, *F. americana*, *Ulmus americana*, *Tilia americana*, fire adapted: *Quercus rubra*, *Betula papyrifera*; see Fire Effect Information System, http://www.fs.fed.us/database/feis/) confirming our hypothesis that genetically fixed characteristics are decisive for post-fire responses of plant species. Understanding fire-sensitivity may help to develop fire-disturbance parameterisations for existing forest-succession models. From a more practical point of view, a fire-sensitivity ranking may also be helpful for forest management and restoration after fires. Furthermore, until now little or no attention has been paid to fire-driven changes in Central and Western European vegetation history. As shown for the southern Alps (Tinner et al. 1999), failing to account for past fire disturbances may lead to spurious conclusions about ecosystem responses to past environmental change.

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