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Temporal and spatial dynamic of stool uprooting in abandoned chestnut coppice forests

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Abstract

Chestnut (*Castanea sativa* Mill.) coppice is a man-made forest type that has been managed for centuries in short rotations to rapidly produce woody biomass. These forests, which nowadays cover significant areas within Europe, experience a general neglect and are subsequently being abandoned. Most of them are now over-aged, very dense, and highly monotone. Little is known about their development. The increasing frequency of uprooting events of stools (i.e. a whole stump including the shoots that originated after coppicing), is raising concern among forest managers who fear a progressive expansion of the phenomenon.

Our objective was (i) to describe the temporal and spatial patterns of the ongoing uprooting processes, (ii) to identify causes and (iii) to estimate future developments. We have analysed the stool uprooting dynamics in a 100 ha abandoned chestnut coppice and have built an empirical, predictive model to estimate the uprooting probability based on topographic, stand and stool characteristics. Finally, detailed uprooting dynamics were reconstructed at the single gap level for three case studies to characterise the process of gap expansion. Tree-rings were used to date the relevant events.

We found that uprooting is primarily caused by precarious tree statics rather than external forcing agents. The empirical model clearly predicts that tall stools located in hollows and gullies are the most likely to uproot. In fact, in this particular situation a non-extreme environmental event suffices to disturb the equilibrium between the higher tree-induced gravitational loads and the weaker root anchorage, resulting in a collapse. Since the stool uprooting is mainly an endogenous process, we expect a progressive increase of this phenomenon with the ageing of abandoned coppices.

From the forest manager's perspective, this situation favours a progressive rejuvenation and diversification of the forest structure. On steep slopes, however, where the forests also play an important role in protecting infrastructure, uprooting events might entail some additional risks. Our results have important management implications for foresters.
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Keywords: *Castanea sativa*; Tree-fall gaps; Stand dynamics; Empirical modelling; Tree-ring; Insubric ecosystems

1. Introduction

Succession is the process through which a plant community evolves and changes into another (Clements, 1916; Gleason, 1917, 1927; Crawley, 1985). In the specific case of forests, these changes are mostly driven by processes of canopy replacement. Disturbance resulting in death of canopy trees has the effect of releasing growing space which is available for other plants. Future canopy composition not only depends on the species, size and abundance of individuals and species that occupy the newly available spaces, but also on the type and number of overstorey trees removed from the canopy (Oliver and Larson, 1996). Catastrophic disturbances, such as windstorms or fires, usually remove large portions of the canopy, leading to complete stand regeneration. Although these disturbances can have a natural origin, their impact can be substantial depending on a forest's function. For protection forests, for instance, such unpredicted disturbances are highly undesirable since they expose settlements and infrastructure to unacceptable risks. Succession can also be progressively achieved through small-scale disturbances involving the death of only a single or few trees. In this case, changes are mainly based on the processes of gap creation and filling; and thus forest cover is present even throughout the transition phase (e.g. Poulson and Platt, 1989; Lertmann, 1992).

Understanding the dynamics of forest replacement helps to clarify management objectives: active forest management

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based on model predictions can mitigate the occurrence of catastrophic disturbances. Although our understanding of canopy gap dynamics and replacement processes in undisturbed forests is substantial (e.g. Uhl et al., 1988; Brokaw and Scheiner, 1989; Manrubia and Solé, 1997; Dubé et al., 2001; Gagnon et al., 2004; King and Antrobus, 2005), these processes have yet to be studied in secondary and abandoned man-made forests, which are more exposed to major disturbances because of their monotonic structure.

Sweet chestnut (*Castanea sativa* Mill.) is a tree species that has been intensively cultivated for centuries as a monoculture (coppices and orchards), even at the limits of its potential ecological range (Pitte, 1986; Bernetti, 1987). Chestnut forest ecosystems still represent an important landscape component in the mountainous regions around the European Mediterranean basin and in the Southern Alps, covering more than 2.2 million ha (Conedera et al., 2004). Since the early 1950s, however, changes in the socio-economic structure of the rural areas and the spread of chestnut diseases such as chestnut blight (*Cryphonectria parasitica* (Murr.) Barr.) and ink disease (*Phythophtora* spp.) have caused a decline in the cultivation of sweet chestnut forests in many European regions (Pitte, 1986). As a result, both coppices and orchards were abandoned and gave way to a more natural forest development (Arnaud et al., 1997; Conedera et al., 2001). Chestnut coppices, which for millennia have been regularly and intensively managed for fast timber production, have long exceeded their usual rotation length (<20 years). Today, they are over-aged and highly monotonic in structure. These stands are mainly located on steep slopes, where they are starting to manifest first signs of decline. Over-aged chestnut stools (i.e. whole stumps including the shoots that originated after coppicing) lose vitality and competitive power (Fonti et al., 2006). Meanwhile, openings within the forest canopy, especially when resulting from stool uprooting events, are becoming more frequent. This novel situation is raising concern among forest managers who fear a general loss in stability of abandoned stands, which may compromise their important protection function.

The aim of this study is to gain a better understanding of the ongoing successional processes occurring in abandoned chestnut coppices in order to evaluate the magnitude of risk involved. In particular, this study intends: (1) to describe the temporal and spatial pattern of stool uprooting dynamics at the stand scale and at the forest gap level, (2) to identify the main factors causing uprooting, and (3) to build an empirical predictive model in order to estimate the probability of chestnut stool uprooting.

2. Materials and methods

2.1. Study sites

We performed analyses on stool uprooting on various abandoned forest plots belonging to the non-native chestnut forest belt of the Southern Swiss Alps, specifically in Ticino. The main study area, a 100-ha chestnut (*C. sativa* Mill.) forest, was selected to describe the stand level occurrence of uprooting and to collect the data necessary to build an empirical model. The area, located between the villages of Gravesano, Manno, Cademario and Bosco Luganese (latitude 46°02′00″N, longitude 8°51′50″E), ranges from 330 to 820 m a.s.l. and is exposed prevailing east–northeast. The slopes are steep, with 52% of the area exhibiting slopes >30° and another 38% between 20° and 30°. The area is completely forested and dominated by chestnut coppices abandoned for more than 50 years. Other hardwood species such as oak (*Quercus* spp.), common alder (*Alnus glutinosa* Gaertn.), ash (*Fraxinus excelsior* L.), sweet cherry (*Prunus avium* L.), and beech (*Fagus sylvatica* L.) occur sporadically. Some abandoned chestnut orchards are located on the gentle slope zones close to villages. The forest has a closed and single layer canopy and regeneration is rare.

In addition to the main area, we selected three small plots (approximately 0.1–0.2 ha) with at least 15 uprooted stools within other abandoned chestnut coppices in order to study the dynamics of uprooting in single forest gaps. The plots are located next to Locarno, Bellinzona, and Gravesano.

2.2. Survey within the main study area

During the early spring of 2005, an inventory of all tree-fall events was completed through ground reconnaissance. We considered only live uprooted trees *sensu* Schaetzl et al. (1989). Groups of fallen trees were assigned to a single event. Only that tree which was supposed to be the origin of the collapse was counted and measured. For each event we annotated the location, species, and the forest management type (coppice or orchard).

To identify differences between uprooted and standing stools, we surveyed a set of topographic, stand and stool parameters relevant for stool stability (Schaetzl et al., 1989) (see Table 1). Since we were especially interested in processes occurring in chestnut coppice, only chestnut coppice stools were measured. A total of 45 uprooted stools were randomly selected from a subset of stools that were unaffected by ivy (*Hedera helix* L.) and that had been uprooted in the last 5–7 years. We used the presence of bark and fine roots as visual selection criteria. Consequently, an equal number of standing coppice stools were randomly selected using a 50 m wide sampling grid. All grid points located at least 25 m away from the inventoried uprooted stools were considered for the draw. Our ultimate selection was the standing chestnut stool closest to the chosen grid point. Due to the relatively homogeneous density of the coppice, this procedure did not result in a biased selection (see Crawley, 2002, pp. 53–55).

We used tree-ring analyses to describe the growth of the selected stools as well as to date the overturning events to the exact year. For each selected stool, either a core or a wood disc was taken from the dominant shoot. Wood samples were taken at about 1 m height in order to avoid root influences. Wood discs and cores were sanded and tree-ring widths measured to the nearest 0.01 mm with a standard tree-ring measuring device (Measuring table Dendrotab Walesch, Effretikon, Switzerland). Ring-width data were visually crossdated with TSAPWIN v0.53 (Frank Rinn, Heidelberg, Germany) and subsequently checked with COFECHA v6.06p (Holmes, 1983; Grissino-Mayer, 2001). Since in some cases fallen stools did not die

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