Forest Ecology and Management 430 (2018) 241–249

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Long-term effects of experimental cutting to convert an abandoned oak coppice into transitional high forest in a protected area of the Italian Mediterranean region

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ARTICLE INFO

Keywords:
Turkey oak coppice
Conversion into high forest
Release density
Dimensional structure
Lorenz curve
Protected area
Mediterranean region
Italy

ABSTRACT

This paper reports the results 20 years after undertaking experimental cutting to convert an abandoned Turkey oak (*Quercus cerris*) coppice into transitional high forest. The basic idea was to convert the coppice into high forest in a single intervention, by way of which an agametic high forest is shaped into an almost permanent compositional and structural arrangement. Two very low release densities, which were unusual both due to legal provisions and to that already tested in Italy, were applied and compared to natural evolution. The experimental thinnings were sustainable from a social and economic perspective, having given rise to positive revenue and not having limited the economic activities of the region. From an ecological perspective, the treated areas experienced an increase in volume between 77% and 80% – recovering from 91% to 100% of the harvested volume – and maintained a persistently low mortality rate for the entire period of observation. In the same period, the areas with natural evolution experienced an increase in volume of less than 14% and a high mortality rate, which, in addition to the Turkey oak individuals, also drastically reduced the presence of other tree species. The experimental thinnings modified the dimensional structure of the treated areas, making it almost uniform and physiognomically similar to that of a one-layer high forest. In the untreated areas, natural evolution produced a dimensional structure that is not very different from that of the treated areas, but over longer times and with selective processes occurring by chance. Twenty years later, the initial hypothesis of undertaking a conversion in a single intervention is corroborated by the results obtained.

1. Introduction

In the inland areas of southern Italy, for decades now, many coppice woods have been in a state of *abandonment*, which consists in the cessation of uses upon completing the usual rotation. The causes of the phenomenon are multiple: depopulation of mountain areas, disadvantageous prices of stumpage due to high labour costs and lack of mechanisation, but also emerging needs for the protection of natural habitats and biodiversity conservation, among others.

Coppices are man-made forests that have been heavily modified in their composition and structure, the existence of which requires periodic coppicing. Once active management ends, the compositional and structural balance, brought about and maintained by centuries of forestry practices, is no longer sustainable by the ecosystem. Therefore, the abandoned coppices over time will tend towards new compositional and structural balances, in accordance with environmental and stand factors. From a physiognomic perspective, they will probably evolve towards high forests, but the course and timeframes of the succession process are mostly unpredictable.

The technical aspects of the conversion of Turkey oak (*Quercus cerris*) coppices into high forest are documented by various Italian studies carried out for this purpose (Amorini et al., 1979; Susmel, 1981; Bernetti, 1983; Ciancio, 1983, 1990; La Marca, 1987). When the decision is made to proceed with conversion into high forest, the options to achieve the objective are essentially:

- *Undetermined ageing:* exploiting the ability of the stand to evolve towards a high forest naturally;
- *Indirect conversion:* after a period of ageing, aimed at restricting the sprouting capacity of the stumps, one proceeds by thinnings with high release densities, creating a transitional high forest of agametic origin.

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https://doi.org/10.1016/j.foreco.2018.08.012
Received 22 February 2018; Received in revised form 3 August 2018; Accepted 5 August 2018

- *Direct conversion:* by progressively leaving standards, releasing upon each coppicing a growing number of individuals from which the high forest from seed will originate (preferable in mixed coppices or in the presence of numerous standards).

For indirect conversion, several studies suggest undertaking light repeated thinnings (Guidi, 1975; Amorini and Fabbio, 1988, 1989; La Marca, 1987; La Marca et al., 2009; Fabbio and Amorini, 2006; Amorini et al., 2006, 2010). This option is sustainable in the event of satisfactory demand for firewood, an adequate road network, stands located in morphological conditions suitable for mechanisation and low labour costs.

The Turkey oak coppices in Gargano, the utilization of which has been abandoned, with the exception of those damaged by fire, by excessive grazing or in degraded sites, are good candidates for conversion into high forest because they react well to cutting in a short timeframe. In addition, those examined fall within the boundary of the Gargano National Park (a headland located in south-eastern Italy, in the northern part of Apulia), in the area in which the protection regulations require management based on natural criteria. The ownership of the woodlands in the area of study is mostly Municipal and is encumbered by public use rights for resident populations (grazing in the woods). These aspects make conversion into high forest a feasible and cost-effective management option.

This paper reports the results 20 years after experimental thinning for indirect conversion into high forest compared with natural ageing and is divided into three parts: (1) progress over time of population parameters; (2) effects of intervention on the structure and evolution over time; (3) conclusions with recommendations for the management of abandoned Turkey oak coppices in protected areas in the Mediterranean environment.

2. Materials

2.1. Area of study

The Turkey oak (*Quercus cerris*) woods in Gargano cover an area of about 17,500 ha, of which about 8000 ha (46%) are pure forests and the remaining 9500 ha (54%) are mixed forests of Turkey oak and other broadleaved tree species (*Fagus sylvatica*, *Carpinus betulus*, *Ostrya carpinifolia*, *Acer opalus*, *Acer campestre*, *Quercus pubescens*, *Quercus ilex*) (La Marca and Vidulich, 1989). Turkey oak woods form an irregularly evolving body, are located mainly in hills and low mountains and constitute a typical element of the Gargano forest landscape (La Marca et al., 2002).

The experimentation was carried out in the district of “Bosco di Manfredonia,” approximately 300 ha in size, property of the Municipality of Manfredonia, but falling within the administrative boundary of the Municipality of Monte Sant’Angelo. The area is located about 700 m above sea level with gradients of 20–25%, facing north-northeast. The soils belong to the brown forest earths formed on limestone of organic origin (Lippi-Boncambi, 1959; Lopez, 2003). The climate is typically Mediterranean with rainfall concentrated in the autumn–winter period and a dry summer period; average annual rainfall amounts to 726 mm; the average annual temperature is around 12 °C.

The forest vegetation in the area of study may be ascribed to the *Physospermum verticillata-Quercus cerris* combination (Biondi et al., 2008). Among the grass and shrub species, there are the *Cyclamen neapolitanum*, *Rosa canina*, *Prunus spinosa*, *Crataegus oxyacantha*, *Pteridium aquilinum*, *Brachipodium pinnatum* and *B. sylvaticus*, *Fragaria vesca*, *Cornus mas*.

In 1996 the coppice under experimentation was 35 years old and almost ten years had passed since the usual rotation. The coppice had a well-defined two-layer vertical structure: (i) a dominant layer made up of old Turkey oak standards (of various ages) and shoots, in a reduced number per stump; (ii) a very dense dominated layer (60–65% of the total of individuals), consisting of *Ostrya carpinifolia, Acer opalus* and *Acer campestre* with a high number of individuals per stump.

3. Methods

3.1. Experimental thinning

Two release densities were tested for transitional high forest: 600 individuals per hectare (A) and 800 individuals per hectare (B). These are very low release densities both with respect to the provisions of local laws (Apulia Region, 2010) and with respect to the literature (La Marca et al., 2002).

The purpose of the low release densities is to create a transitional, low-competition high forest that evolves rapidly and remains fairly stable from a demographic perspective until the adult stage is reached. Therefore, action is taken drastically and selectively with the starting cut without further intervention or, if necessary, by carrying out only one considerably deferred cut, which acts as a preparation cut for the renewal cuts.

Taking into account the extent of ageing, the density of the shoots, the number and level of crown coverage of the standards, the ecological state of the populations, the specific biodiversity, the adequate fertility of the soil and the presence of livestock raised in the wild, to obtain the target densities the following actions were taken: (i) release of one to two individuals of Turkey oak per stump, chosen from among the best ones based on appearance and vigour; (ii) elimination of all individuals with a diameter at breast height less than 7 cm; (iii) release of some old standards as habitat trees and for landscaping reasons; (iv) release of individuals belonging to other tree species, even if their appearance was not good, but they were in a good vegetational state at the time of selection.

3.2. Intensity and grade of experimental thinning

Many methods have been proposed for objectively determining the intensity and type of thinning (Vezina, 1963), but thinning still remains an event that is difficult to model because of the subjective nature of the decisions that make the process of selecting the individuals to be removed intrinsically fuzzy (Kahn, 1994). Intensity is the simplest parameter to quantify. In the case study, it is expressed by the relative weight of the removed basal area (r_G) by way of the ratio: removed basal area/total basal area (Djomo, 2014). On the other hand, the type of thinning is expressed by the ratio between the number of individuals removed (r_N = removed trees/total trees) and r_G (Murray and Gadow, 1991). The ratio r_N/r_G quantitatively expresses selection preferences in terms of the size of individuals (Zhang et al., 2014). Thinning from below by removing proportionately more individuals than the basal area will have a ratio of $r_N/r_G > 1$. Conversely, thinning from above, by removing more basal area than individuals, will have a ratio of $r_N/r_G < 1$. The more r_N/r_G differs from 1, the more the type of thinning is defined (Pommerening et al., 2015).

3.3. Stand structural complexity

Biodiversity is a broad concept and is therefore difficult to measure overall (Sahotra and Margules, 2002). In addition, it takes on a range of different values depending on the context and the purpose for which it is assessed (Williams, 2004). Since we are interested in framing biodiversity according to the extent of forest stand and for management purposes (Ferretti et al., 2006), it is appropriate to use proxies that summarise the relationship between the various components of biodiversity and the variety and/or complexity of structural components (Sahotra and Margules, 2002). Considering that there is no predefined set of descriptors (McElhinny et al., 2005) in terms of forest stand, it is possible to use the dimensional diversity of individuals as a proxy for