

Short Communication

In situ persistence of African wild olive and forest restoration in degraded semiarid savanna

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Abstract

The ability to produce vegetative shoots is a form of persistence in arid and semiarid savannas allowing trees to survive herbivory, fire and cutting. In terms of growth rates and survival, this form of rejuvenation may be more successful than recruitment via seed rain or dormant seeds in the seed bank. For this reason, resprouting could play an important role in the tree canopy and forest microclimate recovery and forest succession.

To assess whether coppice growth of African wild olive (*Olea europaea* ssp. *cuspidata*) should be considered for restoration of dry Afromontane forest, this study investigated olive coppice densities and characteristics in a 100-ha grazing enclosure in northern Ethiopia using random samples and systematic samples along transects. The response to pruning, expected to reactivate a leading shoot and thus contribute to faster tree habit and canopy recovery, was tested as a secondary objective.

Olive coppice was more numerous than seedlings, especially along the natural drainage line of the landscape. While pruning yielded longer top shoots, it did not reactivate leading shoots. On the contrary, it triggered the formation of numerous long shoots on the pruning surface. Its high densities make olive coppice an interesting starting point for forest restoration, but due to its 'quantity-driven' coppicing strategy and tendency for lateral expansion, coppice management to reduce the number of shoots and to restore a tree habit in persistent *Olea* may be needed. To optimize the value of coppice in enclosures, further research on coppicing strategies and responses to various pruning techniques of both the pioneer and climax species is needed.

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1. Introduction

The ability of damaged trees to coppice, i.e. to produce vegetative shoots at the base of a stem, is a key element of resilience in savanna woodlands (Kaschula et al., 2005; Shackleton, 2001). It is a type of persistence which allows trees to survive herbivory, fire and tree cutting, the three most prevalent disturbances to forested areas in arid and semiarid savannas (van Langevelde et al., 2003). Coppice regrowth or basal resprouting is supported by the reserves stored in below-ground biomass, usually a well-developed, deep root system (Paula and Ausas, 2006) or swollen structures at the stem base (lignotubers) (Canadell and López-Soria, 1998). Resprouts are supplied with water from a much larger root system per unit leaf area than twigs on intact trees (Shelden and Sinclair, 2000). As a result, coppice shoots are less susceptible to drought stress and they can grow much faster than seedlings. Persistence through coppice may thus be more successful in terms of growth rates and survival than recruitment via seed rain or dormant seeds in the seed bank (Bond and Midgley, 2001; Ky-Dembele et al., 2007) and significantly contribute to the recovery of a forest canopy and microclimate. For that reason, resprouting could play an important role in forest succession and should be considered for dry forest restoration (Shackleton, 2000; Vieira and Scariot, 2006).

In northern Ethiopia, forest and woodland conservation efforts largely depend on livestock enclosures, where free range grazing by domestic animals and cutting of woody vegetation are prohibited. African wild olive (*Olea europaea* ssp. *cuspidata*) is a valuable secondary climax tree of dry Afromontane forest, able to regenerate naturally in enclosures under the protective cover of specific pioneer shrubs (Aerts et al., 2006). Nevertheless, *Olea* seedling densities are low because the species suffers from typical limitation problems of forest trees in degraded semiarid areas. These problems include the low seed production in the scarce forest fragments (seed limitation), insufficient seed disperser activity (dispersal limitation) and the high seedling mortality (establishment limitation) (Aerts et al., 2007). *Olea* also occurs in enclosures as resprouting dwarf shrubs, as a result of heavy livestock grazing pressure and repetitive coppicing after cutting in the past. To assess whether this coppice growth of African wild olive should be considered for restoration of dry Afromontane forest, this study investigated the coppice densities and characteristics in an enclosure in northern Ethiopia. The response to pruning, expected to improve hydration, reduce intershoot competition, reactivate a leading shoot (du Toit et al., 1990; Shelden and Sinclair, 2000) and thus facilitate tree canopy recovery, was tested as a secondary objective.

2. Methods

The study was carried out in the 10-year-old 100-ha enclosure of Mheni, in the Geba river catchment of central Tigray, northern Ethiopia (13°37'N, 39°21'E, 1980–2000 m a.s.l.). The mean annual temperature is 18 °C and the area receives between 470 and 780 mm of rainfall annually, mostly during June–September. The enclosure is characterized by a discontinuous cover of pioneer shrubs whose height ranges 1–2 m (e.g. *Acacia etbaica*, *Aloe macrocarpa*, *Carissa edulis*, *Euclea racemosa* ssp. *schimperi*, *Leucas abyssinica*), and during the rainy season the space between shrubs is covered by herbaceous species, including Meskel flower (*Bidens prestinaria*) and many ruderal herbs such as *Rumex* spp. and *Solanum incanum*, together with grasses, principally *Hyparrhenia hirta*.

Olea individuals were assumed to be coppice when stress morphology related to coppicing after cutting or browsing was present, usually a clump of shrubby short twigs with considerably smaller, darker and less elongated leaves at the base of the plant (Fig. 1a). Straight shoots without damage were distinguished from true seedlings and treated as (fresh) coppice, if the root collar was substantially larger than the stem diameter (which is not the case in an undamaged seedling). To assess the density of *Olea* coppice, resprouting stumps were assessed along five transects perpendicular to the contour lines of the slope: one transect in a gully along the natural drainage line ($n = 39$ transect points with an interval of 12 m), two at ± 50 m distance from the gully ($n = 38$ with an interval of 50 m) and two at ± 100 m from the gully ($n = 37$ with an interval of 50 m). At each transect point, the distance between the transect point and the nearest *Olea* coppice was measured. Density estimates of *Olea* coppice were calculated using the closest individual plotless density estimator (Engeman et al., 1994; Eq. (1)) for 100 random subsets of 10 sample points per distance class

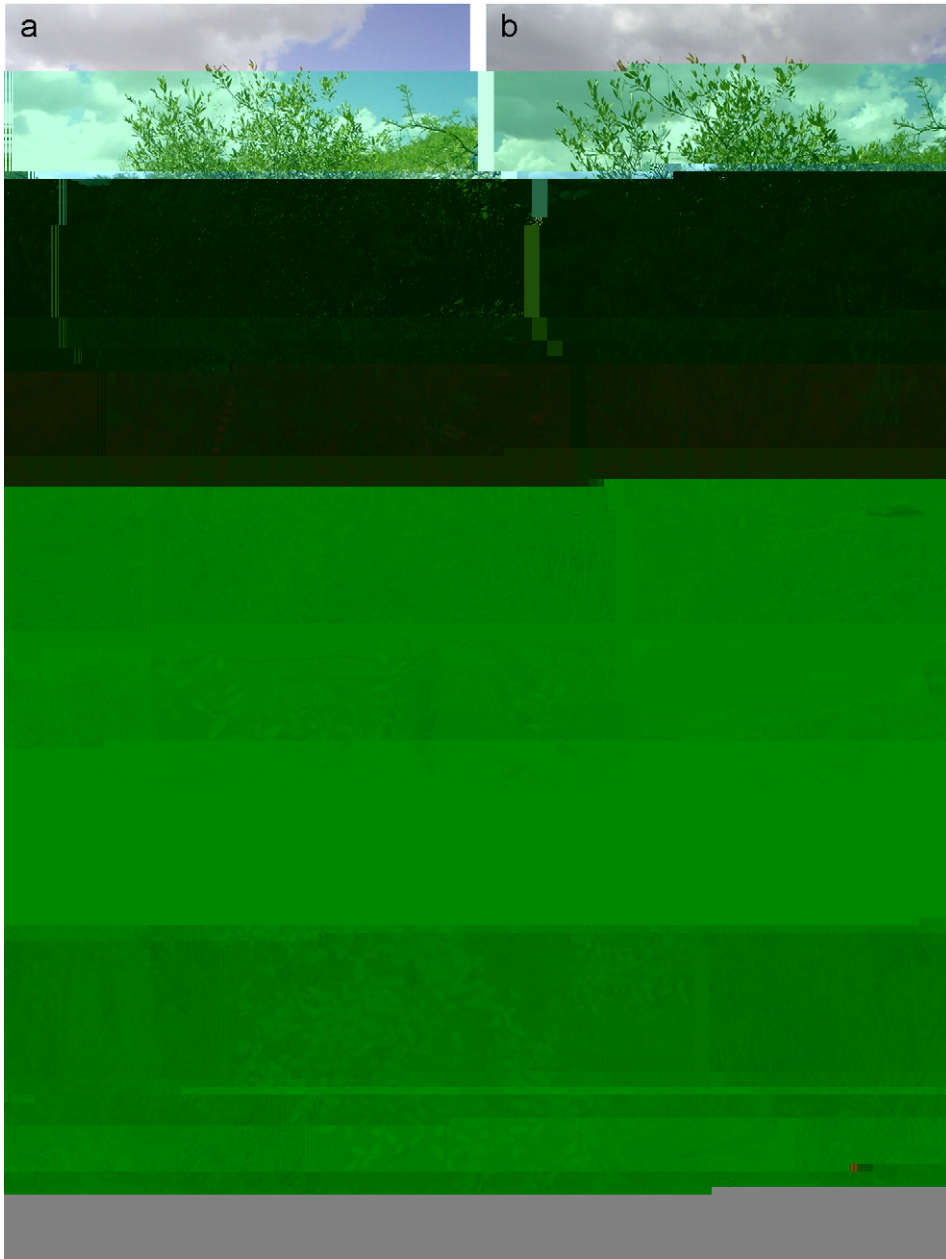


Fig. 1. Resprouting *Olea europaea* ssp. *cuspidata* coppice released from browsing in an enclosure in northern Ethiopia: (a) untreated olive coppice showing stress morphology (shrubby short twigs with smaller, darker leaves) at the base of the plant and vigorous regrowth at the top; (b) the same individual after a pruning treatment, with all shrubby regrowth at the base removed; (c) and (d) the same individual 1 year after the pruning treatment, (c) showing a detail of the numerous long shoots at the pruning surface.

(0, 50 and 100 m from the gully) and for 300 random subsets of the pooled data, obtained through Monte Carlo permutations.

$$\text{BDCI} = \frac{1}{4[\sum_{i=1}^N R_{1(i)}/N]^2}, \quad (1)$$

where BDCI is the closest individual basic distance density estimator (individuals m^{-2}), $R_{(1)i}$ the distance from transect point i to the closest *Olea* dwarf shrub (m), and N the number of sample points (after Engeman et al., 1994). Square brackets denote the greatest integer function.

To assess the size variation of *Olea* coppice, two perpendicular crown diameters, total plant height, browsed height (= the extent of stress morphology in the plant), stem diameter above the root collar, length of four random shoots and root collar height above the ground surface (= exposed root length, an indicator of soil erosion since establishment) were measured for a random sample of 180 individuals found throughout the enclosure.

A systematic sample of 225 individuals along the gully transect was grouped into eight arbitrary plant volume classes representing the full size range of olive coppice in the area (cylindrical volume based on the height and crown diameter <0.5 m^3 , 100 individuals; 0.5–1 m^3 , 42 individuals; 1–1.5 m^3 , 22 individuals; 1.5–2 m^3 , 13 individuals; 2–2.5 m^3 , 12 individuals; 2.5–3 m^3 , 8 individuals; 3–3.5 m^3 , 12 individuals; >3.5 m^3 , 16 individuals). Four individuals were randomly selected in all but the smallest volume class, where 10 plants were selected. In December 2003, half of the selected plants in each class were radically pruned (all excessive shoots and the typical dwarf shrub material below the browsed height were clipped to promote the formation and/or growth of a leading shoot, $n = 19$, Fig. 1b). The other half was used as a control (no clipping, $n = 19$). The total plant height and the length of four random top shoots were measured 1 year after the treatment, at the end of January 2005.

Differences in coppice densities along the transects were analyzed using one-way ANOVA after \log_{10} -transformation of the densities to ensure homogeneity of variance. During the experiment, four pruned individuals and three controls were cut illegally and the coppice of these stumps was not taken into account. The effect of the pruning treatment on the mean top shoot length was analyzed using one-way ANOVA. The effect of pruning on the overall plant height was analyzed using repeated measures ANOVA. To account for potential differences due to plant age, the stem diameter was used as a covariate in both cases. Monte Carlo permutations were performed using the *permtools* extension for Microsoft Excel (Hood, 2005) and statistical analysis was carried out using *SPSS* 12.0 (*SPSS* Inc., Chicago, IL).

3. Results

In the enclosure 30 ± 1 *Olea* individuals ha^{-1} originated from coppice, which was considerably more than the *Olea* seedling density in the same site (5 individuals ha^{-1} ; Aerts et al., 2006). Coppice densities were nearly 10 times higher in the immediate vicinity of the gully (134 ± 5 individuals ha^{-1}) than further away from the gully (15 and 17 ± 1 individuals ha^{-1} at 50 and 100 m from the gully, respectively) ($F_{2,297} = 785.12$, $p < 0.001$). Typical *Olea* coppice was nearly 1 m tall and 1 m wide, showed stress morphology (reduced leaf sizes and thorny branchlets) up to a height of 0.7 m, a stem diameter of 3 cm and over 5 cm of exposed first-order root (Table 1). There was no evidence of adult stumps. Recruitment of the sampled individuals occurred at least 50–60 years ago, based on conservative sheet and rill erosion estimates, taking into account the erosion rate differences between enclosures and degraded grazing lands (Table 1).

Pruning significantly increased the top shoot length ($F_{1,28} = 4.719$, $p = 0.038$), but height growth did not differ between treatments ($F_{1,28} = 0.556$, $p = 0.462$). As a matter of fact plant height of both the treated and untreated shrubs was marginally lower, when plants were measured again after 1 year (Table 1). Pruned dwarf shrubs still showed reduced crown diameters as a result of the clipping treatment, while untreated dwarf shrubs had expanded ($F_{1,28} = 14.702$, $p = 0.001$) (Table 1). The most prominent effect of pruning was the formation of numerous long new shoots on the pruning surface (Fig. 1c).

4. Discussion

Olea saplings can persist for a long time in heavily disturbed landscapes and survive repetitive cutting and browsing as coppice, by increasing the shoot and leaf density, decreasing leaf size and transforming shoots to spines. This disturbance survival strategy has also been documented for European wild olive (*O. europaea* ssp. *sylvestris*) in Mediterranean maquis (Massei and Hartley, 2000) and for many other species in (semiarid)

Table 1

Shrub characteristics of *Olea europaea* coppice and changes in function of a pruning treatment in a 10-year-old grazing enclosure in northern Ethiopia

	Random sample ($n = 180$)		Control sample ($n = 16$)		Pruned sample ($n = 15$)	
	Mean	SE	Mean	SE	Mean	SE
Height (m)						
2003	0.88	0.03	1.31	0.11	1.30	0.11
2005	–	–	1.28	0.12	1.23	0.12
Crown diameter (m)						
2003	0.83	0.03	1.15	0.09	1.18	0.10
2005	–	–	1.22	0.11	0.79	0.12
Top shoot length (mm)						
2005	–	–	120	18	175	18
Random shoot length (mm)						
2003	52	2				
Browsed height (m)						
2003	0.66	0.03				
Stem diameter (mm)						
2003	32	2				
Exposed root length (mm)						
2003	52 ^a	7				

^aCorresponds to seedling recruitment between minimal 50 and 60 years ago, based on a tentative sheet and rill erosion rate of 0.025 cm yr^{-1} in enclosure (for 10 years) and 0.124 cm yr^{-1} in degraded grazing land (the remaining years), assuming a sheet and rill erosion sediment yield of $3.5 \text{ ton ha}^{-1} \text{ yr}^{-1}$ in enclosure and $17.4 \text{ ton ha}^{-1} \text{ yr}^{-1}$ in degraded grazing land (Nyssen et al., 2007) and an estimated soil bulk density of 1.4 ton m^{-3} (Descheemaeker et al., 2006).

habitats ranging from African miombo woodland (Luoga et al., 2004) to the Brazilian caatinga (De Figueiroa et al., 2006). In the studied enclosure its relative high densities make it an interesting starting point for forest restoration. It adds an important secondary climax component to the restoring vegetation in enclosures in the region, which is currently dominated by early-successional shrubs (Aerts et al., 2006; Mengistu et al., 2005). However, due to its ‘quantity-driven’ coppicing strategy—the production of large numbers of relatively small coppice shoots with high length diameter ratio (Kaschula et al., 2005; Neke et al., 2006) consistent with a long history of cutting (Chidumayo, 2004)—and its tendency of lateral expansion rather than growth in height, *Olea* coppice is most likely to grow into shrubs. If left unmanaged, the actual contribution of olive coppice to restore a forest canopy probably remains limited. Removal of the excessive shoots over successive years may force the shrub to allocate its resources in fewer large shoots. Alternatively, dwarf shrubs could be cut completely just above the root collar. This is expected to reduce the number of shoots, and shoots originating from the root crown often suffer from a lower dieback than those growing from the stem (Neke et al., 2006).

Along gullies, olive coppice and other spontaneous vegetation may complement check dam construction and other physical and biological control measures to stabilize gullies, reduce channel incision and prevent sediment deposition downstream (Castillo et al., 2007; Nyssen et al., 2004). Additionally, it enhances the corridor function of gullies, facilitating seed dispersal and recolonization by native vegetation (Levey et al., 2005). Protection of all woody vegetation along gully shoulders, including coppice, both within and outside the perimeters of established enclosures, is therefore strongly recommended.

Thus, olive coppice and resprouting pioneers have important socio-economical values as renewable source of firewood, but also significant conservation values, most prominently as succession facilitators. To optimize these values in enclosures, further research on coppicing strategies and responses to various pruning techniques of both pioneer and climax species is needed.

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