

Restoration of Mediterranean dry grasslands by sowing structuring species

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Abstract: When an ecosystem is damaged, one of the key factors slowing down natural restoration is weeds recolonizing the disturbed area as they prevent the establishment of characteristic species. To restore such ecosystem the best solution is to eliminate weed plant species and change the trajectory by seed introduction. The Nature Reserve *des Coussouls de Crau* is a French Mediterranean dry grassland originating from the combination of a dry climate, particular soil properties and 6,000 years of extensive sheep grazing. During the last century, this ecosystem was submitted to a lot of damages reducing its area to 9,500 hectares. A seed mixture composed of three structuring indigenous steppe species was tested for the first time for the restoration of this dry grassland. The species chosen are two perennials which are the structuring species of the reference steppe ecosystem (*Brachypodium retusum* and *Thymus vulgaris*) and one annual (*Trifolium subterraneum*) which is well known for its ability to quickly cover bare soils. Restoration success was evaluated by carrying out floristic inventories. Sowing of the selected native seed mixture can be considered as a success, in particular to have reintroduced typical structuring steppe species. Changes in restored plant community have also been observed. However, two years of results is not sufficient. It will be necessary to pursue surveys and evaluate the impact of this restoration method on steppe species establishment.

Keywords: 6220 * Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea, fragmentation, land use change

Introduction

In the last centuries, a lot of European dry grasslands or steppe ecosystems has been damaged and fragmented by human activities. Like these ecosystems, the French Mediterranean steppe of La Crau has been submitted a lot of disturbances. Despite its protection status as a Natural Reserve, over 50 hectares out of 9,500 hectares of steppe were destroyed in the past five years. Destructions of soils and/or the herbaceous plant community have detrimental effects on the biodiversity of this unique ecosystem (Römermann et al. 2005, Buisson et al. 2006, Fadda et al. 2008). Plant community does not re-establish integrally thirty years after disturbance cessation, even if the traditional grazing system is restored (Römermann et al. 2005, Buisson et al. 2006). Natural restoration seems to be inhibited by a paucity of colonization sources, the low dispersal capacity of the characteristic steppe species and the high density of weed species in seed bank of disturbed areas which affects steppe species establishment (DeFalco et al. 2009) by competition for resources and space. Reintroduction of local species is often used to recreate herbaceous plant communities and to control weed species. Common methods include transferring soil seed banks, direct sowing with seed mixtures, transferring seeds contained in hay, transplanting seedlings or pieces of grasslands including the upper-layer of the soil (sod cutting) (Padilla et al. 2009). Hay transfer has already been tested on this ecosystem; even if this technique reintroduces a large steppe species pool, it does not re-establish the community integrally, in particular *Brachypodium retusum* is absent and *Thymus vulgaris* abundance is low (Coiffait-Gombault et al. 2010).

Sowing indigenous herbaceous species seems to be the best option to control weeds (Nordbakken et al. 2010). This technique should facilitate the recruitment of steppe species and could accelerate plant succession which is essential in ecosystem restoration (Prach & Pysek 2001). Furthermore, this technique is more sustainable compared to the financial and energy cost of other restoration techniques. The tested seed mixture was composed of three steppe species, two perennials which are the structuring species of the reference steppe ecosystem

(*Brachypodium retusum* and *Thymus vulgaris*) and one annual (*Trifolium subterraneum*) which is well known for its ability to quickly cover bare soils and to fix nitrogen.

Materials and methods

Intensive cultivations are one of the major disturbances applied on the steppe of La Crau during the last century. We chose to test the sowing of structuring species on an abandoned field which formerly was a patch of steppe destroyed in the 60's to cultivate vegetables and cereals. The field was abandoned in 2006 and the experiment was set up in December 2007. Twelve 50×25 meter plots (Figure 1) were slightly ploughed with a chisel. Each plot was split in two 50×12.5 meters subplots: one subplot was sown mechanically with the three selected native steppe species and the other subplot was left unsown. Six of the twelve plots were randomly chosen to be protected from sheep grazing with electrified exclosures to test the impact of this factor in ecological restoration. The ex-arable field and the adjacent steppe were used as controls. We chose to sow a high density of *B. retusum* (47 kg/ha) because its seed viability is low and its establishment was documented to be difficult (Buisson, 2006). *T. subterraneum* and *T. vulgaris* were sown respectively at 13 kg and at 4 kg per hectare. After sowing, seeds were pressed down with a roller to ameliorate germination and reduce seed lost by wind and predation.

To determine the success of this experimental method, floristic inventories were carried out in May 2008 and May 2009 on three quadrats of 4m^2 for each replicate of each treatment. Physical and chemical soil analyses were performed on the ex-arable field and on the steppe.

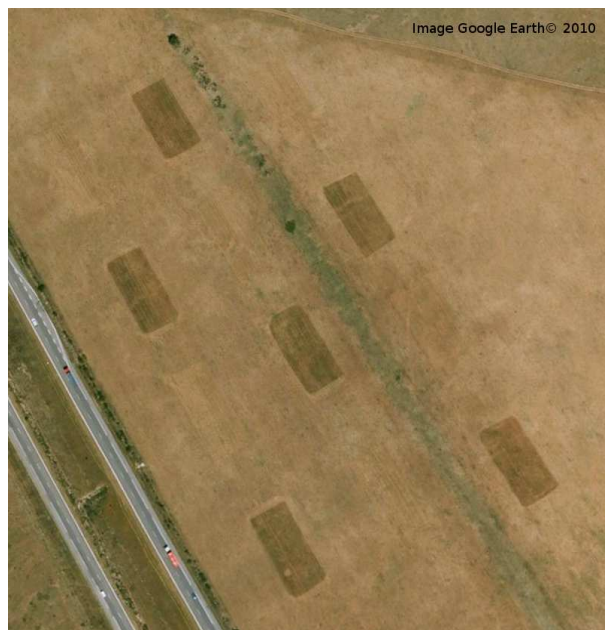


Figure 1. Air view of the experimental device on ex-arable field (Image Google Earth). six of the twelve plots are more visible because they are protected from grazing by exclosures.

Results and discussion

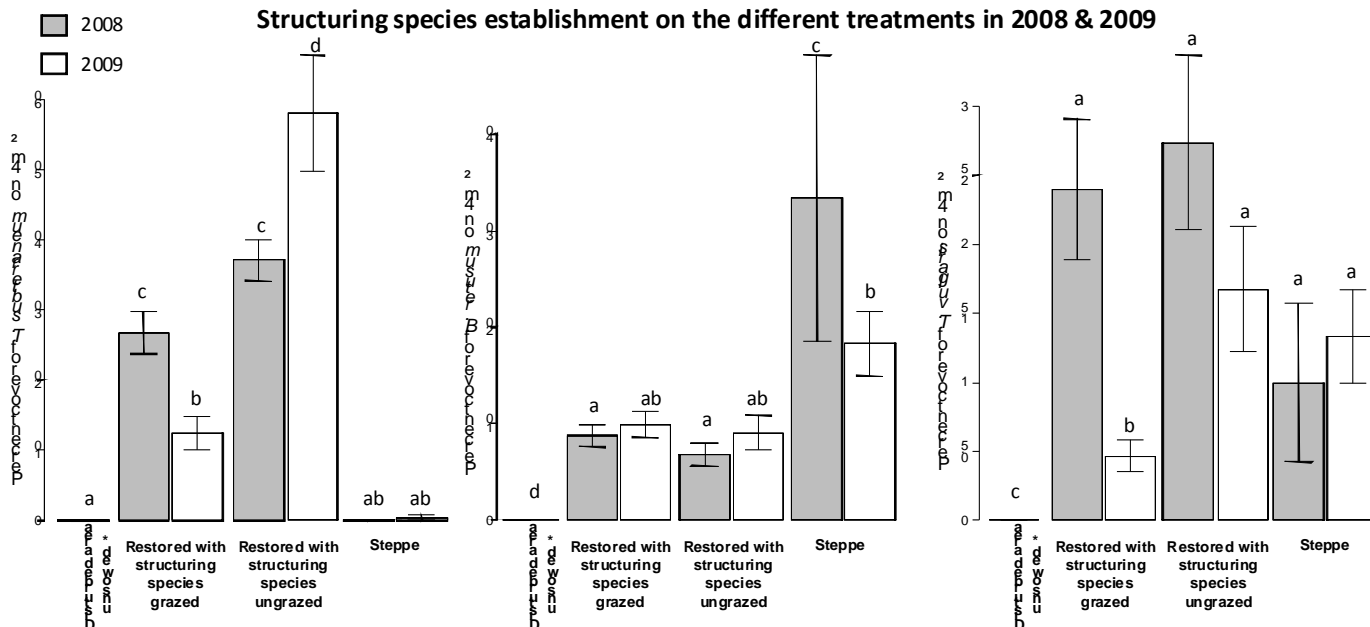
Sowing the selected native seed mixture can be considered as a success for the reintroduction of typical structuring steppe species which does not colonize spontaneously the ex-arable field (Figure 2). *T. subterraneum* is the species which establishes the best on the restored areas, in particular on the ungrazed treatment where it covers 37% of the soil surface in 2008 and 58% in 2009 ($F=57$, $p<0.001$). This cover is significantly higher than the cover on the steppe. Results in 2009 on grazed plots show that the cover of this species can be regulated by sheep grazing. The presence of *T. subterraneum* permits to exclude weed species during the first year succession but its regulation by sheep grazing in second part of restoration is important to open some niches to allow new species to colonize. Soil results show that cultivation has decreased

macronutrients, such as nitrogen . By its capacity to fix nitrogen and to reproduce on the restored area, *T. subterraneum* could modify soil nitrogen concentration on the long-term.

B. retusum establishment is similar on the grazed and ungrazed treatments where structuring species were sown ($F=39.5$, $p<0.001$). In 2009, the mean cover of *B. retusum* on these treatments (9%) is not significantly different from its cover on steppe (18%). This result is encouraging for this species which was never reintroduced successfully from seeds on the steppe with other restoration protocols. The sowing density of around 50 kg/ha is an appropriate density to promote the establishment of enough individuals.

T. vulgaris is less abundant than both other species; there is less than three seedling per 4m², but this species was sown at low density (4kg/ha). Individual number on steppe is not significantly different from the restored area ($F= 16.4$, $p<0.001$), however individuals on steppe are bigger because older. Sowing low quantity of *T. vulgaris* is preferable in the first succession stages because this species may inhibit germination of steppe species by the production of monoterpenes (Tarayre et al. 1995). Its presence is nonetheless important because this pioneer Mediterranean species can positively influence the establishment and survival of associated steppe grasses and forbs.

Figure 2. Establishment of *T. subterraneum*, *B. retusum* and *T. vulgaris* after sowing on steppe and the Structuring species establishment on the different treatments in 2008 & 2009



different treatments on the ex-arable field in 2009, significant differences ($p<0.05$) are shown with letters

Establishment of *B. retusum*, *T. subterraneum* and *T. vulgaris* in first succession stages allows the competitive exclusion (Wassmuth et al. 2009) of weed species which usually characterize ex-arable field and which are responsible for slowing down plant succession toward the desired ecosystem. Floristic surveys show that floristic composition changed during both years after setting the experiment and among the treatments (grazing, sowing). However, floristic changes are difficult to interpret. The experiment needs to be monitored for a longer time to evaluate the long-term effects of grazing and sowing of structuring species on the successional trajectory because their presence will be a key factor for the recruitment of species characteristics of the steppe vegetation.

Conclusions

Sowing structuring species can be used to restore Mediterranean steppe ecosystems. This method has reintroduced characteristic species of the steppe community which have some difficulties to recolonize or do not re-establish spontaneously after disturbance.

Nevertheless, these results have been obtained in a very short period and monitoring must be continued in the future to confirm or not these changes.

Part of the success of this method lie in the timing for sowing: for the Mediterranean area, it has to be done in autumn before weed seedlings emerge, when the soil is moist and when rain fall is expected in subsequent days.

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