PLANT SOCIOLOGY

formerly FITOSOCIOLOGIA

Volume 54 (1) - Suppl. 1 - June 2017

EDITO DALLA SOCIETA' ITALIANA DI SCIENZA DELLA VEGETAZIONE ONLUS - PAVIA - DIRETTORE RESPONSABILE PROF. E. BIONDI - SUPPLEMENTO 1 - VOLUME 1 - I° SEMESTRE 2017

USJ 1875
Université Saint-Joseph de Beyrouth
Faculté des sciences

Project funded by the
EUROPEAN UNION

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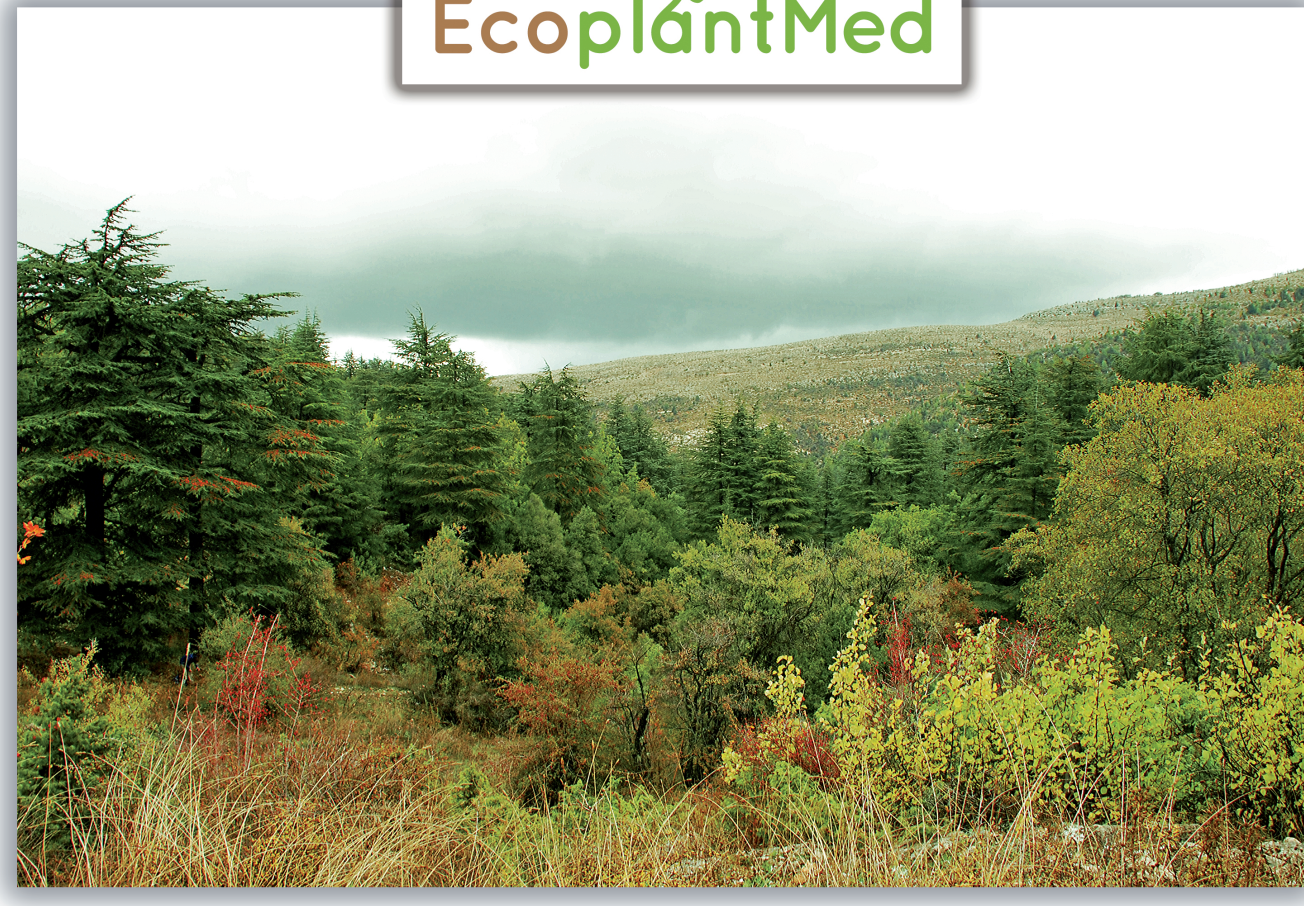

Journal of the Italian Society for Vegetation Science

Plant Sociology, Vol. 54, Suppl. 1, June 2017, pp. 111-118
DOI 10.7338/pls2017541S1/14

PLANT SOCIOLOGY

Adaptive forest landscape restoration as a contribution to more resilient ecosystems in the Shouf Biosphere Reserve (Lebanon)

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Abstract
The Mediterranean Mosaics Project has the objective to increase the resilience of forest ecosystems in the Shouf Biosphere Reserve (SBR) to climate change. The Project has designed adaptive forest restoration and management plans that were applied in a number of pilot sites over the 3 years of Project implementation: (i) sustainable forest thinning and pruning operations were applied in 18.5 ha of *Quercus calliprinos* and *Pinus brutia* forestland; (ii) ecological restoration techniques were tested and demonstrated in 59.11 ha. Seeds and seedlings of about 38 plant species were used, with the objective to restore the forest habitats and ecological processes by which the species populations can self-organize into functional and resilient communities well-adapted to changing climate conditions, while at the same time delivering vital ecosystem services. Ad-hoc plant production protocols were developed to ensure the production of high-quality and well-hardened seedlings. The project has demonstrated the possibility to implement forest restoration without additional water supply to the planted seedlings. The survival rate in the majority of sites after 3 years was between 75% and 100%, with the exception of the direct seed sowing of oak acorns (up to 20%) that were very much affected by rodent predation. Only in instable soil debris direct seed sowing of *Quercus* acorns has achieved a very high survival rate up to 100%. The key factors of success in the Project forest restoration work were: (i) the availability of high quality plant material from the selected species; (ii) a good preparation of the soil and careful planting of seedlings to facilitate the growth of the root system, and increase soil water retention and storage; (iii) the selection of the right planting period, making sure that soil is sufficiently wet. The Project has also demonstrated the environmental and socio-economic benefits of the combined use of forest thinning and pruning products and agriculture waste (olive pomace and waste wood from fruit tree pruning). Lessons learned from the pilot demonstration actions have opened up new opportunities to influence forestation plans in the Country, and regulate the harvesting of forest biomass and its combined use with agricultural waste to control the risk of forest fires, generate economic benefit and contribute to local livelihoods.

Key words: cimate change, ecological restoration, forest, plant production, Shouf Biosphere Reserve.

Introduction

Forest ecosystems in Lebanon are under various pressures, including landscape and habitat fragmentation, changes in land use, land tenure conflicts, urban sprawl, forest fires, pest outbreaks, encroachment of cultivated lands and unsustainable practices such as logging, over and under-grazing, and the massive collection of medicinal and aromatic plants (MoE/UNDP, 2011). These threats have increased the vulnerability of the already fragmented forest stands and are seriously challenging their resilience to climate change impacts, namely the higher frequency and intensity of extreme weather events such as heat weaves and drought, exacerbating forest fires, pest outbreaks and dieback events (Mitri G., 2007).

Reforestation efforts in dryland ecosystems are frequently hampered by drought and limited soil productivity. Both factors tend to interact synergistically to worsen water stress for outplanted seedlings (Vallejo V.R. *et al*., 2012). Climate change projections indicate an increase of drought and more severe fire regime in most of Lebanon (MoE/UNDP, 2011). In this context, the main challenge for forest restoration is keeping a water balance or soil water carrying capacity that enables seedlings to use the amount of water they need, allowing soil water recharge by infiltrated precipitation.

In Lebanon, forests cover 139,376 ha while Other Wooded Lands (OWLs) cover 108,378 ha, representing 13.3% and 10.37% of the country area respectively (FAO, 2010). Forests are broadly divided into three main classes: Mixed Forests (15,610 ha), Broadleaves (78, 887 ha) and Coniferous (44,879 ha). In December 2012, Lebanon launched the 40 Million Trees Program, a national initiative steered by the Ministry of Agriculture to plant 40 million forest trees in public lands within the next 20 years .

The "Mediterranean Mosaics" (MM) project aims to contribute to the 40 million trees programme, increasing the resilience to climate change of forest ecosystems in the Shouf Biosphere Reserve (SBR) and implementing adaptive forest management and forest landscape restoration interventions that help: (i) overcome the growing trend of water scarcity (namely the reduction of annual precipitation and the longer duration of summer drought); (ii) and reduce the vulnerability of the rural landscape agro-ecosystems to extreme weather events such as forest fires and heat waves.

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Materials and Methods

The MM team has undertaken the following forest landscape restoration interventions:

1) Awareness raising events in the target municipalities informing about the project objectives and the proposed forest management and restoration interventions.

2) Training workshops on sustainable forest management and forest landscape restoration, targeting members of the forest committees, forest administration and land users. Provision of learning by doing, on-the-field training to managers and workers involved in tree nursery plant production and field restoration work.

3) Participatory planning actions to identify priority areas for forest restoration in the SBR, and to develop forest restoration plans at the municipal level, including the selection of multi-purpose native species with ecological, social and economic values, and the identification of suitable field restoration techniques. Forest management committees, established at the municipal level, have facilitated the participatory planning work. The forest restoration plans were developed making use of the FAO Global guidelines for the restoration of degraded forests and landscapes in drylands (Berrahmouni *et al*., 2015), and its comprehensive Forest restoration monitoring tool, which aims to plan, analyse and monitor the performance and impact of forest restoration projects.

4) Technical support and supervision to two project partners managing private tree nurseries in the municipality of Ramlieh near the SBR, for the development of plant production protocols for high quality plant material.

5) Technical support and supervision to the workers hired in the field for the effective implementation of the field restoration techniques.

6) Monitoring of the performance and impact of all interventions.

Study area

The Shouf Biosphere Reserve (SBR) lies between longitude 35º 28'- 35º 47' East and latitude 33º 32'- 35º 48' North at an altitude of 1200 to1980 meters. It is located along a steep mountain range of the Barouk and Niha Mountains, a southern extension of the Mount Lebanon running parallel to the Mediterranean coast. Limestone lithology predominates, although sandstone formations often occur at the lower altitudes in the western slopes, where *Pinus pinea* L. forests predominate. Based on the Maasser el Shouf weather station, the average annual precipitation is about 1,000 mm, the average annual temperature is 13.6 ºC, with a physiological drought period from May (19.4 mm) to September (17.8 mm), no precipitations in July and August, and only 2.9 mm in June.

The main forests ecosystems are oak forests (*Quercus calliprinos* Webb and *Quercus infectoria* Oliv. in the lower areas, and *Quercus brantii* ssp. *look* Mouterde in the upper parts), pine forests at low and mid altitudes (*Pinus brutia* Ten. in limestone areas and *Pinus pinea* L. in the sandstone formations), and about 620 ha of cedar forests (*Cedrus libani* A. Rich.) at higher altitudes. These represent the largest stands of Lebanese cedar in the country (Colomer *et al*., 2014). Moreover, the reserve harbours a rich flora that includes medicinal, edible, and aromatic plants.

The SBR includes three zones (Colomer *et al*., 2014): (i) Core zone of approx. 161 km^2, with the main objective to protect and restore the natural and cultural values; (ii) Buffer zone of approx. 54 km^2 that surrounds the core, where development activities compatible with nature conservation can take place; (iii) Transition zone of approx. 233 km^2 with the surround villages, where sustainable resource management practices are promoted.

The project has identified and mapped with GIS (Fig. 1) five priority areas for forest restoration in a landscape unit spanning from the western mountain slopes, to the mountain summit, and the eastern slopes down to the Ammiq wetland in the Beqaa valley.

Area 1: the objective is to connect the isolated cedar stands of Ain Zhalta and Barouk, through the establishment of an oak forest stand (*Quercus brantii* ssp. *look* Mouterde and *Quercus cerris* L.) in the denuded mountain slopes, and building on previous restoration projects (Castro *et al*., 2004; Aerts *et al*., 2007; Sharan *et al*., 2009), to take advantage of the role as nurse-plants that the oaks may play in the future, facilitating the natural regeneration of cedars – thanks to the reduction of solar radiation, the improvement of soil fertility and water retention, and the protection from herbivore damage. The area includes one site of 6 ha, between Ain Zhalta, Bmohray, and Barouk Cedar, in the western side of the Shouf mountain range, at an altitudinal range of 1770-1850 m. The site consists of a steep limestone slope with abundant rocky outcrops and stones in the soil surface, with scattered vegetation cover of grass, small shrubs, (e.g. *Ajuga chia* Schreb., *Alyssum repens* Baumg., *Astragalus coluteoides* Will, *A. emarginatus* Labill.), cushion shrubs (e.g. *Onobrychis cornuta* (L.) Desv., *Prunus prostrata* Lab., *Daphne oleoides* Schreb., *Cotoneaster nummularia* Fisch. & Mey), and small trees (e.g. *Prunus ursina* Ky, *Sorbus torminalis* (L.) Crantz.) shaped by the effect of strong winds.

Area 2: the objective is to enhance tree and shrub species diversity in high mountain forest habitats, and facilitate upwards migration responding to the shifting of bio-climate conditions due to climate change. The area includes one restoration site of 20.5 ha, in Maaser El Shouf, at an altitude of 1750-1925 m. The site consists of moderately to very steep limestone slopes with abundant surface stones. Part of the area was terraced in the framework of a previous, unsuccessful reforestation attempt. The site has sparse vegetation, with grass, cushion shrubs (e.g. *Prunus prostrata*, *Daphne oleoides*, *Astragalus gummifer* Labill.), and scattered small trees (e.g. *Prunus ursina*, *Sorbus torminalis*, *S. flavellifolia* (Spach) Schneider).

Area 3: the objective is to establish species-diverse "woodland islets" in extensive overgrazed areas, to provide an integral set of ecological services, following the proposed approach by other projects (Rey Benayas *et al*. 2008; Razola & Rey Benayas, 2009): (i) act as a centre of propagation, which greatly accelerates woodland development in the surrounding denuded areas; (ii) improve soil fertility and microclimate conditions favourable to the germination and growth of plants; (iii) attract seed dispersal fauna with a key role in natural forest regeneration; (iv) improve conditions for livestock and wildlife during the summer drought, thanks to the longer duration of the green grass under the trees. The area includes 15 fenced sites of 0.5 ha each, in the municipalities of Fraidees, Barouk (1250-1500 m), Mrusti (1635-1680 m), and Baadarane (1135-1150 m). The sites are mostly degraded pastureland.

Area 4: The objective is to restore the natural vegetation cover in the instable talus slopes of an abandoned quarry, as a way to demonstrate good mining restoration practices that might eventually be transferred to neighbouring abandoned quarries. The area is found in the Mrusti municipality, at an altitude of 1325-1400 m. The site consists of an abandoned limestone quarry, with cliffs of vertical friable rock, and talus slopes covered with stone and finer sediments from former quarrying activity.

Area 5: The objective is to create a green barrier between the road and the wetland, and increase the diversity of riparian forest species, to improve the ecological functionality of the wetland, increase the extension of the forest habitat, and increase the habitat requirements for birds (e.g. nesting, shelter and observation sites) and other fauna. The area includes one site in the buffer zone of Ammiq, a wetland close to the main road crossing the Bekaa valley, at an altitude of 900 m.

Methodology

Different forest restoration actions were implemented over the 3 years, covering a total of 59 ha in 19 pilot sites within 5 priority areas. The key factors of success in forest restoration work are:

(i) The availability of high quality plant material of the selected species;

(ii) A good preparation of the soil and careful planting of seedlings so as to avoid transplant shock, that is, the intense stress experienced when transferred from favourable nursery conditions to the adverse field environment. This requires measures such as effective soil preparation techniques to facilitate the growth of the root system, and increase soil water retention and storage.

(iii) Selection of the right planting period. It is critical to take into consideration the environmental conditions of the site, especially water availability during and after planting operations. This requires a careful planning of the period of the year for planting or sowing operations, to ensure that the soil is sufficiently wet (e.g. right after the start of the rainy season when the first rains have moistened sufficiently the soil).

The lack of high quality plant material when the project was designed was a major gap. MM made major investments in the development of plant production protocols for high quality seeds and seedlings with the morphological quality features and the genetic characteristics to optimise adaptation to environmental stress (e.g. tolerance to drought, soil nutrients deficit). The project team and partners selected the seeds and see-

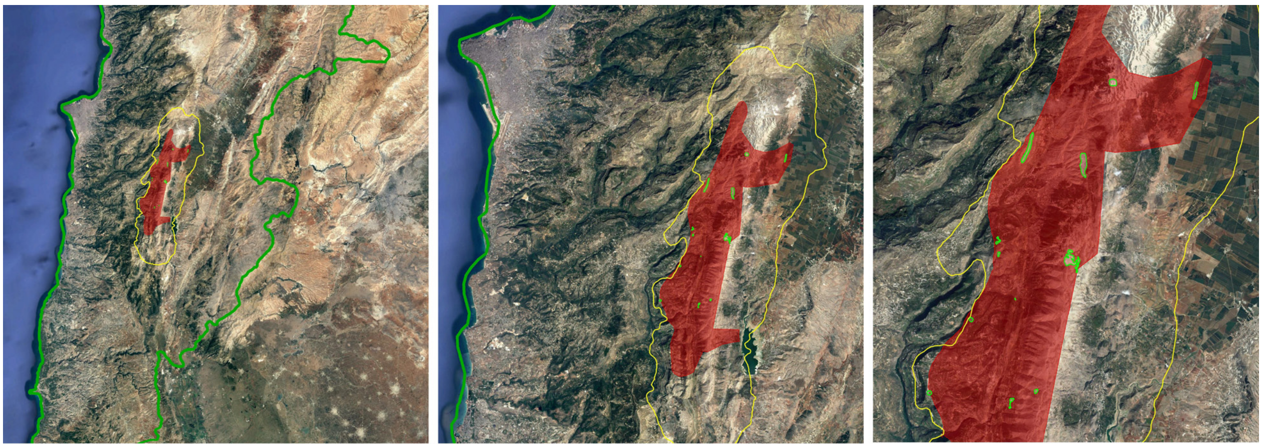

Fig. 1 - The landscape unit and 5 areas where forest restoration actions were implemented in the Shouf Biosphere Reserve.

dlings of 38 plant species (Tab. 1) and used them in the different restoration sites.

When choosing reproductive material, the project took into consideration different factors: (i) region of provenance of the material; (ii) complete fruit ripening in the field; (iii) good management of the material from the collection site to the stocking place prior to its use at nursery; (iv) cleaning-extraction-processing without damaging the seeds, so as to extract the maximum number of seeds, select viable ones, and check seed quality; (v) development of short- and long-term conservation measures; (vi) development of pre-treatment measures to secure germination whenever is needed.

In line with other initiatives developing plant production protocols for Mediterranean plant species (Chirino *et al*., 2009; Vallejo *et al*., 2012), the proposed techniques seek to ensure a balanced growth of the seedlings from the earlier production steps to the final hardening phases before planting. It is necessary to produce seedlings with an appropriate biomass distribution or optimum root/shoot ratio: (i) long-enough root system capable of quickly reaching the deeper soil horizons where soil moisture is still available during the summer; (ii) short aerial part that will have higher chances to stand the winter dormancy, allowing the plant to invest energy in a good root system, and avoiding excessive water transpiration during the first summer season.

The basic rules followed by the MM project are:

(i) The use of 250-400 cc containers (depending on the species) and 14-18 cm depth with internal ribs to avoid root spiralling, especially in the case of *Quercus* spp).

(ii) The use of standardized substrates that allow the optimum oxygenation of the root system, ensure fertility, show increased water holding capacity and water availability, reduce the post-transplant shock, and help the seedlings to bear water stress during the first months after out-planting.

(iii) The application of slow-release fertilizers or ferti-irrigation adapted to each species, with a well-controlled dosage to avoid excessive growth of the aerial part, and a reduced amount of fertilizer towards the end of the production process, to ensure adequate hardening before the autumn planting operations.

(iv) The use of greenhouse conditions mainly for the sowing of small seeds and seeds with difficult germination. After keeping them under the greenhouse until germination, the seedlings were taken out of the greenhouse as a way to ensure a good growth balance and their hardening. The transfer outside the greenhouse was done before spring temperatures become too warm (around May). In the case of *Quercus* acorns and *Cedrus*/*Pinus*, seed sowing was done outside the greenhouse.

(v) A high degree of moisture (about 85%) in the substrate was kept during germination, both outside and inside the greenhouse. Once the seedlings were moved outside the greenhouse, watering was reduced to 70-75% humidity of the substrate. At the end of the production process, and especially 1-1.5 months before planting, watering was decreased to 50-60% in order to guarantee a good hardening. Right before planting, seedlings were heavily irrigated in the nursery and carefully transported to the restoration sites to avoid possible damages.

(vi) The pruning of trees species was avoided, while small shrubs and bushes were occasionally pruned during the production process at the nursery, whenever they grew higher than expected.

Tab. 1 - List of plant species and number of seedlings used in the restoration work.

Native plant species	Nº of Seedlings
Acer tauricorum Boiss. & Bal.	325
Arbutus andrachne L.	50
Berberis libanotica Ehrenb.	500
Cedrus libani A.Rich.	10,595
Celtis australis L.	325
Cotoneaster nummularia Fisch. & Mey.	550
Crataegus azarolus L.	1,540
Crategus monogyna Jacqu.	1,235
Cupressus sempervirens L.	50
Fraxinus syriaca Boiss.	200
Gundelia tournefortii L.	20
Juglans regia L.	50
Juniperus drupacea Labill.	50
Lavandula officinalis Chaix	75
Laurus nobilis L.	50
Malus trilobata (Lab.) Schneider	825
Myrtus communis L.	25
Oryganum syriacum L.	1,275
Pinus brutia Ten.	300
Pinus pinea L.	775
Populus bolleana Lauche	450
Prunus dulcis (Mill.) D.A. Webb	75
Prunus prostrata Lab.	225
Prunus ursina Ky	625
Pyrus syriaca Boiss.	500
Quercus brantii subsp. *look* Mouterde	1,200
Quercus calliprinos Webb	505
Quercus cerris L.	200
Quercus infectoria Oliv.	100
Rhus coriaria L.	500
Salix alba subsp. *micans* (And.) Rech.f.	80
Salvia fruticosa Miller	225
Sorbus flabellifolia (Spach) Schneider	1,235
Sorbus torminalis (L.) Crantz.	2,135
Spartium junceum L.	300
Styrax officinalis L.	30
Thymbra spicata L.	75
Ulmus minor Mill.	475
Total	**27,750**

Plant production protocols for each of the 38 plant species were developed (Colomer *et al*., 2014) and applied for the production of the 27,750 seedlings used in the forest restoration work.

The field restoration techniques comprised the following measures:

(i) The opening of the planting holes was carried out with an auger machine in all the sites where the soil was sufficiently soft. Whenever the augers could not be used due to the rocky substrate, picks and hoes were used. The size of holes for trees/shrubs was at least 40x40x40 cm in order to maximise water uptake by the roots. One-year old (exceptionally, 2 years old) seedlings were planted in holes. Oak acorns were sown in the holes, sometimes with the use of protection tubes to avoid predation.

(ii) The planting density was adjusted to water constraints, ranging between 500-800 seedlings of trees/ha and 1500-1750 seedlings of shrubs/ha.

(iii) The construction of micro-catchments associated to the planting holes favoured runoff capture, increasing soil water storage capacity. Placing stones in the hole around the seedling helped control weed growth competition and had a soil mulching effect, avoiding water evaporation and soil crusting in the dry season, promoting infiltration, reducing the impact of raindrops, and buffering eventual freezing temperatures during winter.

(iv) The natural vegetation of the planting sites was kept, except in the small area where holes were actually made and where the micro-catchment was prepared. In the fenced plots set in degraded pastures, the grass was mowed in spring to reduce competition with the seedlings.

(v) Assisted watering was not taken into consideration by the project assuming that seeds and seedlings from native species well adapted to their environment should be able to grow without irrigation, just as they do in the case of natural regeneration. Also, watering significantly increases the restoration cost and is socially questionable - water is a very scarce good that is very much needed for human development in dry regions.

(vi) Oak acorns were sown in holes (*Project Restoration Action 1*), making use of protection tubes on Year 3 to avoid predation mainly by rodents. Cedar seeds were broadcasted on the snow, or planted in holes after being pre-treated to promote quick germination and minimize predation losses.

Daily workers were trained and hired among Syrian refugees, thus providing much needed income and contributing to their social and economic integration in the social fabric of the region. Hole opening performance was as follows: (i) 7-8 holes/worker/hour when using hoes and picks in rocky places where auger machine could not be used; (ii) 14-16 holes/worker/hour when using augers.

Results

On Year 1 (2012), the project invested most efforts in the production of high quality seeds and seedlings of 38 selected plant species. The authors consider this choice one of the key elements of success in the restoration exercise. The project also focused on building the capacity of the staff in the local tree nurseries, and ensured accurate monitoring and supervision throughout all the plant production stages. This approach led to the development of high quality plant production protocols that were published as part of a forest restoration handbook (Colomer *et al*., 2014)), and to the successful growth of the 27,750 seedlings used in the restoration work on years 2 and 3.

Three years since the project take-off, the average survival rate (after 3 years for Y-1, after 2 years for Y-2, and after 1 year for Y-3) in most sites was between 75% and 95%, with the exception of the direct sowing of oak acorns of Area 1 (up to 20%), where seeds were highly affected by rodent predation (Tab. 2). Generally speaking, these survival rates are remarkably high - especially considering that watering was avoided - and very promising to upscale restoration activities in the Shouf Biosphere Reserve and elsewhere in Lebanon.

Taking into account work performance and the unitary cost of the produced seedlings (USD 1), the restoration cost was about USD 2.5-3 per planted seedling (seedling production cost + the cost of seedling transferring to the field + the cost of soil preparation + the cost of seedling plantation). For an average plantation density of 700 seedlings per hectare, the cost/hectare was between USD 1,750 and USD 2,100, depending on the features of each restoration site (e.g. steepness of the slope, soil rockiness).

Discussion

As previously mentioned, the low survival rate in Area 1 is mainly due to rodent predation. In order to solve predation problems, the project adopted the use of protection tubes in the direct seed sowing operations with acorns of *Quercus brantii* ssp. *look* in November 2014. Two types of protection were tested in an area with 100 holes and 2 acorns per hole: (i) 50 holes with individual plastic tubes of 0.5 meter height that were buried 15 cm and closed with a strip at the top to prevent the entrance of rodents; (ii) 50 holes with small boxes made with a fine wire mesh (not galvanized iron), inside which the acorns were placed. Six months after sowing operations, the plastic tubes have demonstrated to be a good option to prevent predation, with good germination and plant growth. On the contrary, the small boxes could be easily broken by rodents. The project is in contact with other research teams involved in the development and testing of new

Tab. 2 - List of Forest Restoration and Forest Management Actions with Survival Rate.

	Action	Species	Surface (hectares)			Survival rate (%)
			Y-1	Y-2	Y-3	
Area 1	Direct sowing	*Quercus brantii ssp. look* *Quercus cerris var.pseudocerris*	0.28	6	0.11	20%
Area 2	Planting of seedlings	*Quercus brantii look, Cedrus libani, Juniperus drupacea, Acer tauricolum, Crataegus azarolus, Sorbus flabellifolia, S. torminalis Prunus ursina, Prunus prostrata, P. syriaca, Cotoneaster nummularia, Malus trilobata, Berberis libanotica.*	1.18	20.5	15	79%
Area 3	Planting of seedlings in 15 fenced plots.	*Quercus calliprinos, Q. infectoria, Cedrus libani, Crataegus azarolus, C.monogyna, Sorbus flabelifollia, S. torminalis, Prunus ursina, Pinus pinea*	0.5	7	-	95%
Area 4	Combined direct sowing and planting of seedlings,	*Cedrus libani, Pinus brutia, P. pinea, Quercus calliprinos, Celtis australis, Salix alba, Crataegus azarolus, Stirax officinalis, Rhus coriaria, Sorbus flabellifolia, S. torminalis, Cupressus sempervirens, Celtis australis, Cedrus libani, Pinus brutia, P. pinea.*	0.5	4	-	85%-95%
Area 5	Planting of seedlings with irrigation.	*Celtis australis, Populus bolleana, Ulmus minor, Fraxinus syriacus.*	-	2	-	99%
TOTAL = 56.7 hectares			2.46	38.50	15.11	

Note: The survival rate in the last column is an average of the three restoration years. Y1,Y2,Y3 are related to those restoration years (always planting and sowing in November). Regarding the assessment time for survival rate: the data were collected after 3 years for year 1, after 2 years for year 2 and after 1 year for year 3.

devices (Castro *et al*., 2015) that may be effective to avoid rodent predation.

The average survival rate for the species used in Area 2 was 79%. Native fruit tree species (*Sorbus flabellifolia* and *Sorbus torminalis*) have demonstrated a good re-sprouting capacity after summer drought. *Sorbus flabelifolia*, *Crataegus azarolus* and *Acer tauricolum* were the most resistant species with 100% survival rates.

The survival rate achieved in the fenced plots in Area 3 has been extraordinary high (95%) considering that no irrigation was provided. *Crataegus monogyna*, *Sorbus flabellifolia*, and *Quercus infectoria* showed the highest survival rate. These species play an important ecological role, attracting seed-dispersal fauna, and have a significant economic value for local livelihoods – the collection of wild fruits and oak honey.

This restoration technique has demonstrated to be very effective in degraded lands with intense grazing, and could be easily replicated in other areas within the SBR and elsewhere in Lebanon. Moreover, enclosures with no planting could be used to obtain a recovery of the pastures and the growth of new plants from the natural regeneration process, while the employment of enrichment planting could accelerate the development of new tree/shrub communities. Enclosures also had an important awareness-raising function, demonstrating to shepherds how the establishment of temporary enclosures could lead to a fast improvement of the quality of pastures and a diversification of the landscape, with clear benefits for livestock production and local livelihoods. Once convinced of the benefits of the temporary enclosures, shepherds are usually ready to participate in the set-up and management of the fenced plots, with a reduction of the conflict between grazing and nature conservation in the Reserve.

The combined seed sowing and seedling planting in the mining spoils instable soil debris of the abandoned quarry in Area 4 has achieved a very high survival rate of 85% to 95%. It is especially worth noting the high survival rate of the sown acorns (95%), with a very positive response in terms of resistance to predation, compared with the site described in Action 1. The preliminary hypothesis of the Authors is that the instability of the slope debris hinders the access of rodents and facilitates seed germination. In the talus substrate with poor structure, the application of organic amendments and the planting of seeds and seedlings have demonstrated good results in soil erosion control. This pilot experience has been particularly satisfactory, with promising lessons learned vis-à-vis future restoration work in similar places within the SBR and elsewhere in Lebanon.

The survival rate of the seedlings from riparian tree species in Area 5 reached 99%. The new plants are growing very fast, thanks to the implementation of grazing control measures, and the watering provided during the summer drought period. This pilot action was implemented in collaboration with one of the private owners of the organic vineyards and other fruit tree crops bordering the Ammiq wetland. This action was critical as a demonstration of good practices in wetland restoration applied by landowners, and to raise awareness about the environmental services provided by riparian forests, to the benefit of sustainable, high-quality agriculture production in the area. This lesson learned will be introduced to other landowners, so as to encourage further riparian forest restoration around Ammiq.

Taking into account the choice not to provide irrigation (except in Area 5), the above results are very encouraging and demonstrate the possibility to undertake dry forest restoration in Lebanon, provided that the following conditions are fulfilled: (1) production and hardening of high quality seedlings following the new protocols developed by the project; (2) identification of the right planting period, based on the careful observation of field conditions and the precise starting date of the autumn rainy season; (3) careful transfer of the seedlings to the field; (4) proper soil preparation techniques, including deep enough holes, micro-catchments and stone protection to facilitate the development of a long root system and the harvesting and storage of water in the soil.

The MM project managed to abate the forest restoration cost from USD10 per planted seedling to USD 2.5-3. This reduction was due to: (i) accurate plant production protocol avoiding the unnecessary consumption of water and other inputs; (ii) equipment used for soil preparation (auger machine); (iii) empowerment and professionalization of the staff involved in plant production and field planting; (iv) avoidance of watering for the maintenance of the restored sites. It is expected that the improvement of work performance and lower cost of seedlings will further decrease restoration costs per hectare up to USD 1.5-2 in the short- to medium term.

The project has demonstrated the possibility to implement forest restoration without additional field water supply to the seeds and seedlings, which represents a great success towards the reduction of restoration costs and a major contribution to the improvement of the forestation guidelines defined by the Lebanese government in its National Forestation Programme.

Acknowledgements

This paper summarizes some of the achievements of the Mediterranean Mosaics/Phase 1 project, which was implemented in the Sirente-Velino Natural Park (Italy) and the Shouf Biosphere Reserve (Lebanon) by a pool of organizations LIPU, ILEX, ACS, SILVESTRIS, AFDC, with the financial support of the MAVA Foundation. A second phase of Mediterranean Mosaics will run in the same areas for three more years, as from May 2016.

The Authors owe special thanks to the Forest Development Committees, private land owners, local organization, and individuals - including Syrian refugees - in the municipalities of Ain Zhalta, Ammiq, Baadarane, Bmohray, Barouk, Fraidees, Maaser El Shouf, Mrusti. We also sincerely thank Mr. Khaled Sleem and Ms. Maya Nehme for their technical input and suggestions during project implementation.

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