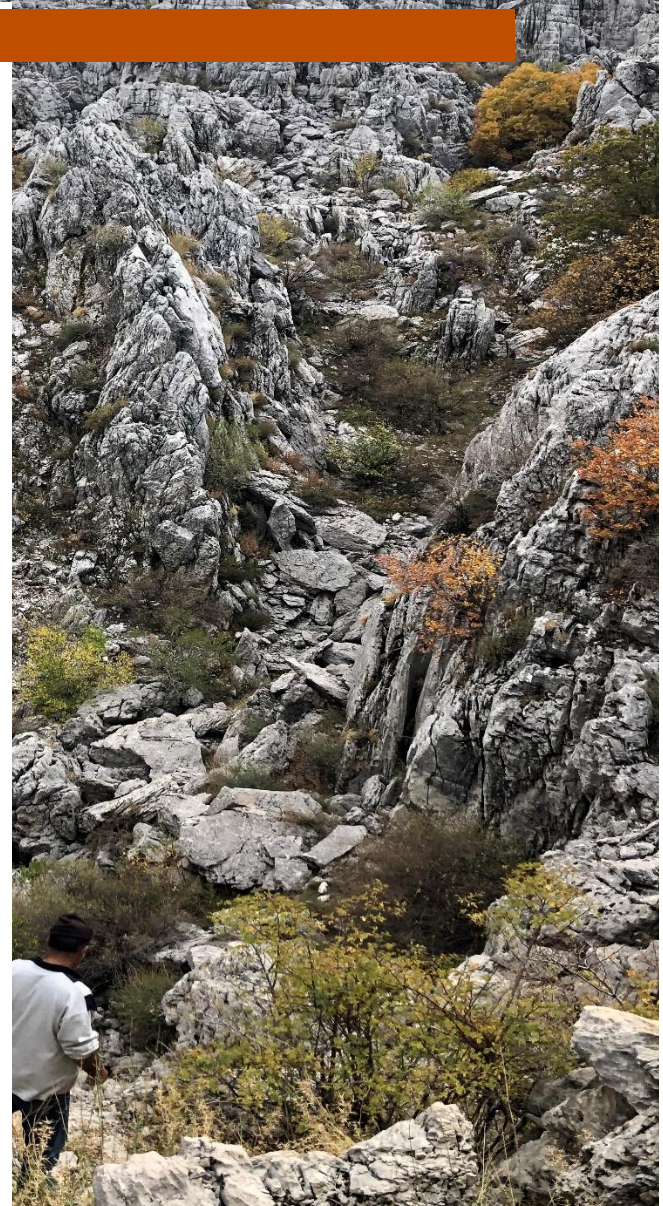
# Identifying biodiversity-related success factors of forest ecological restoration projects



## ECOLOGICAL SUCCESS FACTORS

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FERI

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## I. General context

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER,2014). It aims to recreate, initiate, or accelerate the recovery of an ecosystem that has been disturbed.

Ecosystem degradation mainly due to common disturbance such as logging, damming rivers, intense grazing, hurricanes, floods and fires leads to habitat loss which is one of the most important cause of species extinction. Fragmented habitat on the other hand reduce the diversity of plants and animals by 13 to 75%, with the largest negative effects found in the smallest and most isolated fragments of habitat. Extinctions from habitat loss are often delayed rather than immediate, because many species that tend to linger in the habitat fragments do not have viable populations and are doomed to eventual local extinctions.

The strategic plan for Biodiversity 2011-2020 sets as an objective, the restoration of 15% of degraded ecosystem by 2020. The main reasons for implementing restoration projects are:

- Recovery of individual species
- Strengthening of landscape or seascape-scale ecosystem function
- Connectivity
- Re-establishment or enhancement of various ecosystem services
- Improvement of visitors' experience opportunities.

In the group C activities related to the planning and implementation of ecosystem restoration activities of the STAPR: Short Term Action Plan on Ecosystem Restoration, Biodiversity is well considered in the context of restoration science and practice. In this context, the Forest ecosystem reforestation initiative in collaboration with the CBD has funded a pilot project, implemented by the Saint-Joseph University of Beirut for the ecological restoration of the degraded site of Kfardebian.

> ***"To ensure ecosystem function for the future, forest restoration programs must: (1) learn from the past; (2) integrate ecological knowledge; (3) advance regeneration techniques and systems; (4) overcome biotic and abiotic disturbances and (5) adapt for future forest landscapes."***
>
> ***Löf et al. 2019***

# II. FERI PROJECT

## 1. Introduction

Since the early sixties, Lebanon experienced many reforestation projects. But these efforts were hampered by the war which lasted for more than 30 years and would have had anyway limited impact. Recently, the Lebanese Government launched the 40 million trees programme, a national initiative steered by the Ministry of Agriculture to plant 40 million forest trees in public lands within the next 20 years. All the environmental NGOs are invited to work under this project umbrella. Since 2007, the NGO Jouzour Loubnan is working in this field and, building on the success and failures of the traditional approaches to forest reforestation, introduced the new worldwide-accepted approaches based on Ecosystem restoration rather than on just planting trees.

Jouzour Loubnan and the Faculty of Science – Saint Joseph University signed an MOU in order to optimize plantation techniques, reduce costs and improve processes through a research and development effort adapted to the local context. One of their main collaborative work aims to decipher the relationships among foundation species, associated organisms and their genotypes as well as the implications of such relationships in the successful establishment of diverse and viable tree populations. The following factors considered as contributors to ecological restoration success are currently addressed in the framework of this partnership:

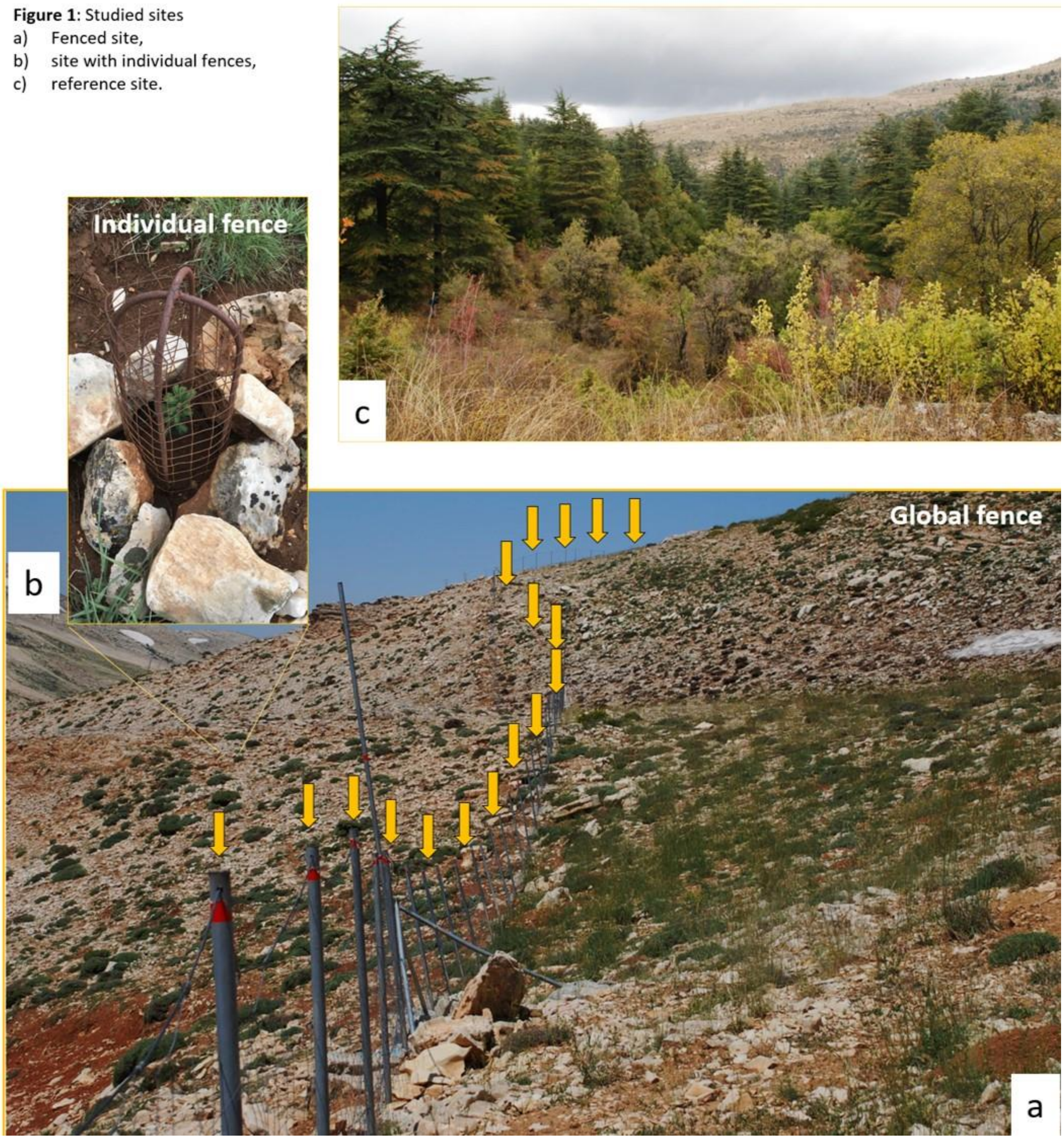
a) explore and restore the below-ground biodiversity,
b) promote the Use of native species for ecosystem restoration and defining their germination protocols,
c) confirm Effect of Nurse Plants and their “facilitation” role,
d) selection of appropriate genetic resources to be used for reforestation,
e) evaluate the effect of Fencing on restored site biodiversity,
f) and evaluate the effect of animal wildlife on the long-term sustainability of the restored forests.

The grant awarded by FERI for Saint Joseph University of Beirut focuses on the point e and f.

## 1. Objectives

For the sake of this project, we relied on a unique opportunity to test *in situ* a set of parameters affecting plant and animal biodiversity interactions under three different situations. To this effect, we have a site of 50 ha globally fenced since 2009 (site A ; fig 1a), another site adjacent to the first one where planted trees are fenced individually (site B; fig1b) and a reference site situated at the same altitude and developing under similar climatic conditions and protected since 1992: the Ehden Nature reserve (site C; fig 1c).

**Figure 1**: Studied sites
a) Fenced site,
b) site with individual fences,
c) reference site.



Having a reference area (site C) that is as near as possible to the natural conditions of the area to be restored is useful as benchmarks, for understanding ecological processes, and as sources of plants and animals to be used in assisted restoration.

While the Project builds on previously implemented actions and profits from lessons learned, it will directly consider role of **wildlife in ecological restoration processes**, by studying what different animals disperse, in relation to plant species over different time frames and **evaluate the role of fencing** in reforestation projects.

Diverse plants that can sustain wildlife year round will be identified to promote the sustainability of the restored ecosystem and its natural regeneration.

The Saint- Joseph University implemented the Project over two years (2017 -2019). The related activities to which the Agreement states include:

a. Selection of appropriate genetic resources to be used for reforestation;
b. Evaluate the effect of fencing on biodiversity of the restored site;
c. Evaluate the effect of animal wildlife on the long-term sustainability of the restored site; and
d. Promote key results in roundtable discussions among different national focal points, and at relevant international meetings, show casing results and exchanging insights for areas facing similar challenges.

Given its novel character in associating different concerned biodiversity partners, this study constitutes a cornerstone to all subsequent reforestation actions in Lebanon and in the Eastern Mediterranean region. It will track implementation outputs, stakeholder engagement and budget expenditures.

### 2.1 Selection of appropriate genetic resources to be used for reforestation

A reference site in the broadest sense is an ecosystem that serves as a model for restoring another ecosystem. They might be less disturbed portions of the matrix in close proximity to the restoration site or more distant relatively intact sites occupying similar topographic positions in the landscape when the restoration site is an isolated fragment. A reference site is similar in successional stage, structure, and [22]function, which provide more defined design parameters. Reference site can also represent a chrono-sequence of succession typical for a specific ecosystem.

This is especially important when the site to be restored is highly disturbed and lacks any biological legacy. This is the case of Kfardebian sites where historical tree cutting and continuous overgrazing led to a depleted soil with poor vegetation.

For this project and in order to identify biodiversity-related success factors of ecological restoration projects we choose Ehden Nature Reserve as reference site since it fits all of the criteria mentioned above Figure 1.

Declared as a nature reserve in 1992, **Horsh Ehden Nature Reserve** (HENR) extends over 1,000 ha. The minimum average rainfall is 1,100 mm and the average temperature registered in the month of January is 3 °C while in August the minimum average temperature is registered as 18 °C. Horsh Ehden nature reserve in Mont Lebanon. Located at N34°49" latitudes and EO36°00" longitude with an altitude range that extends between 1200m and up to 2000 m, HENR is recognized as a nationally outstanding remnant forest sheltering high biological diversity. Home for a great number of plants and animals and where the natural succession stages occurs (Fig. 2).

This reference site will help us elucidate the animal-plant relationship; promote the reoccurrence of wildlife and the natural regeneration in the pilot site. Within this reserve there is a mixed coniferous forest of *C. libani* and other tree species. *Cedrus libani* and *Juniperus excelsa* stage is at the same altitude and same precipitation rate as Kfadebian site. We have listed all the species of trees and shrubs present there. They are presented in Annex 1 and some conifer species are presented in Figure 2. For ecosystem restoration projects, conifer species are the pioneer species able to develop under harsh environmental conditions such as poor soil, absence of shade more than 7 months of drought and very cold winter. At a later stage, when abiotic conditions will be less harsh, broadleaves species will be introduced. Meanwhile, germination protocols for all these species are developed in the laboratory for seed germination and conservation "*Jouzour Loubnan*" at the Faculty of sciences Saint Joseph University. As for animal wildlife, 27 different animal species are reported in the literature as present in HENR.

Gymnosperms

Pinaceae


Cupressaceae


A reference site in the broadest sense is an ecosystem that serves as a model for restoring another ecosystem. They might be less disturbed portions of the matrix in close proximity **Kfardebian** is located in the Mount Lebanon range at an altitude around 2000m. The Mount Lebanon chain is known for its heavy rainfall and therefore a dense vegetation level is expected to be present similar to another present forest enjoying same abiotic factors like the high altitudes of Ehden Nature Reserve. However, Kfardebian was subject to cutting, and grazing disturbance over the past decades that has altered its species composition. Since 2009, Jouzour Loubnan is working on this site in partnership with our team at the Faculty of science – Saint Joseph University. We know almost all the problems and the constraints hindering the reforestation on this site.

An important success factor of the ecological restoration is the understanding of the succession within the degraded site. Ecological succession is the process by which biological community composition, the number and the proportion of different species in ecosystem, recover over time following a disturbance event.

The main question is what are the added benefits of actively restoring ecosystems versus allowing them to recover without human interaction? Knowing that passive recovery should be considered as a potentially cost-effective option for ecosystem recovery, 65.8 ha of Kfardebian site were fenced in 2009. Ten years later, the only woody plants present on the site are those that we planted. So as found by Godefroid et al. 2003, fencing helps spontaneous species recovery on eroded soil. However this spontaneous recovery could be effective for herb layer while it could be very long before vegetation previously present in the ground flora may recover in both density and species composition.

This active restoration involves acceleration of the process by planting late-successional tree species. Conifer trees mainly *Cedrus libani* and *Juniperus exelsa* are planted since 2009 on the site A with a surface of 65.8 ha fenced globally and starting 2011 on the site B with individual fences. In the framework of this project we wanted to test the benefits of the global fence on the diversity of the site and confirm how profitable the installation of a global fence in an ecological restoration project is.

### 2.3 Evaluate the effect of fencing of the restored site on biodiversity

We noticed visually that global site fencing in site A has enhanced macroscopically the plant biodiversity. We can see a global greener aspect of the site, while individual fencing on site B protect better the plantlets from grazing but also from cold wind and burning sun. Which plants benefits directly from the global site fencing? Do we observe a qualitative difference in terms of alpha and beta diversity between the sites A and B? What are the species present in C that don't appear again after almost 10 years of global fencing of B and needs to be introduced?

A total of 6 plots, each of 10x10m were delimited depending on their exposition. Three out of those six plots are present in the fenced area (A) and the other three are present in the non-fenced one (B) (fig. 3). Cliffy rocks and places unsuitable for plantation were excluded.

A flora assessment was conducted periodically, every month in the 6 plots. During project, we have covered a one-year survey (summer 2017, autumn, fall, spring and summer 2018). The flora survey contains the species found in each plot, their frequency and dominance. Plants observed were identified and checklists were prepared for each plot (Annex 2).

Table 1 Six different plots in Kfardebian

| Plot # | Latitude Y | Longitude X | Altitude (m) | Exposition | Description |
|---|---|---|---|---|---|
| 1 | 34.001232 | 35.848433 | 2088 | NE | fenced area |
| 2 | 34.000118 | 35.846592 | 2093 | W | fenced area |
| 3 | 33.997972 | 35.848855 | 2078 | SW | fenced area |
| 4 | 34.003228 | 35.852749 | 2062 | SW | non-fenced area |
| 5 | 34.003233 | 35.852631 | 2027 | NE | non-fenced area |
| 6 | 33.996403 | 35.849805 | 2039 | S | non-fenced area |

Figure 3 : Kfardebian Experimental design. Three plots 1, 2 and 3 are in the site A inside the fence represented by the blue line. Three plots 4, 5 and 6 are in site B outside the fence.

Only 40 species were observed in the 6 studied plots during the present study. They are distributed as follow (Fig 4):

- 20 species were found only in plots 1, 2 and 3 (fenced site: A);
- 3 species were found only in the site B outside the fenced plot;
- 17 species were found inside and outside non-fenced plots;

Figure 4: Number of plant species found in the studied plots

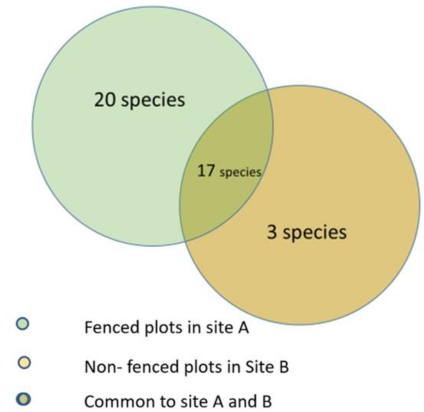
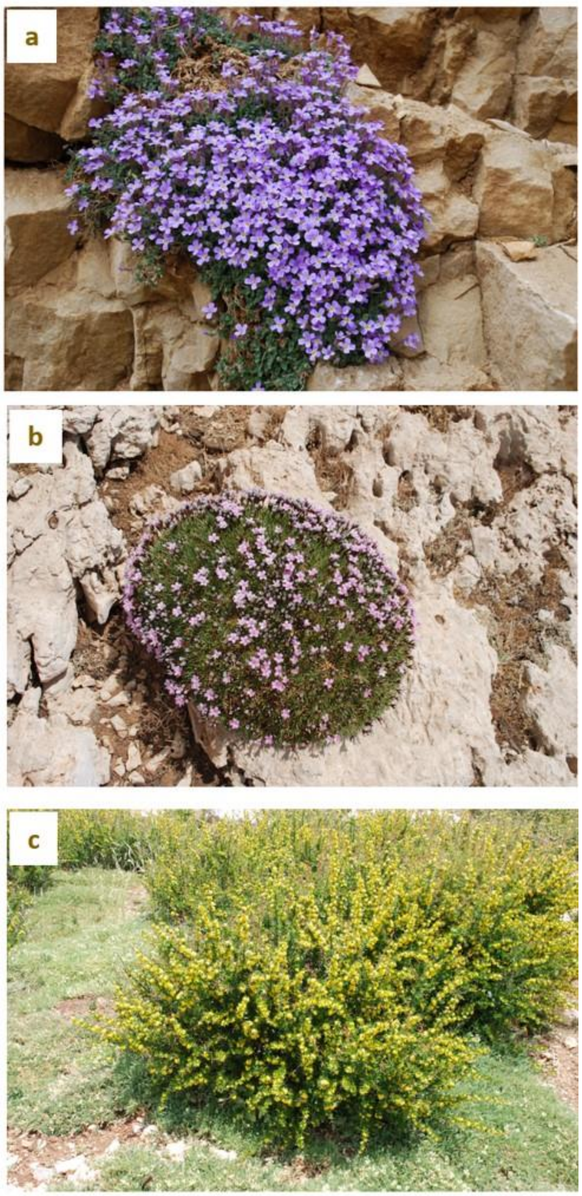



Figure 5: Endemic species present in Kfardebian region: a) *Aubrietia libanotica*, b) *Acantholimon libanoticum*, c) *Berberis libanotica*




The 20 species found only in the plots inside the fence include many endemic species threatened by extinction such as *Viola libanotica* and *Puschkinia scilloides* var. *libanotica*.

The 17 species observed inside and outside the fence seems to challenge overgrazing. They are adapted to grazing by developing survival strategies such as the accumulation of toxic components or by harboring thorny elements.

The 3 species present only outside the fenced area could have been carried to the site by the goats and sheep that roam on different sites in the mountain.

During a non-exhaustive exploration of the fenced site flora that we conducted in 2012, 72 plant species were found .This former study included rocky cliffs, road borders and places unsuitable for plantation that was excluded from the present study. It shows the importance of heterogeneous habitats in the ecosystems.

Lebanon Mountain is known for its richness in endemic species. In fig 5, we present some of these species : *Aubrietia libanotica* occurring only on the rocky cliffs, *Acantholimon libanoticum* and *Berberis libanotica* are both present inside and outside the fence. *Berberis libanotica* is very frequent wile *A. libanoticum* is rare.

This study underlines the importance of the global fencing of the site, since it protect not only the planted trees but favor the whole site diversity. Such evidence of grazing impacts will surely help conservationist to go towards encouraging fencing operations. Our results supports other studies stating that fencing significantly increases vegetation coverage, height, plant diversity, biomass production and litter (Deng et al. 2014).

On another hand, positive effects can be brought by fencing to the soil such as C and N storages, significant improvement of its physico-chemical characters. Preliminary tests showed high Soil compaction that leads to high water runoff, decreasing soil moisture in non fenced area compared ton the fenced one.
We noted during field visit this summer the presence of high number of butterflies, insects and birds in the fenced site compared to the almost bare land in the unfenced and grazed site.

***"Global fencing enhances plant species diversity and subsequently insects diversity"***

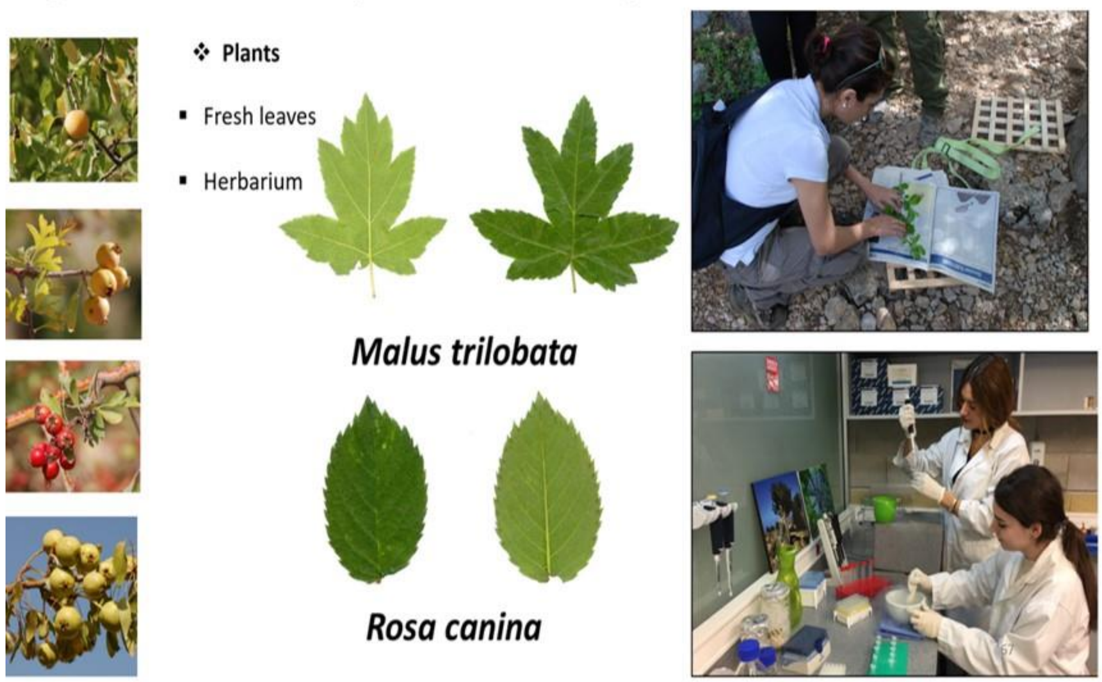
### 2.3 Evaluate the effect of animal wildlife on the long-term sustainability of the restored site

The animal component in the ecological restoration projects is very often overlooked, even though the role of animals acting as pollinators or seeds dispersers is obvious. The self-sustainability of the restored ecosystem relies deeply on animals. For example plants having their seeds transported by the wind normally colonize the sites without human assistance while other can see their seeds brought by birds. Who are these animals? Are they still present in the surroundings of the restored area? Did their site frequentation and their populations after the restoration project increase?
In the framework of this project only the animals dispersing the seeds are studied. The analysis of food webs and their dynamics facilitates the understanding of the mechanistic processes behind community ecology and ecosystem functions. In the framework of the ecological restoration approach, knowing what each animal species eats and through which animal species each plant species disperses its seed, is crucial to help managers decide what to plant if they want to attract and promote wildlife. In addition, it allows us to define which plant needs which animals to disperse its seeds and ensure the ecosystem sustainability.
A suite of approaches has been used based on the identification of consumed species by characterization of animal DNA collected based on non-invasive sampling techniques. Non-invasive DNA analyses involve DNA collected without capturing animals. It means collecting DNA from items that animals leave behind, including feces (scat, dung), hair, feathers, saliva, or shed skin.
After DNA isolation, a standardized DNA region (DNA barcode) is PCR amplified, amplicons are sequenced and then compared to a reference database for identification. The recent development of

next generation sequencing (NGS) has made this approach much more powerful, by allowing the direct characterization of dozens of samples with several thousand sequences per PCR product, and has the potential to reveal many consumed species simultaneously (DNA metabarcoding).
On one hand, unlike carnivorous species, omnivores have to rely on different food sources across the different seasons while, on another hand, a given plant can have its seeds dispersed by several animals. So restoration projects should ensure the presence of plants capable to support animal wildlife **all the yearlong**. Different species will have their fruits ripen at different time of the years. Having information about which animal species eats what and when, will surely help practitioners to determine the adequate choice of the animal and plant species associations.

As a first step, we constructed the first reference library of animal and plant species of Lebanon. This library is crucial since data on biodiversity in the Middle East region are poor and sporadic. To construct this reference library, fresh plant material from Horsh Ehden Nature Reserve are collected (Fig. 6).

Figure 6: Construction of plant reference library



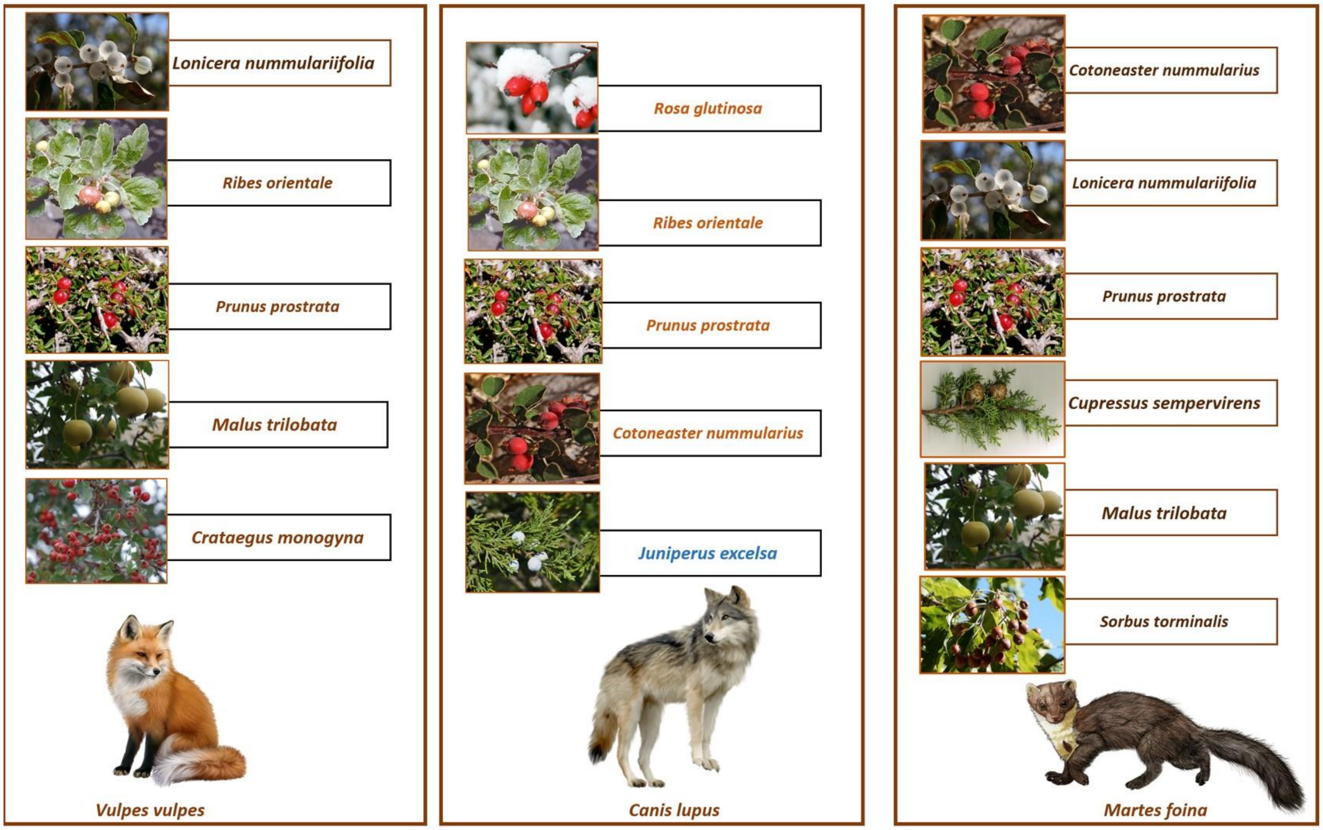

Animal samples from Museums or from dead animals found along roads and were collected (Fig. 7).
We benefited from a complementary fund from the American Embassy in Beirut to prepare the reference library.

Figure 7: Construction of animal reference library


Today this reference library includes sequences for 51 plants and 18 mammals. Scats sampled from HENR revealed the presence of 10 mammal species, 3 birds and one lizard. The number of individuals gathered for each species reflects their natural abundance. The most frequent species was *Vulpes vulpes.*

To date, the metabarcoding technique for the animal scats had led us to the identification of 8 animal species and the plants they ate. Results are confidential. Figure 8 presents three of these mammals and the seeds they disperse. This is the first time that we discover the importance of beech marten in seed dispersal. At least six tree species have their seeds dispersed by this animal.

Figure 8: Plants seeds dispersersed by *Vulpes vulpes*, *Canis lupus* and *Martes foina*




These are the preliminary results of this study. In few months, DNA metabarcoding analysis of more than 200 scat sample will enlarge our knowledge about 10 eastern mammals diet and decipher their role in seed dispersal. The information gathered will help us promote wildlife and its role in the restoration of Lebanon's ecosystem. The outcome of the project could be used as a supportive tool for other ecosystem restoration projects and as a reference for the degraded ecosystems. They will inform management strategies to help with the conservation efforts of these imperiled species. For example, we know that wolfs populations rely deeply on Rosa fruits during the winter when food is scarce. The inclusion of *Rosa* species in the panel of species to be planted in our restoration project will help maintain animal wildlife.

This study is significant as it is the first to employ a DNA dietary analysis on wildlife in the Eastern Mediterranean Region and explicitly considering the role of wildlife in ecological restoration processes.

This DNA barcoding technique allows a full characterization of the dispersal process of any plant species, that is, the identity of the source trees of the dispersed seeds and the frugivore species that contributed to each dispersal event. Given that dispersal distances and the contribution of specific frugivore species can be determined, both methods allow for the direct estimation of the Total Dispersal Kernel (Nathan 2007), that is, the relative contribution of different frugivores in distinct spatial sectors or distances. In conclusion, DNA barcoding can be used for characterizing the functional value of specific frugivore species within diverse mutualistic assemblages.

Answering these questions would allow us to look at the ecosystem in a holistic way and include in management plans tangible steps to address these issues.

**2.4 Promote key results in roundtable discussions among different national focal points**, and at relevant international meetings, show casing results and exchanging insights for areas facing similar challenges.

During the VIth Mediterranean forest week that was organized in Lebanon in April 2019, we prepared and animated a round table session on “Biodiversity for resilience in the restoration of Mediterranean forests”.

Restoring biodiversity in forests promotes their resilience to human-induced pressures and is therefore an essential ‘insurance policy’ and safeguard against expected climate change impacts. Biodiversity should be considered at different scales (stand, landscape, ecosystem, bioregional) and in terms of all elements (genes, species, communities). Increasing the biodiversity in planted forests will have a positive effect on their resilience capacity. This session will explore the following questions: To what extent is this approach feasible in the context of the restoration of Mediterranean forests? What are the data gaps and implementation bottlenecks for scaling up this type of approach? How can we include key stakeholders from various land use sectors in the design of these approaches?

Many plantation projects are limited to planting trees. Very often of the same species and or with exotic species, disregarding the function of the future forest and its resilience.

Taking into consideration the plant species diversity, the plants genetic diversity, the animal and microbiological components are key factors to ensure the success of the ecological restoration action.

The objectives and outputs of the session were:

- to share best practices and foster an exchange of experiences with regards to restoration approaches that include biodiversity for resilience;
- to share their experience and their views and discuss the potential to amend ongoing restoration programs and projects at national and regional levels is foreseen in order to include best practices for inclusion of biodiversity considerations resilience that have proved their effectiveness.

More than 40 participants from different nationalities and domains have attended this session. This session started with an introductory word by Prof Kharrat about the Forest Ecosystem Reforestation Initiatives- FERI program. She explained that the main targets of this initiative are the support of developing country Parties as they develop and operationalize national targets and plans for ecosystem conservation and restoration within the framework of the Strategic Plan for Biodiversity 2011-2020 and its Aichi Biodiversity Targets, especially Targets 5, 14 and 15. In addition to providing countries with best practices and foster an exchange of experiences including challenges and opportunities to contribute towards the planning and implementation of forest ecosystem conservation and restoration.

Prof Kharrat then tackled the FERI project with an in depth review of the main methodology and results of the project showing the success factors of the ecological restoration in the pilot site in Lebanon. The presentation also included some tips on Identifying and using the reference landscapes for restoration as well as some insights on the selection of appropriate tree species for plantation, and documenting their different dispersion mode including animals, dates, and time to introduce in the restoration dynamic including the foster and record of animal biodiversity. She also addressed on how restoration projects have often focused on the use of one or a small number of species. This simplified approach, which neglects the principles of ecological restoration, hinders the effectiveness of ecosystem restoration.

A shift has been made nowadays from this large-scale monospecific reforestation to a more holistic method with multiple objectives, combining several socio-economic and environmental benefits. This change allows the introduction of the link between restoration of ecosystem functions and human beings. Therefore, restoring biodiversity in forests strengthens their resilience to anthropogenic pressures and is therefore is considered as an essential insurance against the expected and known impacts of climate change. Biodiversity should be considered at different scales (population, landscape, ecosystem, biogeographic region) and taking into account all its dimensions (people, species and communities).

During the session, different experts from different domains explained the importance of the resilience restoration of the Mediterranean forests through various aspects:

• Jordi CORTINA, Chair European Chapter of the Society for Ecological Restoration Professor - University of Alicante , talked about “Restoring Resilience in Mediterranean landscapes”. Funded by FAO.

• Grammenos Mastrojeni, Coordinator for the environment and Head of the Science- Science-Policy Interface , Ministry of Foreign Affairs, Italy explained how “Biodiversity is the link between environmental stability and human communities stability”. Funded by the Italian cooperation.

Finally, a panel discussion was animated by Michele Bozzano from the European Forest Institute. On the panel, the newly Silva mediterranea appointed President Mr. Chadi Mohanna, Director of rural development and natural resources at the MOA Lebanon and our presenters. The discussion tackled different questions: to what extent is this approach feasible in the context of the restoration of the Mediterranean forests? What are the missing data and the major implementation obstacles to extend this type of approach? How can we include key stakeholders from different land use sectors to design these approaches?

## Conclusion

On the applied level, the theoretical results of this project will be used for a more efficient ecosystem restoration in high altitude forest ecosystems.

The project is considered as a pioneer subject that will be very strategic for the future of ecosystem restoration, not only in Lebanon but also in other regions having the same species because the methodology is transferable for any other ecosystem. It is very important because it is research-oriented for different future projects that will be applied relatively soon. This research is urgently needed because it widens our understanding about ecosystem functioning and resilience. The Forest and Ecosystem Restoration Initiative of the Convention on Biodiversity of the United Nations will make them available for the international community through FAO channels.

In addition to the above mentioned success stories, this project will help the national authorities to fulfill their commitments towards the international conventions they have signed and ratified and will have concrete material to mobilize decision makers .The Project supports CBD COP decision XII/19, reaffirming the need for enhanced support and cooperation to promote ecosystem restoration efforts of developing countries towards the implementation of the Strategic Plan for Biodiversity 2011–2020 and the achievement of the Aichi Biodiversity Targets, as well as decisions XIII/5 concerning putting in practice the steps contained in the short term action plan on ecosystem restoration.

To avoid failure of ecosystem restoration, the planning phase of this process must be done correctly. One of the most important components of the planning phase is a general assessment of the initial phase. Having insights, in terms of what are the species that are found in the area, the interaction between these different species and the best way to let these species auto sustain the forest will allow us to better understand the ecosystem of the area as well as have a solid first step towards an efficient ecological restoration. In the future, the study range will extend to reach a greater number of animals present in Lebanon as to investigate the animal - plant interaction and how humans have impacted it.

## Annex 1 : List of trees and shrubs of Ehden Naure Reserve

*Abies cilicica* Ant. & Ky
*Acer hermoneum* Bornm. & Schwer.
*Acer syriacum* Boiss. & Gaill.
*Acer tauricolum* Boiss. & Bal.
*Amelanchier ovalis* Medik.
*Cedrus libani*
*Cotoneaster nummularia* Fisch. & Mey.
*Juniperus excelsa* M.Bieb
*Juniperus oxycedrus* L.
*Lonicera etrusca* Santi
*Lonicera nummulariifolia* Jaub. & Spach
*Malus trilobata* (Labill.) C.K. Schneider
*Pinus brutia* Ten.
*Pistacia palaestina* Boiss.
*Platanus orientalis* L.
*Prunus mahaleb* L.
*Prunus prostrata* Labill.
*Prunus ursina* Ky
*Pyrus syriaca* Boiss.
*Quercus calliprinos* Webb
*Quercus cedrorum* Ky
*Quercus cerris* L.
*Quercus infectoria* Olivier
*Quercus pinnatifida* C. C. Gmel.
*Rhamnus cathartica* L.
*Rhamnus libanotica* Boiss.
*Ribes orientale* Desf.
*Rosa canina var. andegavensis* (Bastide) N. H. F. Desp.
*Rosa dumetorum* Thuill.
*Rosa glutinosa* Sibth. & Smith
*Rosa micrantha* Sm.
*Rosa orientalis* Dupont
*Salix libanii* Bornm.
*Sorbus flabellifolia* (Spach) C.K. Schneider
*Sorbus torminalis* (L.) Crantz. var. pinnatifida Boiss.
*Sorbus persica*
*Styrax Officinalis* L.

## Annex 2: Plant species per plot

### Plot 1

*Acantholimon libanoticum Boiss.*
*Alyssum condensatum Boiss. et Hausskn.*
*Astragalus echinus (DC.) Podlech*
*Bromus sp.*
*Centaurea sp.*
*Centaurea triumfetti All.*
*Crocus cancellatus*
*Gagea anisanthos (C.Koch)*
*Galium incanum*
*Geranium libanoticum*
*Helichrysum plicatum DC.*
*Ixiolirion tataricum (Pall.) Schult. & Schult.f.*
*Noaea mucronata humulis*
*Onobrychis cornuta (L.) Desv*
*Plantago lagopus*
*Poaceae family*
*Prunus prostrata Lab.*
*Puschkinia scilloides libanotica*
*Scorzonera cana alpina*
*Taraxacum minimum (Brignati ex Guss.)*
*Taraxacum sp.*
*Veronica anagalloides*

### Plot 2

*Acantholimon libanoticum Boiss.*
*Anthemis sp.*
*Astragalus cruentiflorus Boiss.*
*Astragalus echinus (DC.) Podlech*
*Asyneuma rigidum (Wild.) Grossh subsp. sinai (A. DC.) Damboldt*
*Berberis libanotica Ehrenb. ex C.K.Schneid.*
*Crepis hierolymitana*
*Euphorbia pilulifera L.*
*Galium constrictum*
*Galium verum*

*Geranium libanoticum*
*Ixiolirion tataricum (Pall.) Schult. & Schult.f.*
*Onobrychis cornuta (L.) Desv*
*Prunus prostrata Lab.*
*Puschkinia scilloides libanotica*
*Scabiosa prolifera L.*
*Scorzonera cana alpina (Boiss.)*
*Taraxacum minimum (Brignati ex Guss.)*

## Plot 3

*Acantholimon libanoticum Boiss.*
*Anthemis sp.*
*Astragalus cruentiflorus Boiss.*
*Astragalus echinus (DC.) Podlech*
*Berberis libanotica Ehrenb. ex C.K.Schneid.*
*Bromus sp.*
*Crepis hierolymitana*
*Crocus cancellatus*
*Daphne oleoides Schreb.*
*Erodium cicutarium (L.) L'Her.*
*Euphorbia pilulifera L.*
*Festuca pinifolia sp*
*Galium incanum*
*Geranium libanoticum*
*Glaucium leiocarpum*
*Ixiolirion tataricum (Pall.) Schult. & Schult.f.*
*Onobrychis cornuta (L.) Desv*
*Prunus prostrata Lab.*
*Scabiosa prolifera L.*
*Scorzonera cana alpina*
*Taraxacum minimum (Brignati ex Guss.)*
*Verbascum gaillardotii*
*Vinca libanotica*

## Plot 4

*Acantholimon libanoticum Boiss.*
*Alyssum condensatum Boiss. et Hausskn*
*Astragalus cruentiflorus Boiss.*
*Astragalus echinus (DC.) Podlech*
*Centaurea sp.*

*Crocus cancellatus*
*Euphorbia pilulifera L.*
*Galium incanum*
*Onobrychis cornuta (L.) Desv*
*Prunus prostrata Lab.*
*Taraxacum minimum (Brignati ex Guss.)*

## *Plot 5*

*Acantholimon libanoticum Boiss.*
*Alyssum condensatum Boiss. et Hausskn.*
*Astragalus cruentiflorus Boiss.*
*Astragalus echinus (DC.) Podlech*
*Bromus sp.*
*Crocus cancellatus*
*Euphorbia pilulifera L.*
*Festuca pinifolia sp*
*Gagea anisanthos (C.Koch)*
*Onobrychis cornuta (L.) Desv*
*Prunus prostrata Lab.*
*Scorzonera cana alpina*
*Taraxacum minimum (Brignati ex Guss.)*

## *Plot 6*

*Acantholimon libanoticum Boiss.*
*Allium sp.*
*Astragalus cruentiflorus Boiss.*
*Astragalus echinus (DC.) Podlech*
*Berberis libanotica Ehrenb. ex C.K.Schneid.*
*Centaurea sp.*
*Daphne oleoides Schreb.*
*Euphorbia pilulifera L.*
*Morina persica L.*
*Onobrychis cornuta (L.) Desv*
*Prunus prostata Lab.*
*Scorzonera cana alpina*
*Veronica polifolia*