Convention on Biological Diversity

Forest Ecosystem Restoration Initiative

VI MFW Mediterranean Forest Week

Identifying biodiversity-related success factors of ecological restoration projects

Prof. Magda Bou Dagher Kharrat

Liliane Bou Khdoud, Carole Saliba, Tony Chahine, Rhea Kahale, Anthony Roukoz

USJ Faculté des sciences

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Ecological restoration:

"The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER, 2004)

"Ecological restoration aims to recreate, initiate, or accelerate the recovery of an ecosystem that has been disturbed".

Vaughn, K. J., et al. (2010)

Ecosystem degradation => Habitat loss

is one of the most important cause of species extinction.

Common disturbances include logging, damming rivers, intense grazing, hurricanes, floods, and fires.

Convention on Biological Diversity

Forest Ecosystem Restoration Initiative

The Strategic Plan for Biodiversity 2011–2020 sets as an objective the restoration of 15% of degraded ecosystems by 2020.

Reasons for implementing restoration projects :

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

STAPR

Short Term Action Plan on Ecosystem Restoration

Group of activities C:

Planning and implementation of ecosystem restoration activities

- Biodiversity considerations in the context of restoration science and practice

Fragmented habitats 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.

Underestimation of species extinction rates

faunal collapse or relaxation

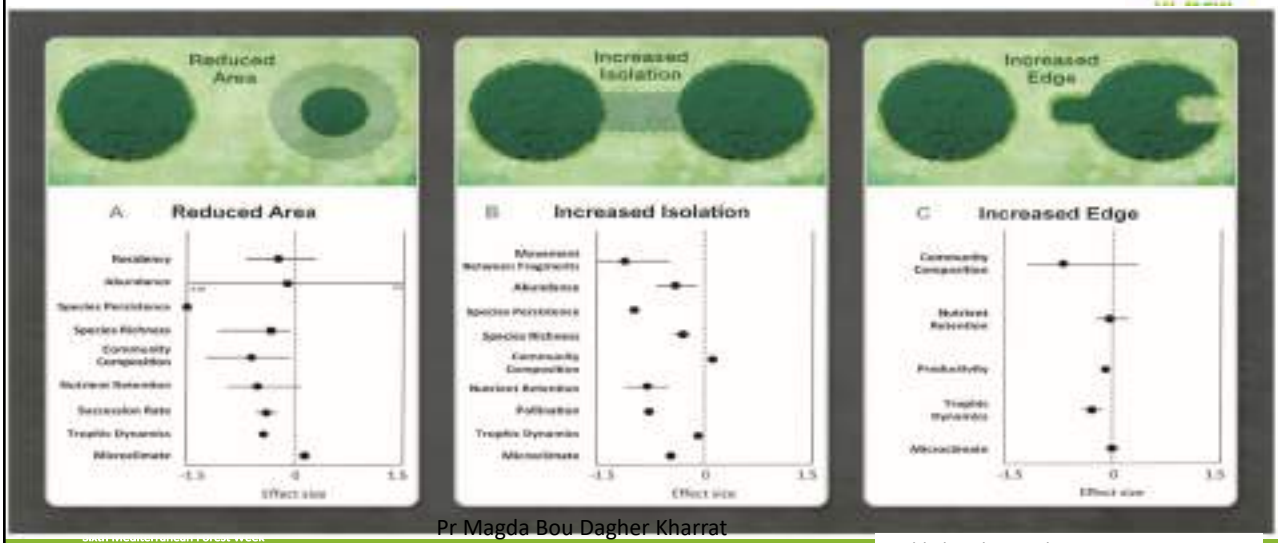
https://www.slideshare.net/OhMiss/habitat-loss-and-fragmentation

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 extinction.

Targeted restoration can reduce extinction rates

Newmark et al. 2017. PNAS 2017. 114 (36) 9635-9640; DOI: 10.1073/pnas.1705834114

Fragmentation effects propagate through the whole ecosystem

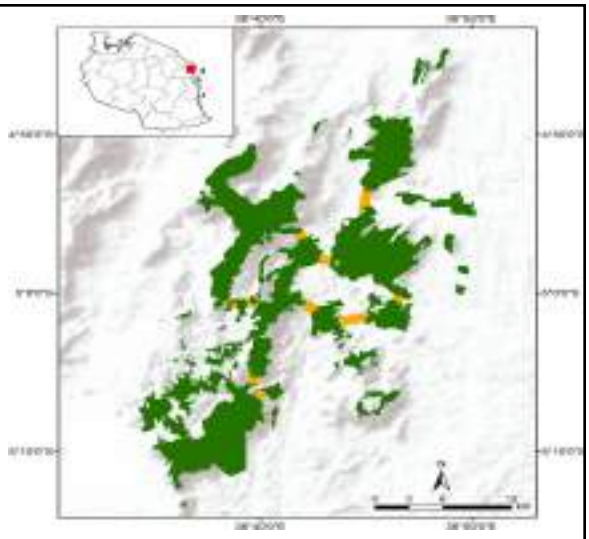


Haddad et al. Sci. Adv. 2015;1:e1500052

Targeted habitat restoration can reduce extinction rates in fragmented forests

ER increase the persistence time for species by a factor of 7

William D. Newmark et al. PNAS 2017;114:36:9635-9640



Map of the East Usambara Mountains, one of nine study locations in the Eastern Arc Mountains of Tanzania.

Disturbances are environmental changes that alter ecosystem structure and function.

John A. et al. (2014) Forest Restoration Paradigms, Journal of Sustainable Forestry, 33:sup1, S161-S194, DOI: 10.1080/10549811.2014.884004

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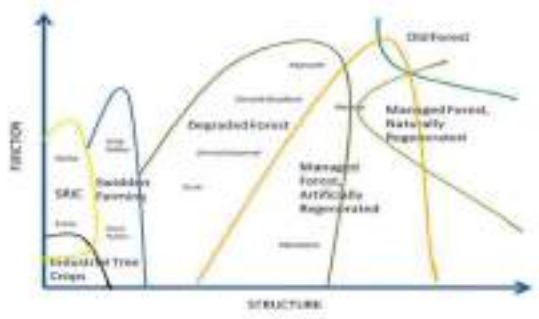
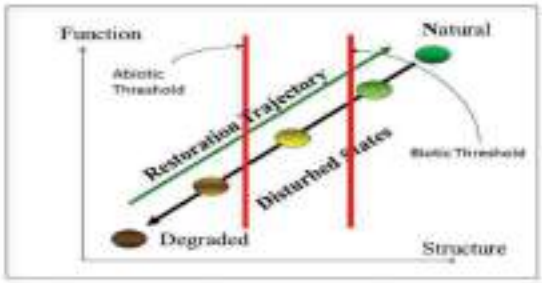
Forest Restoration paradigm



// degradation and restoration trajectories



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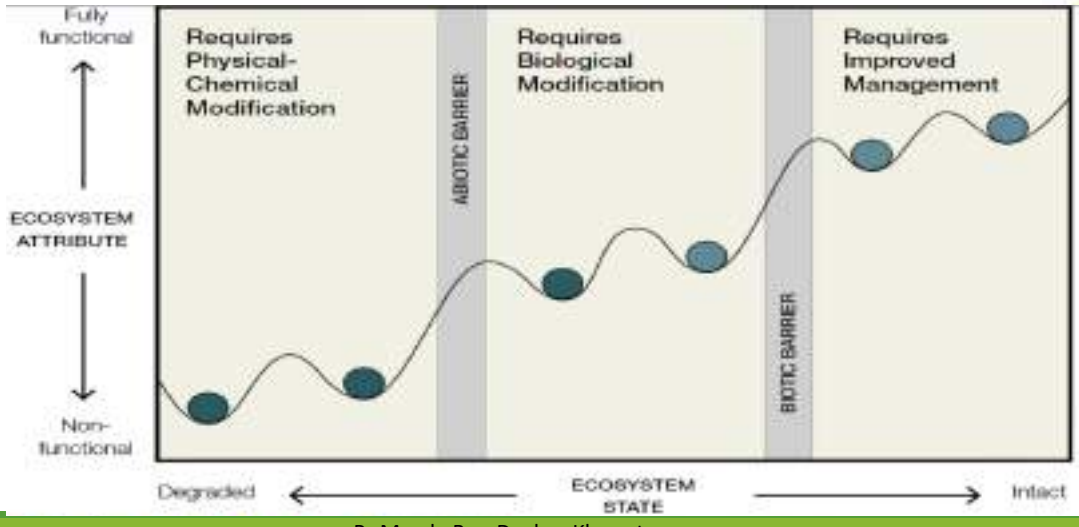
Conceptual model for ecosystem degradation and restoration



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Whisenant, 1999 and Hobbs & Harris, 2001

Ecological succession

Primary succession

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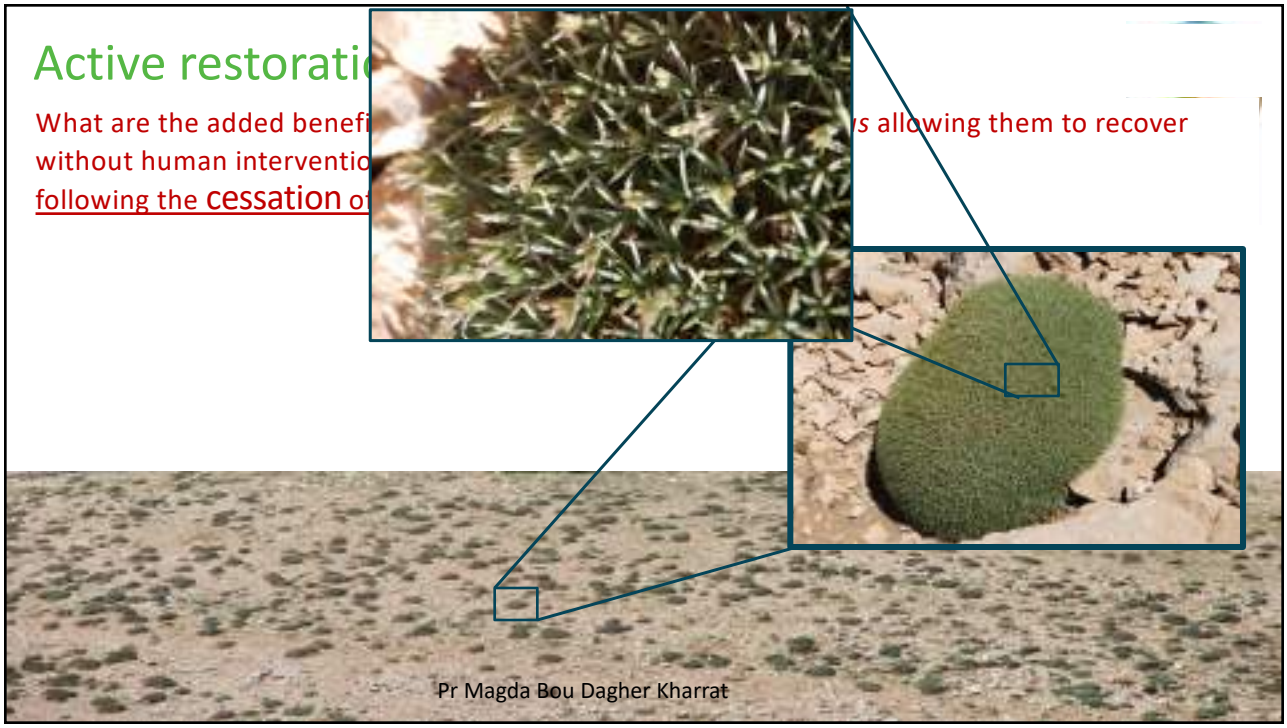
Active restorati

What are the added benefi s allowing them to recover
without human interventio
following the cessation o



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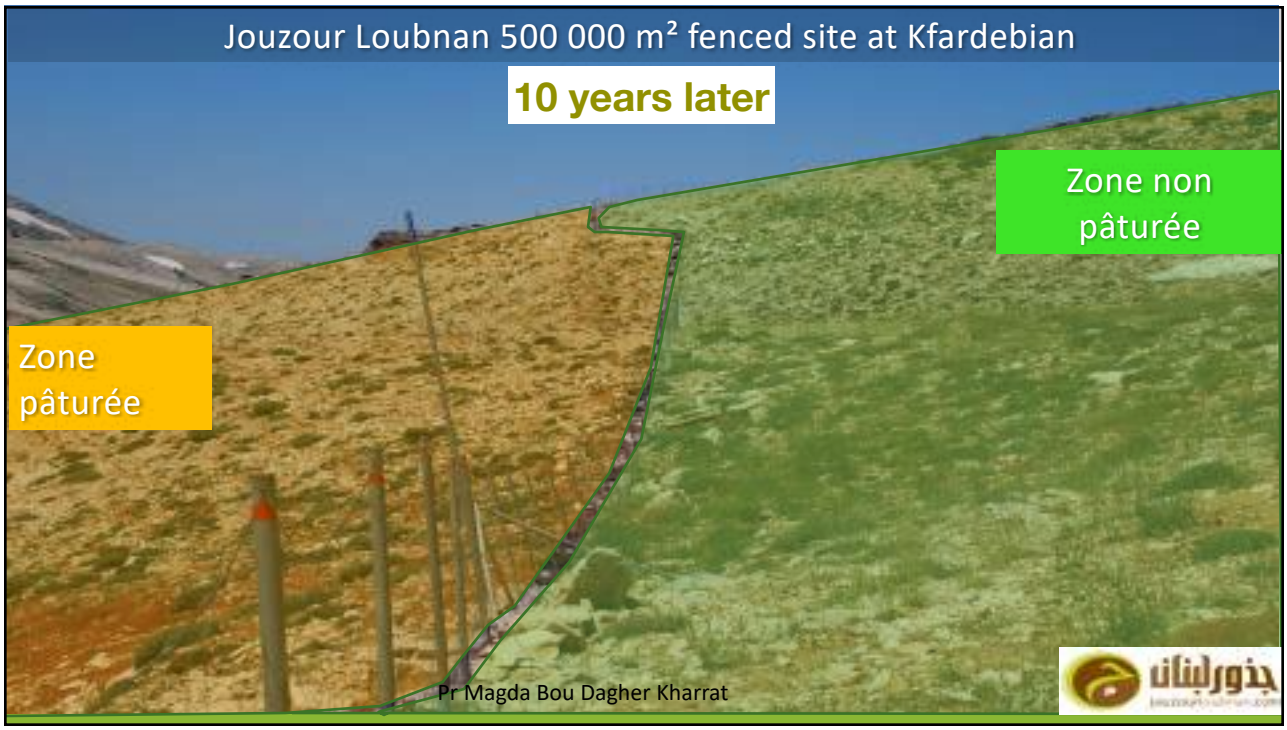
Active restoration *vs* passive recovery

Passive recovery should be considered as a potentially cost-effective option for ecosystem recovery.

If rates of passive recovery are insufficient to achieve project goals, then active restoration strategies should be tailored to the local ecological and socioeconomic conditions;

Jones HP et al. 2018 Restoration and repair of Earth's damaged ecosystems. Proc. R. Soc. B 285 : 20172577.
http://dx.doi.org/10.1098/rspb.2017.2577


Jouzour Loubnan 500 000 m² fenced site at Kfardebian
10 years later
Zone non pâturée
Zone pâturée
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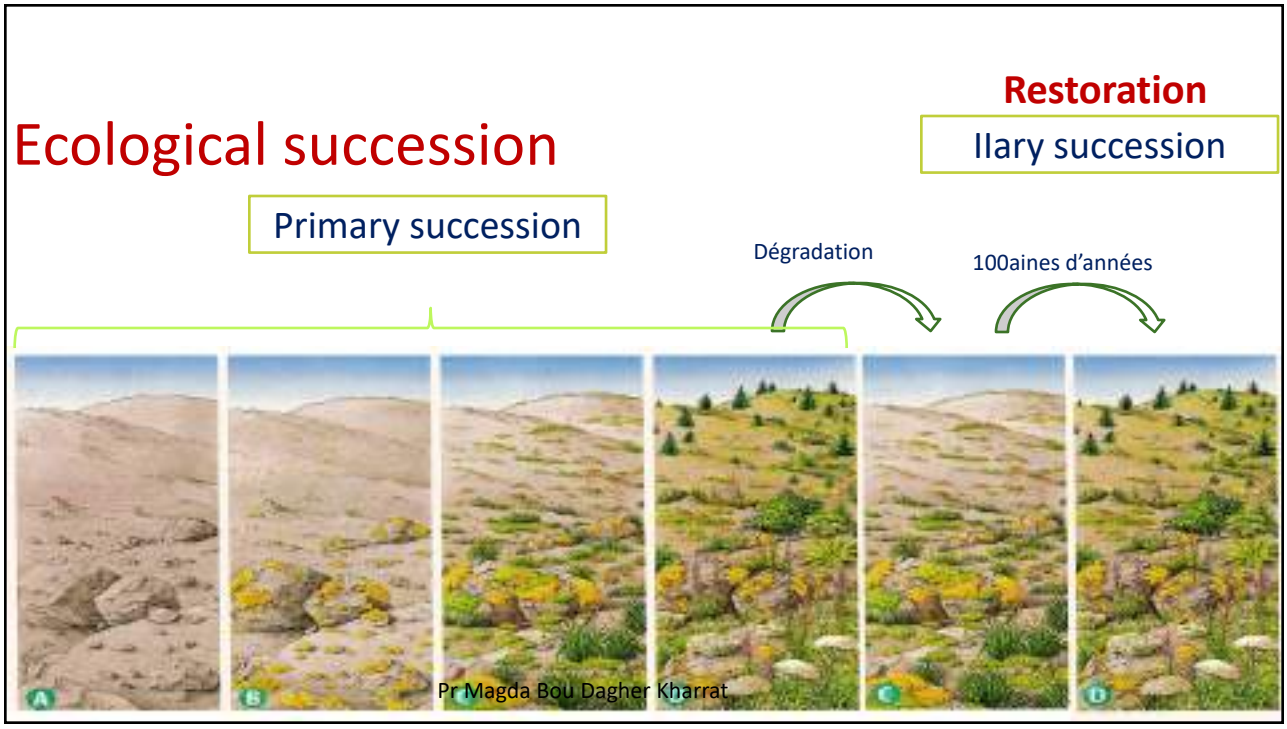
Ecological succession
Restoration
Ilary succession
Primary succession
Dégradation
100aines d'années
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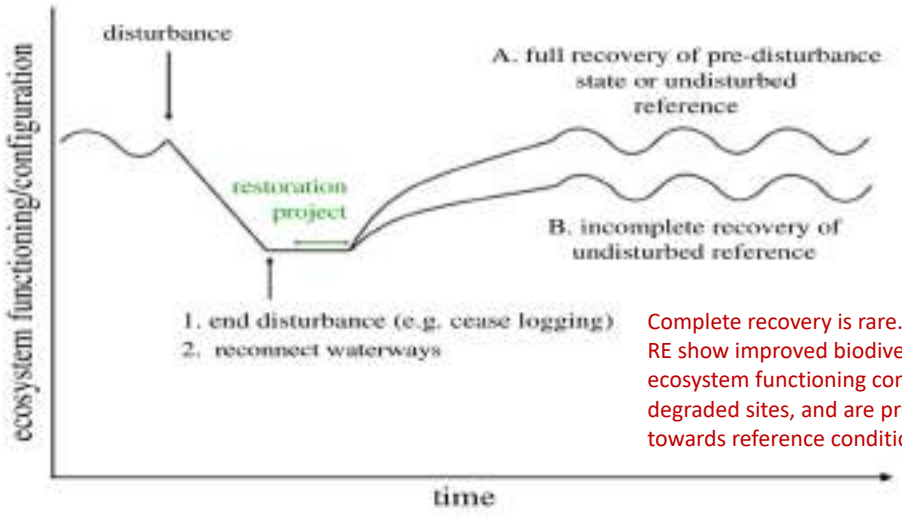

Complete recovery is rare.
RE show improved biodiversity and ecosystem functioning compared with degraded sites, and are progressing towards reference conditions with time.

Jones HP et al. 2018 Restoration and repair of Earth's damaged ecosystems. Proc. R. Soc. B 285 : 20172577. http://dx.doi.org/10.1098/rspb.2017.2577

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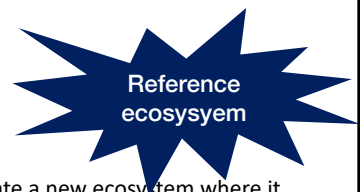
Disturbances are environmental changes that alter ecosystem structure and function.



Restoration activities may be designed to replicate a pre-disturbance ecosystem or to create a new ecosystem where it had not previously occurred.

Restoration ecology is the scientific study of repairing disturbed ecosystems through human intervention.

ABIOTIC factors

Areas with similar elevation, aspect and topographic position.

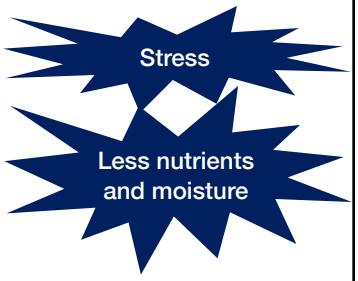
BIOTIC factors

The reference site indicates plant species composition and the site conditions that select for and support those species.

oversimplification

The site conditions that support the seedling establishment of dominant species differ significantly from that of the mature plant community.

Identify a chronosequence of reference sites



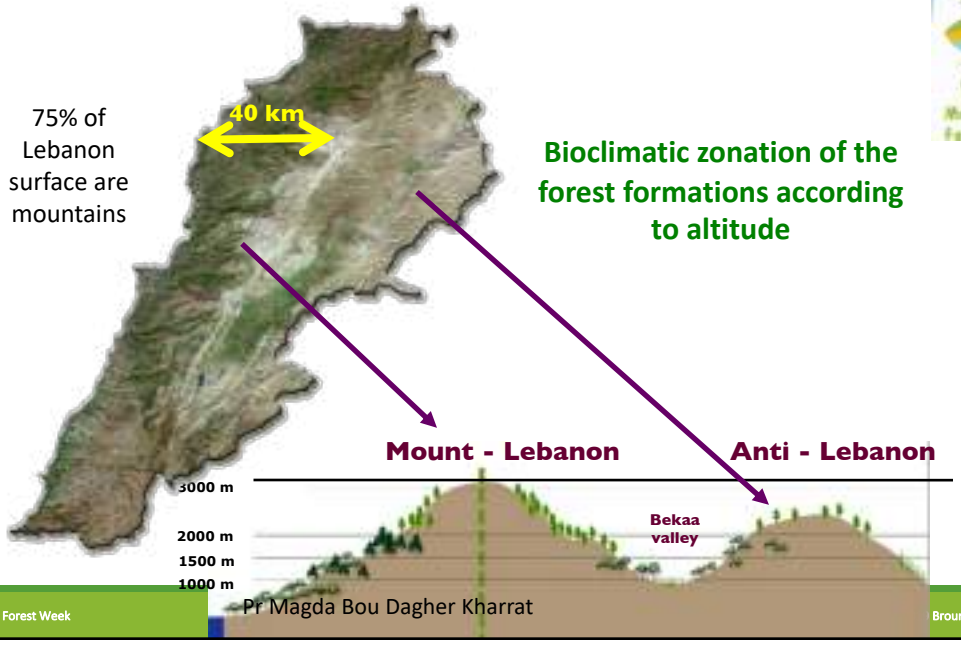
40 Million trees program

2012

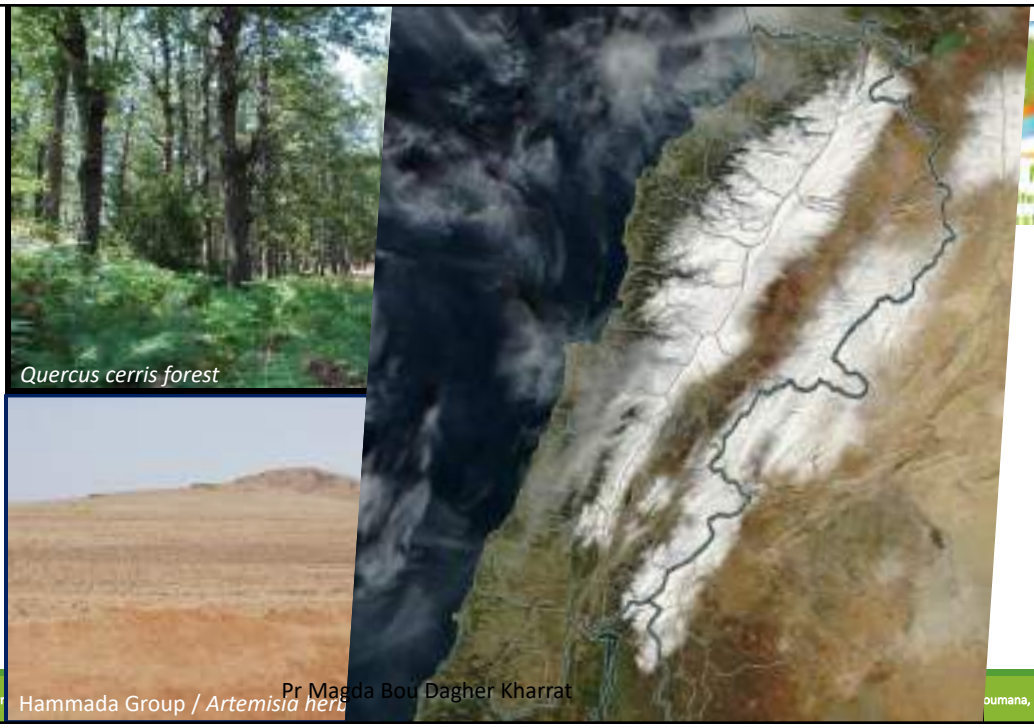
- Increase the forest cover from the current 13% up to 20% of the surface of the country by 2030
- 70,000 ha in public lands through the 40 Million Trees Program

The Mount Lebanon area is rugged; there is a rise from sea level to a parallel mountain range of about 2,000–3,000 m in less than 40 km

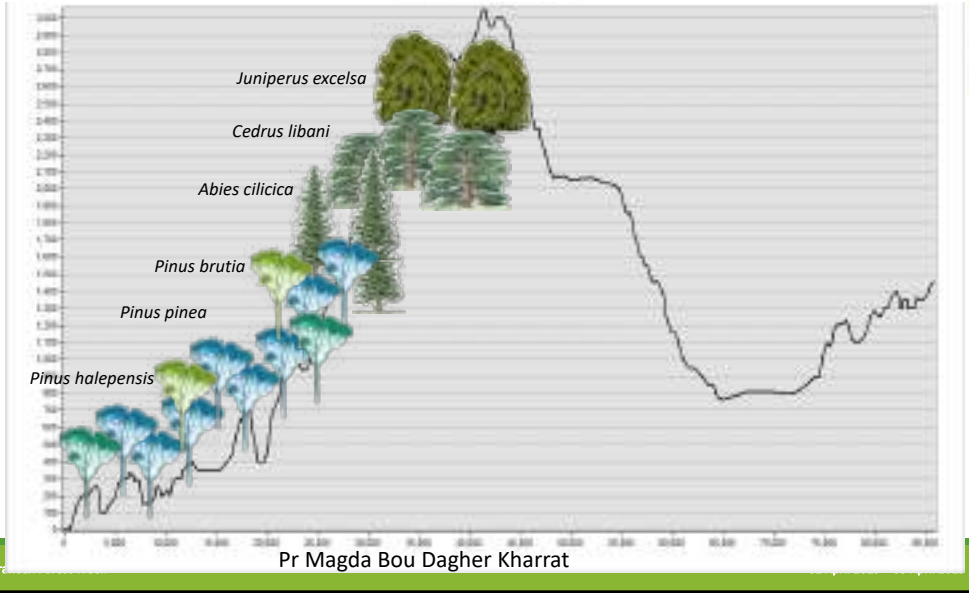
75% of Lebanon surface are mountains



Bioclimatic zonation of the forest formations according to altitude



Altitudinal distribution of some conifer species in Lebanon



Let's plant…

Plantation campaigns

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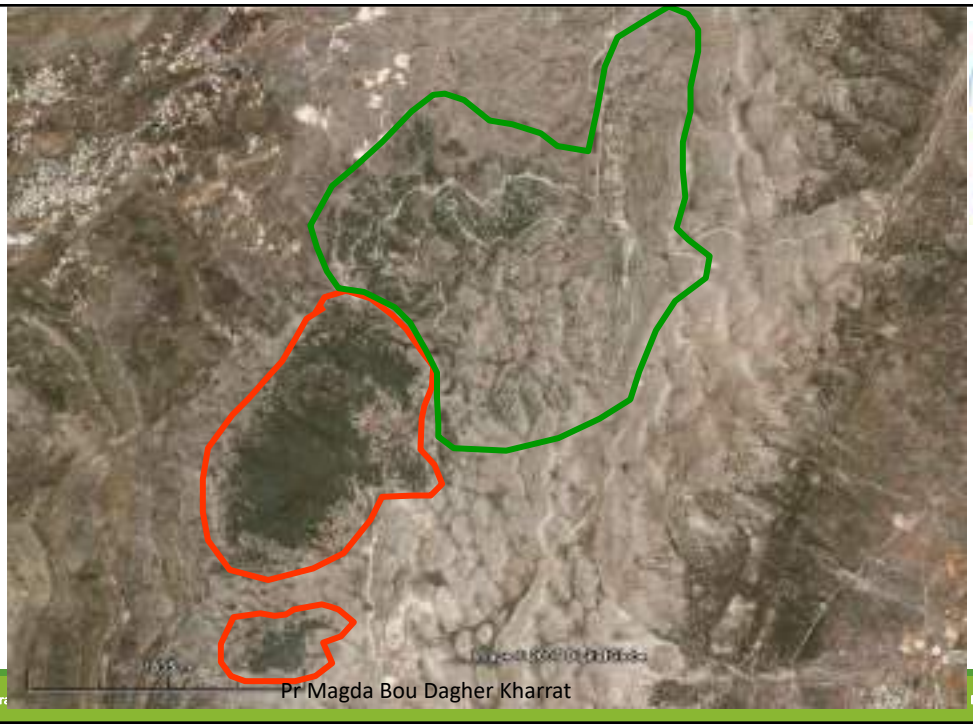

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Forest Restoration
Is
Beyond Planting Trees

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Reforestation *vs* Ecosystem restoration

Boisement monospécifique avec *Pinus pinea* aux alentours de Jezzine.

Community

Plants

Animals

Ecosystème forestier très diversifié dans la réserve naturelle de Ehden.

Since 2001

Genetic charachterisation of plants

Since 2009

Laboratory for seed germination and conservation

Slow and steady wins the race

Invest time in preparation

Concepts Underpinning Restoration

A. Disturbance / Reference site (s)

B. Genetics

C. Succession

D. Community Assembly Theory

E. Landscape Ecology

A- Disturbance

Many scales and different levels of severity

Disturbance events can alter species composition, nutrient cycling, and soil properties.

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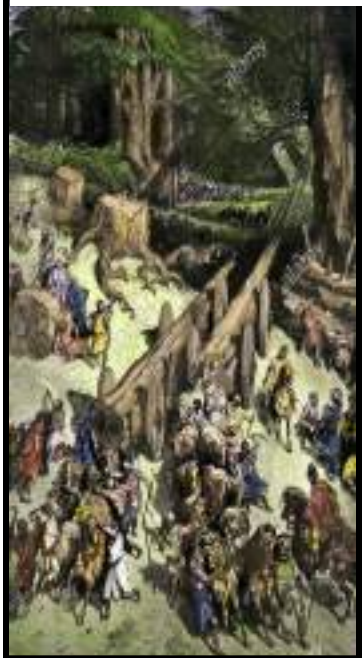
Historical deforestation



Snefru, the first pharaoh of the fourth dynasty, tells of importing cedar from Lebanon:
"*Bringing forty ships filled with cedar logs. Shipbuilding of cedar wood, one...ship,….* Making the doors of the royal palace of cedar wood".

Sarcophagus in cedar wood

Case from cedar wood
(pharaons time)

Khorsabad engraving
(Assyria, VIIIème B. J.C.)

Temples in Egypt much older than Solomon's Temple used cedar wood transported by Phoenician ships.
Buried beside the Great Pyramid of Khufu, (constructed c. 2580–2560 BC) were two boats for the king's use in the afterlife. They were constructed of Lebanese cedar.

"Secondary use"

Of wooden beams *Cedrus libani* and *Cupressus sempervirens*

Al-Aqsa's mosque ancient wooden beams exposed before they were dismantled in the 1930s and 1940s.

Removed from the roof and dome of Al-Aqsa Mosque during restorations in the early 1960s.

The ends of 140 of the beams were sawed off for dendrochronological study, and others were analyzed with carbon-14 testing to reveal an expansive date range: The youngest beams were cut after the initial construction of Al-Aqsa Mosque, while others date to the First Temple period, from the **ninth to the seventh centuries BCE.**

Cedrus libani pollen records in Lebanon, Syria and Turkey

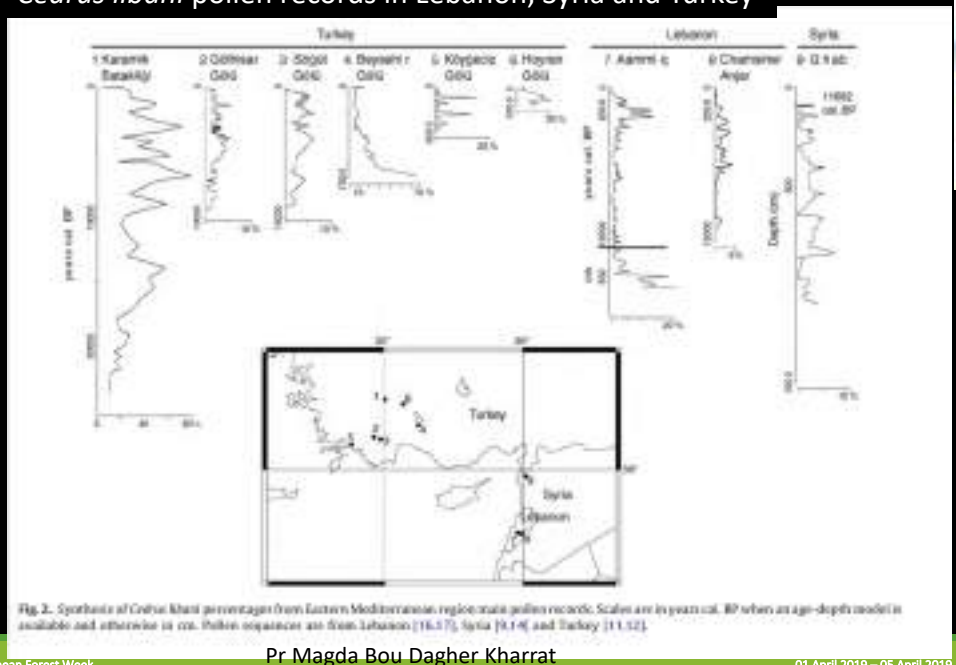


Fig. 2. Synthesis of Cedrus libani percentages from Eastern Mediterranean region main pollen records. Scales are in years cal. BP when an age-depth model is available and otherwise in cm. Pollen sequences are from Lebanon [16,17], Syria [9,14] and Turkey [11,12].

L. Hajar et al. / C. R. Biologies 333 (2010) 622–630

- From 8,000 – 3,500 years before the present "**major deforestation events on Mount Lebanon are recorded**" in the first location.
- From about 3,500 – 2,000 years ago there was "reduced" deforestation on Mt Lebanon, but forest expansion at the other site.
- However, from **2,000-1,000 years ago**, "on both sites, deforestation and grazing practices are inferred"
- Modern period, there were "increasing human perturbations".

WWI: large-scale deforestation of "Mount-Lebanon", wood used instead of coal in steam locomotives


Kfardebian (Mont-Liban)
Aarsal (Anti-Liban)


2000 m – Oyoun orghoch
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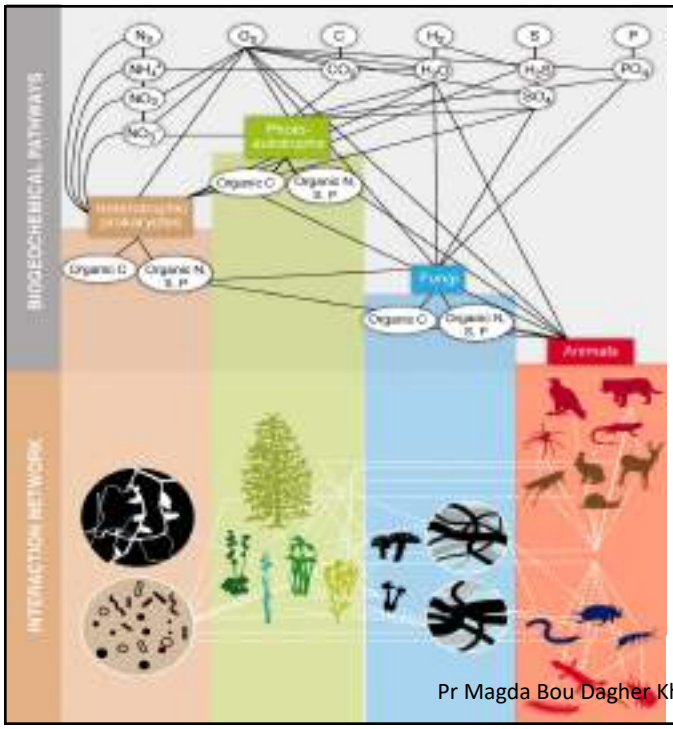

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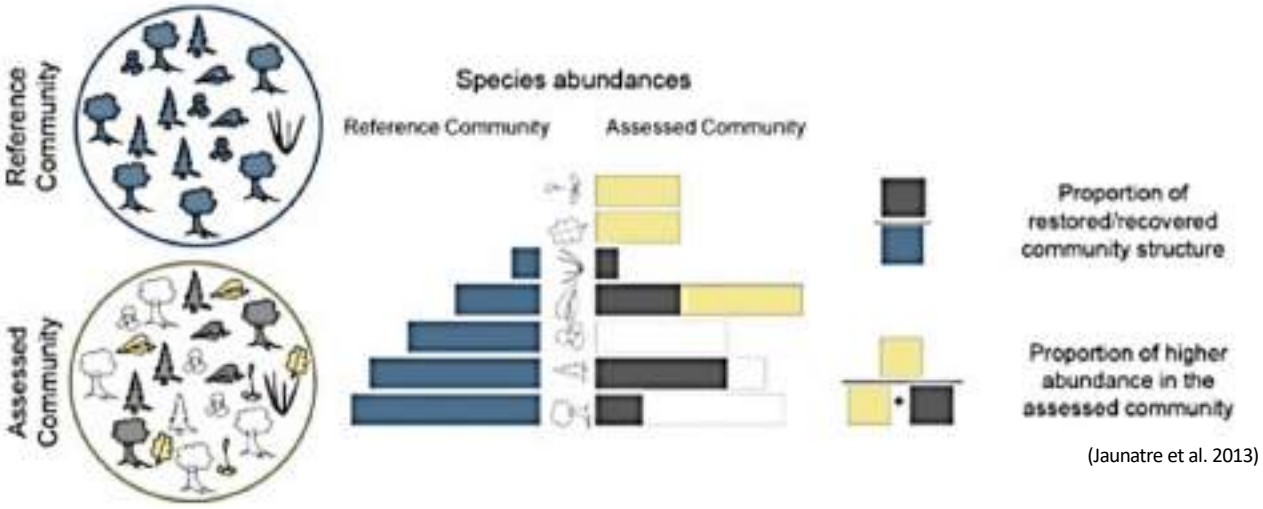
Biotic impoverishment can markedly alter the biogeochemical and dynamic properties of ecosystems.

Naeem S. et al. 2012. The Functions of Biological Diversity in an Age of Extinction. Science: 1401-1406



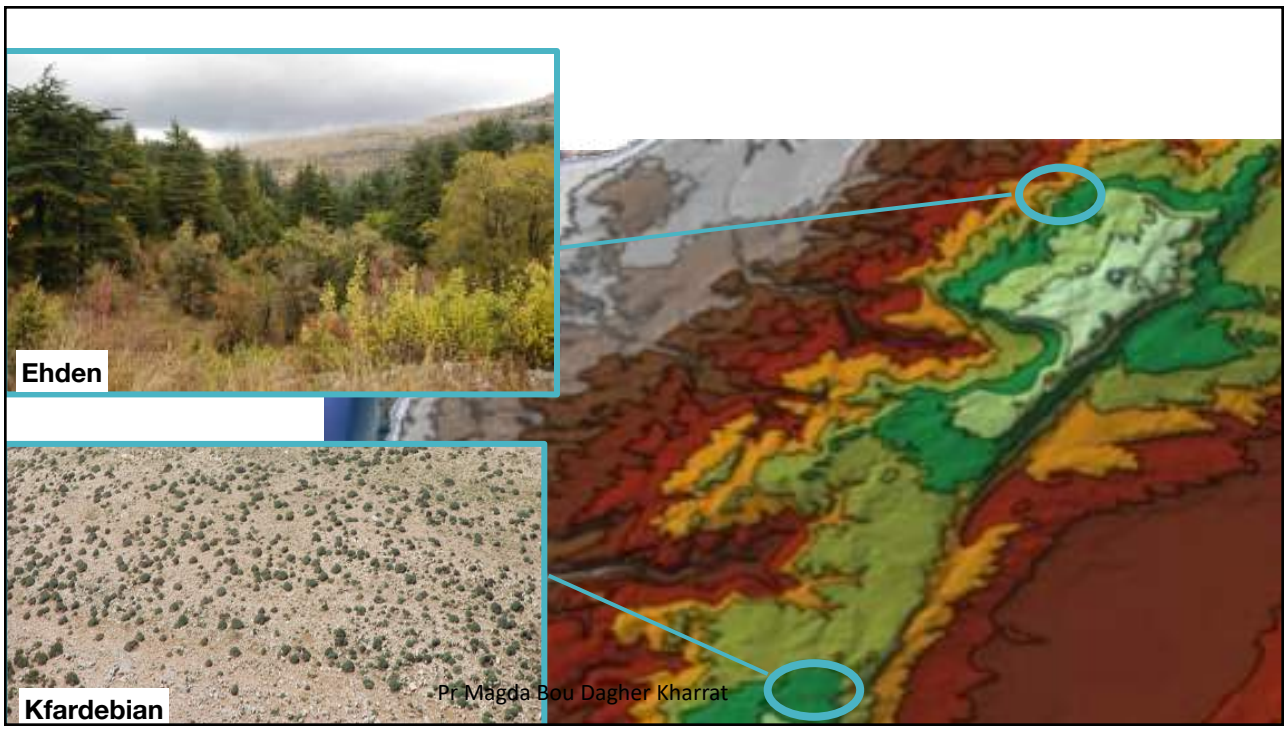
(Jaunatre et al. 2013)

A reference site is an ecosystem that serves as a model for restoring another ecosystem.

(1) The reference site has more intact, autogenic ecological processes, higher functionality, more complex structure, and greater diversity than the system to be restored.

(2) The biophysical site conditions of the reference site closely match those of the restoration site.

Multiple sites as reference



Concepts Underpinning Restoration

A. Disturbance / Reference site (s)

B. <u>Genetics</u>

C. Succession

D. Community Assembly Theory

E. Landscape Ecology

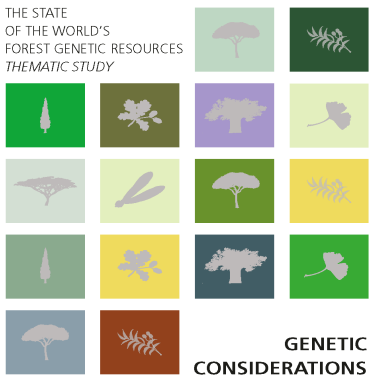
B- Genetics

- Local genetic resources : more likely to be well adapted to the target ecosystem.

- High genetic diversity of planted material : large number of individual can help ensure genetic diversity in the restored populations.

Genetic diversity is thought to be critical to maintaining the ability of populations to evolve and recover from disturbances.

Sufficient genetic diversity (and/or sufficiently large founding populations) to sustain viable, resilient populations for the future.



"Genetic considerations in ecosystem restoration using native tree species"

www.fao.org/3/a-i3938e.pdf


Genetic resources
- Native
- Genetic diversity
?
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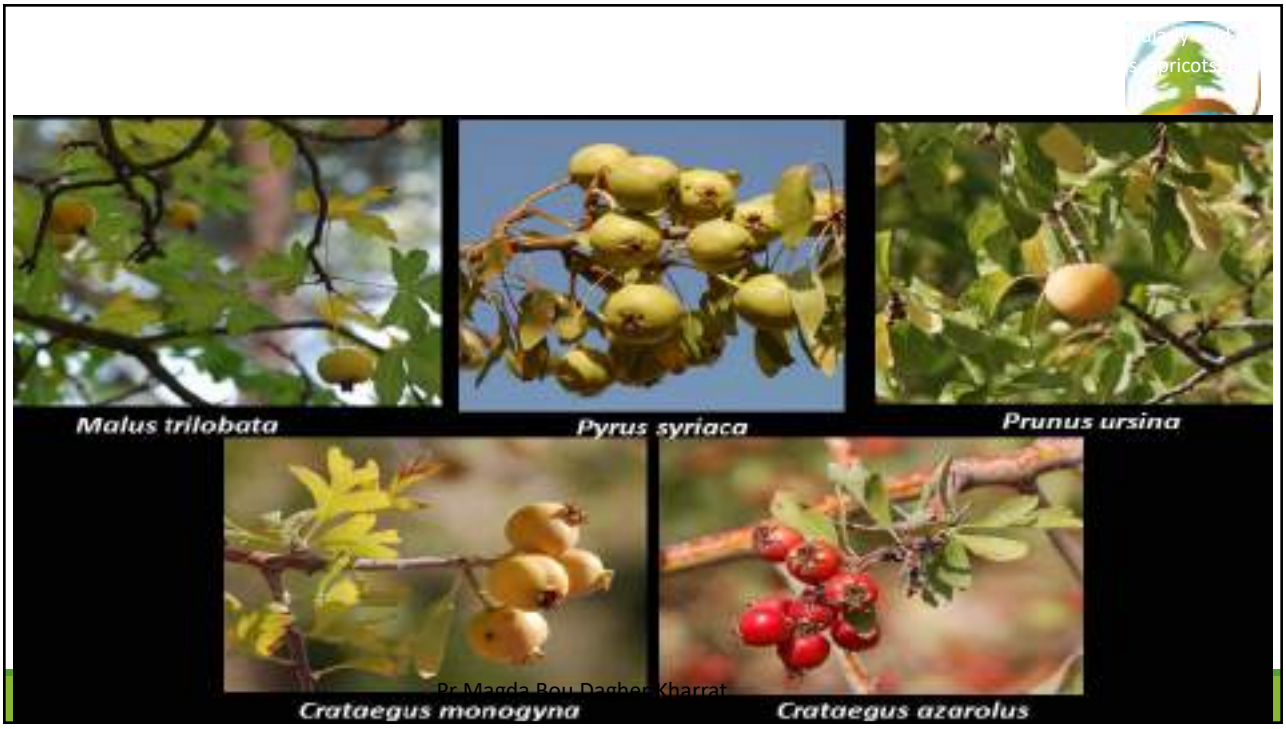
Appropriate genetic resources?
01 April 2019 – 05 April 2019 Broumana, Lebanon


Malus trilobata
Pyrus syriaca
Prunus ursina
Crataegus monogyna
Crataegus azarolus
Pr Magda Bou Dagher Kharrat

جذورلبنان SEED BANK

The LSGC Laboratory for Seed Germination and Conservation was created by the NGO *Jouzour Loubnan* in October 2009 at the Faculty of Sciences of the Saint-Joseph University of Beirut (USJ)

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jouzourloubnan.org

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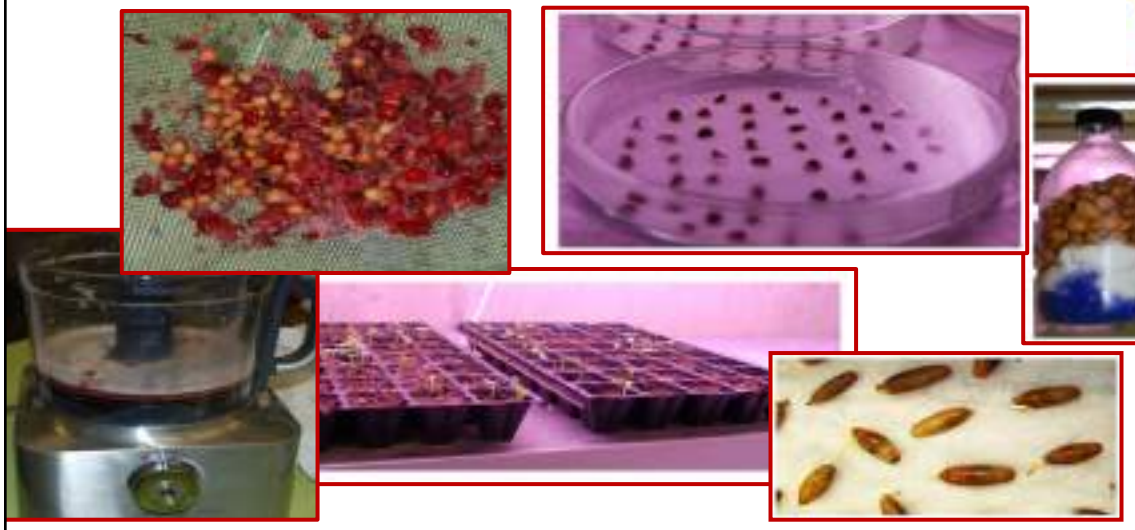
Good practices on seed collection and seed sources

- **Site selection**
- **Nbre of seed per tree**
- Number of trees
- **Phytosanitary status of the tree**
- Quality **of the seeds**



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- Seed collection
- Seed treatment and cleaning
- Seed quality control and testing
- Seed post-maturation
- Seed humidity testing
- Seed quantification
- Germination protocols creation and optimization
- Seed storage and maintenance

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Sixth Mediterranean Forest Week 01 April 2019 – 05 April 2019 Broumana, Lebanon

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Networking
&
Development

2017

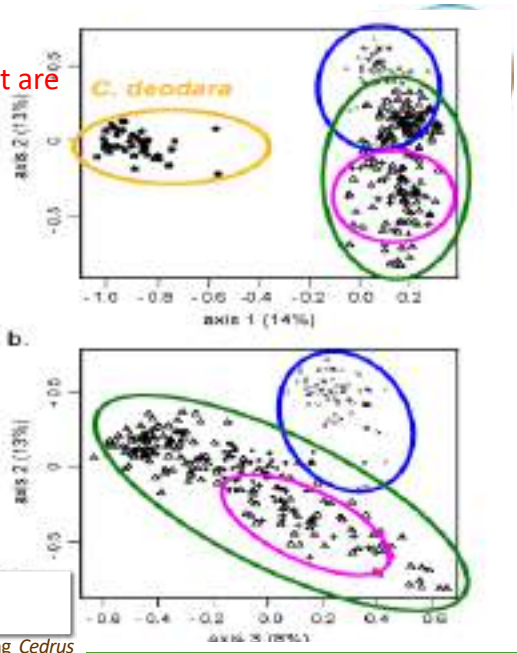
2017

Sixth Mediterranean Forest Week 01 April 2019 – 05 April 2019 Broumana, Lebanon

Special efforts to expand knowledge on native species through setting up community nurseries to propagate native plants.

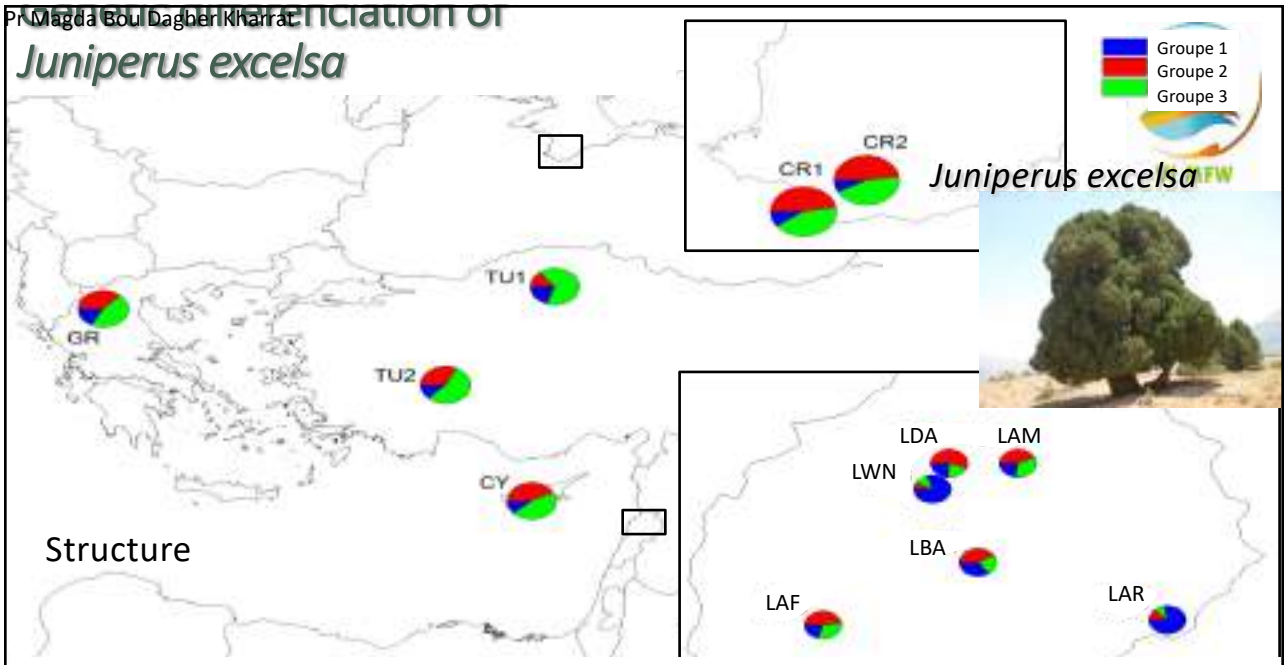
Cedrus Genetic differentiation

Seeds should be chosen from populations that are not highly differentiated from the local population.



Bou Dagher-Kharrat et al. 2007. Geographical diversity and genetic relationships among *Cedrus* species estimated by AFLP. Tree Genetics & Genomes DOI 10.1007/s11295-006-0065-x.

Genetic differentiation of *Juniperus excelsa*



Juniperus excelsa

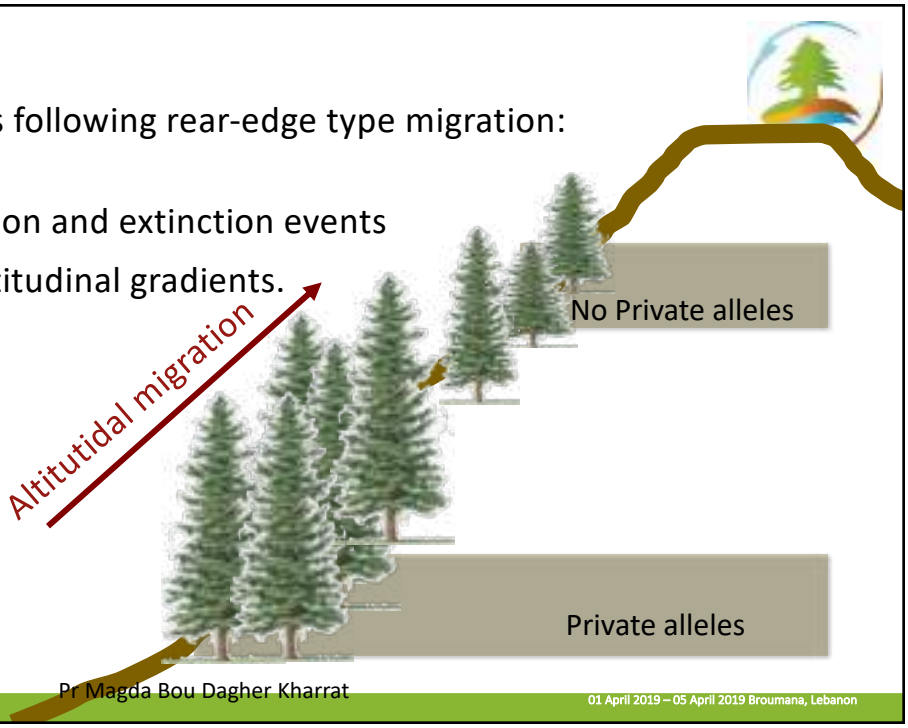
Douaihy, B., Vendramin G., Boratyński A., Machon N., Bou Dagher-Kharrat M. High genetic diversity with moderate differentiation in *Juniperus excelsa* M. Bieb. from Lebanon and the Eastern Mediterranean Region. *AOBPlants*. (2011). DOI: 10.1093/aobpla/PLR003.

Demographic processes following rear-edge type migration:

- Alternating colonization and extinction events
- Range shifts along altitudinal gradients.

Abies cilicica

Abies cilicica



Genetic diversity and Genetic differenciation:

Genetic diversity depends on Life history traits (LHT) and ecological attributes

LHT:

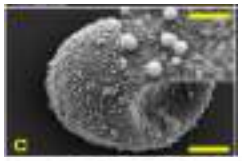
- short- or long-lived species
- reproduce sexually or clonally
- Pollination mode
- Seed dispersion mode
- Existence history

} Gene flow

Ballesteros-Mejia L et al. (2016) Pollination Mode and Mating System Explain Patterns in Genetic Differentiation in Neotropical Plants. PLoS ONE 11 (7): e0158660. doi:10.1371/journal.pone.015866

Effect of the biology on genetic diversity

Gene flow
(pollination, seeds dispersal)



Juniperus sp.

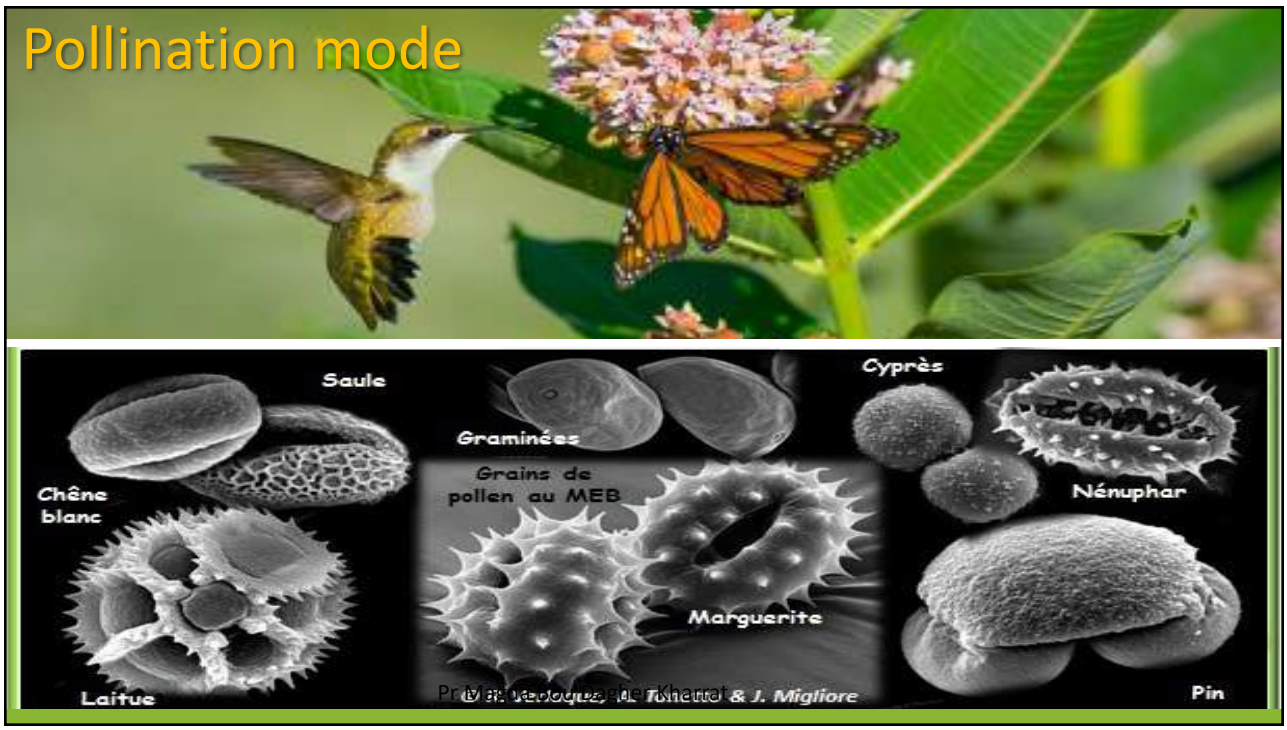
Abies sp.

Cedrus sp.

Avoid self pollination

Self pollination --- > empty seeds

- Pummer et al. (2012). Suspendable macromolecules are responsible for ice nucleation activity of birch and conifer pollen. Atmospheric Chemistry & Physics. 12. 2541-2550.
- Y et al. (2011). Adaptation of male reproductive structures to wind pollination in gymnosperms: Cones and pollen grains. Canadian Journal of Plant Science. 91. 897-906.


Pollination mode
Saule
Graminées
Cyprès
Grains de pollen au MEB
Chêne blanc
Nénuphar
Marguerite
Laitue
© R. Verdoucq, A. Tinetti & J. Migliore
Pin


Seeds dispersal mode
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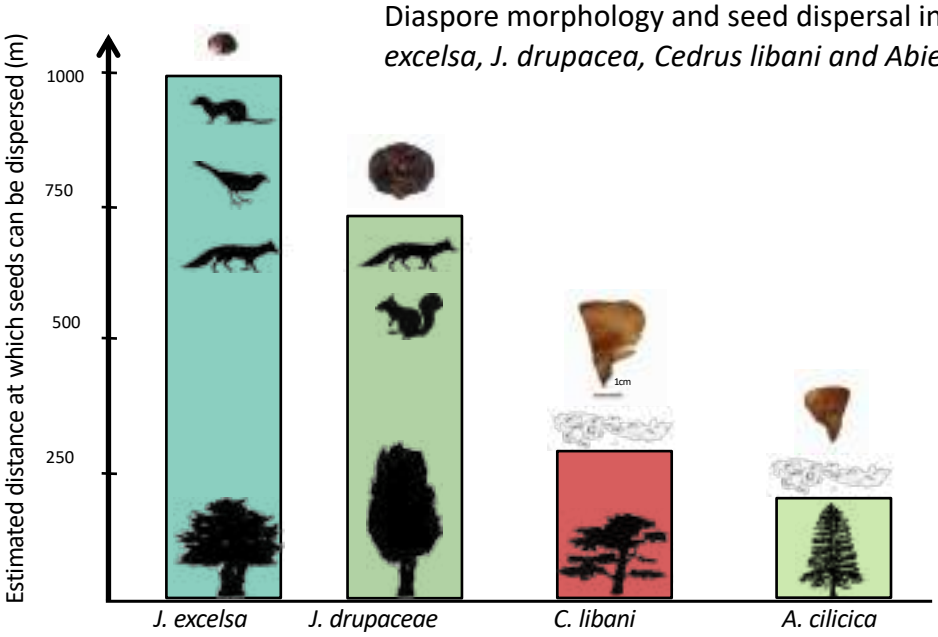
Diaspore morphology and seed dispersal in *Juniperus excelsa, J. drupacea, Cedrus libani and Abies cilicica*



Concepts Underpinning Restoration

A. Disturbance / Reference site (s)

B. Genetics

C. <u>Succession</u>

D. Community Assembly Theory

E. Landscape Ecology

C- Succession

Ecological succession is the process by which biological community composition- the number and proportion of different species in an ecosystem- recover over time following a disturbance event.

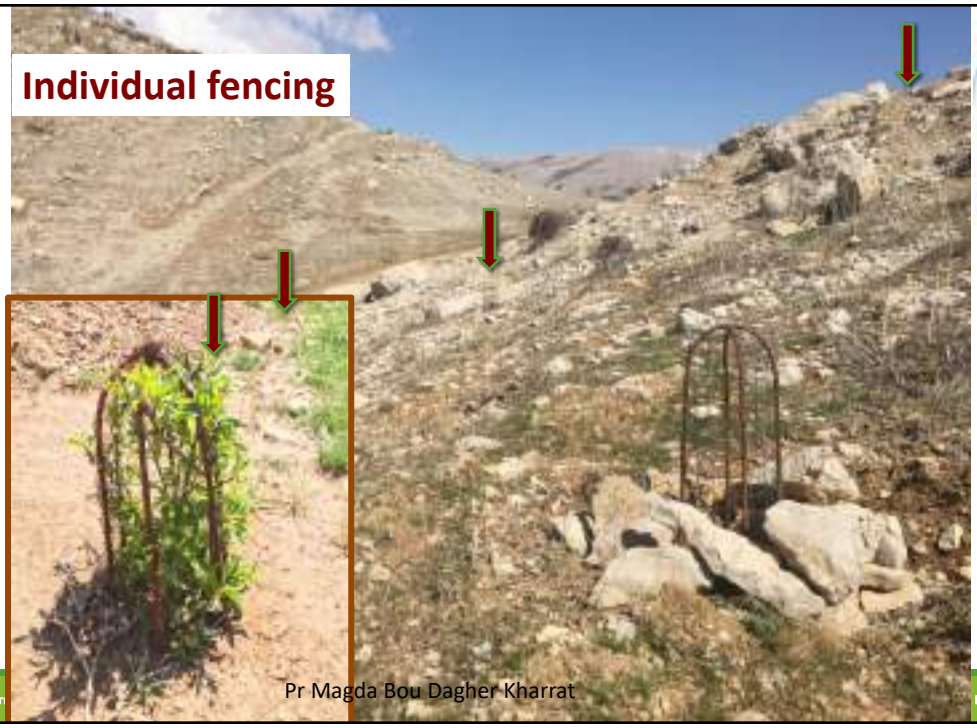
Passive restoration means simply allowing natural succession to occur in an ecosystem after removing a source of disturbance.

Harsh environment (sun, wind, frost…)
Poor soil

Nurse plant

Planting late-successional tree species under early-successional shrubs can be an effective means of restoring forests under high abiotic stress.

Individual fencing



Individual fencing

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Broumana, Lebanon

Jouzour Loubnan 500 000 m² fenced site at Kfardebian

10 years later

Zone non pâturée

Zone pâturée

- **Effect of fencing on site biodiversity and the dynamics of ecological succession;**

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Kfardebian Experimental design

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Kfardebian Experimental design

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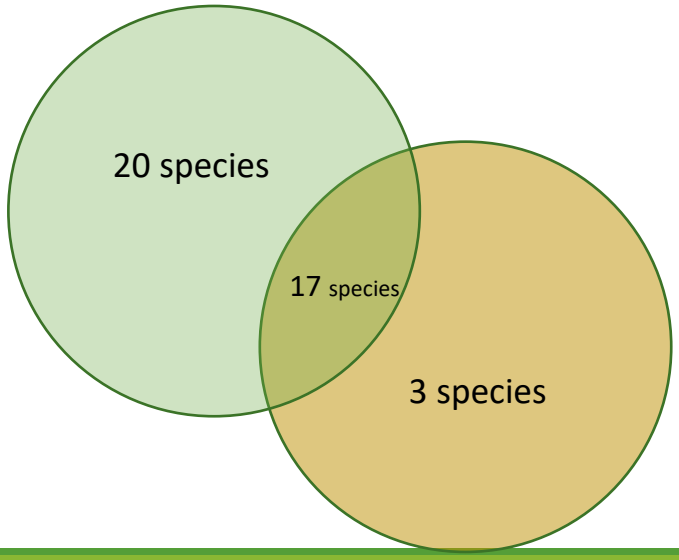
Species assesments



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3. Species observed only inside fenced plots

A total of 20 species were only recorded inside fenced plots

Anthemis sp.
Asyneuma rigidum (Wild.) Grossh subsp. sinai (A. DC.) Damboldt
Centaurea triumfetti All.
Crepis hierolymitana
Erodium cicutarium (L.) L'Her.
Galium constrictum
Galium verum
Geranium libanoticum
Glaucium leiocarpum
Helichrysum plicatum DC.
Ixiolirion tataricum (Pall.) Schult. & Schult.f.
Noaea mucronata humulis
Plantago lagopus
Poaceae family
Puschkinia scilloides libanotica
Scabiosa prolifera L.
Taraxacum sp.
Verbascum gaillardotii
Veronica anagalloides
Vinca libanotica

→ Non resistant to grazing (highly palatable?)

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Concepts Underpinning Restoration

A. Disturbance / Reference site (s)

B. Genetics

C. Succession

D. Community Assembly Theory

E. Landscape Ecology

D- Community Assembly

A biological community is a group of organisms that interact and share an environment.

Within a community, organisms may compete for the same resources (competition), profit from the presence of other organisms (facilitation) or use other organisms as a food source (trophic interaction).

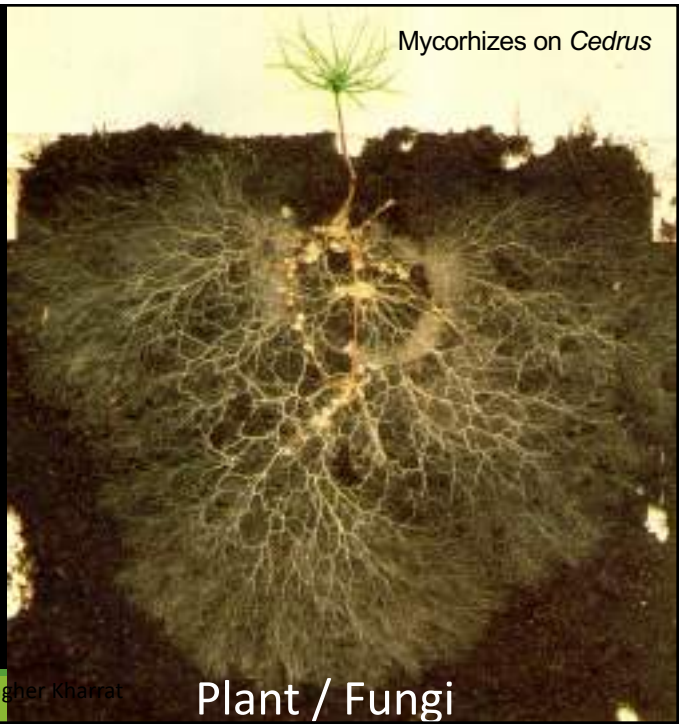
Plant facilitation

Soil microbiota

Seeds dispersers

Soil microbiota mutualism

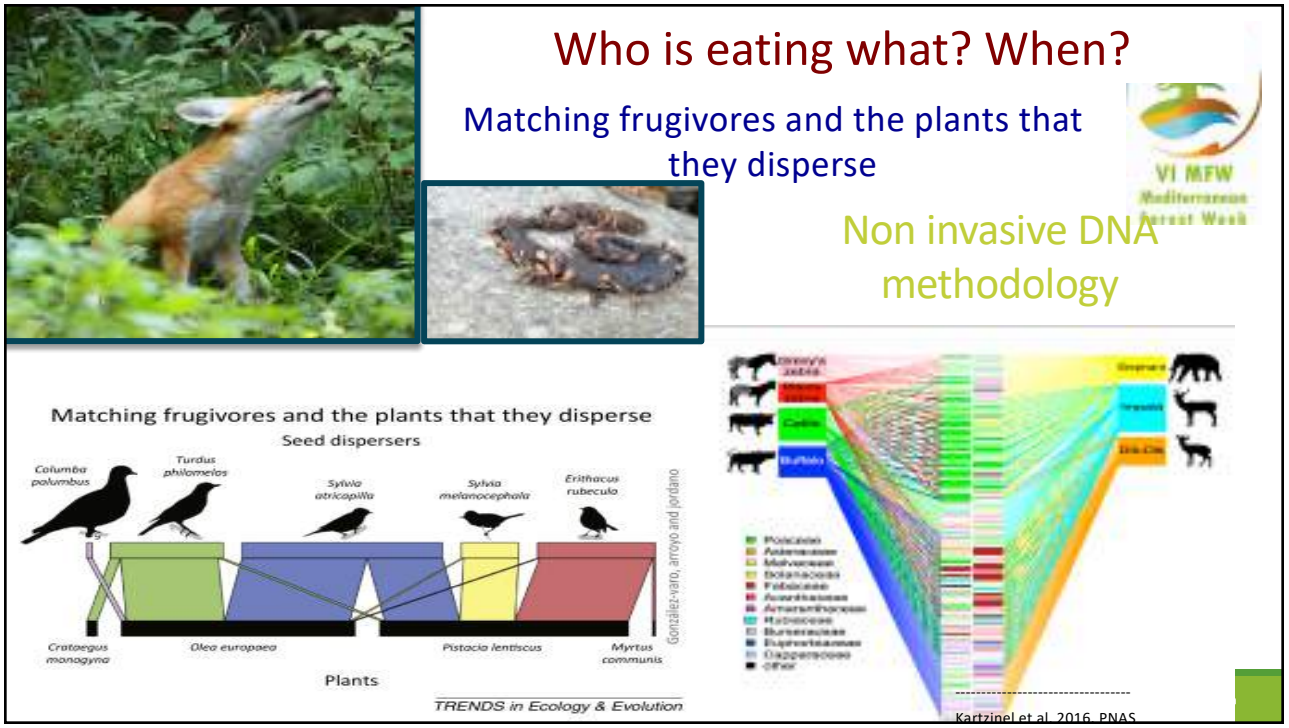
Plant / Bacteria



Plant / Fungi

Mycorhiza on *Cedrus libani.*

Reserve de Barouk Dec 2013


Who is eating what? When?
Matching frugivores and the plants that they disperse
Non invasive DNA methodology
VI MFW
Matching frugivores and the plants that they disperse
Seed dispersers
Columba palumbus
Turdus philomelos
Sylvia atricapilla
Sylvia melanocephala
Erithacus rubecula
Crataegus monogyna
Olea europaea
Pistacia lentiscus
Myrtus communis
Plants
González-varo, arroyo and jordano
TRENDS in Ecology & Evolution
Kartzinel et al. 2016, PNAS


Ecureuil
Blaireau
Lièvre
Hyène rayée
Ratel
EXTINCT
Gazelle
Putois marbré
Chacal doré
Mangouste
Sanglier
Loup
Fouine
Belette
EXTINCT
Ours
EXTINCT
Lynx
Renard
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Samples collection

DNA isolation

Non-invasive sampling

DNA amplification

DNA sequencing

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01 April 2019 – 05 April 2019 Broumana, Lebanon

Non-invasive method of identification: DNA-METABARCODING

Multispecific approach → DNA-METABARCODING

Detect the presence of several species in a single sample taken

DNA barcodes

ITS

COI

matK

*trn*L

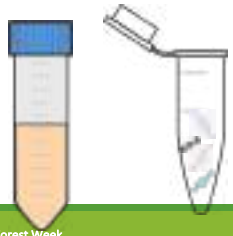
16S

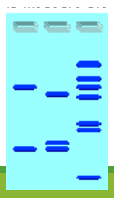
12S

*rbc*L

cytb

1. Collection of the environmental sample
2. DNA extraction
3. Amplification of DNA barcodes (universal primers)
4. NGS and bioinformatics analysis
5. Identification of species (Reference databases)
6. Ecological implications





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international BARCODE OF LIFE

"Identifying species using DNA sequences"
http://www.barcodeoflife.org/

http://ibol.org/site/

Pr Magda Bou Dagher Kharrat

Objectives

- ✓ Construction of a reference library of sequences of potentially existing animals in the region as well as the plants they are likely to consume
- ✓ Identification of Lebanon's mammals and determination of their diets using a non-invasive method based on DNA
- ✓ Implications in the ecological restoration

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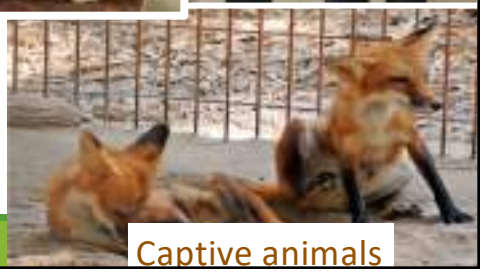
Build our **animal** reference library

Dead animals

Museum animals



Captive animals

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aDNA isolation from Museum animals

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Broumana, Lebanon

Construction of the reference library

2) Stuffed animals

❖ **Mammals**

✓ aDNA
→ **Ancient DNA laboratory**

Hyaena hyaena

Sciurus anomalus

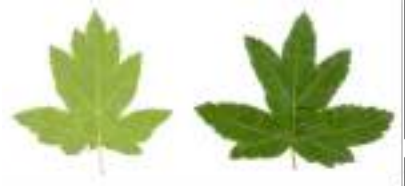
Pr Magda Bou Dagher Kharrat

Smithsonian Conservation Biology Institute

Construction of the reference library

❖ **Plants**

- Fresh leaves
- Herbarium



Malus trilobata

Rosa canina

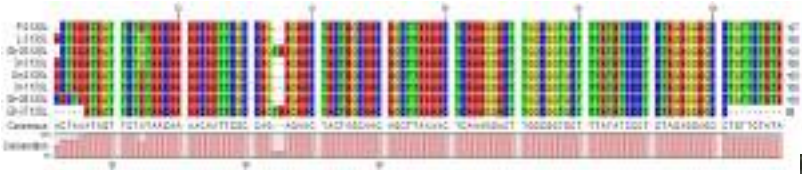

Eh-25


Eh-28


Eh-37


Eh-40

Vulpes vulpes



Alignement des séquences du marqueur 12S-LH des échantillons de *Vulpes vulpes*

Diet analysis

1. Collection of scat samples → 2. Preservation → 3. DNA extraction → 4. Animal identification → 5. Consumed species identification

- **Preliminary results**

✓ 10 mammals species

- ***Canis lupus*: Grey wolf**
- ***Canis aureus*: Golden jackal**
- ***Martes foina*: Marten**
- ***Vulpes vulpes*: Fox**
- ***Meles meles*: Badger**
- ***Mustela nivalis*: Weasel**
- ***Lepus capensis*: Hare**
- ***Felis silvestris*: Wild cat**
- ***Sciurus anomalus*: Squirrel**
- ***Sus scrofa*: Wild boar**

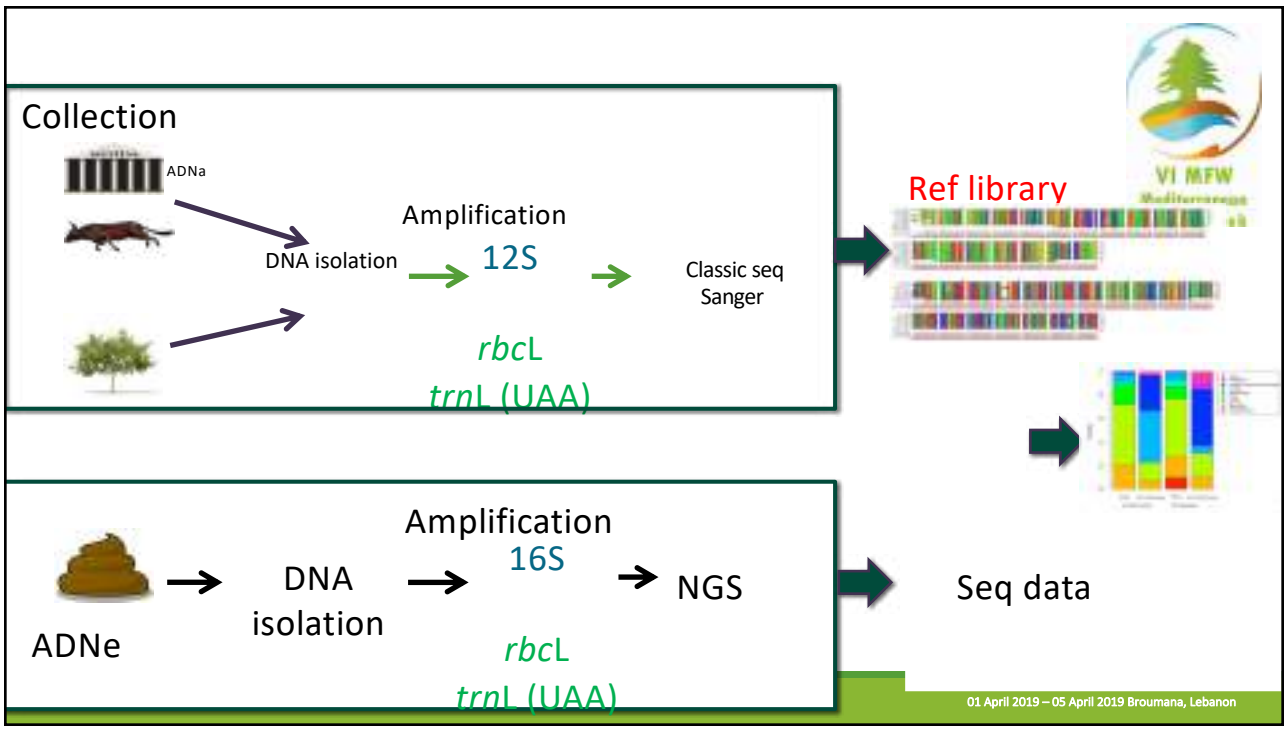
✓ 3 birds species

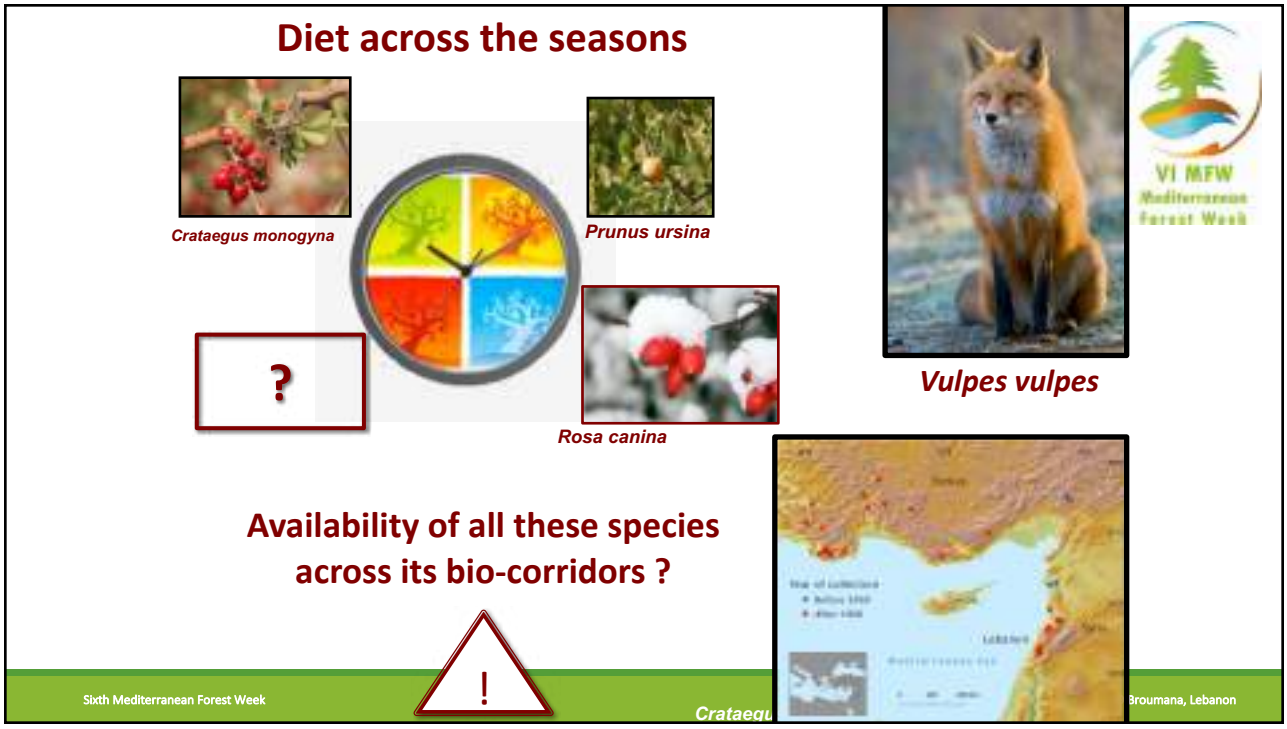
- ***Alectoris chukar:* Perdrix choukar**
- ***Turdus philomelos:* Grive musicienne**
- ***Muscicapa striata:* Gobemouche gris**


Alectoris chukar


Turdus philomelos


Muscicapa striata


Collection
ADNa
DNA isolation
Amplification
12S
rbcL
trnL (UAA)
Classic seq
Sanger
Ref library
VI MFW
ADNe
DNA
isolation
Amplification
16S
rbcL
trnL (UAA)
NGS
Seq data
01 April 2019 – 05 April 2019 Broumana, Lebanon


Diet across the seasons
Crataegus monogyna
Prunus ursina
?
Rosa canina
Vulpes vulpes
VI MFW
Availability of all these species
across its bio-corridors ?
!
Sixth Mediterranean Forest Week
Broumana, Lebanon

Concepts Underpinning Restoration

A. Disturbance / Reference site (s)

B. Genetics

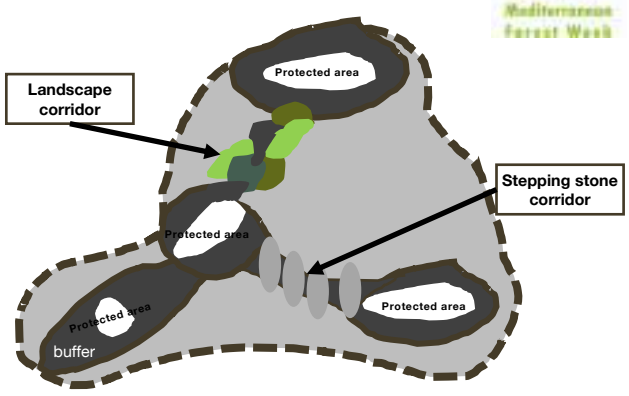
C. Succession

D. Community Assembly Theory

E. <u>Landscape Ecology</u>

Increase the viability of depleted or fragmented populations by habitat expansion and reconnection, and help dispersal of species by increasing connectivity, vegetation buffers and mosaic habitats.

Ecological stepping stone linkages between protected areas: application of *connectivity conservation.*

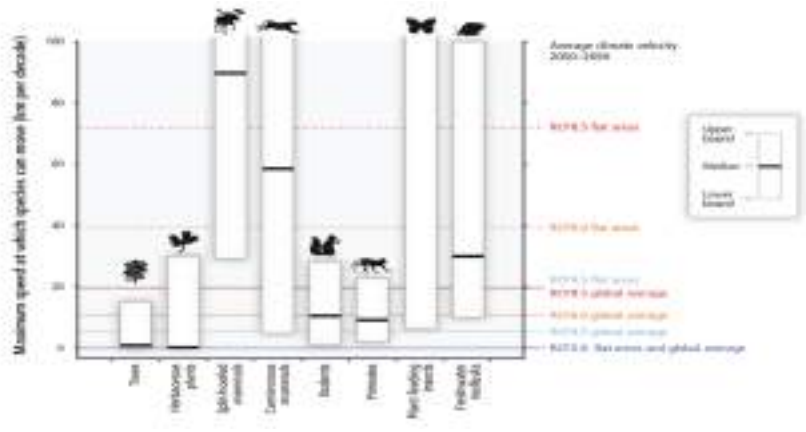


Linking terrestrial ecosystems.
Worboys et al. 2010.

A key step in assessing restoration progress
is finding and agreeing on a reference ecosystem,
though
increasingly considering Climate change!

There is a general trend for species to shift their ranges poleward or up in elevation. Not all species, however, can make such shifts, and these species might experience more rapid declines making trees particularly at risk.

The migration of tree species to track the movement of their bioclimatic envelope along altitudinal or latitudinal gradients is slower than the pace of climate change (IPCC, 2014).



Maximum speeds at which species can move across landscapes

This is particularly true for *C. libani*, *A. cilicica*, *J. drupacea* and *J. excelsa* having relatively low colonization potential.

The 'migration lag' is of a particular concern for trees.

Asssisted migration

Assisted migration applicants

The migration of tree species to track the movement of their bioclimatic envelope along altitudinal or latitudinal gradients is slower than the pace of climate change (IPCC, 2014).

Fig. 4 Assisted migration can be performed along an elevation gradient. In this example, assisted migration of *Abies religiosa* 275 m upwards in altitude may be necessary to mitigate changes in climate so that this species can continue to provide its function as an overwintering host for *Danaus plexippus*. Adapted from Sáenz-Romero et al. (2006)

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Rewilding is emerging as a promising restoration strategy in a human-dominated world to promote self-sustaining ecosystems and enhance the conservation status of biodiversity

Helping hand

Step aside

Restored ecosystems are progressing towards recovery following disturbances, they rarely recover completely.

Conservation of intact ecosystems is THE key strategy for protecting biodiversity.

Torres A et al. 2018 Measuring rewilding progress. Phil. Trans. R. Soc. B 373: 20170433.
http://dx.doi.org/10.1098/rstb.2017.0433

EcoplantMed

ENPI CBCMED

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CRITICAL ECOSYSTEM PARTNERSHIP FUND

MEPI

The U.S.-Middle East Partnership Initiative

جذور لبنان SEED BANK

Convention on Biological Diversity

Forest Ecosystem Restoration Initiative


Thank you
Pr Magda Bou Dagher Kharrat