Identifying biodiversity-related success factors of ecological restoration projects

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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.

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

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

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**.


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 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;

Ecological succession

Primary succession

Restoration

Ilary succession

Jouzour Loubnan 500 000 m² fenced site at Kfardebian

10 years later

Zone non pâturée

Zone pâturée

Dégradation

100aines d’années
Complete recovery is rare. RE show improved biodiversity and ecosystem functioning compared with degraded sites, and are progressing towards reference conditions with time.

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.

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

**BIOTIC factors**

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

- **Stress**
- Less nutrients and moisture
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
The climate is Mediterranean with hot, non-rainy (humid on the coast, dry inland) summers and warm, moist winters.

Min-max rainfall 200–1400 mm/year

Lebanon precipitation map

Quercus cerris forest

Juniperus excelsa
Cedrus libani
Abies cilicica
Pinus brutia
Pinus pinea
Pinus halepensis

Altitudinal distribution of some conifer species in Lebanon
Let’s plant...

Plantation campaigns

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Forest Restoration
Is
Beyond Planting Trees

Reforestation vs Ecosystem restoration

Boisement monospécifique avec Pinus pinea aux alentours de Jezzine.

Ecosystème forestier très diversifié dans la réserve naturelle de Ehden.
Since 2001

Genetic characterisation 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.

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

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

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

2000 m – Oyoun orghoch

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

Pr Magda Bou Dagher Kharrat: 1401-1406
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. Genetics

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”

[Link: www.fao.org/3/a-i3938e.pdf]
Appropriate genetic resources?

Genetic resources
- Native
- Genetic diversity

Rosaceae
Lebanese forests harbour a remarkable concentration of economically important plants, particularly wild crop relatives, such as wheat, rye and barley, as well as nuts and fruits like pistachio, olives, almonds, apricots, pears and apples.
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).

Good practices on seed collection and seed sources

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

Demographic processes following rear-edge type migration:

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

*Abies cilicica*
Genetic diversity and Genetic differentiation:

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


Effect of the biology on genetic diversity


Avoid self pollination
Self pollination --- > empty seeds
Pollination mode

Seeds dispersal mode
Concepts Underpinning Restoration

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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**

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

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Individual fencing

Jouzour Loubnan 500 000 m² fenced site at Kfardebian

10 years later

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

Zone pâturée

Zone non pâturée
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Kfardebian Experimental design

Wire fence

1 NE
2 W
3 SW
4 SW
5 NE
6 W

10m x 10 m
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. sinae (A. DC.) Damboldt
- Centaurea triumfetti All.
- Crepis hierolymitana
- Erodium cicutarium (L.) L’Hér.
- Galium constrictum
- Galium verum
- Geranium libanoticum
- Glaucium leiocarpum
- Helichrysum plicatum DC.
- Ixionion tataricum (Pall.) Schult. & Schult.f.
- Noeoea mucronata humulis
- Plantago lagopus
- Poaceae family
- Puschkinia scilloides libanotica
- Scabiosa proflifer L.
- Taraxacum sp.
- Verbascum gaillardotii
- Veronica anagalloides
- Vinca libanotica

→ Non resistant to grazing (highly palatable?)
Concepts Underpinning Restoration

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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).
Soil microbiota mutualism

Plant / Bacteria

Mycorrhizas on Cedrus

Plant / Fungi

Mycorrhiza 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
Non-invasive method of identification: DNA-METABARCODING

Multispecific approach → DNA-METABARCODING

Detect the presence of several species in a single sample taken

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

DNA barcodes
- ITS
- 16S
- COI
- 12S
- rbcL
- matK
- trnL
- cytb
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
Build our **animal** reference library

### Dead animals

- [Image of a dead animal]

### Museum animals

- [Image of a museum animal]

### Captive animals

- [Image of a captive animal]

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aDNA isolation from Museum animals

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Construction of the reference library

2) Stuffed animals

- Mammals
- aDNA
- Ancient DNA laboratory

Construction of the reference library

- Plants
  - Fresh leaves
  - Herbarium

*Malus trilobata*

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

Animal identification
Collection of scat samples
Consumed species identification
Preservation
DNA extraction

1. 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

2. Consumed species

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

3. 3 birds species
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**Collection**

- ADNa
  - DNA isolation
  - Amplification:
    - $12S$
    - $rbcL$
    - $trnL$ (UAA)
  - Classic seq Sanger

**Ref library**

**Amplification**

- ADNe
  - DNA isolation
  - Amplification:
    - $16S$
    - $rbcL$
    - $trnL$ (UAA)
  - NGS
  - Seq data

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**Diet across the seasons**

- **Crataegus monogyna**
- **Prunus ursina**
- **Rosa canina**

**Vulpes vulpes**

**Availability of all these species across its bio-corridors?**
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D. Community Assembly Theory

E. Landscape Ecology

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).
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.

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).
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.


The U.S.-Middle East Partnership Initiative

Forest Ecosystem Restoration Initiative
Thank you

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