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Overview of habitat restoration and habitat approaches

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NGO Jouzour Loubnan

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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)

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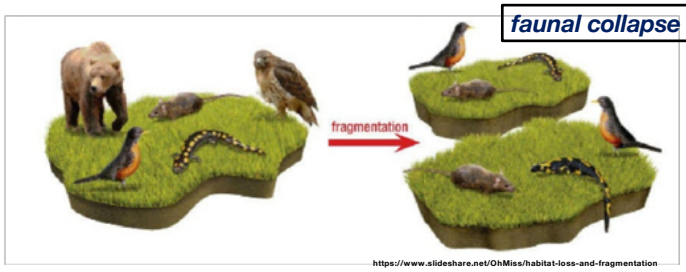
Ecosystem degradation => Habitat loss is one of the most important cause of species extinction.

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

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

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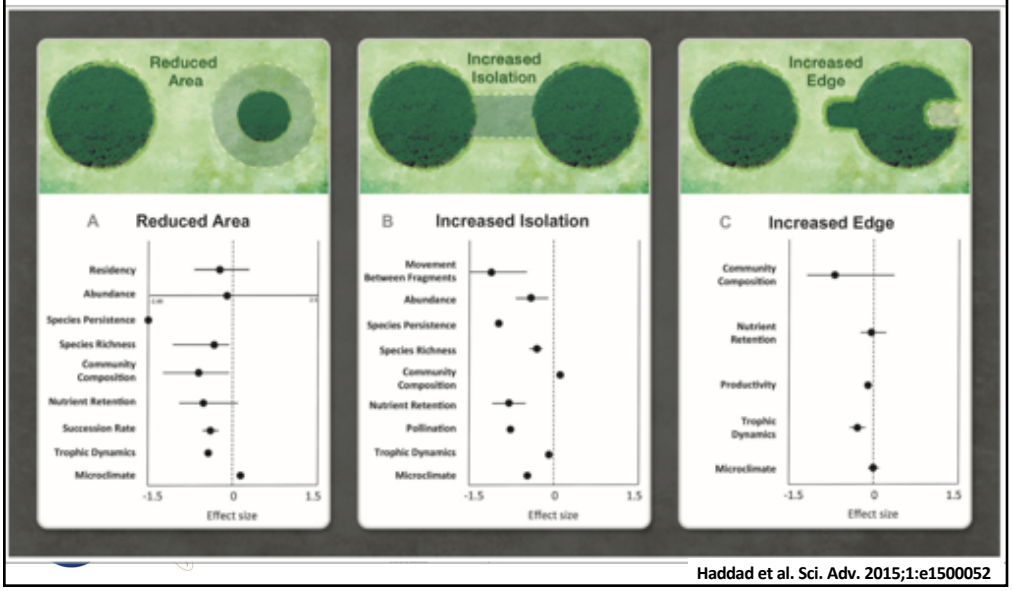
Fragmentation effects propagate through the whole ecosystem



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

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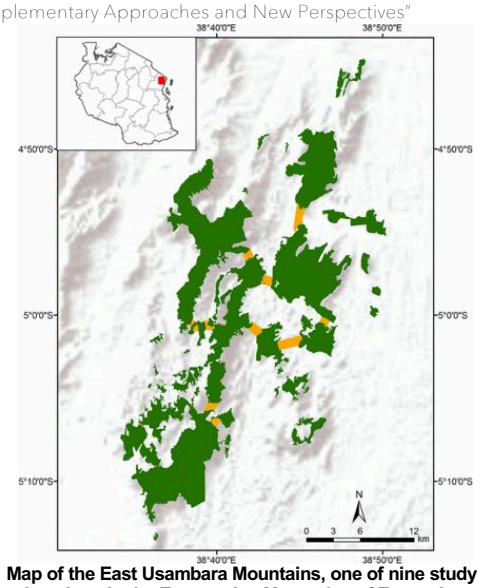
Targeted habitat restoration can reduce extinction rates in fragmented forests

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.

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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

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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

Forest Restoration paradigm

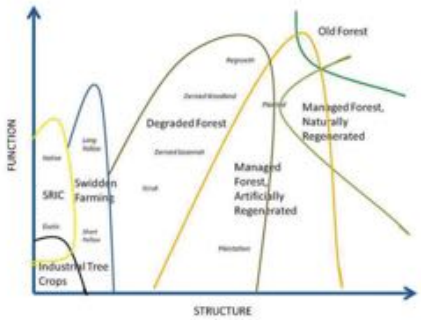

FIGURE 1 Conceptualized forest states in terms of functionality and structure. The degraded to natural continuum is implied, from Industrial Tree Crop to Old Forest. Species composition, particularly native versus nonnative, is contained within functional attributes, for example, short-rotation intensive culture (SRIC) comprised of a native species is higher function compared to SRIC with exotics (adapted from Carle & Holmgren, 2003; Putz & Redford, 2010; Stanturf & Madsen, 2002).

// degradation and restoration trajectories

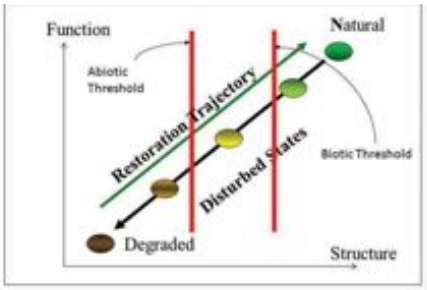

FIGURE 2 The parallel degradation and restoration trajectories in terms of functionality and structure. The intermediate disturbed states (varying degrees of naturalness) are divided by abiotic and biotic thresholds that must be overcome to move to a new stable state. For simplicity these disturbed states are arrayed linearly but in reality, the disturbed ecosystems may be located anywhere and the trajectories can be nonlinear. The Natural endpoint represents an idealized, predisturbance condition (adapted from Bradshaw, 1997).

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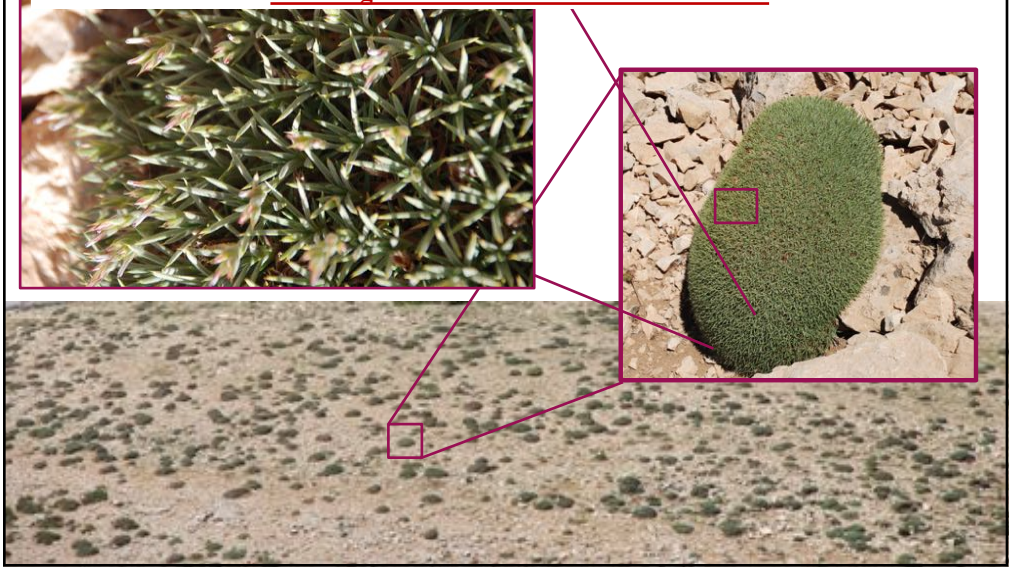
Primary succession

Active restoration *vs* passive recovery

What are the added benefit of actively restoring ecosystems *versus* allowing them to recover without human intervention following the cessation of a disturbance?



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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

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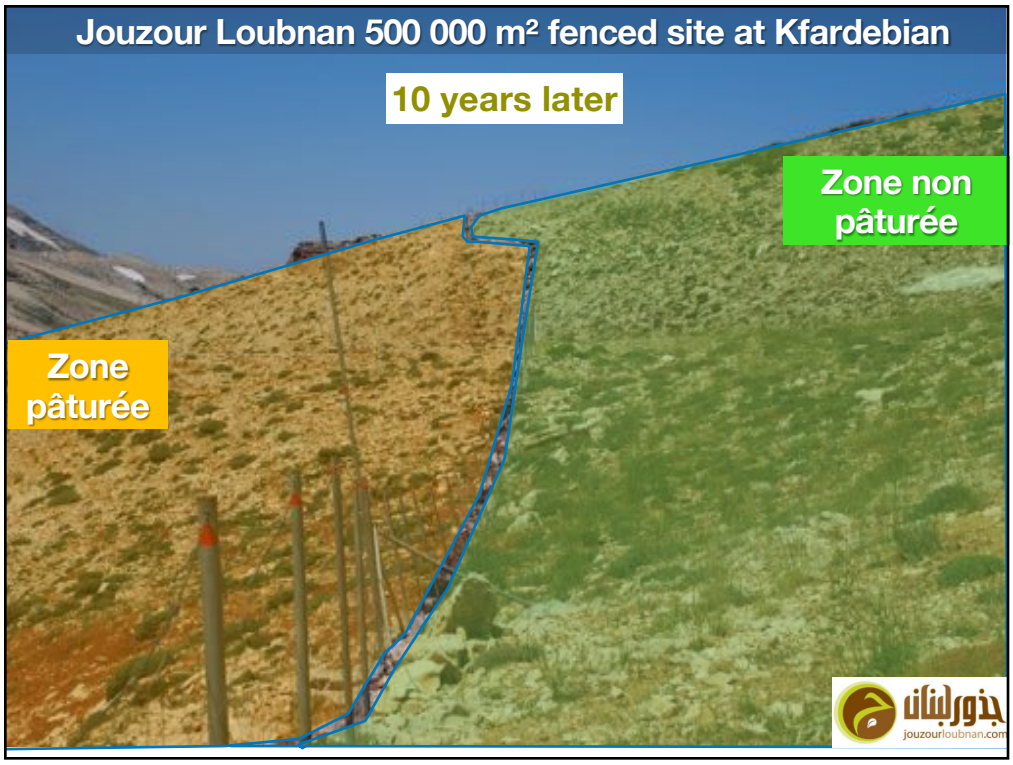

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Ecological succession

Ilary succession

Primary succession

Dégradation **100aines d'années**

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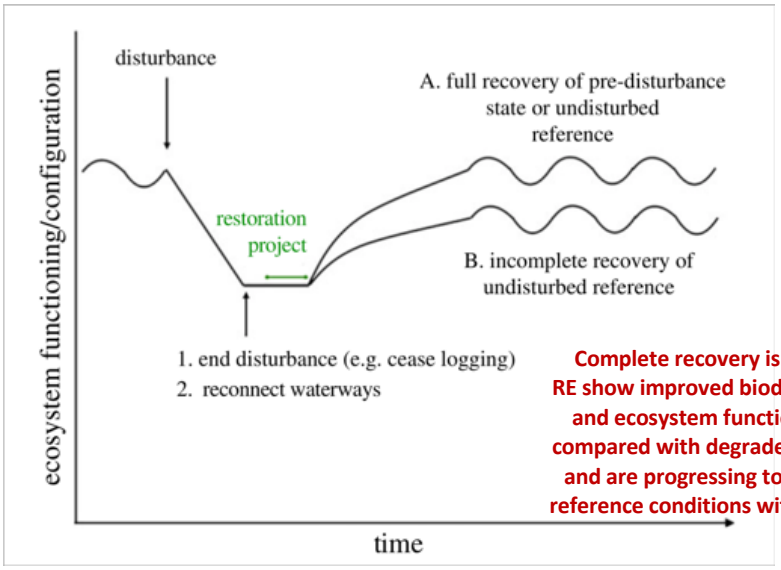
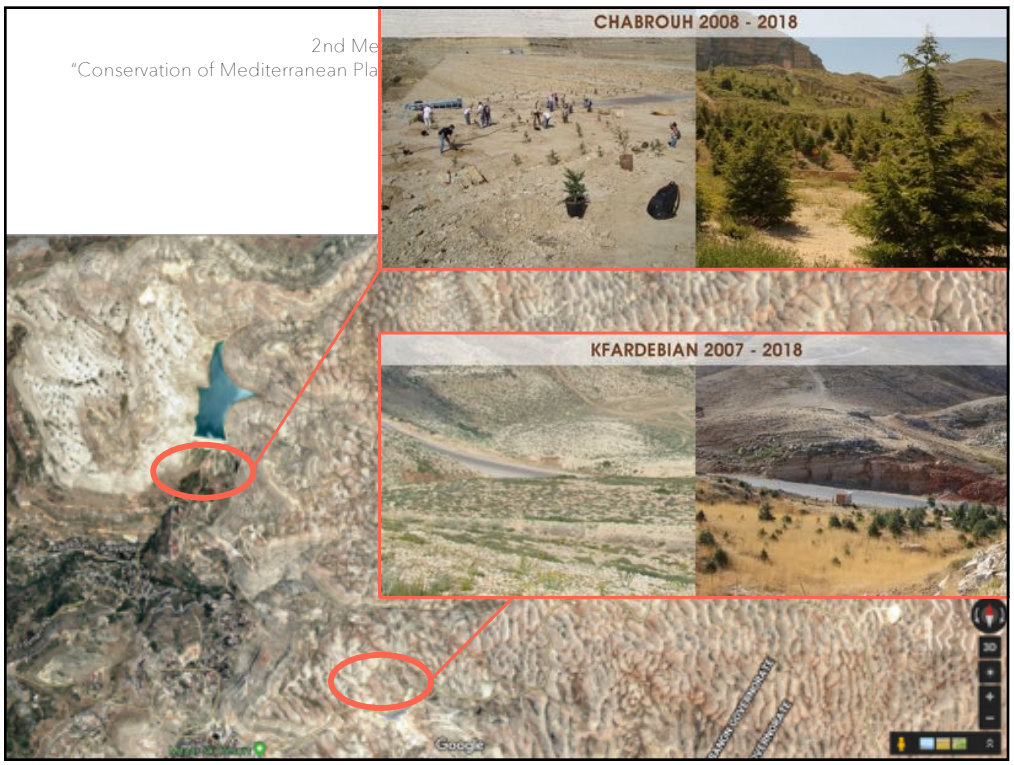


Complete recovery is rare. RE show improved biodiversity and ecosystem functioning compared with degraded sites, and are progressing towards reference conditions with time.

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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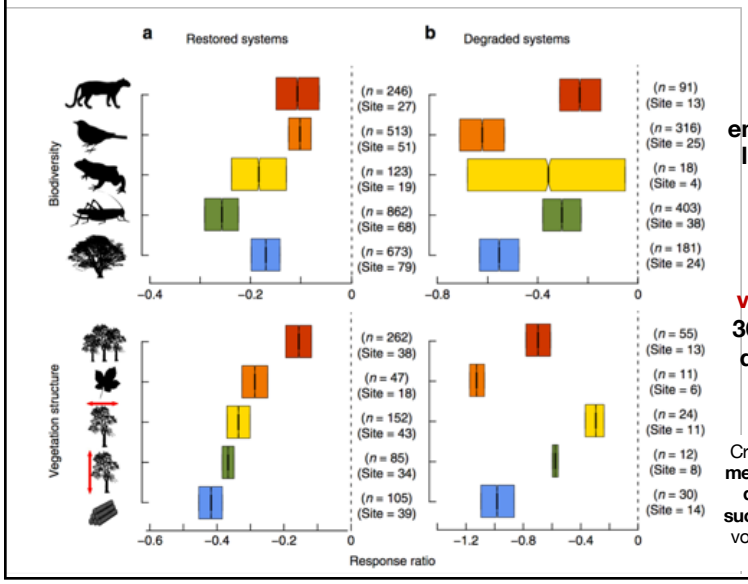
Bootstrapped response ratios for mammals, birds, herpetofauna, invertebrates, plants, density, litter, cover, height and biomass for restored (a) and degraded (b) systems compared with reference systems.



A meta-analysis encompassing 221 study landscapes worldwide reveals forest restoration enhances biodiversity by 15–84% and vegetation structure by 36–77%, compared with degraded ecosystems.

Crouzeilles et al., 2016. **A global meta-analysis on the ecological drivers of forest restoration success.** *Nature Communications* volume 7, Article number: 11666 (2016)

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Disturbances are environmental changes that alter ecosystem structure and function.

Reference ecosysyem

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.

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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

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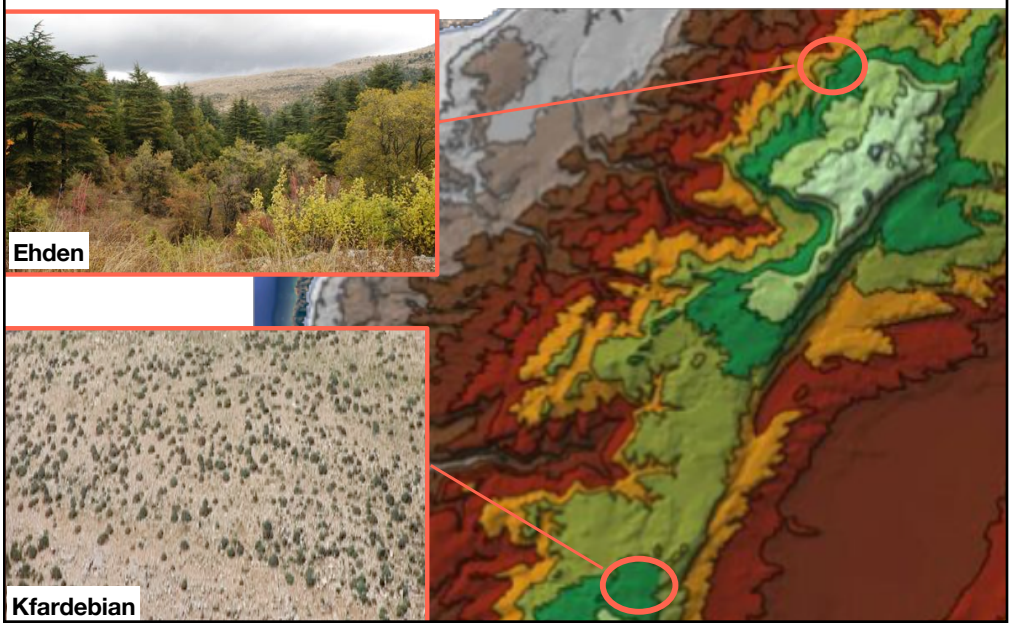

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ABIOTIC factors

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.

Stress

Less nutrients and moisture

Identify a chronosequence of reference sites

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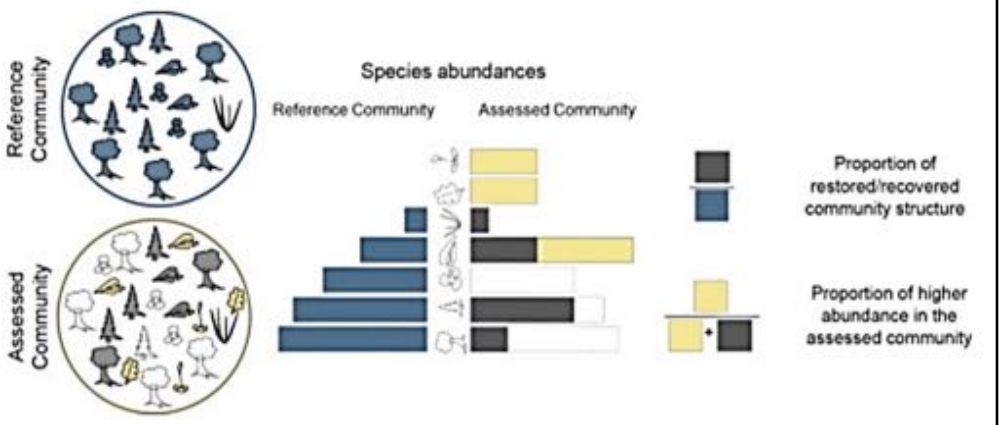

(Jaunatre et al. 2013)

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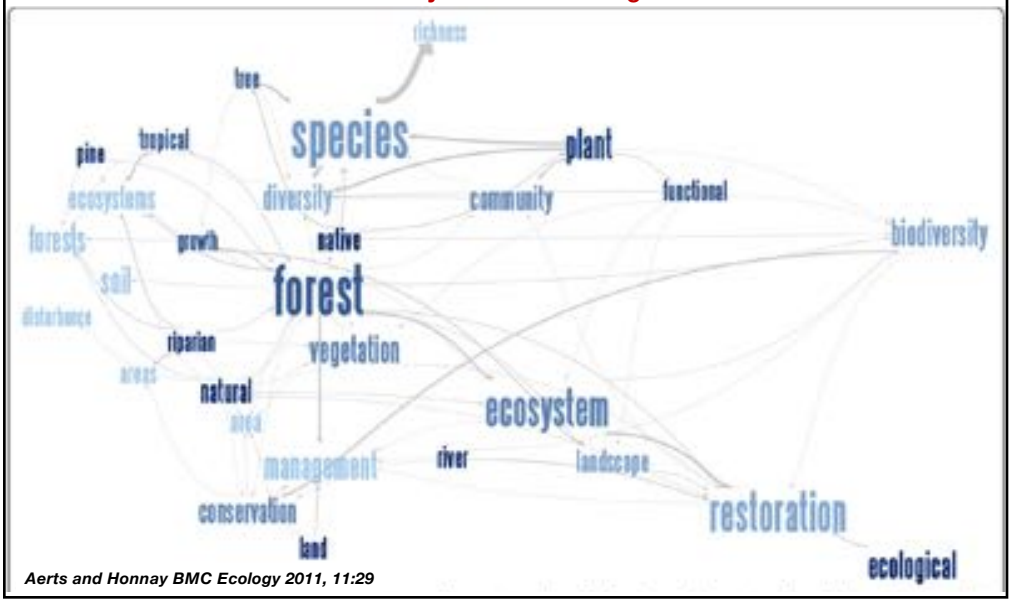
Related concepts in the scientific literature on forest restoration, biodiversity and ecosystem functioning



Aerts and Honnay BMC Ecology 2011, 11:29

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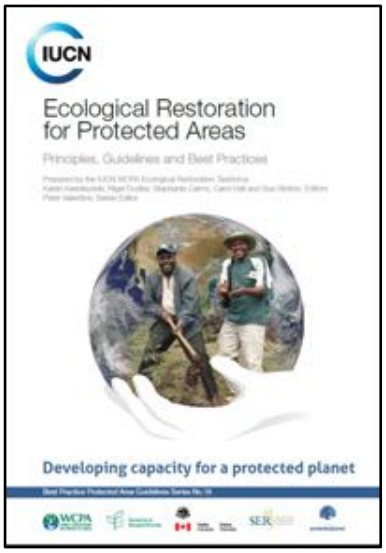

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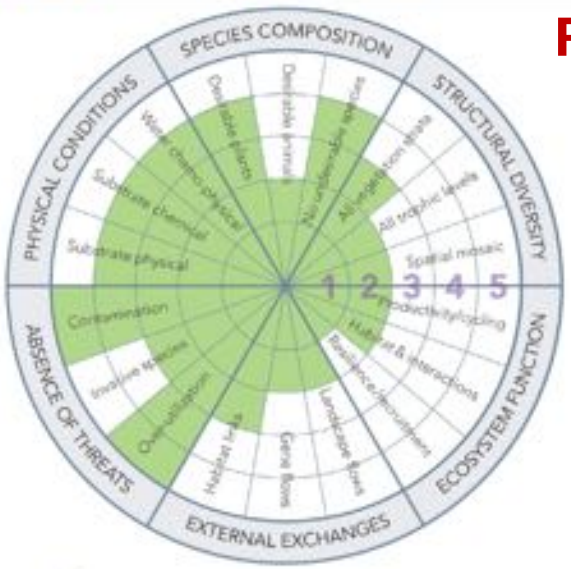

Recovery wheel

(SER, 2016)

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Slow and steady wins the race

Invest time in preparation

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Forest Restoration Is Beyond Planting Trees

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Concepts Underpinning Restoration

A. Disturbance / Reference site (s)

B. Genetics

C. Succession

D. Community Assembly Theory

E. Landscape Ecology

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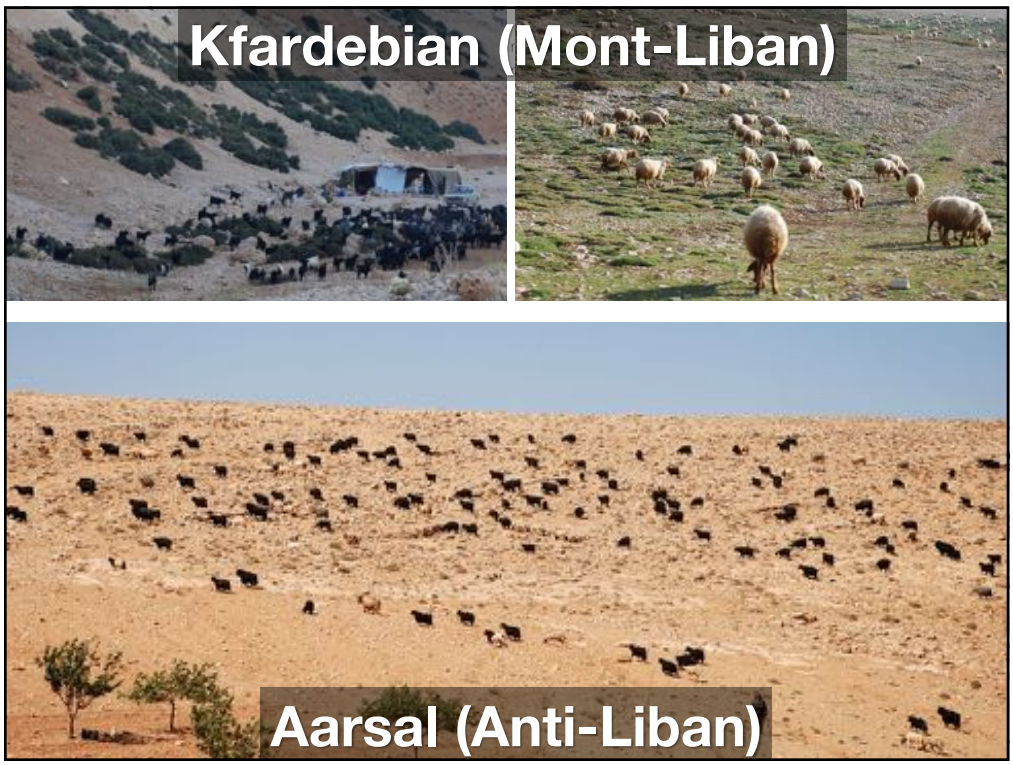
A- Disturbance

Many scales and different levels of severity

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



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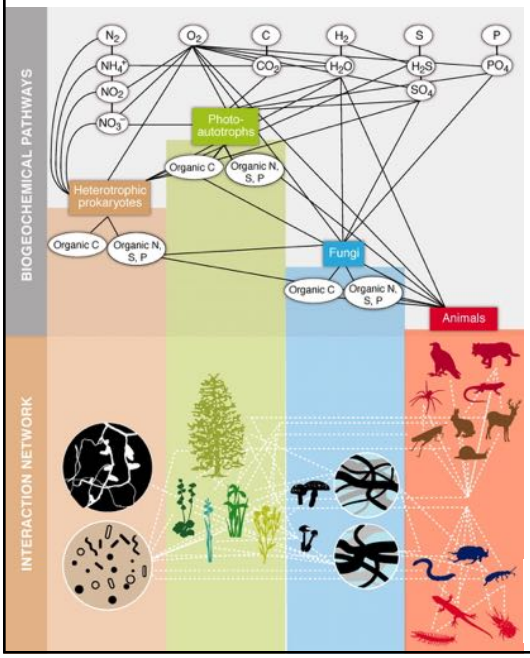

Biotic impoverishment can markedly alter the biogeochemical and dynamic properties of ecosystems.

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

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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.

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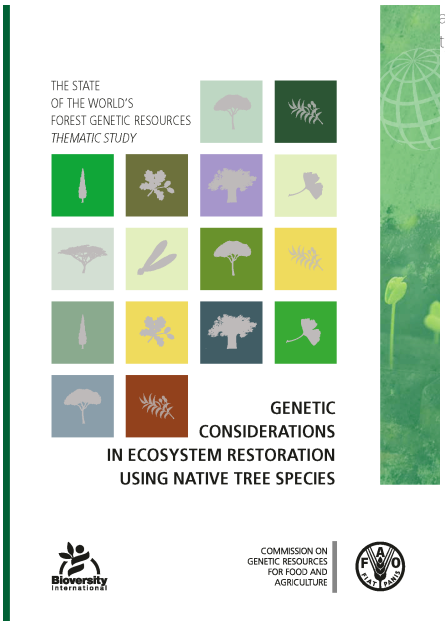
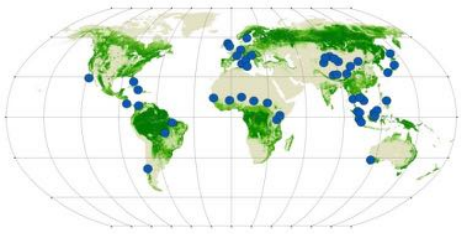


"Genetic considerations in ecosystem restoration using native tree species"

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



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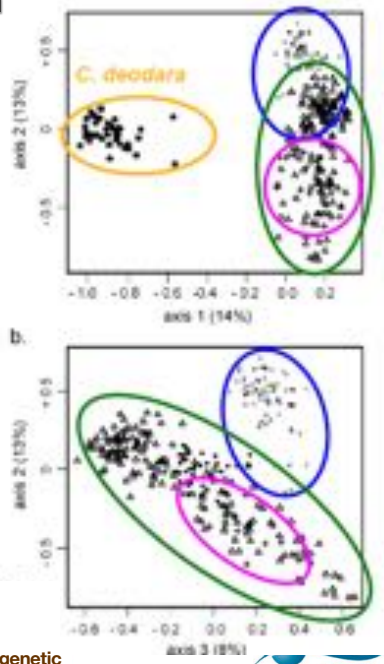
Cedrus Genetic differentiation

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.

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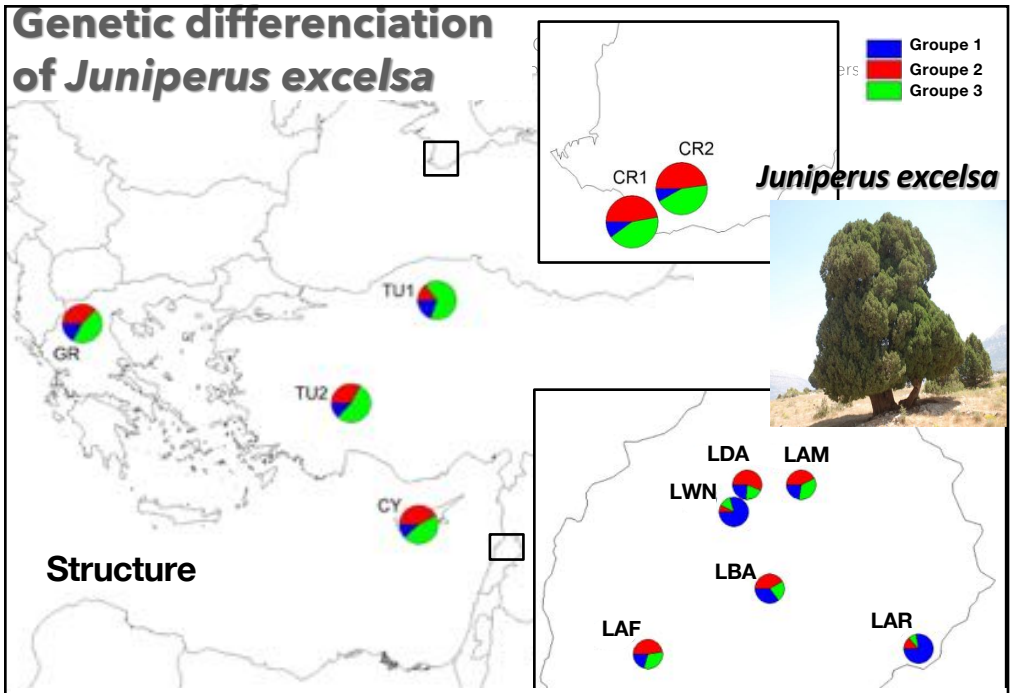
Genetic differenciation of *Juniperus excelsa*



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.

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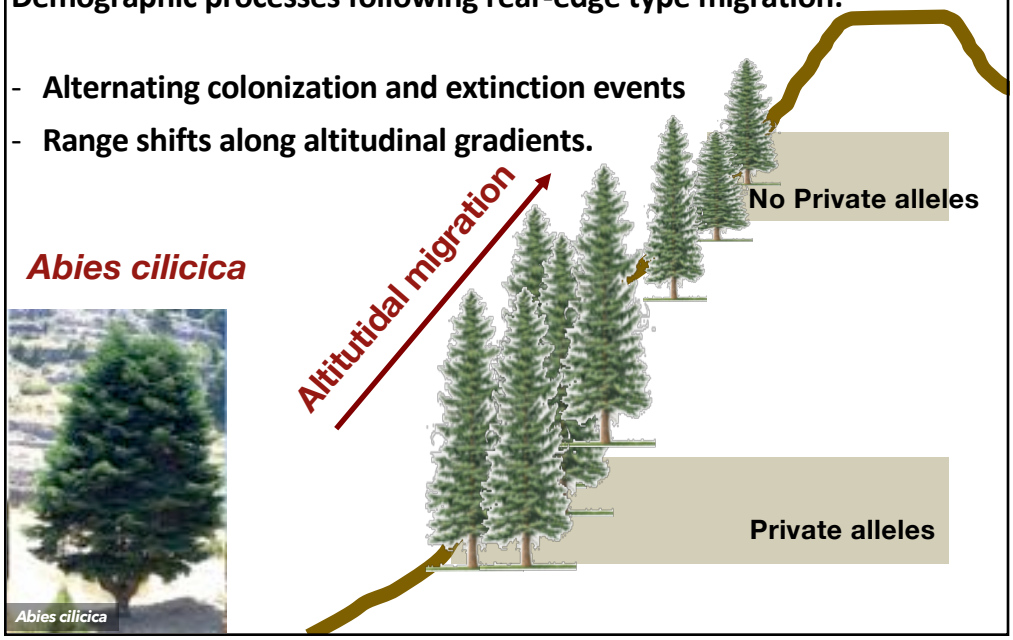
Demographic processes following rear-edge type migration:

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



Abies cilicica

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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

Gene flow

- Existence history

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

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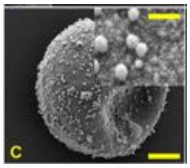
Effect of the biology on genetic diversity

Gene flow
(pollination, seeds dispersal)



Juniperus sp.

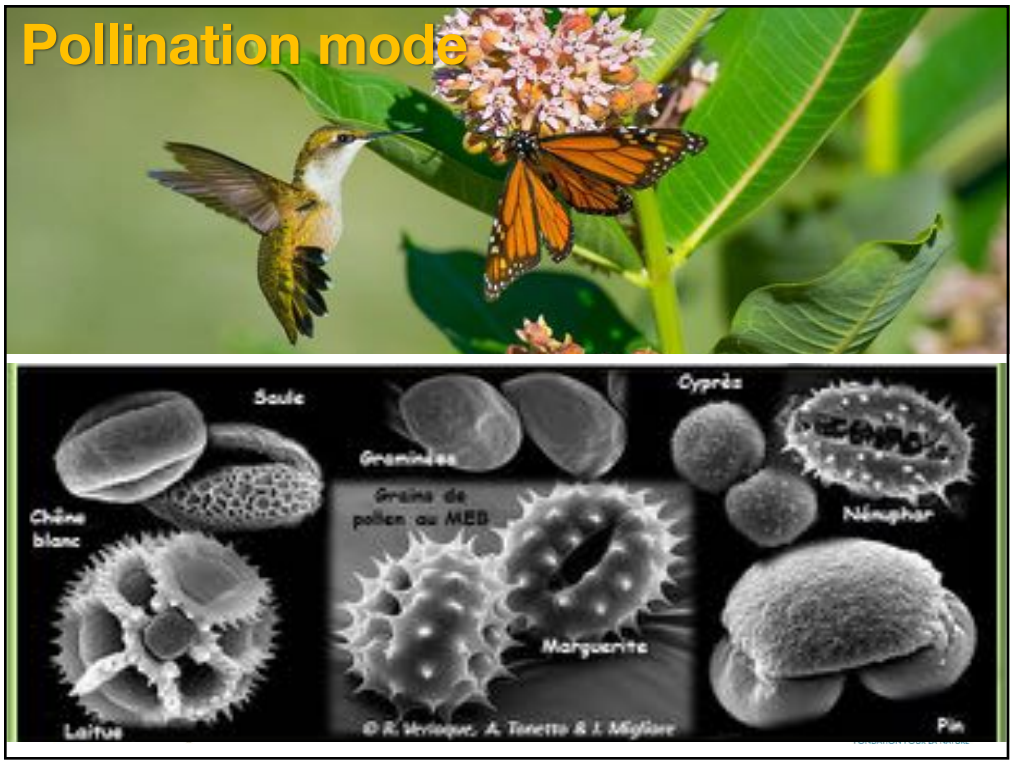
Abies sp.

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.



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Seeds dispersal mode

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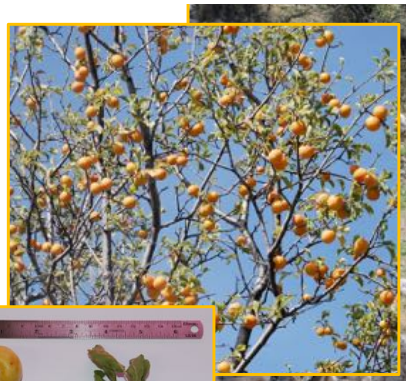
Good practices on seed collection and seed sources



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

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جذور لبنان SEED BANK

جذور لبنان jouzourloubnan.org

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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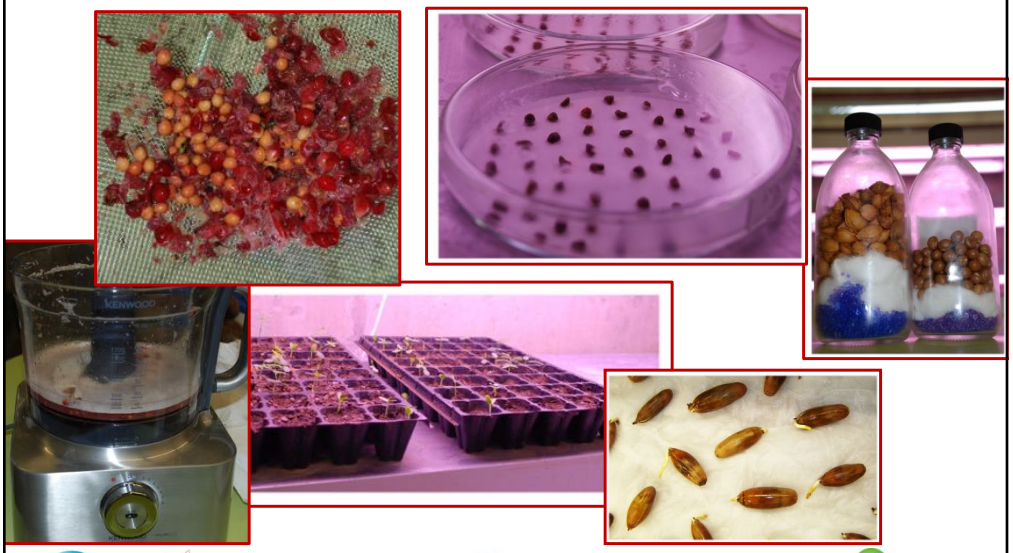

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جذور لبنان SEED BANK

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

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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

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Nurse plant

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

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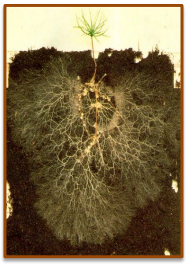
D- Community Assembly

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).

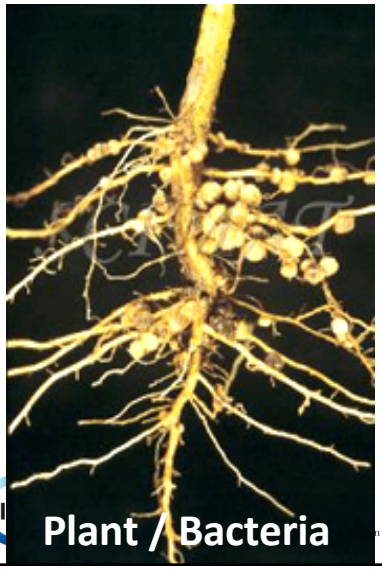
Plant facilitation

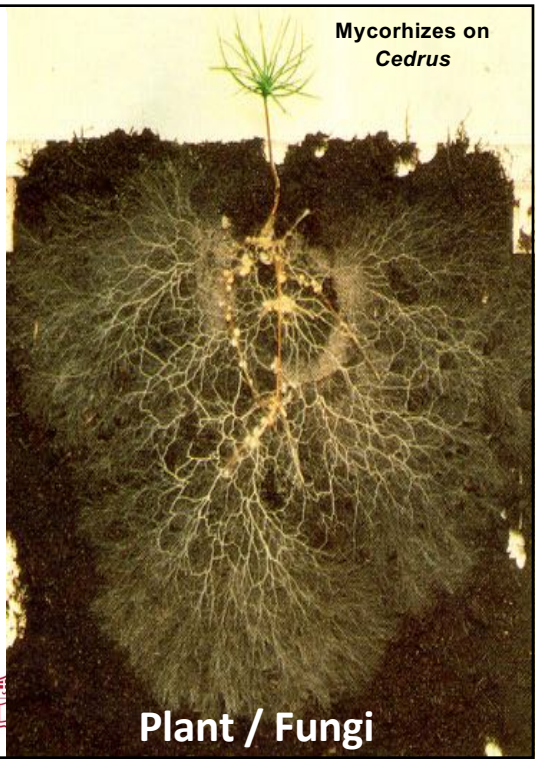


Soil microbiota

Seeds dispersers

Soil microbiota mutualism





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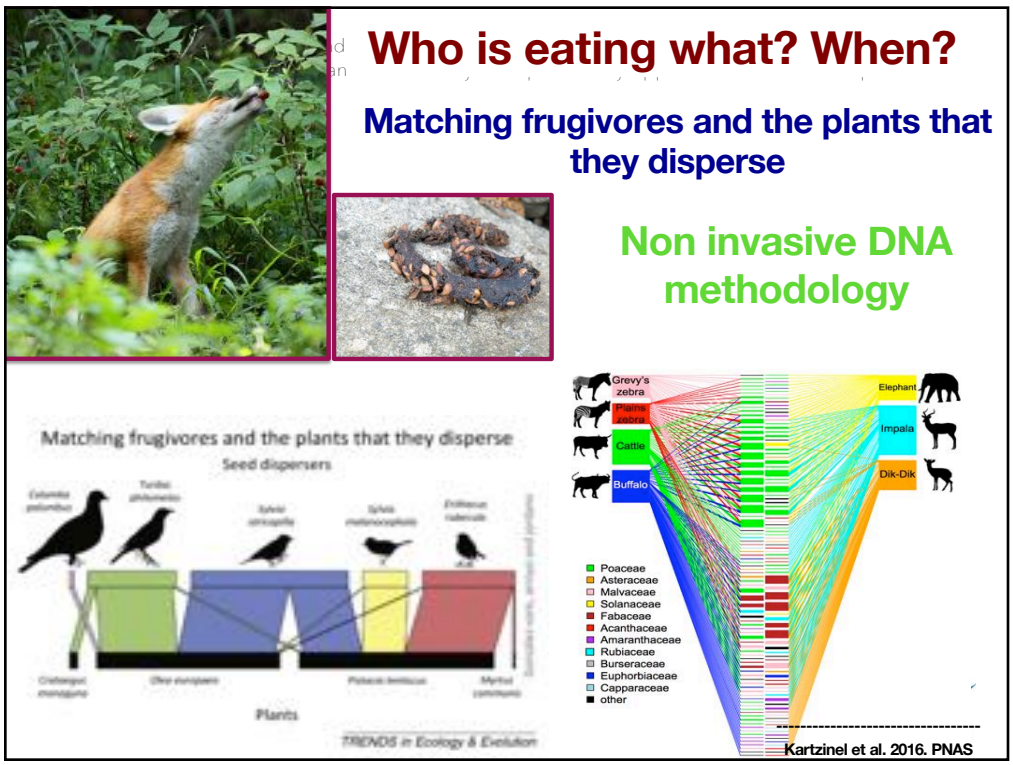
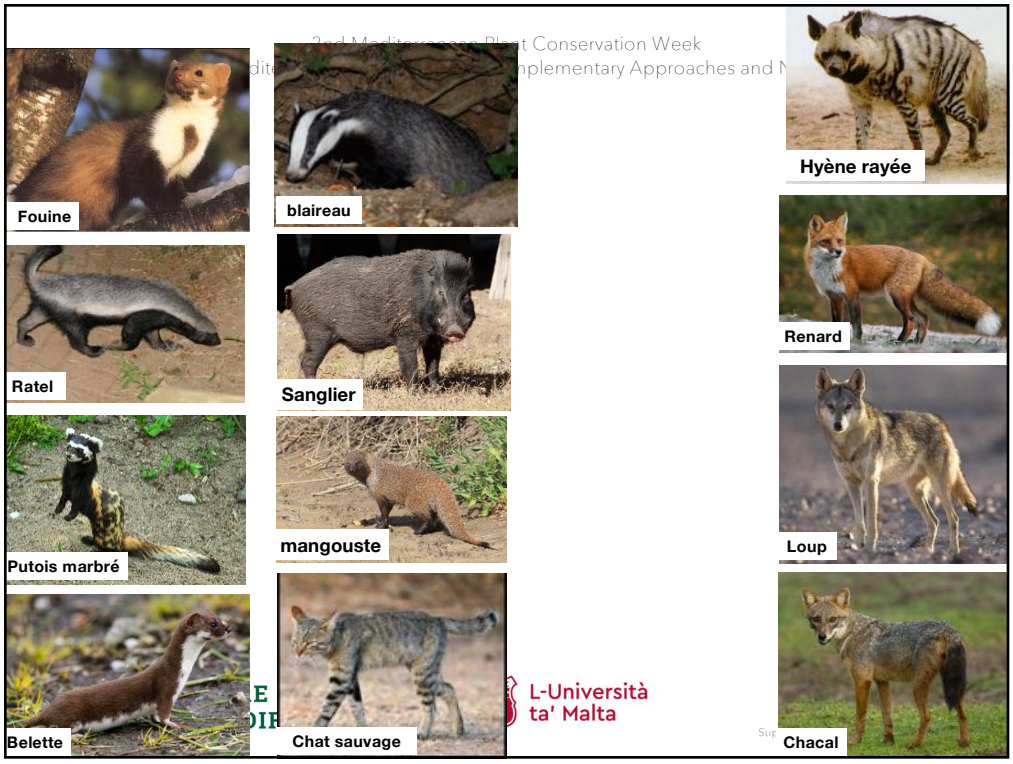
Mycorhiza on *Cedrus libani*.

Reserve de Barouk Dec 2013


Who is eating what? When?
Matching frugivores and the plants that they disperse
Non invasive DNA methodology
Matching frugivores and the plants that they disperse
Seed dispersers
Plants
TRENDS in Ecology & Evolution
Grevy's zebra
Plains zebra
Cattle
Buffalo
Elephant
Impala
Dik-Dik
Poaceae
Asteraceae
Malvaceae
Solanaceae
Fabaceae
Acanthaceae
Amaranthaceae
Rubiaceae
Burseraceae
Euphorbiaceae
Capparaceae
other
Kartzinel et al. 2016. PNAS


Fouine
blaireau
Hyène rayée
Ratel
Sanglier
Renard
Putois marbré
mangouste
Loup
Belette
Chat sauvage
Chacal
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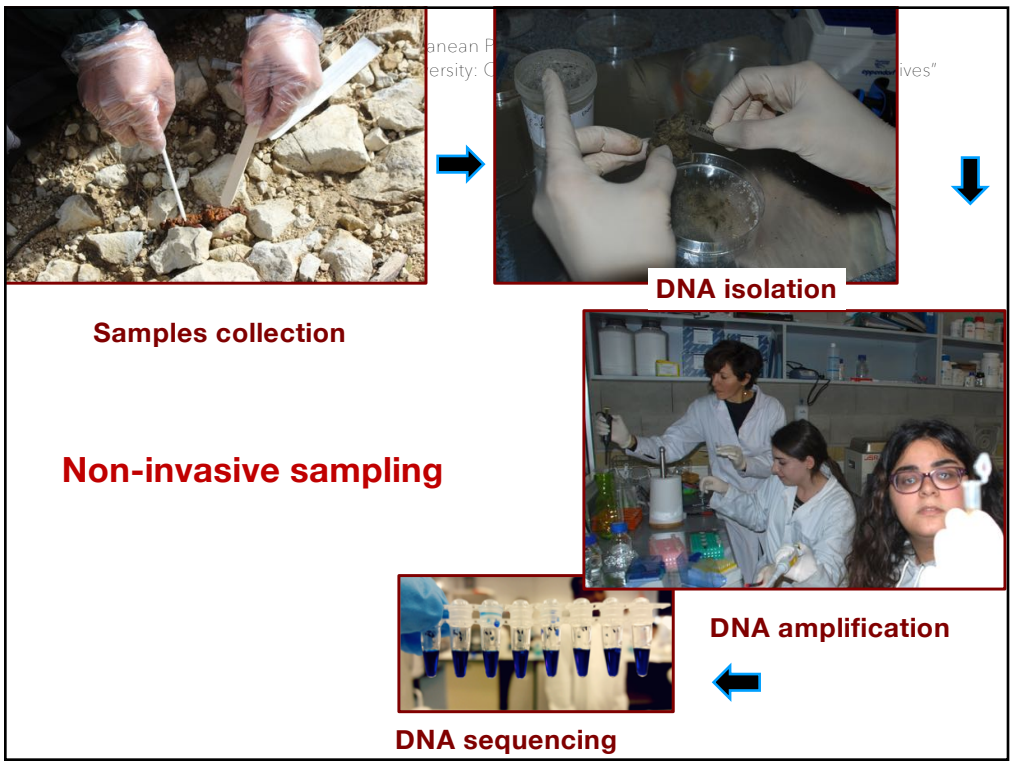

Build our **plant** reference library

Lebanese native tree species reference library

Build our **animal** reference library

Dead animals

Museum animals

Captive animals

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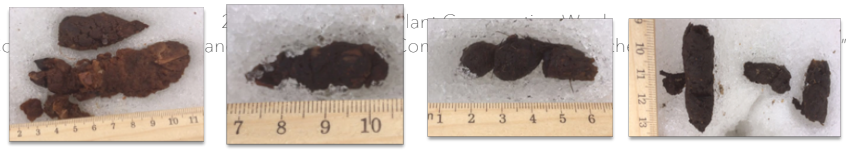
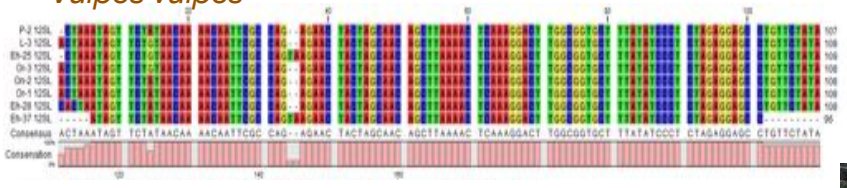


Eh-25 Eh-28 Eh-37 Eh-40

Vulpes vulpes



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

Diet across the seasons

Crataegus monogyna

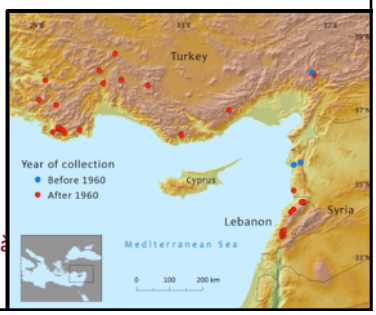
Prunus ursina

?

Rosa canina

Vulpes vulpes

Availability of all these species across its bio-corridors ?



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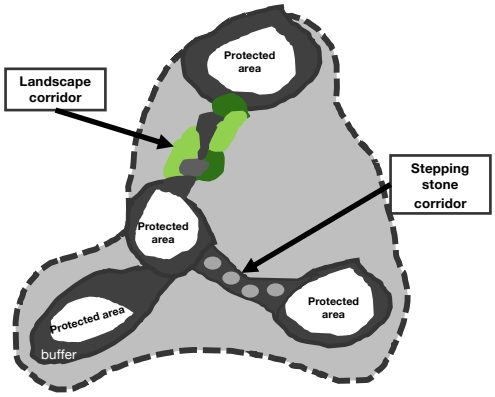
Increase the viability of depleted or fragmented populations by habitat expansion and reconnection, and help dispersal of species by increasing connectivity, vegetation buffers and mosaic habitats.

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



Linking terrestrial ecosystems.
Worboys et al. 2010.

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

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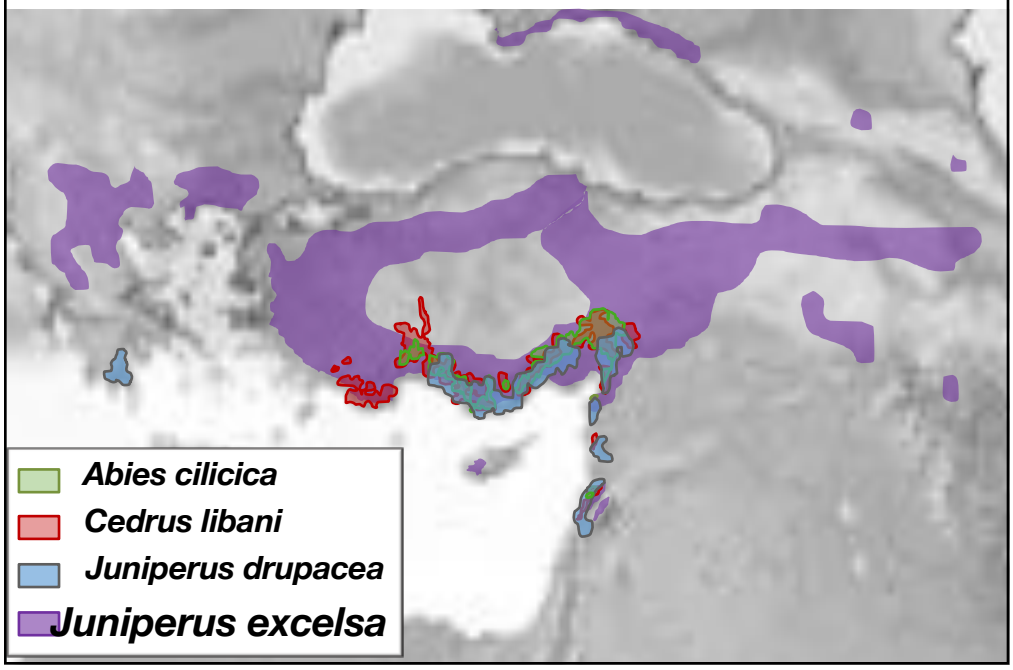
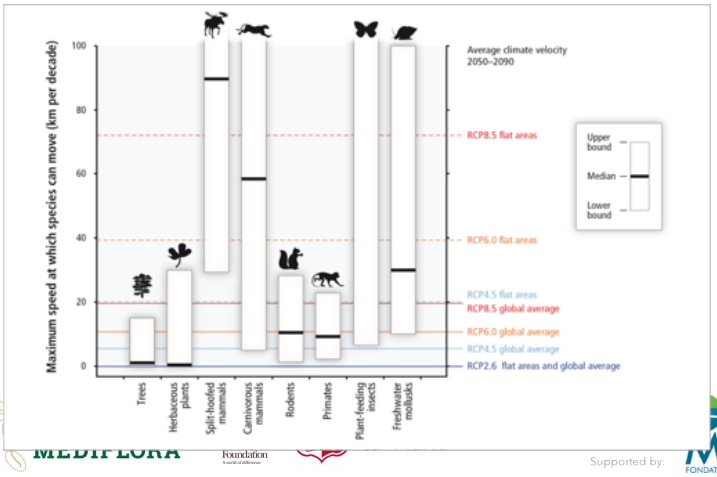
Same History, different stories



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.

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).

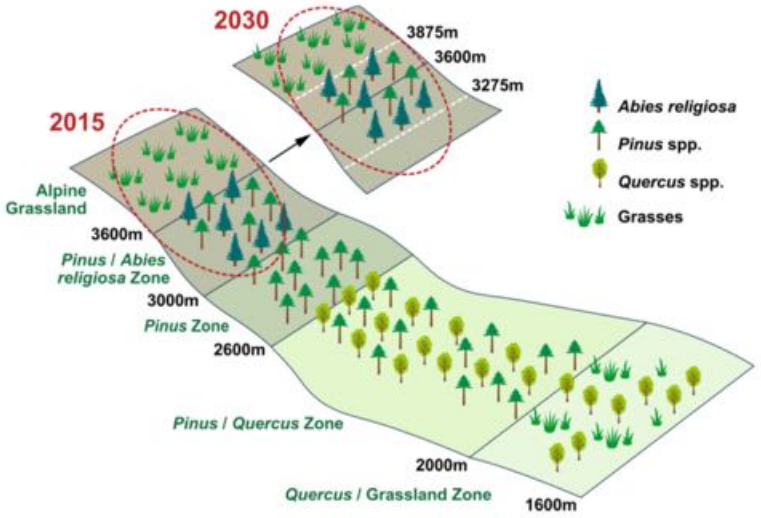


Fig. 4 Assisted migration can be performed along an elevation gradient. In this example, assisted migration of *Abies religiosa* 275 m upwards in altitude may be necessary to mitigate changes in climate so that this species can continue to provide its function as an overwintering host for *Danaus plexippus*.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

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