Restoring ecosystems with ecological engineering techniques : two case studies in Mediterranean France

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Ecological Restoration

The SER International Primer on Ecological Restoration

Ecological restoration:
«The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed »

Rehabilitation: a few functions

Restoration: the whole ecosystem
richness – composition
structure – functions

RESTORATION OBJECTIVES : « NATURAL CAPITAL »

-**Biodiversity**

From genes to landscapes

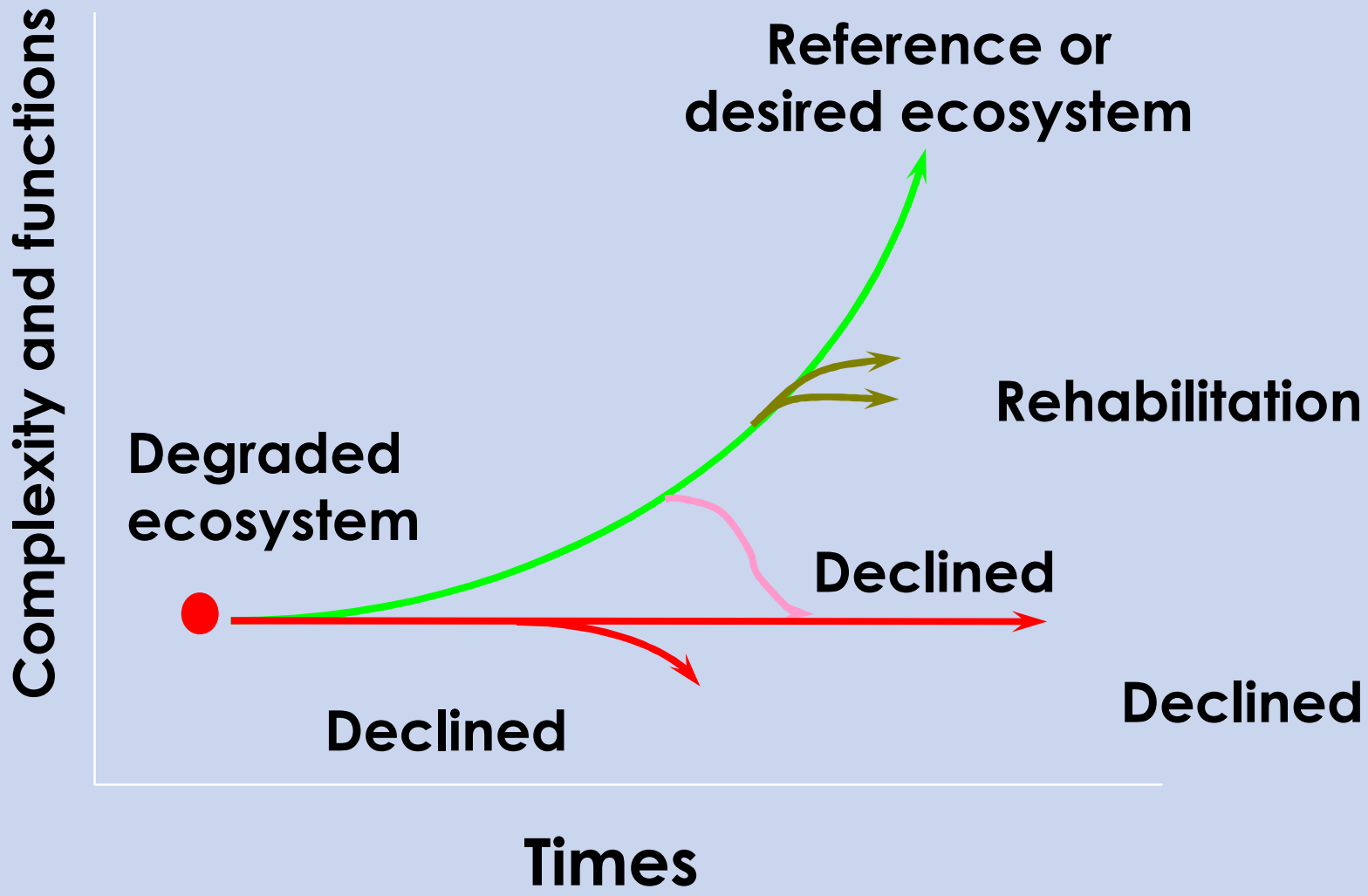
-**Functionality**

Functions and ecosystem services

- **Naturalness and wilderness**

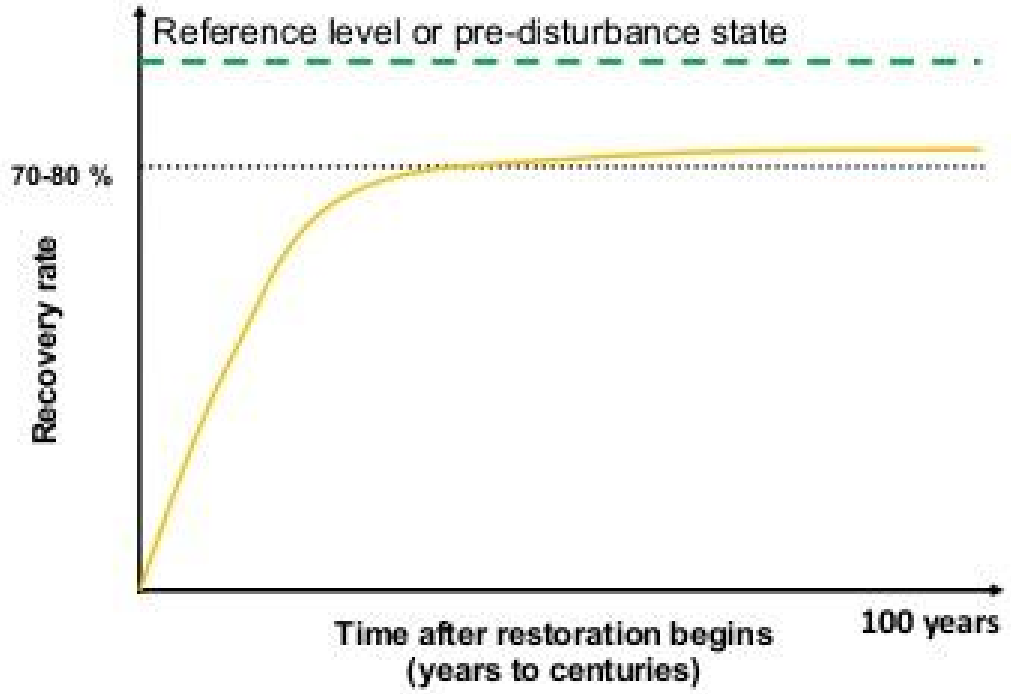
Original, potential, future...

RESTORATION OBJECTIVES :



From Hobbs & Norton 1996. *Restoration Ecology* (modified)

The limits of restoration



From Moreno Mateos *et al. 2012 PLOS Biology*

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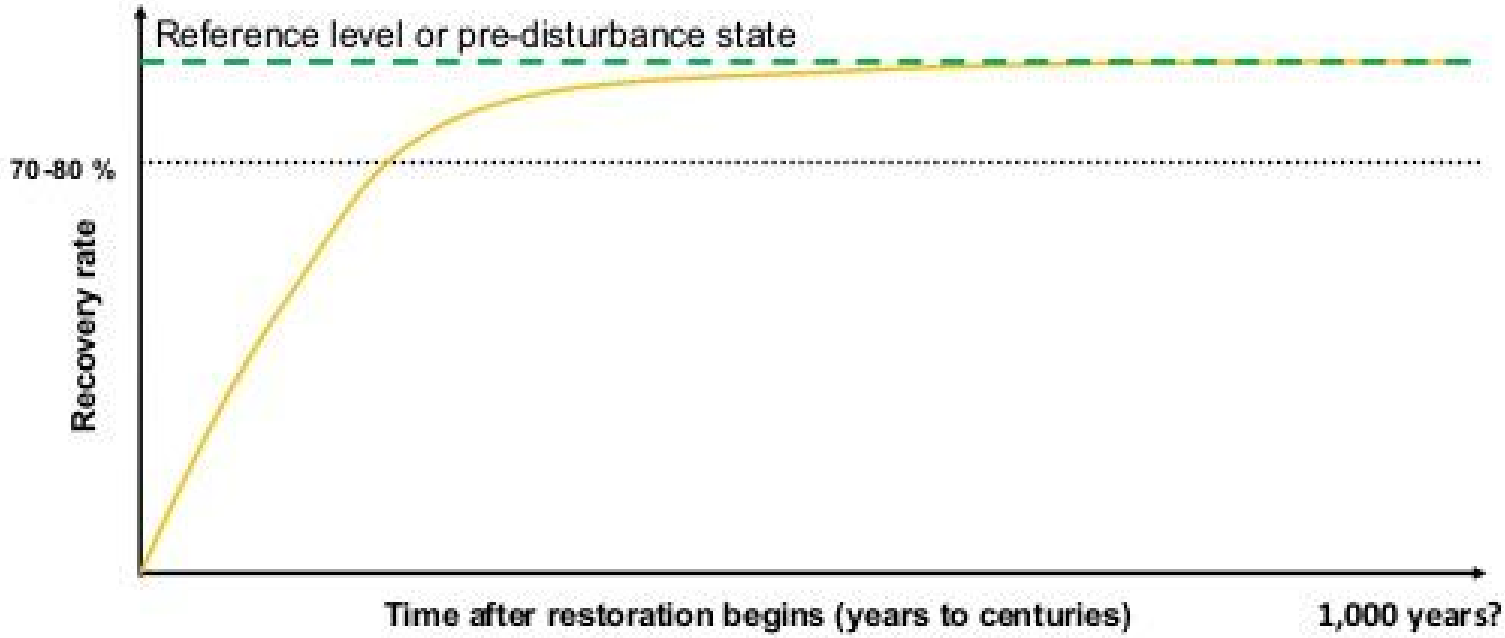
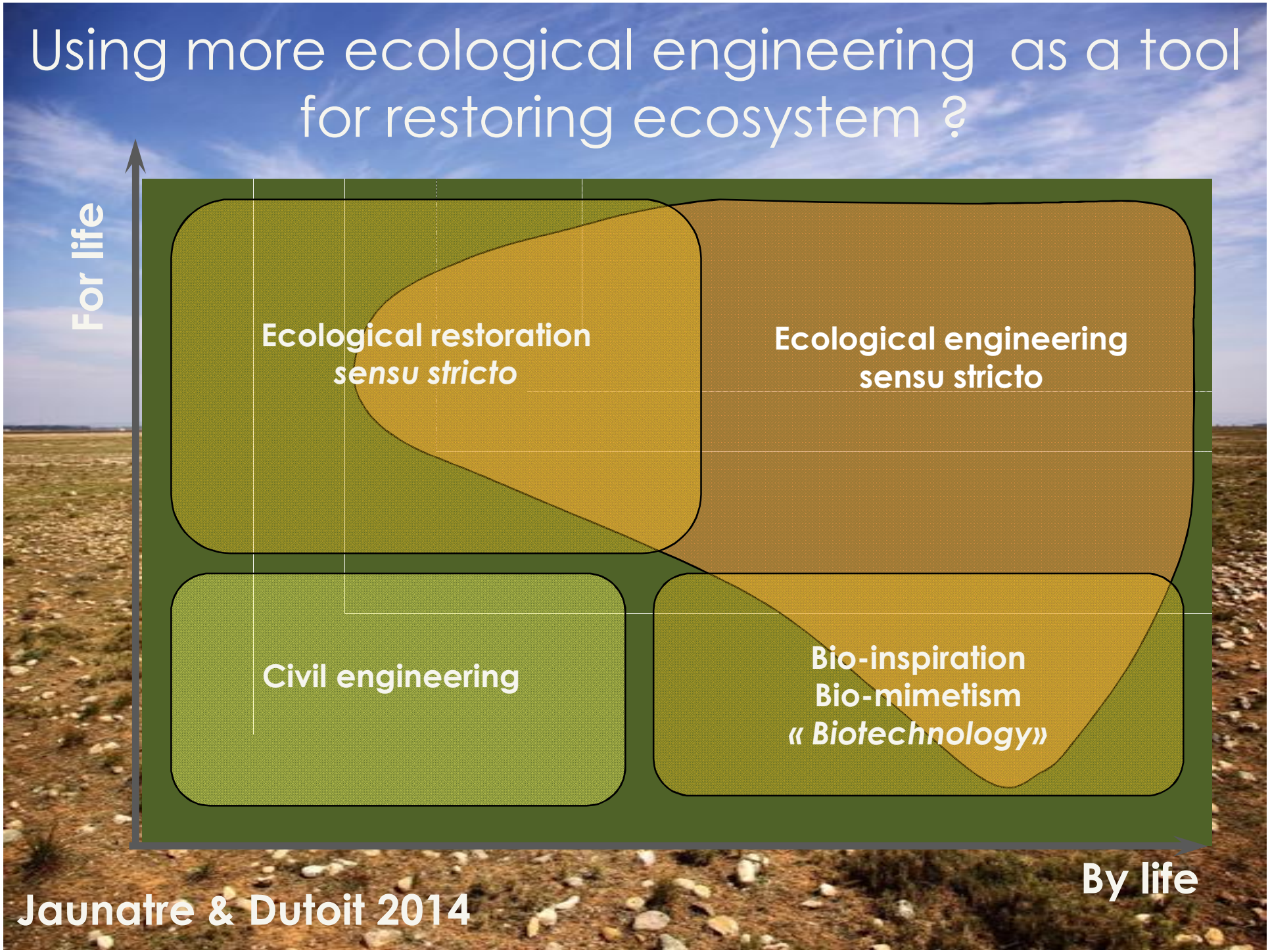


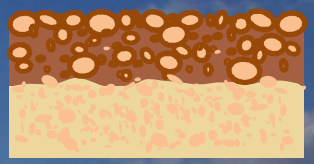
From Moreno Mateos et al. 2012 PLOS Biology

Using more ecological engineering as a tool for restoring ecosystem ?



The La Crau Area

Study Site: The La Crau Area



Mediterranean steppe

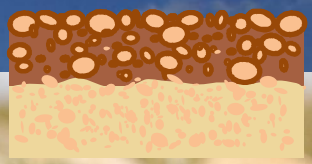
Driven by multi-millenaries of interactions between:

- Mediterranean climate
- Characteristic soil
- Sheep grazing for more than 6000yrs

Study Site: The La Crau Area

Brachypodium retusum

Asphodelus ayardii



Lobularia maritima

More than 40 species / 4m²
50% of annuals

Trifolium scabrum

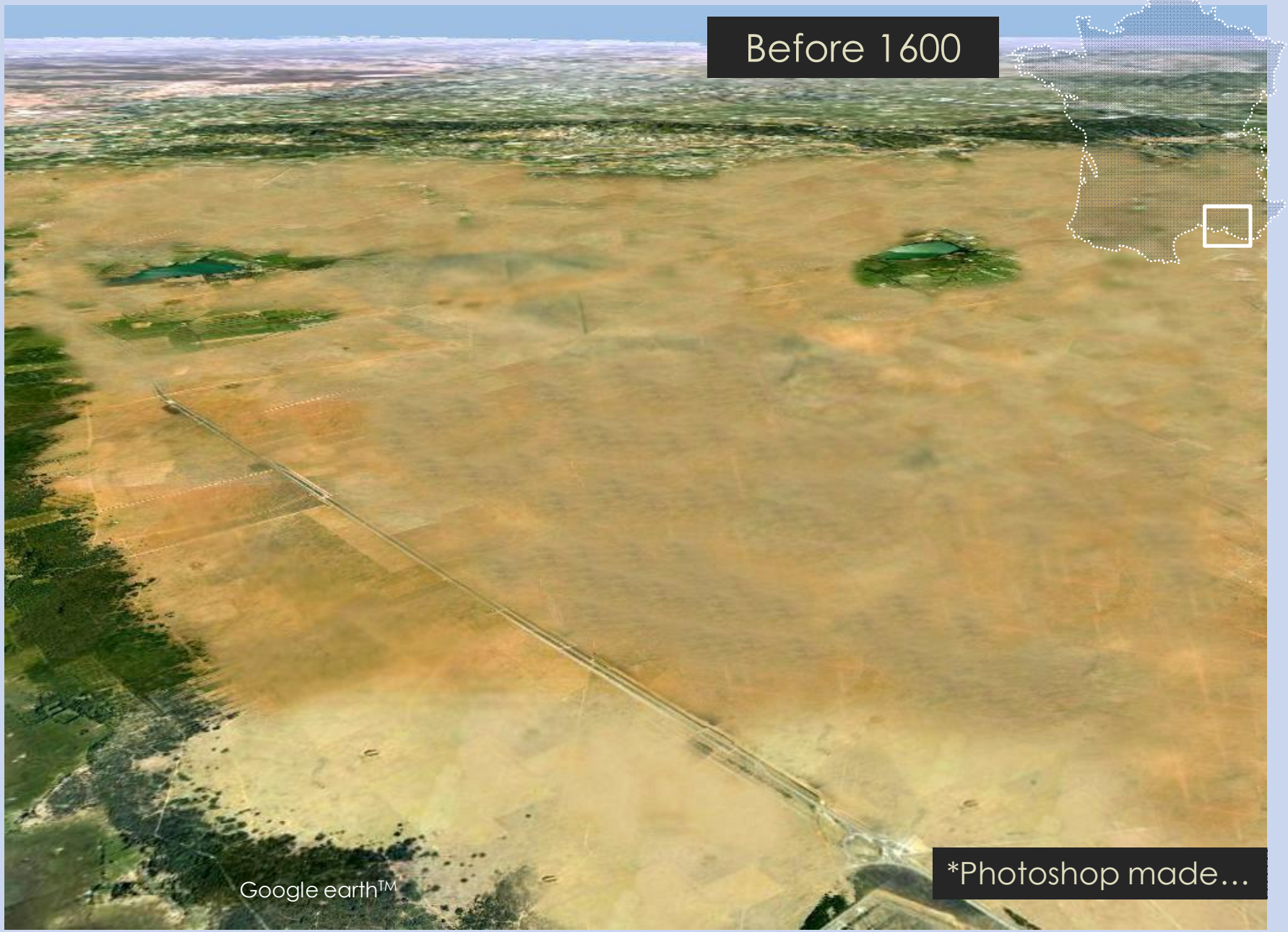
Sanguisorba minor

Sherardia arvensis

Thymus vulgaris

➔Unique community

Study Site: The La Crau Area



Study Site: The La Crau Area

The Cossure Rehabilitation Project

Given the very low resilience, active restoration is needed to restore the steppe plant community.

A rehabilitation project allowing to experiment techniques at large-scale

The Cossure Rehabilitation Project

The objectives:

CDC: rehabilitation of a steppe-like habitat for steppe birds coming back

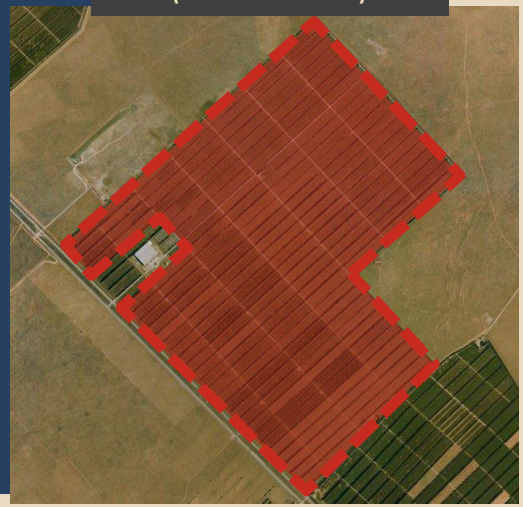
At experimental level :

2-4 years

Short-term : -Minimize unwanted taxa
-Maximize characteristic taxa

50-200 years

Long-term: -Restore steppe richness, structure and composition



The Cossure Rehabilitation Project

Abandonned orchard…

The Cossure Rehabilitation Project

Abandonned orchard… with no water supply

The Cossure Rehabilitation Project

Prunus are cut down…

The Cossure Rehabilitation Project

… as well as for *Populus*

The Cossure Rehabilitation Project

Wood is crushed and exported in energy industry

The Cossure Rehabilitation Project

Soils are levelled

The Cossure Rehabilitation Project

A few months later

The Cossure Rehabilitation Project

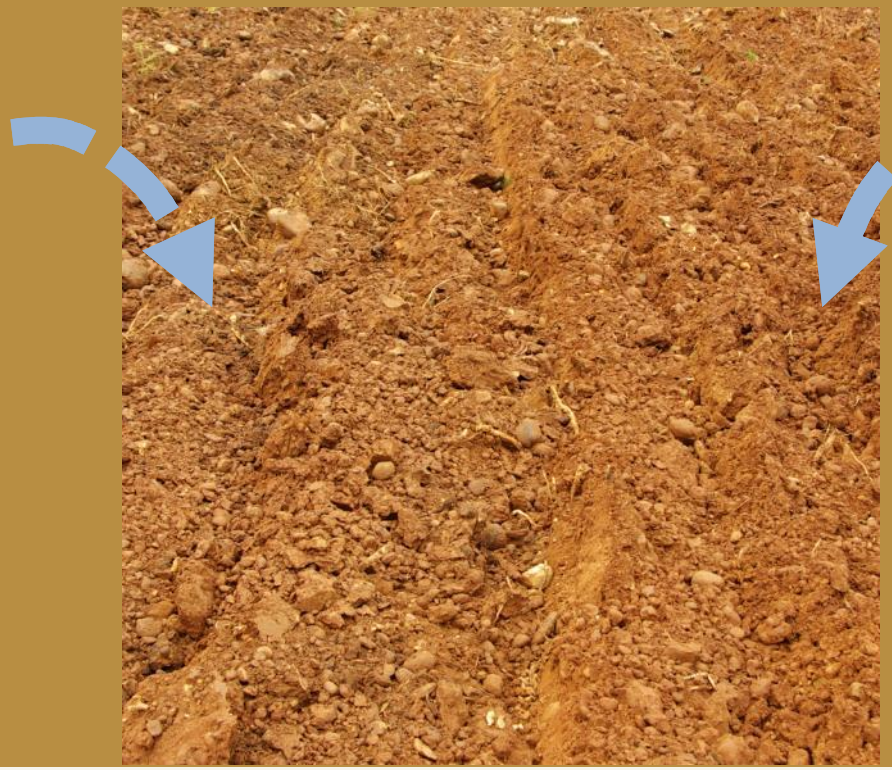
Four restoration techniques (summer -autumn 2009)

Hölzel N., Buisson E., Dutoit T. 2012. Species introduction : a major topic in vegetation restoration. *Applied Vegetation Science* 15: 161-165

Restoration Techniques

Nurse species seeding:

-If nothing is done:



Coiffait C., Buisson E., Dutoit T. 2012. Using a two-phase sowing approach in restoration – sowing foundation species to restore and subordinate species to evaluate restoration success. *Applied Vegetation Science* 15: 277-289.

Restoration Techniques

Nurse species seeding:

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Restoration Techniques

Nurse species seeding:

-Rapid ground cover

Restoration Techniques

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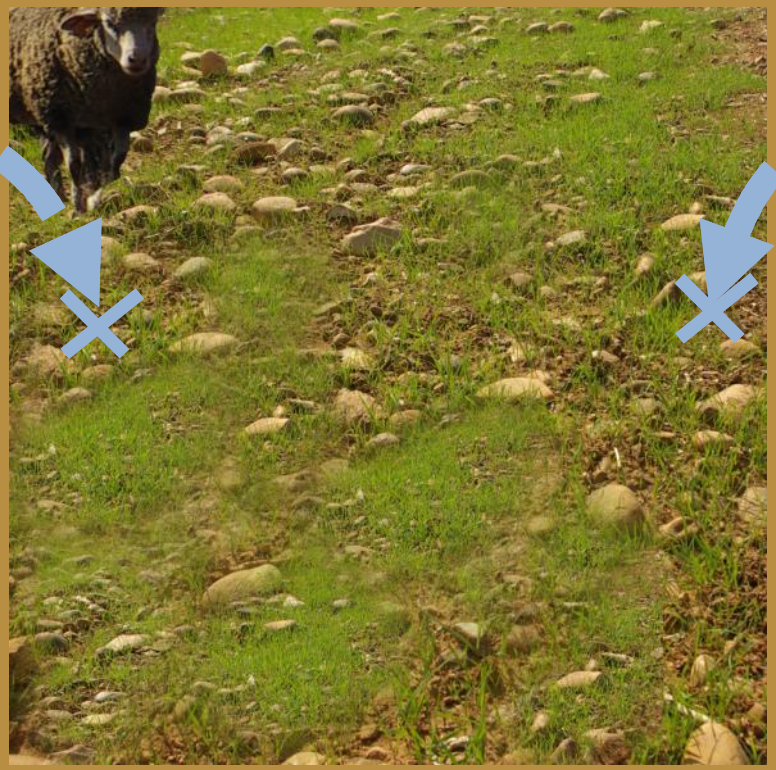
Non-target species

Restoration Techniques

Nurse species seeding:

-Rapid ground cover
-Grazing: creation of safe sites



Non-target species

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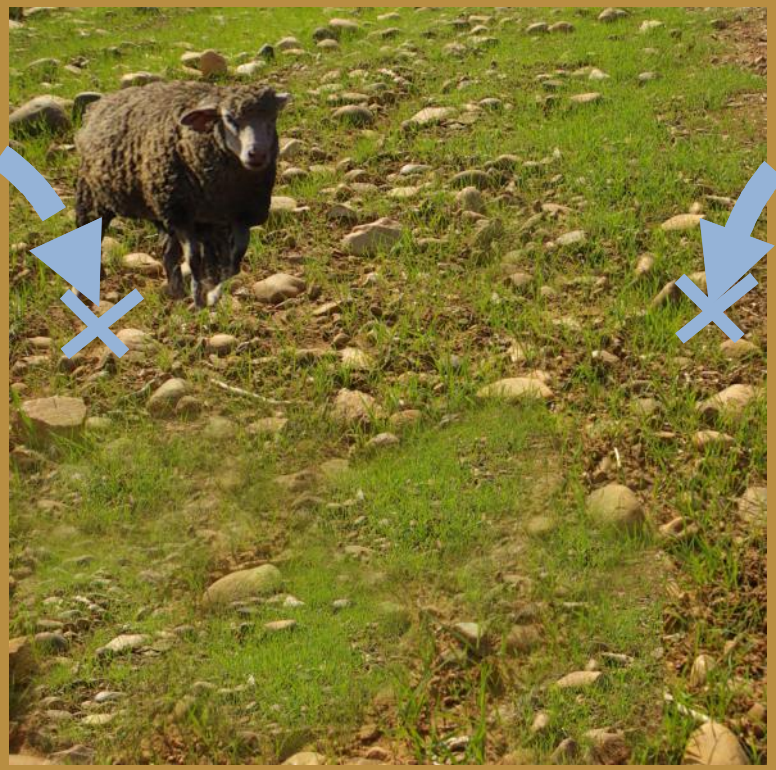

Non-target species

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Non-target species

Target species

Restoration Techniques

Topsoil removal: removing the 20cm upper layer

-removing permanent seed-bank
-lowering soil fertility

Jaunatre R., Buisson E., Dutoit T., 2013. Topsoil removal improves various restoration treatments of a Mediterranean steppe (La Crau, Southeastern France). *Applied Vegetation Science* 17: 236-245.

Restoration Techniques

Hay transfer:

-strengthening dispersion process
-seed gathering by air-vacuum
-spread on the rehabilitated area
-supply of a local species pool

Restoration Techniques

Soil transfer :

-strengthening dispersion process
-gathering + spreading of soil
-supply of a local species seed pool
+ clones
+ microorganisms
-soil dilution

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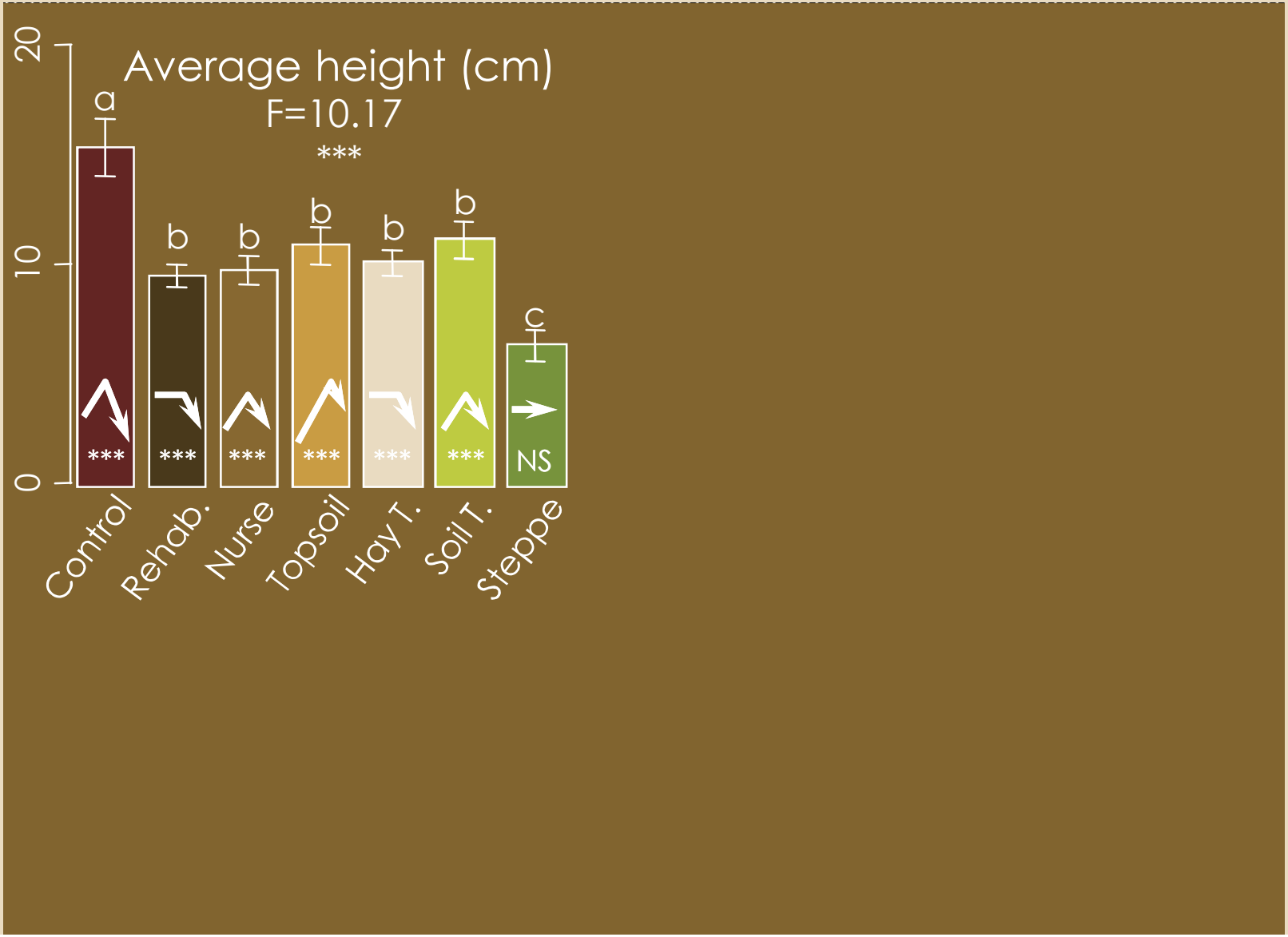
Restoration Techniques

The whole design:
-a trade-off between
price/availibility/expected efficiency
-Nurse species seeding: 60ha
-Hay transfer: 20ha
-Soil transfer: 3ha
-Topsoil removal: 0.5ha

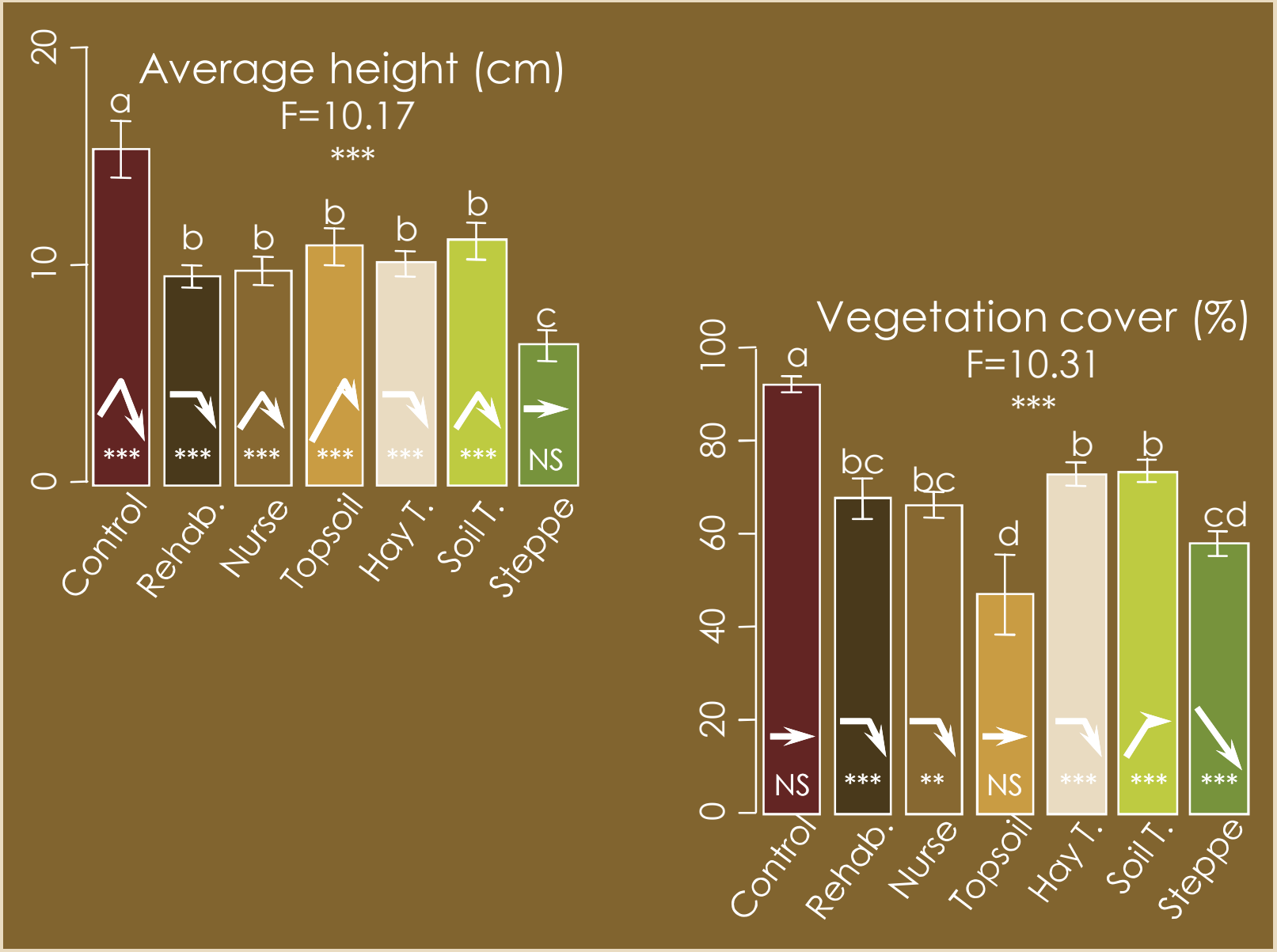
Two 800 sheeps herds on the area:

RESTORATION RESULTS (2012 – 3RD YEAR AND DYNAMIC ↗)



Jaunatre R., Buisson E., Dutoit T. 2012. First-year results of a multi-treatment steppe restoration experiment in La Crau (Provence, France). *Plant Ecology and Evolution* 145: 13-23

RESTORATION RESULTS (2012 – 3RD YEAR AND DYNAMIC ↗)



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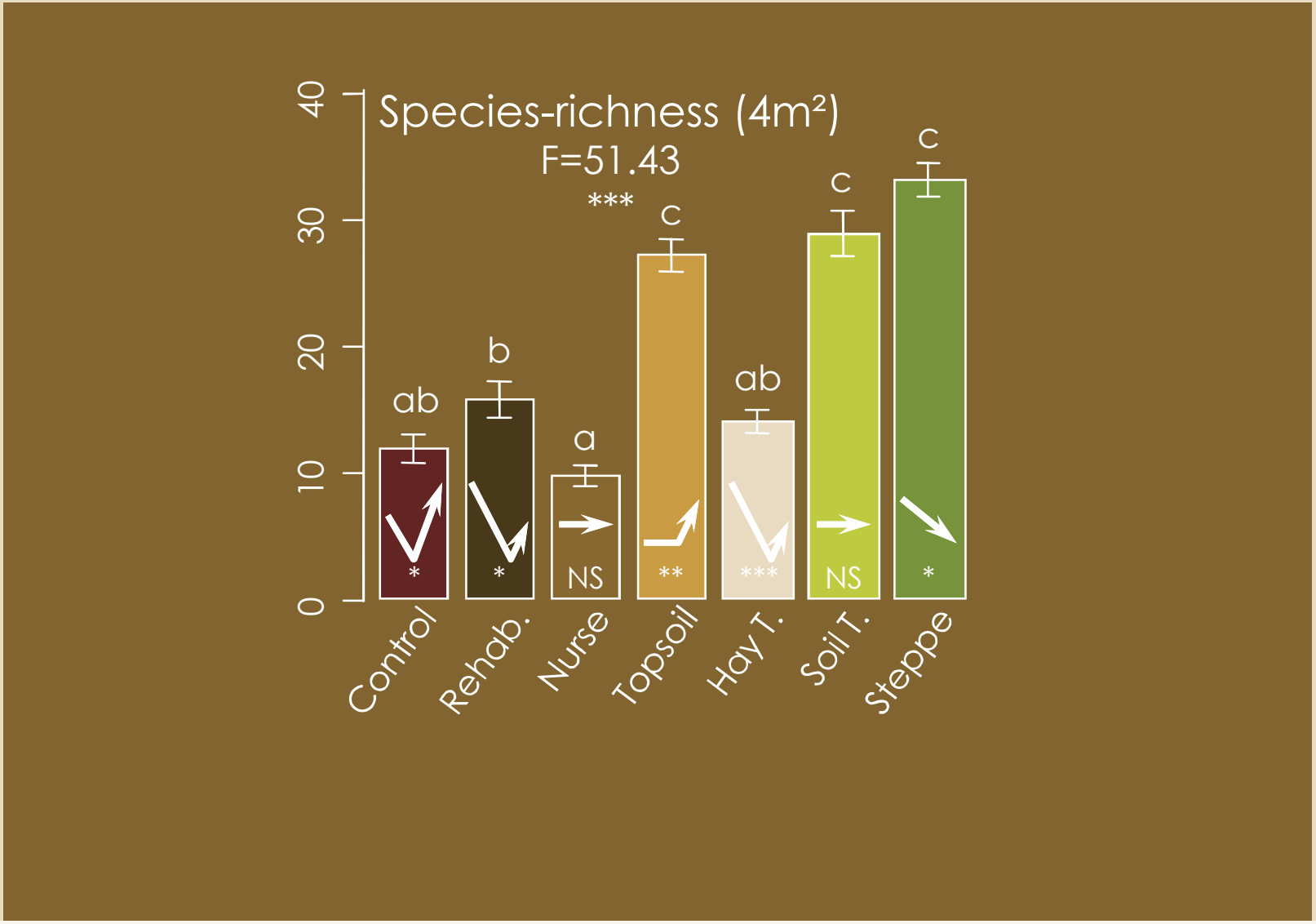

Jaunatre R. Buisson E., Dutoit T. 2014. Can ecological engineering restore Mediterranean rangeland after intensive cultivation? A large-scale experiment in southern France. *Ecological Engineering* 64: 202-212.

Restoration Results (2012 – 3rd Year and dynamic ↗)

Steppe

Control

Stipa capillata
Brachypodium retusum
Poa bulbosa
Lobularia maritima
Evax pygmaea
Brachypodium distachyon
Plantago lagopus
Trifolium scabrum
Sherardia arvensis
Plantago bellardii
Thymus vulgaris
Asphodelus ayardii
Sanguisorba minor
Trifolium stellatum
Festuca arundinacea
Lolium perenne
Cardamine hirsuta
Crepis sancta
Bromus diandrus
Bromus madritensis
Avena barbata
Carduus pycnocephalus
Trifolium campestre
Galactites elegans

NMDS axis 2: 1.5, 1.0, 0.5, 0.0, -0.5
NMDS axis 1: -1.5, -0.5, 0.0, 0.5, 1.5

Restoration Results (2012 – 3rd Year and dynamic ↗)

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Control

Rehabilitated area

NMDS axis 2: 1.5, 1.0, 0.5, 0.0, -0.5
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Restoration Results (2012 – 3rd Year and dynamic ↗)

Topsoil removal

Steppe

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Rehabilitated area

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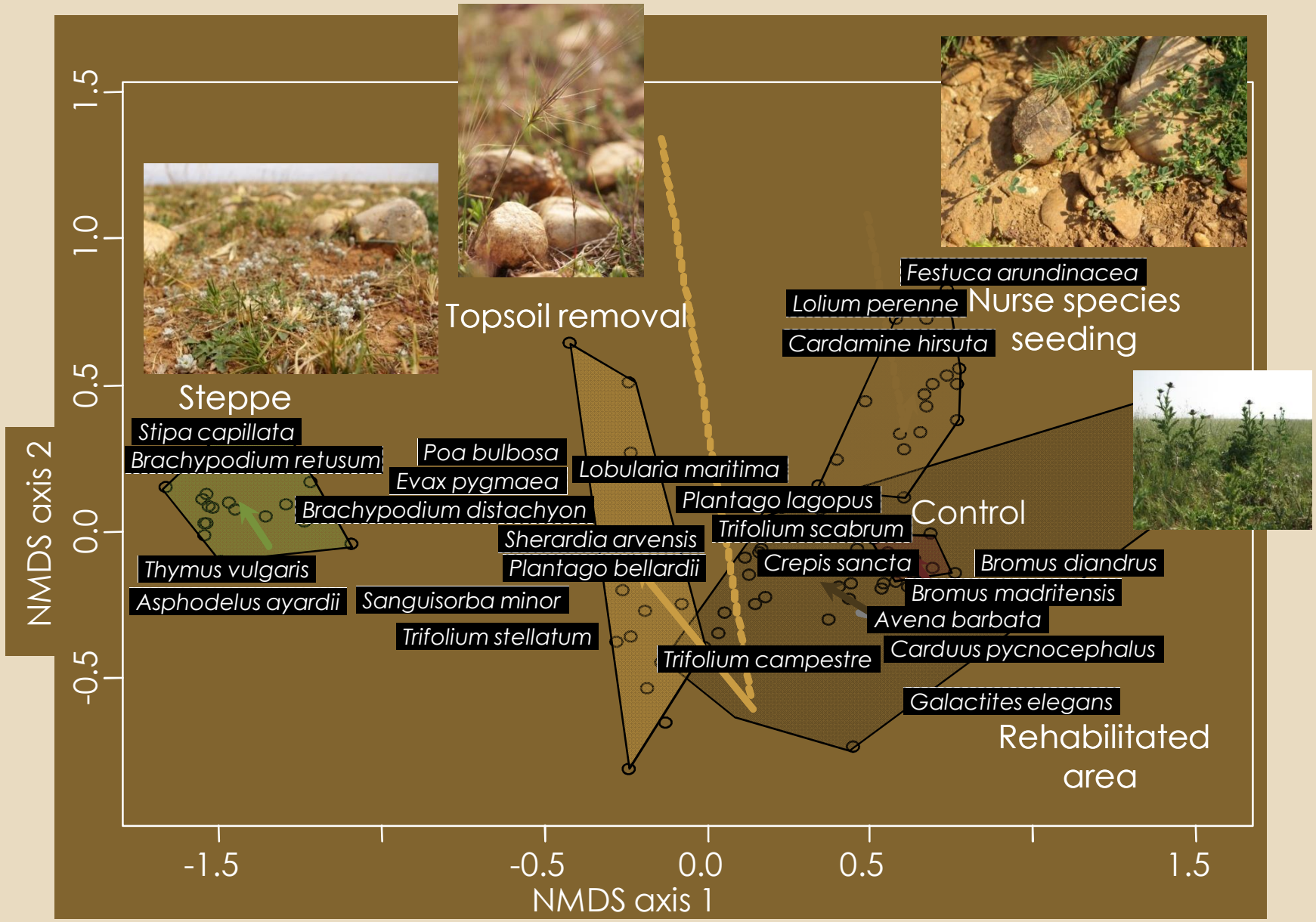

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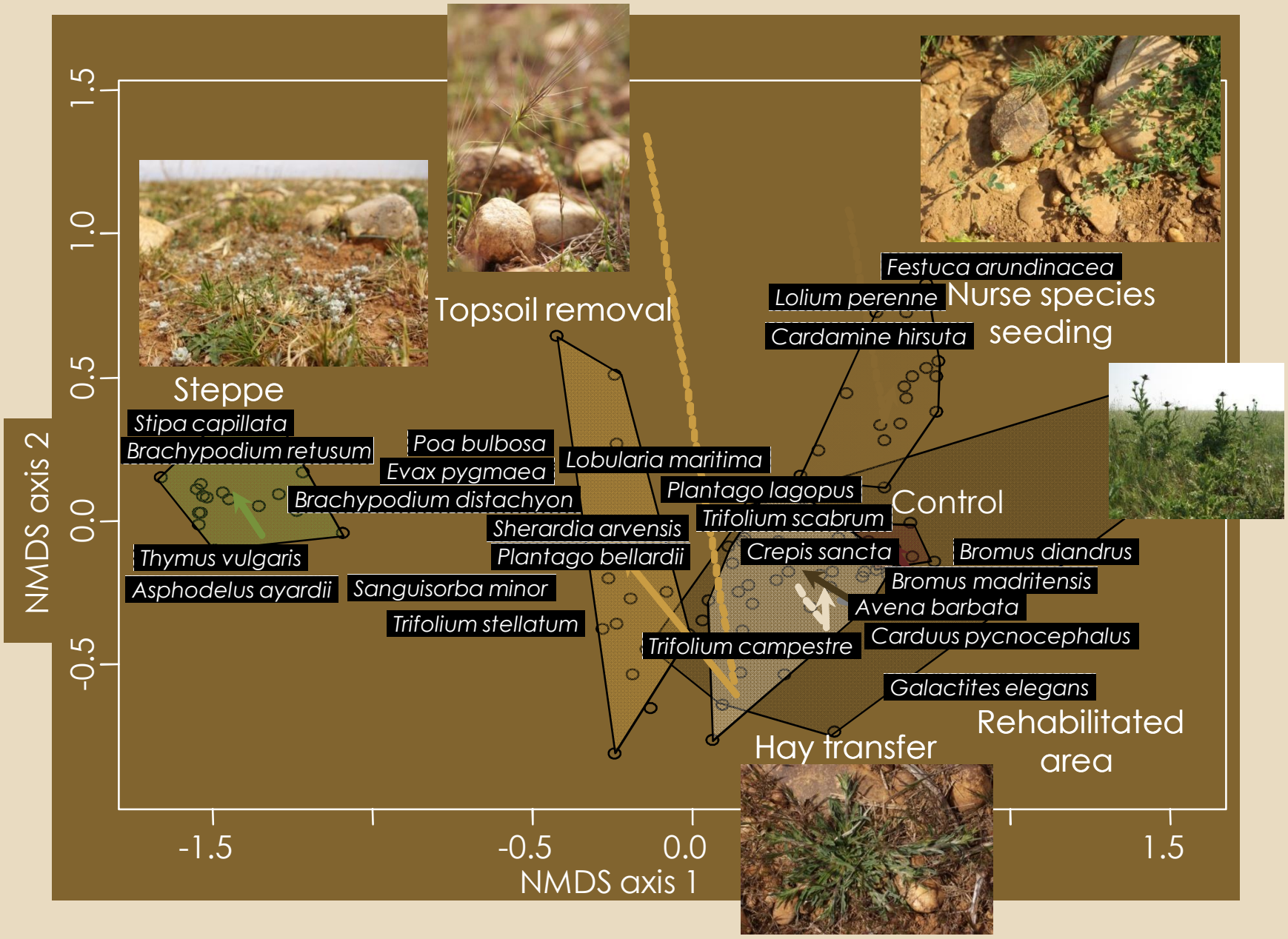

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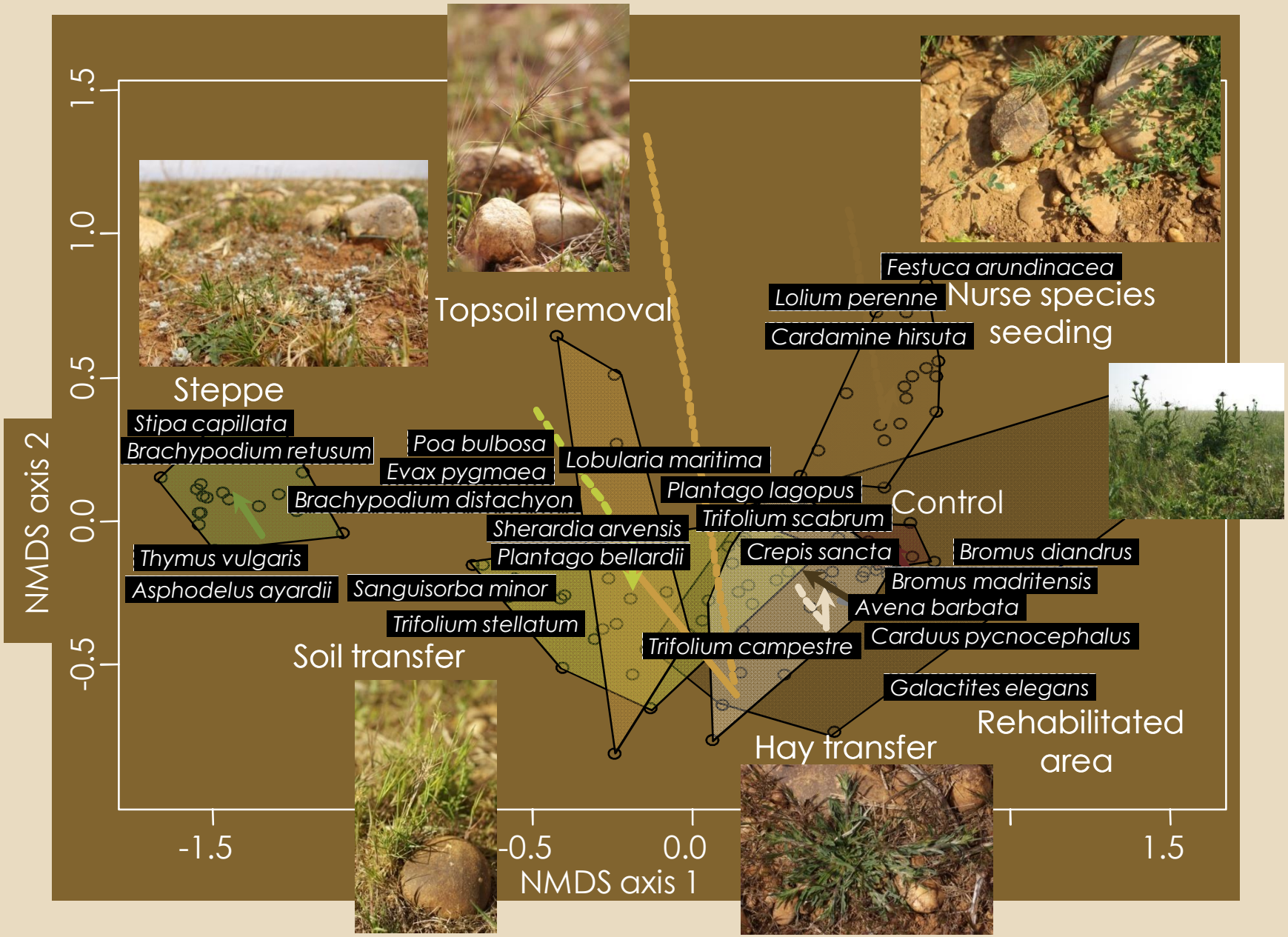

Restoration - Discussion

First years:

-The more the dispersion is strengthened the more the community is restored

Further years:

-The more the environmental conditions are rehabilitated the more the communities are getting closer to the reference

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The ranking of best restoration techniques would be:

1-Soil transfer**
2-Topsoil removal
3-Hay transfer
4-Nurse species seeding**

Jaunatre R. Buisson E., Muller I. Morlon H., Mesléard F, Dutoit T. 2013. New synthetic indicators to assess community resilience and restoration success. *Ecological Indicators* 29: 468-477.

The La Crau Area

Study area

In 2009, the steppe of La Crau → 5.5 ha impacted by a pipeline leak

= a petrol leak of 4700m^3 on the soil surface, undergound and water table

Soil depollution:

- Excavation and remove of the polluted soil (≈ 40cm of depth)

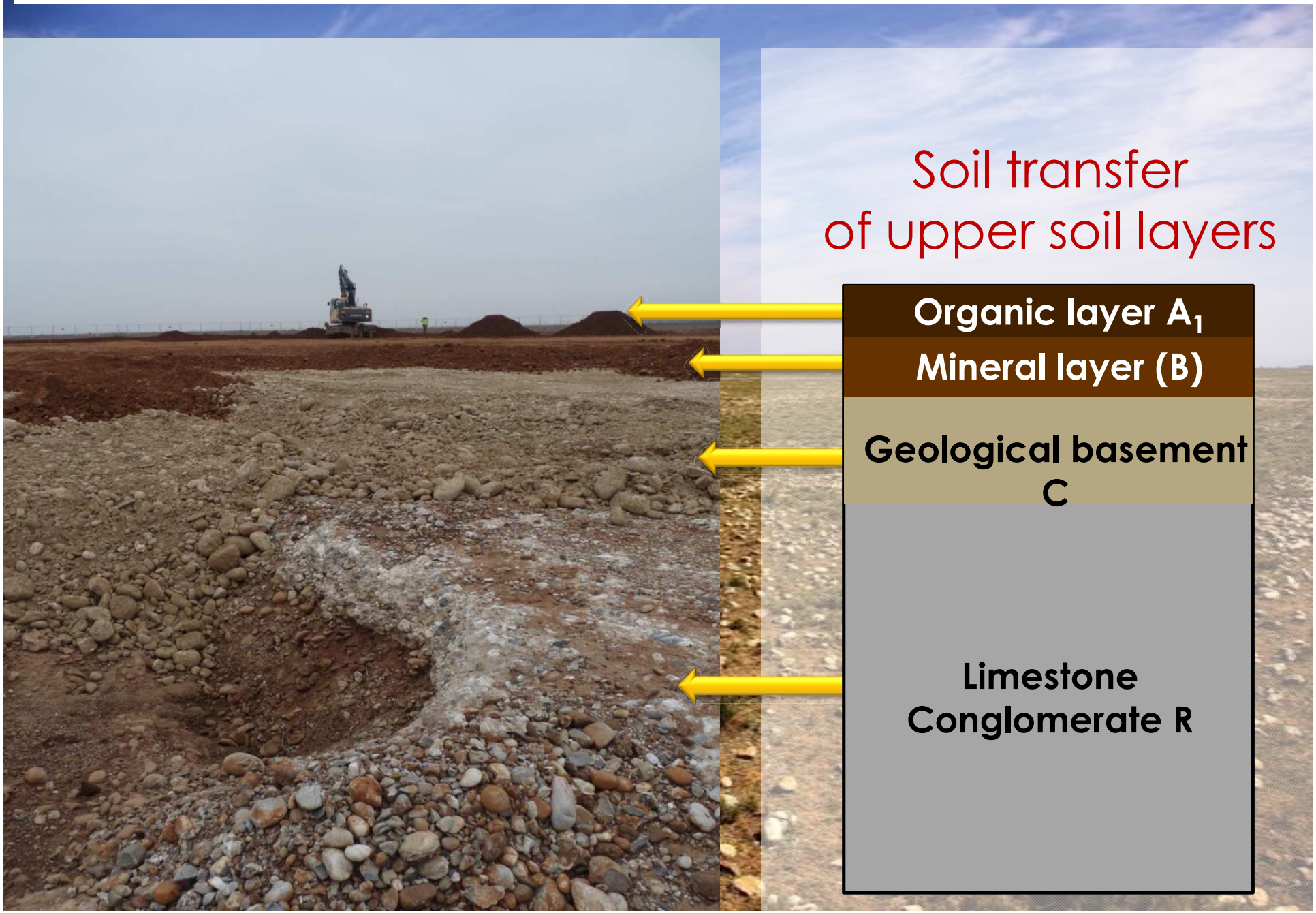
→ 72 000t of polluted soil removed to a specialised dump

Ecological restoration:

→ Study of resilience by a soil transfer

<u>Play on filters</u>
- biotics
- abiotics

Soil transfer: Organisation of the upper soil layers



Soil transfer (January to end of April 2011)

Soil Transfercoming from the intact reference ecosystem

(authorized extension of a nearby quarry before the accident)

Without storage

Spring

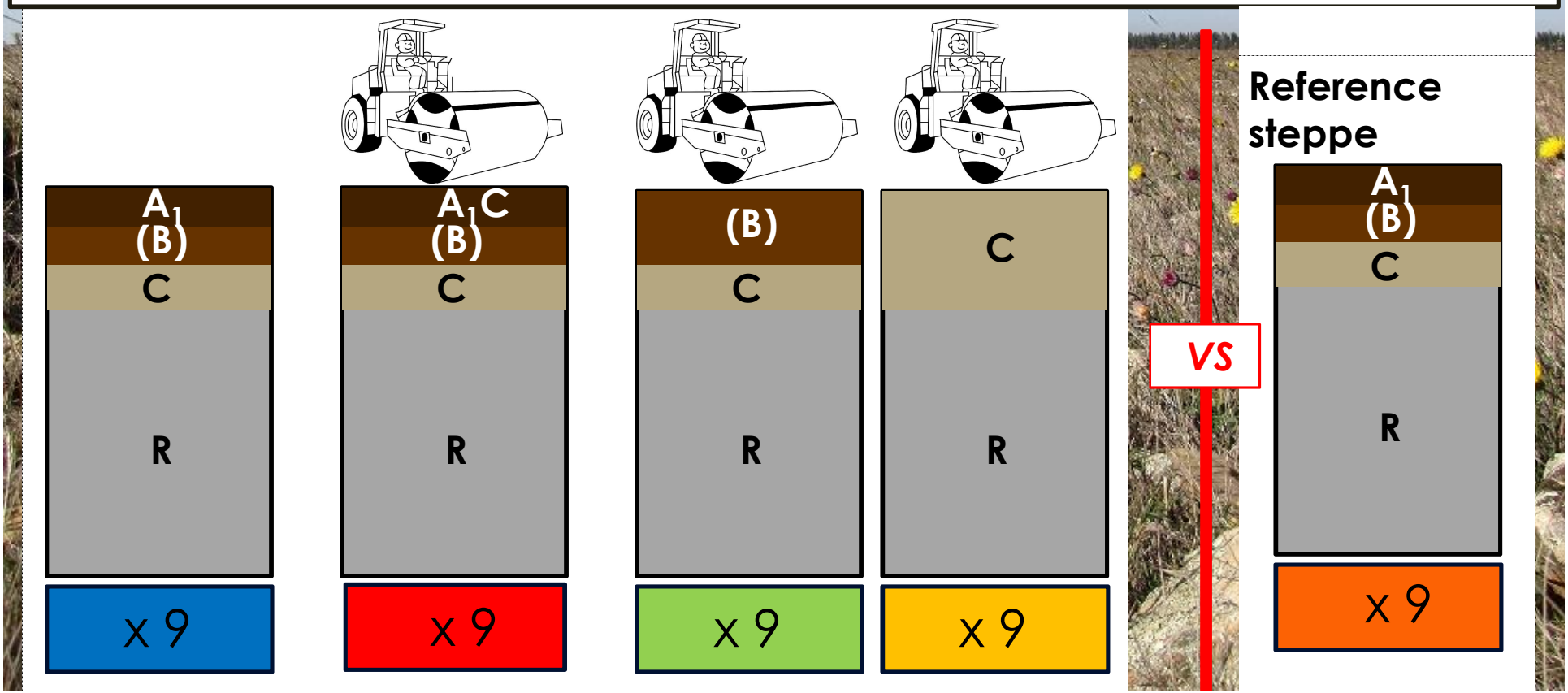
Ratio 1:1

Soil transfer of upper soil layers

Test: Soil transfer of the upper soil layers

→ How plant communities regenerate according various experiments on the soil vertical reconstruction?

- 45 squares (2m x 2m):



Aerial photograph of the site – Summer 2011

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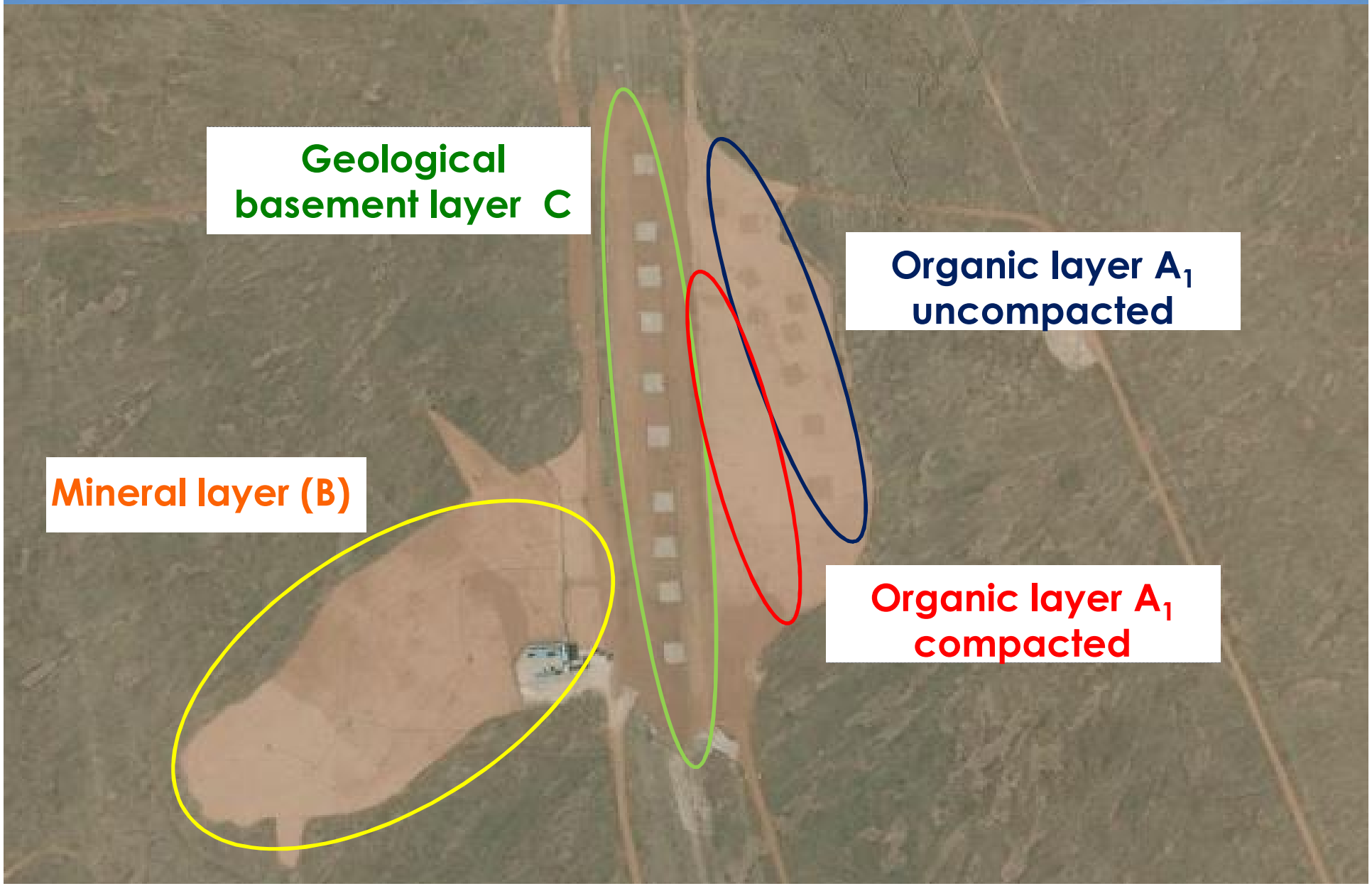


Aerial photograph of the site – Spring 2013

Vegetation analyses

After 3 years – Spring 2013

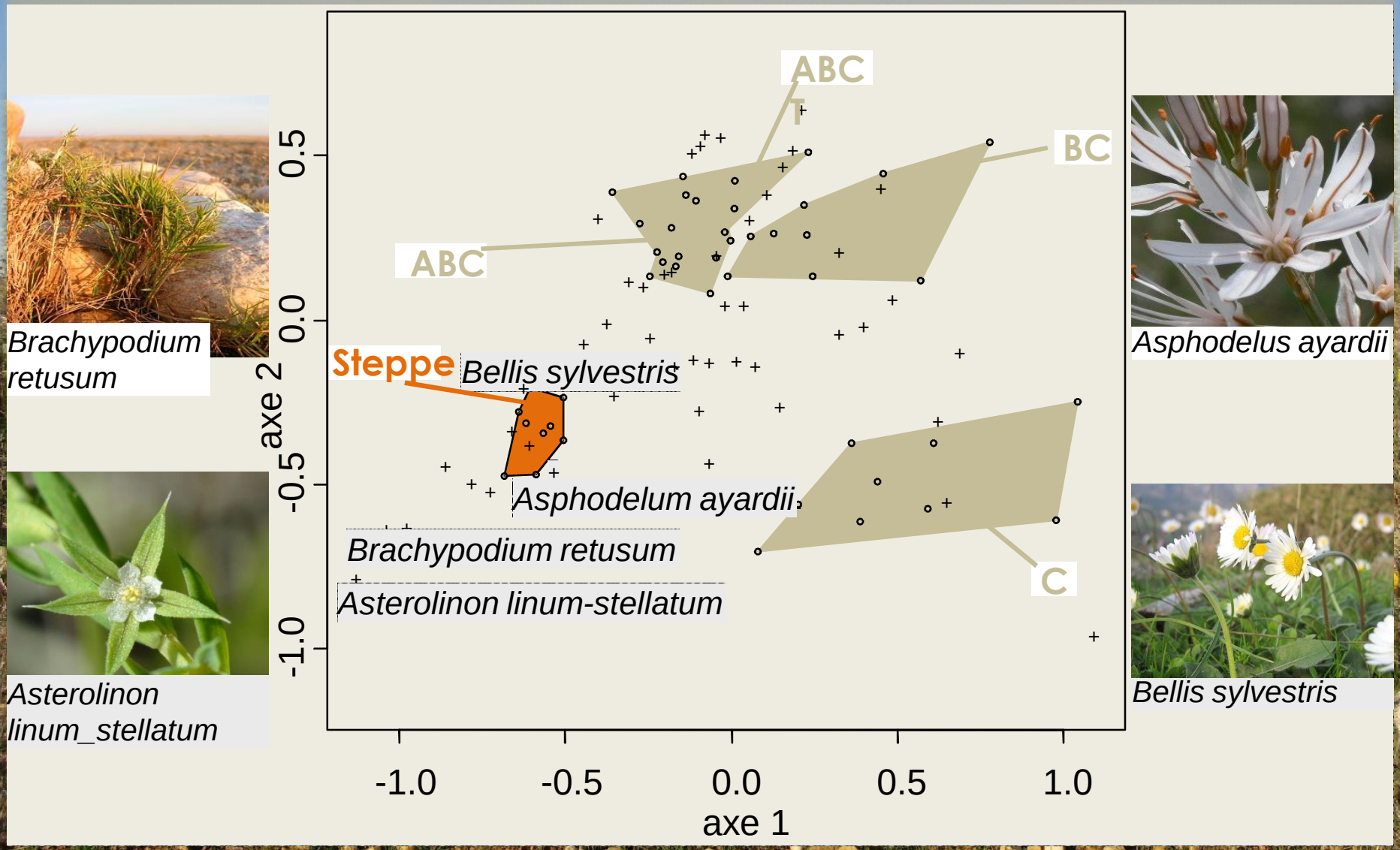
NMDS

Brachypodium retusum

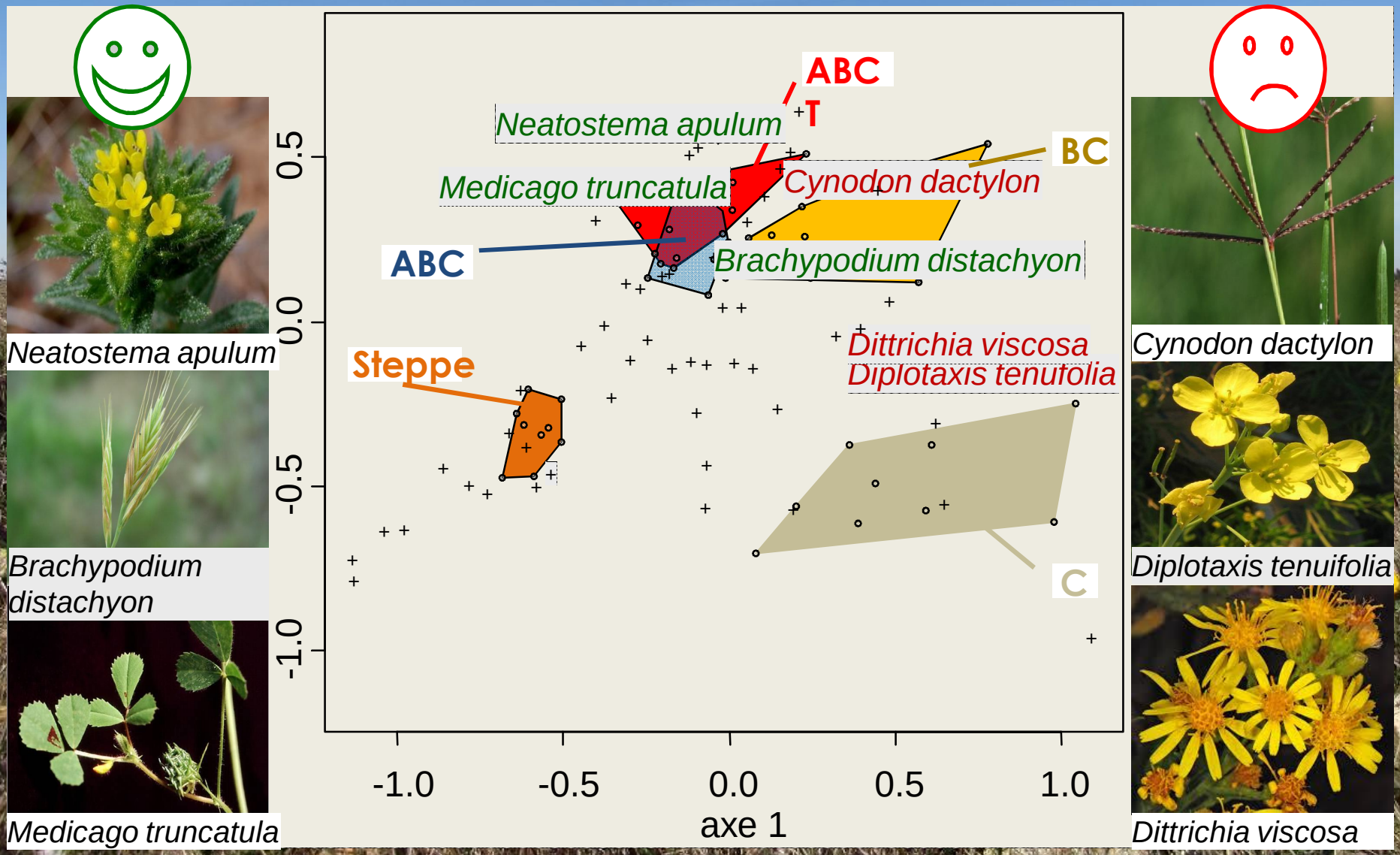
Asterolinon linum_stellatum

Asphodelus ayardii

Bellis sylvestris



NMDS



Neatostema apulum

Brachypodium distachyon

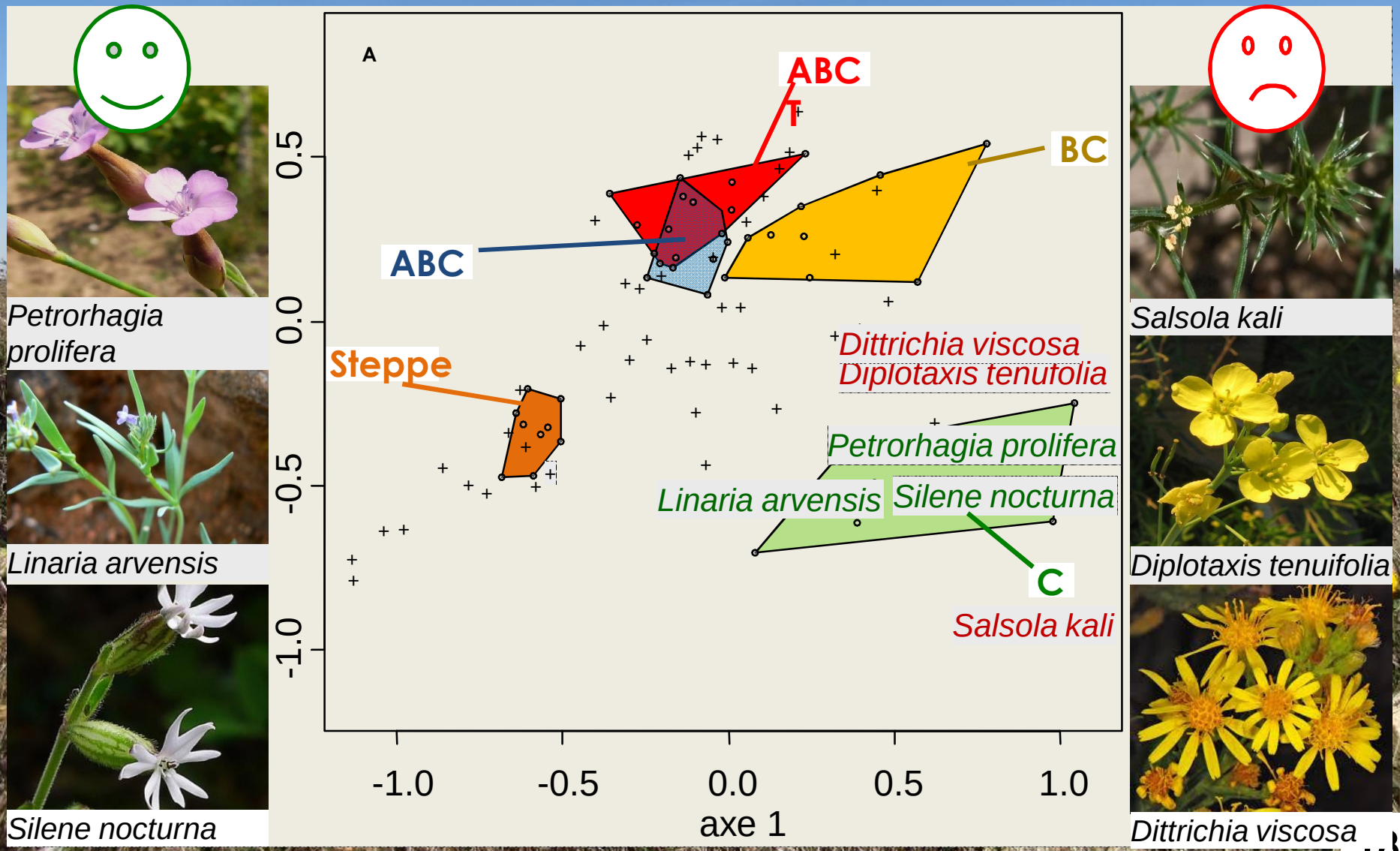
Medicago truncatula

Cynodon dactylon

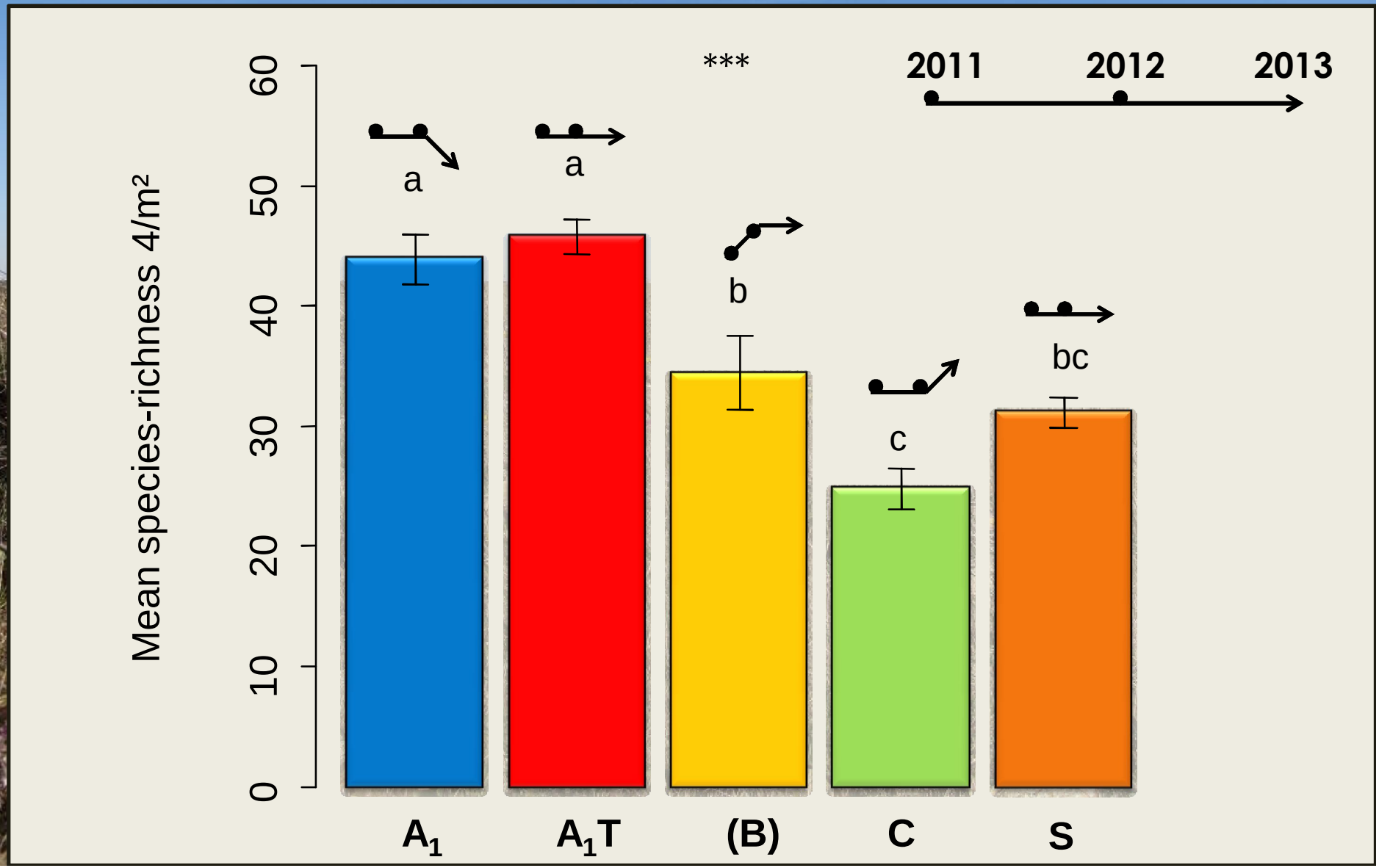
Diplotaxis tenuifolia

Dittrichia viscosa

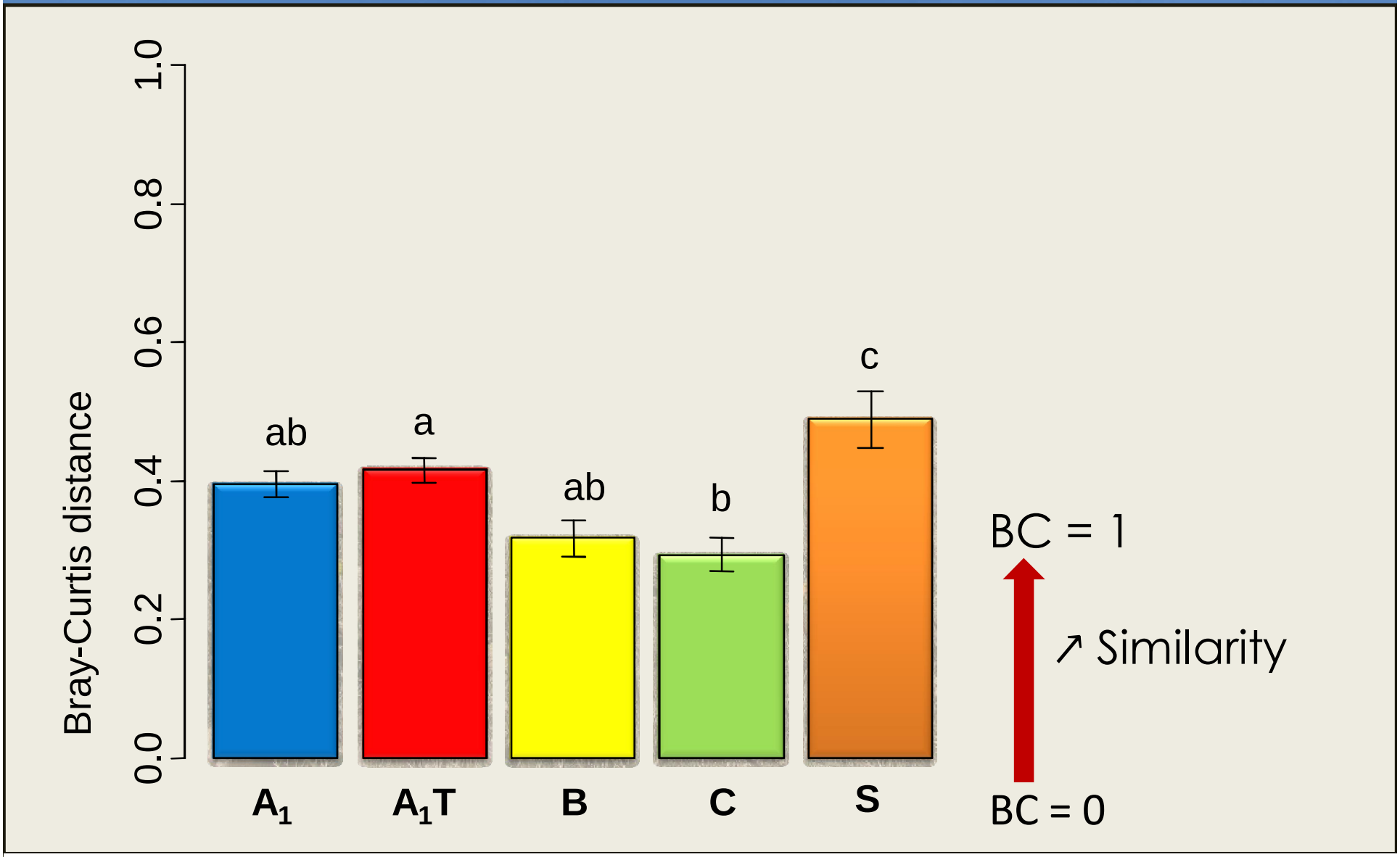
NMDS


A
ABC
T
BC
ABC
Steppe
Dittrichia viscosa
Diplotaxis tenuifolia
Petrorhagia prolifera
Linaria arvensis
Silene nocturna
C
Salsola kali
0.5
0.0
-0.5
-1.0
-1.0
-0.5
0.0
0.5
1.0
axe 1
Petrorhagia prolifera
Linaria arvensis
Silene nocturna
Salsola kali
Diplotaxis tenuifolia
Dittrichia viscosa

Species-richness (alpha diversity)



Similarity (beta diversity)



Bulot A., Provost E., Dutoit T., 2014. A comparison of different soil transfer strategies for restoring a Mediterranean steppe after a pipeline leak (La Crau plain, South-Eastern France). *Ecological Engineering* 71: 690-702.

Perspectives

- Plant community not restored
= Restoration of ecosystem integrity not reached

<u>Next operations:</u>

→ Grazing

→ Ecological engineering

- Using harvester ants to disperse the seeds of the reference steppe to restore the structural similarity

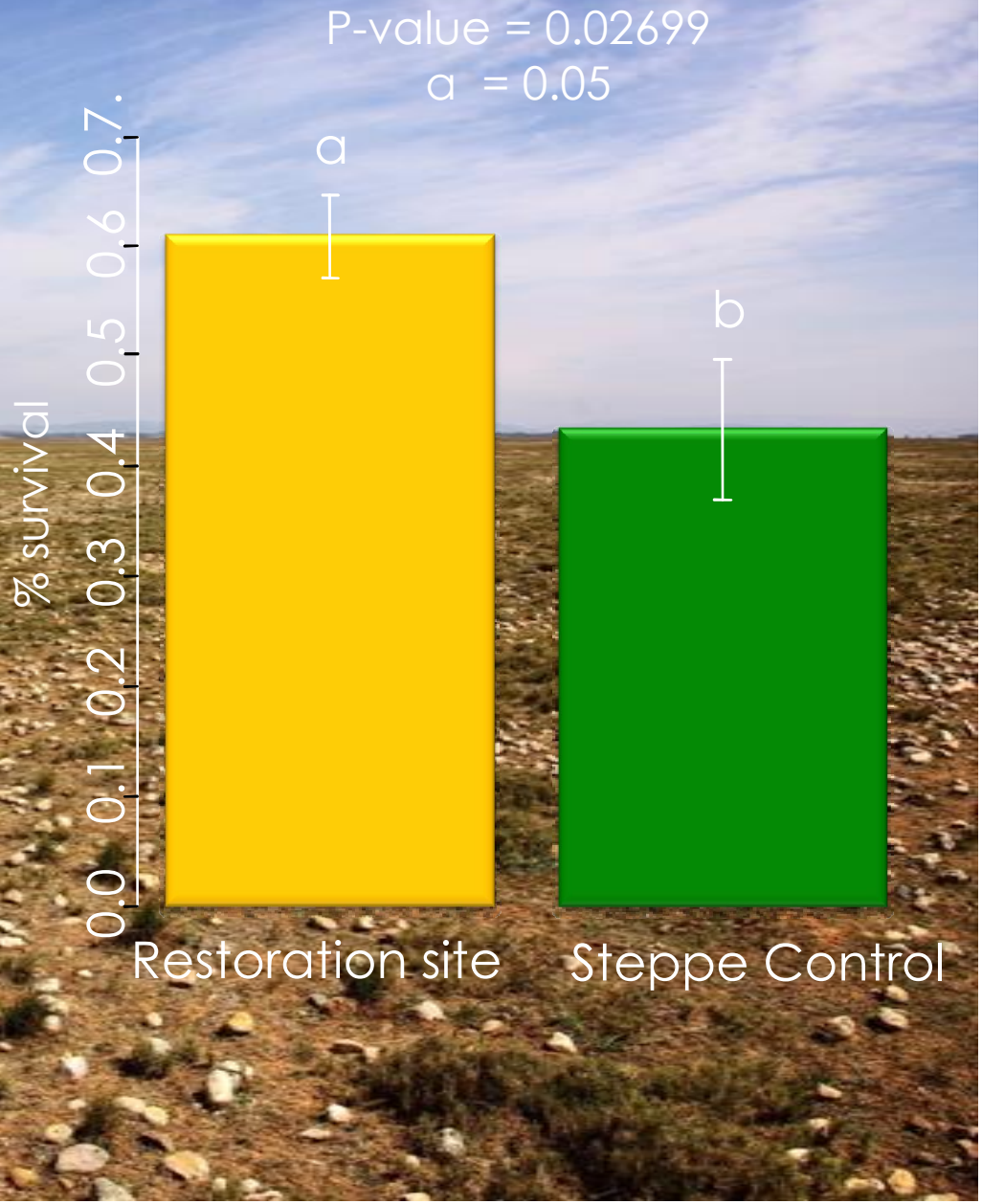
Are ants ecological engineers of the steppe vegetation composition and structure ?

Is it the case of *Messor barbarus* ?

Translocation of funding queens

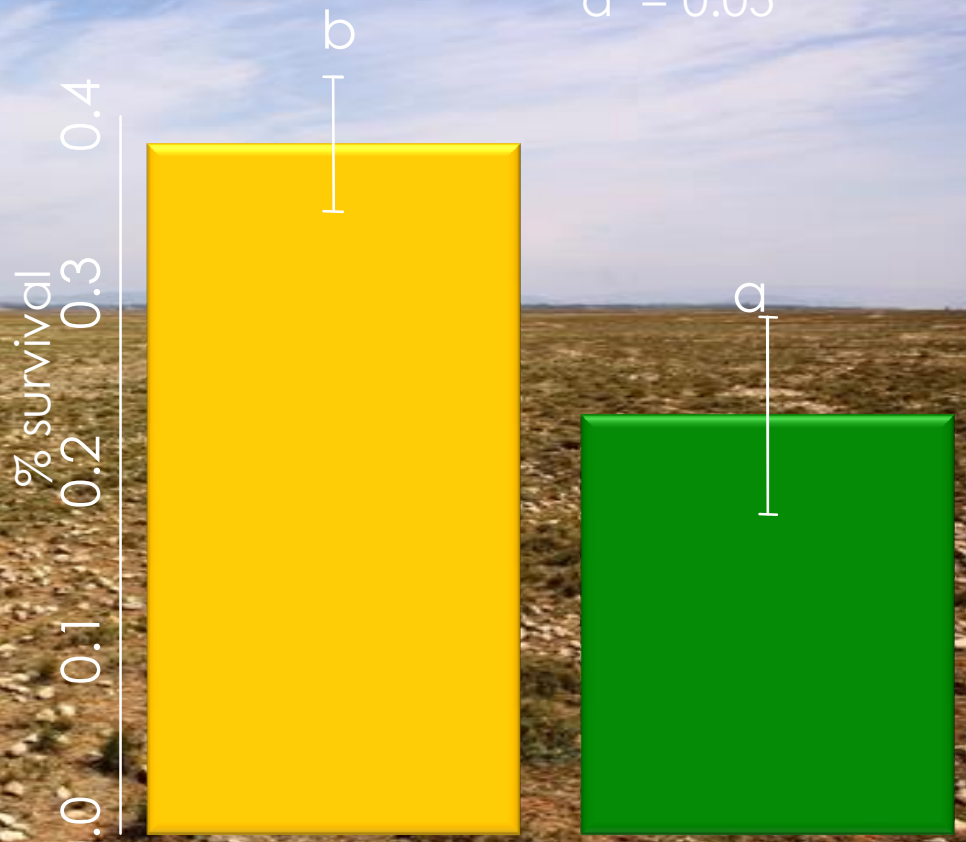
Bulot A., Dutoit T., Rennuci M., Provost E. 2014. A new transplantation protocol for harvester ant queens *Messor barbarus* (Hymenoptera: Formicidae) to improve the restoration of species-rich plant communities in the future. *Myrmecological News* 20:43-52.

% survival in 2012



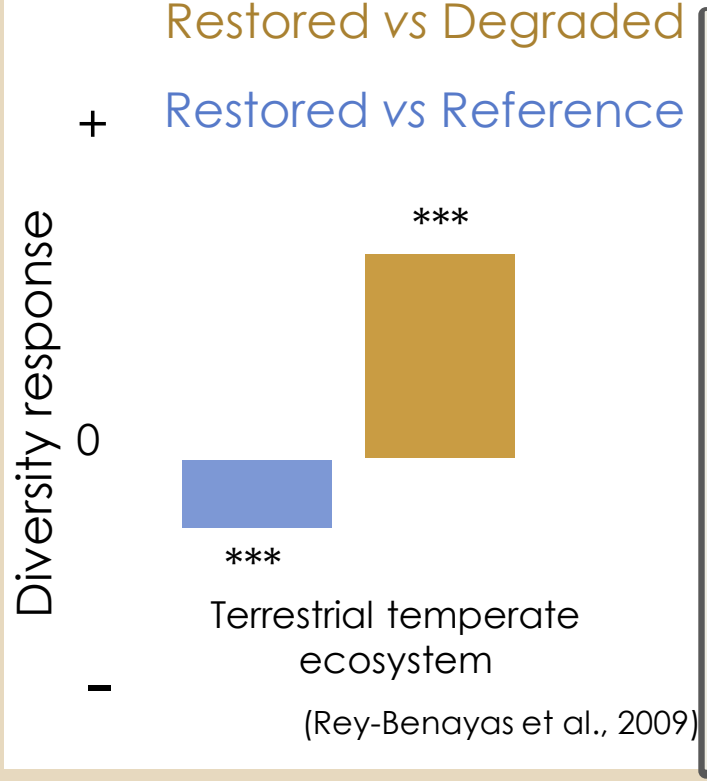
% survival in 2013

P-value = 0.03459
a = 0.05



Conclusion

Encouraging results but not yet restoration *sensu stricto*



Restoration attempt:
richness **O** composition O structure O

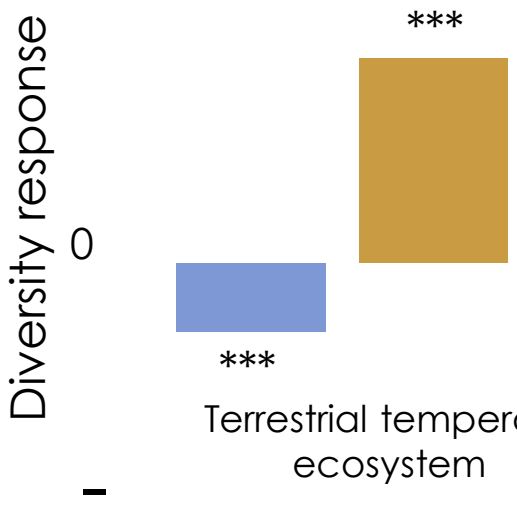
Ecce Homo (Elías García Martínez)

CONCLUSION

Encouraging results but not yet restoration *sensu stricto*

Restored *vs* Degraded

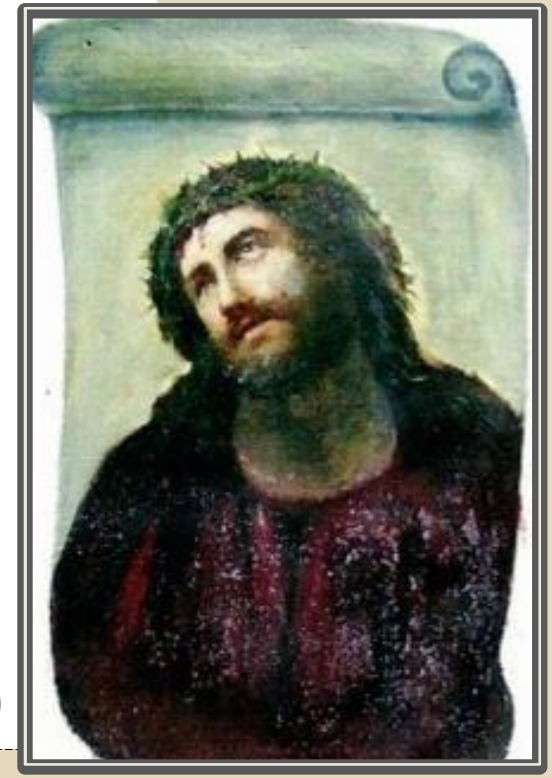
Restored *vs* Reference

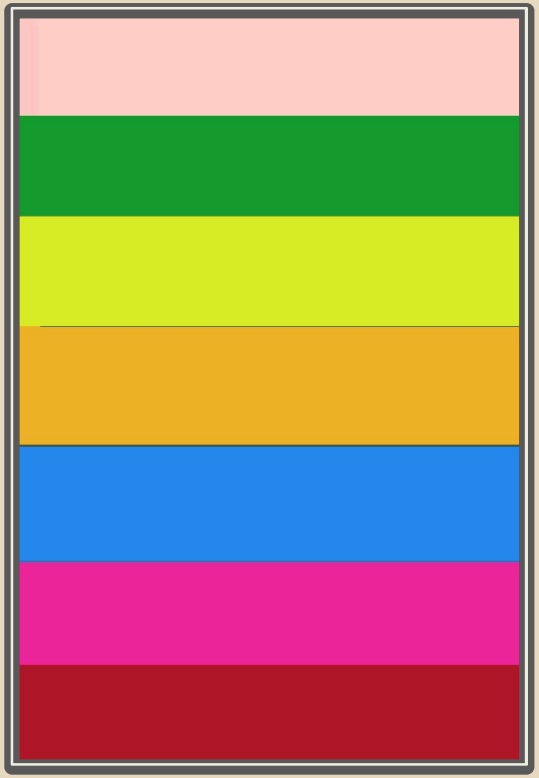


(Rey-Benayas et al., 2009)

Restoration attempt:
richness ã composition O structure O

Ecce Homo (Elías García Martínez)



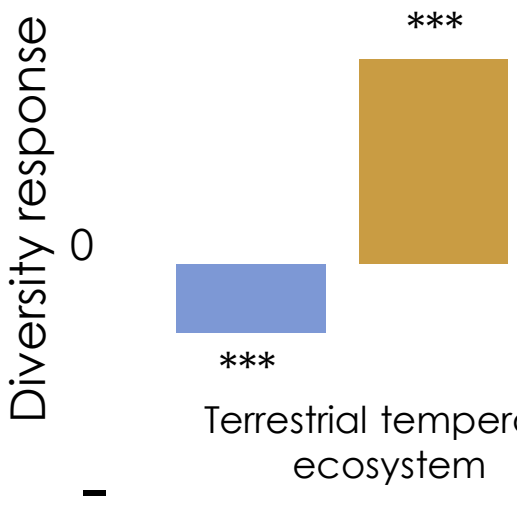


CONCLUSION

Encouraging results but not yet restoration *sensu stricto*

Restored *vs* Degraded

Restored *vs* Reference



(Rey-Benayas et al., 2009)

Restoration attempt:
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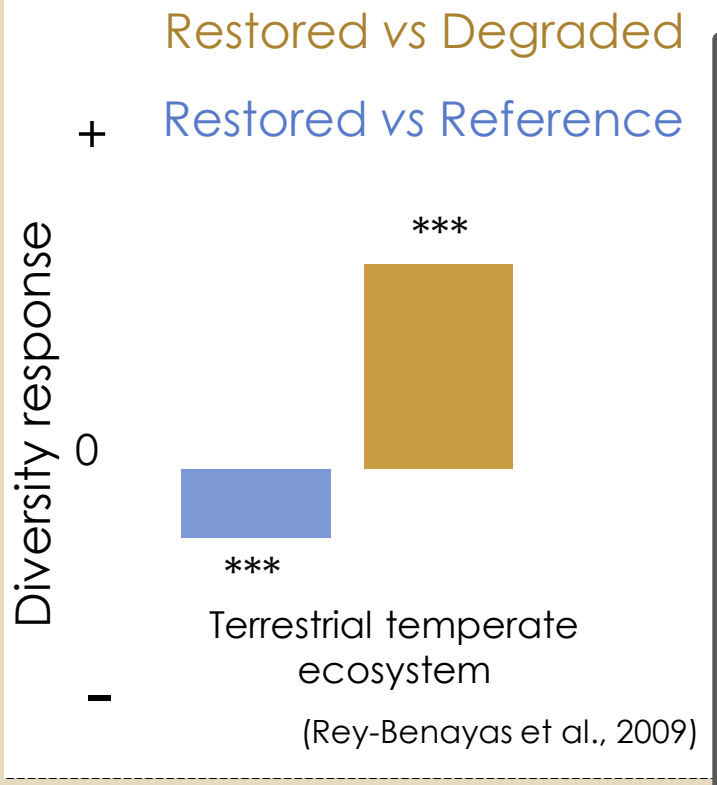
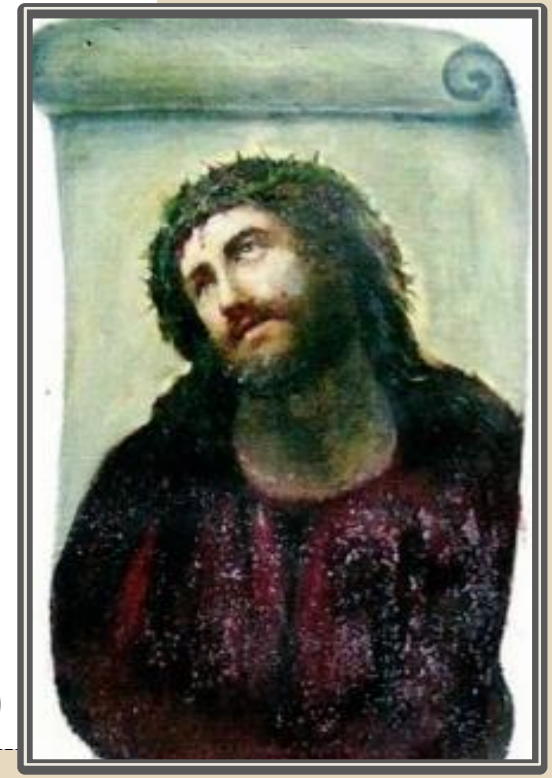
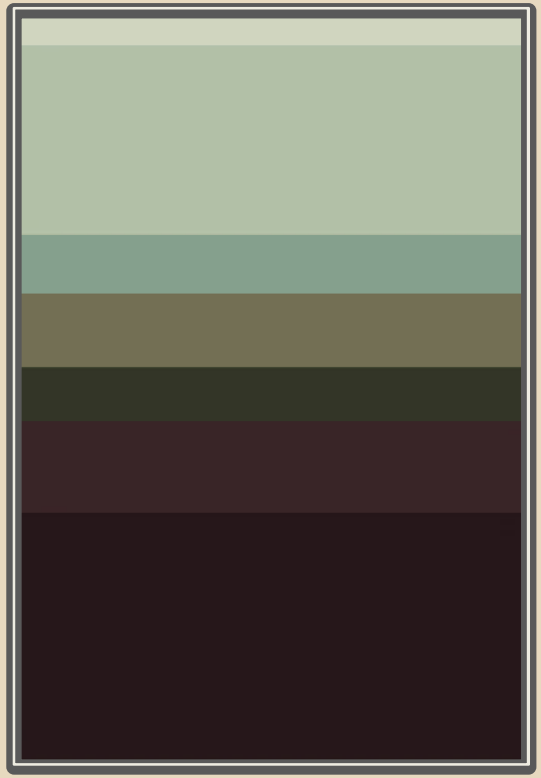


Restoration attempt:
richness ã composition ã structure ~

Ecce Homo (Elías García Martínez)





CONCLUSION

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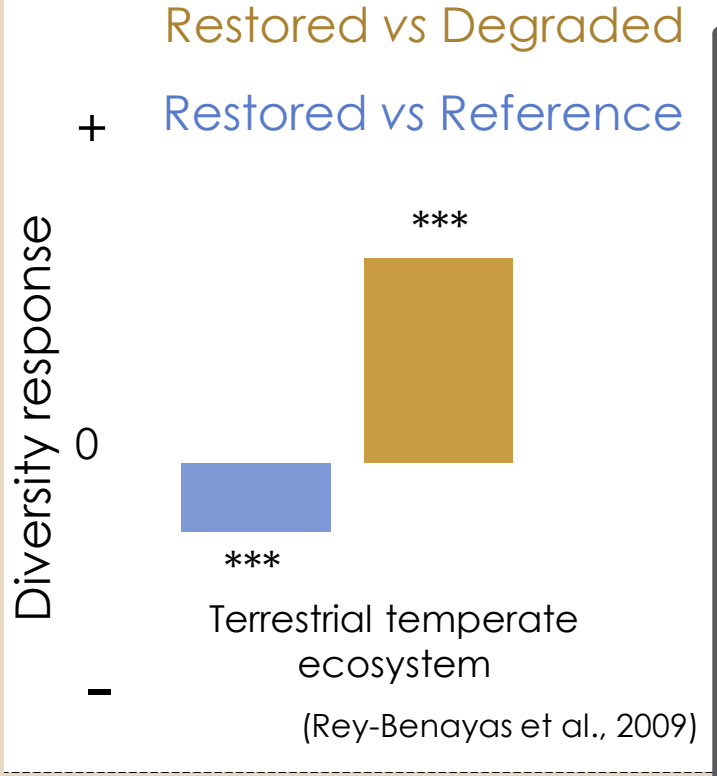

Restoration attempt:
richness ã composition ã structure ~

Ecce Homo (Elías García Martínez)

Conclusion

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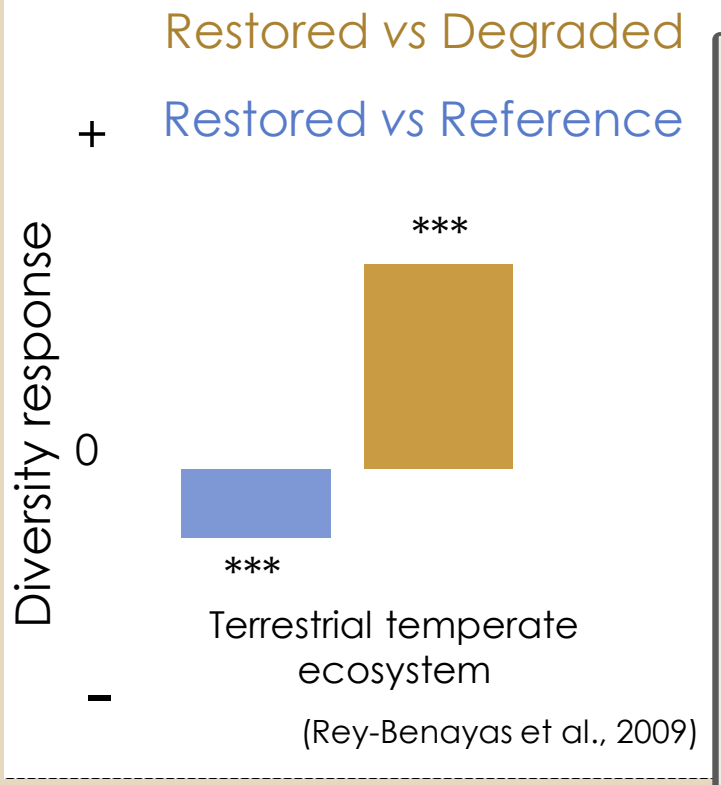
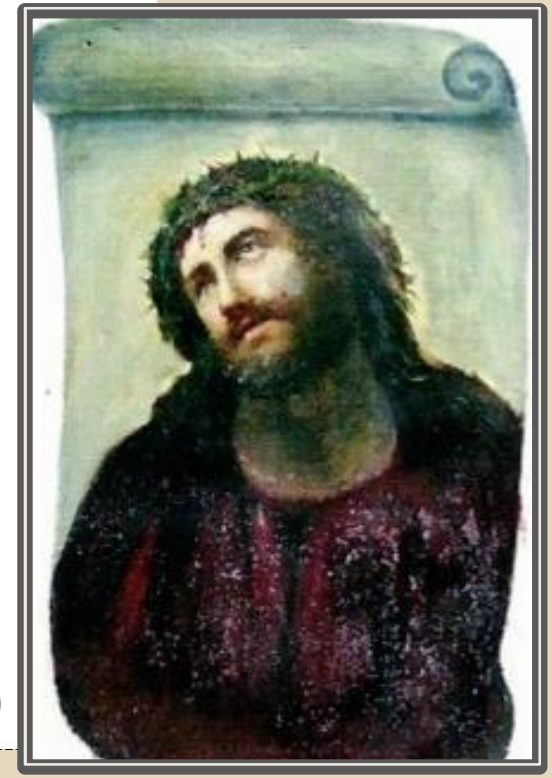


Restoration attempt:
richness ã composition ã structure ~

Ecce Homo (Elías García Martínez)



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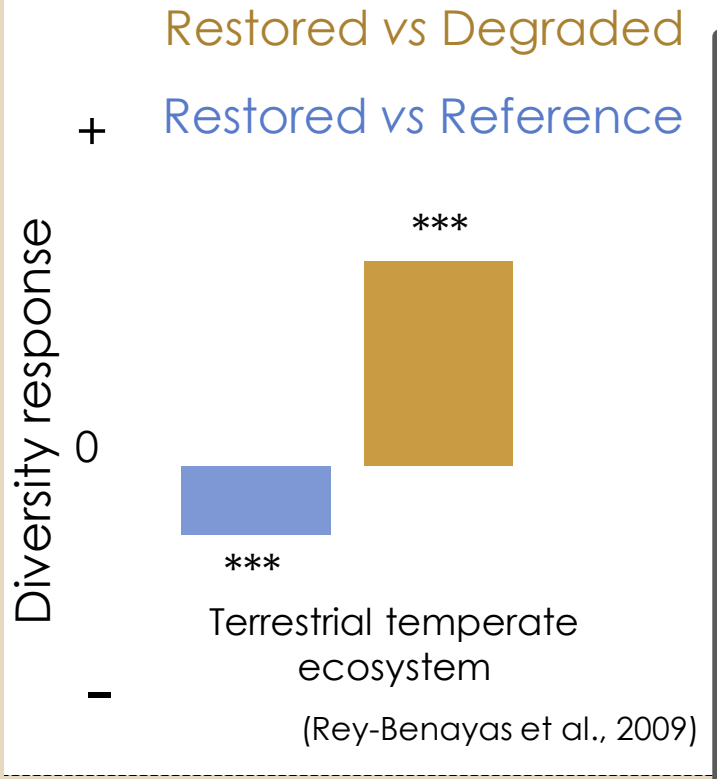
Encouraging results but not yet restoration *sensu stricto*



Restoration attempt:
richness ã composition ã structure ã

Ecce Homo (Elías García Martínez)

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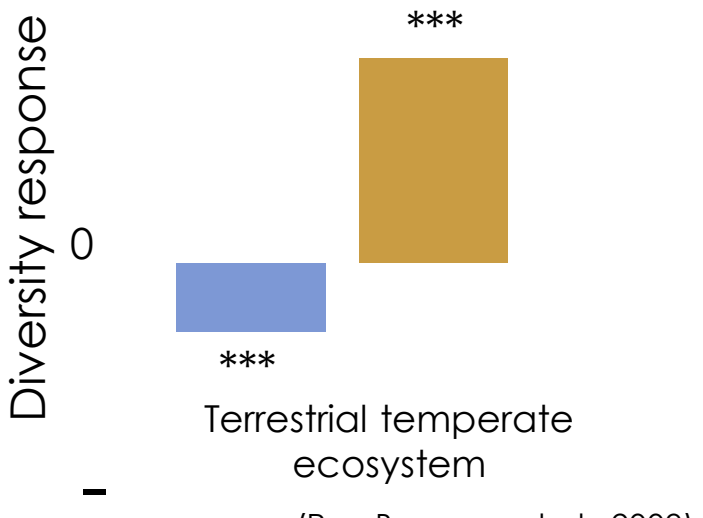
Restored *vs* Degraded

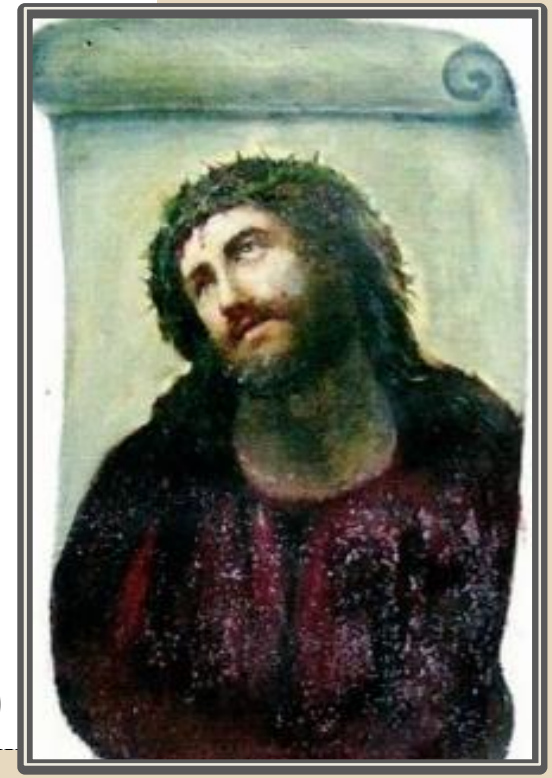
Restored *vs* Reference



(Rey-Benayas et al., 2009)

Restoration attempt:
richness ã composition ã structure ã

Ecce Homo (Elías García Martínez)



Conclusion

Encouraging results b t yet

Restoration attempt:
richness ã composition ã structure ã

Ecce Homo (Elías García Martínez)

Conclusion

Encouraging results b t yet

Restoration attempt:
richness ã composition ã structure ã

Ecce Homo (Elías García Martínez)

Even the worst artistic restoration seems to be closer to the reference that our current best ecological restoration abilities

Conclusion

Encouraging results b t yet

Restoration attempt:
richness ã composition ã structure ã

Ecce Homo (Elías García Martínez)

Even the worst artistic restoration seems to be closer to the reference that our current best ecological restoration abilities

Conservation should still be the priority!

THANKS FOR YOUR ATTENTION