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# A ten years analysis of *Quercus suber* L. afforestation projects in the Mediterranean region of centre-eastern of Portugal

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# Introduction

The aim of this study was to analyze the implementation of the "Afforestation of Agricultural Land" programme (RURIS-AAL) in a Mediterranean region of Portugal, with some desertification problems.

The programme had two monitoring moments, until now:

- Stands establishment stage: during 2000 - 2006
- Stands maintenance stage: 1st during 2006 - 2011.

Based on the data collected during field monitoring campaigns, the possible causes for both successful and unsuccessful afforestation were explored.

# Methods

## Study area

Mediterranean region of centre-eastern of Portugal
BIS - Beira Interior Sul

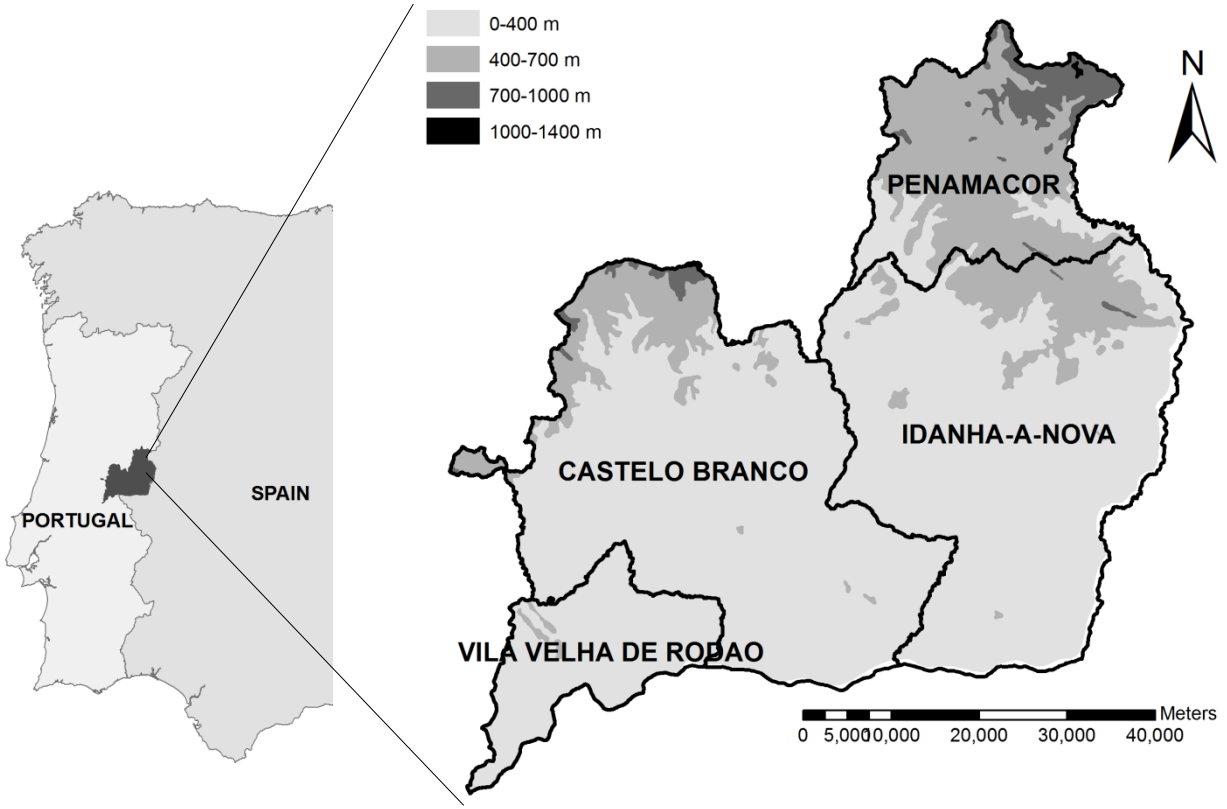



Fig. 1 Study area geographical location

# Data

The information was obtained in 164 afforestation projects established in marginal or abandoned agricultural areas.

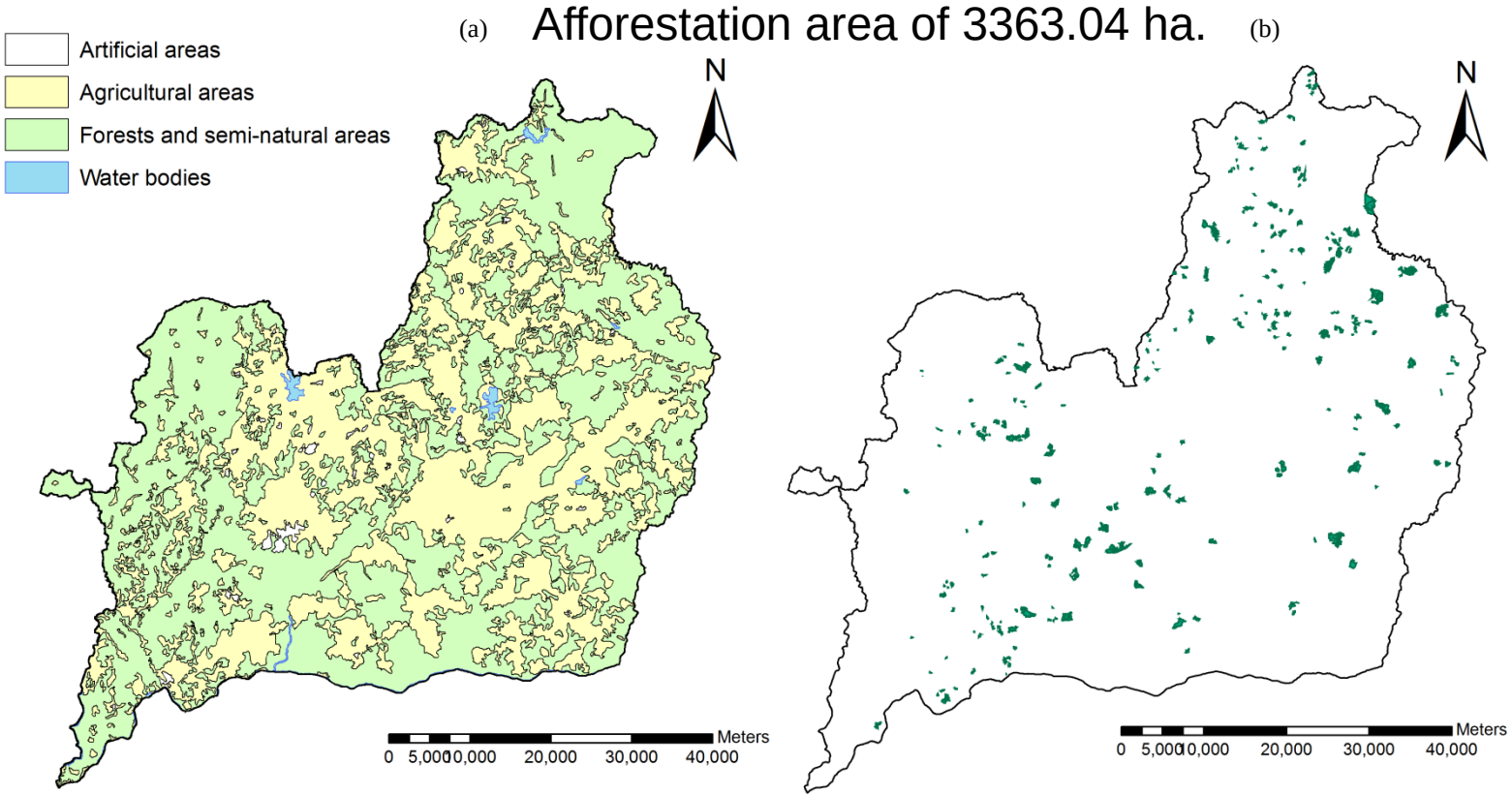



Fig. 2 a) land cover in 2000; b) projects

# Afforestation projects (164)

pure cork oak stands (54%)

mixed stands of cork oak (31%)

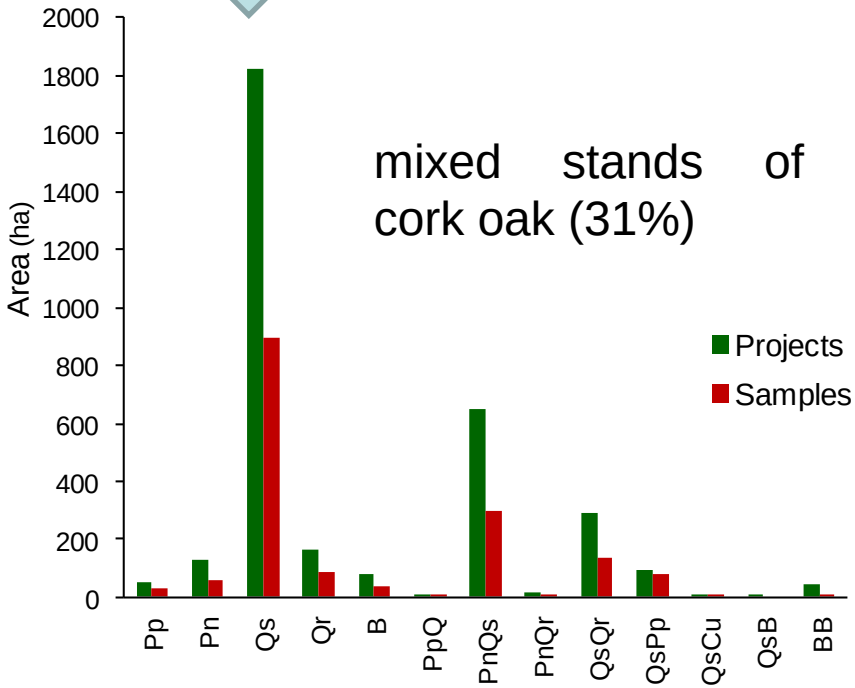



Fig. 3 Species

- Coniferous

Pp - *Pinus pinaster*
Pn - *Pinus pinea*

- Broadleaves

**Qs - *Quercus suber***
Qr - *Quercus rotundifolia*
B - other wood broadleaves (*Fraxinus* sp., *Castanea sativa*, *Juglans nigra*, *Prunus avium*)

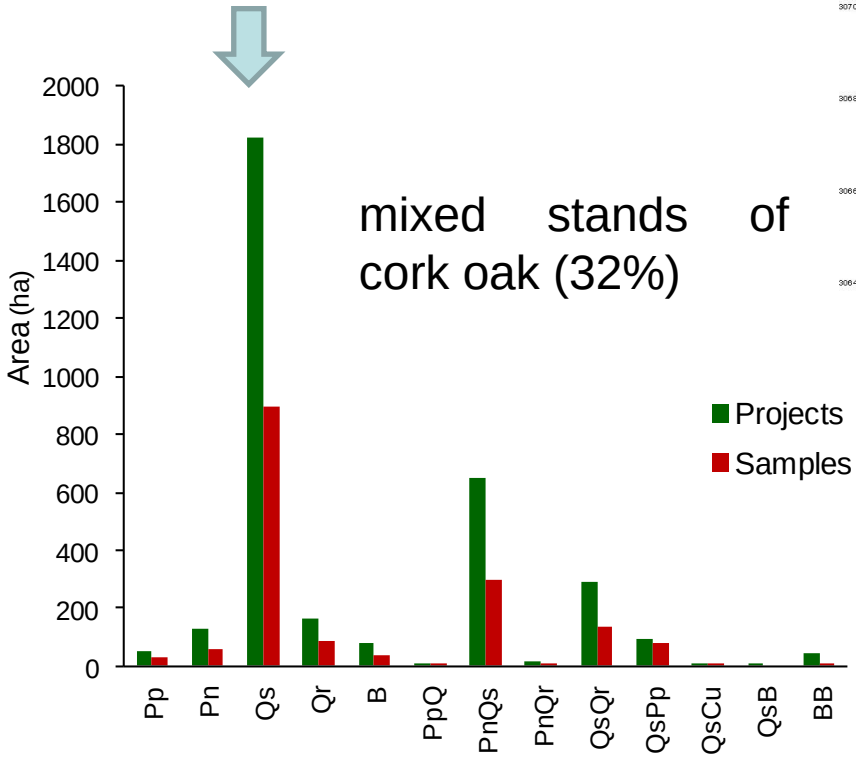
- Mixed

PpQ - *Pinus pinaster* x *Quercus* sp.
**PnQs - *Pinus pinea* x *Quercus suber***
PnQr - *Pinus pinea* x *Quercus rotundifolia*
**QsQr - *Quercus suber* x *Quercus rotundifolia***
QsPp - *Quercus suber* x *Pinus pinaster*
QsCu - *Quercus suber* x *Cupressus sp.*
QsB - mixed of cork oak with broad-leaved
BB - mixed of wood broadleaves

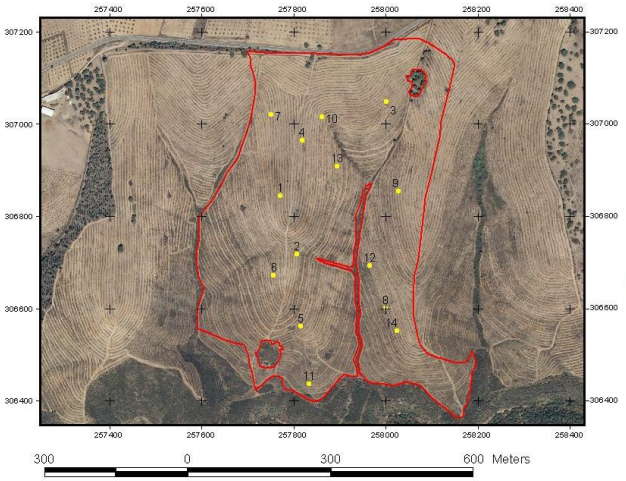
# Field samples (158 – 64 projects)

Field samples: randow sampling; intensity according to project area and site variability (stand density).

pure cork oak stands (48%)




mixed stands of cork oak (32%)




164 - 3363.04 ha
97 - 1640.75 ha

Fig. 4 Projects and field samples

# Information

It was collected information about stand density (*N* – number of trees per ha) to assess if minimum stand density was observed.

And, as well, some additional information concerning to:

- previous land cover,
- stand regeneration,
- site preparation,
- species,
- stand composition,
- elevation,
- soil type and depth,
- individual tree protection,
- fences,
- animal damage

## Table 1 Variables and coding

| Code | Previous Land Cover | Soil type | Soil depth | Altimetry level | Species | Composition | Site preparation | Seedlings protection | Animal damage |
|---|---|---|---|---|---|---|---|---|---|
| 1 | OO | Sa | S | B | Pp | P | MCRB | N | N |
| 2 | NIA | Sc | M | sM | Pn | M | MCS | Y | Y |
| 3 | NG | Gr | D | M | Qs | | MCB | | |
| 4 | F | | | | Qr | | MCHP | | |
| 5 | | | | | B | | NCT | | |
| 6 | | | | | QsQr | | RP | | |
| 7 | | | | | QSPp/PnQs | | RB | | |
| 8 | | | | | PnQr | | S | | |
| 9 | | | | | BB/PpQ | | | | |

Sa - sandstone
Sc - schist
Gr - granite

S - superficial
M - medium
D - deep

P - pure
N - mixed

Y - yes
N - no

OG - olive groves
NIA - non-irrigated arable land
NG - natural grassland
F - forests

B - basal (0-400 m)
sM - sub-montane (400-700 m)
M - montane (700-1000 m)

MCRB - mechanical clearing, ripping and bedding
MCS - mechanical clearing and subsoiling
MCB - mechanical clearing and bedding
MCPH - manual clearing and planting holes
NCT - non-commercial thinning
RP - ripping and plowing
RB - ripping and bedding
S - subsoiling

# Methodology

Field samples - project status
- Regular
- Irregular
  - Lack of minimum stand density
  - Deficiencies meeting management plan goals

Principal Components Analysis (PCA) was used to find out, which variables were the most important on explaining:

- afforestation success (samples with regular status) and
- afforestation success failure (samples with irregular status due to lack of minimum stand density)

and how these variables were correlated.

# Results

## Forest area in BIS region

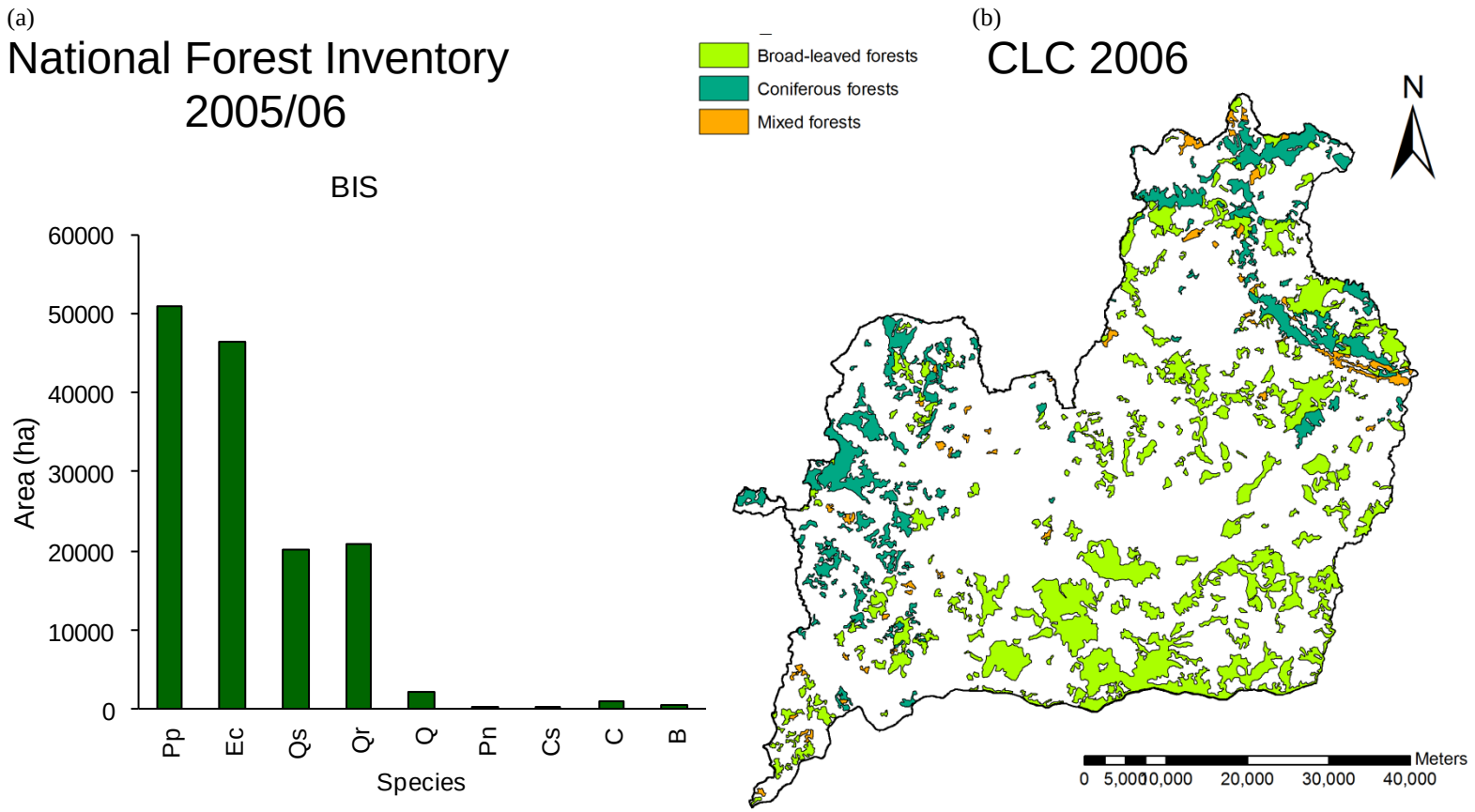



Fig. 5 Forests: a) National Forest Inventory - species areas; b) CLC 2006 - Forests

## Table 2 Afforestation projects

| Previous Land Cover | % | Soil type | % | Soil depth | % | Altimetry level | % | Site preparation | % | Seedlings protection | % | Animal damage | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OO | 5 | Sa | 5 | **S** | **62** | **B** | **60** | **MCRB** | **36.2** | N | 34 | N | 21 |
| NIA | 25 | **Sc** | **71** | M | 32 | sM | 39 | MCS | 0.4 | **Y** | **66** | **Y** | **69** |
| **NG** | **67** | Gr | 24 | D | 2 | M | 2 | MCB | 1.9 | | | | |
| F | 3 | | | | | | | MCHP | 0.2 | | | | |
| | | | | | | | | NCT | 3.0 | | | | |
| | | | | | | | | RP | 7.5 | | | | |
| | | | | | | | | **RB** | **39.5** | | | | |
| | | | | | | | | S | 11.3 | | | | |

OG - olive groves
NIA - non-irrigated arable land
**NG - natural grassland**
F - forests

**S - superficial**
M - medium
D - deep

**MCRB - mechanical clearing, ripping and bedd**ing
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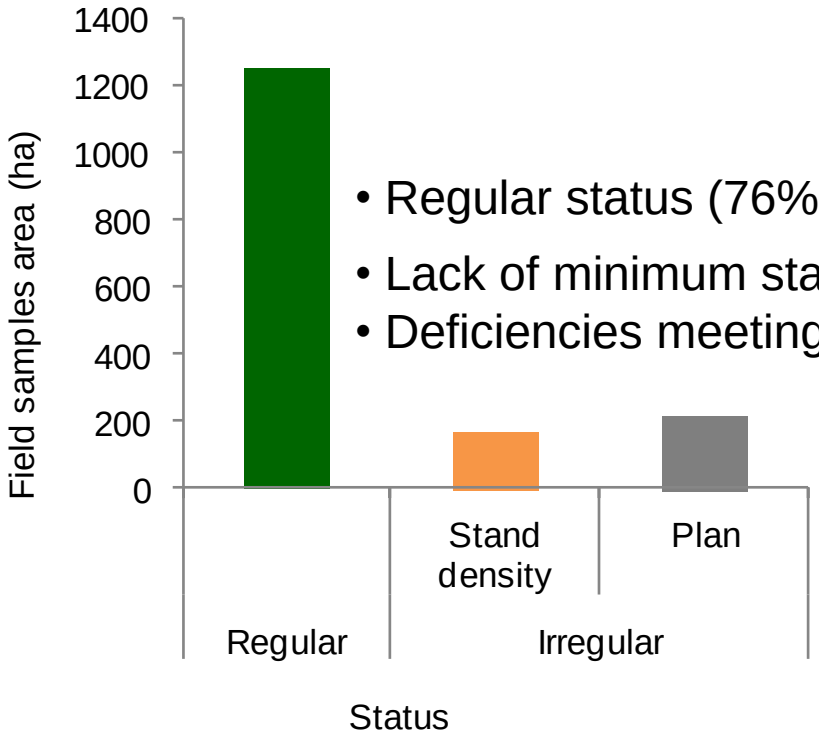



- Regular status (76%)
- Lack of minimum stand density (10%)
- Deficiencies meeting management plan goals (13%)

Fig. 6 Afforestation projects status

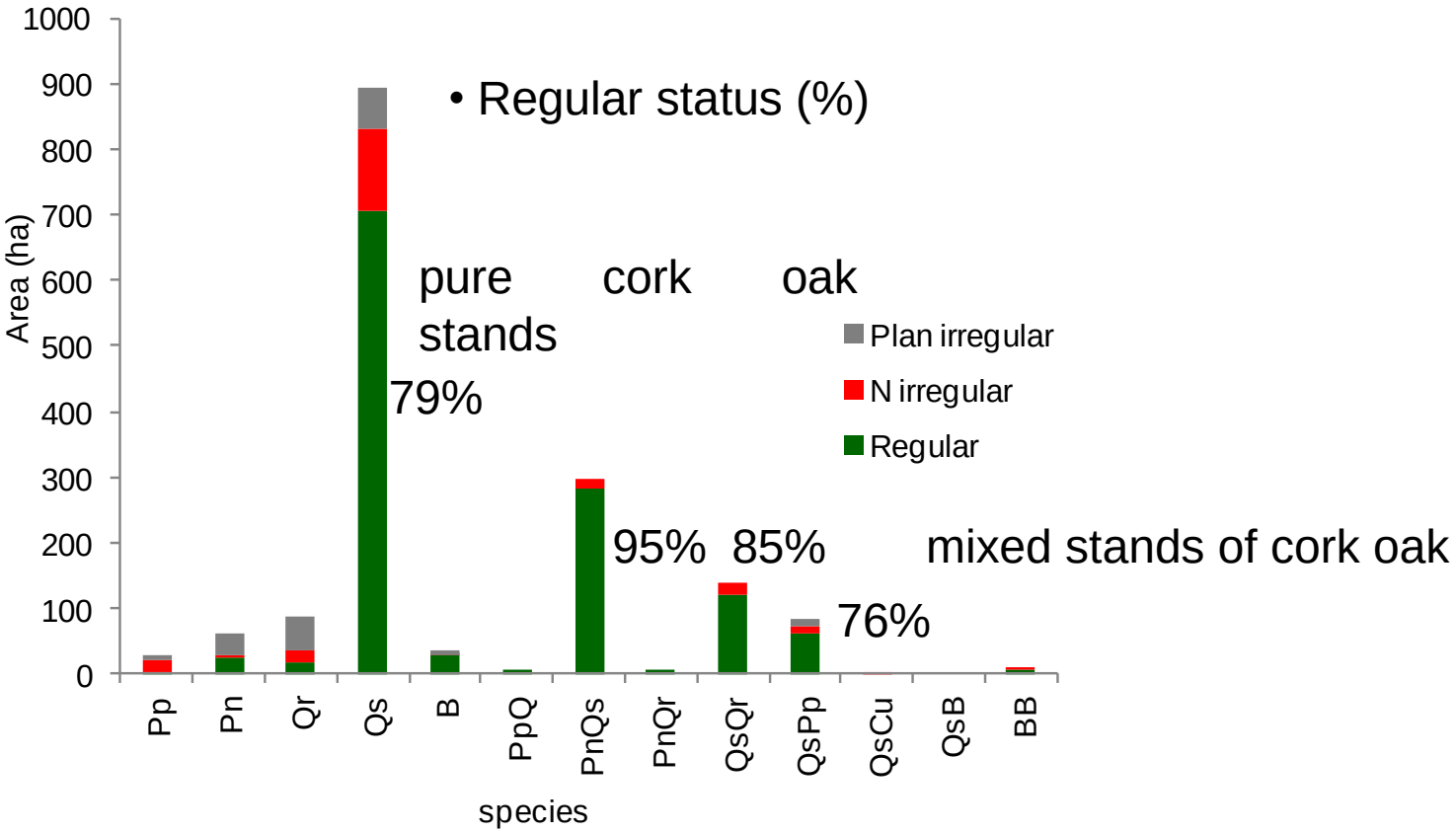



Fig. 7 Projects status – field samples areas

# Afforestation success and failure

PCA 1st and 2nd principal components - explained around 50% of data variability

**Component Loadings**

| Variables | Dimension | |
|---|---|---|
| | 1 | 2 |
| c_ocup_anter | -0,040 | -0,628 |
| c_solos | -0,107 | 0,619 |
| c_prof_solos | -0,411 | 0,629 |
| c_nivel_alt | 0,158 | -0,698 |
| c_especie | 0,922 | 0,134 |
| c_compos | 0,909 | 0,071 |
| c_prep_terre | -0,791 | -0,267 |
| c_protec | 0,571 | -0,045 |
| c_prej_animais | -0,316 | -0,117 |

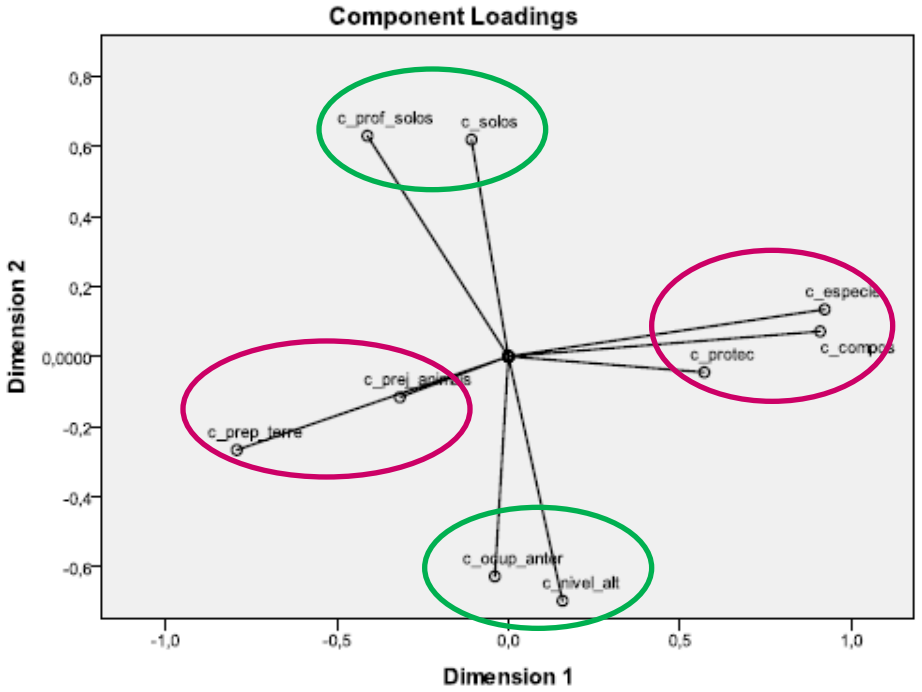
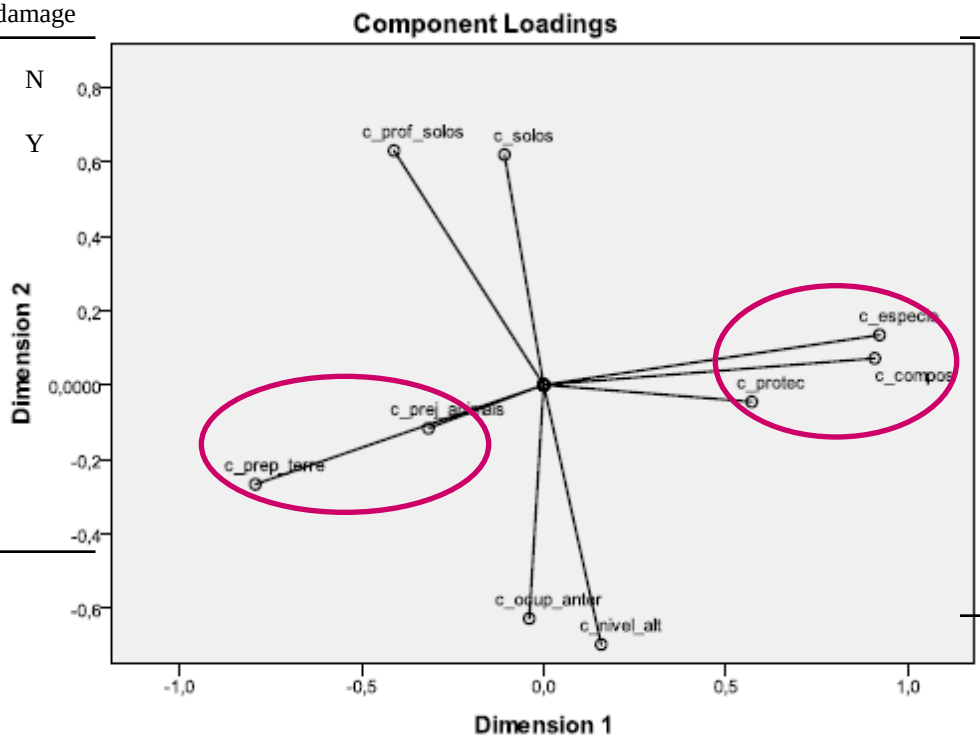



Fig. 8 PCA – Field samples with regular status

PCA clearly indicates that the:

- 1st component is related to stand establishment conditions;
- 2nd component is related to site conditions.

| Code | Site preparation | Animal damage |
|---|---|---|
| 1 | MCRB | N |
| 2 | MCS | Y |
| 3 | MCB | |
| 4 | MCHP | |
| 5 | NCT | |
| 6 | RP | |
| 7 | RB | |
| 8 | S | |

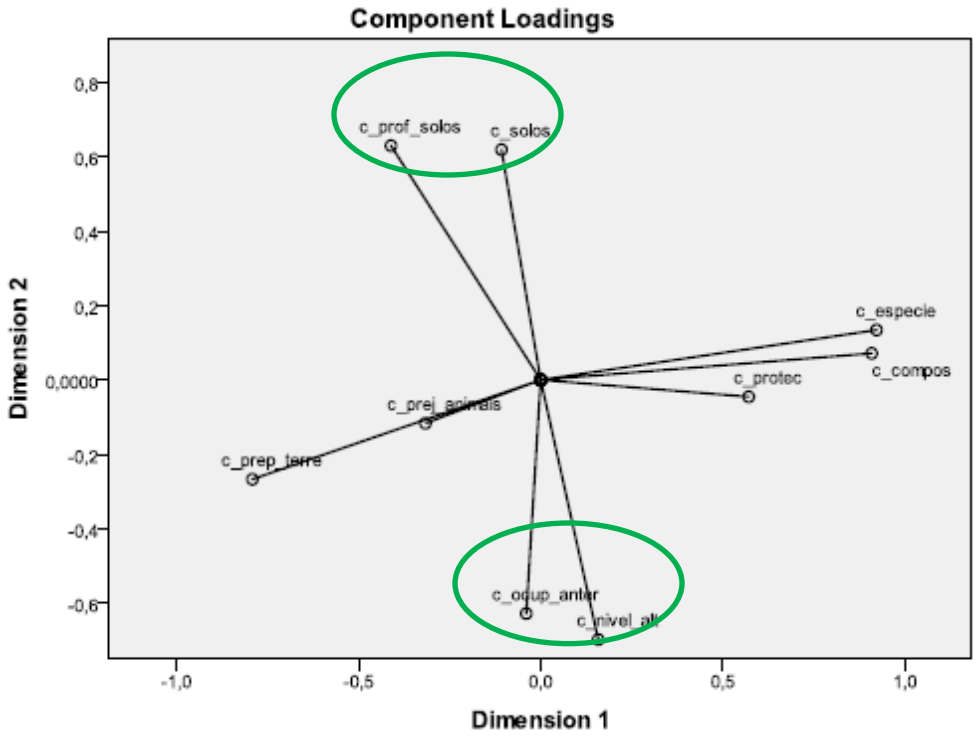



| Code | Species | Seedlings protection |
|---|---|---|
| 1 | Pp P | N |
| 2 | Pn M | Y |
| 3 | Qs | |
| 4 | Qr | |
| 5 | B | |
| 6 | QsQr | |
| 7 | QSPp/PnQs | |
| 8 | PnQr | |
| 9 | BB/PpQ | |

Site preparation and animal damage were found to be negatively correlated to regular status samples. Species, composition and seedlings protection were found to be positively correlated.

| Code | Soil type | Soil depth |
|---|---|---|
| 1 | Sa | S |
| 2 | Sc | M |
| 3 | Gr | D |

| Code | Previous Land Cover | Altimetry level |
|---|---|---|
| 1 | OO | B |
| 2 | NIA | sM |
| 3 | NG | M |
| 4 | F | |




On the other hand, the soil type and depth were found to be positively correlated. While, previous land cover and altimetry level were negatively correlated.

**Component Loadings**

| Variables | Dimension | |
|---|---|---|
| | 1 | 2 |
| c_ocup_anter | -0,108 | 0,721 |
| c_solos | -0,070 | -0,519 |
| c_prof_solos | 0,238 | -0,440 |
| c_nivel_alt | 0,238 | 0,559 |
| c_especie | 0,899 | -0,286 |
| c_compos | 0,876 | -0,246 |
| c_prep_terre | -0,502 | -0,689 |
| c_protec | -0,704 | -0,015 |
| c_prej_animais | 0,377 | 0,346 |

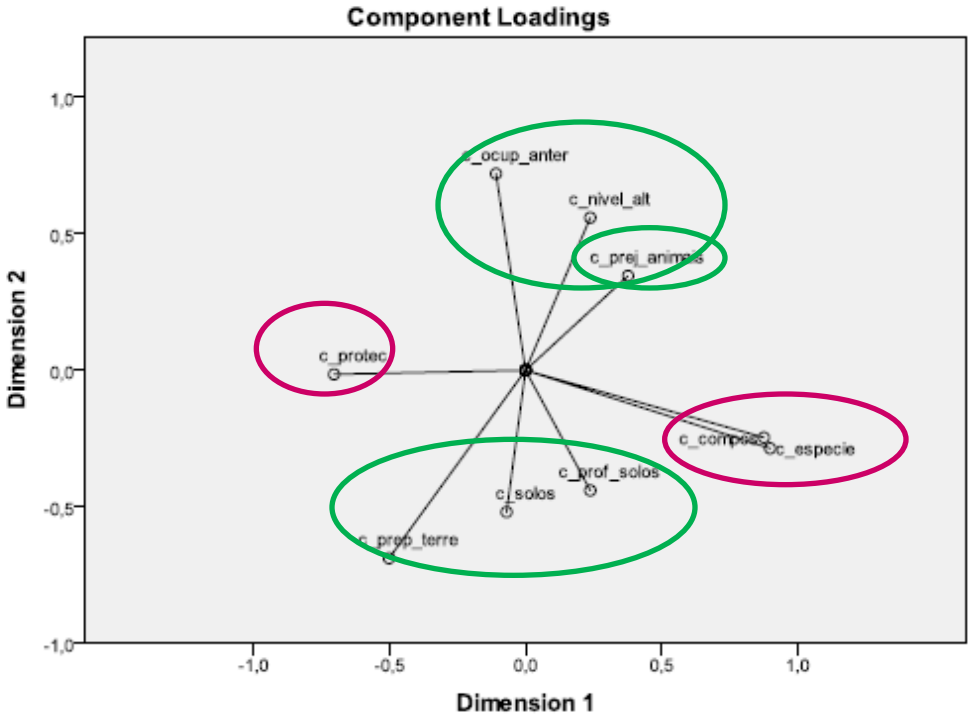



Fig. 9 PCA – Field samples with irregular status due to lack of minimum stand density

Seedlings protection was found to be negatively correlated while animal damage was positively correlated. Variables correlation in 2nd component are upside down.

In short, it seems that afforestation success is best ensured in:

- sites of low elevation (0 to 400 m),
- previously occupied by olive orchards,
- in granitic and depth soils (> 60 cm),
- using species mixes with cork oak and
- when animal damage tree protection is used.

Afforestation will succeed badly in:

- mountain areas (elevation between 700 to 1000 m),
- in sandy and superficial soils (< 30 cm),
- using mixed compositions and
- without any kind of animal damage tree protection.

# Discussion

• Projects with regular status (76%); irregular status: Lack of minimum stand density (10%); Deficiencies meeting management plan goals (13%).

• Some kind of animal damage tree protection should always be used.

•These findings are of great help for planning future afforestation in the region.

• They can also be used as guidelines for other similar Mediterranean regions.

• Other parameters such as those related to climate and to site (e.g. slope, aspect, … ) should be analyzed in future studies.

• Categorical data used in this study should also be validated with quantitative data (e.g. soil samples, …) and more reliable data collection.

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