Shrubland & woodland restoration in Spain and the Mediterranean

V. Ramón Vallejo & J.A. Alloza
CLIMATE CHANGE PROJECTIONS:

fire hazard & restoration

- LONGER AND MORE SEVERE FIRE SEASON
- HEAT WAVES & DROUGHT
- LARGER EXPOSED AREAS

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Changes in CDD interannual variability (standard deviation) in 20-year periods as compared to 1980-1999.
PLANTATIONS (1992)
Post-fire, south-facing slopes, degraded soils

*Pinus halepensis*  

*Quercus ilex* ssp. *ballota*

Marls:  

Limestones:
Drought is the main cause of seedling mortality both for recruitment and in afforestation

(from Alloza & Vallejo, 1999)
% Mortality the 1st post-plantation year

Length of the maximum dry period (days)$^1$

$^1$Consecutive days without any rainfall $> 5$ mm. *** Significant differences at $p < 0.05$
SMALL CHANGES IN SOIL MOISTURE (approx. - 10%) .... can produce increased seedling mortality and reduced growth

**Pinus pinaster**

**Quercus ilex**
TRANSPLANT SHOCK:
ROOT GROWTH AFTER TRANSPLANTING

Plot: Crevillente (Alicante).
Climate: Thermo-mediterranean semiarid
Species: P. lentiscus, J. oxycedrus, Q. coccifera

Fonseca 1999
## Table 11.2 Mediterranean restoration techniques concerned with water

<table>
<thead>
<tr>
<th>Objective</th>
<th>Technique</th>
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<tbody>
<tr>
<td>Increase water-use efficiency</td>
<td>Selection of drought-tolerant species and ecotypes</td>
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<td>Seedling preconditioning</td>
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<td></td>
<td>Improve below-ground performance</td>
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<td>Improve nutritional status</td>
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<td>Increase water supply</td>
<td>Soil preparation and amendment</td>
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<td>Irrigation</td>
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<td>Microsite selection</td>
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<td>Reduce water losses</td>
<td>Tree shelters</td>
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<td>Mulching</td>
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<td></td>
<td>Microsite selection</td>
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<td>Control of competing species</td>
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Vallejo et al 2012
Species survival four years after outplanting

Albatera project, P 280 mm

Survival (%)

Abbreviations: Qc: Quercus coccifera, Cs: Ceratonia siliqua, Pl: Pistacia lentiscus, Ta: Tetaclinis articulata, Ef: Ephedra fragilis, Rl: Rhamnus lycioides, Oe: Olea europaea sylvestris, Ph: Pinus halepensis, Qq: Osyris quadripalitita, Jo: Juniperus oxycedrus, Sg: Salsola genistoides, No: Nerium oleander, Taf: Tamarix africana, Ch: Chamaerops humilis, So: Salsola oppositifolia, Ls: Lygeum spartum, St: Stipa tenacissima.
SPECIES SELECTION
Water-use strategies and response to drought

At field capacity

Leaf water deficit at turgor loss (1-RWC, %)

Stomatal conductance (mmol⁻¹ m⁻² s⁻¹)

Vilagrosa et al., 2009; Hernández, 2010
Dynamics of total standing dead fuel after fire

Baeza et al. 2011
EXPLORING PROVENANCES …

*Quercus ilex*:
Risk of xylem cavitation among populations

Gil & Vilagrosa, unpublished
Quercus suber: Effect provenance and family/mother plant

\[ F_{\text{provenance}} = 0.93 \text{ NS} \]
\[ F_{\text{family}} = 1.96 \text{ *} \]

Morcillo 2006, unpublished
SPECIES DIVERSIFICATION

Planting woody resprouters
WOODY RESPRIUERS RECOVER FASTER AFTER BURNING & ARE LESS FLAMMABLE
SPECIES DIVERSIFICATION

Pistacia lentiscus  
Arbutus unedo  
Rhamnus alaternus
CONSTRAINTS FOR LAND RESTORATION IN DRY MEDITERRANEAN CONDITIONS

CLIMATE
- PREDICTIBLE: SUMMER DROUGHT
- LESS PREDICTIBLE: OUT-OF-SEASON DROUGHTS

SOIL
- SHALLOW/STONY/DISCONTINUOUS
- POOR STRUCTURE (PRONE TO SURFACE CRUSTING: SILTY SOILS)
- POOR BIOLOGICAL FERTILITY AND SOM
- LOW NUTRIENT CONTENT

DISTURBANCE REGIME
- FIRE (RECURRENT)
- GRAZING (FIRE-GRAZING CYCLES)
- EXTREME CLIMATIC EVENTS
TRYING TO IMPROVE SEEDLING PERFORMANCE IN THE FIELD

Overcoming transplanting shock
SEEDLING QUALITY
Drought preconditioning

*Quercus suber*

**Nursery**

- DP (drought preconditioning) produced smaller seedlings with higher R:S ratio.
DP showed a tendency to improve survival.

DP increased the root colonization in the field, deeper in the soil and with greater root biomass.
Quercus spp
USE OF DEEP CONTAINER FOR *Quercus*
ACCLIMATING ROOT SYSTEMS TO CC:

Use of deep container to improve root colonization of seedlings

*Quercus ilex*

Chirino *et al.*, 2009

3 month

18 month
Water manipulation of growing medium: addition of hydrogel and clay in the substrate
Use of hydrogel in seedlings of *Quercus suber* (cork oak)

Increase seedling survival in the field (*Q. suber*; S. Espadán)
THE USE OF TREE-SHELTER
Olea europaea
2005, 2 year
Growth dynamics of *Quercus ilex ssp ballota* seedlings and acorns in relation to some field and nursery treatments

Months since February 1997

- **Hydrogel**
- **Control**
- **Treeshelter (TS)**
Tree-shelters limitations

- Inside the tube, temperature increases a few °C with respect to ambient.
- For temperature > 40-45°C PSII (Fv/Fm) efficiency decreases ⇒ stress in the photosynthetic system.
- Slightly decreases R:S ratio.
- In moist conditions, excessive stem elongation (etiolation) and weakening.
SOIL PREPARATION

Mechanical hole with backhoe *Spider*
TECHNIQUES TO IMPROVE WATER AVAILABILITY TO SEEDLING

Increase Runoff

Enhance Infiltration

Reduce Evaporation
water harvesting
Mortality

Species

% mortality

Quercus ilex spp. Ballota

Pinus halepensis

Hole

Water harvesting

CEAM
IMPROVED MICROCATCHMENT RAIN WATER CAPTURE EFFICIENCY

Rain events < 10 mm
Survival of *Olea europaea* seedlings 2 years after planting in two experimental semiarid stations.
Enhanced accumulation of roots, organic matter faunal activity Preferential water flow
Soil amendments: Biosolids

Pinus halepensis
(20 months after planting)

Fuentes et al 2010
Soil amendments: Biosolids

Fuentes et al. 2010
THE COST OF PLANTATION QUALITY IMPROVEMENT
SEEDLING SURVIVAL VS DROUGHT DURATION
1st PLANTATION YEAR

Vallejo et al., 2012
MEDIUM-TERM EFFECTS OF PLANTATIONS

ALBATERA SITE (SE SPAIN) P ≈ 280 mm
ALBATERA: Functional analysis

Six years after afforestation
ALBATERA: Functional analysis

Six years after afforestation
The role of extant vegetation: facilitation or competition?
Fig. 2. Results of the mixed model for survival. Values reported are the mean effect size ($d_+$) and the 95% CI. The significance ($P$) of the $Q$ statistic for the difference between groups in the effect of nurse shrubs on survival is given. See Methods for a description of the grouping variables.
Quercus suber, post-summer survival. S. Espadà (Castelló, Spain)

We carried out a manipulative experiment to evaluate the importance of competition by pines, competition by the herbaceous understorey, and all other factors pooled.

PC: pine control; OC: open control; PM: dead pine; PH: herbicide for grasses
Alpha grass steppe restoration

Competition by grasses seems to be the most limiting factor for the establishment of woody resprouters

**Pinus halepensis**

**Brachypodium retusum**

**Pistacia lentiscus**

*Maestre et al., 2004*
PLANT-PLANT INTERACTIONS: ALPHA GRASS STEPPES

Which are the main drivers of alpha grass facilitation?
Alpha grass steppe restoration

Alpha grass has a consistent positive effect on the establishment of woody seedlings

Maestre et al., 2001
Alpha grass steppe restoration

Days after plantation

- Tussock control (ECO)
- Tussock no shadow (ESO)
- Tussock no runoff (ECH)
- Open control (BCO)
- Tussock no competition (ECM)
- Open no runoff (BCH)

Survival

- P. lentiscus

Shadow is the main control of facilitation

Maestre et al., 2003
La Hunde site (Ayora, Valencia, Spain)

Secondary pine woodlands.
Stand densities: low, medium and high.
Three replicates (zones): 9 plots and 60 seedlings/plot

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>HIGH DENSITY (HD)</th>
<th>MEDIUM DENSITY (MD)</th>
<th>LOW DENSITY (LD)</th>
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</thead>
<tbody>
<tr>
<td>Stand density</td>
<td>Stand density: 600-900 trees/ha</td>
<td>Stand density: 500-700 trees/ha</td>
<td>Stand density: 100-300 trees/ha</td>
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<tr>
<td></td>
<td>GSF = 0.38</td>
<td>GSF = 0.44</td>
<td>GSF = 0.75</td>
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</tbody>
</table>

Field plantations 2011
### REINTRODUCING RESPouters UNDER PINE CANOPY

<table>
<thead>
<tr>
<th>Species</th>
<th>Life form</th>
<th>Leaf habit</th>
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<tbody>
<tr>
<td><em>Arbutus unedo</em></td>
<td>Shrub</td>
<td>Evergreen</td>
</tr>
<tr>
<td><em>Rhamnus alaternus</em></td>
<td>Shrub</td>
<td>Evergreen</td>
</tr>
<tr>
<td><em>Quercus ilex</em></td>
<td>Tree</td>
<td>Evergreen</td>
</tr>
<tr>
<td><em>Quercus faginea</em></td>
<td>Tree</td>
<td>Deciduous</td>
</tr>
<tr>
<td><em>Fraxinus ornus</em></td>
<td>Tree</td>
<td>Deciduous</td>
</tr>
<tr>
<td><em>Acer granatense</em></td>
<td>Tree</td>
<td>Deciduous</td>
</tr>
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</table>
Results. Survival and RGR per treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>HD</th>
<th>MD</th>
<th>LD</th>
</tr>
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<tbody>
<tr>
<td>RGR Height (year⁻¹)</td>
<td>0.0</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>RGR Diameter (year⁻¹)</td>
<td>0.0</td>
<td>0.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Survival (%)

<table>
<thead>
<tr>
<th>post-transplanting shock</th>
<th>HD</th>
<th>MD</th>
<th>LD</th>
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<tr>
<td>97.7</td>
<td>96.4</td>
<td>99.0</td>
<td></td>
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$p = 0.805$ ns

$p = 0.003$
CONCLUSIONS

• Available ecological restoration technology allows for reintroducing native plants and recovery critical ecosystem functions for many Mediterranean lands

• Higher inputs are required for highly degraded ecosystems, higher stress conditions

...but

• We need understanding the thresholds for cost-effective restoration, both in biophysical and socieconomic terms