# Enhancing forest resilience through mixed stands: an analysis of intra-annual growth dynamics in Spain's Northern Plateau


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## I. STUDY AREA

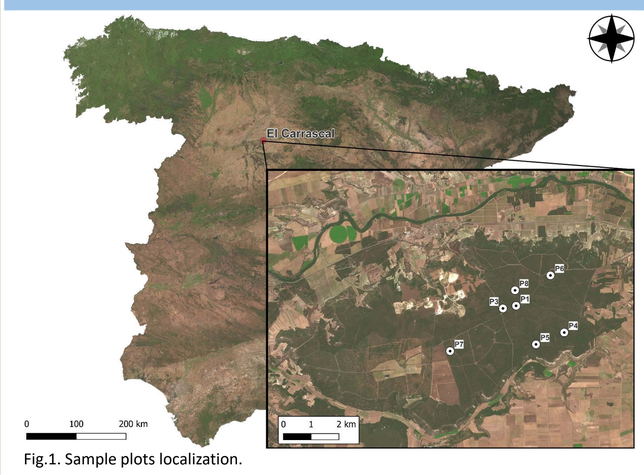


Fig.1. Sample plots localization.

Tab.1. Site information (1996 - 2021).

| | |
|---|---|
| **MUP** | El Carrascal |
| **Coordinates** | 41°35'18.5"N 4°21'26.9"W |
| **Province** | Valladolid |
| **Managed by** | Junta de Castilla y León |
| **Area** | 1500 ha |
| **Average yearly temperature** | 12 °C |
| **Average daily maximum temperature** | 31 °C (July - August) |
| **Average daily minimum temperature** | - 2 °C (January) |
| **Average yearly precipitation sum** | 444 mm |
| **Water deficit** (Thornthwaite PET) | -250 mm year$^{-1}$ |
| **Elevation** | 885 m a.s.l |
| **Soil** | Calcic cambisols |

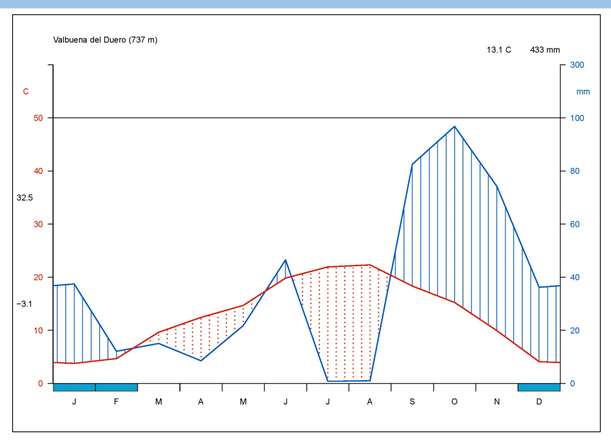


Fig.2. Temperature and precipitation in 2023 (year of analysis).

Fig.3. *Pinus pinea* pure plot.

## II. DATA COLLECTION & METHODS

1) Species analysed: *Pinus pinea*, *Pinus pinaster*, *Juniperus thurifera*, *Quercus ilex*.

2) 7 sample plots: 4 in pure stands of each species, 3 in mixed stands (total area 2.05 ha).

3) 154 band dendrometers installed (~ 15 pcs. / species / plot).

4) Circumference changes measurements every 14 days (winter: 30 days).

6) GAM adjustement to Cumulative Daily Basal Area Variation for each tree:

$CDBV_{ij|DOY} = f(DOY_{ij}) + AR1(DOY_{ij}) + \varepsilon_{ij}$

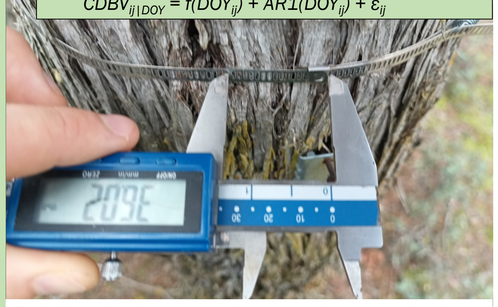

Fig.4. Measuring circumference increment with electronic calliper.

5) Raw data >> circumference >> radius >> raw basal area [mm$^2$] (RB) >> >> Daily Basal Area Variation (DBV) >> >> Cumulative Daily Basal Area Variation ($CDBV_{DOY}$)

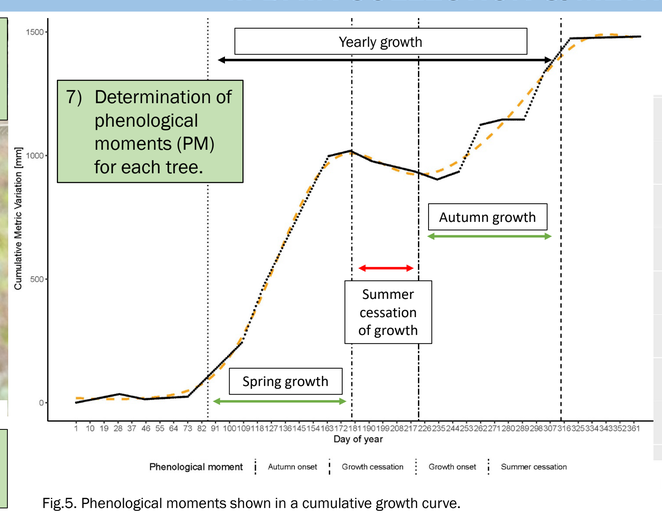


Fig.5. Phenological moments shown in a cumulative growth curve.

8) Yearly Basal Area Variation [mm$^2$]
$YBV = \sum_{DOY=growth\ onset}^{DOY=growth\ cessation}(DBV)$

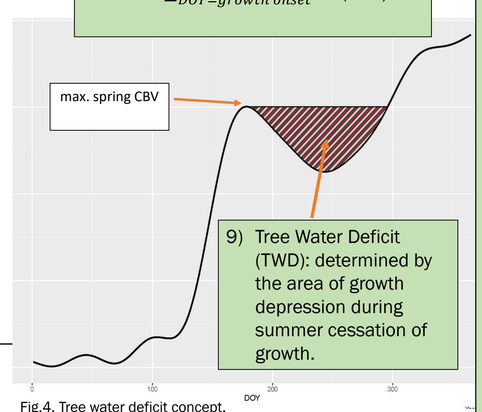


Fig.4. Tree water deficit concept.

QUESTIONS & METHODS.

1) Was the yearly basal area variation (YBV) attained by a species different between pure vs. mixed stand?

$YBV_{ij} = DBH_i + HGCI_i + Species + Type + \mathbf{Species} \times \mathbf{StandType} + u_{PLOT} + \varepsilon_{ij}$

2) Was the phenological moments (PM) occurence or duration influenced by the stand type?

$PM_{ij} = DBH_i + HGCI_i + YBV_{ij} + Species + Type + \mathbf{Species} \times \mathbf{StandType} + u_{PLOT} + \varepsilon_{ij}$

3) The influence of heterogenous species impact ($CI.inter_{\%}$) on the periodical cumulative basal area variation (PBV) may differ between seasons.

$PBV_{ijk} = DBH_{ij} + HGCI_{ij} + Species + \mathbf{Species} \times \mathbf{CI.inter_{\%ij}} + u_{PLOT} + \varepsilon_{ij}$

4) The effect of summer water deficit varied with inter-specific competition.

$TWD_i = HGCI_i + CBV_{ij} + DBH_i + \mathbf{Species_i} \times \mathbf{CI.inter\%_i} + u_{PLOT} + \varepsilon_{ij}$

## III. RESULTS

1) *Juniperus thurifera:* **earlier start** & **longer growth** during spring in mixed stands.
2) Pinus *pinaster*: **later start** & **shorter spring** growth in mixed stands.

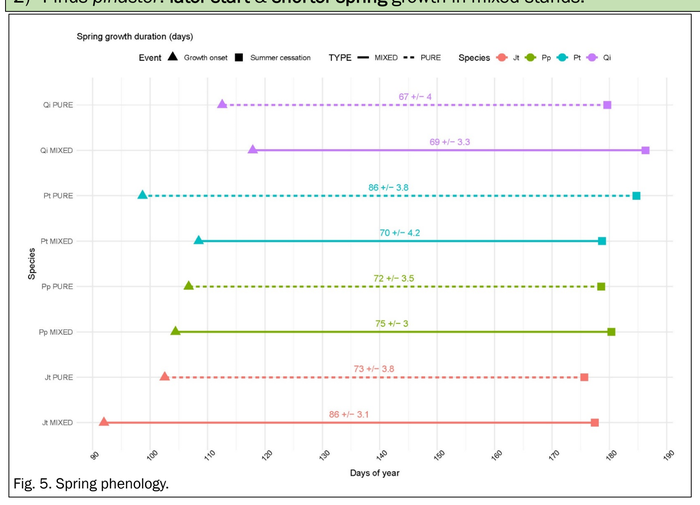


Fig. 5. Spring phenology.

3) *Quercus ilex:* **later and shorter summer cessation of growth** in mixed stands.
4) *P. pinaster:* **earlier summer cessation of growth** in mixed stands.

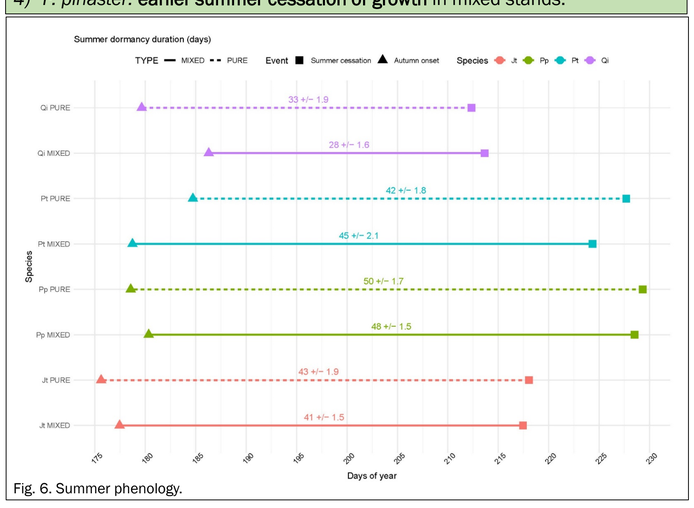


Fig. 6. Summer phenology.

5) *Q. ilex, J. thurifera*: need less time to achieve 95% of growth in mixed stands.
6) *Pinus pinaster:* needs more time to achieve the 95% of growth in mixed stands.

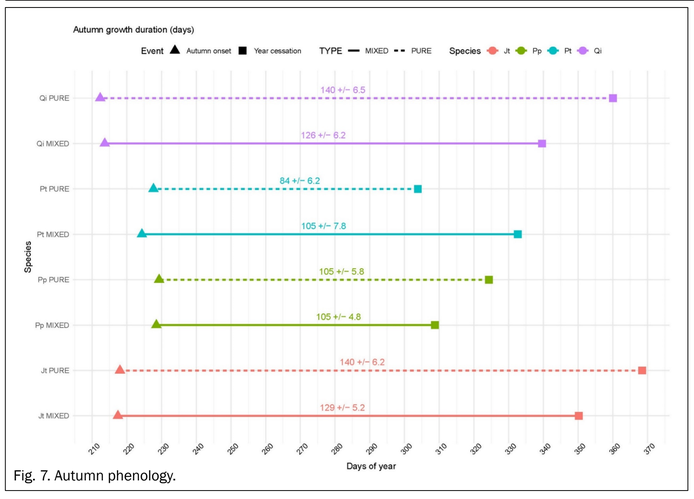


Fig. 7. Autumn phenology.

1) *Juniperus thurifera* accumulated growth was **twice larger in mixed stands**.
2) *Pinus pinaster* growth **was two-fold lower in mixed stands**.

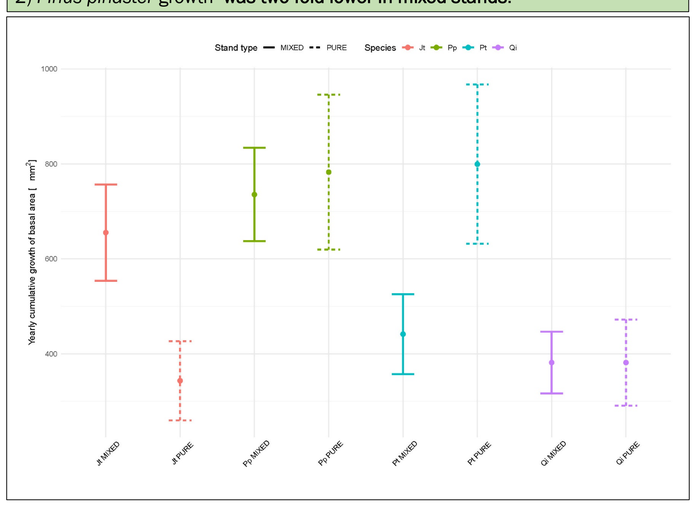


Fig. 8. Cumulative yearly basal area variation across stand types & species.

1) *Pinus pinea* spring & yearly growth variation **enhanced by inter-specific competition**.
2) *Juniperus thurifera* growth enhanced by the inter-specific competition in all periods, except summer.

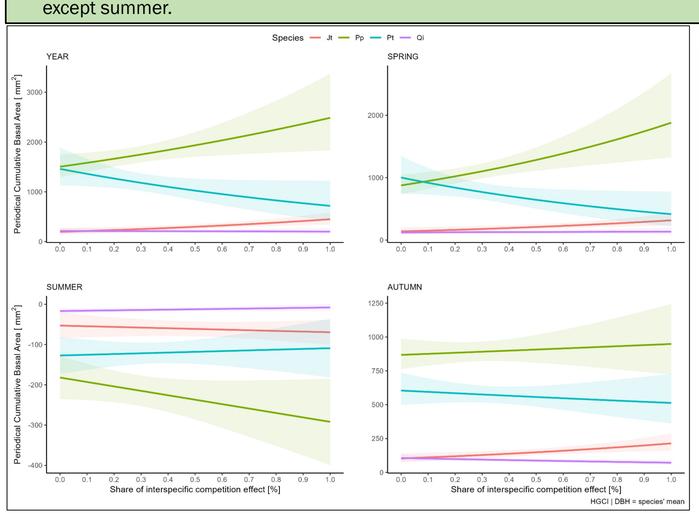


Fig. 9.Dependence of cumulative basal area variation and inter-specific competititon.

3) Increase in inter-specific competititon in summer reduces growth of **all species**, except *Quercus ilex*

1) Increasing rate of inter-specific competition **causes deeper water deficit** for all species, except for *Quercus ilex*.

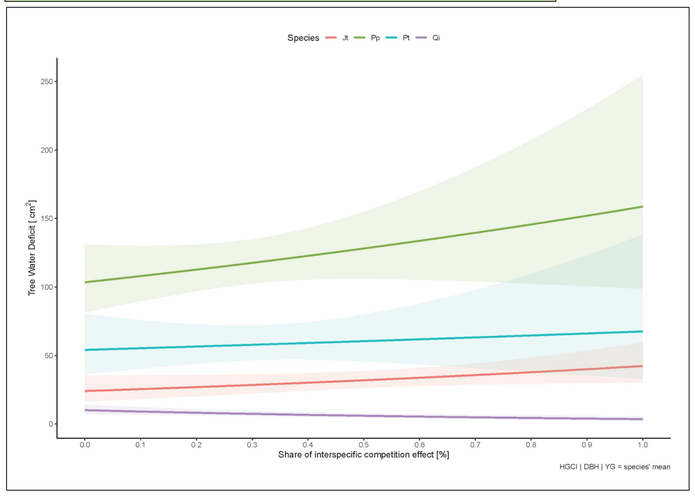


Fig. 10. Tree water deficit change on inter-specific competition, across species.

## IV. CONCLUSIONS

1) Species that **started growing earlier in spring** and **maintained growth activity longer before summer cessation** also achieved **higher annual growth**.

2) The increasing impact of **heterogeneous species positively affected** the growth of P. pinea and J. thurifera **during seasons when water was abundant**, specifically in spring and autumn.

3) During summer, this trend reverses: interactions between species become negative, leading to significantly reduced periodic growth in *J. thurifera* and *P. pinea*. Inter-specific competititon also causes deeper water deficit for the species in question.

4) *Quercus ilex* wasindifferent, in terms of growth, to other species' impact.

5) From our preliminary analysis we can conclude, that mixing species in the Spanish Northern Plateau enhance their growth. Nevertheless, **the complementarity effects occur only during periods when water is not constrained**. This is in accordance with the stress gradient hypothesis.

## V. REFERENCES


**Aldea J, Bravo F, Bravo-Oviedo A, et al (2017)** Thinning enhances the species-specific radial increment response to drought in Mediterranean pine-oak stands. Agricultural and Forest Meteorology 237–238:371–383. https://doi.org/10.1016/j.agrformet.2017.02.009

**Camarero JJ, Rubio-Cuadrado Á, Gazol A (2021)** Climate windows of intra-annual growth and post-drought recovery in Mediterranean trees. Agricultural and Forest Meteorology 308–309:108606. https://doi.org/10.1016/j.agrformet.2021.108606

**de-Dios-García J, Manso R, Calama R, et al (2018)** A new multifactorial approach for studying intra-annual secondary growth dynamics in Mediterranean mixed forests: integrating biotic and abiotic interactions. Can J For Res 48:333–344. https://doi.org/10/gdbqwp

**Moreno-Fernández D, Aldea J, Gea-Izquierdo G, et al (2021)** Influence of climate and thinning on Quercus pyrenaica Willd. coppices growth dynamics. Eur J Forest Res 140:187–197. https://doi.org/10.1007/s10342-020-01322-3


## V. ACKNOWLEDGEMENTS


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