Enhancing forest stability through silvicultural interventions: tree size diversification and species mixtures as adaptation strategies of *Abies alba* Mill. to drought stress

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Outline
Discussion & conclusions
Study design & analysis
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Global change

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Species diversity
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Tree size diversity
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Tree size diversity represents the amount of three-dimensional variation in the forest.
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Research objective:

We aim to understand whether there is a general pattern in the relationship between tree size diversity and the growth response of silver fir (*Abies alba* Mill.) to drought, and if this relationship is influenced by climatic conditions, stand characteristics, and tree size.


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Where?

4 localizations
140 circular plots
6744 trees > 7 cm DBH
2452 seedlings & saplings
655 increment cores

apx. 70-**80** full days
in the field

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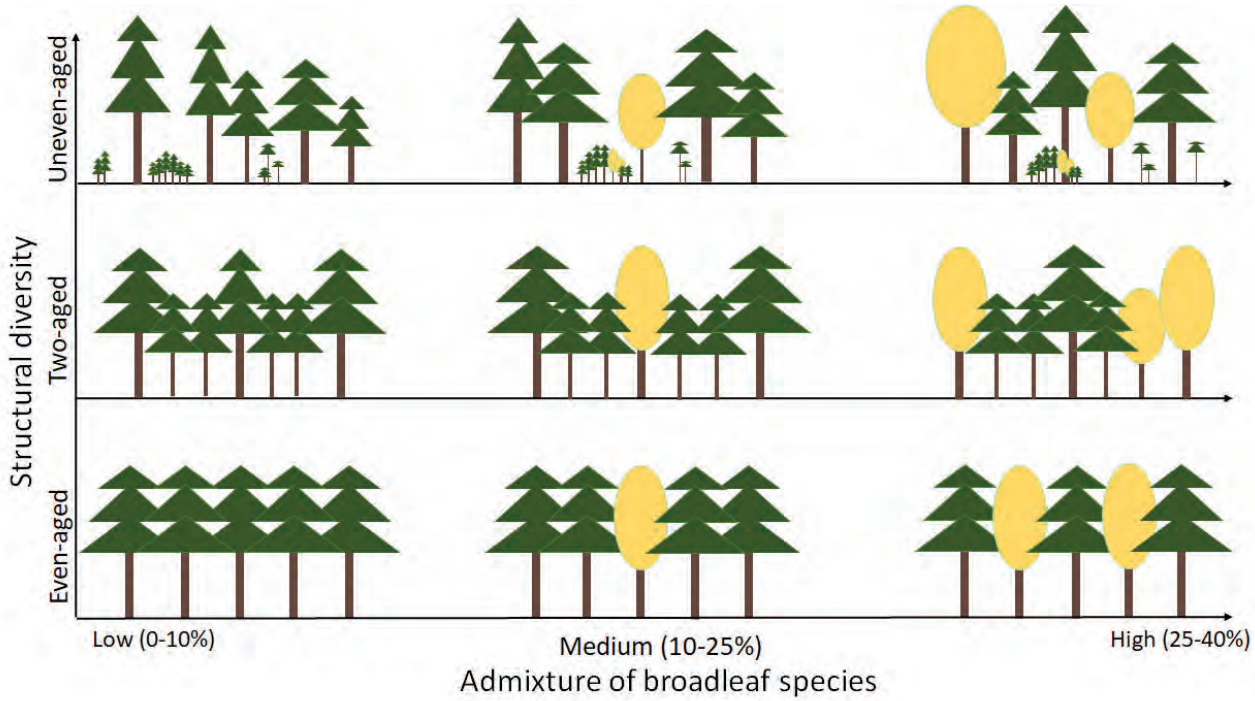

Plot selection matrix, including tree size diversity (vertical axis) and admixture of broadleaf tree species (horizontal axis). This design was used for plot selection purposes in the field to ensure that at each site plots equally cover compositional and structural gradients.

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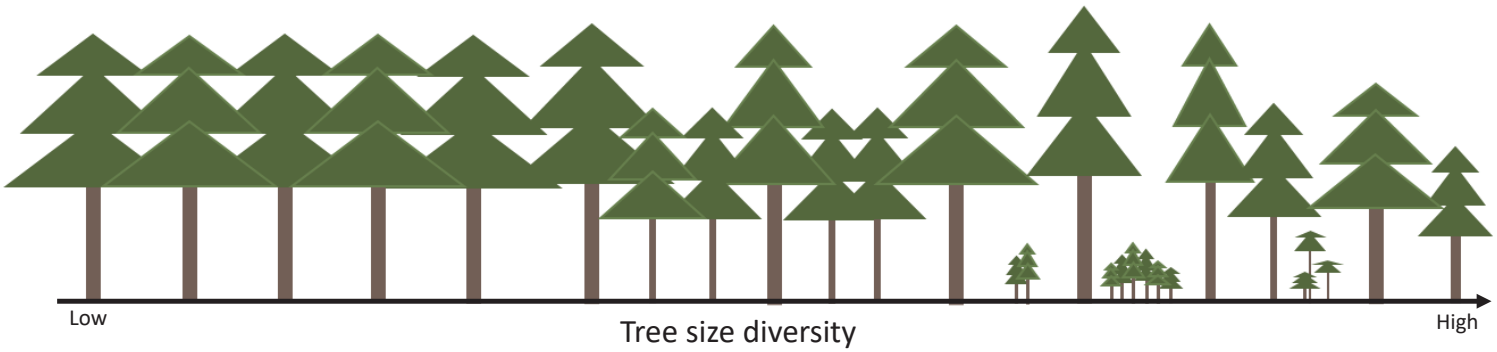
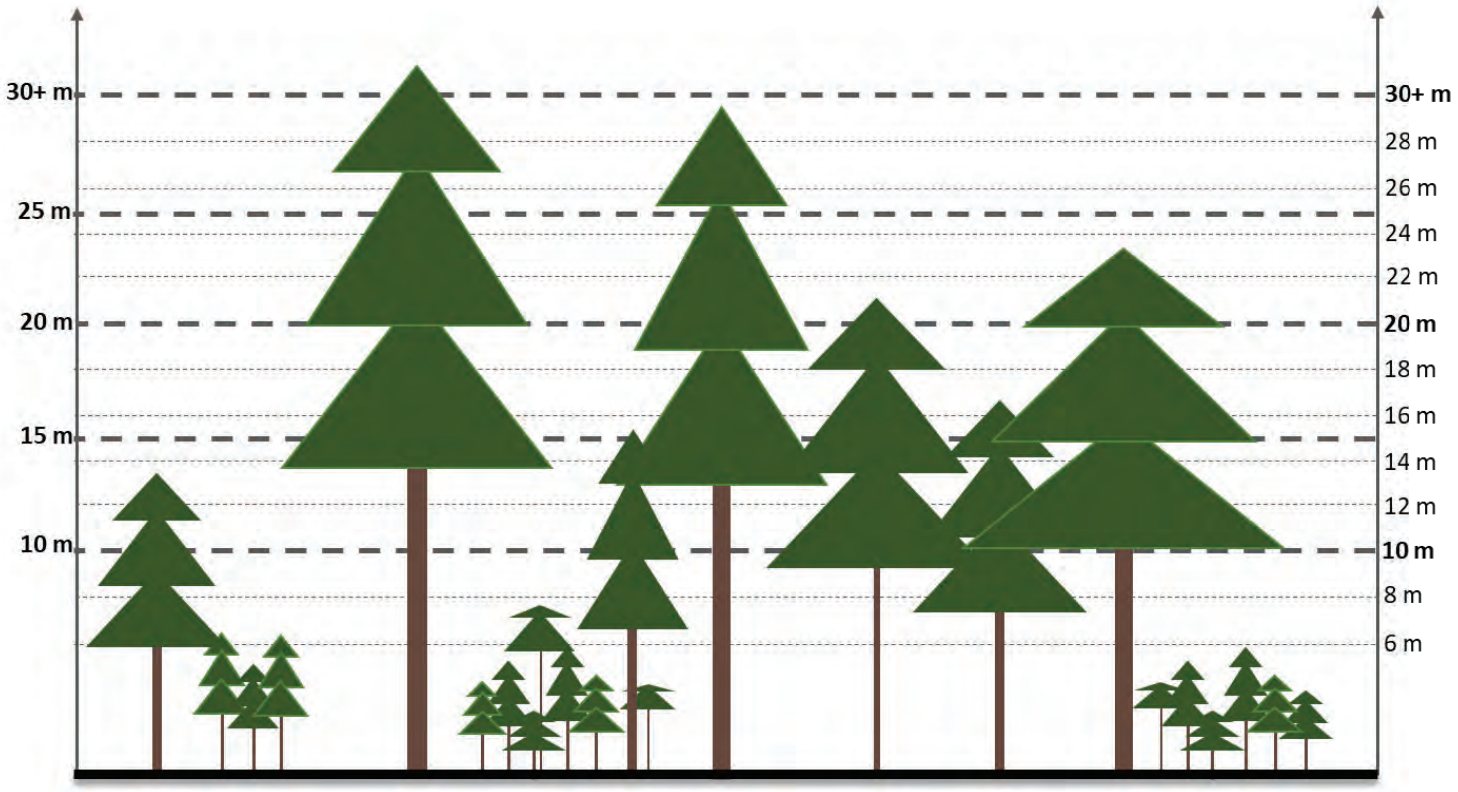
Tree size diversity



$$ShD = -\sum_{i=1}^{N} p_i \times \ln(p_i),$$

where:

- N – is the number of **height** classes;
- *pi*– proportion of trees in the i-th class.



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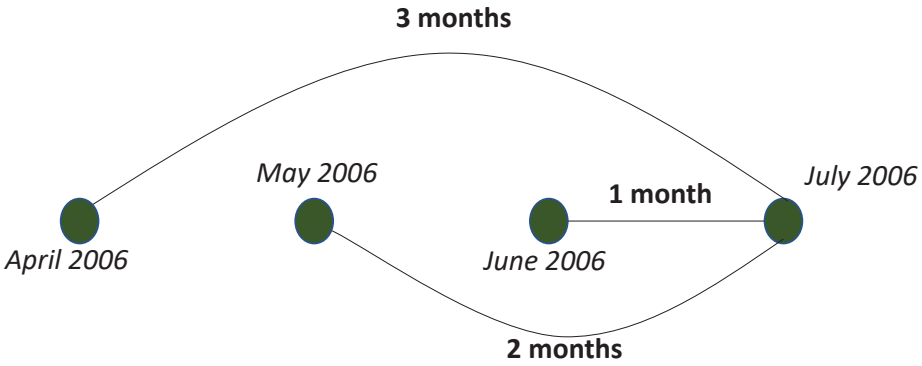
Drought years?

The Standardised Precipitation-Evapotranspiration Index (SPEI)



- Water balance & temperature
- 1:12 months

Aridity of the climate?

IDŐJÁRÁS

Quarterly Journal of the Hungarian Meteorological Service
Vol. 115, No. 3, July–September 2011, pp. 205–216

Application of a new aridity index in Hungarian forestry practice

Ernő Führer[1]*, László Horváth[2], Anikó Jagodics[1], Attila Machon[2,3,4], and Ildikó Szabados[5]

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Growth response to drought stress
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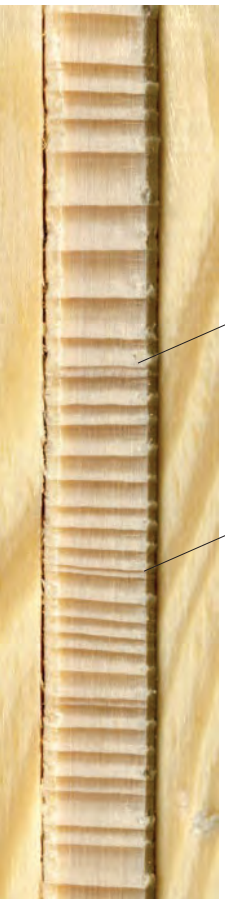
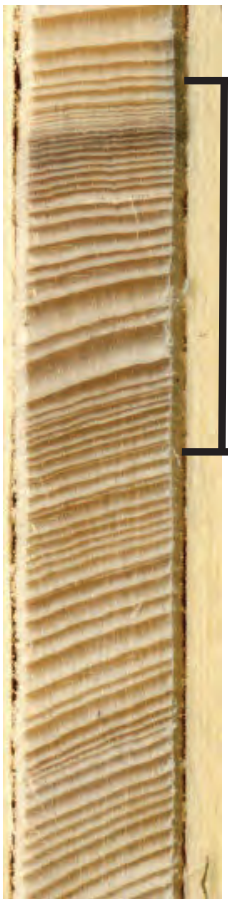

False ring
True ring


1 cm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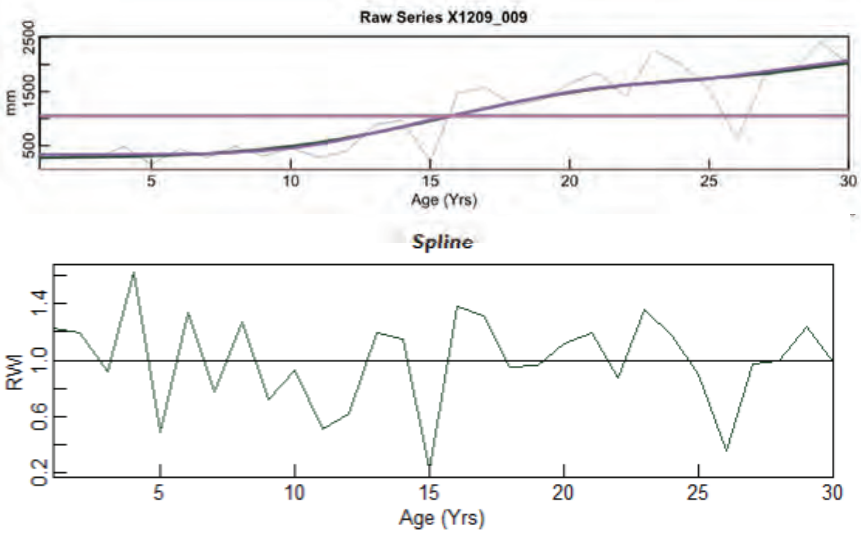
Raw Series X1209_009
mm
2500
1500
500
5
10
15
20
25
30
Age (Yrs)
Spline
RWI
1.4
1.0
0.6
0.2
5
10
15
20
25
30
Age (Yrs)


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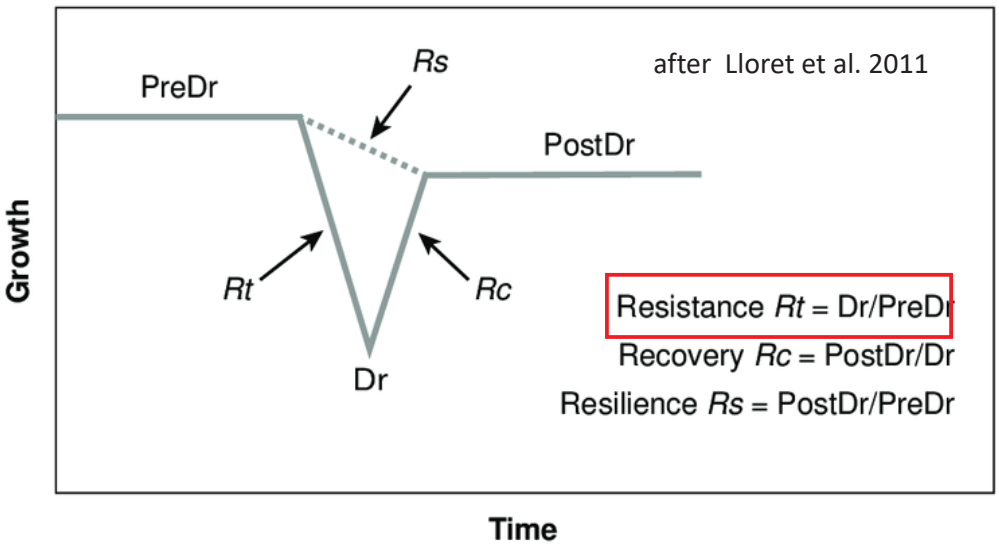
Growth
PreDr
Rs
PostDr
Rt
Rc
Dr
Time
after Lloret et al. 2011
Resistance Rt = Dr/PreDr
Recovery Rc = PostDr/Dr
Resilience Rs = PostDr/PreDr


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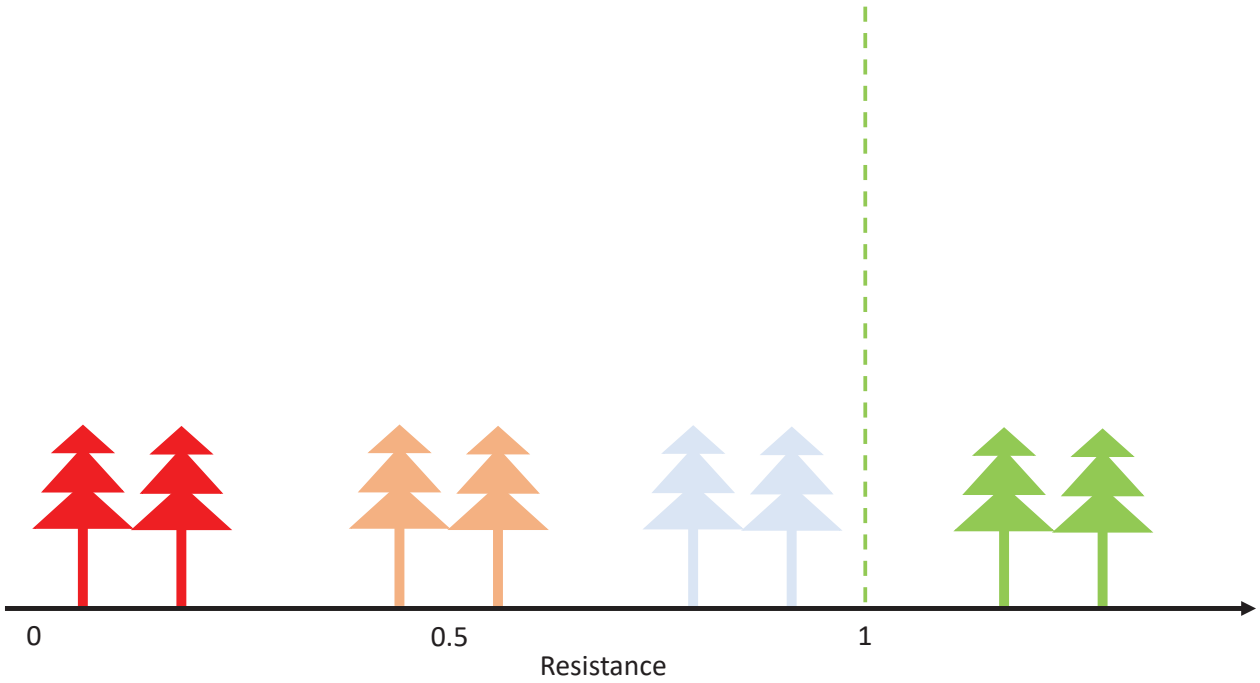
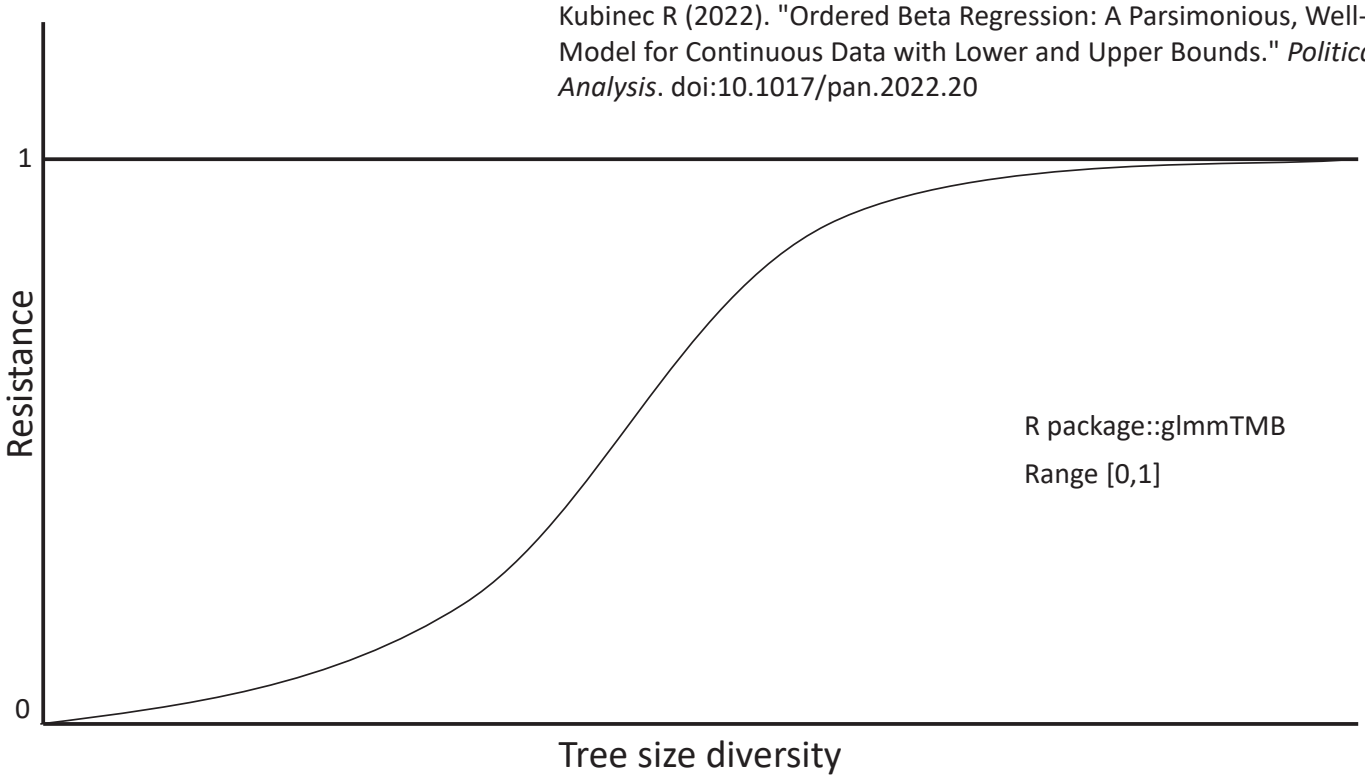

0
0.5
1
Resistance

Kubinec R (2022). "Ordered Beta Regression: A Parsimonious, Well-Fitting Model for Continuous Data with Lower and Upper Bounds." *Political Analysis*. doi:10.1017/pan.2022.20



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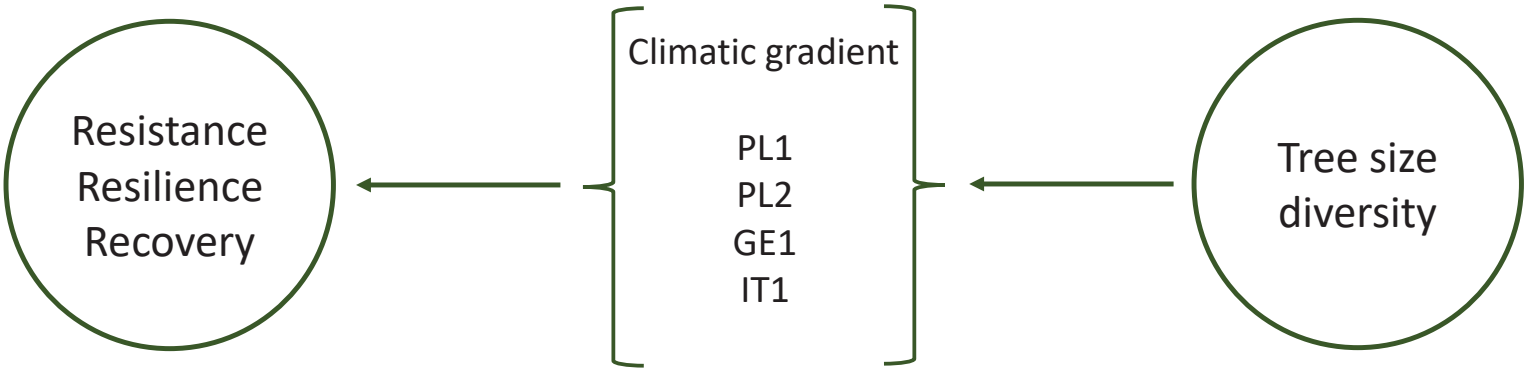
Hypothesis

H1: Tree size diversity increases the resistance, resilience, and recovery of silver fir trees to drought stress.

H2: The effects of tree size diversity on drought response vary across different climatic gradients.

H3: The effects of tree size diversity on drought response are mediated by the admixture of broadleaf tree species.

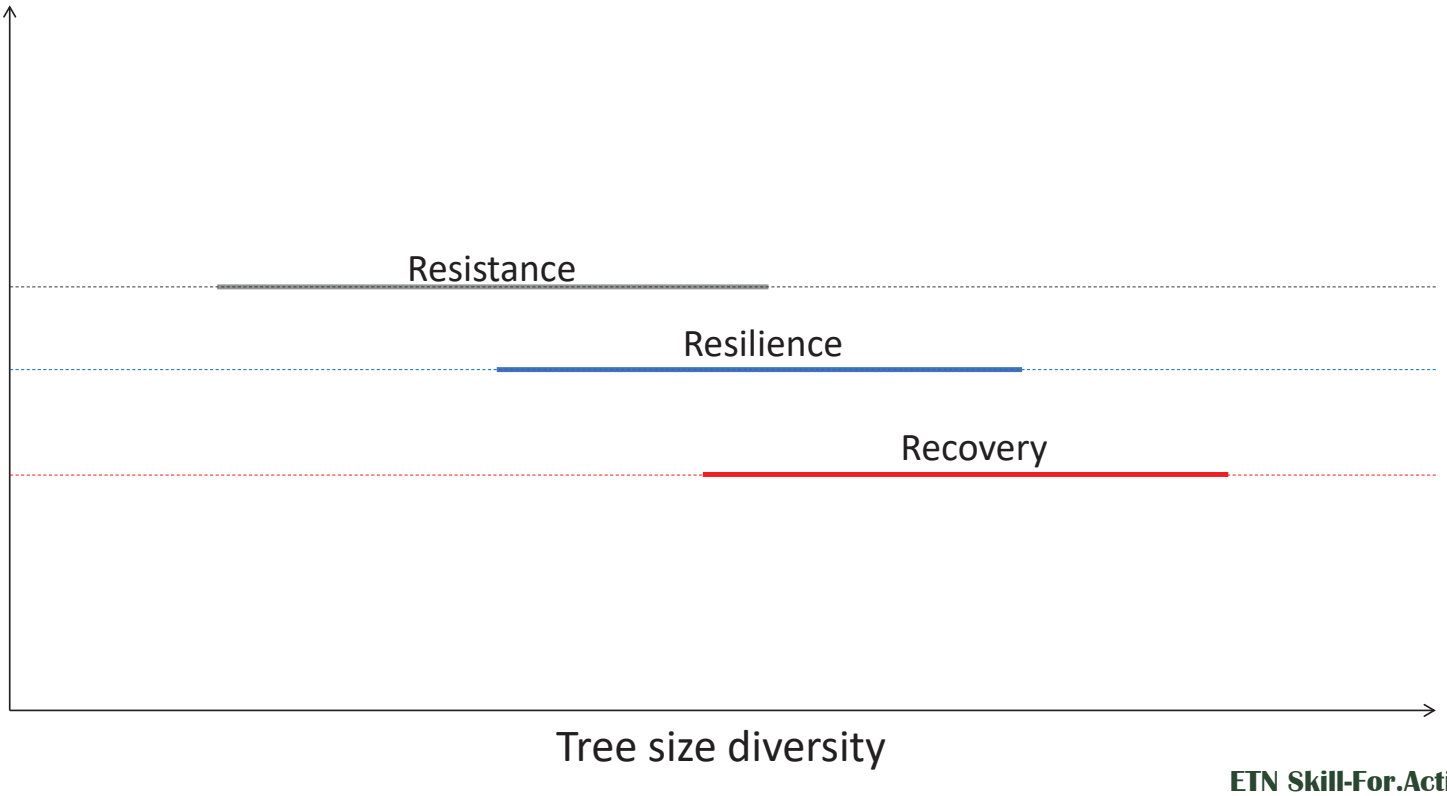
H4: Smaller silver fir trees exhibit a reduced response to drought stress.



$(Rt, Rs, Rc) \sim \beta_0 + \beta_1 * ShD\_H2\_BA\_Normalized + (1 + \beta_2 * ShD\_H2\_BA\_Normalized \mid Site) + \varepsilon$

where:

- Rt, Rs, and Rc are the response variables (resistance, resilience, and recovery correspondingly).
- ShD_H2_BA_Normalized is the fixed effect of the normalized Shannon diversity index based on the height classes.
- $(1 + \beta_2 * ShD\_H2\_BA\_Normalized \mid Location/Year)$ represents the random slopes and intercepts for each site and each drought year.
- ε is the residual error.



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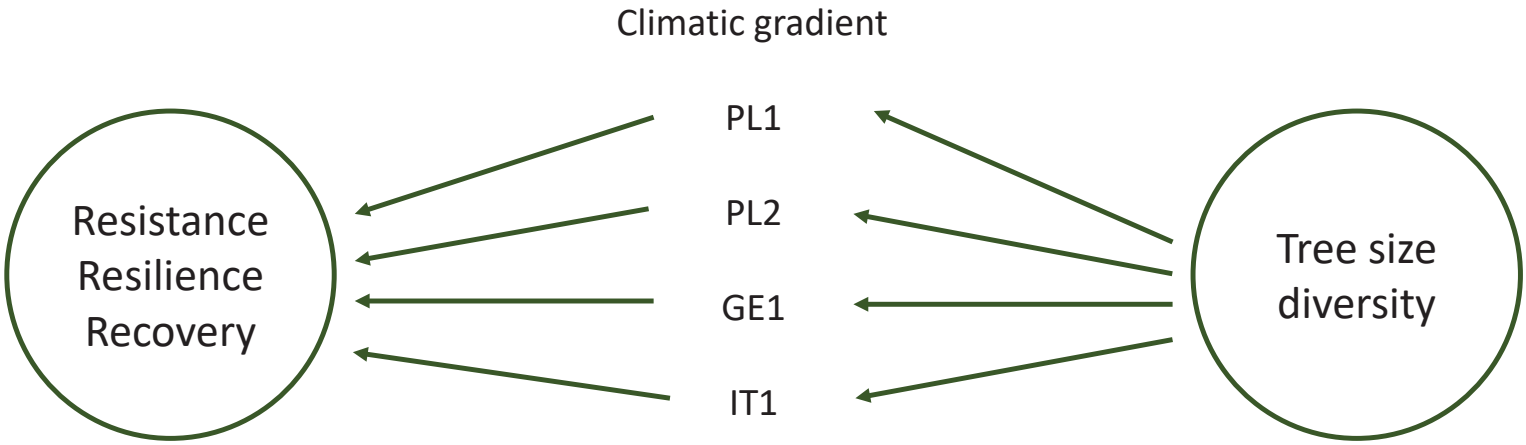
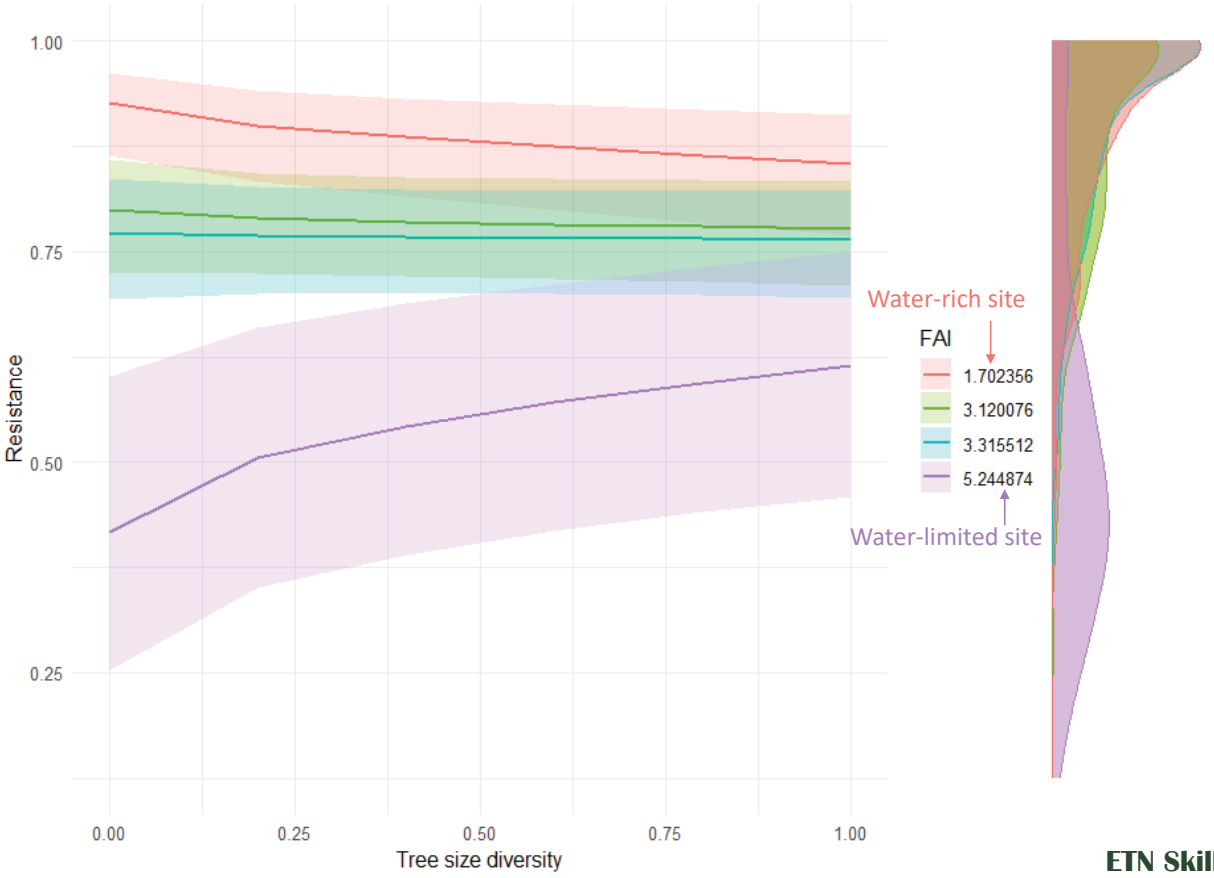


$(Rt, Rs, Rc) \sim \beta_0 + \beta1 *ShD\_H2\_BA\_Normalized + \beta2 *FAI + \beta3* Normalized*FAI + (1 \mid Site/Year) + \varepsilon$

where:

- Rt, Rs, and Rc are the response variables (resistance, resilience, and recovery correspondingly).
- ShD_H2_BA_Normalized is the fixed effect of the normalized Shannon diversity index based on the height classes.
- FAI – Forest Aridity Index
- (1 | Site/Year) represents the random intercepts for each site and each drought year.
- ε is the residual error.



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Linking forest growth with stand structure: Tree size inequality, tree growth or resource partitioning and the asymmetry of competition

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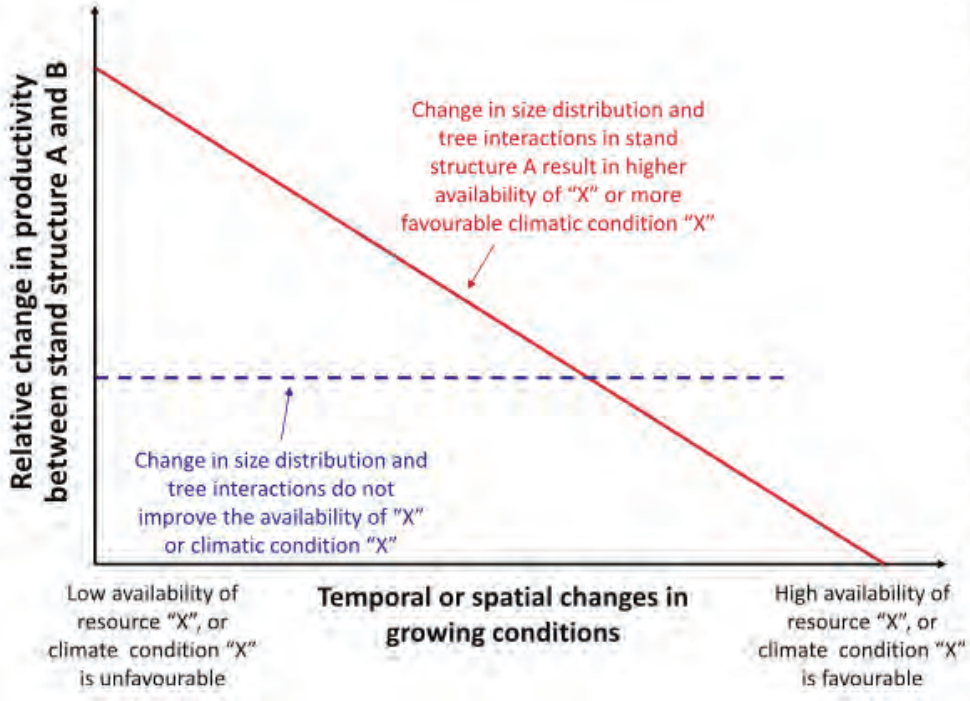

Fig. 6. A framework illustrating how the productivity of a given stand structure A relative to another structure B could change along temporal or spatial gradients in resource availability or climatic conditions. The solid red line shows a general pattern where the relative productivity of stand structure A (compared with B) increases as the availability of resource "X" declines (or climatic condition "X" becomes harsher) as a result of a structure that improves the availability, uptake, or use efficiency of resource X (or interactions improve climatic condition X). For example, a structure A that improves water availability, uptake or use could result in an increase in growth compared with structure B, and the relative difference could increase as the availability of water declines. The blue dashed line is a case where the differences in structure do not lead to any change in growth along the gradient because the structure does not influence resource availability, uptake or use efficiency. Modified from Forrester and Bauhus (2016).

Hypothesis

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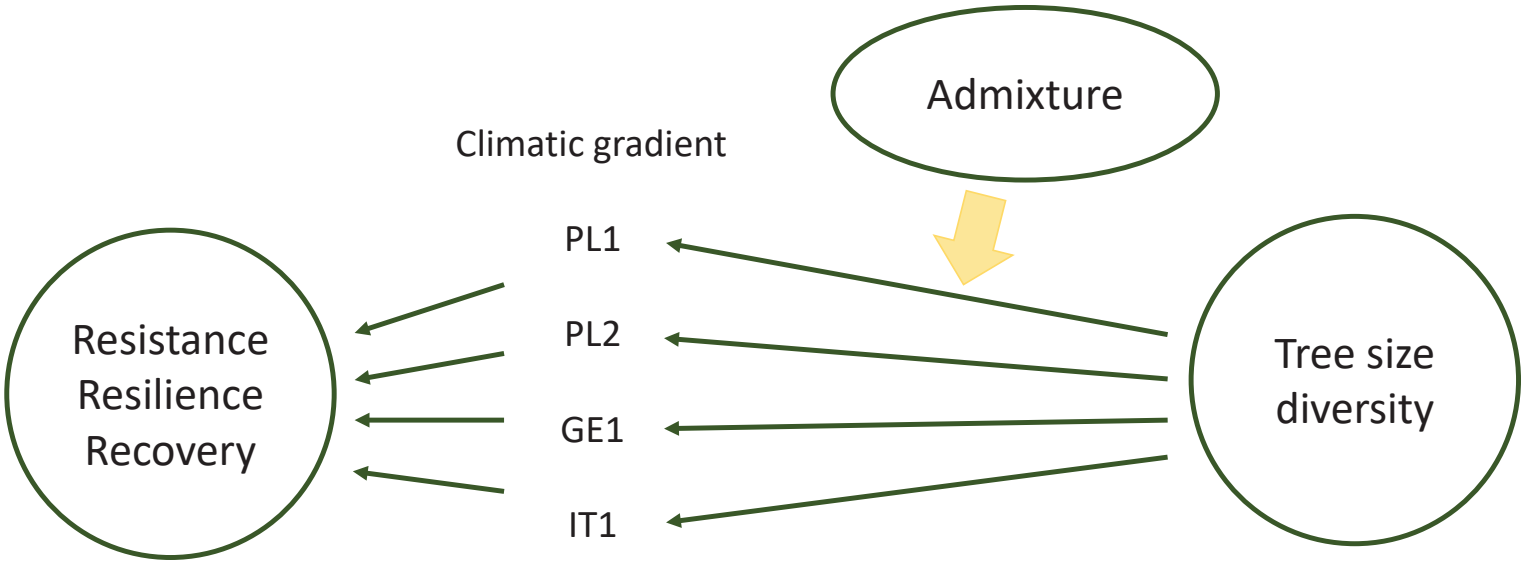
H2: The effects of tree size diversity on drought response vary across different climatic gradients.

H3: The effects of tree size diversity on drought response are mediated by the admixture of broadleaf tree species.

H4: Smaller silver fir trees exhibit a reduced response to drought stress.



$(Rt, Rs, Rc) \sim \beta_0 + \beta1 * ShD\_H2\_BA\_Normalized + \beta2 * FAI + \beta3 * (TBA) + \beta4 * (Adm) + \beta5 * Normalized * FAI * TBA + \beta6 * Normalized * FAI * Adm + (1 | Site/Year) + \varepsilon$

where:

- Rt, Rs, and Rc are the response variables (resistance, resilience, and recovery correspondingly).
- ShD_H2_BA_Normalized is the fixed effect of the normalized Shannon diversity index based on the height classes.

FAI – Forest Aridity Index

TBA – Total Basal Area (density of the forest stand)

Adm – admixture of broadleaf tree species

(1 | Site/Year) represents the random intercepts for each site and each drought year.

ε is the residual error.

Hypothesis

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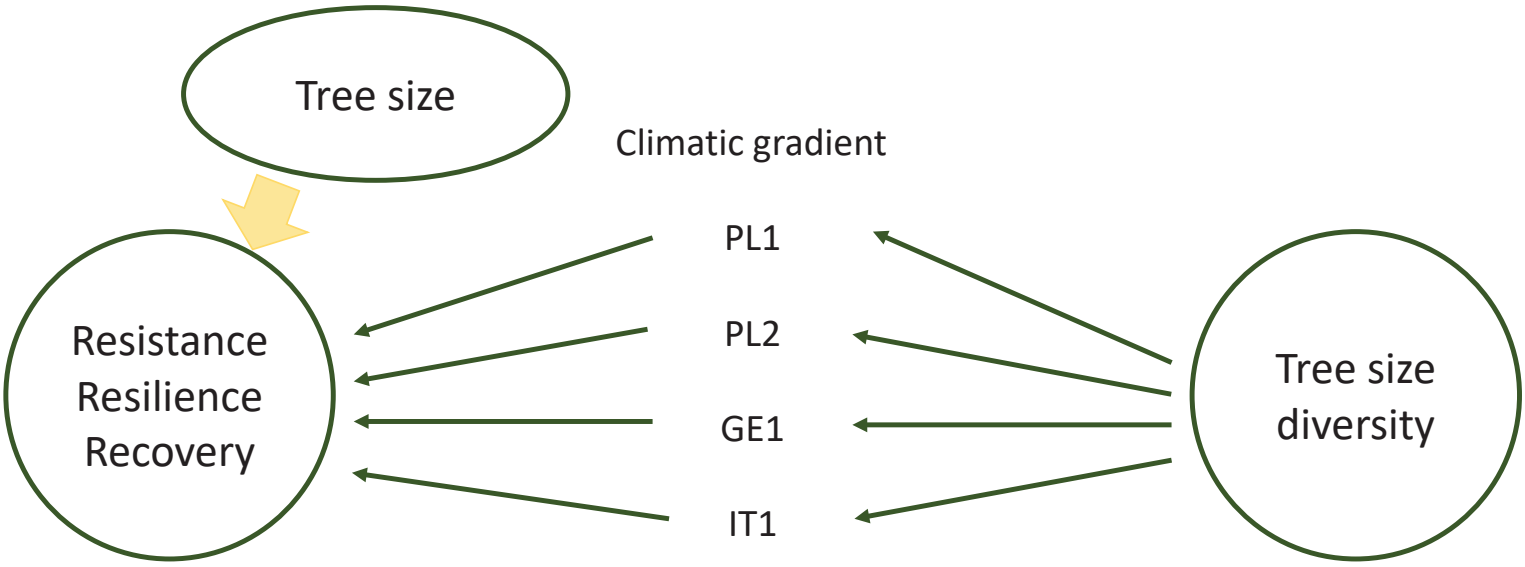
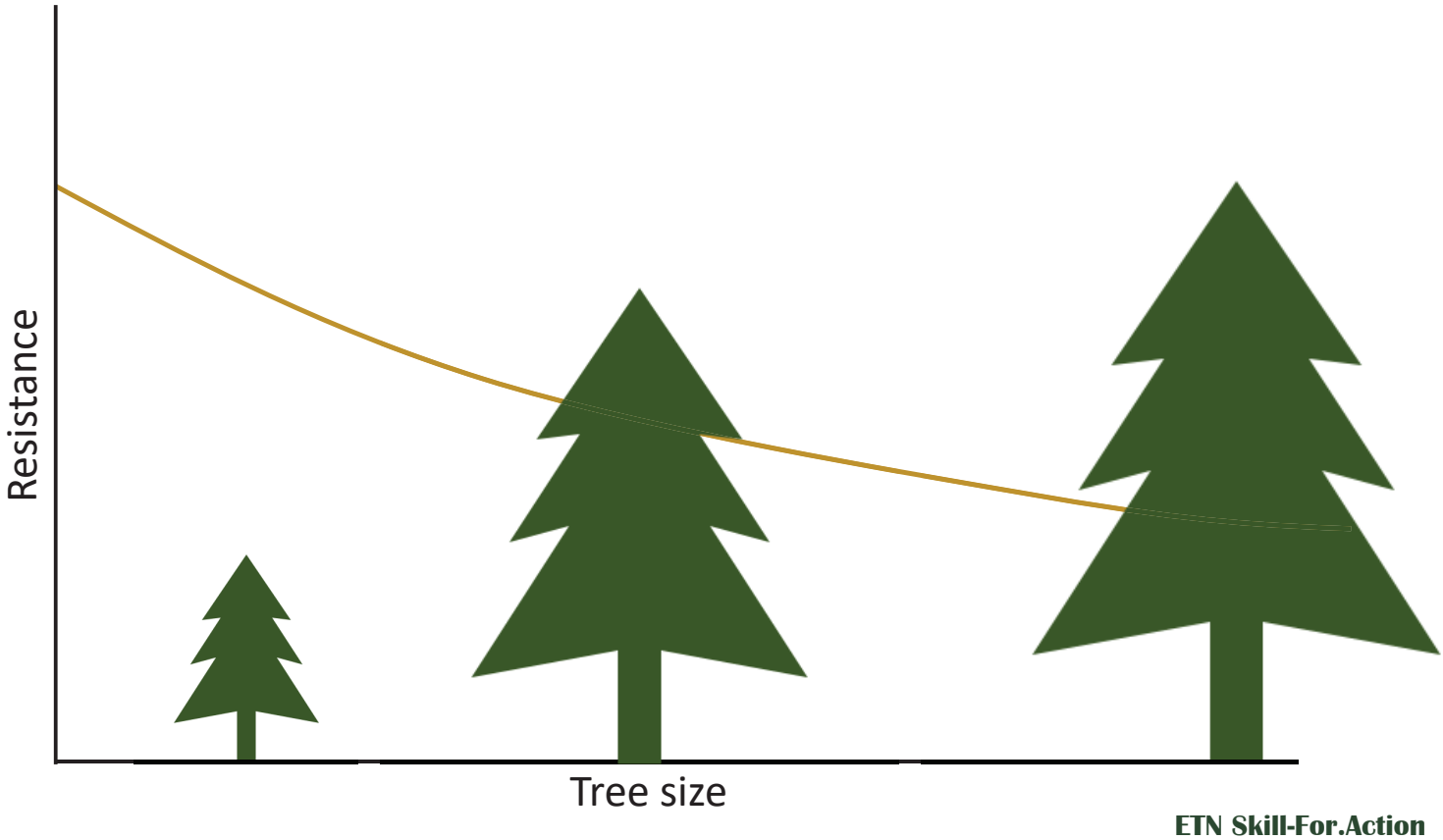


$(Rt, Rs, Rc) \sim \beta_0 + \beta1 * ShD\_H2\_BA\_Normalized + \beta2 * FAI + \beta3 * (TBA) + \beta4 * (\log(DBH)) + \beta5 * Normalized * FAI * (1 \mid Site/Year) + \varepsilon$

where:

- Rt, Rs, and Rc are the response variables (resistance, resilience, and recovery correspondingly).
- ShD_H2_BA_Normalized is the fixed effect of the normalized Shannon diversity index based on the height classes.
- FAI – Forest Aridity Index
- DBH – tree size
- (1 | Site/Year) represents the random intercepts for each site and each drought year.
- ε is the residual error.



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Conclusions:
- There is no general trend for the impact of tree size diversity on resistance, resilience, and recovery.
- The impact of tree size diversity on the resistance is more prominent in arid climates.
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Conclusions:

- The admixture of broadleaf tree species does not mediate the effects of tree size diversity on drought response.

- Regardless of the stand structure – smaller trees react relatively less to the drought stress


Questions?
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