Growth Exploration & Initial Models

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Last Update: March 02, 2025

Contents


```
library(tidyverse)
library(lme4)

# Data prepped for competition indexes
load("D:/Projects/SubalpineTopoGrowth/data/growth_long/subalpine_non_spatial.RData")
df <- subalpine_non_spatial
df <- na.omit(df)
names(df)
```

```
##  [1] "id"               "Plot"             "Spec"
##  [4] "Census"           "rgr_basal_area"   "height"
##  [7] "competition"      "dead"             "dead_census"
```

```
## [10] "elevation"         "slope"             "aspect"
## [13] "soil_moisture"     "soil_temperature"  "air_temperature"
## [16] "relative_humidity" "moisture_class"    "X"
## [19] "Y"
```

Question & Hypotheses

1.How does soil moisture availability and competition influence subalpine tree growth?

Hypothesis 1: Tree growth will be greater in wetter sites particularly for species that are less tolerant of drought.

Hypothesis 2: Tree growth will be limited by not only soil moisture but an interaction with competition, with trees growth being suppressed in areas of low soil moisture availability and high competition.

Base Regression Model

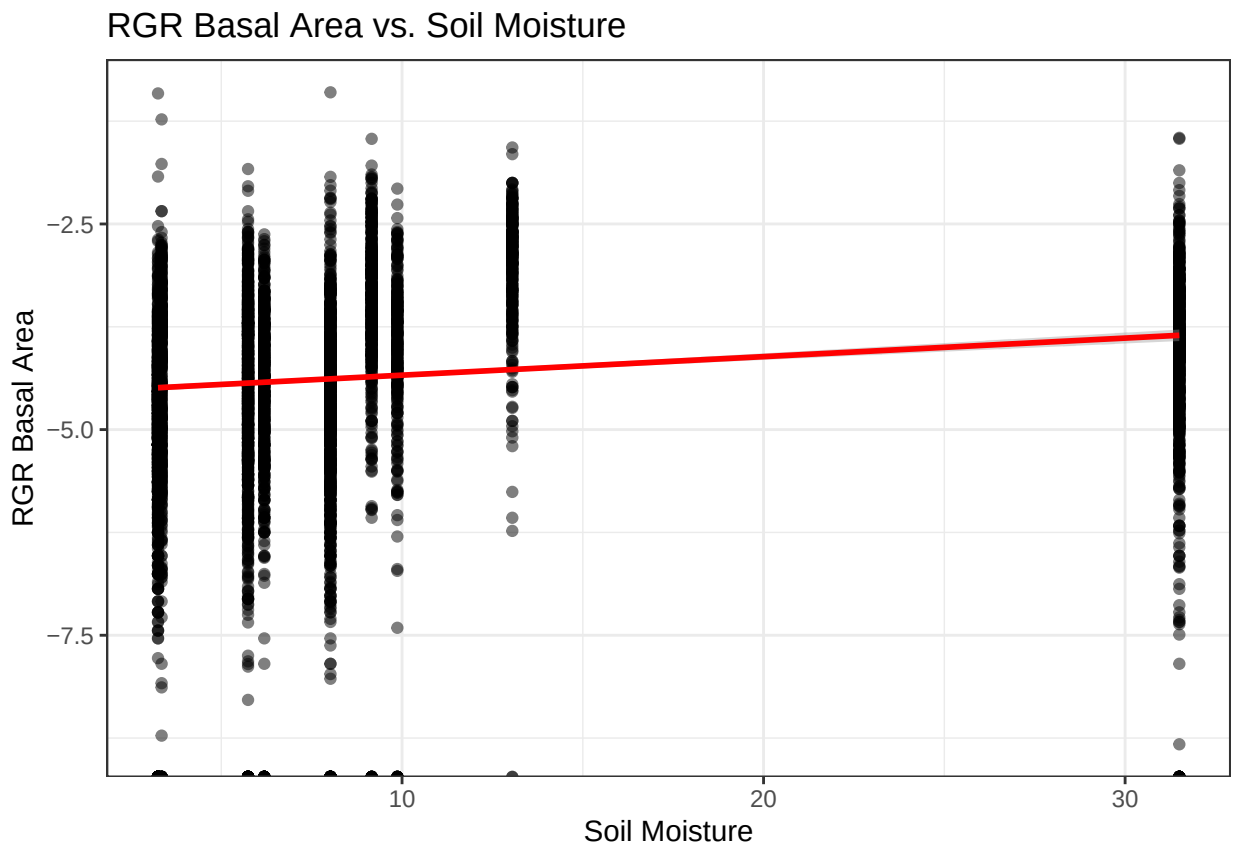
To test if tree growth is positively related to soil moisture only.

Equation

$$BAI = \beta + \beta_1 * SM + \varepsilon$$

Plots

```r
# RGR ~ Soil Moisture / Species
ggplot(df, aes(x = soil_moisture, y = log(rgr_basal_area))) +
  geom_point(alpha = 0.5) +
  geom_smooth(method = "lm", se = TRUE, color = "red") +
  theme_bw() +
  labs(title = "RGR Basal Area vs. Soil Moisture",
       x = "Soil Moisture",
       y = "RGR Basal Area")
```



Model

```
base_model <- lm(rgr_basal_area ~ soil_moisture, data = df)
summary(base_model)
```

```
##
## Call:
## lm(formula = rgr_basal_area ~ soil_moisture, data = df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.95608 -0.01211 -0.00483  0.00728  0.39140
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)   1.245e-02  5.265e-04  23.646   <2e-16 ***
## soil_moisture 3.555e-04  4.006e-05   8.874   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.02896 on 6535 degrees of freedom
## Multiple R-squared:  0.01191,    Adjusted R-squared:  0.01176
## F-statistic: 78.75 on 1 and 6535 DF,  p-value: < 2.2e-16
```

Takeaways

Results:

1. Soil moisture is significant, suggesting it influences tree growth.
2. Effect size is small. 3.555e-04, meaning smaller growth per unit of soil moisture increase.

Low Rsquared of 1.2, meaning other factors must contribute to the relationship.

Soil Moisture * Competition interaction

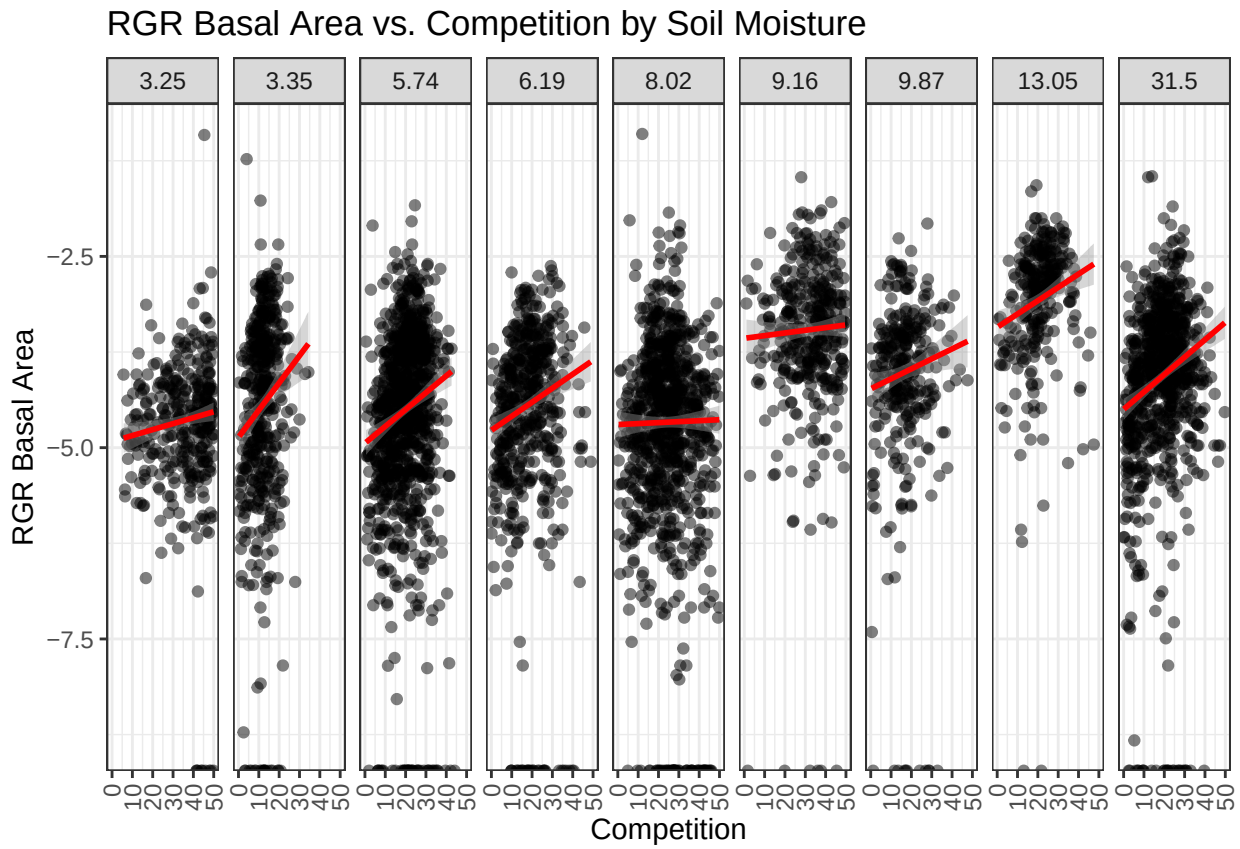
To test if there is an interaction among competition and soil moisture. Hypothesis 2.

Equation

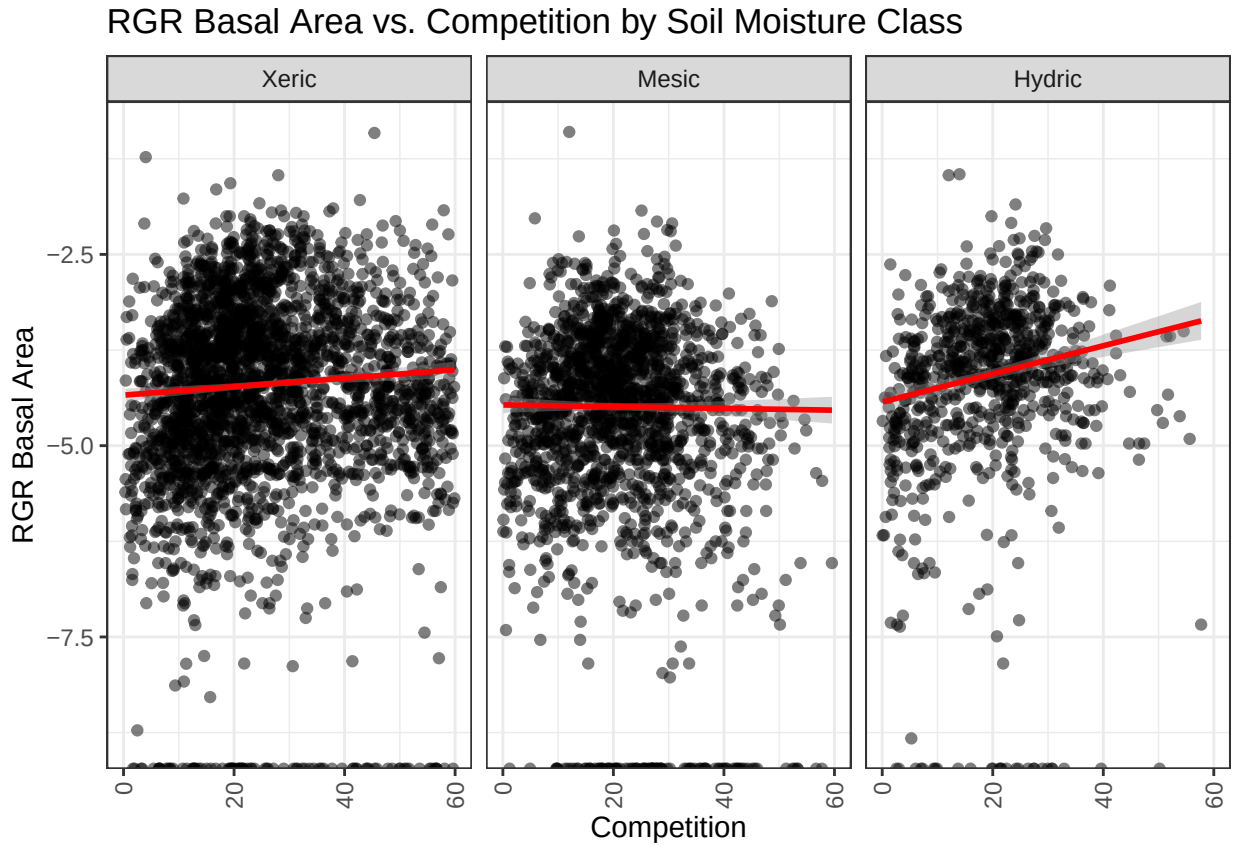
$$BAI = \beta + \beta_1 * SM + \beta_2 * Competition + \varepsilon$$

Plots

```
# RGR ~ Competition / soil moisture
ggplot(df, aes(x = competition, y = log(rgr_basal_area))) +
  geom_point(alpha = 0.5) +
  geom_smooth(method = "lm", se = TRUE, color = "red") +
  facet_grid(~soil_moisture) +
  xlim(c(0,50)) +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1)) +
  labs(title = "RGR Basal Area vs. Competition by Soil Moisture",
       x = "Competition",
       y = "RGR Basal Area")
```




```r
# RGR ~ Competition / soil moisture
ggplot(df, aes(x = competition, y = log(rgr_basal_area))) +
  geom_point(alpha = 0.5) +
  geom_smooth(method = "lm", se = TRUE, color = "red") +
  facet_grid(~moisture_class) +
  xlim(c(0,60)) +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1)) +
  labs(title = "RGR Basal Area vs. Competition by Soil Moisture Class",
       x = "Competition",
       y = "RGR Basal Area")
```



Model

```
interaction_model <- lm(rgr_basal_area ~ soil_moisture * competition,
                        data = df)

summary(interaction_model)
```

```
##
## Call:
## lm(formula = rgr_basal_area ~ soil_moisture * competition, data = df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.86418 -0.01240 -0.00424  0.00686  0.38850
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  1.722e-02  8.013e-04  21.494  < 2e-16 ***
## soil_moisture                5.238e-04  6.782e-05   7.724 1.30e-14 ***
## competition                 -8.545e-05  1.796e-05  -4.757 2.01e-06 ***
## soil_moisture:competition -1.504e-05  2.648e-06  -5.678 1.42e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 0.02861 on 6533 degrees of freedom
## Multiple R-squared:  0.0363, Adjusted R-squared:  0.03586
## F-statistic: 82.03 on 3 and 6533 DF,  p-value: < 2.2e-16
```

Takeaways

1. Soil moisture influences soil moisture positively (significant).
2. Competition negatively influences growth (significant)
3. Interaction between soil moisture and competition is negative, meaning compettion suppresses growth in drier conditions.
4. Rsquared is still small, ~3.6%

Mixed-effects model (Random Intercept: Species)

To test whether the interactions differ by species

Equation

$$BAI = \beta_0 + \beta_1 * SM + \beta_2 * Competition + \beta_3 * (SM * Competition) + (1|Species) + \epsilon$$

Model

```
mixed_model <- lmer(rgr_basal_area ~ soil_moisture * competition + (1 | Spec), data = df)
summary(mixed_model)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: rgr_basal_area ~ soil_moisture * competition + (1 | Spec)
##    Data: df
##
## REML criterion at convergence: -27988.6
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -29.5051  -0.4222  -0.1211   0.2400  13.9372
##
## Random effects:
##  Groups   Name        Variance  Std.Dev.
##  Spec     (Intercept) 3.754e-05 0.006127
##  Residual             7.988e-04 0.028263
## Number of obs: 6537, groups:  Spec, 4
##
## Fixed effects:
##                              Estimate Std. Error t value
## (Intercept)                 1.447e-02  3.173e-03   4.561
## soil_moisture               5.306e-04  6.779e-05   7.827
```

```
## competition                3.167e-05  2.151e-05   1.473
## soil_moisture:competition -2.409e-05  2.730e-06  -8.823
##
## Correlation of Fixed Effects:
##             (Intr) sl_mst cmpttn
## soil_moistr -0.162
## competition -0.185  0.572
## sl_mstr:cmp  0.098 -0.768 -0.678
```

Takeaways

1. Growth increases with soil moisture
2. Weakly positive effect
3. Interaction: negative interaction, competition suppresses growth in drier sites
4. Different species have different growth baselines but it's small

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Soil Moisture by Species

Random intercept on species: Each species can have different baseline growth, allowing for species level variation in growth.

Random slope on soil moisture within species: Soil moisture influence on growth can vary across species.

Trying to capture species-specific varations in growth acorss moisture.

```
newmodel <- lmer(rgr_basal_area ~ soil_moisture * competition + elevation + soil_temperature + height +
summary(newmodel)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## rgr_basal_area ~ soil_moisture * competition + elevation + soil_temperature +
##     height + Spec + soil_moisture + (1 | Spec) + (0 + soil_moisture |
##     Spec)
##    Data: df
##
## REML criterion at convergence: -28816.8
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -28.3980  -0.3962  -0.0538   0.3289  14.7836
##
## Random effects:
##  Groups   Name          Variance  Std.Dev.
##  Spec     (Intercept)   5.373e-04 0.023180
##  Spec.1   soil_moisture 6.749e-06 0.002598
##  Residual               6.937e-04 0.026338
## Number of obs: 6537, groups:  Spec, 4
##
## Fixed effects:
```

```
##                              Estimate Std. Error t value
## (Intercept)                -6.195e-02  2.530e-02  -2.449
## soil_moisture               2.507e-03  1.318e-03   1.902
## competition                -2.352e-04  2.506e-05  -9.384
## elevation                  -3.086e-06  4.292e-06  -0.719
## soil_temperature            1.995e-02  9.439e-04  21.132
## heightCo-Dominant          -1.101e-02  8.744e-04 -12.592
## heightDominant             -1.995e-02  9.898e-04 -20.153
## SpecPIFL                    2.796e-02  3.309e-02   0.845
## SpecABLA                    4.739e-02  3.312e-02   1.431
## SpecPIEN                    4.462e-02  3.311e-02   1.348
## soil_moisture:competition -3.345e-05  2.696e-06 -12.410
##
## Correlation of Fixed Effects:
##             (Intr) sl_mst cmpttn elevtn sl_tmp hghC-D hghtDm SpPIFL SpABLA
## soil_moistr  0.020
## competition -0.066  0.042
## elevation   -0.344 -0.113  0.070
## soil_tmprtr  0.036  0.105 -0.255 -0.523
## hghtC-Dmnnt  0.011  0.015 -0.003 -0.096  0.008
## heightDmnnt  0.007  0.023  0.252 -0.107 -0.077  0.583
## SpecPIFL    -0.639  0.014  0.030 -0.065  0.091  0.007  0.013
## SpecABLA    -0.624  0.021  0.025 -0.104  0.104  0.017  0.027  0.506
## SpecPIEN    -0.625  0.021  0.027 -0.101  0.104  0.014  0.024  0.506  0.509
## sl_mstr:cmp  0.051 -0.041 -0.578 -0.066  0.012  0.188  0.198 -0.015 -0.008
##             SpPIEN
## soil_moistr
## competition
## elevation
## soil_tmprtr
## hghtC-Dmnnt
## heightDmnnt
## SpecPIFL
## SpecABLA
## SpecPIEN
## sl_mstr:cmp -0.011
```

Takeaways

1. Competition has a strong negative effect on growth (estimate: -2.352e-04, t value: -9.384)
2. Competition effects are amplified in wetter sites (estimate = -3.345e-05, t = -12.410)
3. Soil moisture has small positive but significant effect on growth (Estimate = 2.507e-03, t = 1.902)
4. Elevation plays no role here, but rather facilitates other covariates. A correlation among predictors would be useful here.
5. Soil temperature is positively correlated with growth, potentially meaning longer growing season? estimate = 1.995e-02, t = 21.132.