Assignment 7: GLMs week 2 (Linear Regression and beyond)

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OVERVIEW

This exercise accompanies the lessons in Environmental Data Analytics on generalized linear models.

Directions

1. Change "Student Name" on line 3 (above) with your name.
2. Work through the steps, **creating code and output** that fulfill each instruction.
3. Be sure to **answer the questions** in this assignment document.
4. When you have completed the assignment, **Knit** the text and code into a single PDF file.
5. After Knitting, submit the completed exercise (PDF file) to the dropbox in Sakai. Add your last name into the file name (e.g., "Salk_A06_GLMs_Week1.Rmd") prior to submission.

The completed exercise is due on Tuesday, February 25 at 1:00 pm.

Set up your session

1. Set up your session. Check your working directory, load the tidyverse, nlme, and piecewiseSEM packages, import the *raw* NTL-LTER raw data file for chemistry/physics, and import the processed litter dataset. You will not work with dates, so no need to format your date columns this time.

2. Build a ggplot theme and set it as your default theme.

```
#1
#Loading packages and data
getwd()
```

```
## [1] "/Users/clairemullaney/Desktop/ENV 872/Environmental_Data_Analytics_2020"
```

```
library(tidyverse)
library(nlme)
library(piecewiseSEM)

NTL_LTER <- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")
Litter <- read.csv("./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv")

#2
#Setting default theme
deftheme <- theme_classic(base_size = 14) +
  theme(axis.text = element_text(color = "black"),
        legend.position = "right")
theme_set(deftheme)
```

NTL-LTER test

Research question: What is the best set of predictors for lake temperatures in July across the monitoring period at the North Temperate Lakes LTER?

3. Wrangle your NTL-LTER dataset with a pipe function so that it contains only the following criteria:

- Only dates in July (hint: use the daynum column). No need to consider leap years.
- Only the columns: lakename, year4, daynum, depth, temperature_C
- Only complete cases (i.e., remove NAs)

4. Run an AIC to determine what set of explanatory variables (year4, daynum, depth) is best suited to predict temperature. Run a multiple regression on the recommended set of variables.

```
#3
#Filtering by dates in July, selecting relevant columns, and removing NAs

NTL_LTER_wr <-
  NTL_LTER %>%
  filter(daynum >= 182 & daynum <= 212) %>%
  select(lakename, year4, daynum, depth, temperature_C) %>%
  na.omit()

#4
#Determing the best multiple linear regression model for predicting temperature

TempAIC <- lm(data = NTL_LTER_wr, temperature_C ~ year4 + daynum + depth)

step(TempAIC)
```

```
## Start:  AIC=26016.31
## temperature_C ~ year4 + daynum + depth
##
##          Df Sum of Sq    RSS   AIC
## <none>                 141118 26016
## - year4   1        80 141198 26020
## - daynum  1      1333 142450 26106
## - depth   1    403925 545042 39151
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL_LTER_wr)
##
## Coefficients:
## (Intercept)        year4       daynum        depth
##    -6.45556      0.01013      0.04134     -1.94726
```

```
Temp <- lm(data = NTL_LTER_wr, temperature_C ~ year4 + daynum + depth)

summary(Temp)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL_LTER_wr)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6517 -2.9937  0.0855  2.9692 13.6171
##
## Coefficients:
##              Estimate Std. Error  t value Pr(>|t|)
## (Intercept) -6.455560   8.638808   -0.747   0.4549
## year4        0.010131   0.004303    2.354   0.0186 *
```

```
## daynum       0.041336   0.004315    9.580   <2e-16 ***
## depth       -1.947264   0.011676 -166.782   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.811 on 9718 degrees of freedom
## Multiple R-squared:  0.7417, Adjusted R-squared:  0.7417
## F-statistic:  9303 on 3 and 9718 DF,  p-value: < 2.2e-16
```

5. What is the final set of explanatory variables that predict temperature from your multiple regression? How much of the observed variance does this model explain?

   Answer: According to the AIC analysis, the final set of explanatory variables that predict temperature includes year4 (year), daynum (numerical day of the year), and depth. This model explains 74.17% of the observed variance in temperature.

6. Run an interaction effects ANCOVA to predict temperature based on depth and lakename from the same wrangled dataset.

```
#6

Temp.2 <- lm(data = NTL_LTER_wr, temperature_C ~ depth * lakename)

summary(Temp.2)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth * lakename, data = NTL_LTER_wr)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.6455 -2.9133 -0.2879  2.7567 16.3606
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      22.9455     0.5861  39.147  < 2e-16 ***
## depth                            -2.5820     0.2411 -10.711  < 2e-16 ***
## lakenameCrampton Lake             2.2173     0.6804   3.259  0.00112 **
## lakenameEast Long Lake           -4.3884     0.6191  -7.089 1.45e-12 ***
## lakenameHummingbird Lake         -2.4126     0.8379  -2.879  0.00399 **
## lakenamePaul Lake                 0.6105     0.5983   1.020  0.30754
## lakenamePeter Lake                0.2998     0.5970   0.502  0.61552
## lakenameTuesday Lake             -2.8932     0.6060  -4.774 1.83e-06 ***
## lakenameWard Lake                 2.4180     0.8434   2.867  0.00415 **
## lakenameWest Long Lake           -2.4663     0.6168  -3.999 6.42e-05 ***
## depth:lakenameCrampton Lake       0.8058     0.2465   3.268  0.00109 **
## depth:lakenameEast Long Lake      0.9465     0.2433   3.891  0.00010 ***
## depth:lakenameHummingbird Lake   -0.6026     0.2919  -2.064  0.03903 *
## depth:lakenamePaul Lake           0.4022     0.2421   1.662  0.09664 .
## depth:lakenamePeter Lake          0.5799     0.2418   2.398  0.01649 *
## depth:lakenameTuesday Lake        0.6605     0.2426   2.723  0.00648 **
## depth:lakenameWard Lake          -0.6930     0.2862  -2.421  0.01548 *
## depth:lakenameWest Long Lake      0.8154     0.2431   3.354  0.00080 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 3.471 on 9704 degrees of freedom
## Multiple R-squared:  0.7861, Adjusted R-squared:  0.7857
## F-statistic:  2097 on 17 and 9704 DF,  p-value: < 2.2e-16
```

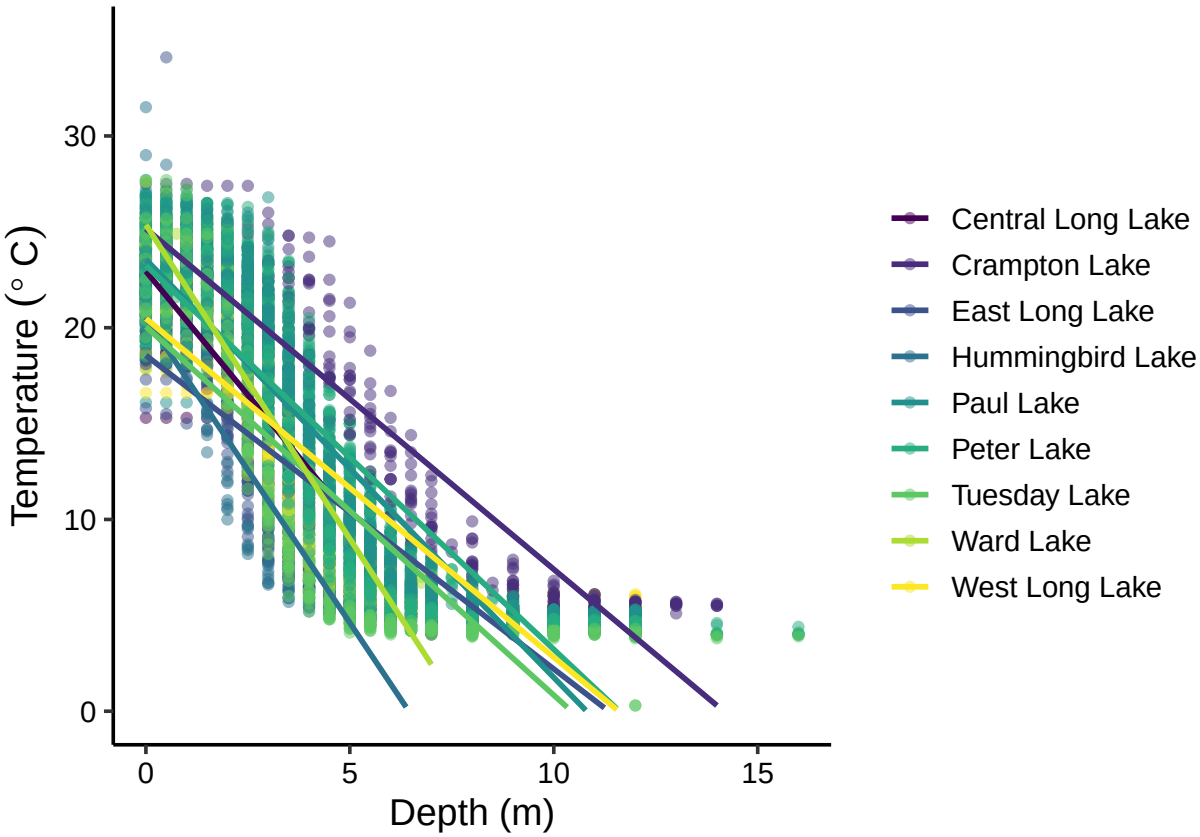
7. Is there a significant interaction between depth and lakename? How much variance in the temperature observations does this explain?

   Answer: Yes, there is a significant interaction between depth and lakename. For the overall model, $p < 0.0001$, and most of the individual interaction terms in the model (e.g., the interaction between depth and Peter Lake) significantly affect temperature. A model that uses the interaction effects between depth and lakename to predict temperature explains 78.57% of the observed variance in temperature.

8. Create a graph that depicts temperature by depth, with a separate color for each lake. Add a geom_smooth (method = "lm", se = FALSE) for each lake. Make your points 50 % transparent. Adjust your y axis limits to go from 0 to 35 degrees. Clean up your graph to make it pretty.

```
#8
#Creating a graph of temperature vs. depth
temp.depth <- ggplot(data = NTL_LTER_wr,
                     aes(x = depth, y = temperature_C, color = lakename)) +
  geom_point(alpha = 0.5) +
  geom_smooth(method = "lm", se = FALSE) +
  labs(x = "Depth (m)", y = expression("Temperature " (degree~C)),
       color = "") +
  ylim(0, 35) +
  scale_color_viridis_d()

print(temp.depth)
```



9. Run a mixed effects model to predict dry mass of litter. We already know that nlcdClass and functionalGroup have a significant interaction, so we will specify those two variables as fixed effects with an interaction. We also know that litter mass varies across plot ID, but we are less interested in the actual effect of the plot itself but rather in accounting for the variance among plots. Plot ID will be our random effect.

a. Build and run a mixed effects model.
b. Check the difference between the marginal and conditional R2 of the model.

```
#Mixed effects model
dryMass.lme <- lme(data = Litter,
              dryMass ~ nlcdClass * functionalGroup,
              random = ~1|plotID)

summary(dryMass.lme)
```

```
## Linear mixed-effects model fit by REML
##  Data: Litter
##        AIC      BIC    logLik
##   9038.575 9179.479 -4493.287
##
## Random effects:
##  Formula: ~1 | plotID
##         (Intercept) Residual
## StdDev:   0.5899105 3.456817
##
## Fixed effects: dryMass ~ nlcdClass * functionalGroup
##                                                                  Value
## (Intercept)                                                   0.155492
## nlcdClassgrasslandHerbaceous                                 -0.156004
## nlcdClassshrubScrub                                          -0.107080
## functionalGroupLeaves                                        -0.126008
## functionalGroupMixed                                          1.477797
## functionalGroupNeedles                                        7.284064
## functionalGroupOther                                         -0.048525
## functionalGroupSeeds                                         -0.058702
## functionalGroupTwigs/branches                                 1.929441
## functionalGroupWoody material                                 1.068772
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves            0.181416
## nlcdClassshrubScrub:functionalGroupLeaves                     0.173857
## nlcdClassgrasslandHerbaceous:functionalGroupMixed            -0.467648
## nlcdClassshrubScrub:functionalGroupMixed                      0.633876
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles          -2.118299
## nlcdClassshrubScrub:functionalGroupNeedles                   -2.909142
## nlcdClassgrasslandHerbaceous:functionalGroupOther             0.143603
## nlcdClassshrubScrub:functionalGroupOther                      0.104935
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds             0.049290
## nlcdClassshrubScrub:functionalGroupSeeds                      0.076708
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches   -0.986627
## nlcdClassshrubScrub:functionalGroupTwigs/branches            -1.503446
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material   -1.017803
## nlcdClassshrubScrub:functionalGroupWoody material            -0.979078
##                                                              Std.Error   DF
## (Intercept)                                                  0.4863580 1659
## nlcdClassgrasslandHerbaceous                                 0.7789816    9
```

```
## nlcdClassshrubScrub                                          0.6636775    9
## functionalGroupLeaves                                        0.5501061 1659
## functionalGroupMixed                                         0.6323043 1659
## functionalGroupNeedles                                       0.5313161 1659
## functionalGroupOther                                         0.5500878 1659
## functionalGroupSeeds                                         0.5501061 1659
## functionalGroupTwigs/branches                                0.5385556 1659
## functionalGroupWoody material                                0.5259330 1659
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves           0.8847246 1659
## nlcdClassshrubScrub:functionalGroupLeaves                    0.7510320 1659
## nlcdClassgrasslandHerbaceous:functionalGroupMixed            1.1201304 1659
## nlcdClassshrubScrub:functionalGroupMixed                     0.9217911 1659
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles          0.8705440 1659
## nlcdClassshrubScrub:functionalGroupNeedles                   0.7347172 1659
## nlcdClassgrasslandHerbaceous:functionalGroupOther            0.8976715 1659
## nlcdClassshrubScrub:functionalGroupOther                     0.7528434 1659
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds            0.8976827 1659
## nlcdClassshrubScrub:functionalGroupSeeds                     0.7547591 1659
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.8850639 1659
## nlcdClassshrubScrub:functionalGroupTwigs/branches            0.7409024 1659
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.8802289 1659
## nlcdClassshrubScrub:functionalGroupWoody material            0.7317033 1659
##                                                                t-value
## (Intercept)                                                   0.319706
## nlcdClassgrasslandHerbaceous                                 -0.200266
## nlcdClassshrubScrub                                          -0.161343
## functionalGroupLeaves                                        -0.229061
## functionalGroupMixed                                          2.337160
## functionalGroupNeedles                                       13.709474
## functionalGroupOther                                         -0.088213
## functionalGroupSeeds                                         -0.106711
## functionalGroupTwigs/branches                                 3.582622
## functionalGroupWoody material                                 2.032144
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves            0.205053
## nlcdClassshrubScrub:functionalGroupLeaves                     0.231490
## nlcdClassgrasslandHerbaceous:functionalGroupMixed            -0.417495
## nlcdClassshrubScrub:functionalGroupMixed                      0.687657
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles          -2.433305
## nlcdClassshrubScrub:functionalGroupNeedles                   -3.959540
## nlcdClassgrasslandHerbaceous:functionalGroupOther             0.159972
## nlcdClassshrubScrub:functionalGroupOther                      0.139385
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds             0.054908
## nlcdClassshrubScrub:functionalGroupSeeds                      0.101632
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -1.114752
## nlcdClassshrubScrub:functionalGroupTwigs/branches            -2.029209
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -1.156293
## nlcdClassshrubScrub:functionalGroupWoody material            -1.338081
##                                                                p-value
## (Intercept)                                                    0.7492
## nlcdClassgrasslandHerbaceous                                   0.8457
## nlcdClassshrubScrub                                            0.8754
## functionalGroupLeaves                                          0.8188
## functionalGroupMixed                                           0.0195
## functionalGroupNeedles                                         0.0000
```

```
## functionalGroupOther                                          0.9297
## functionalGroupSeeds                                          0.9150
## functionalGroupTwigs/branches                                 0.0003
## functionalGroupWoody material                                 0.0423
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves            0.8376
## nlcdClassshrubScrub:functionalGroupLeaves                     0.8170
## nlcdClassgrasslandHerbaceous:functionalGroupMixed             0.6764
## nlcdClassshrubScrub:functionalGroupMixed                      0.4918
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles           0.0151
## nlcdClassshrubScrub:functionalGroupNeedles                    0.0001
## nlcdClassgrasslandHerbaceous:functionalGroupOther             0.8729
## nlcdClassshrubScrub:functionalGroupOther                      0.8892
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds             0.9562
## nlcdClassshrubScrub:functionalGroupSeeds                      0.9191
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches    0.2651
## nlcdClassshrubScrub:functionalGroupTwigs/branches             0.0426
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material    0.2477
## nlcdClassshrubScrub:functionalGroupWoody material             0.1811
##  Correlation:
##                                                              (Intr) nlcdCH
## nlcdClassgrasslandHerbaceous                                 -0.624
## nlcdClassshrubScrub                                          -0.733  0.458
## functionalGroupLeaves                                        -0.559  0.349
## functionalGroupMixed                                         -0.485  0.303
## functionalGroupNeedles                                       -0.579  0.361
## functionalGroupOther                                         -0.559  0.349
## functionalGroupSeeds                                         -0.559  0.349
## functionalGroupTwigs/branches                                -0.571  0.356
## functionalGroupWoody material                                -0.584  0.365
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves            0.347 -0.586
## nlcdClassshrubScrub:functionalGroupLeaves                     0.409 -0.255
## nlcdClassgrasslandHerbaceous:functionalGroupMixed             0.274 -0.462
## nlcdClassshrubScrub:functionalGroupMixed                      0.333 -0.208
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles           0.353 -0.595
## nlcdClassshrubScrub:functionalGroupNeedles                    0.418 -0.261
## nlcdClassgrasslandHerbaceous:functionalGroupOther             0.342 -0.577
## nlcdClassshrubScrub:functionalGroupOther                      0.408 -0.255
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds             0.342 -0.577
## nlcdClassshrubScrub:functionalGroupSeeds                      0.407 -0.254
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches    0.347 -0.586
## nlcdClassshrubScrub:functionalGroupTwigs/branches             0.415 -0.259
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material    0.349 -0.589
## nlcdClassshrubScrub:functionalGroupWoody material             0.420 -0.262
##                                                              nlcdCS fnctGL
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves                                         0.409
## functionalGroupMixed                                          0.356  0.429
## functionalGroupNeedles                                        0.424  0.511
## functionalGroupOther                                          0.409  0.494
## functionalGroupSeeds                                          0.409  0.494
## functionalGroupTwigs/branches                                 0.418  0.504
## functionalGroupWoody material                                 0.428  0.516
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves           -0.255 -0.622
```

```
## nlcdClassshrubScrub:functionalGroupLeaves                  -0.569 -0.732
## nlcdClassgrasslandHerbaceous:functionalGroupMixed          -0.201 -0.242
## nlcdClassshrubScrub:functionalGroupMixed                   -0.464 -0.295
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        -0.259 -0.312
## nlcdClassshrubScrub:functionalGroupNeedles                 -0.582 -0.370
## nlcdClassgrasslandHerbaceous:functionalGroupOther          -0.251 -0.303
## nlcdClassshrubScrub:functionalGroupOther                   -0.568 -0.361
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds          -0.251 -0.303
## nlcdClassshrubScrub:functionalGroupSeeds                   -0.566 -0.360
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.254 -0.307
## nlcdClassshrubScrub:functionalGroupTwigs/branches          -0.577 -0.367
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.256 -0.309
## nlcdClassshrubScrub:functionalGroupWoody material          -0.584 -0.371
##                                                            fnctGM fnctGN
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles                                      0.445
## functionalGroupOther                                        0.430  0.511
## functionalGroupSeeds                                        0.429  0.511
## functionalGroupTwigs/branches                               0.439  0.522
## functionalGroupWoody material                               0.449  0.535
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves         -0.267 -0.318
## nlcdClassshrubScrub:functionalGroupLeaves                  -0.314 -0.374
## nlcdClassgrasslandHerbaceous:functionalGroupMixed          -0.564 -0.251
## nlcdClassshrubScrub:functionalGroupMixed                   -0.686 -0.305
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        -0.272 -0.610
## nlcdClassshrubScrub:functionalGroupNeedles                 -0.322 -0.723
## nlcdClassgrasslandHerbaceous:functionalGroupOther          -0.263 -0.313
## nlcdClassshrubScrub:functionalGroupOther                   -0.314 -0.374
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds          -0.263 -0.313
## nlcdClassshrubScrub:functionalGroupSeeds                   -0.313 -0.373
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.267 -0.318
## nlcdClassshrubScrub:functionalGroupTwigs/branches          -0.319 -0.380
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.268 -0.320
## nlcdClassshrubScrub:functionalGroupWoody material          -0.322 -0.384
##                                                            fnctGO fnctGS
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds                                        0.494
## functionalGroupTwigs/branches                               0.504  0.504
## functionalGroupWoody material                               0.516  0.517
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves         -0.307 -0.307
## nlcdClassshrubScrub:functionalGroupLeaves                  -0.362 -0.362
## nlcdClassgrasslandHerbaceous:functionalGroupMixed          -0.243 -0.242
## nlcdClassshrubScrub:functionalGroupMixed                   -0.295 -0.294
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        -0.312 -0.312
## nlcdClassshrubScrub:functionalGroupNeedles                 -0.370 -0.370
## nlcdClassgrasslandHerbaceous:functionalGroupOther          -0.613 -0.303
```

```
## nlcdClassshrubScrub:functionalGroupOther                    -0.731 -0.361
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           -0.303 -0.613
## nlcdClassshrubScrub:functionalGroupSeeds                    -0.360 -0.729
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.307
## nlcdClassshrubScrub:functionalGroupTwigs/branches           -0.367 -0.367
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.309
## nlcdClassshrubScrub:functionalGroupWoody material           -0.371 -0.371
##                                                             fncGT/ fncGWm
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material                                0.528
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves          -0.314 -0.321
## nlcdClassshrubScrub:functionalGroupLeaves                   -0.369 -0.378
## nlcdClassgrasslandHerbaceous:functionalGroupMixed           -0.248 -0.253
## nlcdClassshrubScrub:functionalGroupMixed                    -0.301 -0.308
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles         -0.319 -0.326
## nlcdClassshrubScrub:functionalGroupNeedles                  -0.378 -0.387
## nlcdClassgrasslandHerbaceous:functionalGroupOther           -0.309 -0.316
## nlcdClassshrubScrub:functionalGroupOther                    -0.369 -0.377
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           -0.309 -0.317
## nlcdClassshrubScrub:functionalGroupSeeds                    -0.368 -0.376
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.608 -0.321
## nlcdClassshrubScrub:functionalGroupTwigs/branches           -0.727 -0.384
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.315 -0.597
## nlcdClassshrubScrub:functionalGroupWoody material           -0.379 -0.719
##                                                             nCH:GL nCS:GL
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves                    0.455
## nlcdClassgrasslandHerbaceous:functionalGroupMixed            0.406  0.178
## nlcdClassshrubScrub:functionalGroupMixed                     0.183  0.410
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles          0.524  0.229
## nlcdClassshrubScrub:functionalGroupNeedles                   0.230  0.514
## nlcdClassgrasslandHerbaceous:functionalGroupOther            0.508  0.222
## nlcdClassshrubScrub:functionalGroupOther                     0.224  0.502
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds            0.508  0.222
## nlcdClassshrubScrub:functionalGroupSeeds                     0.224  0.500
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches   0.515  0.225
## nlcdClassshrubScrub:functionalGroupTwigs/branches            0.228  0.510
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material   0.518  0.226
```

```
## nlcdClassshrubScrub:functionalGroupWoody material           0.231  0.516
##                                                           nCH:GM nCS:GM
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed                    0.387
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles         0.414  0.186
## nlcdClassshrubScrub:functionalGroupNeedles                  0.182  0.419
## nlcdClassgrasslandHerbaceous:functionalGroupOther           0.401  0.181
## nlcdClassshrubScrub:functionalGroupOther                    0.177  0.409
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.402  0.180
## nlcdClassshrubScrub:functionalGroupSeeds                    0.177  0.408
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.407  0.183
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.180  0.416
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.409  0.184
## nlcdClassshrubScrub:functionalGroupWoody material           0.182  0.420
##                                                           nCH:GN nCS:GN
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles                  0.441
## nlcdClassgrasslandHerbaceous:functionalGroupOther           0.517  0.227
## nlcdClassshrubScrub:functionalGroupOther                    0.228  0.513
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.517  0.227
## nlcdClassshrubScrub:functionalGroupSeeds                    0.227  0.512
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.524  0.230
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.232  0.521
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.527  0.231
## nlcdClassshrubScrub:functionalGroupWoody material           0.235  0.528
##                                                           nCH:GO nCS:GO
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
```

```
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther                    0.448
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.501  0.221
## nlcdClassshrubScrub:functionalGroupSeeds                    0.221  0.499
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.508  0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.225  0.509
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.511  0.225
## nlcdClassshrubScrub:functionalGroupWoody material           0.227  0.515
##                                                            nCH:GS nCS:GS
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds                    0.447
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.508  0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.225  0.507
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.511  0.225
## nlcdClassshrubScrub:functionalGroupWoody material           0.228  0.514
##                                                            nCH:GT nCS:GT
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
```

```
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.442
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.518  0.229
## nlcdClassshrubScrub:functionalGroupWoody material           0.231  0.523
##                                                            nCH:Gm
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches
## nlcdClassshrubScrub:functionalGroupTwigs/branches
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material
## nlcdClassshrubScrub:functionalGroupWoody material           0.429
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -1.96496855 -0.23842984 -0.01535880  0.09027291 14.27434811
##
## Number of Observations: 1692
## Number of Groups: 12
```

```
#Marginal r-squared: fixed effects
#Conditional r-quared: r-squared when you add in the random effects
rsquared(dryMass.lme)
```

```
##   Response   family     link method  Marginal Conditional
## 1  dryMass gaussian identity   none 0.2465822   0.2679023
```

b. continued... How much more variance is explained by adding the random effect to the model?

Answer: About 2% (more exactly, 2.132%) more variance is explained by adding the random effect to the model; the fixed effects explain about 24.658% of the variance and the fixed and

random effects explain about 26.790%.

c. Run the same model without the random effect.
d. Run an anova on the two tests.

```
#Same model without random effect
dryMass.lm <- lm(data = Litter,
              dryMass ~ nlcdClass * functionalGroup)

summary(dryMass.lm)
```

```
##
## Call:
## lm(formula = dryMass ~ nlcdClass * functionalGroup, data = Litter)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -6.612 -0.480 -0.058 -0.005 49.051
##
## Coefficients:
##                                                              Estimate
## (Intercept)                                                   0.11963
## nlcdClassgrasslandHerbaceous                                 -0.11420
## nlcdClassshrubScrub                                          -0.10412
## functionalGroupLeaves                                        -0.10360
## functionalGroupMixed                                          1.50475
## functionalGroupNeedles                                        7.31226
## functionalGroupOther                                         -0.03482
## functionalGroupSeeds                                         -0.04616
## functionalGroupTwigs/branches                                 1.95967
## functionalGroupWoody material                                 1.08431
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves            0.12865
## nlcdClassshrubScrub:functionalGroupLeaves                     0.14703
## nlcdClassgrasslandHerbaceous:functionalGroupMixed            -0.38118
## nlcdClassshrubScrub:functionalGroupMixed                      0.74593
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles          -2.13880
## nlcdClassshrubScrub:functionalGroupNeedles                   -2.92148
## nlcdClassgrasslandHerbaceous:functionalGroupOther             0.12606
## nlcdClassshrubScrub:functionalGroupOther                      0.08589
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds             0.04615
## nlcdClassshrubScrub:functionalGroupSeeds                      0.05944
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches   -1.01519
## nlcdClassshrubScrub:functionalGroupTwigs/branches            -1.49559
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material   -1.04086
## nlcdClassshrubScrub:functionalGroupWoody material            -0.97185
##                                                              Std. Error
## (Intercept)                                                     0.39070
## nlcdClassgrasslandHerbaceous                                    0.64223
## nlcdClassshrubScrub                                             0.53838
## functionalGroupLeaves                                           0.55606
## functionalGroupMixed                                            0.63800
## functionalGroupNeedles                                          0.53696
## functionalGroupOther                                            0.55606
## functionalGroupSeeds                                            0.55606
## functionalGroupTwigs/branches                                   0.54434
```

```
## functionalGroupWoody material                                    0.53156
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves               0.89410
## nlcdClassshrubScrub:functionalGroupLeaves                        0.75915
## nlcdClassgrasslandHerbaceous:functionalGroupMixed                1.13024
## nlcdClassshrubScrub:functionalGroupMixed                         0.93038
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles              0.87993
## nlcdClassshrubScrub:functionalGroupNeedles                       0.74258
## nlcdClassgrasslandHerbaceous:functionalGroupOther                0.90743
## nlcdClassshrubScrub:functionalGroupOther                         0.76101
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds                0.90743
## nlcdClassshrubScrub:functionalGroupSeeds                         0.76295
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches       0.89462
## nlcdClassshrubScrub:functionalGroupTwigs/branches                0.74881
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material       0.88971
## nlcdClassshrubScrub:functionalGroupWoody material                0.73957
##                                                                t value
## (Intercept)                                                      0.306
## nlcdClassgrasslandHerbaceous                                    -0.178
## nlcdClassshrubScrub                                             -0.193
## functionalGroupLeaves                                           -0.186
## functionalGroupMixed                                             2.359
## functionalGroupNeedles                                          13.618
## functionalGroupOther                                            -0.063
## functionalGroupSeeds                                            -0.083
## functionalGroupTwigs/branches                                    3.600
## functionalGroupWoody material                                    2.040
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves               0.144
## nlcdClassshrubScrub:functionalGroupLeaves                        0.194
## nlcdClassgrasslandHerbaceous:functionalGroupMixed               -0.337
## nlcdClassshrubScrub:functionalGroupMixed                         0.802
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles             -2.431
## nlcdClassshrubScrub:functionalGroupNeedles                      -3.934
## nlcdClassgrasslandHerbaceous:functionalGroupOther                0.139
## nlcdClassshrubScrub:functionalGroupOther                         0.113
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds                0.051
## nlcdClassshrubScrub:functionalGroupSeeds                         0.078
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches      -1.135
## nlcdClassshrubScrub:functionalGroupTwigs/branches               -1.997
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material      -1.170
## nlcdClassshrubScrub:functionalGroupWoody material               -1.314
##                                                                Pr(>|t|)
## (Intercept)                                                    0.759502
## nlcdClassgrasslandHerbaceous                                   0.858888
## nlcdClassshrubScrub                                            0.846673
## functionalGroupLeaves                                          0.852224
## functionalGroupMixed                                           0.018462 *
## functionalGroupNeedles                                          < 2e-16 ***
## functionalGroupOther                                           0.950081
## functionalGroupSeeds                                           0.933846
## functionalGroupTwigs/branches                                  0.000327 ***
## functionalGroupWoody material                                  0.041519 *
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves             0.885611
## nlcdClassshrubScrub:functionalGroupLeaves                      0.846453
## nlcdClassgrasslandHerbaceous:functionalGroupMixed              0.735969
```

```
## nlcdClassshrubScrub:functionalGroupMixed                    0.422814
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        0.015177 *
## nlcdClassshrubScrub:functionalGroupNeedles                  8.69e-05 ***
## nlcdClassgrasslandHerbaceous:functionalGroupOther          0.889531
## nlcdClassshrubScrub:functionalGroupOther                    0.910155
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds          0.959441
## nlcdClassshrubScrub:functionalGroupSeeds                    0.937915
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.256634
## nlcdClassshrubScrub:functionalGroupTwigs/branches          0.045956 *
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.242213
## nlcdClassshrubScrub:functionalGroupWoody material          0.189001
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.494 on 1668 degrees of freedom
## Multiple R-squared:  0.2516, Adjusted R-squared:  0.2413
## F-statistic: 24.38 on 23 and 1668 DF,  p-value: < 2.2e-16
```

```
#Comparing the results of the two models
anova(dryMass.lme, dryMass.lm)
```

```
##             Model df      AIC      BIC    logLik   Test  L.Ratio p-value
## dryMass.lme     1 26 9038.575 9179.479 -4493.287
## dryMass.lm      2 25 9058.088 9193.573 -4504.044 1 vs 2 21.51338  <.0001
```

d. continued... Is the mixed effects model a better model than the fixed effects model? How do you know?

Answer: The mixed effects model is better than the fixed effects model; its AIC is lower by a value of about 20. The p-value for the comparison of the two models is <.0001, confirming that this lower AIC value indicates that the mixed effects model has a significantly different (and, in this case, better) fit than the fixed effects model.