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
getwd()
```

```
## [1] "C:/Users/26059/OneDrive/Desktop/ENV 872 R/Yang_ENV872"
```

```
library(tidyverse)
library(nlme)
library(piecewiseSEM)
lake<- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")

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

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
lake.july <-
lake%>%
filter(daynum >181 & daynum <213)%>%
select(lakename, year4, daynum, depth, temperature_C)%>%
na.omit()


#4
lake.AIC <- lm(data = lake.july,temperature_C ~ depth + year4 + lakename+ daynum )

step(lake.AIC)
```

```
## Start:  AIC=24461.34
## temperature_C ~ depth + year4 + lakename + daynum
##
##            Df Sum of Sq    RSS   AIC
## <none>                  120062 24461
## - year4     1       184 120245 24474
## - daynum    1      1346 121407 24568
## - lakename  8     21056 141118 26016
## - depth     1    403139 523201 38770

##
## Call:
## lm(formula = temperature_C ~ depth + year4 + lakename + daynum,
##     data = lake.july)
##
## Coefficients:
##              (Intercept)                     depth
##                 45.17306                  -1.96540
##                    year4     lakenameCrampton Lake
##                  -0.01588                   4.71362
##   lakenameEast Long Lake  lakenameHummingbird Lake
##                  -1.46041                  -4.73042
##        lakenamePaul Lake        lakenamePeter Lake
##                   0.99422                   1.44048
##     lakenameTuesday Lake         lakenameWard Lake
##                  -1.38445                  -0.46590
##   lakenameWest Long Lake                    daynum
##                  -0.16847                   0.04157
```

```
lake.main<-lm (data = lake.july,temperature_C ~ depth + year4 + lakename+ daynum )
summary(lake.main)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth + year4 + lakename + daynum,
##     data = lake.july)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.8938 -3.0274 -0.2114  2.7781 15.2926
##
## Coefficients:
##                             Estimate Std. Error  t value Pr(>|t|)
## (Intercept)               45.173063   8.248578    5.476 4.45e-08 ***
## depth                     -1.965403   0.010885 -180.566  < 2e-16 ***
## year4                     -0.015885   0.004118   -3.857 0.000115 ***
## lakenameCrampton Lake      4.713617   0.382185   12.333  < 2e-16 ***
## lakenameEast Long Lake    -1.460406   0.343271   -4.254 2.12e-05 ***
## lakenameHummingbird Lake -4.730421   0.459795  -10.288  < 2e-16 ***
## lakenamePaul Lake          0.994222   0.331643    2.998 0.002726 **
## lakenamePeter Lake         1.440479   0.331406    4.347 1.40e-05 ***
## lakenameTuesday Lake      -1.384450   0.336476   -4.115 3.91e-05 ***
## lakenameWard Lake         -0.465900   0.464619   -1.003 0.316003
## lakenameWest Long Lake    -0.168474   0.341961   -0.493 0.622257
## daynum                     0.041574   0.003985   10.432  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.516 on 9710 degrees of freedom
## Multiple R-squared:  0.7803, Adjusted R-squared:   0.78
## F-statistic:  3135 on 11 and 9710 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: The final explanatory variables include depth, year, lakename and day number. This model explains 77.87% of the observed variance.

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

```
#6
lake.inter <- lm(data = lake.july, temperature_C ~ depth * lakename)
summary(lake.inter)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth * lakename, data = lake.july)
##
## 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, the interaction between depth and lakename is significant ($F(17,9390)=2009$, p value<0.001).This model explains 78.39% of the variance in the temperature observations.

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.

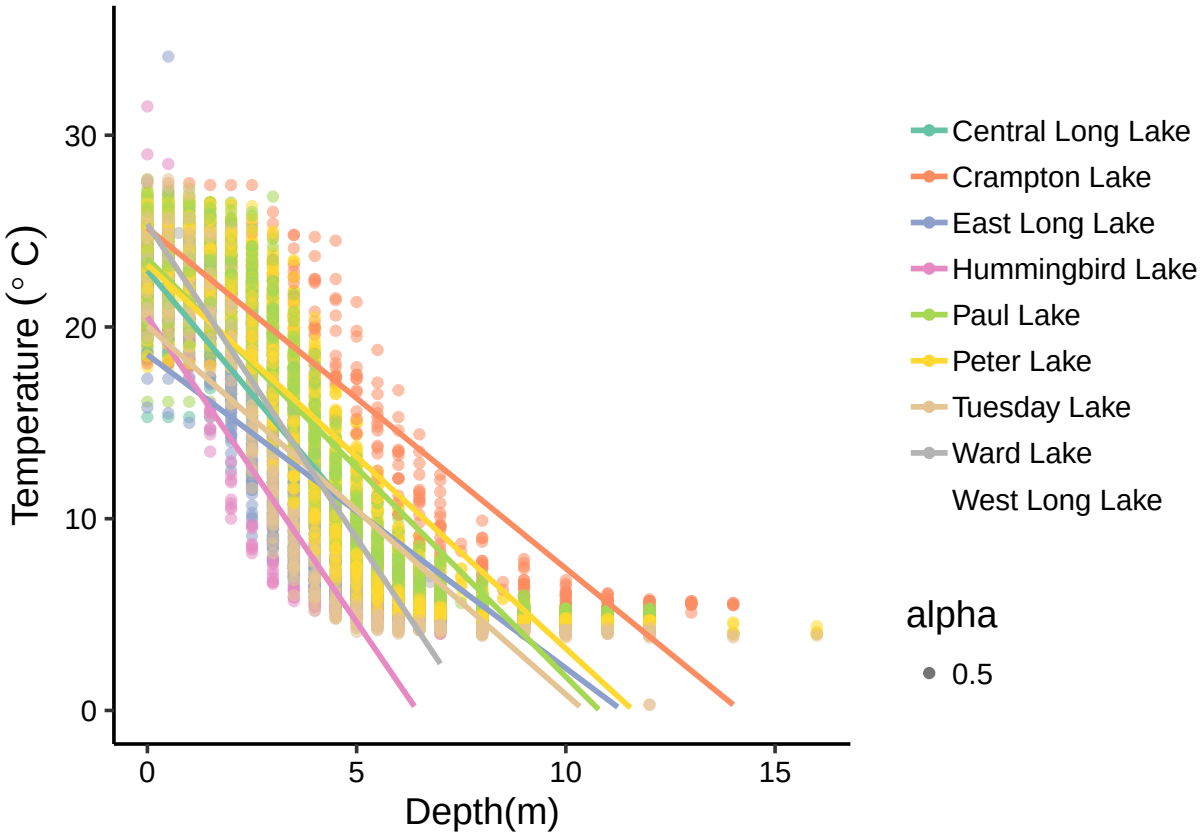
```
#8
lake.plot <-
ggplot(lake.july, aes(x = depth, y = temperature_C,color=lakename)) +
  geom_point(aes(alpha=0.5)) +
  geom_smooth(method="lm",se=FALSE)+
  scale_color_brewer(palette = "Set2",direction = 1) +
  labs(x = "Depth(m)", y = expression("Temperature " ( degree~C)), color = "") +
  ylim(0,35)+
  theme(legend.spacing.x = unit(0, "cm"))

print(lake.plot)
```

```
## Warning in RColorBrewer::brewer.pal(n, pal): n too large, allowed maximum for palette Set2 is 8
## Returning the palette you asked for with that many colors
```

```
## Warning: Removed 1043 rows containing missing values (geom_point).
```

```
## Warning: Removed 73 rows containing missing values (geom_smooth).
```



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.

```
litter<- read.csv("./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv")

litter.mixed <- lme(data = litter,
                    dryMass ~ nlcdClass*functionalGroup,
                    random = ~1|plotID)
summary(litter.mixed)
```

```
## 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
```

```
r2<-rsquared(litter.mixed)
r2
```

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

```
r2$Conditional
```

```
## [1] 0.2679023
```

```
r2$Marginal
```

```
## [1] 0.2465822
```

```
#marginal is the fixed effect, conditional R2 is after adding random effect
```

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

   Answer: 2.13 % more variance is explained by adding the random effect to the model.

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

```r
litter.fixed <- lm(data = litter,
                       dryMass ~ nlcdClass*functionalGroup )

summary(litter.fixed)
```

```
##
## 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
```

```
anova(litter.mixed, litter.fixed)
```

```
##              Model df      AIC      BIC    logLik   Test  L.Ratio p-value
## litter.mixed     1 26 9038.575 9179.479 -4493.287
## litter.fixed     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 because it has a higher R2 value comparing to the fixed effects model. It means the mixed model has higher power in explaining the variance of the data. In addition, the mixed model has a lower AIC compared to the fixed model.