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/Peaceful Pierre/Documents/Academics/Spring 2020/Environmental Data Analytics/Environmer
```

```
library("tidyverse")
```

```
## -- Attaching packages ---------------------------------------------------------------------- tidyverse 1

## v ggplot2 3.2.1     v purrr   0.3.3
## v tibble  2.1.3     v dplyr   0.8.4
## v tidyr   1.0.2     v stringr 1.4.0
## v readr   1.3.1     v forcats 0.4.0

## -- Conflicts ------------------------------------------------------------------------- tidyverse_conflic
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library("nlme")
```

```
##
## Attaching package: 'nlme'

## The following object is masked from 'package:dplyr':
##
##     collapse
```

```
library("piecewiseSEM")
```

```
## Registered S3 methods overwritten by 'lme4':
##   method                           from
##   cooks.distance.influence.merMod car
##   influence.merMod                 car
##   dfbeta.influence.merMod          car
##   dfbetas.influence.merMod         car

##
##   This is piecewiseSEM version 2.1.0.
##
##
##   Questions or bugs can be addressed to <LefcheckJ@si.edu>.
```

```
library("RColorBrewer")
lake <- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")
litter <- read.csv("./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv")

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

theme_set(peaceful.theme)
```

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.

```r
#3
lake_filter <-
  lake %>%
  filter ((lake$daynum > 181) & (lake$daynum <= 213)) %>%
  select(lakename, year4, daynum, depth, temperature_C) %>%
  na.omit()

#4
lakeAIC <- lm(data = lake_filter, temperature_C ~ year4 + daynum + depth)
step(lakeAIC)
```

```
## Start:  AIC=26781.56
## temperature_C ~ year4 + daynum + depth
##
##          Df Sum of Sq    RSS   AIC
## <none>                 146054 26782
## - year4   1       154 146209 26790
## - daynum  1      1582 147636 26887
## - depth   1    414049 560103 40189
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = lake_filter)
##
## Coefficients:
## (Intercept)        year4       daynum        depth
##   -14.33180      0.01386      0.04337     -1.94112
```

```r
lake_model <- lm(data = lake_filter, temperature_C ~ year4 + daynum + depth)
summary(lake_model)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = lake_filter)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -9.669 -3.014  0.091  2.977 13.606
##
## Coefficients:
##               Estimate Std. Error  t value Pr(>|t|)
## (Intercept) -14.331802   8.582522   -1.670  0.09497 .
## year4         0.013861   0.004274    3.243  0.00119 **
## daynum        0.043368   0.004173   10.393  < 2e-16 ***
## depth        -1.941121   0.011545 -168.135  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.827 on 9972 degrees of freedom
## Multiple R-squared:  0.7399, Adjusted R-squared:  0.7398
## F-statistic:  9457 on 3 and 9972 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 three explanatory variables year, day number and lake depth significantly predict lake temperatures (Multiple linear regression, $F(3,9972)=9457$, $p < 0.001$). Our model accounts for 73.98% of the variance in observed temperatures.

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

```
#6
lake_ancova <- lm(data = lake_filter, temperature_C ~ depth * lakename)
summary(lake_ancova)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth * lakename, data = lake_filter)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.6410 -2.9075 -0.2944  2.7531 16.3358
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      22.8748     0.5658  40.427  < 2e-16 ***
## depth                            -2.5543     0.2331 -10.960  < 2e-16 ***
## lakenameCrampton Lake             2.5625     0.6518   3.932 8.49e-05 ***
## lakenameEast Long Lake           -4.2925     0.5993  -7.163 8.46e-13 ***
## lakenameHummingbird Lake         -2.1903     0.8044  -2.723 0.006483 **
## lakenamePaul Lake                 0.7115     0.5784   1.230 0.218684
## lakenamePeter Lake                0.3862     0.5770   0.669 0.503250
## lakenameTuesday Lake             -2.8635     0.5857  -4.889 1.03e-06 ***
## lakenameWard Lake                 2.4887     0.8299   2.999 0.002718 **
## lakenameWest Long Lake           -2.4193     0.5959  -4.060 4.94e-05 ***
## depth:lakenameCrampton Lake       0.7704     0.2379   3.238 0.001208 **
## depth:lakenameEast Long Lake      0.9181     0.2353   3.902 9.60e-05 ***
## depth:lakenameHummingbird Lake   -0.6738     0.2831  -2.380 0.017323 *
## depth:lakenamePaul Lake           0.3716     0.2341   1.587 0.112452
## depth:lakenamePeter Lake          0.5503     0.2338   2.354 0.018612 *
## depth:lakenameTuesday Lake        0.6486     0.2345   2.766 0.005687 **
## depth:lakenameWard Lake          -0.7207     0.2796  -2.578 0.009962 **
## depth:lakenameWest Long Lake      0.7928     0.2351   3.373 0.000747 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.475 on 9958 degrees of freedom
## Multiple R-squared:  0.7859, Adjusted R-squared:  0.7855
## F-statistic:  2150 on 17 and 9958 DF,  p-value: < 2.2e-16
```

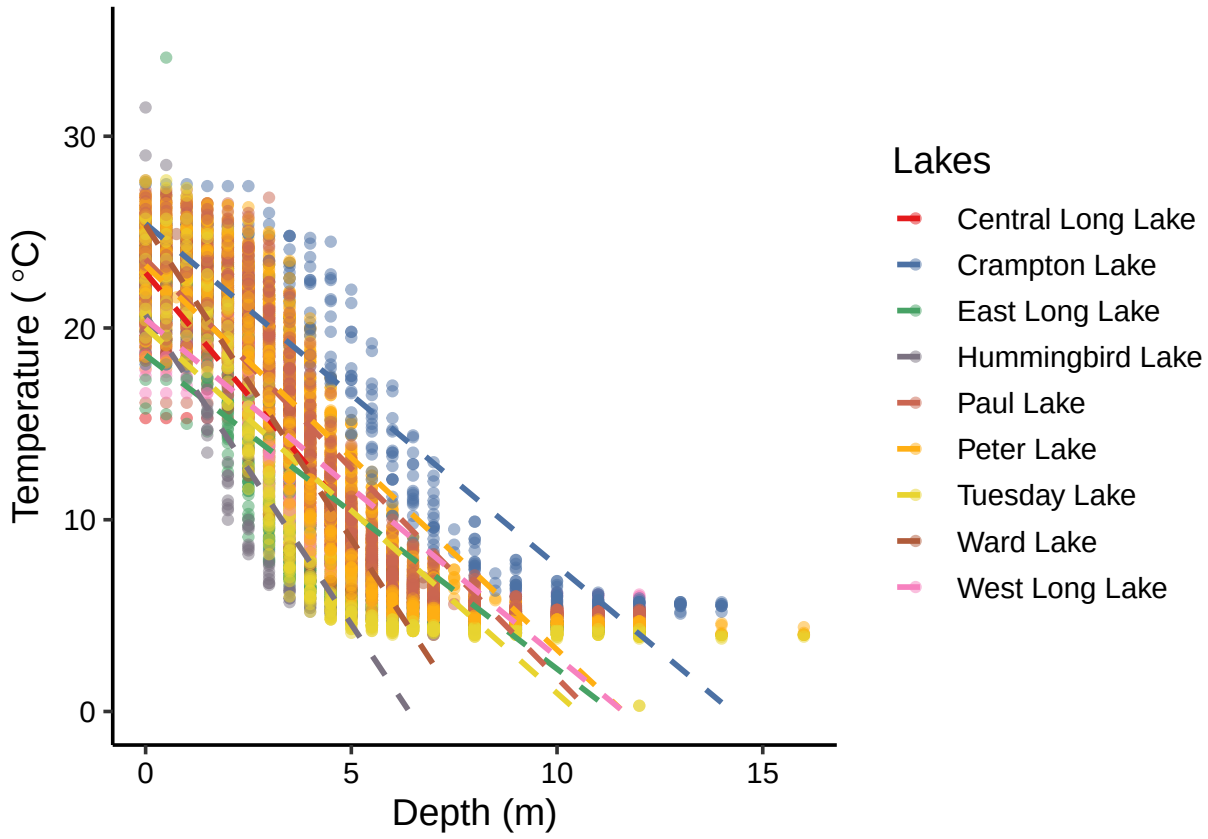
7. Is there a significant interaction between depth and lakename? How much variance in the temperature observations does this explain?

Answer: Yes there is a significant interaction effect between depth and lakename. All th interaction effects are significant with a p-value of less than 0.05 except the interaction of depth and paul lake whose p-value is 0.11. 78.55% of variance in the temperature observations can explained by the ANCOVA.

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
ggplot(data = lake_filter, aes(x = depth, y=temperature_C, color=lakename)) +
  geom_point(alpha = 0.5) +
  ylim(0,35) +
  geom_smooth (method = "lm", se = FALSE, size = 1, lty = 2) +
  labs (x = "Depth (m)", y = expression("Temperature ("~degree*"C)"), color = "Lakes") +
  scale_color_manual (values = colorRampPalette(brewer.pal(8, "Set1"))(9))
```

```
## 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.

```
#a.
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 Std.Error
## (Intercept)                                                     0.155492 0.4863580
## nlcdClassgrasslandHerbaceous                                   -0.156004 0.7789816
## nlcdClassshrubScrub                                            -0.107080 0.6636775
## functionalGroupLeaves                                          -0.126008 0.5501061
## functionalGroupMixed                                            1.477797 0.6323043
## functionalGroupNeedles                                          7.284064 0.5313161
## functionalGroupOther                                           -0.048525 0.5500878
## functionalGroupSeeds                                           -0.058702 0.5501061
## functionalGroupTwigs/branches                                   1.929441 0.5385556
## functionalGroupWoody material                                   1.068772 0.5259330
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves              0.181416 0.8847246
## nlcdClassshrubScrub:functionalGroupLeaves                       0.173857 0.7510320
## nlcdClassgrasslandHerbaceous:functionalGroupMixed              -0.467648 1.1201304
## nlcdClassshrubScrub:functionalGroupMixed                        0.633876 0.9217911
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles            -2.118299 0.8705440
## nlcdClassshrubScrub:functionalGroupNeedles                     -2.909142 0.7347172
## nlcdClassgrasslandHerbaceous:functionalGroupOther               0.143603 0.8976715
## nlcdClassshrubScrub:functionalGroupOther                        0.104935 0.7528434
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds               0.049290 0.8976827
## nlcdClassshrubScrub:functionalGroupSeeds                        0.076708 0.7547591
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches     -0.986627 0.8850639
## nlcdClassshrubScrub:functionalGroupTwigs/branches              -1.503446 0.7409024
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material     -1.017803 0.8802289
## nlcdClassshrubScrub:functionalGroupWoody material              -0.979078 0.7317033
##                                                                   DF   t-value
## (Intercept)                                                     1659  0.319706
## nlcdClassgrasslandHerbaceous                                       9 -0.200266
## nlcdClassshrubScrub                                                9 -0.161343
## functionalGroupLeaves                                           1659 -0.229061
## functionalGroupMixed                                            1659  2.337160
## functionalGroupNeedles                                          1659 13.709474
## functionalGroupOther                                            1659 -0.088213
## functionalGroupSeeds                                            1659 -0.106711
## functionalGroupTwigs/branches                                   1659  3.582622
```

```
## functionalGroupWoody material                                    1659  2.032144
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves               1659  0.205053
## nlcdClassshrubScrub:functionalGroupLeaves                        1659  0.231490
## nlcdClassgrasslandHerbaceous:functionalGroupMixed                1659 -0.417495
## nlcdClassshrubScrub:functionalGroupMixed                         1659  0.687657
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles              1659 -2.433305
## nlcdClassshrubScrub:functionalGroupNeedles                       1659 -3.959540
## nlcdClassgrasslandHerbaceous:functionalGroupOther                1659  0.159972
## nlcdClassshrubScrub:functionalGroupOther                         1659  0.139385
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds                1659  0.054908
## nlcdClassshrubScrub:functionalGroupSeeds                         1659  0.101632
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches       1659 -1.114752
## nlcdClassshrubScrub:functionalGroupTwigs/branches                1659 -2.029209
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material       1659 -1.156293
## nlcdClassshrubScrub:functionalGroupWoody material                1659 -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 nlcdCS
## nlcdClassgrasslandHerbaceous                                     -0.624
## nlcdClassshrubScrub                                              -0.733  0.458
## functionalGroupLeaves                                            -0.559  0.349  0.409
## functionalGroupMixed                                             -0.485  0.303  0.356
## functionalGroupNeedles                                           -0.579  0.361  0.424
## functionalGroupOther                                             -0.559  0.349  0.409
## functionalGroupSeeds                                             -0.559  0.349  0.409
## functionalGroupTwigs/branches                                    -0.571  0.356  0.418
## functionalGroupWoody material                                    -0.584  0.365  0.428
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves                0.347 -0.586 -0.255
## nlcdClassshrubScrub:functionalGroupLeaves                         0.409 -0.255 -0.569
## nlcdClassgrasslandHerbaceous:functionalGroupMixed                 0.274 -0.462 -0.201
```

```
## nlcdClassshrubScrub:functionalGroupMixed                     0.333 -0.208 -0.464
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles          0.353 -0.595 -0.259
## nlcdClassshrubScrub:functionalGroupNeedles                   0.418 -0.261 -0.582
## nlcdClassgrasslandHerbaceous:functionalGroupOther            0.342 -0.577 -0.251
## nlcdClassshrubScrub:functionalGroupOther                     0.408 -0.255 -0.568
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds            0.342 -0.577 -0.251
## nlcdClassshrubScrub:functionalGroupSeeds                     0.407 -0.254 -0.566
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches   0.347 -0.586 -0.254
## nlcdClassshrubScrub:functionalGroupTwigs/branches            0.415 -0.259 -0.577
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material   0.349 -0.589 -0.256
## nlcdClassshrubScrub:functionalGroupWoody material            0.420 -0.262 -0.584
##                                                             fnctGL fnctGM fnctGN
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed                                         0.429
## functionalGroupNeedles                                       0.511  0.445
## functionalGroupOther                                         0.494  0.430  0.511
## functionalGroupSeeds                                         0.494  0.429  0.511
## functionalGroupTwigs/branches                                0.504  0.439  0.522
## functionalGroupWoody material                                0.516  0.449  0.535
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves          -0.622 -0.267 -0.318
## nlcdClassshrubScrub:functionalGroupLeaves                   -0.732 -0.314 -0.374
## nlcdClassgrasslandHerbaceous:functionalGroupMixed           -0.242 -0.564 -0.251
## nlcdClassshrubScrub:functionalGroupMixed                    -0.295 -0.686 -0.305
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles         -0.312 -0.272 -0.610
## nlcdClassshrubScrub:functionalGroupNeedles                  -0.370 -0.322 -0.723
## nlcdClassgrasslandHerbaceous:functionalGroupOther           -0.303 -0.263 -0.313
## nlcdClassshrubScrub:functionalGroupOther                    -0.361 -0.314 -0.374
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           -0.303 -0.263 -0.313
## nlcdClassshrubScrub:functionalGroupSeeds                    -0.360 -0.313 -0.373
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.267 -0.318
## nlcdClassshrubScrub:functionalGroupTwigs/branches           -0.367 -0.319 -0.380
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.268 -0.320
## nlcdClassshrubScrub:functionalGroupWoody material           -0.371 -0.322 -0.384
##                                                             fnctGO fnctGS fncGT/
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds                                         0.494
## functionalGroupTwigs/branches                                0.504  0.504
## functionalGroupWoody material                                0.516  0.517  0.528
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves          -0.307 -0.307 -0.314
## nlcdClassshrubScrub:functionalGroupLeaves                   -0.362 -0.362 -0.369
## nlcdClassgrasslandHerbaceous:functionalGroupMixed           -0.243 -0.242 -0.248
## nlcdClassshrubScrub:functionalGroupMixed                    -0.295 -0.294 -0.301
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles         -0.312 -0.312 -0.319
## nlcdClassshrubScrub:functionalGroupNeedles                  -0.370 -0.370 -0.378
## nlcdClassgrasslandHerbaceous:functionalGroupOther           -0.613 -0.303 -0.309
## nlcdClassshrubScrub:functionalGroupOther                    -0.731 -0.361 -0.369
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           -0.303 -0.613 -0.309
```

```
## nlcdClassshrubScrub:functionalGroupSeeds                    -0.360 -0.729 -0.368
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.307 -0.608
## nlcdClassshrubScrub:functionalGroupTwigs/branches          -0.367 -0.367 -0.727
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.309 -0.315
## nlcdClassshrubScrub:functionalGroupWoody material          -0.371 -0.371 -0.379
##                                                            fncGWm nCH:GL nCS:GL
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves         -0.321
## nlcdClassshrubScrub:functionalGroupLeaves                  -0.378  0.455
## nlcdClassgrasslandHerbaceous:functionalGroupMixed          -0.253  0.406  0.178
## nlcdClassshrubScrub:functionalGroupMixed                   -0.308  0.183  0.410
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        -0.326  0.524  0.229
## nlcdClassshrubScrub:functionalGroupNeedles                 -0.387  0.230  0.514
## nlcdClassgrasslandHerbaceous:functionalGroupOther          -0.316  0.508  0.222
## nlcdClassshrubScrub:functionalGroupOther                   -0.377  0.224  0.502
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds          -0.317  0.508  0.222
## nlcdClassshrubScrub:functionalGroupSeeds                   -0.376  0.224  0.500
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.321  0.515  0.225
## nlcdClassshrubScrub:functionalGroupTwigs/branches          -0.384  0.228  0.510
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.597  0.518  0.226
## nlcdClassshrubScrub:functionalGroupWoody material          -0.719  0.231  0.516
##                                                            nCH:GM nCS:GM nCH:GN
## 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  0.441
## nlcdClassgrasslandHerbaceous:functionalGroupOther           0.401  0.181  0.517
## nlcdClassshrubScrub:functionalGroupOther                    0.177  0.409  0.228
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.402  0.180  0.517
## nlcdClassshrubScrub:functionalGroupSeeds                    0.177  0.408  0.227
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.407  0.183  0.524
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.180  0.416  0.232
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.409  0.184  0.527
## nlcdClassshrubScrub:functionalGroupWoody material           0.182  0.420  0.235
##                                                            nCS:GN 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           0.227
## nlcdClassshrubScrub:functionalGroupOther                    0.513  0.448
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.227  0.501  0.221
## nlcdClassshrubScrub:functionalGroupSeeds                    0.512  0.221  0.499
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.230  0.508  0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.521  0.225  0.509
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.231  0.511  0.225
## nlcdClassshrubScrub:functionalGroupWoody material           0.528  0.227  0.515
##                                                            nCH:GS nCS:GS nCH: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                    0.447
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.508  0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.225  0.507  0.442
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.511  0.225  0.518
## nlcdClassshrubScrub:functionalGroupWoody material           0.228  0.514  0.231
##                                                            nCS:GT 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  0.229
## nlcdClassshrubScrub:functionalGroupWoody material           0.523  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
```

```
#b.
rsquared(litter_mixed)
```

```
##   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: The variance increased by 2.132 % 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.

```
#c.
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 Std. Error
```

```
## (Intercept)                                                 0.11963    0.39070
## nlcdClassgrasslandHerbaceous                               -0.11420    0.64223
## nlcdClassshrubScrub                                        -0.10412    0.53838
## functionalGroupLeaves                                      -0.10360    0.55606
## functionalGroupMixed                                        1.50475    0.63800
## functionalGroupNeedles                                      7.31226    0.53696
## functionalGroupOther                                       -0.03482    0.55606
## functionalGroupSeeds                                       -0.04616    0.55606
## functionalGroupTwigs/branches                               1.95967    0.54434
## functionalGroupWoody material                               1.08431    0.53156
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves          0.12865    0.89410
## nlcdClassshrubScrub:functionalGroupLeaves                   0.14703    0.75915
## nlcdClassgrasslandHerbaceous:functionalGroupMixed          -0.38118    1.13024
## nlcdClassshrubScrub:functionalGroupMixed                    0.74593    0.93038
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        -2.13880    0.87993
## nlcdClassshrubScrub:functionalGroupNeedles                 -2.92148    0.74258
## nlcdClassgrasslandHerbaceous:functionalGroupOther           0.12606    0.90743
## nlcdClassshrubScrub:functionalGroupOther                    0.08589    0.76101
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.04615    0.90743
## nlcdClassshrubScrub:functionalGroupSeeds                    0.05944    0.76295
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -1.01519    0.89462
## nlcdClassshrubScrub:functionalGroupTwigs/branches          -1.49559    0.74881
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -1.04086    0.88971
## nlcdClassshrubScrub:functionalGroupWoody material          -0.97185    0.73957
##                                                            t value Pr(>|t|)
## (Intercept)                                                  0.306 0.759502
## nlcdClassgrasslandHerbaceous                                -0.178 0.858888
## nlcdClassshrubScrub                                         -0.193 0.846673
## functionalGroupLeaves                                       -0.186 0.852224
## functionalGroupMixed                                         2.359 0.018462 *
## functionalGroupNeedles                                      13.618  < 2e-16 ***
## functionalGroupOther                                        -0.063 0.950081
## functionalGroupSeeds                                        -0.083 0.933846
## functionalGroupTwigs/branches                                3.600 0.000327 ***
## functionalGroupWoody material                                2.040 0.041519 *
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves           0.144 0.885611
## nlcdClassshrubScrub:functionalGroupLeaves                    0.194 0.846453
## nlcdClassgrasslandHerbaceous:functionalGroupMixed           -0.337 0.735969
## nlcdClassshrubScrub:functionalGroupMixed                     0.802 0.422814
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles         -2.431 0.015177 *
## nlcdClassshrubScrub:functionalGroupNeedles                  -3.934 8.69e-05 ***
## nlcdClassgrasslandHerbaceous:functionalGroupOther            0.139 0.889531
## nlcdClassshrubScrub:functionalGroupOther                     0.113 0.910155
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds            0.051 0.959441
## nlcdClassshrubScrub:functionalGroupSeeds                     0.078 0.937915
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  -1.135 0.256634
## nlcdClassshrubScrub:functionalGroupTwigs/branches           -1.997 0.045956 *
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  -1.170 0.242213
## nlcdClassshrubScrub:functionalGroupWoody material           -1.314 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
```

```
#d.
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: Our ANOVA returned a p-value less than 0.0001 meaning that both the models have a significantly different fit. The mixed effects model is a better model because it has a lower AIC and BIC value.