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] "/Users/mashaedmondson/Desktop/Environmental_Data_Analytics_2020"
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------------------------- tidyverse 1.3.0 --
```

```
## v ggplot2 3.2.1     v purrr   0.3.3
## v tibble  2.1.3     v dplyr   0.8.3
## v tidyr   1.0.0     v stringr 1.4.0
## v readr   1.3.1     v forcats 0.4.0
```

```
## -- Conflicts ------------------------------------------------------------ tidyverse_conflicts() --
## 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>.
```

```
NTL_LTER_Chem_Raw <- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")
NTL_LTER_Litter<- read.csv("./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv")

#2
mytheme <- theme_classic(base_size = 14) +
  theme(axis.text = element_text(color = "black"),
        legend.position = "top")
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
NTL.July <-
  NTL_LTER_Chem_Raw %>%
  filter(daynum > 182 & daynum < 213)%>%
  select(lakename, temperature_C, year4 , daynum , depth) %>%
  na.exclude()

#4
NTLAIC <- lm(data = NTL.July, temperature_C~ year4 + daynum + depth)
step(NTLAIC)
```

```
## Start:  AIC=25233.58
## temperature_C ~ year4 + daynum + depth
##
##          Df Sum of Sq    RSS   AIC
## <none>                137124 25234
## - year4   1       115 137239 25239
## - daynum  1      1015 138139 25301
## - depth   1    392438 529563 37958
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL.July)
##
## Coefficients:
## (Intercept)        year4       daynum        depth
##   -10.13919      0.01232      0.03789     -1.94770
```

```
NTLmodel <- lm(data = NTL.July, temperature_C~ year4 + daynum + depth)
summary(NTLmodel)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL.July)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6680 -3.0016  0.0914  2.9773 13.6150
##
## Coefficients:
##               Estimate Std. Error  t value Pr(>|t|)
## (Intercept) -10.139191   8.801260   -1.152  0.24934
## year4         0.012323   0.004385    2.810  0.00496 **
## daynum        0.037893   0.004539    8.348  < 2e-16 ***
## depth        -1.947704   0.011865 -164.149  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.816 on 9415 degrees of freedom
## Multiple R-squared:  0.7416, Adjusted R-squared:  0.7415
## F-statistic:  9008 on 3 and 9415 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 analysis from the multiple regression shows there is a signficant correlation between temperature, day, and depth ($P < 0.0001$). There is a strong linear relationship between the independent varbles and the dependant variables showing that 74% of the observed variance is explained in the model (multiple R-squared = 0.7415).

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

```
#6
NTL.ancova.main <- lm(data = NTL.July, temperature_C ~ depth*lakename)
summary(NTL.ancova.main)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth * lakename, data = NTL.July)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.6773 -2.8928 -0.2863  2.7567 16.3606
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)                     22.9455     0.5860  39.156  < 2e-16 ***
## depth                           -2.5820     0.2410 -10.713  < 2e-16 ***
## lakenameCrampton Lake            2.2173     0.6802   3.260 0.001119 **
## lakenameEast Long Lake          -4.3884     0.6189  -7.090 1.43e-12 ***
## lakenameHummingbird Lake        -2.8915     0.8634  -3.349 0.000814 ***
## lakenamePaul Lake                0.6607     0.5986   1.104 0.269716
## lakenamePeter Lake               0.3459     0.5973   0.579 0.562564
## lakenameTuesday Lake            -2.8622     0.6066  -4.718 2.41e-06 ***
## lakenameWard Lake                2.4180     0.8432   2.868 0.004145 **
## lakenameWest Long Lake          -2.3753     0.6184  -3.841 0.000123 ***
## depth:lakenameCrampton Lake      0.8058     0.2465   3.269 0.001083 **
## depth:lakenameEast Long Lake     0.9465     0.2432   3.892 0.000100 ***
## depth:lakenameHummingbird Lake  -0.4840     0.2971  -1.629 0.103394
## depth:lakenamePaul Lake          0.4005     0.2421   1.655 0.098027 .
## depth:lakenamePeter Lake         0.5792     0.2418   2.395 0.016619 *
## depth:lakenameTuesday Lake       0.6574     0.2426   2.710 0.006737 **
## depth:lakenameWard Lake         -0.6930     0.2861  -2.422 0.015457 *
## depth:lakenameWest Long Lake     0.8090     0.2432   3.327 0.000883 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.47 on 9401 degrees of freedom
## Multiple R-squared:  0.7867, Adjusted R-squared:  0.7863
## F-statistic:  2040 on 17 and 9401 DF,  p-value: < 2.2e-16
```

```
NTL.ancova.interaction <- lm(data = NTL.July, temperature_C ~ depth*lakename)
summary(NTL.ancova.interaction)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth * lakename, data = NTL.July)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.6773 -2.8928 -0.2863  2.7567 16.3606
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                     22.9455     0.5860  39.156  < 2e-16 ***
## depth                           -2.5820     0.2410 -10.713  < 2e-16 ***
## lakenameCrampton Lake            2.2173     0.6802   3.260 0.001119 **
## lakenameEast Long Lake          -4.3884     0.6189  -7.090 1.43e-12 ***
## lakenameHummingbird Lake        -2.8915     0.8634  -3.349 0.000814 ***
## lakenamePaul Lake                0.6607     0.5986   1.104 0.269716
## lakenamePeter Lake               0.3459     0.5973   0.579 0.562564
## lakenameTuesday Lake            -2.8622     0.6066  -4.718 2.41e-06 ***
## lakenameWard Lake                2.4180     0.8432   2.868 0.004145 **
## lakenameWest Long Lake          -2.3753     0.6184  -3.841 0.000123 ***
## depth:lakenameCrampton Lake      0.8058     0.2465   3.269 0.001083 **
## depth:lakenameEast Long Lake     0.9465     0.2432   3.892 0.000100 ***
## depth:lakenameHummingbird Lake  -0.4840     0.2971  -1.629 0.103394
## depth:lakenamePaul Lake          0.4005     0.2421   1.655 0.098027 .
## depth:lakenamePeter Lake         0.5792     0.2418   2.395 0.016619 *
## depth:lakenameTuesday Lake       0.6574     0.2426   2.710 0.006737 **
## depth:lakenameWard Lake         -0.6930     0.2861  -2.422 0.015457 *
```

```
## depth:lakenameWest Long Lake     0.8090     0.2432   3.327 0.000883 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.47 on 9401 degrees of freedom
## Multiple R-squared:  0.7867, Adjusted R-squared:  0.7863
## F-statistic:  2040 on 17 and 9401 DF,  p-value: < 2.2e-16
```

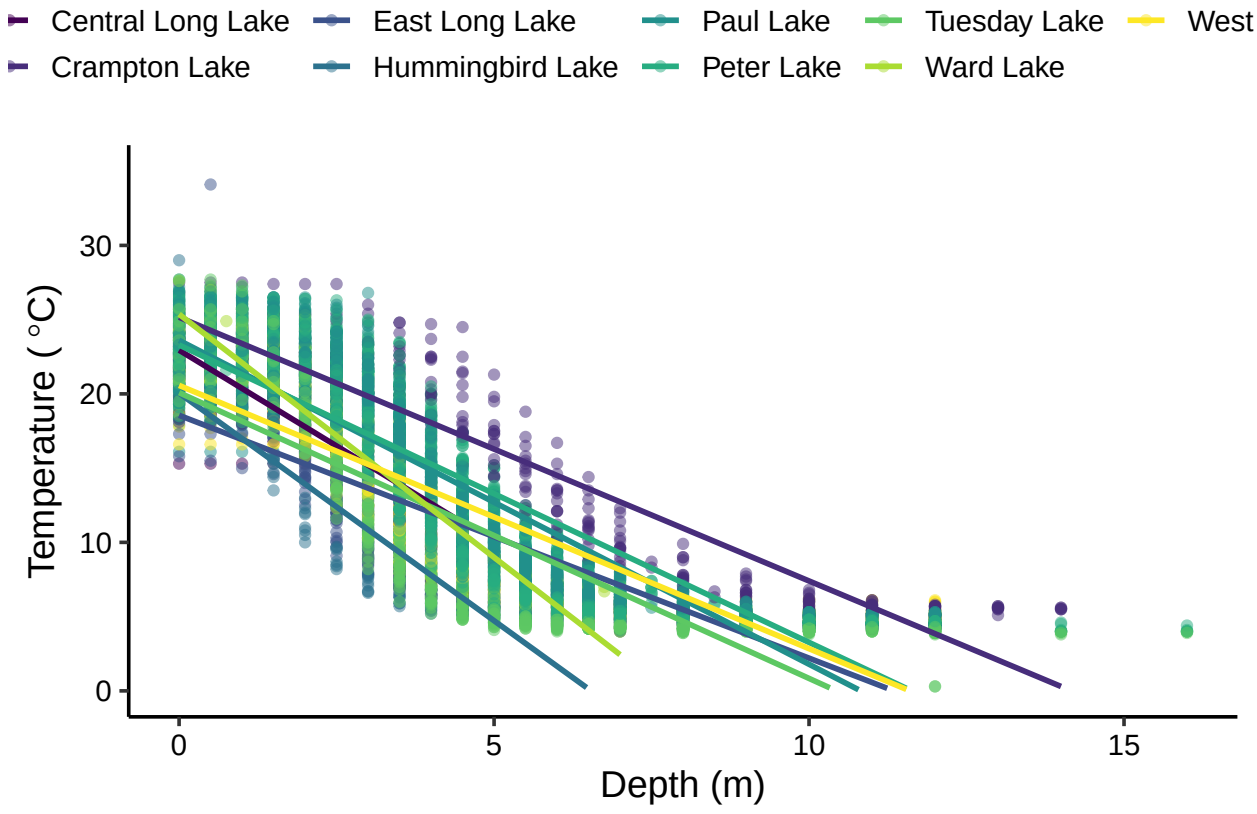
7. Is there a significant interaction between depth and lakename? How much variance in the temperature observations does this explain?

   Answer: There is a significant interaction between depth and many of the lakes ($P < 0.0001$). Around 78% of the variance is explained in the model (Multiple R-squared = 0.7867).

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 -
ANCOVAplot <- ggplot(NTL.July, aes(x = depth, y = temperature_C, color = lakename)) +
  geom_point(alpha= 0.5) +
  scale_color_viridis_d()+
  labs(x= "Depth (m)", y = expression('Temperature ('*~degree*C*')'), color = "")+
  geom_smooth(method = "lm", se = FALSE) +
  ylim(0, 35)
print(ANCOVAplot)
```

```
## Warning: Removed 72 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_mixed_random <- lme(data = NTL_LTER_Litter,
                           dryMass ~ nlcdClass * functionalGroup,
                           random = ~1 | plotID)
summary(litter_mixed_random)
```

```
## Linear mixed-effects model fit by REML
##  Data: NTL_LTER_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
```

```
rsquared(litter_mixed_random)
```

```
##   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: 2 %

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

```
#c.
litter_mixed <- lm(data = NTL_LTER_Litter, dryMass ~ nlcdClass * functionalGroup)
summary(litter_mixed)
```

```
##
## Call:
## lm(formula = dryMass ~ nlcdClass * functionalGroup, data = NTL_LTER_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
```

```r
rsquared(litter_mixed)
```

```
##   Response   family     link method R.squared
## 1  dryMass gaussian identity   none 0.2515836
```

```r
#d.
anova(litter_mixed_random, litter_mixed)
```

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

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

Answer: I believe that the model without random effects is better than the fixed effect model through comparing the linear relationships and the AIC. The AIC value for the mixed effect model (litter_mixed_random) is 9038, and the AIC value for the fixed effect model (litter mixed) is 9058. I also compared the linerar relationship through the r-squared values. The R-squared value for the model without random effect is 0.2516, while the R-squared value for the random effect model in 0.26. From this analysis I believe that litter_mixed, the model without random effect is the better model.