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() # Checks my working directory
```

```
## [1] "/Users/monishaeadala/Environmental_Data_Analytics_2020"
```

```
library(tidyverse)
```

```
## ── Attaching packages
─────────────────────────────────────────────────── tidyverse 1.3.0 ──
```

```
## ✓ ggplot2 3.2.1     ✓ purrr   0.3.3
## ✓ tibble  2.1.3     ✓ dplyr   0.8.3
## ✓ tidyr   1.0.2     ✓ stringr 1.4.0
## ✓ readr   1.3.1     ✓ 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) # Loads the necessary packages

## 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>.

Lakes.ChemPhys <- read.csv("./Data/Raw/NTL-
LTER_Lake_ChemistryPhysics_Raw.csv")
Litter <-
read.csv("./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv") #
Imports the necessary files

#2
theme_set(theme_classic()) # Builds a ggplot theme and sets it as my default
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
Lakes.ChemPhys.July <- Lakes.ChemPhys %>%
  filter(daynum > 181 & daynum <= 213) %>% # Keeps only dates in July
  select(lakename:daynum, depth, temperature_C) %>% # Keeps only the columns:
lakename, year4, daynum, depth, temperature_C
  na.omit() # Removes NAs

#4
Temp.AIC <- lm(data = Lakes.ChemPhys.July, temperature_C ~ year4 + daynum +
depth) # Runs an AIC to determine what set of explanatory variables (year4,
daynum, depth) is best suited to predict temperature
step(Temp.AIC) # Confirms that I should be using all the variables since that
model has the lowest AIC

## 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 =
Lakes.ChemPhys.July)
##
## Coefficients:
## (Intercept)        year4       daynum        depth
##   -14.33180      0.01386      0.04337     -1.94112

Temp.model <- lm(data = Lakes.ChemPhys.July, temperature_C ~ year4 + daynum +
depth) # Asserts the chosen model
summary(Temp.AIC) # Runs a multiple regression on the above recommended set
of variables

##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data =
Lakes.ChemPhys.July)
##
## 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 model with the lowest AIC is the final set of explanatory variables. Therefore, the final set of explanatory variables are year4, daynum and depth (as also mentioned above). The observed variance is the adjusted R-squared = 0.7398

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

```
#6
Temp.ancova.interaction <- lm(data = Lakes.ChemPhys.July, temperature_C ~
lakename * depth)
summary(Temp.ancova.interaction) # Runs an interaction effects ANCOVA to
predict temperature based on depth and lakename from the same wrangled
dataset

##
## Call:
## lm(formula = temperature_C ~ lakename * depth, data = Lakes.ChemPhys.July)
##
## 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 ***
## 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                           -2.5543     0.2331 -10.960  < 2e-16 ***
## lakenameCrampton Lake:depth      0.7704     0.2379   3.238 0.001208 **
## lakenameEast Long Lake:depth     0.9181     0.2353   3.902 9.60e-05 ***
## lakenameHummingbird Lake:depth  -0.6738     0.2831  -2.380 0.017323 *
## lakenamePaul Lake:depth          0.3716     0.2341   1.587 0.112452
## lakenamePeter Lake:depth         0.5503     0.2338   2.354 0.018612 *
## lakenameTuesday Lake:depth       0.6486     0.2345   2.766 0.005687 **
## lakenameWard Lake:depth         -0.7207     0.2796  -2.578 0.009962 **
```

```
## lakenameWest Long Lake:depth     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
```

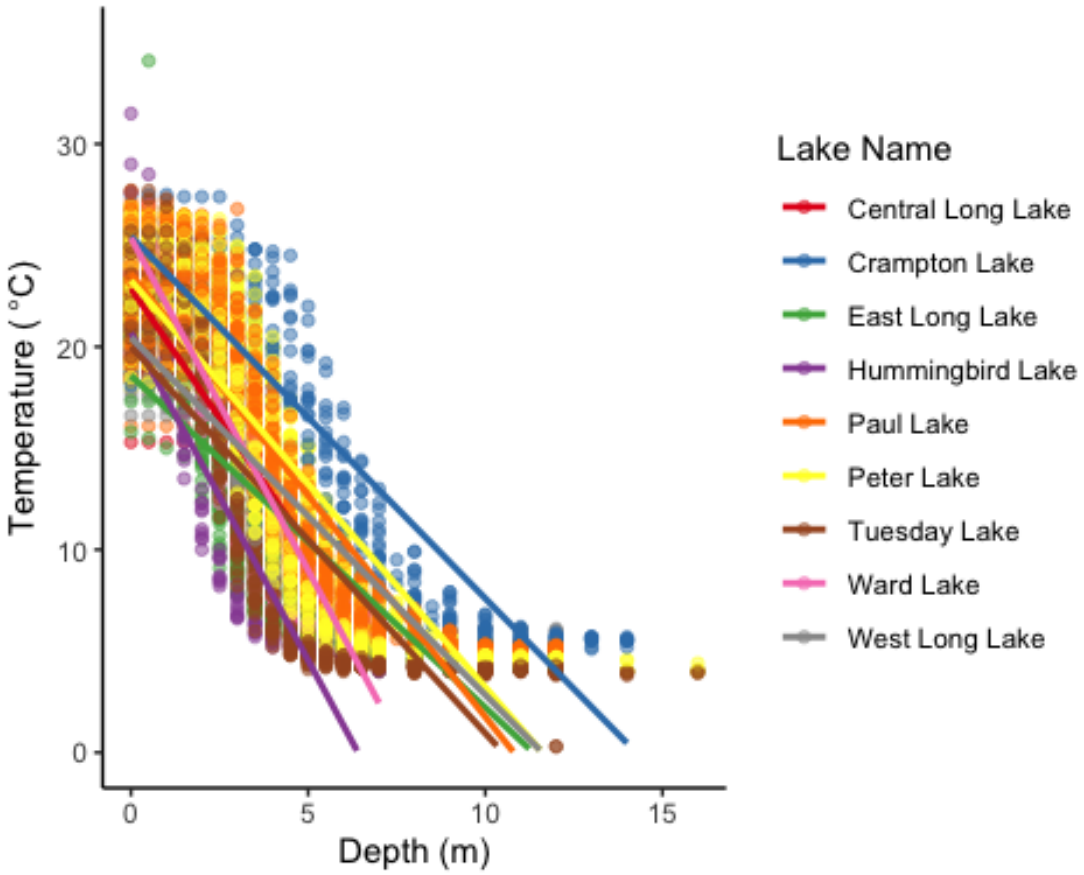
7. Is there a significant interaction between depth and lakename? How much variance in the temperature observations does this explain?

Answer: There is significant interaction between depth and lakeneme for all the lakes other than Paul Lake. Adjusted R-squared gives us the variance, which is 0.7855.

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
Temp.plot <- ggplot(Lakes.ChemPhys.July, aes(x = depth, y = temperature_C,
color = lakename)) + # Creates a graph that depicts temperature by depth,
with a separate color for each lake
  geom_point(alpha = 0.5) + # Makes my points 50% transparent
  geom_smooth(method = "lm", se = FALSE) + # Adds a geom_smooth for each lake
  scale_color_brewer(palette = "Set1", direction = 1) + # Asserts a specific
color palette that makes the graph effective and pretty
  ylim(0,35) + # Adjusts your y axis limits to go from 0 to 35 degrees
  labs(x = "Depth (m)", y = expression("Temperature ("*~degree*C*")"), color
= "Lake Name") # Labels everything on the graph appropriately
print(Temp.plot)

## 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.

```
#9a
Litter.drymass.mixed <- lme(data = Litter,
                            dryMass ~ nlcdClass*functionalGroup,
                            random = ~1|plotID) # Builds a mixed effects
model
summary(Litter.drymass.mixed) # Runs the mixed effects model

## 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
```

```
#9b
rsquared(Litter.drymass.mixed) # Gives me the marginal and conditional R2 of
the model
```

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

# We see that the difference between the marginal and conditional R2 is 2.13%
```

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

Answer: 2.13%

c. Run the same model without the random effect.

d. Run an anova on the two tests.

```
#9c
Litter.drymass.fixed <- gls(data = Litter,
                      dryMass ~ nlcdClass*functionalGroup)
summary(Litter.drymass.fixed) # Runs the same model without the random effect

## Generalized least squares fit by REML
##   Model: dryMass ~ nlcdClass * functionalGroup
##   Data: Litter
##        AIC      BIC    logLik
##   9058.088 9193.573 -4504.044
##
## Coefficients:
##                                                          Value
Std.Error
## (Intercept)                                           0.119625
0.3906950
## nlcdClassgrasslandHerbaceous                         -0.114199
0.6422303
## nlcdClassshrubScrub                                  -0.104119
0.5383767
## functionalGroupLeaves                                -0.103599
0.5560568
## functionalGroupMixed                                  1.504750
0.6380023
## functionalGroupNeedles                                7.312264
0.5369590
## functionalGroupOther                                 -0.034817
0.5560568
## functionalGroupSeeds                                 -0.046163
0.5560568
## functionalGroupTwigs/branches                         1.959669
0.5443402
## functionalGroupWoody material                         1.084311
0.5315555
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves    0.128646
0.8941030
## nlcdClassshrubScrub:functionalGroupLeaves             0.147030
0.7591538
## nlcdClassgrasslandHerbaceous:functionalGroupMixed    -0.381176
```

```
1.1302365
## nlcdClassshrubScrub:functionalGroupMixed                      0.745929
0.9303798
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        -2.138801
0.8799314
## nlcdClassshrubScrub:functionalGroupNeedles                 -2.921481
0.7425783
## nlcdClassgrasslandHerbaceous:functionalGroupOther           0.126058
0.9074253
## nlcdClassshrubScrub:functionalGroupOther                    0.085888
0.7610116
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.046155
0.9074253
## nlcdClassshrubScrub:functionalGroupSeeds                    0.059436
0.7629471
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -1.015195
0.8946237
## nlcdClassshrubScrub:functionalGroupTwigs/branches          -1.495591
0.7488092
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -1.040859
0.8897083
## nlcdClassshrubScrub:functionalGroupWoody material          -0.971848
0.7395676
##                                                              t-value p-
value
## (Intercept)                                                 0.306185
0.7595
## nlcdClassgrasslandHerbaceous                               -0.177817
0.8589
## nlcdClassshrubScrub                                        -0.193395
0.8467
## functionalGroupLeaves                                      -0.186311
0.8522
## functionalGroupMixed                                        2.358534
0.0185
## functionalGroupNeedles                                     13.617920
0.0000
## functionalGroupOther                                       -0.062615
0.9501
## functionalGroupSeeds                                       -0.083019
0.9338
## functionalGroupTwigs/branches                               3.600082
0.0003
## functionalGroupWoody material                               2.039883
0.0415
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves          0.143882
0.8856
## nlcdClassshrubScrub:functionalGroupLeaves                   0.193676
0.8465
## nlcdClassgrasslandHerbaceous:functionalGroupMixed          -0.337253
```

```
0.7360
## nlcdClassshrubScrub:functionalGroupMixed                      0.801746
0.4228
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        -2.430645
0.0152
## nlcdClassshrubScrub:functionalGroupNeedles                 -3.934239
0.0001
## nlcdClassgrasslandHerbaceous:functionalGroupOther           0.138919
0.8895
## nlcdClassshrubScrub:functionalGroupOther                    0.112860
0.9102
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.050863
0.9594
## nlcdClassshrubScrub:functionalGroupSeeds                    0.077903
0.9379
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -1.134773
0.2566
## nlcdClassshrubScrub:functionalGroupTwigs/branches          -1.997293
0.0460
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -1.169888
0.2422
## nlcdClassshrubScrub:functionalGroupWoody material          -1.314076
0.1890
##
##  Correlation:
##                                                            (Intr) nlcdCH
nlcdCS
## nlcdClassgrasslandHerbaceous                               -0.608
## nlcdClassshrubScrub                                        -0.726  0.441
## functionalGroupLeaves                                      -0.703  0.427
0.510
## functionalGroupMixed                                       -0.612  0.373
0.444
## functionalGroupNeedles                                     -0.728  0.443
0.528
## functionalGroupOther                                       -0.703  0.427
0.510
## functionalGroupSeeds                                       -0.703  0.427
0.510
## functionalGroupTwigs/branches                              -0.718  0.437
0.521
## functionalGroupWoody material                              -0.735  0.447
0.533
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves          0.437 -0.718 -
0.317
## nlcdClassshrubScrub:functionalGroupLeaves                   0.515 -0.313 -
0.709
## nlcdClassgrasslandHerbaceous:functionalGroupMixed           0.346 -0.568 -
0.251
## nlcdClassshrubScrub:functionalGroupMixed                    0.420 -0.255 -
```

```
0.579
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles         0.444 -0.730 -
0.322
## nlcdClassshrubScrub:functionalGroupNeedles                  0.526 -0.320 -
0.725
## nlcdClassgrasslandHerbaceous:functionalGroupOther           0.431 -0.708 -
0.312
## nlcdClassshrubScrub:functionalGroupOther                    0.513 -0.312 -
0.707
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.431 -0.708 -
0.312
## nlcdClassshrubScrub:functionalGroupSeeds                    0.512 -0.312 -
0.706
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.437 -0.718 -
0.317
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.522 -0.317 -
0.719
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.439 -0.722 -
0.319
## nlcdClassshrubScrub:functionalGroupWoody material           0.528 -0.321 -
0.728
##                                                            fnctGL fnctGM
fnctGN
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed                                        0.430
## functionalGroupNeedles                                      0.511  0.446
## functionalGroupOther                                        0.494  0.430
0.511
## functionalGroupSeeds                                        0.494  0.430
0.511
## functionalGroupTwigs/branches                               0.504  0.440
0.522
## functionalGroupWoody material                               0.516  0.450
0.535
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves         -0.622 -0.268 -
0.318
## nlcdClassshrubScrub:functionalGroupLeaves                  -0.732 -0.315 -
0.374
## nlcdClassgrasslandHerbaceous:functionalGroupMixed          -0.243 -0.564 -
0.252
## nlcdClassshrubScrub:functionalGroupMixed                   -0.295 -0.686 -
0.306
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles        -0.312 -0.272 -
0.610
## nlcdClassshrubScrub:functionalGroupNeedles                 -0.370 -0.322 -
0.723
## nlcdClassgrasslandHerbaceous:functionalGroupOther          -0.303 -0.264 -
0.313
```

```
## nlcdClassshrubScrub:functionalGroupOther                    -0.361 -0.314 -
0.374
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           -0.303 -0.264 -
0.313
## nlcdClassshrubScrub:functionalGroupSeeds                    -0.360 -0.314 -
0.373
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.267 -
0.318
## nlcdClassshrubScrub:functionalGroupTwigs/branches           -0.367 -0.320 -
0.380
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.269 -
0.320
## nlcdClassshrubScrub:functionalGroupWoody material           -0.371 -0.324 -
0.384
##                                                            fnctGO fnctGS
fncGT/
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds                                        0.494
## functionalGroupTwigs/branches                               0.504  0.504
## functionalGroupWoody material                               0.516  0.516
0.528
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves          -0.307 -0.307 -
0.314
## nlcdClassshrubScrub:functionalGroupLeaves                   -0.362 -0.362 -
0.369
## nlcdClassgrasslandHerbaceous:functionalGroupMixed           -0.243 -0.243 -
0.248
## nlcdClassshrubScrub:functionalGroupMixed                    -0.295 -0.295 -
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 -
0.368
## 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  0.456
## nlcdClassgrasslandHerbaceous:functionalGroupMixed          -0.254  0.408
0.178
## nlcdClassshrubScrub:functionalGroupMixed                   -0.309  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          -0.316  0.508
0.222
## nlcdClassshrubScrub:functionalGroupSeeds                   -0.376  0.224
0.500
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.321  0.516
0.225
## nlcdClassshrubScrub:functionalGroupTwigs/branches          -0.383  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         0.415  0.186
## nlcdClassshrubScrub:functionalGroupNeedles                  0.182  0.420
0.441
## nlcdClassgrasslandHerbaceous:functionalGroupOther           0.402  0.181
0.517
## nlcdClassshrubScrub:functionalGroupOther                    0.177  0.409
0.228
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds           0.402  0.181
0.517
## nlcdClassshrubScrub:functionalGroupSeeds                    0.177  0.408
0.227
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches  0.408  0.183
0.524
## nlcdClassshrubScrub:functionalGroupTwigs/branches           0.180  0.416
0.232
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material  0.410  0.184
0.527
## nlcdClassshrubScrub:functionalGroupWoody material           0.183  0.421
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  0.220
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           0.227  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 residuals:
##         Min          Q1         Med          Q3         Max
## -1.89209382 -0.13724016 -0.01672707 -0.00155260 14.03673076
##
## Residual standard error: 3.494483
## Degrees of freedom: 1692 total; 1668 residual

#9d
anova(Litter.drymass.mixed, Litter.drymass.fixed) # Runs an anova on the two
tests

##                      Model df      AIC      BIC    logLik   Test  L.Ratio
## Litter.drymass.mixed     1 26 9038.575 9179.479 -4493.287
## Litter.drymass.fixed     2 25 9058.088 9193.573 -4504.044 1 vs 2 21.51338
##                      p-value
## Litter.drymass.mixed
## Litter.drymass.fixed  <.0001

# The lower the AIC, the better
# The p-value tells us whether those models have a significantly different
fit
```

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 a better model than the fixed effects model since it has a lower AIC. The P-value is less than 0.0001; so it means that both the models have significantly different fit.