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/rachelgonsenhauser/Documents/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   0.8.4
## 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(dplyr)
#install.packages("nlme")
library(nlme)
```

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

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

```r
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>.
```

```r
Chemistry.raw <- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")
Litter.processed <- read.csv("./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv")

#2
mytheme <- theme_classic(base_size = 12) +
  theme(axis.text = element_text(color = "black"),
        legend.position = "bottom")
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.

```r
#3
Chemistry.wrangled <-
  Chemistry.raw %>%
  filter(daynum > 181 & daynum < 213) %>%
  select(lakename:daynum, depth, temperature_C) %>%
  na.omit()

#4
Chemistry.AIC <- lm(data = Chemistry.wrangled, temperature_C ~ year4 + daynum + depth)
step(Chemistry.AIC)
```

```
## Start:  AIC=26016.31
## temperature_C ~ year4 + daynum + depth
##
##         Df Sum of Sq    RSS   AIC
## <none>                141118 26016
```

2

```
## - year4    1         80 141198 26020
## - daynum   1       1333 142450 26106
## - depth    1     403925 545042 39151
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = Chemistry.wrangled)
##
## Coefficients:
## (Intercept)        year4        daynum         depth
##    -6.45556      0.01013       0.04134      -1.94726
```

```r
Chemistry.model <- lm(data = Chemistry.wrangled, temperature_C ~ year4 + daynum + depth)
summary(Chemistry.model)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = Chemistry.wrangled)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6517 -2.9937  0.0855  2.9692 13.6171
##
## Coefficients:
##               Estimate Std. Error  t value Pr(>|t|)
## (Intercept) -6.455560   8.638808   -0.747   0.4549
## year4        0.010131   0.004303    2.354   0.0186 *
## daynum       0.041336   0.004315    9.580   <2e-16 ***
## depth       -1.947264   0.011676 -166.782   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.811 on 9718 degrees of freedom
## Multiple R-squared:  0.7417, Adjusted R-squared:  0.7417
## F-statistic:  9303 on 3 and 9718 DF,  p-value: < 2.2e-16
```

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

   Answer: The final set of explanatory variables that predict temperature are year, day number, and depth. Year, day number, and depth all significantly predict temperature (multiple linear regression: F=9303, df=3 and 9718, p<0.0001). This model explains 74.2% of the observed variance in temperature (R2=0.7417).

   1/1

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

   2/2

```r
#6
Chemistry.ancova.interaction <- lm(data = Chemistry.wrangled, temperature_C ~ lakename * depth)
summary(Chemistry.ancova.interaction)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename * depth, data = Chemistry.wrangled)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
```

```
## -7.6455 -2.9133 -0.2879  2.7567 16.3606
## 
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    22.9455     0.5861  39.147  < 2e-16 ***
## lakenameCrampton Lake           2.2173     0.6804   3.259  0.00112 **
## lakenameEast Long Lake         -4.3884     0.6191  -7.089 1.45e-12 ***
## lakenameHummingbird Lake       -2.4126     0.8379  -2.879  0.00399 **
## lakenamePaul Lake               0.6105     0.5983   1.020  0.30754
## lakenamePeter Lake              0.2998     0.5970   0.502  0.61552
## lakenameTuesday Lake           -2.8932     0.6060  -4.774 1.83e-06 ***
## lakenameWard Lake               2.4180     0.8434   2.867  0.00415 **
## lakenameWest Long Lake         -2.4663     0.6168  -3.999 6.42e-05 ***
## depth                          -2.5820     0.2411 -10.711  < 2e-16 ***
## lakenameCrampton Lake:depth     0.8058     0.2465   3.268  0.00109 **
## lakenameEast Long Lake:depth    0.9465     0.2433   3.891  0.00010 ***
## lakenameHummingbird Lake:depth -0.6026     0.2919  -2.064  0.03903 *
## lakenamePaul Lake:depth         0.4022     0.2421   1.662  0.09664 .
## lakenamePeter Lake:depth        0.5799     0.2418   2.398  0.01649 *
## lakenameTuesday Lake:depth      0.6605     0.2426   2.723  0.00648 **
## lakenameWard Lake:depth        -0.6930     0.2862  -2.421  0.01548 *
## lakenameWest Long Lake:depth    0.8154     0.2431   3.354  0.00080 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 3.471 on 9704 degrees of freedom
## Multiple R-squared:  0.7861, Adjusted R-squared:  0.7857
## F-statistic:  2097 on 17 and 9704 DF,  p-value: < 2.2e-16
```

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

   Answer: Yes, there is a significant interaction between depth and lake name (ANCOVA: F=2097, df=17 and 9704, p<0.0001). This model explains 78.6% of observed variation in temperature 1/1 (R2=0.7857).

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 2/2 your y axis limits to go from 0 to 35 degrees. Clean up your graph to make it pretty.

```
#8
#library(RColorBrewer)

Tempplot <- ggplot(Chemistry.wrangled, aes(x = depth, y = temperature_C, color = lakename)) +
  geom_point(alpha = 0.5) +
  geom_smooth(method = "lm", se = FALSE) +
  ylim(0, 35) +
labs(x = "Depth (m)", y = "Temperature (C)", color = "Lake name") +
  scale_color_brewer(palette = "Paired") +
  theme(legend.position = "top")
print(Tempplot)
```

```
## Warning: Removed 73 rows containing missing values (geom_smooth).
```
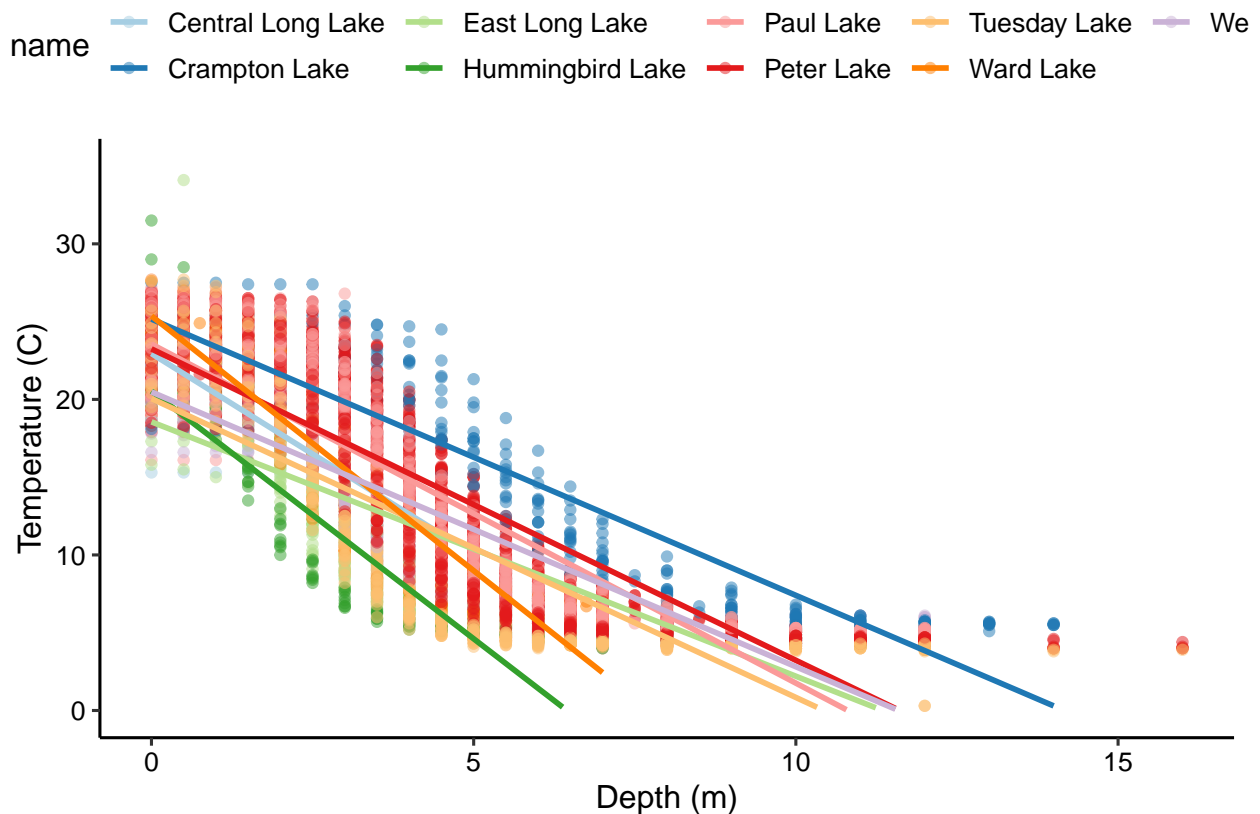
9. Run a mixed effects model to predict dry mass of litter. We already know that nlcdClass and functionalGroup have a significant interaction, so we will specify those two variables as fixed effects with an interaction. We also know that litter mass varies across plot ID, but we are less interested in 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. 2/2

b. Check the difference between the marginal and conditional R2 of the model.

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

```
## Linear mixed-effects model fit by REML
##  Data: Litter.processed
##        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
```

5

```
## 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)
```

```
##   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: 26.8% of variance in dry mass is explained by the model when the random effect is added (as compared to 24.7% without the random effect). As such, about 2.13% more variance is explained by adding the random effect to the model.

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

```
Litter.fixed <- gls(data = Litter.processed,
                    dryMass ~ nlcdClass * functionalGroup)
summary(Litter.fixed)
```

```
## Generalized least squares fit by REML
##   Model: dryMass ~ nlcdClass * functionalGroup
##   Data: Litter.processed
##        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
```

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

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

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

Answer: The mixed effects model is the better model because it has a lower AIC value (p<0.0001). This means that the mixed effects model is more parsimonious while also accounting for a good amount of variation in the response variable.

1/1