

# 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/Victoria/Environmental_Data_Analytics_2020"

library(tidyverse)

## Warning: package 'tidyverse' was built under R version 3.5.2
## -- Attaching packages ----- tidyverse 1.3.0 --
## v ggplot2 3.2.1      v purrr   0.3.3
## v tibble  2.1.3      v dplyr   0.8.3
## v tidyr   1.0.0      v stringr 1.4.0
## v readr   1.3.1      v forcats 0.4.0
## Warning: package 'ggplot2' was built under R version 3.5.2
## Warning: package 'tibble' was built under R version 3.5.2
## Warning: package 'tidyr' was built under R version 3.5.2
## Warning: package 'purrr' was built under R version 3.5.2
## Warning: package 'dplyr' was built under R version 3.5.2
## Warning: package 'stringr' was built under R version 3.5.2
## Warning: package 'forcats' was built under R version 3.5.2
```

```
## -- 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)

## Warning: package 'piecewiseSEM' was built under R version 3.5.2

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

NTLraw <- read.csv('./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv')
Litter <- read.csv('./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv')

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

## NTL-LTER test

Research question: What is the best set of predictors for lake temperatures in July across the monitoring period at the North Temperate Lakes LTER?

3. Wrangle your NTL-LTER dataset with a pipe function so that it contains only the following criteria:
  - Only dates in July (hint: use the daynum column). No need to consider leap years.
  - Only the columns: lakename, year4, daynum, depth, temperature\_C
  - Only complete cases (i.e., remove NAs)
4. Run an AIC to determine what set of explanatory variables (year4, daynum, depth) is best suited to predict temperature. Run a multiple regression on the recommended set of variables.

```
#3
NTLsel <-
  NTLraw %>%
  select(lakename:daynum, depth, temperature_C) %>%
  filter(daynum > 181 & daynum < 213) %>%
  na.exclude()

#4
TEMPAIC <- lm(data=NTLsel, temperature_C ~ year4 + daynum + depth)
step(TEMPAIC)

## Start: AIC=26016.31
## temperature_C ~ year4 + daynum + depth
```

```
##
##           Df Sum of Sq    RSS   AIC
## <none>                141118 26016
## - year4      1         80 141198 26020
## - daynum     1        1333 142450 26106
## - depth      1       403925 545042 39151

##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTLsel)
##
## Coefficients:
## (Intercept)      year4      daynum      depth
##    -6.45556     0.01013     0.04134    -1.94726

TEMPmodel <- lm(data=NTLsel, temperature_C ~ year4 + daynum + depth)
summary(TEMPmodel)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTLsel)
##
## 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 are years, day numbers and depth (temperature\_C ~ year4 + daynum + depth), which indicates all selected explanatory variables are important to predict temperature in this multiple regression. According to the adjusted R-squared, there is about 74.17% observed variance explained in this model (linear regression,  $R^2 = 0.7417$ ,  $df = 9718$ ,  $p < 0.0001$ ).

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

```
#6
NTLinter <- lm(data=NTLsel, temperature_C ~ depth * lakenname)
summary(NTLinter)
```

```
##
## Call:
```

```
## lm(formula = temperature_C ~ depth * lakename, data = NTLsel)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.6455 -2.9133 -0.2879  2.7567 16.3606
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      22.9455     0.5861   39.147 < 2e-16 ***
## depth           -2.5820     0.2411  -10.711 < 2e-16 ***
## lakenameCrampton Lake    2.2173     0.6804    3.259  0.00112 **
## lakenameEast Long Lake  -4.3884     0.6191   -7.089  1.45e-12 ***
## lakenameHummingbird Lake -2.4126     0.8379   -2.879  0.00399 **
## lakenamePaul Lake       0.6105     0.5983    1.020  0.30754
## lakenamePeter Lake      0.2998     0.5970    0.502  0.61552
## lakenameTuesday Lake   -2.8932     0.6060   -4.774  1.83e-06 ***
## lakenameWard Lake       2.4180     0.8434    2.867  0.00415 **
## lakenameWest Long Lake  -2.4663     0.6168   -3.999  6.42e-05 ***
## depth:lakenameCrampton Lake  0.8058     0.2465    3.268  0.00109 **
## depth:lakenameEast Long Lake  0.9465     0.2433    3.891  0.00010 ***
## depth:lakenameHummingbird Lake -0.6026     0.2919   -2.064  0.03903 *
## depth:lakenamePaul Lake    0.4022     0.2421    1.662  0.09664 .
## depth:lakenamePeter Lake    0.5799     0.2418    2.398  0.01649 *
## depth:lakenameTuesday Lake  0.6605     0.2426    2.723  0.00648 **
## depth:lakenameWard Lake    -0.6930     0.2862   -2.421  0.01548 *
## depth:lakenameWest Long Lake  0.8154     0.2431    3.354  0.00080 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.471 on 9704 degrees of freedom
## Multiple R-squared:  0.7861, Adjusted R-squared:  0.7857
## F-statistic: 2097 on 17 and 9704 DF, p-value: < 2.2e-16
```

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

Answer: There are significant interactions between depth and some lakenames, but not all lakenames have significant interactions with depth - for example, Paul Lake, whose p-value of interaction with depth is greater than 0.05. According to the adjusted R-squared, there is about 78.57% observed variance explained in this model (linear regression, adjusted  $R^2 = 0.7857$ ,  $df = 9704$ ,  $p < 0.0001$ ).

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
library(viridis)

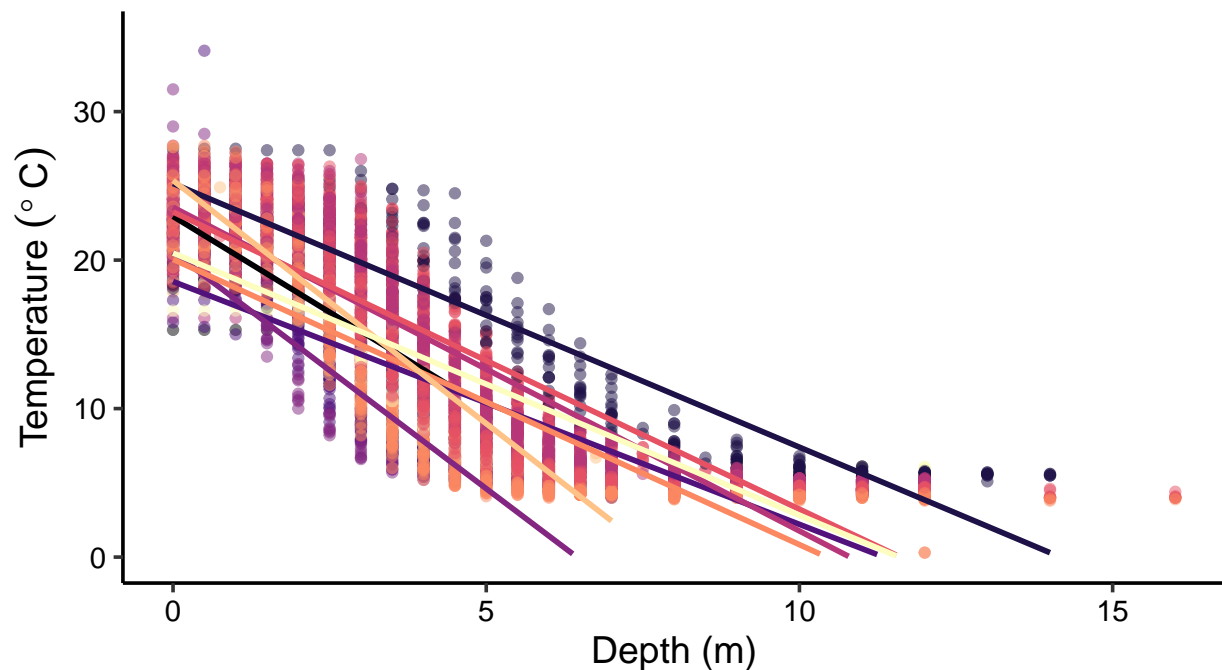
## Loading required package: viridisLite

NTLplot <- ggplot(NTLsel, aes(x=depth, y=temperature_C, color = lakename))+
  geom_point(alpha=0.5)+
  scale_color_viridis(discrete = TRUE, option = "magma", end = 1)+
  geom_smooth(method = 'lm', se = FALSE)+
  ylim(0,35)+
  labs(x = "Depth (m)", y = expression("Temperature " ( degree~C)), color = "")
```

```
plot(NTLplot)
```

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

Central Long Lake   East Long Lake   Paul Lake   Tuesday Lake   West  
 Crampton Lake   Hummingbird Lake   Peter Lake   Ward Lake



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.

- Build and run a mixed effects model.
- Check the difference between the marginal and conditional R<sup>2</sup> of the model.

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

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

```

## nlcdClassshrubScrub	-0.161343
## functionalGroupLeaves	-0.229061
## functionalGroupMixed	2.337160
## functionalGroupNeedles	13.709474
## functionalGroupOther	-0.088213
## functionalGroupSeeds	-0.106711
## functionalGroupTwigs/branches	3.582622
## functionalGroupWoody material	2.032144
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.205053
## nlcdClassshrubScrub:functionalGroupLeaves	0.231490
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.417495
## nlcdClassshrubScrub:functionalGroupMixed	0.687657
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-2.433305
## nlcdClassshrubScrub:functionalGroupNeedles	-3.959540
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.159972
## nlcdClassshrubScrub:functionalGroupOther	0.139385
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.054908
## nlcdClassshrubScrub:functionalGroupSeeds	0.101632
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-1.114752
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-2.029209
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-1.156293
## nlcdClassshrubScrub:functionalGroupWoody material	-1.338081
##	p-value
## (Intercept)	0.7492
## nlcdClassgrasslandHerbaceous	0.8457
## nlcdClassshrubScrub	0.8754
## functionalGroupLeaves	0.8188
## functionalGroupMixed	0.0195
## functionalGroupNeedles	0.0000
## functionalGroupOther	0.9297
## functionalGroupSeeds	0.9150
## functionalGroupTwigs/branches	0.0003
## functionalGroupWoody material	0.0423
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.8376
## nlcdClassshrubScrub:functionalGroupLeaves	0.8170
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.6764
## nlcdClassshrubScrub:functionalGroupMixed	0.4918
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.0151
## nlcdClassshrubScrub:functionalGroupNeedles	0.0001
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.8729
## nlcdClassshrubScrub:functionalGroupOther	0.8892
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.9562
## nlcdClassshrubScrub:functionalGroupSeeds	0.9191
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.2651
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.0426
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.2477
## nlcdClassshrubScrub:functionalGroupWoody material	0.1811
## Correlation:	
##	(Intr) nlcdCH
## nlcdClassgrasslandHerbaceous	-0.624
## nlcdClassshrubScrub	-0.733 0.458
## functionalGroupLeaves	-0.559 0.349
## functionalGroupMixed	-0.485 0.303
## functionalGroupNeedles	-0.579 0.361

## functionalGroupOther	-0.559	0.349
## functionalGroupSeeds	-0.559	0.349
## functionalGroupTwigs/branches	-0.571	0.356
## functionalGroupWoody material	-0.584	0.365
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.347	-0.586
## nlcdClassshrubScrub:functionalGroupLeaves	0.409	-0.255
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.274	-0.462
## nlcdClassshrubScrub:functionalGroupMixed	0.333	-0.208
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.353	-0.595
## nlcdClassshrubScrub:functionalGroupNeedles	0.418	-0.261
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.342	-0.577
## nlcdClassshrubScrub:functionalGroupOther	0.408	-0.255
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.342	-0.577
## nlcdClassshrubScrub:functionalGroupSeeds	0.407	-0.254
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.347	-0.586
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.415	-0.259
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.349	-0.589
## nlcdClassshrubScrub:functionalGroupWoody material	0.420	-0.262
##	nlcdCS	fnctGL
## nlcdClassgrasslandHerbaceous		
## nlcdClassshrubScrub		
## functionalGroupLeaves	0.409	
## functionalGroupMixed	0.356	0.429
## functionalGroupNeedles	0.424	0.511
## functionalGroupOther	0.409	0.494
## functionalGroupSeeds	0.409	0.494
## functionalGroupTwigs/branches	0.418	0.504
## functionalGroupWoody material	0.428	0.516
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.255	-0.622
## nlcdClassshrubScrub:functionalGroupLeaves	-0.569	-0.732
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.201	-0.242
## nlcdClassshrubScrub:functionalGroupMixed	-0.464	-0.295
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.259	-0.312
## nlcdClassshrubScrub:functionalGroupNeedles	-0.582	-0.370
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.251	-0.303
## nlcdClassshrubScrub:functionalGroupOther	-0.568	-0.361
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.251	-0.303
## nlcdClassshrubScrub:functionalGroupSeeds	-0.566	-0.360
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.254	-0.307
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.577	-0.367
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.256	-0.309
## nlcdClassshrubScrub:functionalGroupWoody material	-0.584	-0.371
##	fnctGM	fnctGN
## nlcdClassgrasslandHerbaceous		
## nlcdClassshrubScrub		
## functionalGroupLeaves		
## functionalGroupMixed		
## functionalGroupNeedles	0.445	
## functionalGroupOther	0.430	0.511
## functionalGroupSeeds	0.429	0.511
## functionalGroupTwigs/branches	0.439	0.522
## functionalGroupWoody material	0.449	0.535
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.267	-0.318
## nlcdClassshrubScrub:functionalGroupLeaves	-0.314	-0.374



## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.564	-0.251
## nlcdClassshrubScrub:functionalGroupMixed	-0.686	-0.305
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.272	-0.610
## nlcdClassshrubScrub:functionalGroupNeedles	-0.322	-0.723
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.263	-0.313
## nlcdClassshrubScrub:functionalGroupOther	-0.314	-0.374
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.263	-0.313
## nlcdClassshrubScrub:functionalGroupSeeds	-0.313	-0.373
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.267	-0.318
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.319	-0.380
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.268	-0.320
## nlcdClassshrubScrub:functionalGroupWoody material	-0.322	-0.384
##	fncTG0	fncTGS
## nlcdClassgrasslandHerbaceous		
## nlcdClassshrubScrub		
## functionalGroupLeaves		
## functionalGroupMixed		
## functionalGroupNeedles		
## functionalGroupOther		
## functionalGroupSeeds	0.494	
## functionalGroupTwigs/branches	0.504	0.504
## functionalGroupWoody material	0.516	0.517
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.307	-0.307
## nlcdClassshrubScrub:functionalGroupLeaves	-0.362	-0.362
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.243	-0.242
## nlcdClassshrubScrub:functionalGroupMixed	-0.295	-0.294
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.312	-0.312
## nlcdClassshrubScrub:functionalGroupNeedles	-0.370	-0.370
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.613	-0.303
## nlcdClassshrubScrub:functionalGroupOther	-0.731	-0.361
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.303	-0.613
## nlcdClassshrubScrub:functionalGroupSeeds	-0.360	-0.729
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.307	-0.307
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.367	-0.367
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.309	-0.309
## nlcdClassshrubScrub:functionalGroupWoody material	-0.371	-0.371
##	fncGT/	fncGWm
## nlcdClassgrasslandHerbaceous		
## nlcdClassshrubScrub		
## functionalGroupLeaves		
## functionalGroupMixed		
## functionalGroupNeedles		
## functionalGroupOther		
## functionalGroupSeeds		
## functionalGroupTwigs/branches		
## functionalGroupWoody material	0.528	
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.314	-0.321
## nlcdClassshrubScrub:functionalGroupLeaves	-0.369	-0.378
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.248	-0.253
## nlcdClassshrubScrub:functionalGroupMixed	-0.301	-0.308
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.319	-0.326
## nlcdClassshrubScrub:functionalGroupNeedles	-0.378	-0.387
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.309	-0.316
## nlcdClassshrubScrub:functionalGroupOther	-0.369	-0.377

## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.309	-0.317
## nlcdClassshrubScrub:functionalGroupSeeds	-0.368	-0.376
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.608	-0.321
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.727	-0.384
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.315	-0.597
## nlcdClassshrubScrub:functionalGroupWoody material	-0.379	-0.719
##	nCH:GL	nCS:GL
## nlcdClassgrasslandHerbaceous		
## nlcdClassshrubScrub		
## functionalGroupLeaves		
## functionalGroupMixed		
## functionalGroupNeedles		
## functionalGroupOther		
## functionalGroupSeeds		
## functionalGroupTwigs/branches		
## functionalGroupWoody material		
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves		
## nlcdClassshrubScrub:functionalGroupLeaves	0.455	
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.406	0.178
## nlcdClassshrubScrub:functionalGroupMixed	0.183	0.410
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.524	0.229
## nlcdClassshrubScrub:functionalGroupNeedles	0.230	0.514
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.508	0.222
## nlcdClassshrubScrub:functionalGroupOther	0.224	0.502
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.508	0.222
## nlcdClassshrubScrub:functionalGroupSeeds	0.224	0.500
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.515	0.225
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.228	0.510
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.518	0.226
## nlcdClassshrubScrub:functionalGroupWoody material	0.231	0.516
##	nCH:GM	nCS:GM
## nlcdClassgrasslandHerbaceous		
## nlcdClassshrubScrub		
## functionalGroupLeaves		
## functionalGroupMixed		
## functionalGroupNeedles		
## functionalGroupOther		
## functionalGroupSeeds		
## functionalGroupTwigs/branches		
## functionalGroupWoody material		
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves		
## nlcdClassshrubScrub:functionalGroupLeaves		
## nlcdClassgrasslandHerbaceous:functionalGroupMixed		
## nlcdClassshrubScrub:functionalGroupMixed	0.387	
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.414	0.186
## nlcdClassshrubScrub:functionalGroupNeedles	0.182	0.419
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.401	0.181
## nlcdClassshrubScrub:functionalGroupOther	0.177	0.409
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.402	0.180
## nlcdClassshrubScrub:functionalGroupSeeds	0.177	0.408
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.407	0.183
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.180	0.416
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.409	0.184
## nlcdClassshrubScrub:functionalGroupWoody material	0.182	0.420

```

## nCH:GN nCS:GN
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles 0.441
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.517 0.227
## nlcdClassshrubScrub:functionalGroupOther 0.228 0.513
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.517 0.227
## nlcdClassshrubScrub:functionalGroupSeeds 0.227 0.512
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.524 0.230
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.232 0.521
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.527 0.231
## nlcdClassshrubScrub:functionalGroupWoody material 0.235 0.528
## nCH:GO nCS:GO
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther 0.448
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.501 0.221
## nlcdClassshrubScrub:functionalGroupSeeds 0.221 0.499
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.508 0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.225 0.509
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.511 0.225
## nlcdClassshrubScrub:functionalGroupWoody material 0.227 0.515
## nCH:GS nCS:GS
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles

```

```

## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds 0.447
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.508 0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.225 0.507
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.511 0.225
## nlcdClassshrubScrub:functionalGroupWoody material 0.228 0.514
## nCH:GT nCS:GT
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.442
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.518 0.229
## nlcdClassshrubScrub:functionalGroupWoody material 0.231 0.523
## nCH:Gm
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves

```

```
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches
## nlcdClassshrubScrub:functionalGroupTwigs/branches
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material
## nlcdClassshrubScrub:functionalGroupWoody material      0.429
##
## Standardized Within-Group Residuals:
##      Min      Q1      Med      Q3      Max
## -1.96496855 -0.23842984 -0.01535880  0.09027291 14.27434811
##
## Number of Observations: 1692
## Number of Groups: 12
```

```
rsquared(Litter.mix)
```

```
## 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: Marginal R<sup>2</sup> of the model is 24.66% while conditional R<sup>2</sup> of the model is 26.79%.  
Therefore, there is about 2% 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.fix <- gls(data = Litter, dryMass ~ nlcdClass * functionalGroup)
summary(Litter.fix)
```

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

## nlcdClassshrubScrub:functionalGroupMixed	0.745929
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-2.138801
## nlcdClassshrubScrub:functionalGroupNeedles	-2.921481
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.126058
## nlcdClassshrubScrub:functionalGroupOther	0.085888
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.046155
## nlcdClassshrubScrub:functionalGroupSeeds	0.059436
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-1.015195
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-1.495591
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-1.040859
## nlcdClassshrubScrub:functionalGroupWoody material	-0.971848
##	Std.Error
## (Intercept)	0.3906950
## nlcdClassgrasslandHerbaceous	0.6422303
## nlcdClassshrubScrub	0.5383767
## functionalGroupLeaves	0.5560568
## functionalGroupMixed	0.6380023
## functionalGroupNeedles	0.5369590
## functionalGroupOther	0.5560568
## functionalGroupSeeds	0.5560568
## functionalGroupTwigs/branches	0.5443402
## functionalGroupWoody material	0.5315555
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.8941030
## nlcdClassshrubScrub:functionalGroupLeaves	0.7591538
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	1.1302365
## nlcdClassshrubScrub:functionalGroupMixed	0.9303798
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.8799314
## nlcdClassshrubScrub:functionalGroupNeedles	0.7425783
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.9074253
## nlcdClassshrubScrub:functionalGroupOther	0.7610116
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.9074253
## nlcdClassshrubScrub:functionalGroupSeeds	0.7629471
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.8946237
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.7488092
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.8897083
## nlcdClassshrubScrub:functionalGroupWoody material	0.7395676
##	t-value
## (Intercept)	0.306185
## nlcdClassgrasslandHerbaceous	-0.177817
## nlcdClassshrubScrub	-0.193395
## functionalGroupLeaves	-0.186311
## functionalGroupMixed	2.358534
## functionalGroupNeedles	13.617920
## functionalGroupOther	-0.062615
## functionalGroupSeeds	-0.083019
## functionalGroupTwigs/branches	3.600082
## functionalGroupWoody material	2.039883
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.143882
## nlcdClassshrubScrub:functionalGroupLeaves	0.193676
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.337253
## nlcdClassshrubScrub:functionalGroupMixed	0.801746
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-2.430645
## nlcdClassshrubScrub:functionalGroupNeedles	-3.934239
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.138919

## nlcdClassshrubScrub:functionalGroupOther	0.112860
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.050863
## nlcdClassshrubScrub:functionalGroupSeeds	0.077903
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-1.134773
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-1.997293
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-1.169888
## nlcdClassshrubScrub:functionalGroupWoody material	-1.314076
##	p-value
## (Intercept)	0.7595
## nlcdClassgrasslandHerbaceous	0.8589
## nlcdClassshrubScrub	0.8467
## functionalGroupLeaves	0.8522
## functionalGroupMixed	0.0185
## functionalGroupNeedles	0.0000
## functionalGroupOther	0.9501
## functionalGroupSeeds	0.9338
## functionalGroupTwigs/branches	0.0003
## functionalGroupWoody material	0.0415
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.8856
## nlcdClassshrubScrub:functionalGroupLeaves	0.8465
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.7360
## nlcdClassshrubScrub:functionalGroupMixed	0.4228
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.0152
## nlcdClassshrubScrub:functionalGroupNeedles	0.0001
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.8895
## nlcdClassshrubScrub:functionalGroupOther	0.9102
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.9594
## nlcdClassshrubScrub:functionalGroupSeeds	0.9379
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.2566
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.0460
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.2422
## nlcdClassshrubScrub:functionalGroupWoody material	0.1890
##	
## Correlation:	
##	(Intr) nlcdCH
## nlcdClassgrasslandHerbaceous	-0.608
## nlcdClassshrubScrub	-0.726 0.441
## functionalGroupLeaves	-0.703 0.427
## functionalGroupMixed	-0.612 0.373
## functionalGroupNeedles	-0.728 0.443
## functionalGroupOther	-0.703 0.427
## functionalGroupSeeds	-0.703 0.427
## functionalGroupTwigs/branches	-0.718 0.437
## functionalGroupWoody material	-0.735 0.447
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.437 -0.718
## nlcdClassshrubScrub:functionalGroupLeaves	0.515 -0.313
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.346 -0.568
## nlcdClassshrubScrub:functionalGroupMixed	0.420 -0.255
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.444 -0.730
## nlcdClassshrubScrub:functionalGroupNeedles	0.526 -0.320
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.431 -0.708
## nlcdClassshrubScrub:functionalGroupOther	0.513 -0.312
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.431 -0.708
## nlcdClassshrubScrub:functionalGroupSeeds	0.512 -0.312

```

## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.437 -0.718
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.522 -0.317
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.439 -0.722
## nlcdClassshrubScrub:functionalGroupWoody material 0.528 -0.321
## nlcdCS fnctGL
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves 0.510
## functionalGroupMixed 0.444 0.430
## functionalGroupNeedles 0.528 0.511
## functionalGroupOther 0.510 0.494
## functionalGroupSeeds 0.510 0.494
## functionalGroupTwigs/branches 0.521 0.504
## functionalGroupWoody material 0.533 0.516
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.317 -0.622
## nlcdClassshrubScrub:functionalGroupLeaves -0.709 -0.732
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.251 -0.243
## nlcdClassshrubScrub:functionalGroupMixed -0.579 -0.295
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.322 -0.312
## nlcdClassshrubScrub:functionalGroupNeedles -0.725 -0.370
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.312 -0.303
## nlcdClassshrubScrub:functionalGroupOther -0.707 -0.361
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.312 -0.303
## nlcdClassshrubScrub:functionalGroupSeeds -0.706 -0.360
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.317 -0.307
## nlcdClassshrubScrub:functionalGroupTwigs/branches -0.719 -0.367
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.319 -0.309
## nlcdClassshrubScrub:functionalGroupWoody material -0.728 -0.371
## fnctGM fnctGN
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles 0.446
## functionalGroupOther 0.430 0.511
## functionalGroupSeeds 0.430 0.511
## functionalGroupTwigs/branches 0.440 0.522
## functionalGroupWoody material 0.450 0.535
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.268 -0.318
## nlcdClassshrubScrub:functionalGroupLeaves -0.315 -0.374
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.564 -0.252
## nlcdClassshrubScrub:functionalGroupMixed -0.686 -0.306
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.272 -0.610
## nlcdClassshrubScrub:functionalGroupNeedles -0.322 -0.723
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.264 -0.313
## nlcdClassshrubScrub:functionalGroupOther -0.314 -0.374
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.264 -0.313
## nlcdClassshrubScrub:functionalGroupSeeds -0.314 -0.373
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.267 -0.318
## nlcdClassshrubScrub:functionalGroupTwigs/branches -0.320 -0.380
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.269 -0.320
## nlcdClassshrubScrub:functionalGroupWoody material -0.324 -0.384
## fnctG0 fnctGS
## nlcdClassgrasslandHerbaceous

```



```

## nlcdClasssshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds 0.494
## functionalGroupTwigs/branches 0.504 0.504
## functionalGroupWoody material 0.516 0.516
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.307 -0.307
## nlcdClasssshrubScrub:functionalGroupLeaves -0.362 -0.362
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.243 -0.243
## nlcdClasssshrubScrub:functionalGroupMixed -0.295 -0.295
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.312 -0.312
## nlcdClasssshrubScrub:functionalGroupNeedles -0.370 -0.370
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.613 -0.303
## nlcdClasssshrubScrub:functionalGroupOther -0.731 -0.361
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.303 -0.613
## nlcdClasssshrubScrub:functionalGroupSeeds -0.360 -0.729
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.307
## nlcdClasssshrubScrub:functionalGroupTwigs/branches -0.367 -0.367
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.309
## nlcdClasssshrubScrub:functionalGroupWoody material -0.371 -0.371
## fncGT/ fncGWm
## nlcdClassgrasslandHerbaceous
## nlcdClasssshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material 0.528
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.314 -0.321
## nlcdClasssshrubScrub:functionalGroupLeaves -0.369 -0.378
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.248 -0.254
## nlcdClasssshrubScrub:functionalGroupMixed -0.301 -0.309
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.319 -0.326
## nlcdClasssshrubScrub:functionalGroupNeedles -0.378 -0.387
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.309 -0.316
## nlcdClasssshrubScrub:functionalGroupOther -0.368 -0.377
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.309 -0.316
## nlcdClasssshrubScrub:functionalGroupSeeds -0.368 -0.376
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.608 -0.321
## nlcdClasssshrubScrub:functionalGroupTwigs/branches -0.727 -0.383
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.315 -0.597
## nlcdClasssshrubScrub:functionalGroupWoody material -0.379 -0.719
## nCH:GL nCS:GL
## nlcdClassgrasslandHerbaceous
## nlcdClasssshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds

```

```

## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves 0.456
## nlcdClassgrasslandHerbaceous:functionalGroupMixed 0.408 0.178
## nlcdClassshrubScrub:functionalGroupMixed 0.183 0.410
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles 0.524 0.229
## nlcdClassshrubScrub:functionalGroupNeedles 0.230 0.514
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.508 0.222
## nlcdClassshrubScrub:functionalGroupOther 0.224 0.502
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.508 0.222
## nlcdClassshrubScrub:functionalGroupSeeds 0.224 0.500
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.516 0.225
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.228 0.510
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.518 0.226
## nlcdClassshrubScrub:functionalGroupWoody material 0.231 0.516
## nCH:GM nCS:GM
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed 0.387
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles 0.415 0.186
## nlcdClassshrubScrub:functionalGroupNeedles 0.182 0.420
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.402 0.181
## nlcdClassshrubScrub:functionalGroupOther 0.177 0.409
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.402 0.181
## nlcdClassshrubScrub:functionalGroupSeeds 0.177 0.408
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.408 0.183
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.180 0.416
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.410 0.184
## nlcdClassshrubScrub:functionalGroupWoody material 0.183 0.421
## nCH:GN nCS:GN
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed

```

```

## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles 0.441
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.517 0.227
## nlcdClassshrubScrub:functionalGroupOther 0.228 0.513
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.517 0.227
## nlcdClassshrubScrub:functionalGroupSeeds 0.227 0.512
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.524 0.230
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.232 0.521
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.527 0.231
## nlcdClassshrubScrub:functionalGroupWoody material 0.235 0.528
## nCH:GO nCS:GO
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther 0.448
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.501 0.221
## nlcdClassshrubScrub:functionalGroupSeeds 0.220 0.499
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.508 0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.225 0.509
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.511 0.225
## nlcdClassshrubScrub:functionalGroupWoody material 0.227 0.515
## nCH:GS nCS:GS
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds 0.447

```

```

## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.508 0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.225 0.507
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.511 0.225
## nlcdClassshrubScrub:functionalGroupWoody material 0.227 0.514
## nCH:GT nCS:GT
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.442
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.518 0.229
## nlcdClassshrubScrub:functionalGroupWoody material 0.231 0.523
## nCH:Gm
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches
## nlcdClassshrubScrub:functionalGroupTwigs/branches
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material
## nlcdClassshrubScrub:functionalGroupWoody material 0.429
##
## Standardized 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.mix, Litter.fix)
```

```
##           Model df          AIC          BIC      logLik    Test  L.Ratio p-value
## Litter.mix      1 26 9038.575 9179.479 -4493.287
## Litter.fix      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: Yes, the mixed effects model is better, because AIC value for the mixed effects model is lower. There is a significant difference between two models as  $p\text{-value} < 0.0001$ .