

Assignment 7: GLMs week 2 (Linear Regression and beyond)

Nikki Shintaku

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/nikkishintaku/Desktop/Environmental872/Environmental_Data_Analytics_2020"
```

```
library(tidyverse)
```

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

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

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

```
library(nlme)
```

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

```
library(piecewiseSEM)
```

```
## Registered S3 methods overwritten by 'lme4':  
##   method                      from  
##   cooks.distance.influence.merMod car  
##   influence.merMod             car  
##   dfbeta.influence.merMod      car  
##   dfbetas.influence.merMod    car  
  
##  
## This is piecewiseSEM version 2.1.0.  
##  
##  
## Questions or bugs can be addressed to <LefcheckJ@si.edu>.
```

```
library(ggthemes)
```

```
NTL.chem <- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")  
NTL.litter <- read.csv("./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv")  
  
#2  
mytheme <- theme_stata(base_size = 14, base_family = "sans", scheme = "s2mono") +  
  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
lake_temperatures_july <-
  NTL.chem %>%
  select(lakename, year4, daynum, depth, temperature_C) %>%
  filter(daynum > 182 & daynum < 214) %>%
  na.exclude()

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

## Start: AIC=25998.22
## temperature_C ~ year4 + daynum + depth
##
##           Df Sum of Sq    RSS   AIC
## <none>                 142056 25998
## - year4    1         201 142257 26010
## - daynum   1         1237 143293 26080
## - depth    1        402549 544605 38995

##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = lake_temperatures_july)
##
## Coefficients:
## (Intercept)      year4      daynum      depth
##   -18.19700     0.01611     0.04024    -1.94133

#AIC is highest when none of the explanatory variables are removed

#Temp AIC is the multiple regression on the recommended variables
summary(Temp_AIC)

##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = lake_temperatures_july)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -9.6857 -3.0267  0.1055  2.9937 13.6038
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -18.196998   8.741236  -2.082 0.037392 *
## year4         0.016113   0.004353   3.701 0.000216 ***
## daynum        0.040237   0.004385   9.176 < 2e-16 ***
## depth        -1.941328   0.011728 -165.528 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.833 on 9669 degrees of freedom
## Multiple R-squared:  0.7398, Adjusted R-squared:  0.7397
## F-statistic: 9162 on 3 and 9669 DF, p-value: < 2.2e-16

```

#year, daynum, and depth are all significant predictors of lake temperature

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: Explanatory variables that predict lake temperatures are year, day number, and depth. Year, day number, and depth variables account for ~74% of variance in lake temperature.

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

#6

```
Temp_ancova_interaction <- lm(data = NTL.chem, temperature_C ~ lakenam * depth)
summary(Temp_ancova_interaction)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakenam * depth, data = NTL.chem)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -16.9720  -2.9341  -0.3193   2.8623  21.8362
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    21.81001    0.32302   67.519 < 2e-16 ***
## lakenamCrampton Lake    0.87406    0.37769    2.314  0.0207 *
## lakenamEast Long Lake  -4.50962    0.34147  -13.206 < 2e-16 ***
## lakenamHummingbird Lake -3.37196    0.47925   -7.036 2.02e-12 ***
## lakenamPaul Lake      -0.43805    0.33017   -1.327  0.1846
## lakenamPeter Lake     -0.73982    0.32946   -2.246  0.0247 *
## lakenamTuesday Lake   -3.46667    0.33428  -10.370 < 2e-16 ***
## lakenamWard Lake      -0.69719    0.44266   -1.575  0.1153
## lakenamWest Long Lake  -2.66126    0.34028   -7.821 5.40e-15 ***
## depth          -2.45643    0.13123  -18.718 < 2e-16 ***
## lakenamCrampton Lake:depth    0.98153    0.13418    7.315 2.63e-13 ***
## lakenamEast Long Lake:depth    0.97170    0.13247    7.335 2.27e-13 ***
## lakenamHummingbird Lake:depth -0.27735    0.16329   -1.698  0.0894 .
## lakenamPaul Lake:depth    0.55102    0.13183    4.180 2.93e-05 ***
## lakenamPeter Lake:depth    0.70144    0.13166    5.328 1.00e-07 ***
## lakenamTuesday Lake:depth    0.77356    0.13206    5.858 4.74e-09 ***
## lakenamWard Lake:depth   -0.07747    0.15103   -0.513  0.6080
## lakenamWest Long Lake:depth    0.85627    0.13240    6.467 1.01e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.698 on 34738 degrees of freedom
## (3858 observations deleted due to missingness)
## Multiple R-squared:  0.7161, Adjusted R-squared:  0.716
## F-statistic: 5155 on 17 and 34738 DF, p-value: < 2.2e-16
```

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

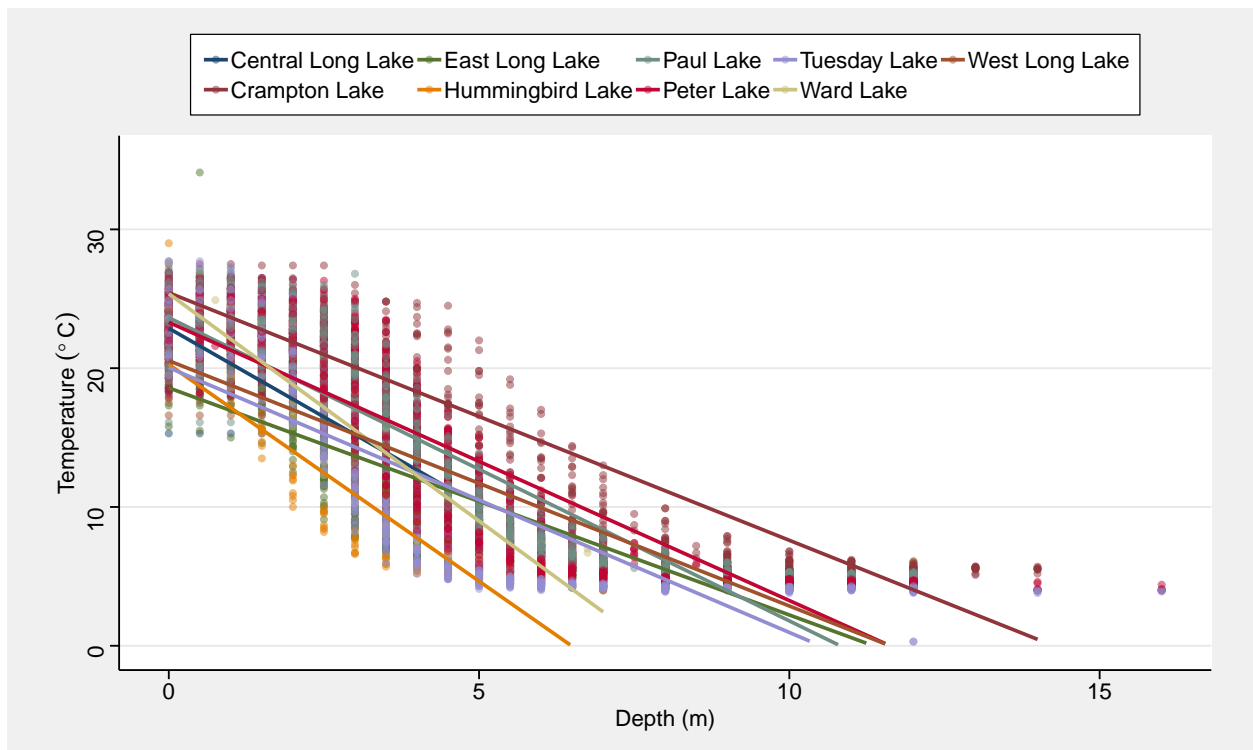
Answer: Many of the different lakes have a significant interaction with depth except Ward Lake and depth. Lake name and depth account for ~72% variance in lake temperature observations.

8. Create a graph that depicts temperature by depth, with a separate color for each lake. Add a `geom_smooth` (method = "lm", se = FALSE) for each lake. Make your points 50 % transparent. Adjust your y axis limits to go from 0 to 35 degrees. Clean up your graph to make it pretty.

```
#8
temp_plot <- ggplot(lake_temperatures_july, aes(x = depth, y = temperature_C, color = lakename)) +
  geom_point(alpha = 0.5) +
  labs(x = "Depth (m)", y = expression("Temperature " ( degree~C)), color = "") +
  #scale_color_viridis_d() +
  scale_color_stata("s2color") +
  geom_smooth(method = "lm", se = FALSE) +
  ylim(0, 35) +
  theme(legend.spacing.x = unit(0, "cm"))

print(temp_plot)
```

```
## Warning: Removed 72 rows containing missing values (geom_smooth).
```



9. Run a mixed effects model to predict dry mass of litter. We already know that `nlcdClass` and `functionalGroup` have a significant interaction, so we will specify those two variables as fixed effects with an interaction. We also know that litter mass varies across plot ID, but we are less interested in the actual effect of the plot itself but rather in accounting for the variance among plots. Plot ID will be our random effect.

- a. Build and run a mixed effects model.

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

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

```
## Linear mixed-effects model fit by REML
## Data: NTL.litter
##      AIC      BIC    logLik
##  9038.575 9179.479 -4493.287
##
## Random effects:
## Formula: ~1 | plotID
##      (Intercept) Residual
## StdDev:    0.5899105 3.456817
##
## Fixed effects: dryMass ~ nlcdClass * functionalGroup
##
##                                     Value
## (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

## nlcdClasssshrubScrub:functionalGroupSeeds	-0.566	-0.360
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.254	-0.307
## nlcdClasssshrubScrub:functionalGroupTwigs/branches	-0.577	-0.367
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.256	-0.309
## nlcdClasssshrubScrub:functionalGroupWoody material	-0.584	-0.371
##	fncGM	fncGN
## nlcdClassgrasslandHerbaceous		
## nlcdClasssshrubScrub		
## 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
## nlcdClasssshrubScrub:functionalGroupLeaves	-0.314	-0.374
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.564	-0.251
## nlcdClasssshrubScrub:functionalGroupMixed	-0.686	-0.305
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.272	-0.610
## nlcdClasssshrubScrub:functionalGroupNeedles	-0.322	-0.723
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.263	-0.313
## nlcdClasssshrubScrub:functionalGroupOther	-0.314	-0.374
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.263	-0.313
## nlcdClasssshrubScrub:functionalGroupSeeds	-0.313	-0.373
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.267	-0.318
## nlcdClasssshrubScrub:functionalGroupTwigs/branches	-0.319	-0.380
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.268	-0.320
## nlcdClasssshrubScrub:functionalGroupWoody material	-0.322	-0.384
##	fncG0	fncGS
## nlcdClassgrasslandHerbaceous		
## nlcdClasssshrubScrub		
## 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
## nlcdClasssshrubScrub:functionalGroupLeaves	-0.362	-0.362
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.243	-0.242
## nlcdClasssshrubScrub:functionalGroupMixed	-0.295	-0.294
## 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
## 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_mixed_random)
```

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

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

Answer: 2 %

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

```
litter_mixed <- gls(data = NTL.litter,
                    dryMass ~ nlcdClass * functionalGroup)
summary(litter_mixed)
```

```

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

```

## nlcdClasssshrubScrub:functionalGroupTwigs/branches	0.7488092
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.8897083
## nlcdClasssshrubScrub:functionalGroupWoody material	0.7395676
##	t-value
## (Intercept)	0.306185
## nlcdClassgrasslandHerbaceous	-0.177817
## nlcdClasssshrubScrub	-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
## nlcdClasssshrubScrub:functionalGroupLeaves	0.193676
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.337253
## nlcdClasssshrubScrub:functionalGroupMixed	0.801746
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-2.430645
## nlcdClasssshrubScrub:functionalGroupNeedles	-3.934239
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.138919
## nlcdClasssshrubScrub:functionalGroupOther	0.112860
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.050863
## nlcdClasssshrubScrub:functionalGroupSeeds	0.077903
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-1.134773
## nlcdClasssshrubScrub:functionalGroupTwigs/branches	-1.997293
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-1.169888
## nlcdClasssshrubScrub:functionalGroupWoody material	-1.314076
##	p-value
## (Intercept)	0.7595
## nlcdClassgrasslandHerbaceous	0.8589
## nlcdClasssshrubScrub	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
## nlcdClasssshrubScrub:functionalGroupLeaves	0.8465
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.7360
## nlcdClasssshrubScrub:functionalGroupMixed	0.4228
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.0152
## nlcdClasssshrubScrub:functionalGroupNeedles	0.0001
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.8895
## nlcdClasssshrubScrub:functionalGroupOther	0.9102
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.9594
## nlcdClasssshrubScrub:functionalGroupSeeds	0.9379
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.2566
## nlcdClasssshrubScrub:functionalGroupTwigs/branches	0.0460
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.2422
## nlcdClasssshrubScrub:functionalGroupWoody material	0.1890
##	

```

## Correlation:
##
## nlcdClassgrasslandHerbaceous      (Intr) nlcdCH      -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		
## nlcdClassshrubScrub		
## 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
## nlcdClassshrubScrub:functionalGroupLeaves	-0.362	-0.362
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.243	-0.243
## nlcdClassshrubScrub:functionalGroupMixed	-0.295	-0.295
## 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

## 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		
## nlcdClasssshrubScrub:functionalGroupLeaves	0.456	
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.408	0.178
## nlcdClasssshrubScrub:functionalGroupMixed	0.183	0.410
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.524	0.229
## nlcdClasssshrubScrub:functionalGroupNeedles	0.230	0.514
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.508	0.222
## nlcdClasssshrubScrub:functionalGroupOther	0.224	0.502
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.508	0.222
## nlcdClasssshrubScrub:functionalGroupSeeds	0.224	0.500
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.516	0.225
## nlcdClasssshrubScrub:functionalGroupTwigs/branches	0.228	0.510
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.518	0.226
## nlcdClasssshrubScrub:functionalGroupWoody material	0.231	0.516
##	nCH:GM	nCS:GM
## nlcdClassgrasslandHerbaceous		
## nlcdClasssshrubScrub		
## functionalGroupLeaves		
## functionalGroupMixed		
## functionalGroupNeedles		
## functionalGroupOther		
## functionalGroupSeeds		
## functionalGroupTwigs/branches		
## functionalGroupWoody material		
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves		
## nlcdClasssshrubScrub:functionalGroupLeaves		
## nlcdClassgrasslandHerbaceous:functionalGroupMixed		
## nlcdClasssshrubScrub:functionalGroupMixed	0.387	
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.415	0.186
## nlcdClasssshrubScrub: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_mixed_random, litter_mixed)
```

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

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

Answer: Mixed effects model is a better model because the AIC is lower than the model without random effects. The low p-value indicates that the models have a significantly different fit.