

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() #verify working directory

## [1] "C:/Users/sierr/Documents/Duke University/ENVIRON-872L/Environmental_Data_Analytics_2020"

library(tidyverse) #load tidyverse packages

## -- Attaching packages -----
## 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 -----
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(nlme) #load nlme package

##
## Attaching package: 'nlme'

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

```

library(piecewiseSEM) #load piecewiseSEM package

## 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>.

LakeChemData.raw <-
  read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")
#import the raw NTL-LTER lake chemistry/physics dataset
Litter.processed <-
  read.csv("./Data/Processed/NEON_NIWO_Litter_mass_trap_Processed.csv")
#import the processed litter dataset

#2
sierratheme <- theme_classic(base_size = 14) +
  theme(axis.text = element_text(color = "black"),
        legend.position = "top")
#build new theme 'sierratheme' and define its parameters
theme_set(sierratheme) #set sierratheme as default plot theme

```

NTL-LTER test

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

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

```

#3
LakeChemData.raw.filtered <-
  LakeChemData.raw %>%
  filter(daynum > 181 & daynum < 213) %>% #only select data from dates in July
  select(lakename, year4, daynum, depth, temperature_C) %>% #select only the specified columns
  na.exclude() #remove incomplete cases containing NAs

#4
LakeChemData.AIC <- lm(data = LakeChemData.raw.filtered, temperature_C ~ year4 + daynum +
  depth)
step(LakeChemData.AIC)

## 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 = LakeChemData.raw.filtered)
##
## Coefficients:
## (Intercept)      year4      daynum      depth
##    -6.45556     0.01013     0.04134    -1.94726

#run an AIC to determine variables best suited for predicting temperature
LakesChem.multregression <- lm(data = LakeChemData.raw.filtered, temperature_C ~ year4 +
                               daynum + depth) #run a multiple regression on recommended variables
summary(LakesChem.multregression)

##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = LakeChemData.raw.filtered)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -9.6517 -2.9937  0.0855  2.9692 13.6171
##
## Coefficients:
##              Estimate Std. Error  t value Pr(>|t|)
## (Intercept) -6.455560   8.638808  -0.747   0.4549
## year4        0.010131   0.004303   2.354   0.0186 *
## daynum       0.041336   0.004315   9.580  <2e-16 ***
## depth       -1.947264   0.011676 -166.782 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

##
## Residual standard error: 3.811 on 9718 degrees of freedom
## Multiple R-squared:  0.7417, Adjusted R-squared:  0.7417
## F-statistic: 9303 on 3 and 9718 DF,  p-value: < 2.2e-16
```

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

Answer: The final set of explanatory variables that predict temperature from my multiple regression include year4, daynum, and depth. Approximately 74.17% of the observed variance is explained by this model.

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

```
#6
LakeChem.ancova.interaction <- lm(data = LakeChemData.raw.filtered,
                                   temperature_C ~ lakenam * depth)
#run interaction effects ANCOVA to predict temperature from depth & lakenam
summary(LakeChem.ancova.interaction)

##
```

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

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

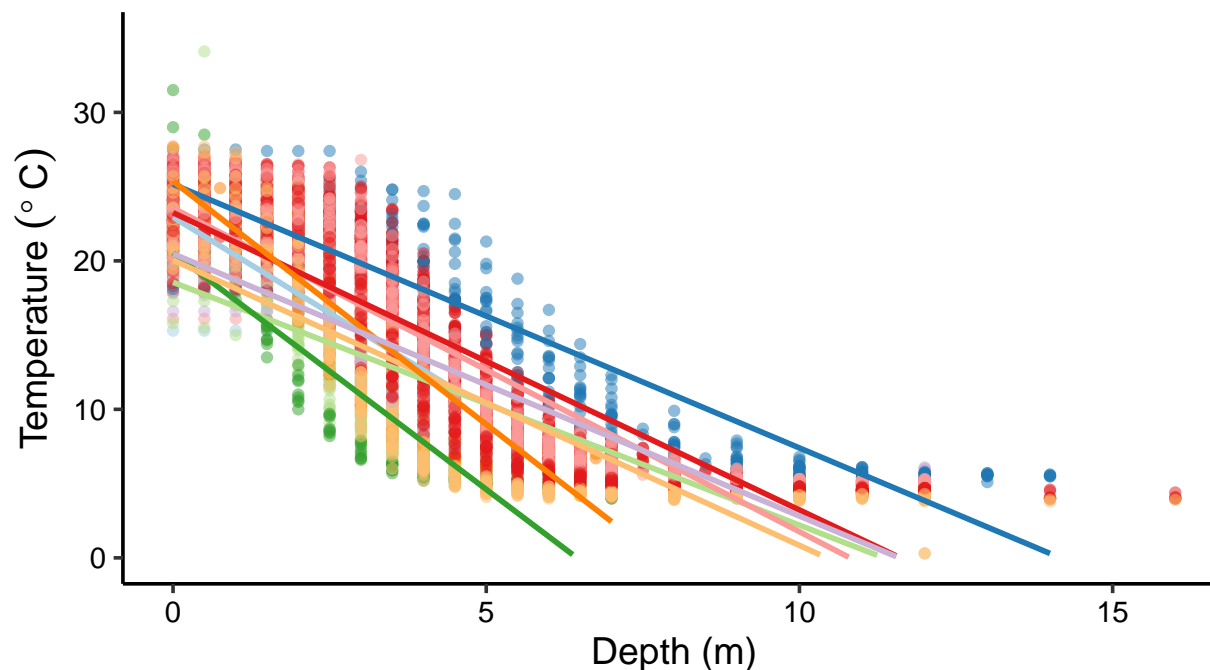
Answer: Yes, there is a significant interaction between depth and lakename. This explains approximately 78.57% of the variance in the temperature observations.

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
Lakes.plot <- ggplot(LakeChemData.raw.filtered,
  aes(x = depth, y = temperature_C, color = lakename)) +
  geom_point(alpha = 0.5) + #make points 50% transparent
  geom_smooth(method = "lm", se = FALSE) + #add geom_smooth for each lake
  labs(x = "Depth (m)", y = expression("Temperature " ( degree~C)), color = "") + #axis labels
  scale_color_brewer(palette = "Paired") + #define color palette
  ylim(0,35) #define y-axis limits
print(Lakes.plot)
```

```
## 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 R² of the model.

```
LitterTest.mixed <- lme(data = Litter.processed,
                        dryMass ~ nlcdClass * functionalGroup,
                        random = ~1|plotID)
#run mixed effects model to predict dry mass with nlcdClass and functionalGroup
#as fixed effects w/ interaction and plotID as a random effect
summary(LitterTest.mixed)
```

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

	Value	Std.Error
## (Intercept)	0.155492	0.4863580
## nlcdClassgrasslandHerbaceous	-0.156004	0.7789816
## nlcdClassshrubScrub	-0.107080	0.6636775
## functionalGroupLeaves	-0.126008	0.5501061
## functionalGroupMixed	1.477797	0.6323043
## functionalGroupNeedles	7.284064	0.5313161
## functionalGroupOther	-0.048525	0.5500878
## functionalGroupSeeds	-0.058702	0.5501061
## functionalGroupTwigs/branches	1.929441	0.5385556
## functionalGroupWoody material	1.068772	0.5259330
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.181416	0.8847246
## nlcdClassshrubScrub:functionalGroupLeaves	0.173857	0.7510320
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.467648	1.1201304
## nlcdClassshrubScrub:functionalGroupMixed	0.633876	0.9217911
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-2.118299	0.8705440
## nlcdClassshrubScrub:functionalGroupNeedles	-2.909142	0.7347172
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.143603	0.8976715
## nlcdClassshrubScrub:functionalGroupOther	0.104935	0.7528434
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.049290	0.8976827
## nlcdClassshrubScrub:functionalGroupSeeds	0.076708	0.7547591
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.986627	0.8850639
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-1.503446	0.7409024
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-1.017803	0.8802289
## nlcdClassshrubScrub:functionalGroupWoody material	-0.979078	0.7317033
##	DF	t-value
## (Intercept)	1659	0.319706
## nlcdClassgrasslandHerbaceous	9	-0.200266
## nlcdClassshrubScrub	9	-0.161343
## functionalGroupLeaves	1659	-0.229061
## functionalGroupMixed	1659	2.337160
## functionalGroupNeedles	1659	13.709474
## functionalGroupOther	1659	-0.088213
## functionalGroupSeeds	1659	-0.106711
## functionalGroupTwigs/branches	1659	3.582622
## functionalGroupWoody material	1659	2.032144
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	1659	0.205053
## nlcdClassshrubScrub:functionalGroupLeaves	1659	0.231490
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	1659	-0.417495
## nlcdClassshrubScrub:functionalGroupMixed	1659	0.687657
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	1659	-2.433305
## nlcdClassshrubScrub:functionalGroupNeedles	1659	-3.959540
## nlcdClassgrasslandHerbaceous:functionalGroupOther	1659	0.159972
## nlcdClassshrubScrub:functionalGroupOther	1659	0.139385
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	1659	0.054908
## nlcdClassshrubScrub:functionalGroupSeeds	1659	0.101632
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	1659	-1.114752
## nlcdClassshrubScrub:functionalGroupTwigs/branches	1659	-2.029209
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	1659	-1.156293
## nlcdClassshrubScrub:functionalGroupWoody material	1659	-1.338081
##	p-value	
## (Intercept)	0.7492	
## nlcdClassgrasslandHerbaceous	0.8457	
## nlcdClassshrubScrub	0.8754	

## functionalGroupLeaves	0.8188		
## functionalGroupMixed	0.0195		
## functionalGroupNeedles	0.0000		
## functionalGroupOther	0.9297		
## functionalGroupSeeds	0.9150		
## functionalGroupTwigs/branches	0.0003		
## functionalGroupWoody material	0.0423		
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.8376		
## nlcdClassshrubScrub:functionalGroupLeaves	0.8170		
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.6764		
## nlcdClassshrubScrub:functionalGroupMixed	0.4918		
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.0151		
## nlcdClassshrubScrub:functionalGroupNeedles	0.0001		
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.8729		
## nlcdClassshrubScrub:functionalGroupOther	0.8892		
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.9562		
## nlcdClassshrubScrub:functionalGroupSeeds	0.9191		
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.2651		
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.0426		
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.2477		
## nlcdClassshrubScrub:functionalGroupWoody material	0.1811		
## Correlation:			
##	(Intr)	nlcdCH	nlcdCS
## nlcdClassgrasslandHerbaceous	-0.624		
## nlcdClassshrubScrub	-0.733	0.458	
## functionalGroupLeaves	-0.559	0.349	0.409
## functionalGroupMixed	-0.485	0.303	0.356
## functionalGroupNeedles	-0.579	0.361	0.424
## functionalGroupOther	-0.559	0.349	0.409
## functionalGroupSeeds	-0.559	0.349	0.409
## functionalGroupTwigs/branches	-0.571	0.356	0.418
## functionalGroupWoody material	-0.584	0.365	0.428
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.347	-0.586	-0.255
## nlcdClassshrubScrub:functionalGroupLeaves	0.409	-0.255	-0.569
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.274	-0.462	-0.201
## nlcdClassshrubScrub:functionalGroupMixed	0.333	-0.208	-0.464
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.353	-0.595	-0.259
## nlcdClassshrubScrub:functionalGroupNeedles	0.418	-0.261	-0.582
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.342	-0.577	-0.251
## nlcdClassshrubScrub:functionalGroupOther	0.408	-0.255	-0.568
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.342	-0.577	-0.251
## nlcdClassshrubScrub:functionalGroupSeeds	0.407	-0.254	-0.566
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.347	-0.586	-0.254
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.415	-0.259	-0.577
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.349	-0.589	-0.256
## nlcdClassshrubScrub:functionalGroupWoody material	0.420	-0.262	-0.584
##	fnctGL	fnctGM	fnctGN
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed	0.429		
## functionalGroupNeedles	0.511	0.445	
## functionalGroupOther	0.494	0.430	0.511
## functionalGroupSeeds	0.494	0.429	0.511

## functionalGroupTwigs/branches	0.504	0.439	0.522
## functionalGroupWoody material	0.516	0.449	0.535
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.622	-0.267	-0.318
## nlcdClassshrubScrub:functionalGroupLeaves	-0.732	-0.314	-0.374
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.242	-0.564	-0.251
## nlcdClassshrubScrub:functionalGroupMixed	-0.295	-0.686	-0.305
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.312	-0.272	-0.610
## nlcdClassshrubScrub:functionalGroupNeedles	-0.370	-0.322	-0.723
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.303	-0.263	-0.313
## nlcdClassshrubScrub:functionalGroupOther	-0.361	-0.314	-0.374
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.303	-0.263	-0.313
## nlcdClassshrubScrub:functionalGroupSeeds	-0.360	-0.313	-0.373
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.307	-0.267	-0.318
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.367	-0.319	-0.380
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.309	-0.268	-0.320
## nlcdClassshrubScrub:functionalGroupWoody material	-0.371	-0.322	-0.384
##	fnctG0	fnctGS	fncGT/
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds	0.494		
## functionalGroupTwigs/branches	0.504	0.504	
## functionalGroupWoody material	0.516	0.517	0.528
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.307	-0.307	-0.314
## nlcdClassshrubScrub:functionalGroupLeaves	-0.362	-0.362	-0.369
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.243	-0.242	-0.248
## nlcdClassshrubScrub:functionalGroupMixed	-0.295	-0.294	-0.301
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.312	-0.312	-0.319
## nlcdClassshrubScrub:functionalGroupNeedles	-0.370	-0.370	-0.378
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.613	-0.303	-0.309
## nlcdClassshrubScrub:functionalGroupOther	-0.731	-0.361	-0.369
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.303	-0.613	-0.309
## nlcdClassshrubScrub:functionalGroupSeeds	-0.360	-0.729	-0.368
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.307	-0.307	-0.608
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.367	-0.367	-0.727
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.309	-0.309	-0.315
## nlcdClassshrubScrub:functionalGroupWoody material	-0.371	-0.371	-0.379
##	fncGWm	nCH:GL	nCS:GL
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds			
## functionalGroupTwigs/branches			
## functionalGroupWoody material			
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.321		
## nlcdClassshrubScrub:functionalGroupLeaves	-0.378	0.455	
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.253	0.406	0.178
## nlcdClassshrubScrub:functionalGroupMixed	-0.308	0.183	0.410

## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.326	0.524	0.229
## nlcdClassshrubScrub:functionalGroupNeedles	-0.387	0.230	0.514
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.316	0.508	0.222
## nlcdClassshrubScrub:functionalGroupOther	-0.377	0.224	0.502
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.317	0.508	0.222
## nlcdClassshrubScrub:functionalGroupSeeds	-0.376	0.224	0.500
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.321	0.515	0.225
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.384	0.228	0.510
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.597	0.518	0.226
## nlcdClassshrubScrub:functionalGroupWoody material	-0.719	0.231	0.516
##	nCH:GM	nCS:GM	nCH:GN
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds			
## functionalGroupTwigs/branches			
## functionalGroupWoody material			
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves			
## nlcdClassshrubScrub:functionalGroupLeaves			
## nlcdClassgrasslandHerbaceous:functionalGroupMixed			
## nlcdClassshrubScrub:functionalGroupMixed	0.387		
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.414	0.186	
## nlcdClassshrubScrub:functionalGroupNeedles	0.182	0.419	0.441
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.401	0.181	0.517
## nlcdClassshrubScrub:functionalGroupOther	0.177	0.409	0.228
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.402	0.180	0.517
## nlcdClassshrubScrub:functionalGroupSeeds	0.177	0.408	0.227
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.407	0.183	0.524
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.180	0.416	0.232
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.409	0.184	0.527
## nlcdClassshrubScrub:functionalGroupWoody material	0.182	0.420	0.235
##	nCS:GN	nCH:GO	nCS:GO
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds			
## functionalGroupTwigs/branches			
## functionalGroupWoody material			
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves			
## nlcdClassshrubScrub:functionalGroupLeaves			
## nlcdClassgrasslandHerbaceous:functionalGroupMixed			
## nlcdClassshrubScrub:functionalGroupMixed			
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles			
## nlcdClassshrubScrub:functionalGroupNeedles			
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.227		
## nlcdClassshrubScrub:functionalGroupOther	0.513	0.448	
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.227	0.501	0.221
## nlcdClassshrubScrub:functionalGroupSeeds	0.512	0.221	0.499

```

## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.230 0.508 0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.521 0.225 0.509
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.231 0.511 0.225
## nlcdClassshrubScrub:functionalGroupWoody material 0.528 0.227 0.515
## nCH:GS nCS:GS nCH:GT
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds 0.447
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.508 0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.225 0.507 0.442
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.511 0.225 0.518
## nlcdClassshrubScrub:functionalGroupWoody material 0.228 0.514 0.231
## nCS:GT nCH:Gm
## nlcdClassgrasslandHerbaceous
## nlcdClassshrubScrub
## functionalGroupLeaves
## functionalGroupMixed
## functionalGroupNeedles
## functionalGroupOther
## functionalGroupSeeds
## functionalGroupTwigs/branches
## functionalGroupWoody material
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves
## nlcdClassshrubScrub:functionalGroupLeaves
## nlcdClassgrasslandHerbaceous:functionalGroupMixed
## nlcdClassshrubScrub:functionalGroupMixed
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles
## nlcdClassshrubScrub:functionalGroupNeedles
## nlcdClassgrasslandHerbaceous:functionalGroupOther
## nlcdClassshrubScrub:functionalGroupOther
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds
## nlcdClassshrubScrub:functionalGroupSeeds
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches
## nlcdClassshrubScrub:functionalGroupTwigs/branches
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.229
## nlcdClassshrubScrub:functionalGroupWoody material 0.523 0.429
##
## Standardized Within-Group Residuals:

```

```
##           Min           Q1           Med           Q3           Max
## -1.96496855 -0.23842984 -0.01535880  0.09027291 14.27434811
##
## Number of Observations: 1692
## Number of Groups: 12
```

```
rsquared(LitterTest.mixed) #check marginal & conditional R2 values of model
```

```
## 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: Approximately 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.

```
LitterTest.fixed <- gls(data = Litter.processed,
  dryMass ~ nlcdClass * functionalGroup)
#run fixed effects model to predict dry mass with nlcdClass and functionalGroup
#as fixed effects w/ interaction (no random effects included)
summary(LitterTest.fixed)
```

```
## Generalized least squares fit by REML
## Model: dryMass ~ nlcdClass * functionalGroup
## Data: Litter.processed
## AIC BIC logLik
## 9058.088 9193.573 -4504.044
##
## Coefficients:
## Value Std.Error
## (Intercept) 0.119625 0.3906950
## nlcdClassgrasslandHerbaceous -0.114199 0.6422303
## nlcdClassshrubScrub -0.104119 0.5383767
## functionalGroupLeaves -0.103599 0.5560568
## functionalGroupMixed 1.504750 0.6380023
## functionalGroupNeedles 7.312264 0.5369590
## functionalGroupOther -0.034817 0.5560568
## functionalGroupSeeds -0.046163 0.5560568
## functionalGroupTwigs/branches 1.959669 0.5443402
## functionalGroupWoody material 1.084311 0.5315555
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves 0.128646 0.8941030
## nlcdClassshrubScrub:functionalGroupLeaves 0.147030 0.7591538
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.381176 1.1302365
## nlcdClassshrubScrub:functionalGroupMixed 0.745929 0.9303798
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -2.138801 0.8799314
## nlcdClassshrubScrub:functionalGroupNeedles -2.921481 0.7425783
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.126058 0.9074253
## nlcdClassshrubScrub:functionalGroupOther 0.085888 0.7610116
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.046155 0.9074253
## nlcdClassshrubScrub:functionalGroupSeeds 0.059436 0.7629471
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -1.015195 0.8946237
## nlcdClassshrubScrub:functionalGroupTwigs/branches -1.495591 0.7488092
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -1.040859 0.8897083
## nlcdClassshrubScrub:functionalGroupWoody material -0.971848 0.7395676
## t-value p-value
```

## (Intercept)	0.306185	0.7595
## nlcdClassgrasslandHerbaceous	-0.177817	0.8589
## nlcdClassshrubScrub	-0.193395	0.8467
## functionalGroupLeaves	-0.186311	0.8522
## functionalGroupMixed	2.358534	0.0185
## functionalGroupNeedles	13.617920	0.0000
## functionalGroupOther	-0.062615	0.9501
## functionalGroupSeeds	-0.083019	0.9338
## functionalGroupTwigs/branches	3.600082	0.0003
## functionalGroupWoody material	2.039883	0.0415
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.143882	0.8856
## nlcdClassshrubScrub:functionalGroupLeaves	0.193676	0.8465
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.337253	0.7360
## nlcdClassshrubScrub:functionalGroupMixed	0.801746	0.4228
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-2.430645	0.0152
## nlcdClassshrubScrub:functionalGroupNeedles	-3.934239	0.0001
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.138919	0.8895
## nlcdClassshrubScrub:functionalGroupOther	0.112860	0.9102
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.050863	0.9594
## nlcdClassshrubScrub:functionalGroupSeeds	0.077903	0.9379
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-1.134773	0.2566
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-1.997293	0.0460
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-1.169888	0.2422
## nlcdClassshrubScrub:functionalGroupWoody material	-1.314076	0.1890
##		
## Correlation:		
##	(Intr)	nlcdCH nlcdCS
## nlcdClassgrasslandHerbaceous	-0.608	
## nlcdClassshrubScrub	-0.726	0.441
## functionalGroupLeaves	-0.703	0.427 0.510
## functionalGroupMixed	-0.612	0.373 0.444
## functionalGroupNeedles	-0.728	0.443 0.528
## functionalGroupOther	-0.703	0.427 0.510
## functionalGroupSeeds	-0.703	0.427 0.510
## functionalGroupTwigs/branches	-0.718	0.437 0.521
## functionalGroupWoody material	-0.735	0.447 0.533
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	0.437	-0.718 -0.317
## nlcdClassshrubScrub:functionalGroupLeaves	0.515	-0.313 -0.709
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	0.346	-0.568 -0.251
## nlcdClassshrubScrub:functionalGroupMixed	0.420	-0.255 -0.579
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.444	-0.730 -0.322
## nlcdClassshrubScrub:functionalGroupNeedles	0.526	-0.320 -0.725
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.431	-0.708 -0.312
## nlcdClassshrubScrub:functionalGroupOther	0.513	-0.312 -0.707
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.431	-0.708 -0.312
## nlcdClassshrubScrub:functionalGroupSeeds	0.512	-0.312 -0.706
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.437	-0.718 -0.317
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.522	-0.317 -0.719
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.439	-0.722 -0.319
## nlcdClassshrubScrub:functionalGroupWoody material	0.528	-0.321 -0.728
##	fnctGL	fnctGM fnctGN
## nlcdClassgrasslandHerbaceous		
## nlcdClassshrubScrub		
## functionalGroupLeaves		

## functionalGroupMixed	0.430		
## functionalGroupNeedles	0.511	0.446	
## functionalGroupOther	0.494	0.430	0.511
## functionalGroupSeeds	0.494	0.430	0.511
## functionalGroupTwigs/branches	0.504	0.440	0.522
## functionalGroupWoody material	0.516	0.450	0.535
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.622	-0.268	-0.318
## nlcdClassshrubScrub:functionalGroupLeaves	-0.732	-0.315	-0.374
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.243	-0.564	-0.252
## nlcdClassshrubScrub:functionalGroupMixed	-0.295	-0.686	-0.306
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.312	-0.272	-0.610
## nlcdClassshrubScrub:functionalGroupNeedles	-0.370	-0.322	-0.723
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.303	-0.264	-0.313
## nlcdClassshrubScrub:functionalGroupOther	-0.361	-0.314	-0.374
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.303	-0.264	-0.313
## nlcdClassshrubScrub:functionalGroupSeeds	-0.360	-0.314	-0.373
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.307	-0.267	-0.318
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.367	-0.320	-0.380
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.309	-0.269	-0.320
## nlcdClassshrubScrub:functionalGroupWoody material	-0.371	-0.324	-0.384
##	fnctG0	fnctGS	fnctGT/
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds	0.494		
## functionalGroupTwigs/branches	0.504	0.504	
## functionalGroupWoody material	0.516	0.516	0.528
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.307	-0.307	-0.314
## nlcdClassshrubScrub:functionalGroupLeaves	-0.362	-0.362	-0.369
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.243	-0.243	-0.248
## nlcdClassshrubScrub:functionalGroupMixed	-0.295	-0.295	-0.301
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.312	-0.312	-0.319
## nlcdClassshrubScrub:functionalGroupNeedles	-0.370	-0.370	-0.378
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.613	-0.303	-0.309
## nlcdClassshrubScrub:functionalGroupOther	-0.731	-0.361	-0.368
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.303	-0.613	-0.309
## nlcdClassshrubScrub:functionalGroupSeeds	-0.360	-0.729	-0.368
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.307	-0.307	-0.608
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.367	-0.367	-0.727
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.309	-0.309	-0.315
## nlcdClassshrubScrub:functionalGroupWoody material	-0.371	-0.371	-0.379
##	fncGWm	nCH:GL	nCS:GL
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds			
## functionalGroupTwigs/branches			
## functionalGroupWoody material			

## nlcdClassgrasslandHerbaceous:functionalGroupLeaves	-0.321		
## nlcdClassshrubScrub:functionalGroupLeaves	-0.378	0.456	
## nlcdClassgrasslandHerbaceous:functionalGroupMixed	-0.254	0.408	0.178
## nlcdClassshrubScrub:functionalGroupMixed	-0.309	0.183	0.410
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	-0.326	0.524	0.229
## nlcdClassshrubScrub:functionalGroupNeedles	-0.387	0.230	0.514
## nlcdClassgrasslandHerbaceous:functionalGroupOther	-0.316	0.508	0.222
## nlcdClassshrubScrub:functionalGroupOther	-0.377	0.224	0.502
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	-0.316	0.508	0.222
## nlcdClassshrubScrub:functionalGroupSeeds	-0.376	0.224	0.500
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	-0.321	0.516	0.225
## nlcdClassshrubScrub:functionalGroupTwigs/branches	-0.383	0.228	0.510
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	-0.597	0.518	0.226
## nlcdClassshrubScrub:functionalGroupWoody material	-0.719	0.231	0.516
##	nCH:GM	nCS:GM	nCH:GN
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds			
## functionalGroupTwigs/branches			
## functionalGroupWoody material			
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves			
## nlcdClassshrubScrub:functionalGroupLeaves			
## nlcdClassgrasslandHerbaceous:functionalGroupMixed			
## nlcdClassshrubScrub:functionalGroupMixed	0.387		
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles	0.415	0.186	
## nlcdClassshrubScrub:functionalGroupNeedles	0.182	0.420	0.441
## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.402	0.181	0.517
## nlcdClassshrubScrub:functionalGroupOther	0.177	0.409	0.228
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.402	0.181	0.517
## nlcdClassshrubScrub:functionalGroupSeeds	0.177	0.408	0.227
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.408	0.183	0.524
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.180	0.416	0.232
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.410	0.184	0.527
## nlcdClassshrubScrub:functionalGroupWoody material	0.183	0.421	0.235
##	nCS:GN	nCH:GO	nCS:GO
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds			
## functionalGroupTwigs/branches			
## functionalGroupWoody material			
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves			
## nlcdClassshrubScrub:functionalGroupLeaves			
## nlcdClassgrasslandHerbaceous:functionalGroupMixed			
## nlcdClassshrubScrub:functionalGroupMixed			
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles			
## nlcdClassshrubScrub:functionalGroupNeedles			

## nlcdClassgrasslandHerbaceous:functionalGroupOther	0.227		
## nlcdClassshrubScrub:functionalGroupOther	0.513	0.448	
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds	0.227	0.501	0.221
## nlcdClassshrubScrub:functionalGroupSeeds	0.512	0.220	0.499
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.230	0.508	0.224
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.521	0.225	0.509
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.231	0.511	0.225
## nlcdClassshrubScrub:functionalGroupWoody material	0.528	0.227	0.515
##	nCH:GS	nCS:GS	nCH:GT
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds			
## functionalGroupTwigs/branches			
## functionalGroupWoody material			
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves			
## nlcdClassshrubScrub:functionalGroupLeaves			
## nlcdClassgrasslandHerbaceous:functionalGroupMixed			
## nlcdClassshrubScrub:functionalGroupMixed			
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles			
## nlcdClassshrubScrub:functionalGroupNeedles			
## nlcdClassgrasslandHerbaceous:functionalGroupOther			
## nlcdClassshrubScrub:functionalGroupOther			
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds			
## nlcdClassshrubScrub:functionalGroupSeeds	0.447		
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches	0.508	0.224	
## nlcdClassshrubScrub:functionalGroupTwigs/branches	0.225	0.507	0.442
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material	0.511	0.225	0.518
## nlcdClassshrubScrub:functionalGroupWoody material	0.227	0.514	0.231
##	nCS:GT	nCH:Gm	
## nlcdClassgrasslandHerbaceous			
## nlcdClassshrubScrub			
## functionalGroupLeaves			
## functionalGroupMixed			
## functionalGroupNeedles			
## functionalGroupOther			
## functionalGroupSeeds			
## functionalGroupTwigs/branches			
## functionalGroupWoody material			
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves			
## nlcdClassshrubScrub:functionalGroupLeaves			
## nlcdClassgrasslandHerbaceous:functionalGroupMixed			
## nlcdClassshrubScrub:functionalGroupMixed			
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles			
## nlcdClassshrubScrub:functionalGroupNeedles			
## nlcdClassgrasslandHerbaceous:functionalGroupOther			
## nlcdClassshrubScrub:functionalGroupOther			
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds			
## nlcdClassshrubScrub:functionalGroupSeeds			
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches			
## nlcdClassshrubScrub:functionalGroupTwigs/branches			

```
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.229
## nlcdClassshrubScrub:functionalGroupWoody material 0.523 0.429
##
## Standardized residuals:
##      Min      Q1      Med      Q3      Max
## -1.89209382 -0.13724016 -0.01672707 -0.00155260 14.03673076
##
## Residual standard error: 3.494483
## Degrees of freedom: 1692 total; 1668 residual
rsquared(LitterTest.fixed) #check R2 value of the model

## Response family link method R.squared
## 1 dryMass gaussian identity none 0.2515836
anova(LitterTest.mixed, LitterTest.fixed) #run ANOVA on mixed & fixed tests

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

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

Answer: Yes, the mixed effects model (with the random effect included) is a better model than the fixed effects model (with no random effect), as it is able to explain a (slightly) larger percentage of the variance in the data and yields a (slightly) lower AIC value. The fact that the p-value of the ANOVA (run in part 9d) is less than the significance level indicates that we can reject the null hypothesis and say that there is, indeed, a statistically significant difference in the fit of the two models.