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

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## OVERVIEW

This exercise accompanies the lessons in Environmental Data Analytics on generalized linear models.

## Directions

1. Change “Student Name” on line 3 (above) with your name.
2. Work through the steps, **creating code and output** that fulfill each instruction.
3. Be sure to **answer the questions** in this assignment document.
4. When you have completed the assignment, **Knit** the text and code into a single PDF file.
5. After Knitting, submit the completed exercise (PDF file) to the dropbox in Sakai. Add your last name into the file name (e.g., “Salk\_A06\_GLMs\_Week1.Rmd”) prior to submission.

The completed exercise is due on Tuesday, February 25 at 1:00 pm.

## Set up your session

1. Set up your session. Check your working directory, load the tidyverse, nlme, and piecewiseSEM packages, import the *raw* NTL-LTER raw data file for chemistry/physics, and import the processed litter dataset. You will not work with dates, so no need to format your date columns this time.
2. Build a ggplot theme and set it as your default theme.

#1  
getwd() # Checks my working directory

## [1] "/Users/monishaeadala/Environmental\_Data\_Analytics\_2020"

library(tidyverse)

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

## ✓ ggplot2 3.2.1 ✓ purrr 0.3.3  
## ✓ tibble 2.1.3 ✓ dplyr 0.8.3  
## ✓ tidyr 1.0.2 ✓ stringr 1.4.0  
## ✓ readr 1.3.1 ✓ forcats 0.4.0

## ── Conflicts ────────────────────────────────────────────────────────── tidyverse\_conflicts() ──  
## x dplyr::filter() masks stats::filter()  
## x dplyr::lag() masks stats::lag()

library(nlme)

##   
## Attaching package: 'nlme'

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

library(piecewiseSEM) # Loads the necessary packages

## Registered S3 methods overwritten by 'lme4':  
## method from  
## cooks.distance.influence.merMod car   
## influence.merMod car   
## dfbeta.influence.merMod car   
## dfbetas.influence.merMod car

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

Lakes.ChemPhys <- read.csv("./Data/Raw/NTL-LTER\_Lake\_ChemistryPhysics\_Raw.csv")  
Litter <- read.csv("./Data/Processed/NEON\_NIWO\_Litter\_mass\_trap\_Processed.csv") # Imports the necessary files  
  
#2  
theme\_set(theme\_classic()) # Builds a ggplot theme and sets it as my default theme

## NTL-LTER test

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

1. 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)

1. 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  
Lakes.ChemPhys.July <- Lakes.ChemPhys %>%   
 filter(daynum > 181 & daynum <= 213) %>% # Keeps only dates in July  
 select(lakename:daynum, depth, temperature\_C) %>% # Keeps only the columns: lakename, year4, daynum, depth, temperature\_C  
 na.omit() # Removes NAs  
  
#4  
Temp.AIC <- lm(data = Lakes.ChemPhys.July, temperature\_C ~ year4 + daynum + depth) # Runs an AIC to determine what set of explanatory variables (year4, daynum, depth) is best suited to predict temperature  
step(Temp.AIC) # Confirms that I should be using all the variables since that model has the lowest AIC

## Start: AIC=26781.56  
## temperature\_C ~ year4 + daynum + depth  
##   
## Df Sum of Sq RSS AIC  
## <none> 146054 26782  
## - year4 1 154 146209 26790  
## - daynum 1 1582 147636 26887  
## - depth 1 414049 560103 40189

##   
## Call:  
## lm(formula = temperature\_C ~ year4 + daynum + depth, data = Lakes.ChemPhys.July)  
##   
## Coefficients:  
## (Intercept) year4 daynum depth   
## -14.33180 0.01386 0.04337 -1.94112

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

##   
## Call:  
## lm(formula = temperature\_C ~ year4 + daynum + depth, data = Lakes.ChemPhys.July)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -9.669 -3.014 0.091 2.977 13.606   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -14.331802 8.582522 -1.670 0.09497 .   
## year4 0.013861 0.004274 3.243 0.00119 \*\*   
## daynum 0.043368 0.004173 10.393 < 2e-16 \*\*\*  
## depth -1.941121 0.011545 -168.135 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 3.827 on 9972 degrees of freedom  
## Multiple R-squared: 0.7399, Adjusted R-squared: 0.7398   
## F-statistic: 9457 on 3 and 9972 DF, p-value: < 2.2e-16

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

Answer: The model with the lowest AIC is the final set of explanatory variables. Therefore, the final set of explanatory variables are year4, daynum and depth (as also mentioned above). The observed variance is the adjusted R-squared = 0.7398

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

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

##   
## Call:  
## lm(formula = temperature\_C ~ lakename \* depth, data = Lakes.ChemPhys.July)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -7.6410 -2.9075 -0.2944 2.7531 16.3358   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 22.8748 0.5658 40.427 < 2e-16 \*\*\*  
## lakenameCrampton Lake 2.5625 0.6518 3.932 8.49e-05 \*\*\*  
## lakenameEast Long Lake -4.2925 0.5993 -7.163 8.46e-13 \*\*\*  
## lakenameHummingbird Lake -2.1903 0.8044 -2.723 0.006483 \*\*   
## lakenamePaul Lake 0.7115 0.5784 1.230 0.218684   
## lakenamePeter Lake 0.3862 0.5770 0.669 0.503250   
## lakenameTuesday Lake -2.8635 0.5857 -4.889 1.03e-06 \*\*\*  
## lakenameWard Lake 2.4887 0.8299 2.999 0.002718 \*\*   
## lakenameWest Long Lake -2.4193 0.5959 -4.060 4.94e-05 \*\*\*  
## depth -2.5543 0.2331 -10.960 < 2e-16 \*\*\*  
## lakenameCrampton Lake:depth 0.7704 0.2379 3.238 0.001208 \*\*   
## lakenameEast Long Lake:depth 0.9181 0.2353 3.902 9.60e-05 \*\*\*  
## lakenameHummingbird Lake:depth -0.6738 0.2831 -2.380 0.017323 \*   
## lakenamePaul Lake:depth 0.3716 0.2341 1.587 0.112452   
## lakenamePeter Lake:depth 0.5503 0.2338 2.354 0.018612 \*   
## lakenameTuesday Lake:depth 0.6486 0.2345 2.766 0.005687 \*\*   
## lakenameWard Lake:depth -0.7207 0.2796 -2.578 0.009962 \*\*   
## lakenameWest Long Lake:depth 0.7928 0.2351 3.373 0.000747 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 3.475 on 9958 degrees of freedom  
## Multiple R-squared: 0.7859, Adjusted R-squared: 0.7855   
## F-statistic: 2150 on 17 and 9958 DF, p-value: < 2.2e-16

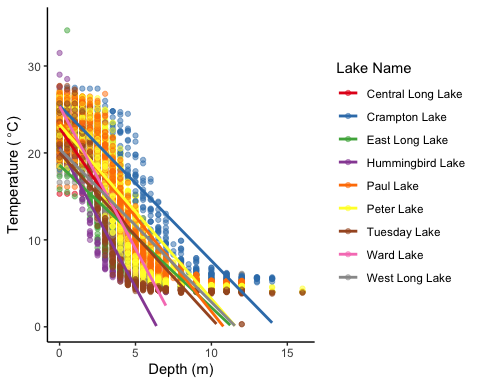
1. Is there a significant interaction between depth and lakename? How much variance in the temperature observations does this explain?

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

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

#8  
Temp.plot <- ggplot(Lakes.ChemPhys.July, aes(x = depth, y = temperature\_C, color = lakename)) + # Creates a graph that depicts temperature by depth, with a separate color for each lake  
 geom\_point(alpha = 0.5) + # Makes my points 50% transparent  
 geom\_smooth(method = "lm", se = FALSE) + # Adds a geom\_smooth for each lake  
 scale\_color\_brewer(palette = "Set1", direction = 1) + # Asserts a specific color palette that makes the graph effective and pretty  
 ylim(0,35) + # Adjusts your y axis limits to go from 0 to 35 degrees  
 labs(x = "Depth (m)", y = expression("Temperature ("\*~degree\*C\*")"), color = "Lake Name") # Labels everything on the graph appropriately   
print(Temp.plot)

## Warning: Removed 73 rows containing missing values (geom\_smooth).



1. 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.
2. Build and run a mixed effects model.
3. Check the difference between the marginal and conditional R2 of the model.

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

## Linear mixed-effects model fit by REML  
## Data: Litter   
## AIC BIC logLik  
## 9038.575 9179.479 -4493.287  
##   
## Random effects:  
## Formula: ~1 | plotID  
## (Intercept) Residual  
## StdDev: 0.5899105 3.456817  
##   
## Fixed effects: dryMass ~ nlcdClass \* functionalGroup   
## Value Std.Error  
## (Intercept) 0.155492 0.4863580  
## nlcdClassgrasslandHerbaceous -0.156004 0.7789816  
## nlcdClassshrubScrub -0.107080 0.6636775  
## functionalGroupLeaves -0.126008 0.5501061  
## functionalGroupMixed 1.477797 0.6323043  
## functionalGroupNeedles 7.284064 0.5313161  
## functionalGroupOther -0.048525 0.5500878  
## functionalGroupSeeds -0.058702 0.5501061  
## functionalGroupTwigs/branches 1.929441 0.5385556  
## functionalGroupWoody material 1.068772 0.5259330  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves 0.181416 0.8847246  
## nlcdClassshrubScrub:functionalGroupLeaves 0.173857 0.7510320  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.467648 1.1201304  
## nlcdClassshrubScrub:functionalGroupMixed 0.633876 0.9217911  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -2.118299 0.8705440  
## nlcdClassshrubScrub:functionalGroupNeedles -2.909142 0.7347172  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.143603 0.8976715  
## nlcdClassshrubScrub:functionalGroupOther 0.104935 0.7528434  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.049290 0.8976827  
## nlcdClassshrubScrub:functionalGroupSeeds 0.076708 0.7547591  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.986627 0.8850639  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -1.503446 0.7409024  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -1.017803 0.8802289  
## nlcdClassshrubScrub:functionalGroupWoody material -0.979078 0.7317033  
## DF t-value  
## (Intercept) 1659 0.319706  
## nlcdClassgrasslandHerbaceous 9 -0.200266  
## nlcdClassshrubScrub 9 -0.161343  
## functionalGroupLeaves 1659 -0.229061  
## functionalGroupMixed 1659 2.337160  
## functionalGroupNeedles 1659 13.709474  
## functionalGroupOther 1659 -0.088213  
## functionalGroupSeeds 1659 -0.106711  
## functionalGroupTwigs/branches 1659 3.582622  
## functionalGroupWoody material 1659 2.032144  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves 1659 0.205053  
## nlcdClassshrubScrub:functionalGroupLeaves 1659 0.231490  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed 1659 -0.417495  
## nlcdClassshrubScrub:functionalGroupMixed 1659 0.687657  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles 1659 -2.433305  
## nlcdClassshrubScrub:functionalGroupNeedles 1659 -3.959540  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 1659 0.159972  
## nlcdClassshrubScrub:functionalGroupOther 1659 0.139385  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 1659 0.054908  
## nlcdClassshrubScrub:functionalGroupSeeds 1659 0.101632  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 1659 -1.114752  
## nlcdClassshrubScrub:functionalGroupTwigs/branches 1659 -2.029209  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 1659 -1.156293  
## nlcdClassshrubScrub:functionalGroupWoody material 1659 -1.338081  
## p-value  
## (Intercept) 0.7492  
## nlcdClassgrasslandHerbaceous 0.8457  
## nlcdClassshrubScrub 0.8754  
## functionalGroupLeaves 0.8188  
## functionalGroupMixed 0.0195  
## functionalGroupNeedles 0.0000  
## functionalGroupOther 0.9297  
## functionalGroupSeeds 0.9150  
## functionalGroupTwigs/branches 0.0003  
## functionalGroupWoody material 0.0423  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves 0.8376  
## nlcdClassshrubScrub:functionalGroupLeaves 0.8170  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed 0.6764  
## nlcdClassshrubScrub:functionalGroupMixed 0.4918  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles 0.0151  
## nlcdClassshrubScrub:functionalGroupNeedles 0.0001  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.8729  
## nlcdClassshrubScrub:functionalGroupOther 0.8892  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.9562  
## nlcdClassshrubScrub:functionalGroupSeeds 0.9191  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.2651  
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.0426  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.2477  
## nlcdClassshrubScrub:functionalGroupWoody material 0.1811  
## Correlation:   
## (Intr) nlcdCH nlcdCS  
## nlcdClassgrasslandHerbaceous -0.624   
## nlcdClassshrubScrub -0.733 0.458   
## functionalGroupLeaves -0.559 0.349 0.409  
## functionalGroupMixed -0.485 0.303 0.356  
## functionalGroupNeedles -0.579 0.361 0.424  
## functionalGroupOther -0.559 0.349 0.409  
## functionalGroupSeeds -0.559 0.349 0.409  
## functionalGroupTwigs/branches -0.571 0.356 0.418  
## functionalGroupWoody material -0.584 0.365 0.428  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves 0.347 -0.586 -0.255  
## nlcdClassshrubScrub:functionalGroupLeaves 0.409 -0.255 -0.569  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed 0.274 -0.462 -0.201  
## nlcdClassshrubScrub:functionalGroupMixed 0.333 -0.208 -0.464  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles 0.353 -0.595 -0.259  
## nlcdClassshrubScrub:functionalGroupNeedles 0.418 -0.261 -0.582  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.342 -0.577 -0.251  
## nlcdClassshrubScrub:functionalGroupOther 0.408 -0.255 -0.568  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.342 -0.577 -0.251  
## nlcdClassshrubScrub:functionalGroupSeeds 0.407 -0.254 -0.566  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.347 -0.586 -0.254  
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.415 -0.259 -0.577  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.349 -0.589 -0.256  
## nlcdClassshrubScrub:functionalGroupWoody material 0.420 -0.262 -0.584  
## fnctGL fnctGM fnctGN  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed 0.429   
## functionalGroupNeedles 0.511 0.445   
## functionalGroupOther 0.494 0.430 0.511  
## functionalGroupSeeds 0.494 0.429 0.511  
## functionalGroupTwigs/branches 0.504 0.439 0.522  
## functionalGroupWoody material 0.516 0.449 0.535  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.622 -0.267 -0.318  
## nlcdClassshrubScrub:functionalGroupLeaves -0.732 -0.314 -0.374  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.242 -0.564 -0.251  
## nlcdClassshrubScrub:functionalGroupMixed -0.295 -0.686 -0.305  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.312 -0.272 -0.610  
## nlcdClassshrubScrub:functionalGroupNeedles -0.370 -0.322 -0.723  
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.303 -0.263 -0.313  
## nlcdClassshrubScrub:functionalGroupOther -0.361 -0.314 -0.374  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.303 -0.263 -0.313  
## nlcdClassshrubScrub:functionalGroupSeeds -0.360 -0.313 -0.373  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.267 -0.318  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -0.367 -0.319 -0.380  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.268 -0.320  
## nlcdClassshrubScrub:functionalGroupWoody material -0.371 -0.322 -0.384  
## fnctGO fnctGS fncGT/  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds 0.494   
## functionalGroupTwigs/branches 0.504 0.504   
## functionalGroupWoody material 0.516 0.517 0.528  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.307 -0.307 -0.314  
## nlcdClassshrubScrub:functionalGroupLeaves -0.362 -0.362 -0.369  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.243 -0.242 -0.248  
## nlcdClassshrubScrub:functionalGroupMixed -0.295 -0.294 -0.301  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.312 -0.312 -0.319  
## nlcdClassshrubScrub:functionalGroupNeedles -0.370 -0.370 -0.378  
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.613 -0.303 -0.309  
## nlcdClassshrubScrub:functionalGroupOther -0.731 -0.361 -0.369  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.303 -0.613 -0.309  
## nlcdClassshrubScrub:functionalGroupSeeds -0.360 -0.729 -0.368  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.307 -0.608  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -0.367 -0.367 -0.727  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.309 -0.315  
## nlcdClassshrubScrub:functionalGroupWoody material -0.371 -0.371 -0.379  
## fncGWm nCH:GL nCS:GL  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.321   
## nlcdClassshrubScrub:functionalGroupLeaves -0.378 0.455   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.253 0.406 0.178  
## nlcdClassshrubScrub:functionalGroupMixed -0.308 0.183 0.410  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.326 0.524 0.229  
## nlcdClassshrubScrub:functionalGroupNeedles -0.387 0.230 0.514  
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.316 0.508 0.222  
## nlcdClassshrubScrub:functionalGroupOther -0.377 0.224 0.502  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.317 0.508 0.222  
## nlcdClassshrubScrub:functionalGroupSeeds -0.376 0.224 0.500  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.321 0.515 0.225  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -0.384 0.228 0.510  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.597 0.518 0.226  
## nlcdClassshrubScrub:functionalGroupWoody material -0.719 0.231 0.516  
## nCH:GM nCS:GM nCH:GN  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves   
## nlcdClassshrubScrub:functionalGroupLeaves   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed   
## nlcdClassshrubScrub:functionalGroupMixed 0.387   
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles 0.414 0.186   
## nlcdClassshrubScrub:functionalGroupNeedles 0.182 0.419 0.441  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.401 0.181 0.517  
## nlcdClassshrubScrub:functionalGroupOther 0.177 0.409 0.228  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.402 0.180 0.517  
## nlcdClassshrubScrub:functionalGroupSeeds 0.177 0.408 0.227  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.407 0.183 0.524  
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.180 0.416 0.232  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.409 0.184 0.527  
## nlcdClassshrubScrub:functionalGroupWoody material 0.182 0.420 0.235  
## nCS:GN nCH:GO nCS:GO  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves   
## nlcdClassshrubScrub:functionalGroupLeaves   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed   
## nlcdClassshrubScrub:functionalGroupMixed   
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles   
## nlcdClassshrubScrub:functionalGroupNeedles   
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.227   
## nlcdClassshrubScrub:functionalGroupOther 0.513 0.448   
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.227 0.501 0.221  
## nlcdClassshrubScrub:functionalGroupSeeds 0.512 0.221 0.499  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.230 0.508 0.224  
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.521 0.225 0.509  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.231 0.511 0.225  
## nlcdClassshrubScrub:functionalGroupWoody material 0.528 0.227 0.515  
## nCH:GS nCS:GS nCH:GT  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves   
## nlcdClassshrubScrub:functionalGroupLeaves   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed   
## nlcdClassshrubScrub:functionalGroupMixed   
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles   
## nlcdClassshrubScrub:functionalGroupNeedles   
## nlcdClassgrasslandHerbaceous:functionalGroupOther   
## nlcdClassshrubScrub:functionalGroupOther   
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds   
## nlcdClassshrubScrub:functionalGroupSeeds 0.447   
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.508 0.224   
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.225 0.507 0.442  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.511 0.225 0.518  
## nlcdClassshrubScrub:functionalGroupWoody material 0.228 0.514 0.231  
## nCS:GT nCH:Gm  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves   
## nlcdClassshrubScrub:functionalGroupLeaves   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed   
## nlcdClassshrubScrub:functionalGroupMixed   
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles   
## nlcdClassshrubScrub:functionalGroupNeedles   
## nlcdClassgrasslandHerbaceous:functionalGroupOther   
## nlcdClassshrubScrub:functionalGroupOther   
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds   
## nlcdClassshrubScrub:functionalGroupSeeds   
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches   
## nlcdClassshrubScrub:functionalGroupTwigs/branches   
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.229   
## nlcdClassshrubScrub:functionalGroupWoody material 0.523 0.429  
##   
## Standardized Within-Group Residuals:  
## Min Q1 Med Q3 Max   
## -1.96496855 -0.23842984 -0.01535880 0.09027291 14.27434811   
##   
## Number of Observations: 1692  
## Number of Groups: 12

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

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

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

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

Answer: 2.13%

1. Run the same model without the random effect.
2. Run an anova on the two tests.

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

## Generalized least squares fit by REML  
## Model: dryMass ~ nlcdClass \* functionalGroup   
## Data: Litter   
## AIC BIC logLik  
## 9058.088 9193.573 -4504.044  
##   
## Coefficients:  
## Value Std.Error  
## (Intercept) 0.119625 0.3906950  
## nlcdClassgrasslandHerbaceous -0.114199 0.6422303  
## nlcdClassshrubScrub -0.104119 0.5383767  
## functionalGroupLeaves -0.103599 0.5560568  
## functionalGroupMixed 1.504750 0.6380023  
## functionalGroupNeedles 7.312264 0.5369590  
## functionalGroupOther -0.034817 0.5560568  
## functionalGroupSeeds -0.046163 0.5560568  
## functionalGroupTwigs/branches 1.959669 0.5443402  
## functionalGroupWoody material 1.084311 0.5315555  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves 0.128646 0.8941030  
## nlcdClassshrubScrub:functionalGroupLeaves 0.147030 0.7591538  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.381176 1.1302365  
## nlcdClassshrubScrub:functionalGroupMixed 0.745929 0.9303798  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -2.138801 0.8799314  
## nlcdClassshrubScrub:functionalGroupNeedles -2.921481 0.7425783  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.126058 0.9074253  
## nlcdClassshrubScrub:functionalGroupOther 0.085888 0.7610116  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.046155 0.9074253  
## nlcdClassshrubScrub:functionalGroupSeeds 0.059436 0.7629471  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -1.015195 0.8946237  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -1.495591 0.7488092  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -1.040859 0.8897083  
## nlcdClassshrubScrub:functionalGroupWoody material -0.971848 0.7395676  
## t-value p-value  
## (Intercept) 0.306185 0.7595  
## nlcdClassgrasslandHerbaceous -0.177817 0.8589  
## nlcdClassshrubScrub -0.193395 0.8467  
## functionalGroupLeaves -0.186311 0.8522  
## functionalGroupMixed 2.358534 0.0185  
## functionalGroupNeedles 13.617920 0.0000  
## functionalGroupOther -0.062615 0.9501  
## functionalGroupSeeds -0.083019 0.9338  
## functionalGroupTwigs/branches 3.600082 0.0003  
## functionalGroupWoody material 2.039883 0.0415  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves 0.143882 0.8856  
## nlcdClassshrubScrub:functionalGroupLeaves 0.193676 0.8465  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.337253 0.7360  
## nlcdClassshrubScrub:functionalGroupMixed 0.801746 0.4228  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -2.430645 0.0152  
## nlcdClassshrubScrub:functionalGroupNeedles -3.934239 0.0001  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.138919 0.8895  
## nlcdClassshrubScrub:functionalGroupOther 0.112860 0.9102  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.050863 0.9594  
## nlcdClassshrubScrub:functionalGroupSeeds 0.077903 0.9379  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -1.134773 0.2566  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -1.997293 0.0460  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -1.169888 0.2422  
## nlcdClassshrubScrub:functionalGroupWoody material -1.314076 0.1890  
##   
## Correlation:   
## (Intr) nlcdCH nlcdCS  
## nlcdClassgrasslandHerbaceous -0.608   
## nlcdClassshrubScrub -0.726 0.441   
## functionalGroupLeaves -0.703 0.427 0.510  
## functionalGroupMixed -0.612 0.373 0.444  
## functionalGroupNeedles -0.728 0.443 0.528  
## functionalGroupOther -0.703 0.427 0.510  
## functionalGroupSeeds -0.703 0.427 0.510  
## functionalGroupTwigs/branches -0.718 0.437 0.521  
## functionalGroupWoody material -0.735 0.447 0.533  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves 0.437 -0.718 -0.317  
## nlcdClassshrubScrub:functionalGroupLeaves 0.515 -0.313 -0.709  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed 0.346 -0.568 -0.251  
## nlcdClassshrubScrub:functionalGroupMixed 0.420 -0.255 -0.579  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles 0.444 -0.730 -0.322  
## nlcdClassshrubScrub:functionalGroupNeedles 0.526 -0.320 -0.725  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.431 -0.708 -0.312  
## nlcdClassshrubScrub:functionalGroupOther 0.513 -0.312 -0.707  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.431 -0.708 -0.312  
## nlcdClassshrubScrub:functionalGroupSeeds 0.512 -0.312 -0.706  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.437 -0.718 -0.317  
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.522 -0.317 -0.719  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.439 -0.722 -0.319  
## nlcdClassshrubScrub:functionalGroupWoody material 0.528 -0.321 -0.728  
## fnctGL fnctGM fnctGN  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed 0.430   
## functionalGroupNeedles 0.511 0.446   
## functionalGroupOther 0.494 0.430 0.511  
## functionalGroupSeeds 0.494 0.430 0.511  
## functionalGroupTwigs/branches 0.504 0.440 0.522  
## functionalGroupWoody material 0.516 0.450 0.535  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.622 -0.268 -0.318  
## nlcdClassshrubScrub:functionalGroupLeaves -0.732 -0.315 -0.374  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.243 -0.564 -0.252  
## nlcdClassshrubScrub:functionalGroupMixed -0.295 -0.686 -0.306  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.312 -0.272 -0.610  
## nlcdClassshrubScrub:functionalGroupNeedles -0.370 -0.322 -0.723  
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.303 -0.264 -0.313  
## nlcdClassshrubScrub:functionalGroupOther -0.361 -0.314 -0.374  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.303 -0.264 -0.313  
## nlcdClassshrubScrub:functionalGroupSeeds -0.360 -0.314 -0.373  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.267 -0.318  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -0.367 -0.320 -0.380  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.269 -0.320  
## nlcdClassshrubScrub:functionalGroupWoody material -0.371 -0.324 -0.384  
## fnctGO fnctGS fncGT/  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds 0.494   
## functionalGroupTwigs/branches 0.504 0.504   
## functionalGroupWoody material 0.516 0.516 0.528  
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.307 -0.307 -0.314  
## nlcdClassshrubScrub:functionalGroupLeaves -0.362 -0.362 -0.369  
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.243 -0.243 -0.248  
## nlcdClassshrubScrub:functionalGroupMixed -0.295 -0.295 -0.301  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.312 -0.312 -0.319  
## nlcdClassshrubScrub:functionalGroupNeedles -0.370 -0.370 -0.378  
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.613 -0.303 -0.309  
## nlcdClassshrubScrub:functionalGroupOther -0.731 -0.361 -0.368  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.303 -0.613 -0.309  
## nlcdClassshrubScrub:functionalGroupSeeds -0.360 -0.729 -0.368  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.307 -0.307 -0.608  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -0.367 -0.367 -0.727  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.309 -0.309 -0.315  
## nlcdClassshrubScrub:functionalGroupWoody material -0.371 -0.371 -0.379  
## fncGWm nCH:GL nCS:GL  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves -0.321   
## nlcdClassshrubScrub:functionalGroupLeaves -0.378 0.456   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed -0.254 0.408 0.178  
## nlcdClassshrubScrub:functionalGroupMixed -0.309 0.183 0.410  
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles -0.326 0.524 0.229  
## nlcdClassshrubScrub:functionalGroupNeedles -0.387 0.230 0.514  
## nlcdClassgrasslandHerbaceous:functionalGroupOther -0.316 0.508 0.222  
## nlcdClassshrubScrub:functionalGroupOther -0.377 0.224 0.502  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds -0.316 0.508 0.222  
## nlcdClassshrubScrub:functionalGroupSeeds -0.376 0.224 0.500  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches -0.321 0.516 0.225  
## nlcdClassshrubScrub:functionalGroupTwigs/branches -0.383 0.228 0.510  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material -0.597 0.518 0.226  
## nlcdClassshrubScrub:functionalGroupWoody material -0.719 0.231 0.516  
## nCH:GM nCS:GM nCH:GN  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves   
## nlcdClassshrubScrub:functionalGroupLeaves   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed   
## nlcdClassshrubScrub:functionalGroupMixed 0.387   
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles 0.415 0.186   
## nlcdClassshrubScrub:functionalGroupNeedles 0.182 0.420 0.441  
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.402 0.181 0.517  
## nlcdClassshrubScrub:functionalGroupOther 0.177 0.409 0.228  
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.402 0.181 0.517  
## nlcdClassshrubScrub:functionalGroupSeeds 0.177 0.408 0.227  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.408 0.183 0.524  
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.180 0.416 0.232  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.410 0.184 0.527  
## nlcdClassshrubScrub:functionalGroupWoody material 0.183 0.421 0.235  
## nCS:GN nCH:GO nCS:GO  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves   
## nlcdClassshrubScrub:functionalGroupLeaves   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed   
## nlcdClassshrubScrub:functionalGroupMixed   
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles   
## nlcdClassshrubScrub:functionalGroupNeedles   
## nlcdClassgrasslandHerbaceous:functionalGroupOther 0.227   
## nlcdClassshrubScrub:functionalGroupOther 0.513 0.448   
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds 0.227 0.501 0.221  
## nlcdClassshrubScrub:functionalGroupSeeds 0.512 0.220 0.499  
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.230 0.508 0.224  
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.521 0.225 0.509  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.231 0.511 0.225  
## nlcdClassshrubScrub:functionalGroupWoody material 0.528 0.227 0.515  
## nCH:GS nCS:GS nCH:GT  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves   
## nlcdClassshrubScrub:functionalGroupLeaves   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed   
## nlcdClassshrubScrub:functionalGroupMixed   
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles   
## nlcdClassshrubScrub:functionalGroupNeedles   
## nlcdClassgrasslandHerbaceous:functionalGroupOther   
## nlcdClassshrubScrub:functionalGroupOther   
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds   
## nlcdClassshrubScrub:functionalGroupSeeds 0.447   
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches 0.508 0.224   
## nlcdClassshrubScrub:functionalGroupTwigs/branches 0.225 0.507 0.442  
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.511 0.225 0.518  
## nlcdClassshrubScrub:functionalGroupWoody material 0.227 0.514 0.231  
## nCS:GT nCH:Gm  
## nlcdClassgrasslandHerbaceous   
## nlcdClassshrubScrub   
## functionalGroupLeaves   
## functionalGroupMixed   
## functionalGroupNeedles   
## functionalGroupOther   
## functionalGroupSeeds   
## functionalGroupTwigs/branches   
## functionalGroupWoody material   
## nlcdClassgrasslandHerbaceous:functionalGroupLeaves   
## nlcdClassshrubScrub:functionalGroupLeaves   
## nlcdClassgrasslandHerbaceous:functionalGroupMixed   
## nlcdClassshrubScrub:functionalGroupMixed   
## nlcdClassgrasslandHerbaceous:functionalGroupNeedles   
## nlcdClassshrubScrub:functionalGroupNeedles   
## nlcdClassgrasslandHerbaceous:functionalGroupOther   
## nlcdClassshrubScrub:functionalGroupOther   
## nlcdClassgrasslandHerbaceous:functionalGroupSeeds   
## nlcdClassshrubScrub:functionalGroupSeeds   
## nlcdClassgrasslandHerbaceous:functionalGroupTwigs/branches   
## nlcdClassshrubScrub:functionalGroupTwigs/branches   
## nlcdClassgrasslandHerbaceous:functionalGroupWoody material 0.229   
## nlcdClassshrubScrub:functionalGroupWoody material 0.523 0.429  
##   
## Standardized residuals:  
## Min Q1 Med Q3 Max   
## -1.89209382 -0.13724016 -0.01672707 -0.00155260 14.03673076   
##   
## Residual standard error: 3.494483   
## Degrees of freedom: 1692 total; 1668 residual

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

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

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

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

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