mdi_pitchpine_analyses.R

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```
# script to analyze mdi pitch pine data

library(tidyverse)
```

```
## -- Attaching packages ------------------------------------------------------ tidyverse 1.2.1 --
```

```
## v ggplot2 3.1.1     v purrr   0.3.2
## v tibble  2.1.1     v dplyr   0.8.1
## v tidyr   0.8.3     v stringr 1.4.0
## v readr   1.3.1     v forcats 0.4.0
```

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

```
library(emmeans)

## read in cleaned data
data = read.csv('../data/mdi_all_clean.csv')
data$CN_foliar = data$C_foliar/data$N_foliar
data$CN_soil = data$C_soil/data$N_soil
head(data)
```

```
##   X                   ID Name height canopy diam   d13C  d15N C_foliar
## 1 1  PP-1-HIGHELEV-DIST  CAD  207.3  179.8  8.1 -27.65 -1.76    46.55
## 2 2 PP-10-HIGHELEV-DIST  CAD     NA     NA   NA -27.29 -5.55    49.60
## 3 3 PP-11-HIGHELEV-DIST  CAD     NA     NA   NA     NA    NA       NA
## 4 4 PP-12-HIGHELEV-DIST  CAD     NA     NA   NA     NA    NA       NA
## 5 5  PP-2-HIGHELEV-DIST  CAD  243.8  192.0  5.7 -28.85 -6.17    49.84
## 6 6  PP-3-HIGHELEV-DIST  CAD  185.9  152.4  7.6 -27.66 -0.30    37.57
##   N_foliar Ca_foliar P_foliar K_foliar Mg_foliar Al_foliar Zn_foliar
## 1     1.35       400      710     2070       550       285      15.8
## 2     0.86      1100     1060      473      1020       476      25.1
## 3       NA       930      970      688       840       449      33.2
## 4       NA      1030      970      618      1030       354      27.6
## 5     1.21       660     4780      720       750       254      32.3
## 6     1.06       480     3860      640       820       349      19.7
##   Ca_soil P_soil K_soil Mg_soil Al_soil Zn_soil  pH  CEC C_soil N_soil
## 1     835    9.4    268     387      29     5.1 3.8 28.6  21.18   0.50
## 2      NA     NA     NA      NA      NA      NA  NA   NA     NA     NA
## 3      NA     NA     NA      NA      NA      NA  NA   NA     NA     NA
## 4      NA     NA     NA      NA      NA      NA  NA   NA     NA     NA
## 5     726    9.7    297     400      33     5.2 3.9 30.7  23.20   0.72
## 6     225    0.8     33      22     133     0.9 4.4 10.7  19.26   0.87
##   retention CN_foliar  CN_soil
## 1      32.2  34.48148 42.36000
## 2      13.6  57.67442       NA
## 3      18.4        NA       NA
## 4        NA        NA       NA
```

```
## 5      24.5  41.19008 32.22222
## 6      37.7  35.44340 22.13793
```

```
## fit models and explore results

### height
height_lm = lm(log(height) ~ Name, data = data)
#plot(resid(height_lm) ~ fitted(height_lm))
anova(height_lm)
```

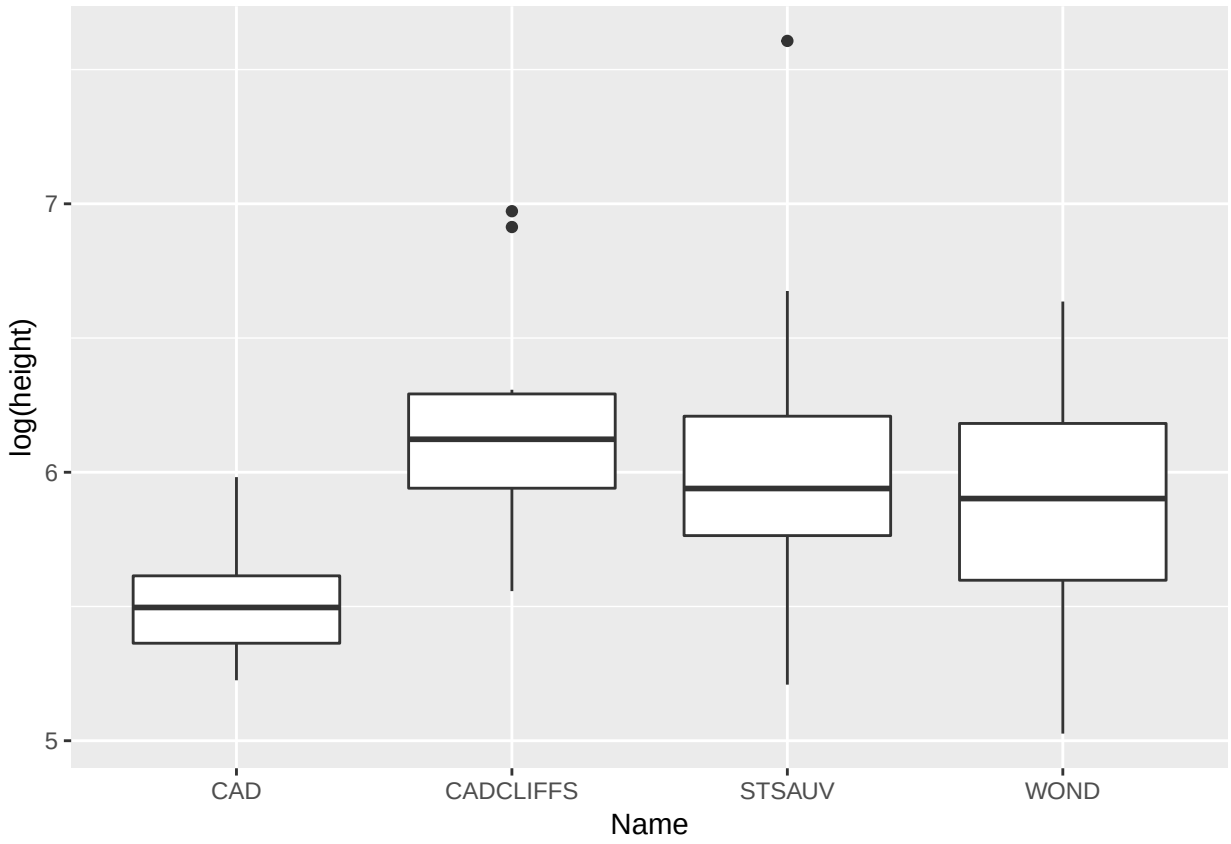
```
## Analysis of Variance Table
##
## Response: log(height)
##           Df Sum Sq Mean Sq F value Pr(>F)
## Name       3 2.3760 0.79199  3.3319 0.0301 *
## Residuals 36 8.5573 0.23770
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(height_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  CAD         5.53 0.163 36     5.20     5.86  1
##  WOND        5.88 0.154 36     5.56     6.19  12
##  STSAUV      6.06 0.147 36     5.76     6.36  12
##  CADCLIFFS   6.20 0.154 36     5.89     6.51   2
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = log(height))) +
  geom_boxplot()
```

```
## Warning: Removed 6 rows containing non-finite values (stat_boxplot).
```




```
### canopy
canopy_lm = lm(log(canopy) ~ Name, data = data)
#plot(resid(canopy_lm) ~ fitted(canopy_lm))
anova(canopy_lm)
```

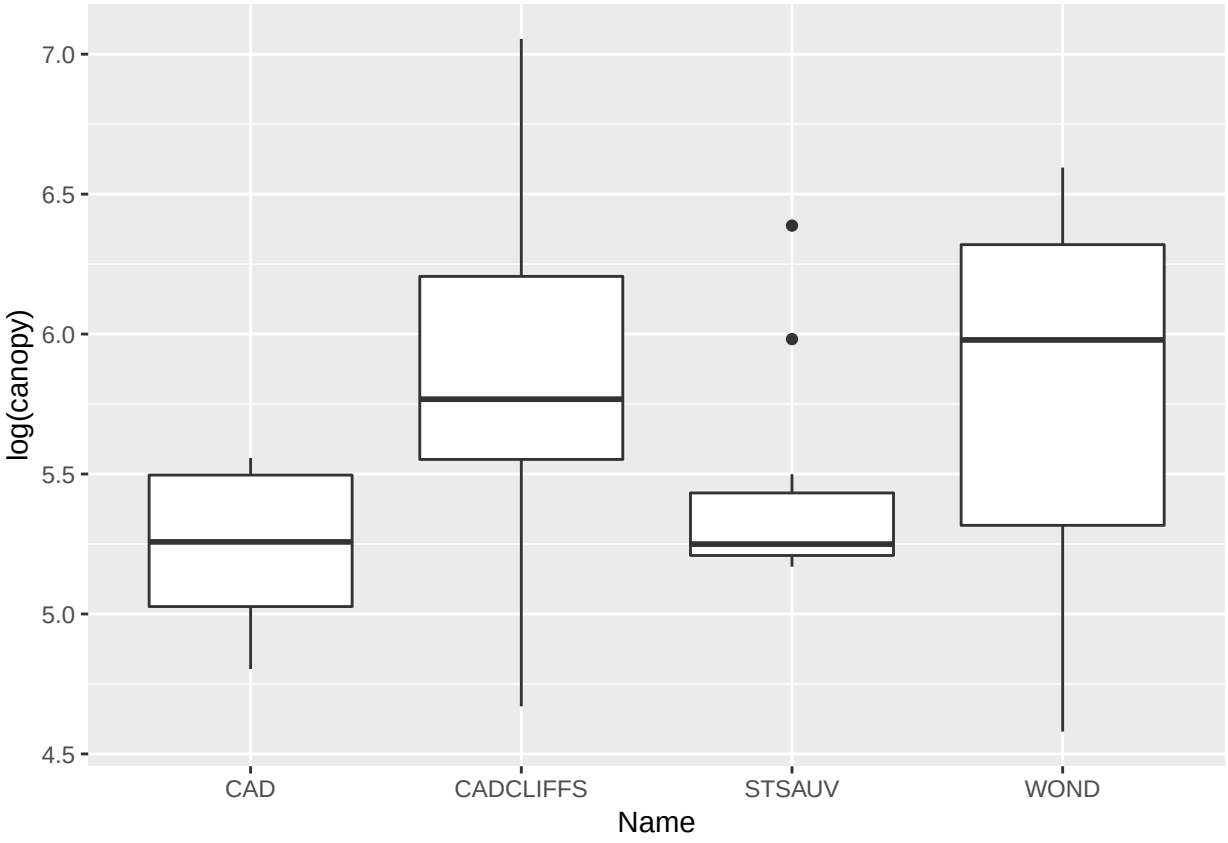
```
## Analysis of Variance Table
##
## Response: log(canopy)
##           Df Sum Sq Mean Sq F value  Pr(>F)
## Name       3 2.6406 0.88020  3.1881 0.03517 *
## Residuals 36 9.9391 0.27609
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(canopy_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  CAD         5.23 0.175 36     4.87     5.58  1
##  STSAUV      5.44 0.158 36     5.12     5.76  1
##  WOND        5.82 0.166 36     5.49     6.16  1
##  CADCLIFFS   5.85 0.166 36     5.51     6.19  1
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = log(canopy))) +
  geom_boxplot()
```

```
## Warning: Removed 6 rows containing non-finite values (stat_boxplot).
```




```
### diam
diam_lm = lm(log(diam) ~ Name, data = data)
#plot(resid(diam_lm) ~ fitted(diam_lm))
anova(diam_lm)
```

```
## Analysis of Variance Table
##
## Response: log(diam)
##           Df Sum Sq Mean Sq F value    Pr(>F)
## Name       3 4.2931 1.43102  6.8211 0.0009314 ***
## Residuals 36 7.5526 0.20979
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

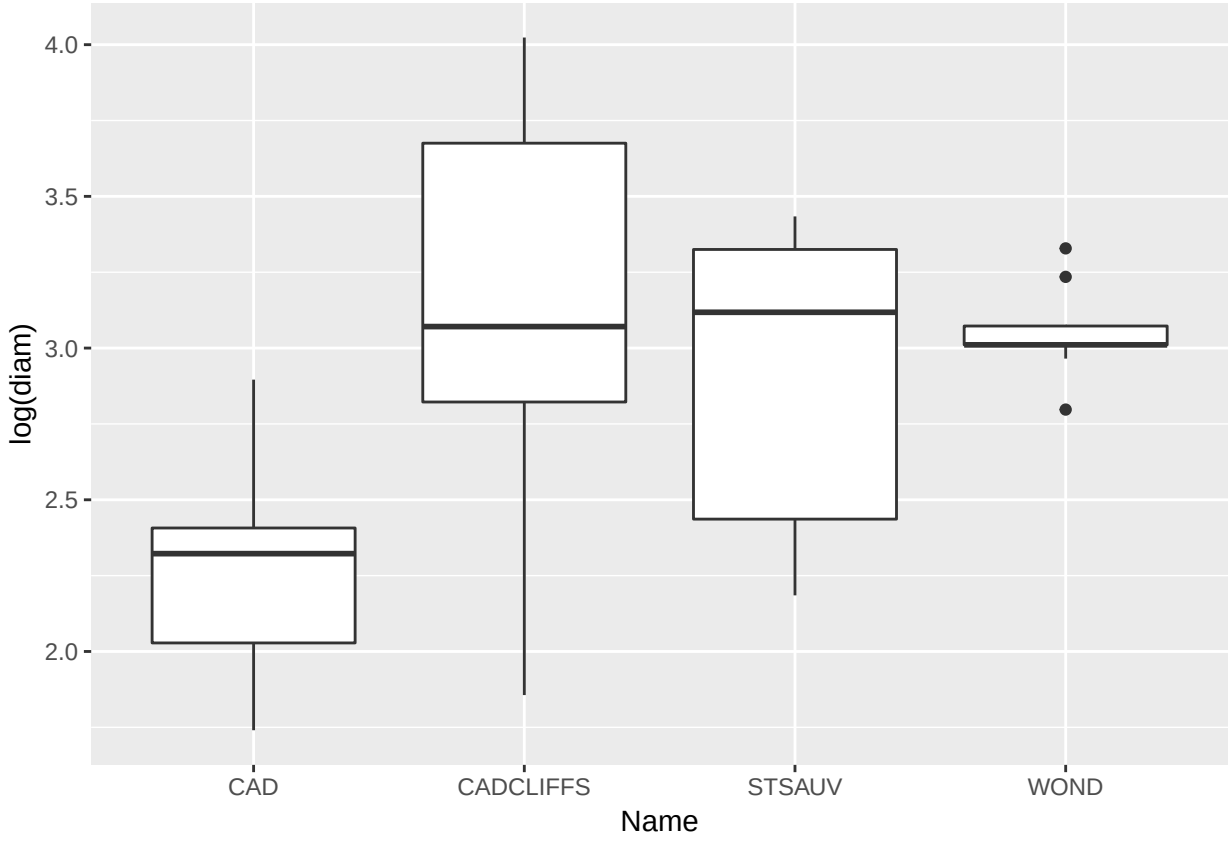
```
cld(emmeans(diam_lm, ~Name))
```

```
##  Name       emmean    SE df lower.CL upper.CL .group
##  CAD          2.27 0.153 36     1.96     2.58  1
##  STSAUV       2.90 0.138 36     2.62     3.18   2
##  WOND         3.05 0.145 36     2.76     3.35   2
##  CADCLIFFS    3.14 0.145 36     2.85     3.43   2
##
## Results are given on the log (not the response) scale.
```

```
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = log(diam))) +
  geom_boxplot()
```

```
## Warning: Removed 6 rows containing non-finite values (stat_boxplot).
```




```
### d13C
d13C_lm = lm((d13C) ~ Name, data = data)
#plot(resid(d13C_lm) ~ fitted(d13C_lm))
anova(d13C_lm)
```

```
## Analysis of Variance Table
##
## Response: (d13C)
##           Df Sum Sq Mean Sq F value   Pr(>F)
## Name       3 13.099  4.3662  5.1792 0.004342 **
## Residuals 37 31.192  0.8430
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

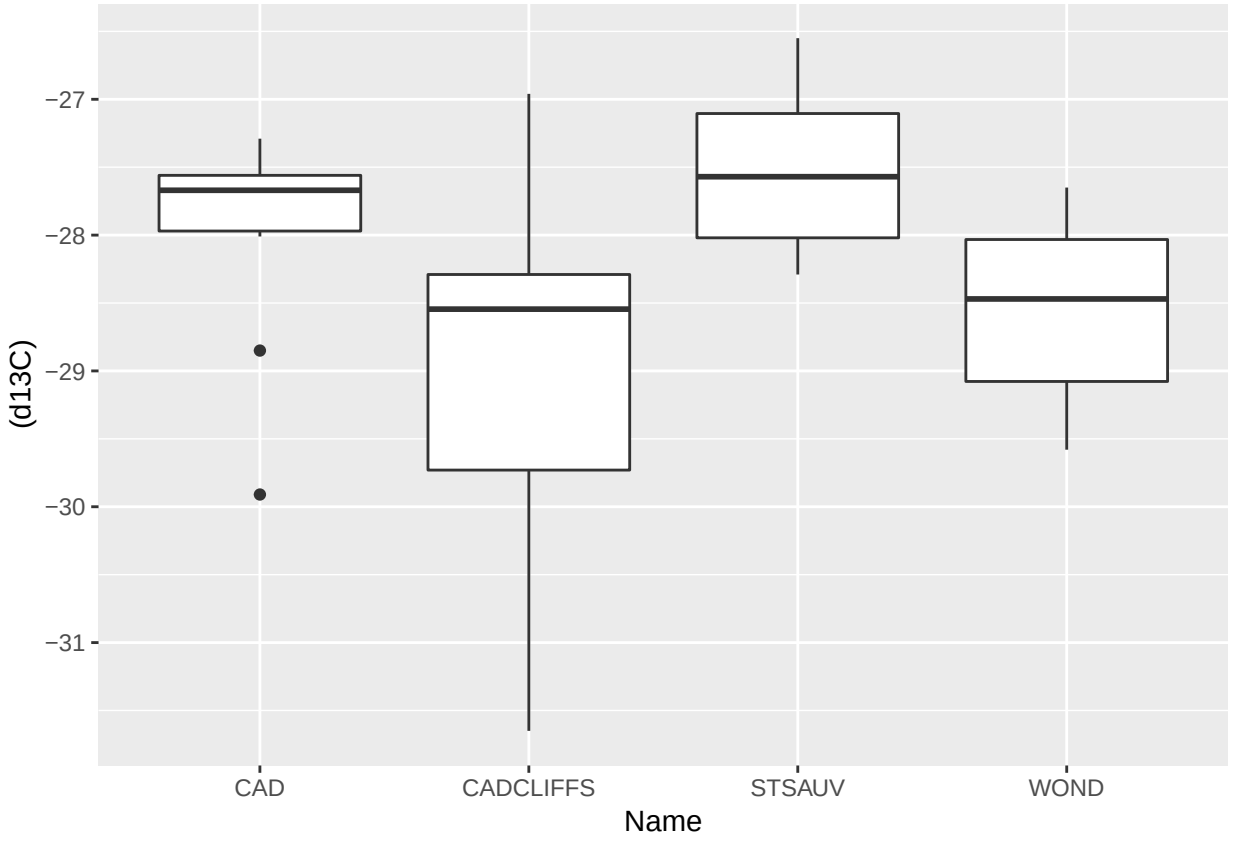
```
cld(emmeans(d13C_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  CADCLIFFS  -29.0 0.290 37    -29.6    -28.4  1
##  WOND       -28.5 0.290 37    -29.1    -28.0  12
##  CAD        -28.0 0.290 37    -28.6    -27.4  12
```

```
##  STSAUV     -27.5 0.277 37    -28.1    -27.0   2
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (d13C))) +
  geom_boxplot()
```

```
## Warning: Removed 5 rows containing non-finite values (stat_boxplot).
```




```
### d15N
d15N_lm = lm((d15N) ~ Name, data = data)
#plot(resid(d15N_lm) ~ fitted(d15N_lm))
anova(d15N_lm)
```

```
## Analysis of Variance Table
##
## Response: (d15N)
##           Df Sum Sq Mean Sq F value Pr(>F)
## Name       3  11.77  3.9249  0.3466 0.7918
## Residuals 37 418.99 11.3241
```

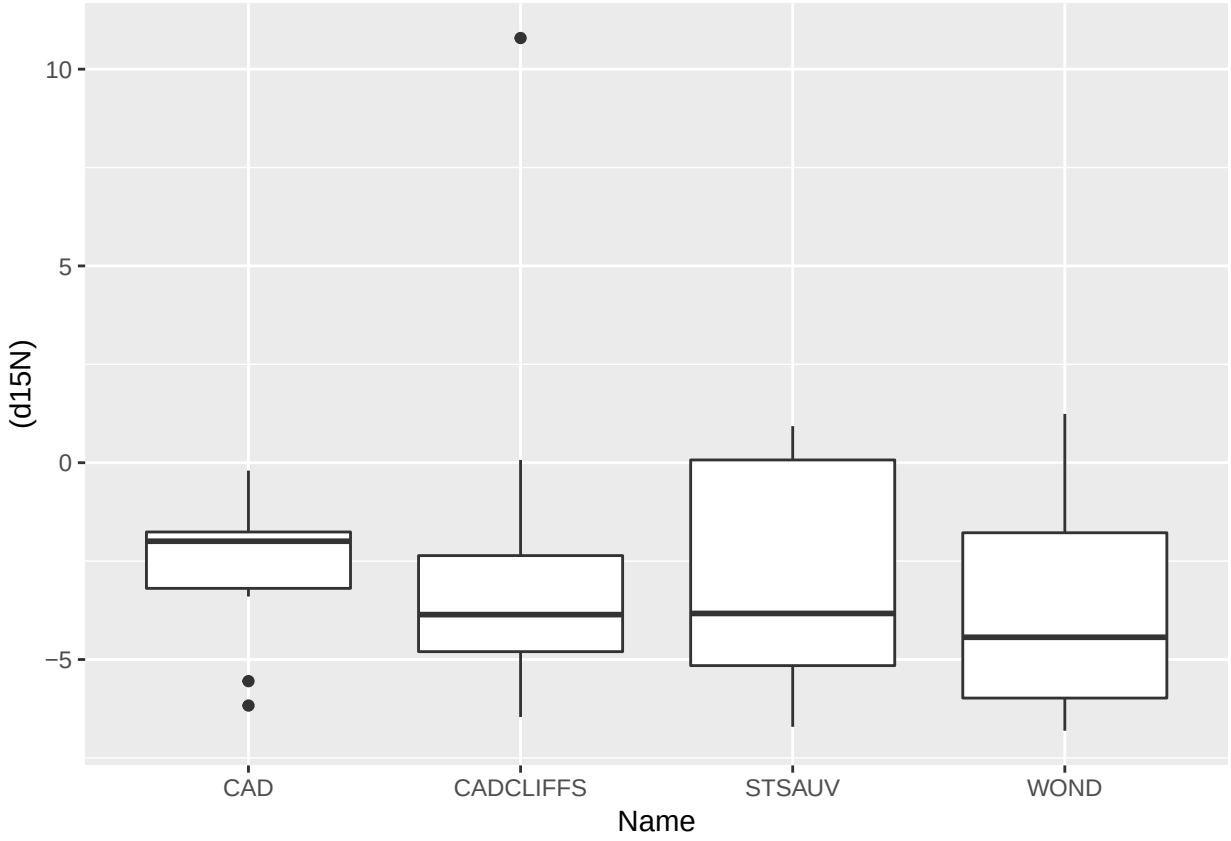
```
cld(emmeans(d15N_lm, ~Name))
```

```
##  Name      emmean   SE df lower.CL upper.CL .group
##  WOND       -3.81 1.06 37    -5.97   -1.654  1
##  STSAUV     -2.99 1.01 37    -5.05   -0.936  1
```

```
##  CAD        -2.57 1.06 37    -4.73   -0.414  1
##  CADCLIFFS  -2.41 1.06 37    -4.57   -0.254  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (d15N))) +
  geom_boxplot()
```

```
## Warning: Removed 5 rows containing non-finite values (stat_boxplot).
```




```
### C_foliar
C_foliar_lm = lm((C_foliar) ~ Name, data = data)
#plot(resid(C_foliar_lm) ~ fitted(C_foliar_lm))
anova(C_foliar_lm)
```

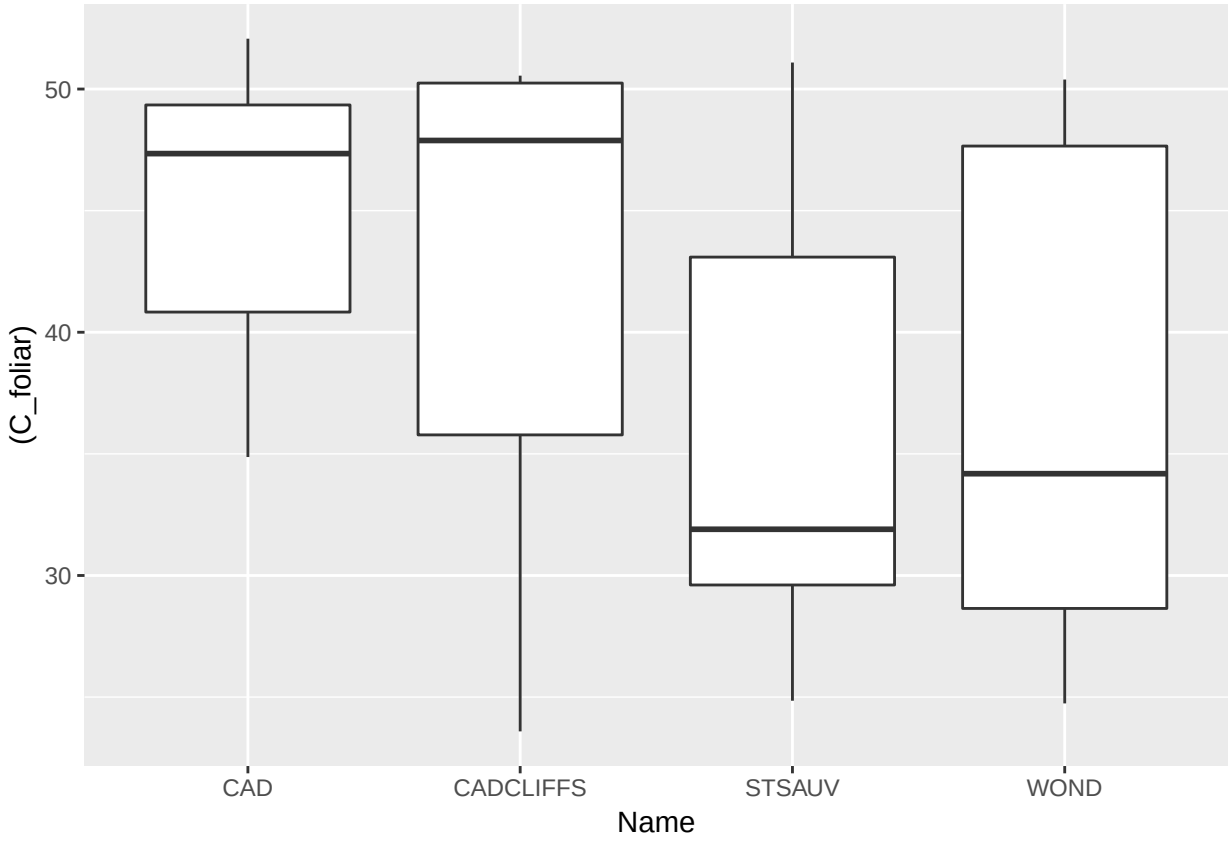
```
## Analysis of Variance Table
##
## Response: (C_foliar)
##           Df  Sum Sq Mean Sq F value  Pr(>F)
## Name       3  660.03 220.009  2.7439 0.05679 .
## Residuals 37 2966.73  80.182
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(C_foliar_lm, ~Name))
```

```
##  Name       emmean   SE df lower.CL upper.CL .group
##  STSAUV       35.4 2.70 37     29.9     40.9  1
##  WOND         37.1 2.83 37     31.3     42.8  1
##  CADCLIFFS    42.9 2.83 37     37.2     48.7  1
##  CAD          45.1 2.83 37     39.3     50.8  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (C_foliar))) +
  geom_boxplot()
```

```
## Warning: Removed 5 rows containing non-finite values (stat_boxplot).
```



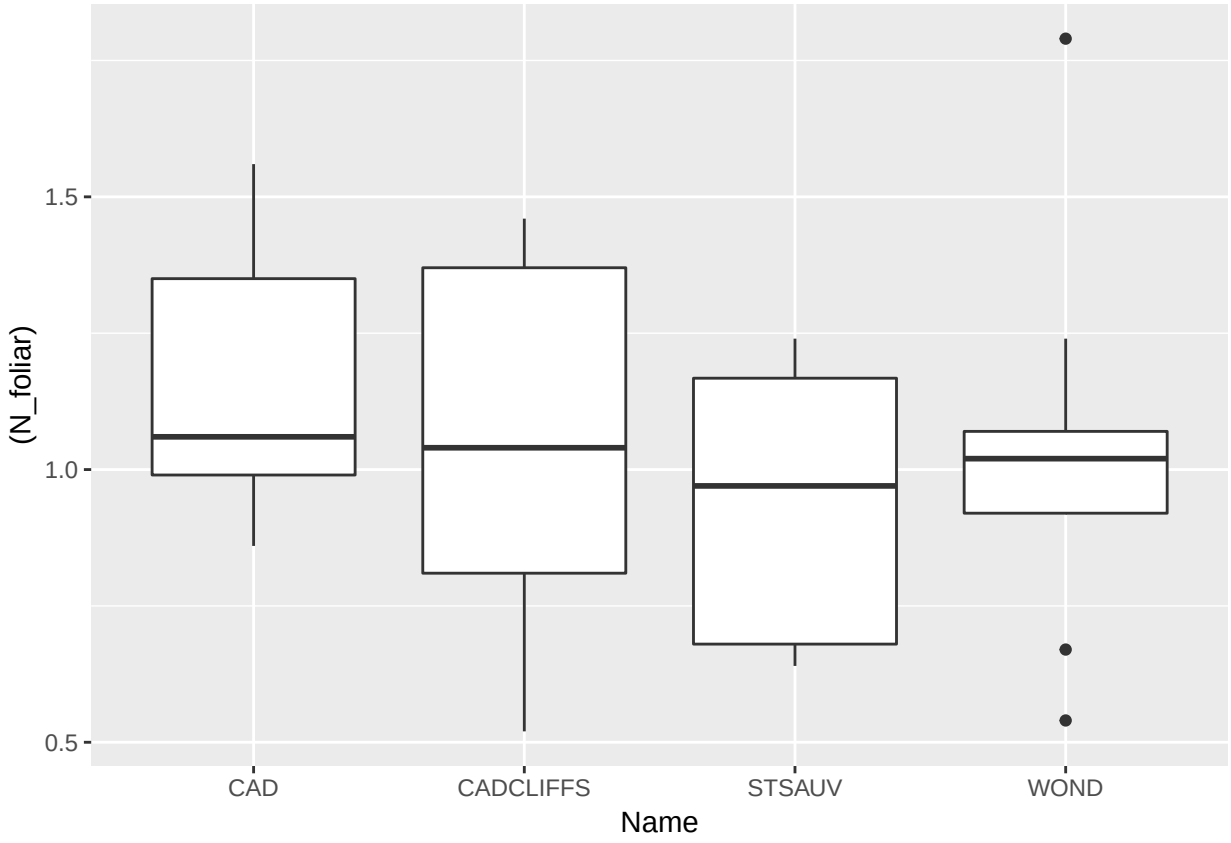

```
### N_foliar
N_foliar_lm = lm((N_foliar) ~ Name, data = subset(data, N_foliar < 5))
#plot(resid(N_foliar_lm) ~ fitted(N_foliar_lm))
anova(N_foliar_lm)
```

```
## Analysis of Variance Table
##
## Response: (N_foliar)
##           Df  Sum Sq  Mean Sq F value Pr(>F)
## Name       3 0.22818 0.076060  0.8299  0.487
## Residuals 33 3.02434 0.091647
```

```
cld(emmeans(N_foliar_lm, ~Name))
```

```
##  Name       emmean     SE df lower.CL upper.CL .group
##  STSAUV      0.938 0.0957 33    0.743     1.13  1
##  WOND        1.026 0.1009 33    0.820     1.23  1
##  CADCLIFFS   1.032 0.1009 33    0.827     1.24  1
##  CAD         1.157 0.1009 33    0.951     1.36  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = subset(data, N_foliar < 5), aes(x = Name, y = (N_foliar))) +
  geom_boxplot()
```



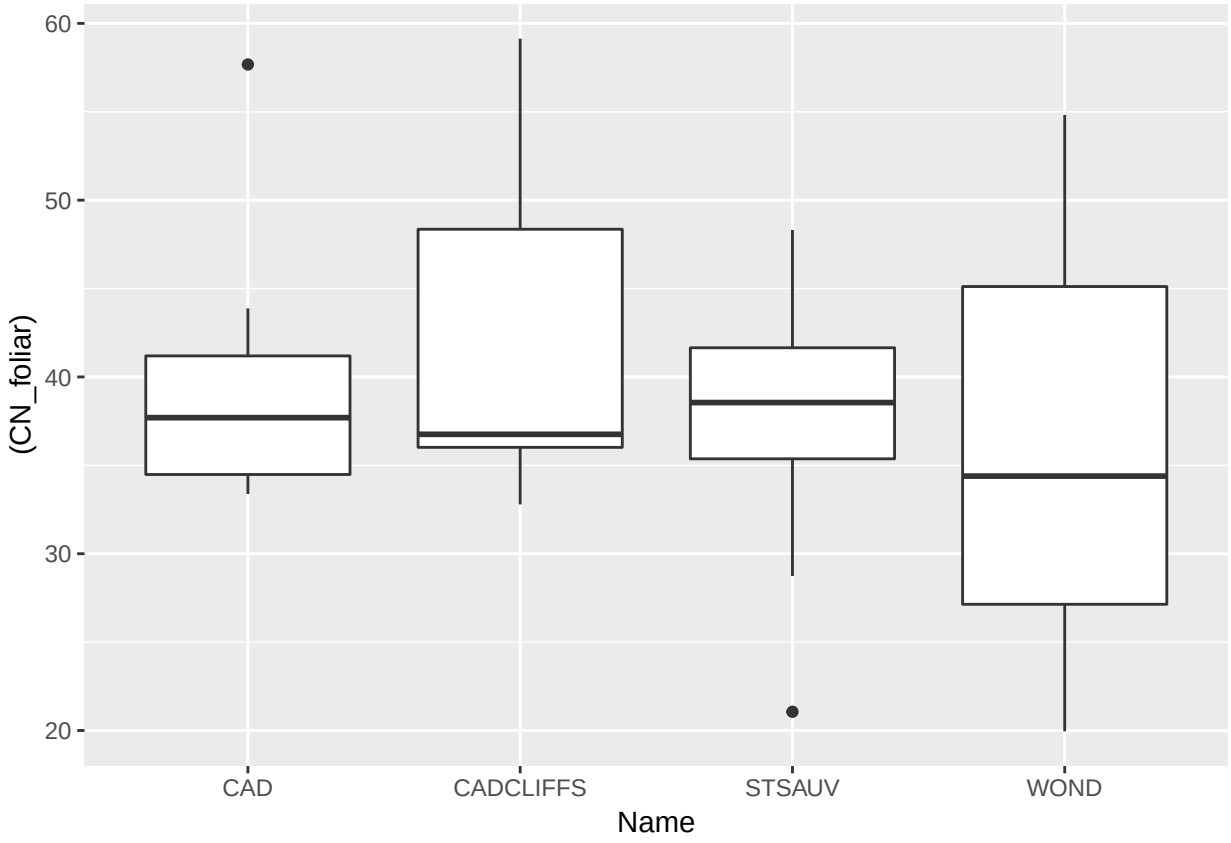

```
### CN_foliar
CN_foliar_lm = lm((CN_foliar) ~ Name, data = subset(data, N_foliar < 5))
#plot(resid(CN_foliar_lm) ~ fitted(CN_foliar_lm))
anova(CN_foliar_lm)
```

```
## Analysis of Variance Table
##
## Response: (CN_foliar)
##           Df  Sum Sq Mean Sq F value Pr(>F)
## Name       3  185.83  61.944   0.676 0.5729
## Residuals 33 3023.81  91.631
```

```
cld(emmeans(CN_foliar_lm, ~Name))
```

```
##  Name       emmean   SE df lower.CL upper.CL .group
##  STSAUV       37.3 3.03 33     31.1     43.4  1
##  WOND         37.4 3.19 33     30.9     43.9  1
##  CAD          39.6 3.19 33     33.1     46.1  1
##  CADCLIFFS    42.8 3.19 33     36.3     49.3  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = subset(data, N_foliar < 5), aes(x = Name, y = (CN_foliar))) +
  geom_boxplot()
```




```
### Ca_foliar
Ca_foliar_lm = lm((Ca_foliar) ~ Name, data = data)
#plot(resid(Ca_foliar_lm) ~ fitted(Ca_foliar_lm))
anova(Ca_foliar_lm)
```

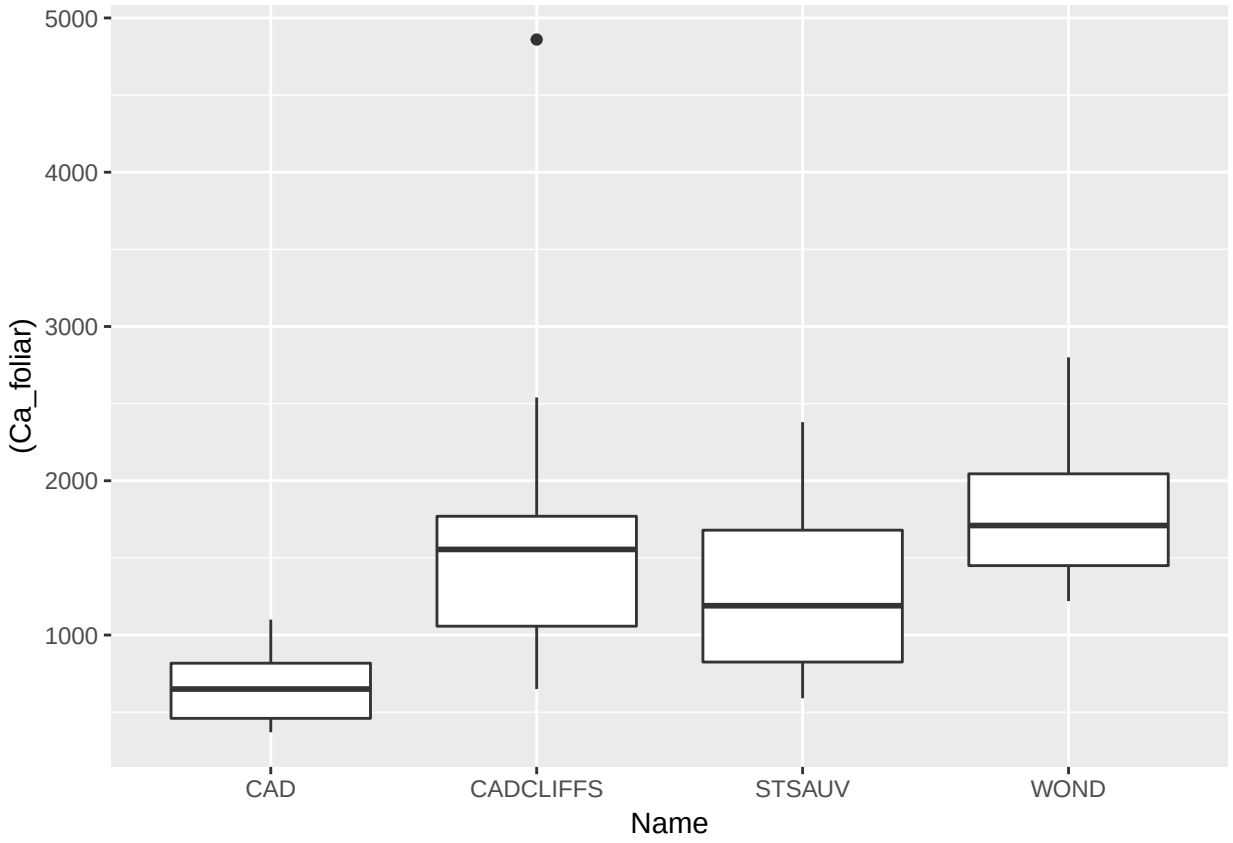
```
## Analysis of Variance Table
##
## Response: (Ca_foliar)
##           Df   Sum Sq Mean Sq F value    Pr(>F)
## Name       3  9956096 3318699  6.6236 0.0009145 ***
## Residuals 42 21043802  501043
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(Ca_foliar_lm, ~Name))
```

```
##  Name      emmean  SE df lower.CL upper.CL .group
##  CAD          661 204 42      248     1073  1
##  STSAUV      1326 213 42      896     1757  12
##  CADCLIFFS   1746 204 42     1333     2158   2
##  WOND        1818 213 42     1387     2249   2
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (Ca_foliar))) +
  geom_boxplot()
```




```
### P_foliar
P_foliar_lm = lm(log(P_foliar) ~ Name, data = data)
#plot(resid(P_foliar_lm) ~ fitted(P_foliar_lm))
anova(P_foliar_lm)
```

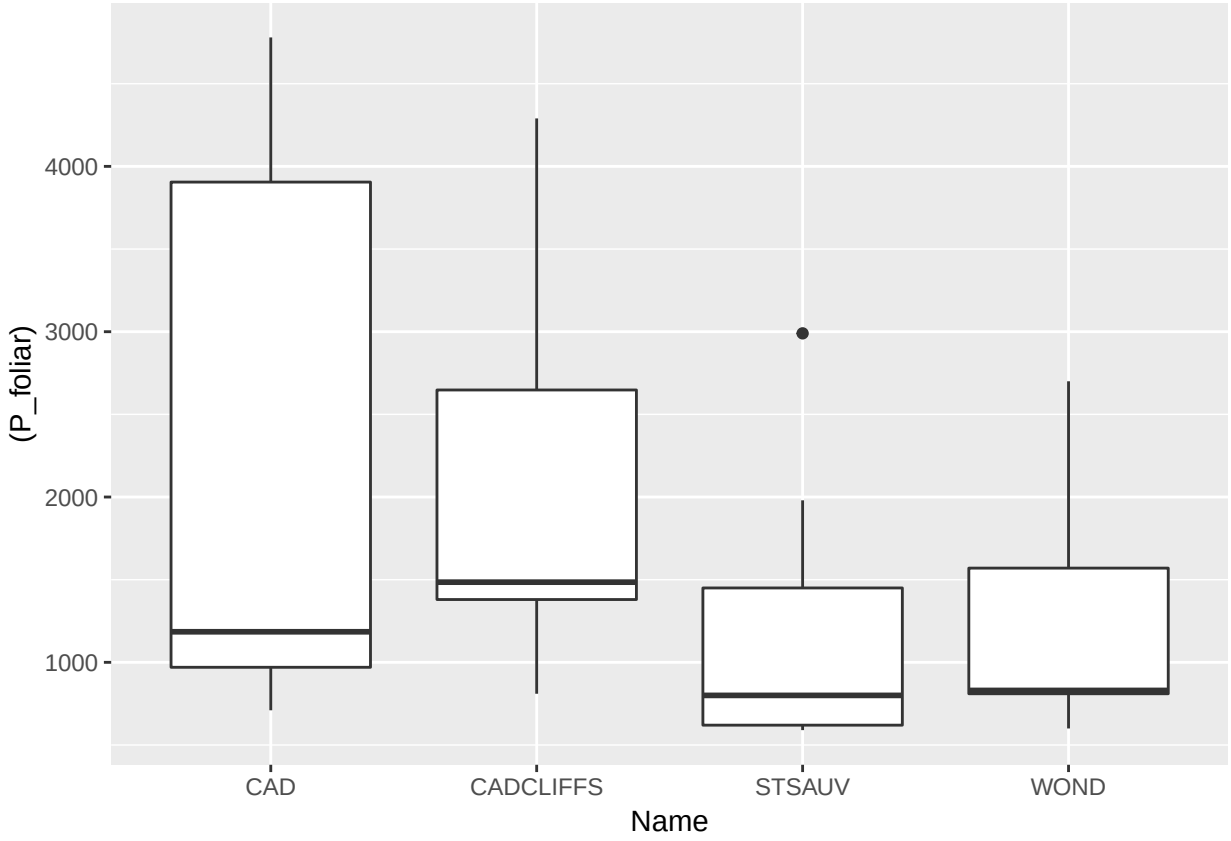
```
## Analysis of Variance Table
##
## Response: log(P_foliar)
##           Df  Sum Sq Mean Sq F value  Pr(>F)
## Name       3  3.4381 1.14602  3.1989 0.03291 *
## Residuals 42 15.0467 0.35826
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(P_foliar_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  STSAUV      6.88 0.180 42     6.52     7.25  1
##  WOND        7.00 0.180 42     6.64     7.36  1
##  CAD         7.46 0.173 42     7.11     7.81  1
##  CADCLIFFS   7.50 0.173 42     7.16     7.85  1
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (P_foliar))) +
  geom_boxplot()
```




```
### K_foliar
K_foliar_lm = lm(log(K_foliar) ~ Name, data = data)
#plot(resid(K_foliar_lm) ~ fitted(K_foliar_lm))
anova(K_foliar_lm)
```

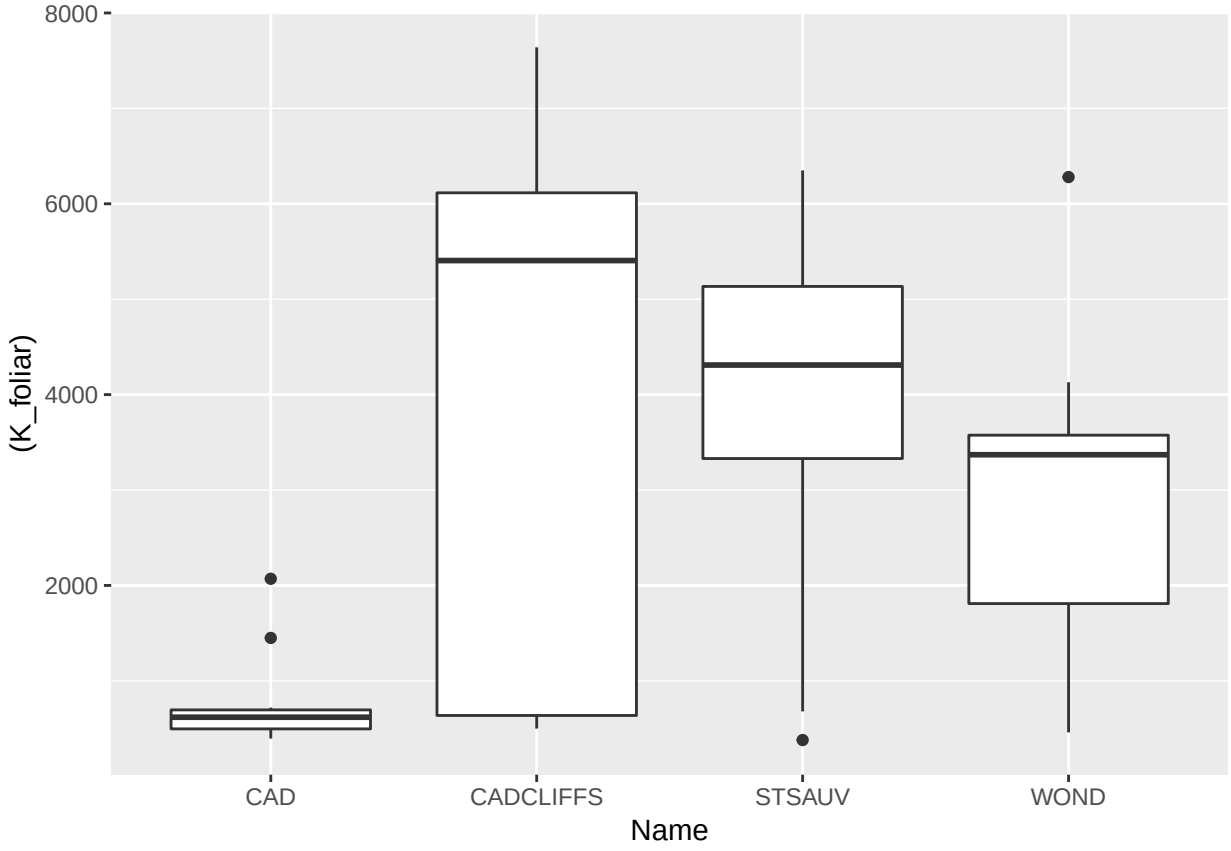
```
## Analysis of Variance Table
##
## Response: log(K_foliar)
##           Df Sum Sq Mean Sq F value    Pr(>F)
## Name       3 16.629  5.5431  6.8255 0.0007519 ***
```

```
## Residuals 42 34.109  0.8121
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(K_foliar_lm, ~Name))
```

```
##  Name       emmean    SE df lower.CL upper.CL .group
##  CAD          6.51 0.260 42     5.99     7.04  1
##  WOND         7.69 0.272 42     7.14     8.24   2
##  CADCLIFFS    7.88 0.260 42     7.36     8.41   2
##  STSAUV       8.01 0.272 42     7.46     8.56   2
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (K_foliar))) +
  geom_boxplot()
```




```
### Mg_foliar
Mg_foliar_lm = lm((Mg_foliar) ~ Name, data = data)
#plot(resid(Mg_foliar_lm) ~ fitted(Mg_foliar_lm))
anova(Mg_foliar_lm)
```

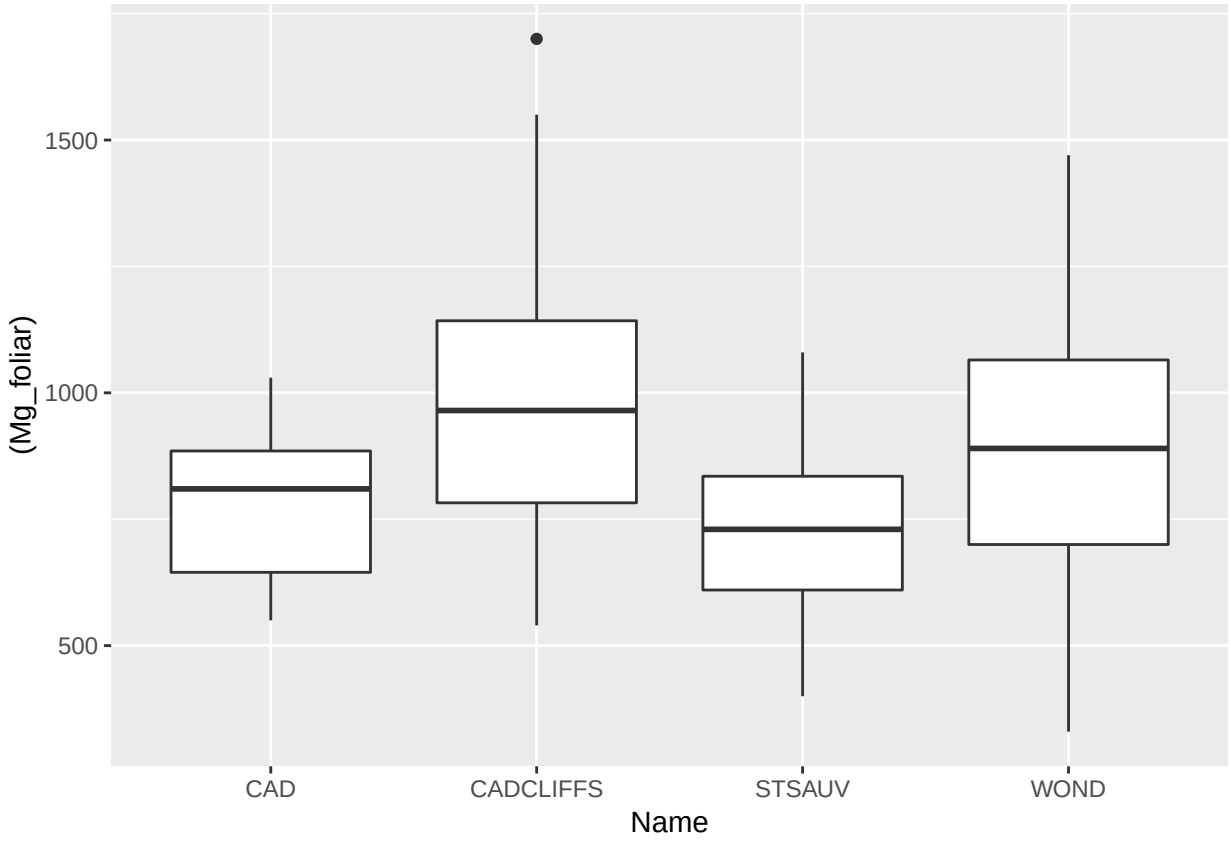
```
## Analysis of Variance Table
##
## Response: (Mg_foliar)
##           Df  Sum Sq Mean Sq F value Pr(>F)
```

```
## Name       3  496027  165342  2.0252 0.1249
## Residuals 42 3428947   81642
```

```
cld(emmeans(Mg_foliar_lm, ~Name))
```

```
##  Name      emmean   SE df lower.CL upper.CL .group
##  STSAUV       725 86.2 42      552      899  1
##  CAD          791 82.5 42      624      957  1
##  WOND         889 86.2 42      715     1063  1
##  CADCLIFFS    999 82.5 42      833     1166  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (Mg_foliar))) +
  geom_boxplot()
```




```
### Al_foliar
Al_foliar_lm = lm((Al_foliar) ~ Name, data = data)
#plot(resid(Al_foliar_lm) ~ fitted(Al_foliar_lm))
anova(Al_foliar_lm)
```

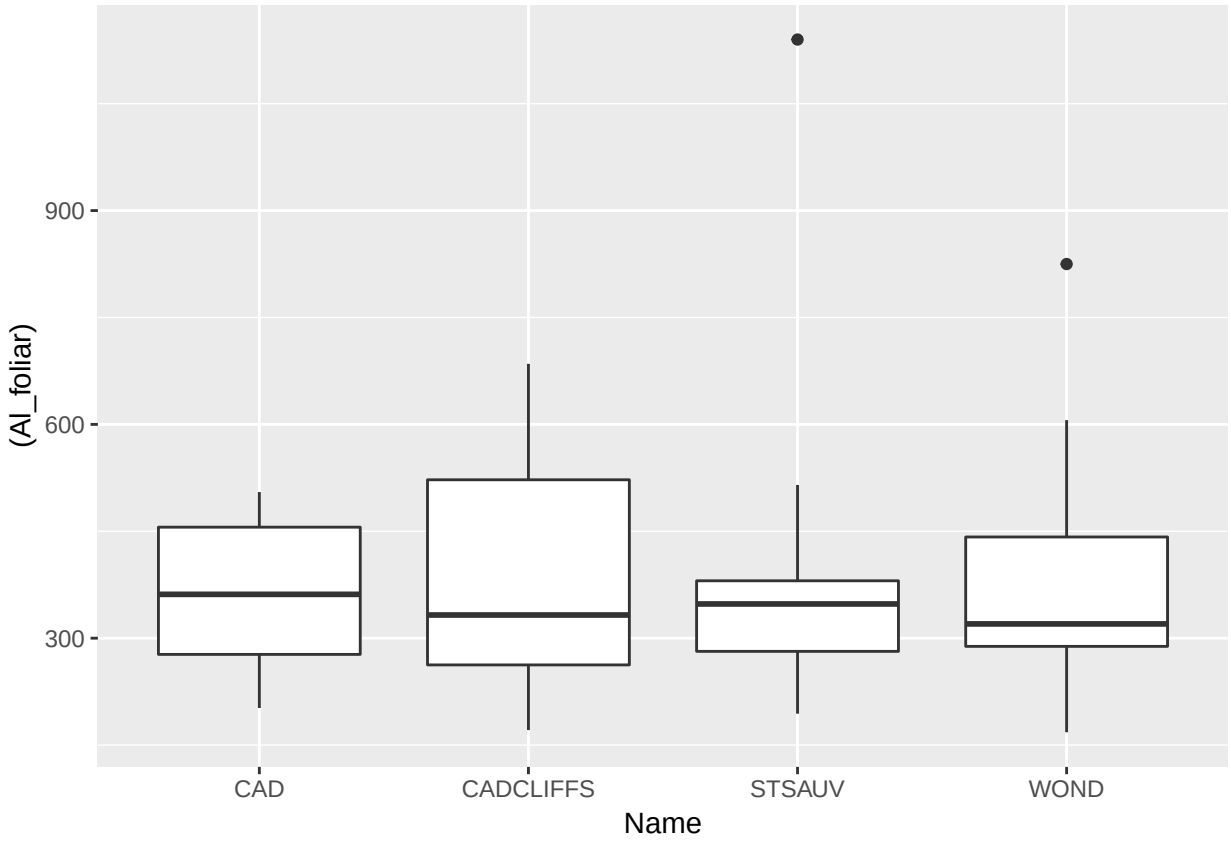
```
## Analysis of Variance Table
##
## Response: (Al_foliar)
##           Df  Sum Sq Mean Sq F value Pr(>F)
## Name       3   10628    3543  0.1023 0.9583
```

```
## Residuals 42 1454721   34636
```

```
cld(emmeans(Al_foliar_lm, ~Name))
```

```
##  Name      emmean   SE df lower.CL upper.CL .group
##  CAD          361 53.7 42      253      470  1
##  WOND         385 56.1 42      271      498  1
##  CADCLIFFS    391 53.7 42      283      500  1
##  STSAUV       403 56.1 42      289      516  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (Al_foliar))) +
  geom_boxplot()
```




```
### Zn_foliar
Zn_foliar_lm = lm(log(Zn_foliar) ~ Name, data = data)
#plot(resid(Zn_foliar_lm) ~ fitted(Zn_foliar_lm))
anova(Zn_foliar_lm)
```

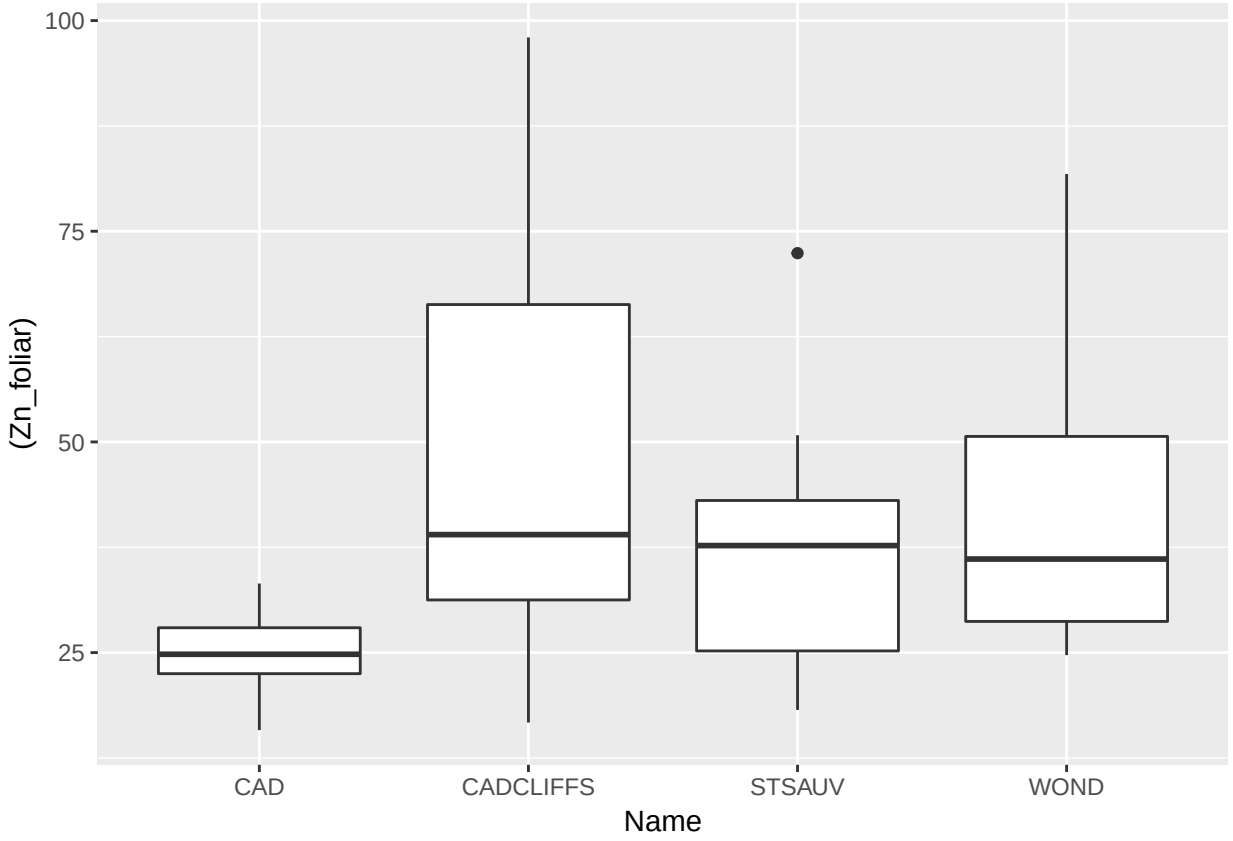
```
## Analysis of Variance Table
##
## Response: log(Zn_foliar)
##           Df Sum Sq Mean Sq F value   Pr(>F)
## Name       3 2.1934 0.73113  4.4557 0.008334 **
## Residuals 42 6.8918 0.16409
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(Zn_foliar_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  CAD         3.20 0.117 42     2.97     3.44  1
##  STSAUV      3.53 0.122 42     3.29     3.78  12
##  WOND        3.67 0.122 42     3.43     3.92   2
##  CADCLIFFS   3.77 0.117 42     3.54     4.01   2
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (Zn_foliar))) +
  geom_boxplot()
```




```
### Ca_soil
Ca_soil_lm = lm((Ca_soil) ~ Name, data = data)
#plot(resid(Ca_soil_lm) ~ fitted(Ca_soil_lm))
anova(Ca_soil_lm)
```

```
## Analysis of Variance Table
##
## Response: (Ca_soil)
##           Df  Sum Sq Mean Sq F value  Pr(>F)
## Name       3 1220842  406947  2.6919 0.06605 .
```

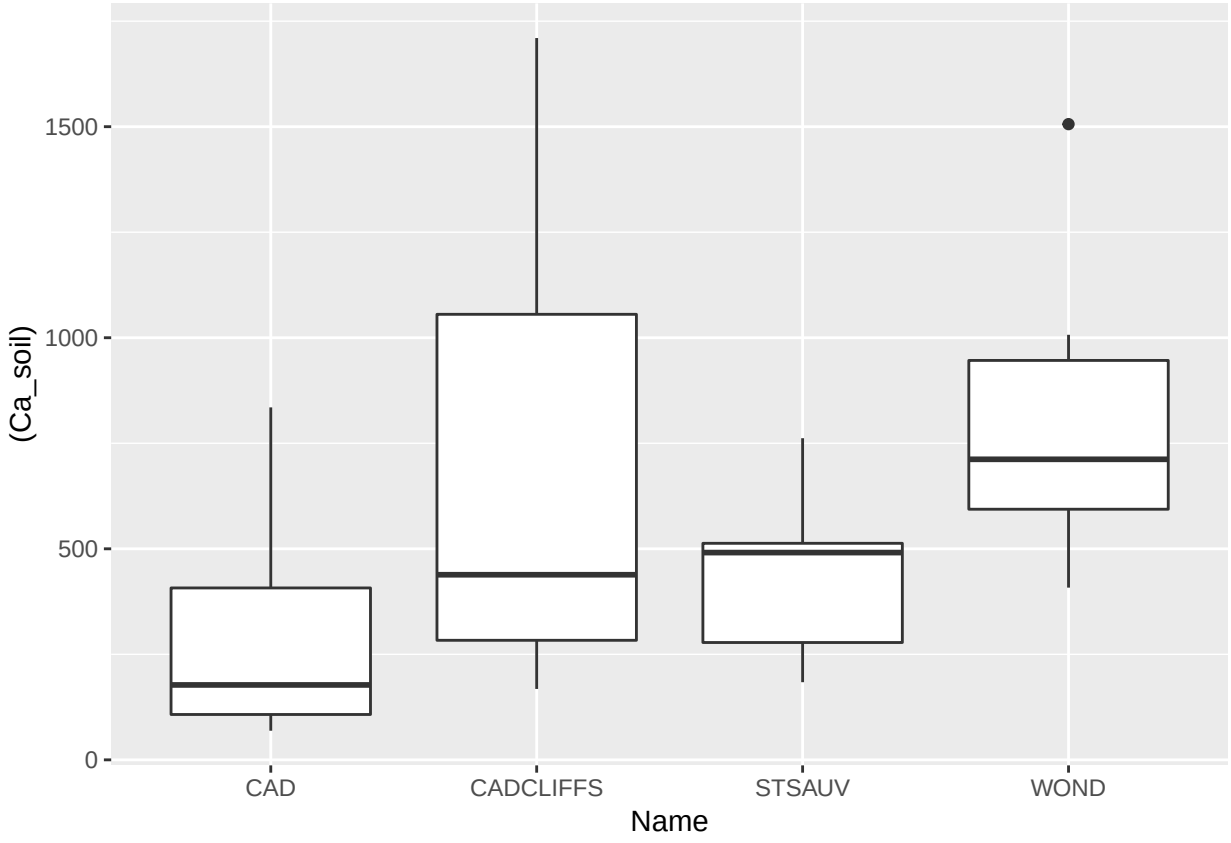
```
## Residuals 27 4081653  151172
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(Ca_soil_lm, ~Name))
```

```
##  Name       emmean  SE df lower.CL upper.CL .group
##  CAD           312 137 27     29.7      594  1
##  STSAUV        431 147 27    129.8      733  1
##  CADCLIFFS     702 137 27    419.9      984  1
##  WOND          798 137 27    515.4     1080  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (Ca_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```




```
### P_soil
P_soil_lm = lm(log(P_soil) ~ Name, data = data)
#plot(resid(P_soil_lm) ~ fitted(P_soil_lm))
anova(P_soil_lm)
```

```
## Analysis of Variance Table
##
```

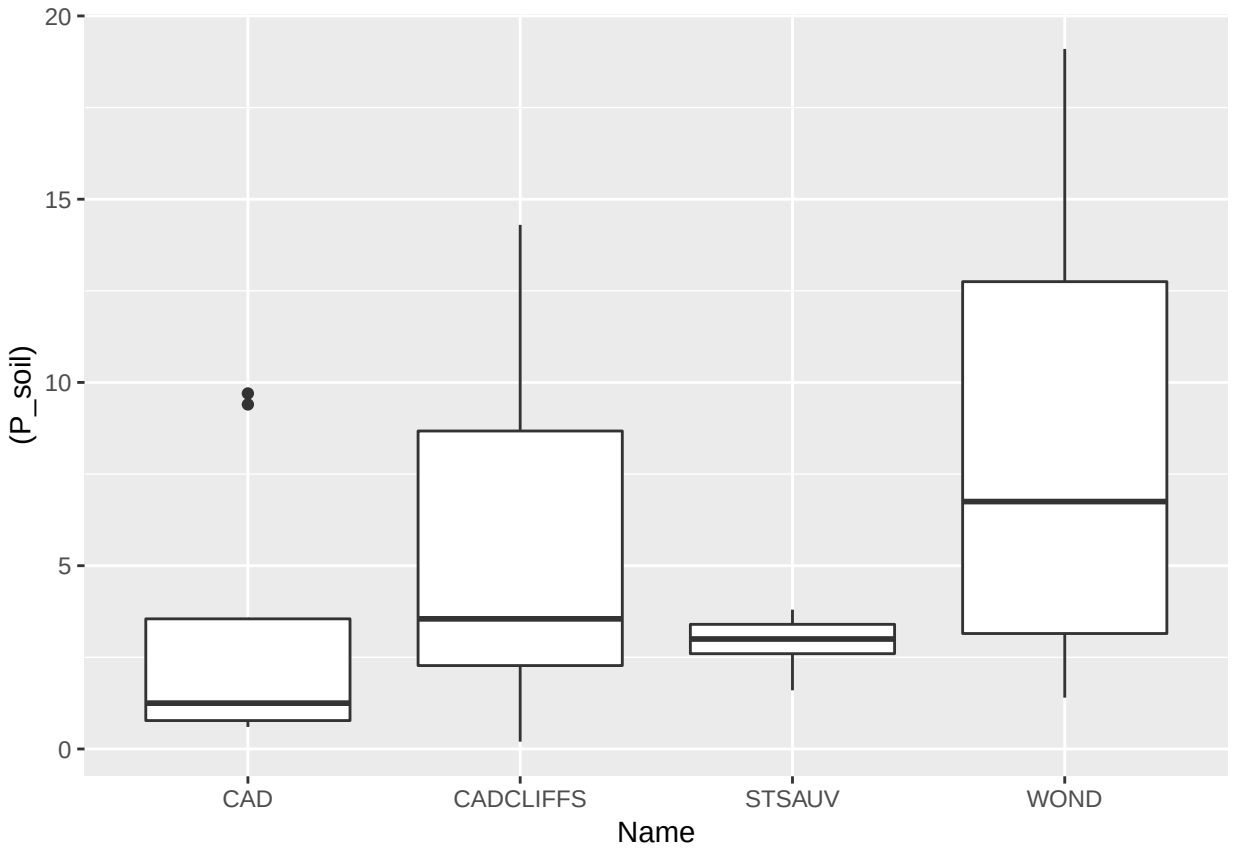
```
## Response: log(P_soil)
##           Df  Sum Sq Mean Sq F value Pr(>F)
## Name       3  5.7145  1.9048  1.7531 0.1799
## Residuals 27 29.3360  1.0865
```

```
cld(emmeans(P_soil_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  CAD         0.54 0.369 27   -0.216     1.30  1
##  STSAUV      1.03 0.394 27    0.225     1.84  1
##  CADCLIFFS   1.17 0.369 27    0.417     1.93  1
##  WOND        1.73 0.369 27    0.971     2.48  1
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (P_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```




```
### K_soil
K_soil_lm = lm((K_soil) ~ Name, data = data)
#plot(resid(K_soil_lm) ~ fitted(K_soil_lm))
anova(K_soil_lm)
```

```
## Analysis of Variance Table
```

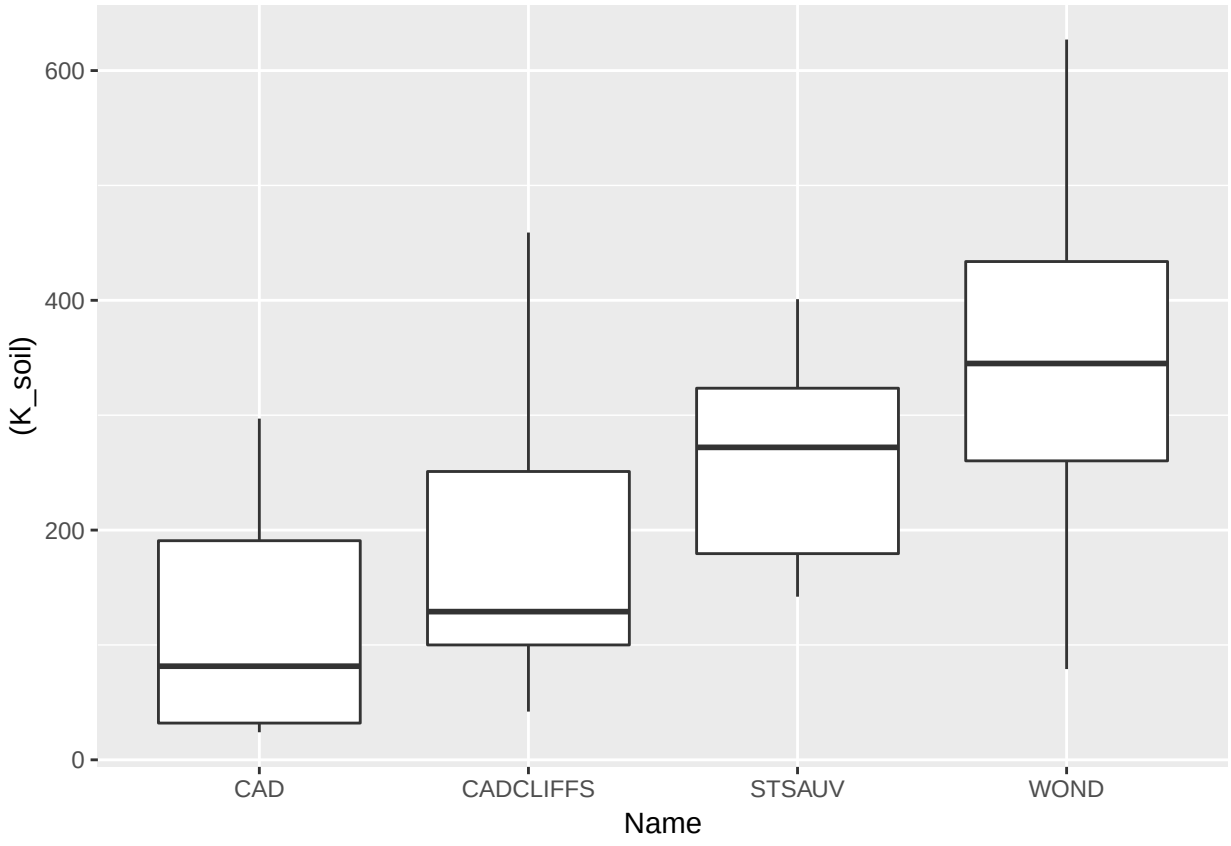
```
##
## Response: (K_soil)
##           Df Sum Sq Mean Sq F value  Pr(>F)
## Name       3 216562   72187  3.9086 0.01934 *
## Residuals 27 498657   18469
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(K_soil_lm, ~Name))
```

```
##  Name      emmean   SE df lower.CL upper.CL .group
##  CAD          122 48.0 27     23.8      221  1
##  CADCLIFFS    192 48.0 27     93.0      290  12
##  STSAUV       260 51.4 27    154.7      366  12
##  WOND         345 48.0 27    246.4      444   2
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (K_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```




```
### Mg_soil
Mg_soil_lm = lm((Mg_soil) ~ Name, data = data)
#plot(resid(Mg_soil_lm) ~ fitted(Mg_soil_lm))
```

```r
anova(Mg_soil_lm)
```

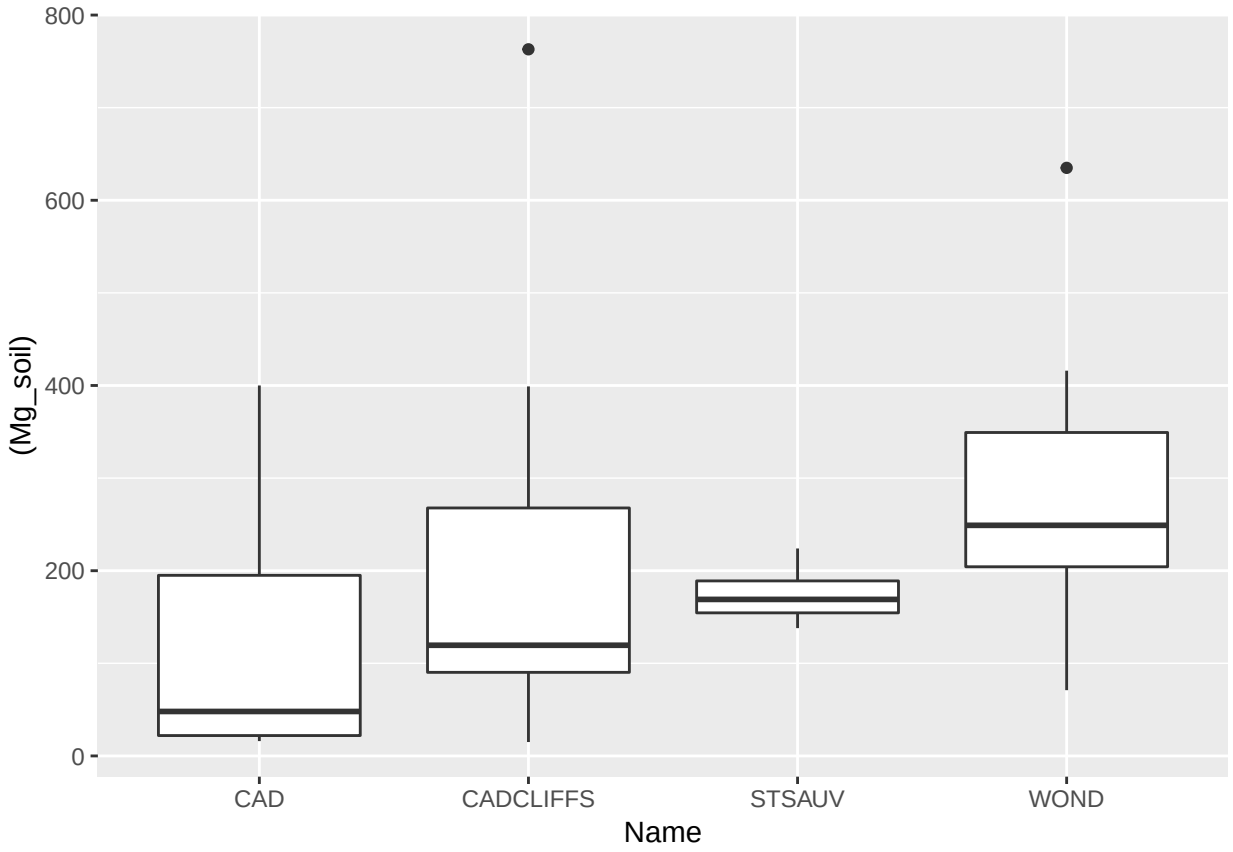
```
## Analysis of Variance Table
##
## Response: (Mg_soil)
##           Df Sum Sq Mean Sq F value Pr(>F)
## Name       3 113203   37734  1.2344 0.3165
## Residuals 27 825345   30568
```

```r
cld(emmeans(Mg_soil_lm, ~Name))
```

```
##  Name      emmean   SE df lower.CL upper.CL .group
##  CAD          134 61.8 27     7.42      261  1
##  STSAUV       174 66.1 27    38.41      310  1
##  CADCLIFFS    227 61.8 27    99.79      353  1
##  WOND         294 61.8 27   166.92      421  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```r
ggplot(data = data, aes(x = Name, y = (Mg_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```



```r
### Al_soil
Al_soil_lm = lm(log(Al_soil) ~ Name, data = data)
#plot(resid(Al_soil_lm) ~ fitted(Al_soil_lm))
anova(Al_soil_lm)
```

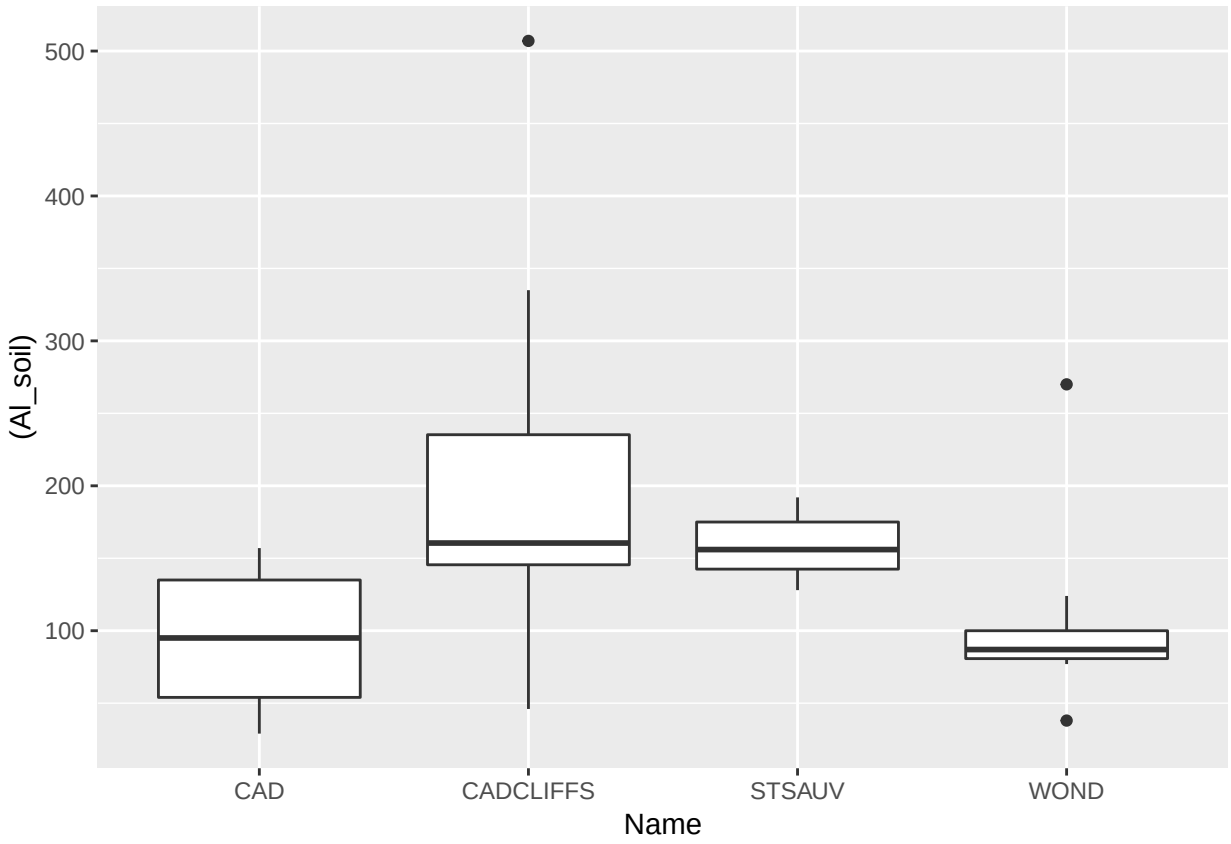
```
## Analysis of Variance Table
##
## Response: log(Al_soil)
##           Df Sum Sq Mean Sq F value  Pr(>F)
## Name       3 3.4814 1.16047   3.564 0.02715 *
## Residuals 27 8.7915 0.32561
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
cld(emmeans(Al_soil_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  CAD         4.37 0.202 27     3.95     4.78  1
##  WOND        4.53 0.202 27     4.12     4.95  12
##  STSAUV      5.06 0.216 27     4.62     5.50  12
##  CADCLIFFS   5.15 0.202 27     4.73     5.56   2
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```r
ggplot(data = data, aes(x = Name, y = (Al_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```




```
### Zn_soil
Zn_soil_lm = lm(log(Zn_soil) ~ Name, data = data)
#plot(resid(Zn_soil_lm) ~ fitted(Zn_soil_lm))
anova(Zn_soil_lm)
```

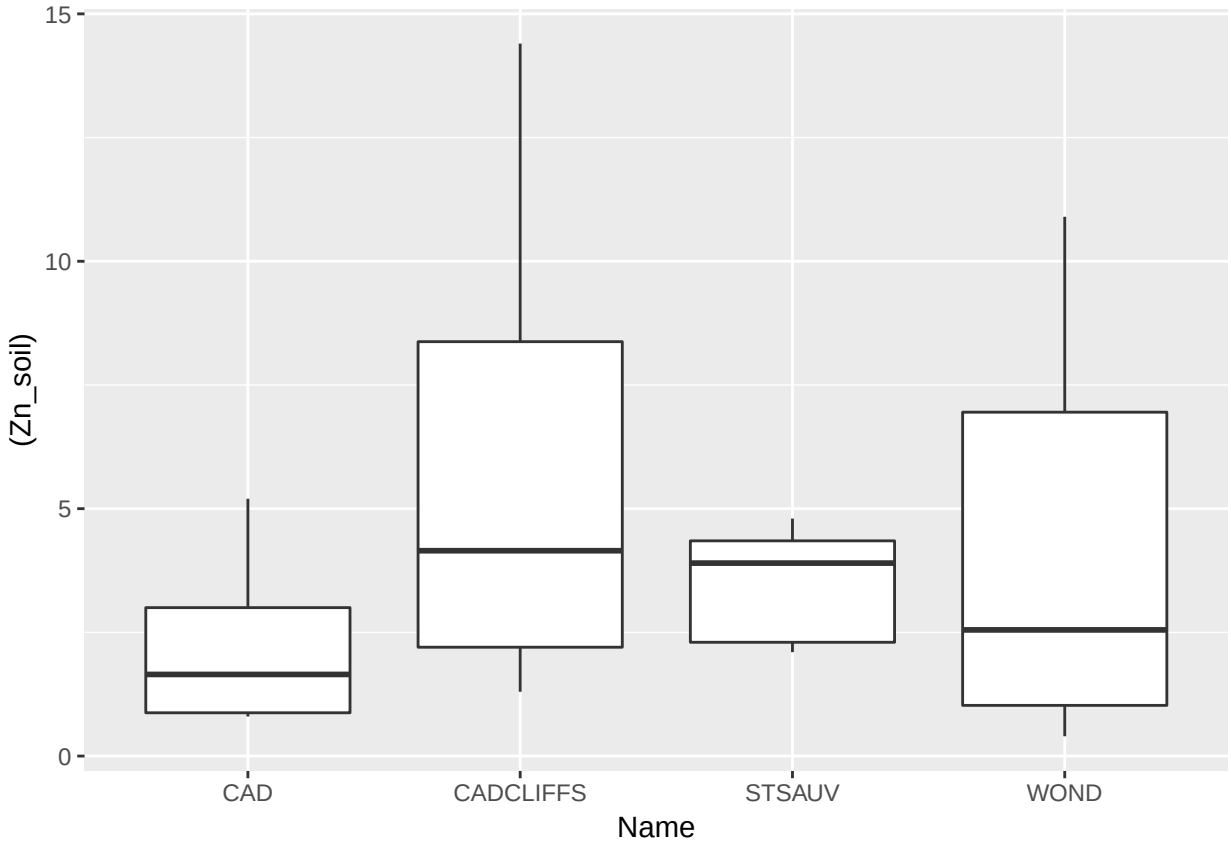
```
## Analysis of Variance Table
##
## Response: log(Zn_soil)
##           Df  Sum Sq Mean Sq F value Pr(>F)
## Name       3  3.4213 1.14043  1.5357 0.2279
## Residuals 27 20.0504 0.74261
```

```
cld(emmeans(Zn_soil_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  CAD        0.569 0.305 27  -0.0561     1.19  1
##  WOND       0.895 0.305 27   0.2696     1.52  1
##  STSAUV     1.182 0.326 27   0.5135     1.85  1
##  CADCLIFFS  1.451 0.305 27   0.8258     2.08  1
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (Zn_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```




```
### pH
pH_lm = lm((pH) ~ Name, data = data)
#plot(resid(pH_lm) ~ fitted(pH_lm))
anova(pH_lm)
```

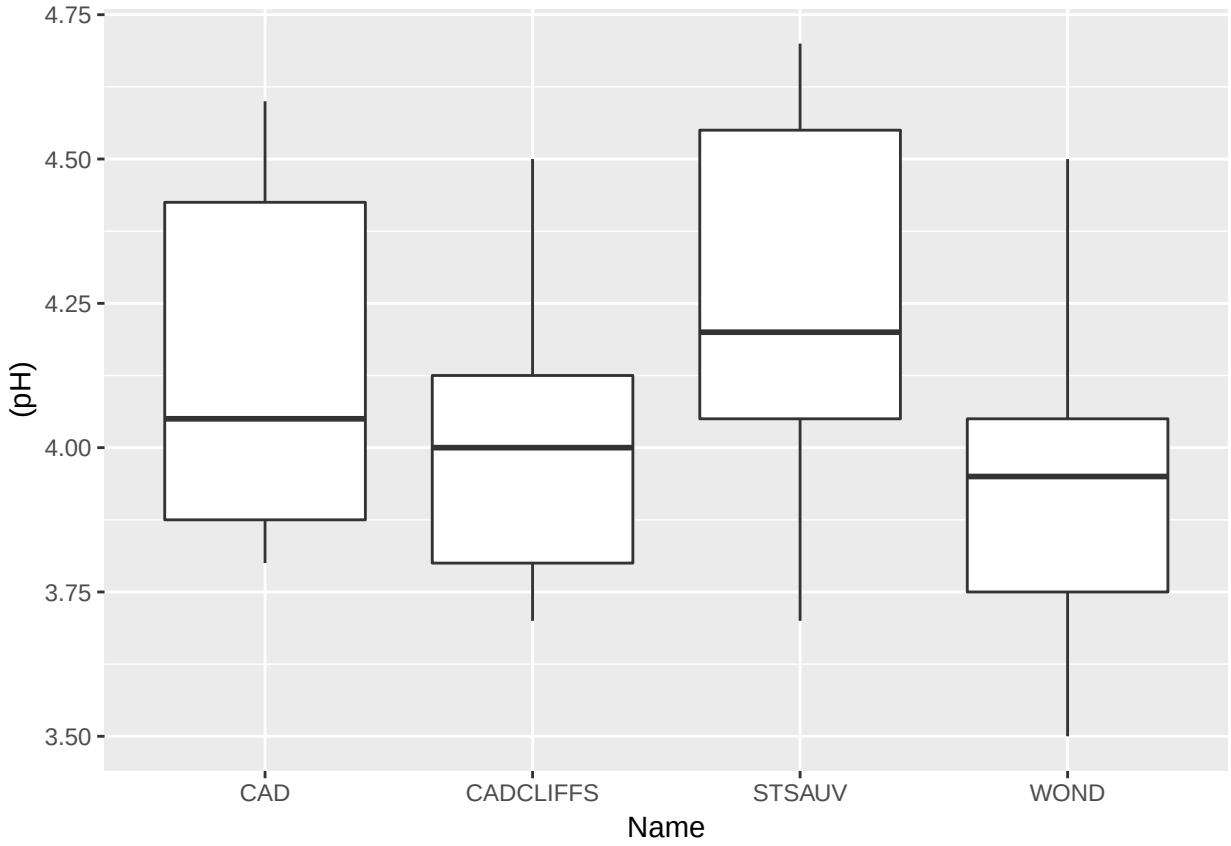
```
## Analysis of Variance Table
##
## Response: (pH)
##           Df  Sum Sq Mean Sq F value Pr(>F)
## Name       3 0.44499 0.14833  1.4493 0.2505
## Residuals 27 2.76339 0.10235
```

```
cld(emmeans(pH_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  WOND        3.94 0.113 27     3.71     4.17  1
##  CADCLIFFS   4.01 0.113 27     3.78     4.24  1
##  CAD         4.14 0.113 27     3.91     4.37  1
##  STSAUV      4.26 0.121 27     4.01     4.51  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (pH))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```




```
### CEC
CEC_lm = lm((CEC) ~ Name, data = data)
#plot(resid(CEC_lm) ~ fitted(CEC_lm))
anova(CEC_lm)
```

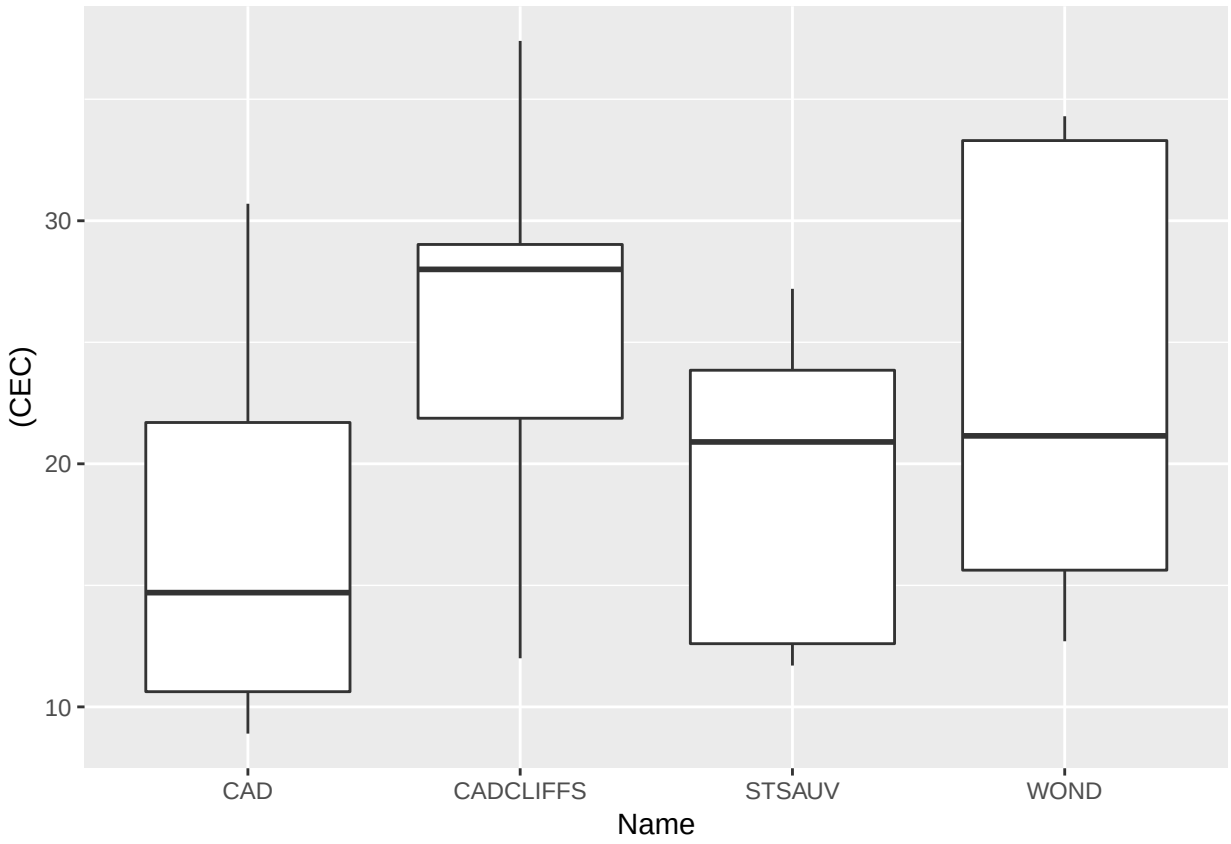
```
## Analysis of Variance Table
##
## Response: (CEC)
##           Df  Sum Sq Mean Sq F value Pr(>F)
## Name       3  347.66 115.888  1.7751 0.1757
## Residuals 27 1762.65  65.283
```

```
cld(emmeans(CEC_lm, ~Name))
```

```
##  Name      emmean   SE df lower.CL upper.CL .group
##  CAD         17.3 2.86 27     11.4     23.1  1
##  STSAUV      19.0 3.05 27     12.7     25.2  1
##  WOND        23.4 2.86 27     17.5     29.2  1
##  CADCLIFFS   25.6 2.86 27     19.7     31.4  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (CEC))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```




```
### C_soil
C_soil_lm = lm((C_soil) ~ Name, data = data)
#plot(resid(C_soil_lm) ~ fitted(C_soil_lm))
anova(C_soil_lm)
```

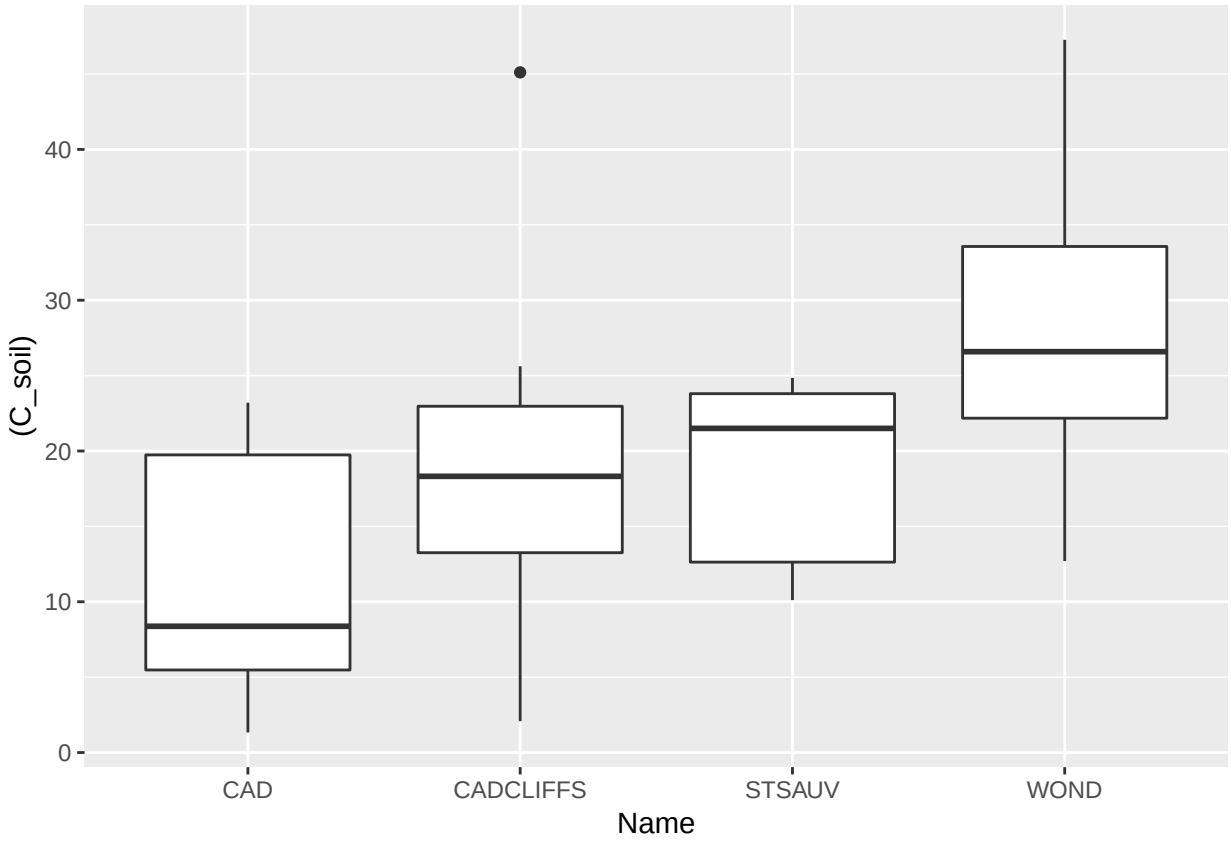
```
## Analysis of Variance Table
##
## Response: (C_soil)
##           Df Sum Sq Mean Sq F value  Pr(>F)
## Name       3 1125.7  375.24   3.726 0.02313 *
## Residuals 27 2719.2  100.71
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(C_soil_lm, ~Name))
```

```
##  Name      emmean   SE df lower.CL upper.CL .group
##  CAD         11.4 3.55 27     4.14     18.7  1
##  STSAUV      18.5 3.79 27    10.69     26.3  12
##  CADCLIFFS   19.5 3.55 27    12.21     26.8  12
##  WOND        28.1 3.55 27    20.85     35.4   2
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (C_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```




```
### N_soil
N_soil_lm = lm((N_soil) ~ Name, data = data)
#plot(resid(N_soil_lm) ~ fitted(N_soil_lm))
anova(N_soil_lm)
```

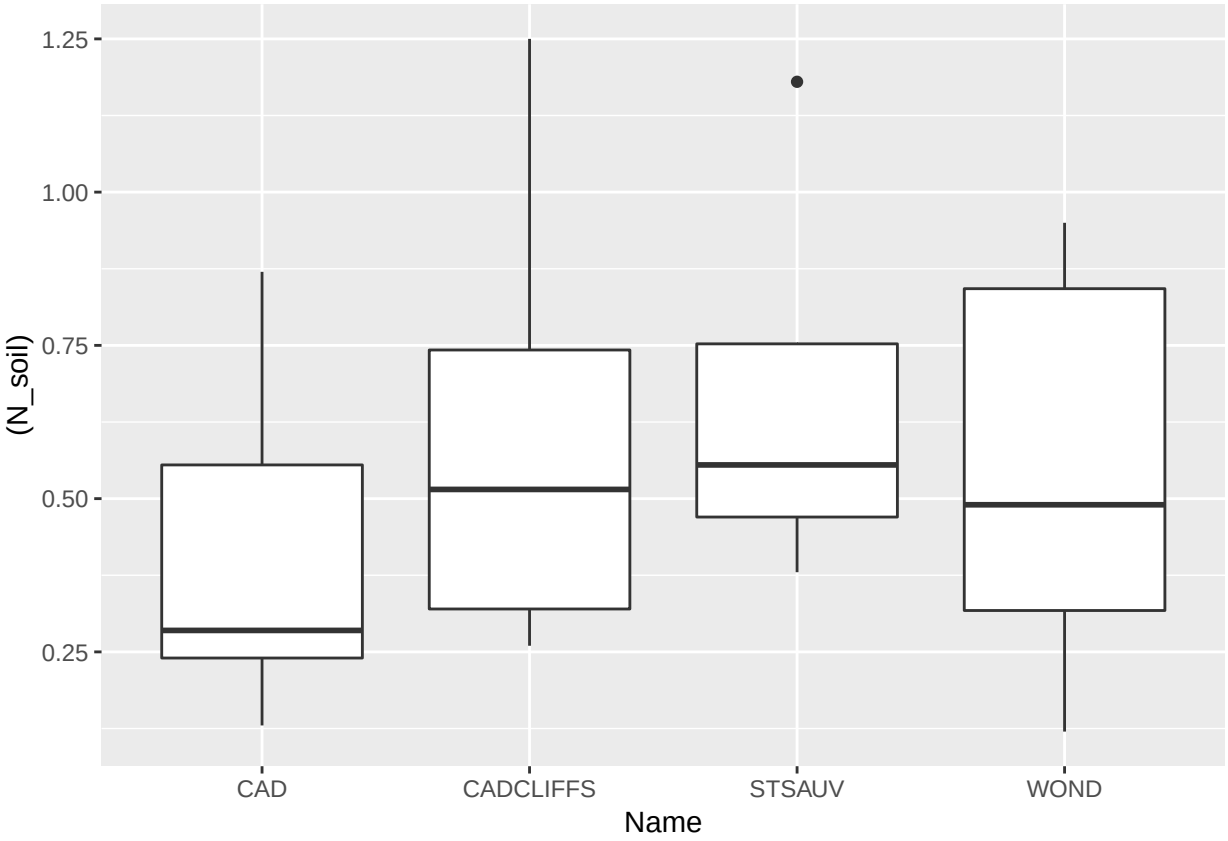
```
## Analysis of Variance Table
##
## Response: (N_soil)
##           Df Sum Sq Mean Sq F value Pr(>F)
## Name       3 0.2355 0.07850  0.7197 0.5508
## Residuals 22 2.3995 0.10907
```

```
cld(emmeans(N_soil_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  CAD        0.409 0.117 22    0.167    0.651  1
##  WOND       0.545 0.135 22    0.265    0.825  1
##  CADCLIFFS  0.604 0.117 22    0.362    0.846  1
##  STSAUV     0.667 0.165 22    0.325    1.010  1
##
## Results are given on the ( (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (N_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 20 rows containing non-finite values (stat_boxplot).
```




```
### CN_soil
CN_soil_lm = lm(log(CN_soil) ~ Name, data = data)
#plot(resid(CN_soil_lm) ~ fitted(CN_soil_lm))
anova(CN_soil_lm)
```

```
## Analysis of Variance Table
##
## Response: log(CN_soil)
##           Df Sum Sq Mean Sq F value  Pr(>F)
## Name       3 3.1169 1.03898  3.2896 0.03968 *
## Residuals 22 6.9485 0.31584
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

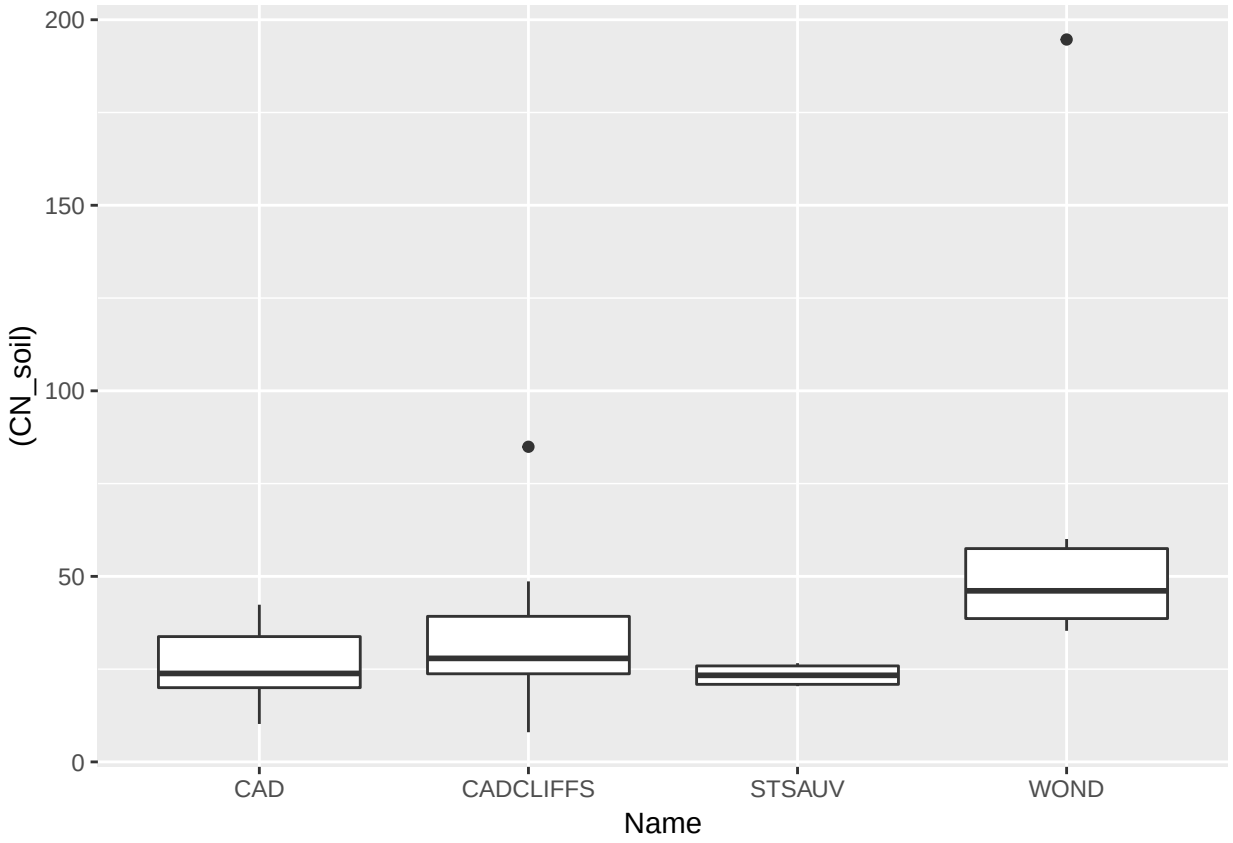
```
cld(emmeans(CN_soil_lm, ~Name))
```

```
##  Name      emmean    SE df lower.CL upper.CL .group
##  STSAUV      3.15 0.281 22     2.56     3.73  12
##  CAD         3.16 0.199 22     2.75     3.57  1
##  CADCLIFFS   3.37 0.199 22     2.96     3.78  12
##  WOND        4.03 0.229 22     3.56     4.51   2
##
## Results are given on the log (not the response) scale.
```

```
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (CN_soil))) +
  geom_boxplot()
```

```
## Warning: Removed 20 rows containing non-finite values (stat_boxplot).
```




```
### retention
retention_lm = lm(asin(sqrt(0.01 * retention)) ~ Name, data = data)
#plot(resid(retention_lm) ~ fitted(retention_lm))
anova(retention_lm)
```

```
## Analysis of Variance Table
##
## Response: asin(sqrt(0.01 * retention))
##           Df  Sum Sq  Mean Sq F value    Pr(>F)
## Name       3 0.22537 0.075124  9.6708 7.096e-05 ***
## Residuals 38 0.29519 0.007768
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
cld(emmeans(retention_lm, ~Name))
```

```
##  Name      emmean     SE df lower.CL upper.CL .group
##  WOND       0.470 0.0279 38    0.414    0.526  1
##  CAD        0.528 0.0266 38    0.474    0.581  1
##  STSAUV     0.546 0.0266 38    0.492    0.600  1
```

```
##  CADCLIFFS  0.675 0.0279 38    0.619    0.731   2
##
## Results are given on the asin(sqrt(mu)) (not the response) scale.
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 4 estimates
## significance level used: alpha = 0.05
```

```
ggplot(data = data, aes(x = Name, y = (retention))) +
  geom_boxplot()
```

```
## Warning: Removed 4 rows containing non-finite values (stat_boxplot).
```