Masticated Fuels Analyses

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Masticated 1-hr fuels

TC = pre-treatment tree cover (%)

yst = years since treatment; 0 represents pre-treatment

scode = site

```
m <- lmer(sqrt(kgha_1h) ~ TC + yst + TC:yst + (1 + yst|scode), data = d)
summary(m)
```

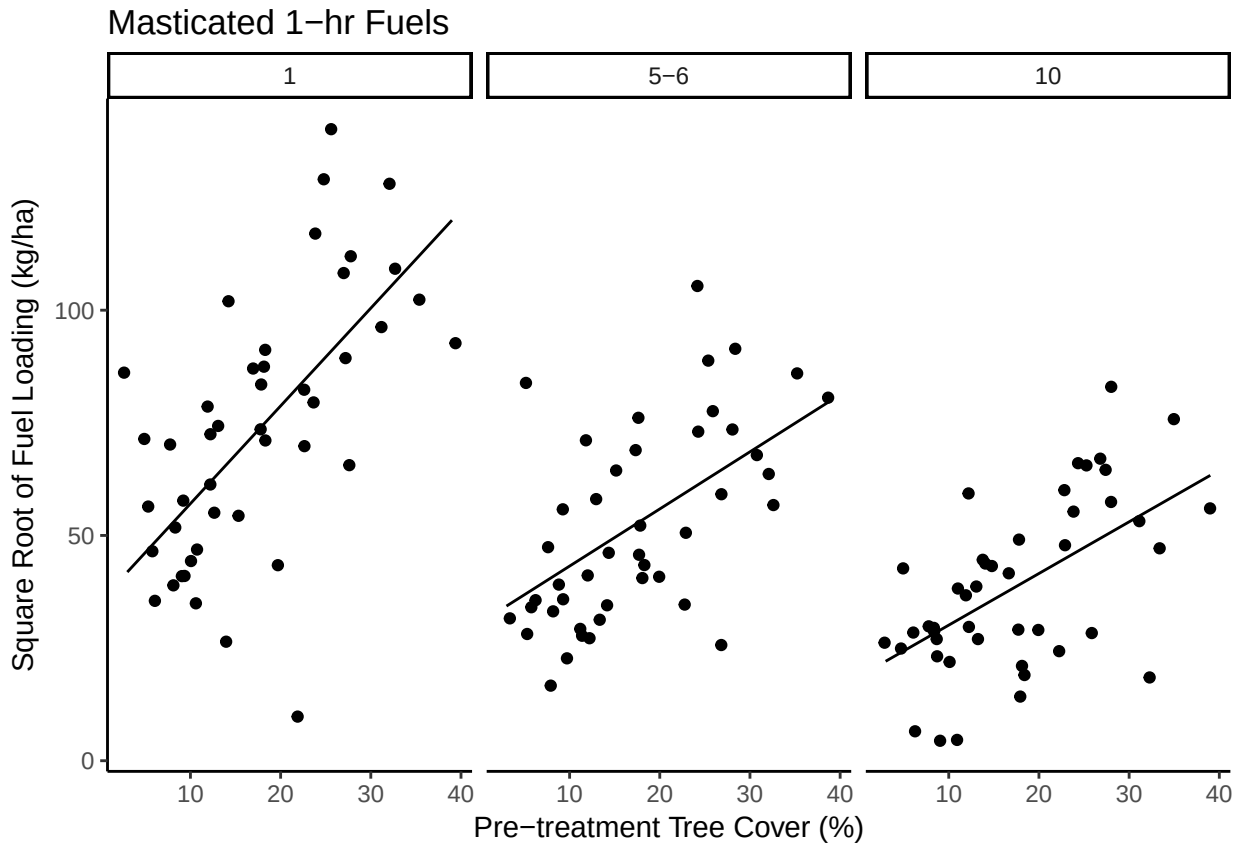
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(kgha_1h) ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 1142.3
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.6599 -0.5922  0.0228  0.5698  2.3503
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 131.3    11.46
##           yst5-6      350.1    18.71    -1.00
##           yst10       291.0    17.06    -1.00  1.00
##  Residual             319.7    17.88
## Number of obs: 134, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  35.3686     8.8419   4.000
## TC            2.1692     0.2980   7.280
## yst5-6       -4.8545    13.6407  -0.356
## yst10       -16.7389    12.8850  -1.299
## TC:yst5-6    -0.9009     0.4234  -2.128
## TC:yst10     -1.0228     0.4219  -2.425
##
## Correlation of Fixed Effects:
##           (Intr) TC     yst5-6 yst10  TC:5-6
## TC        -0.591
## yst5-6    -0.882  0.389
## yst10     -0.877  0.410  0.807
## TC:yst5-6  0.422 -0.713 -0.543 -0.295
## TC:yst10   0.422 -0.714 -0.280 -0.574  0.512
```

```
lincon(m)
```

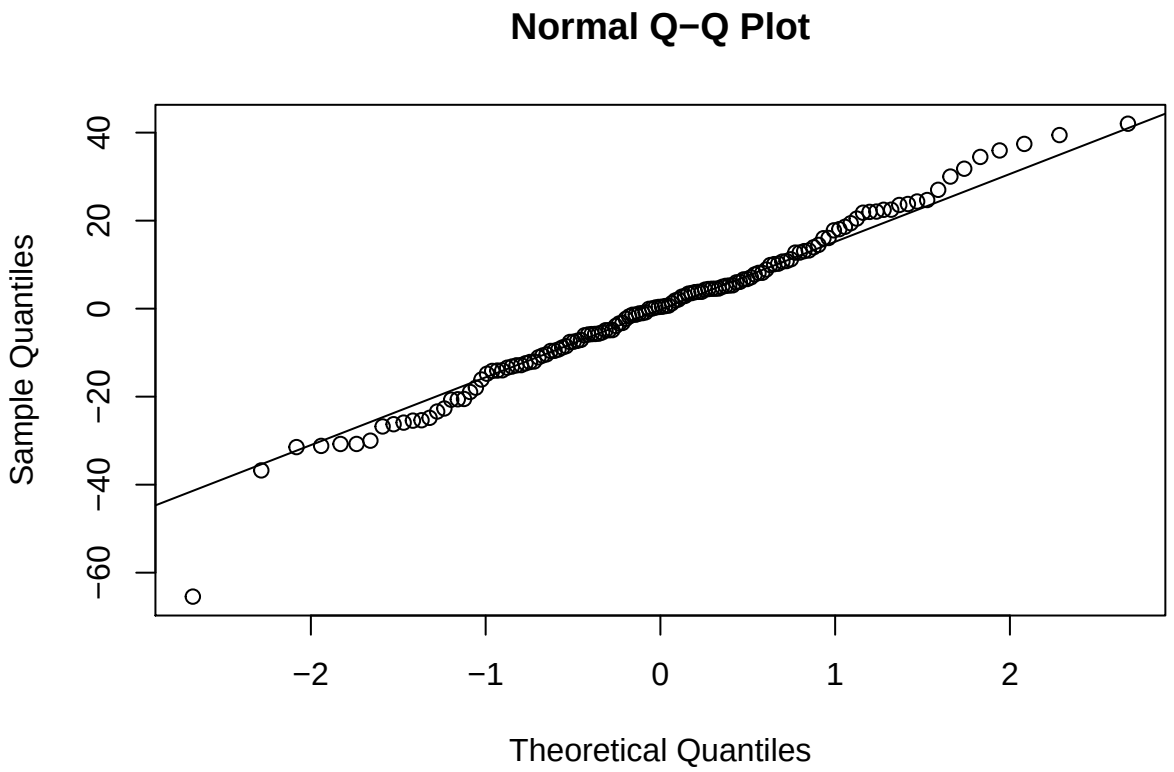
```
##                estimate         se      lower       upper     tvalue  df
```

```
## (Intercept)  35.3686086  8.8419287  18.038747 52.69847036  4.0001011 Inf
## TC            2.1692377  0.2979538   1.585259  2.75321643  7.2804504 Inf
## yst5-6       -4.8544822 13.6406637 -31.589692 21.88072751 -0.3558831 Inf
## yst10       -16.7388532 12.8849981 -41.992985  8.51527908 -1.2990963 Inf
## TC:yst5-6    -0.9008783  0.4233614  -1.730651 -0.07110511 -2.1279177 Inf
## TC:yst10     -1.0228380  0.4218680  -1.849684 -0.19599200 -2.4245454 Inf
##                     pvalue
## (Intercept) 6.331543e-05
## TC          3.327076e-13
## yst5-6      7.219281e-01
## yst10       1.939109e-01
## TC:yst5-6   3.334391e-02
## TC:yst10    1.532757e-02
```

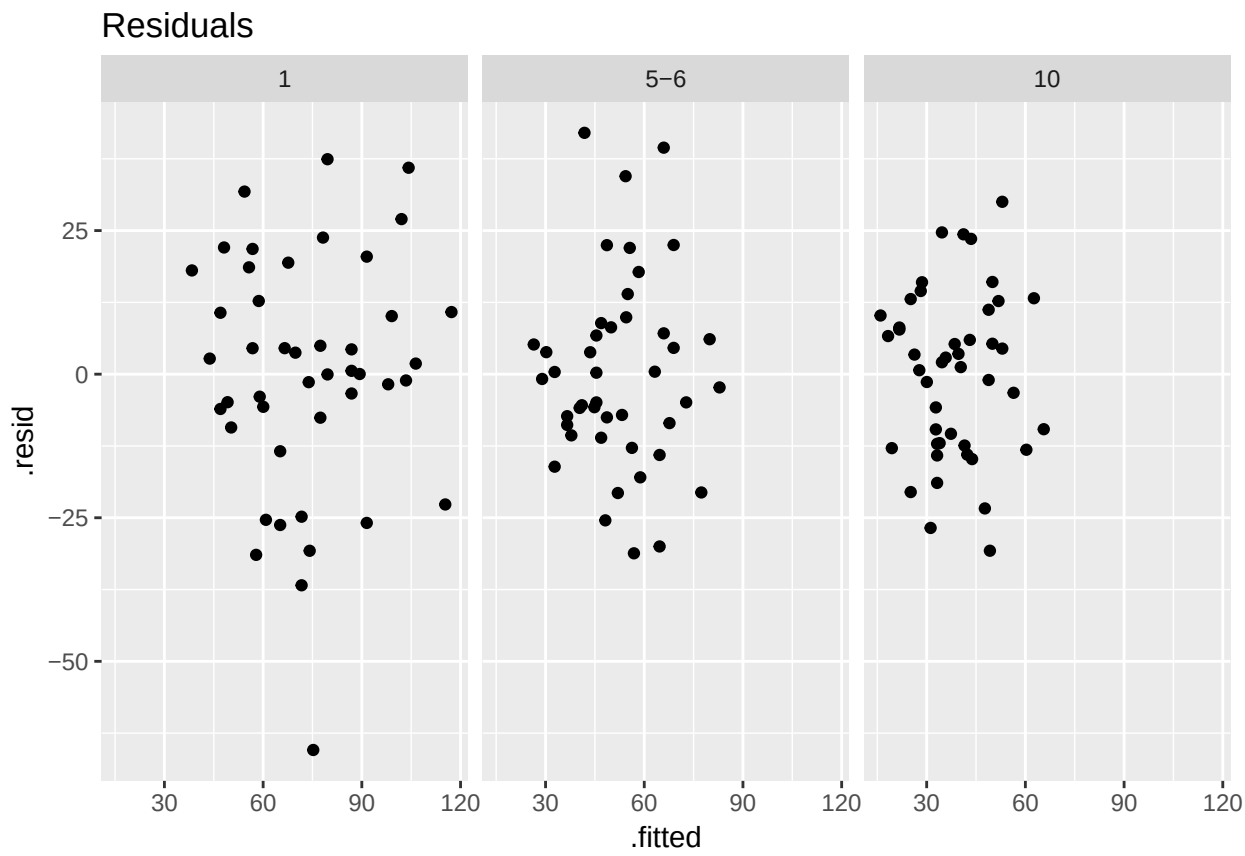
```r
#by yst; averaged across scode (sites)
d$yhat1 <- predict(m, re.form = NA)

p <- ggplot(data = d, aes(x = TC, y = sqrt(kgha_1h)))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat1))
p <- p + theme_classic()
p <- p + labs(title = 'Masticated 1-hr Fuels',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)')
p <- p + facet_wrap(~yst)
plot(p)
```



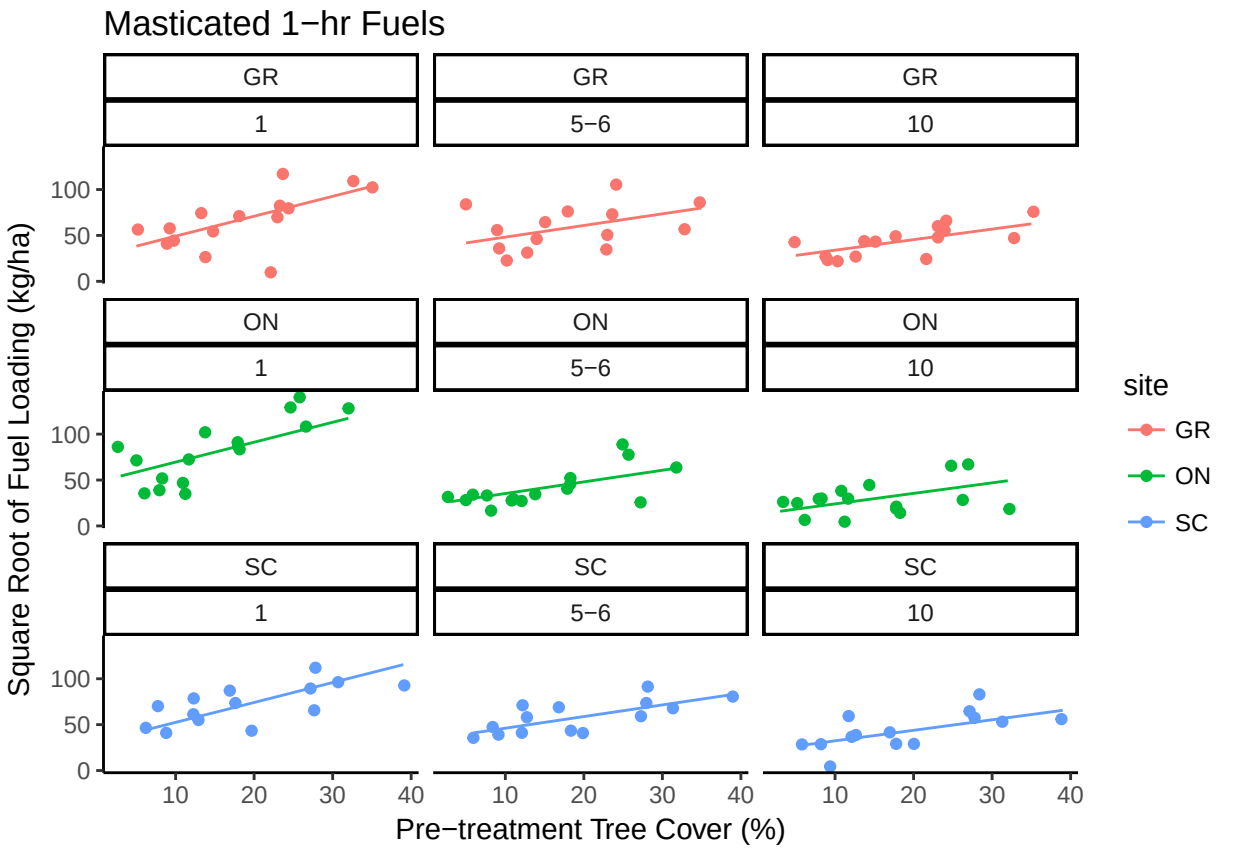
```
qqnorm(resid(m)); qqline(resid(m))
```



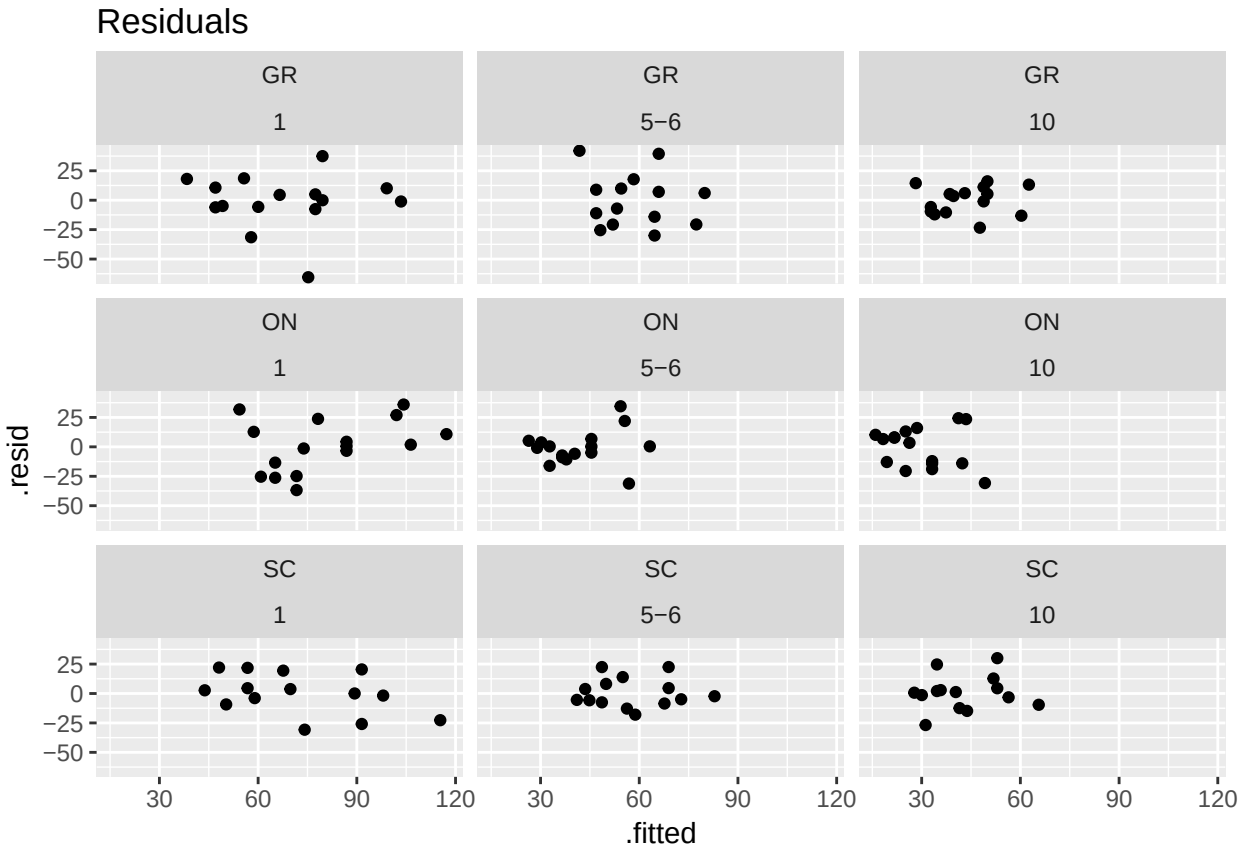

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst) + labs(title = 'Residuals')
```




```
d$yhat1 <- predict(m)

#by yst and scode
p <- ggplot(data = d, aes(x = TC, y = sqrt(kgha_1h), color = scode))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat1))
p <- p + theme_classic()
p <- p + labs(title = 'Masticated 1-hr Fuels',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)',
              color = 'site')
p <- p + facet_wrap(scode~yst)
plot(p)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst) + labs(title = 'Residuals
```



Masticated 10-hr fuels

TC = pre-treatment tree cover (%)

yst = years since treatment

```
m <- lmer(sqrt(kgha_10h) ~ TC + yst + TC:yst + (1 + yst|scode), data = d)
summary(m)
```

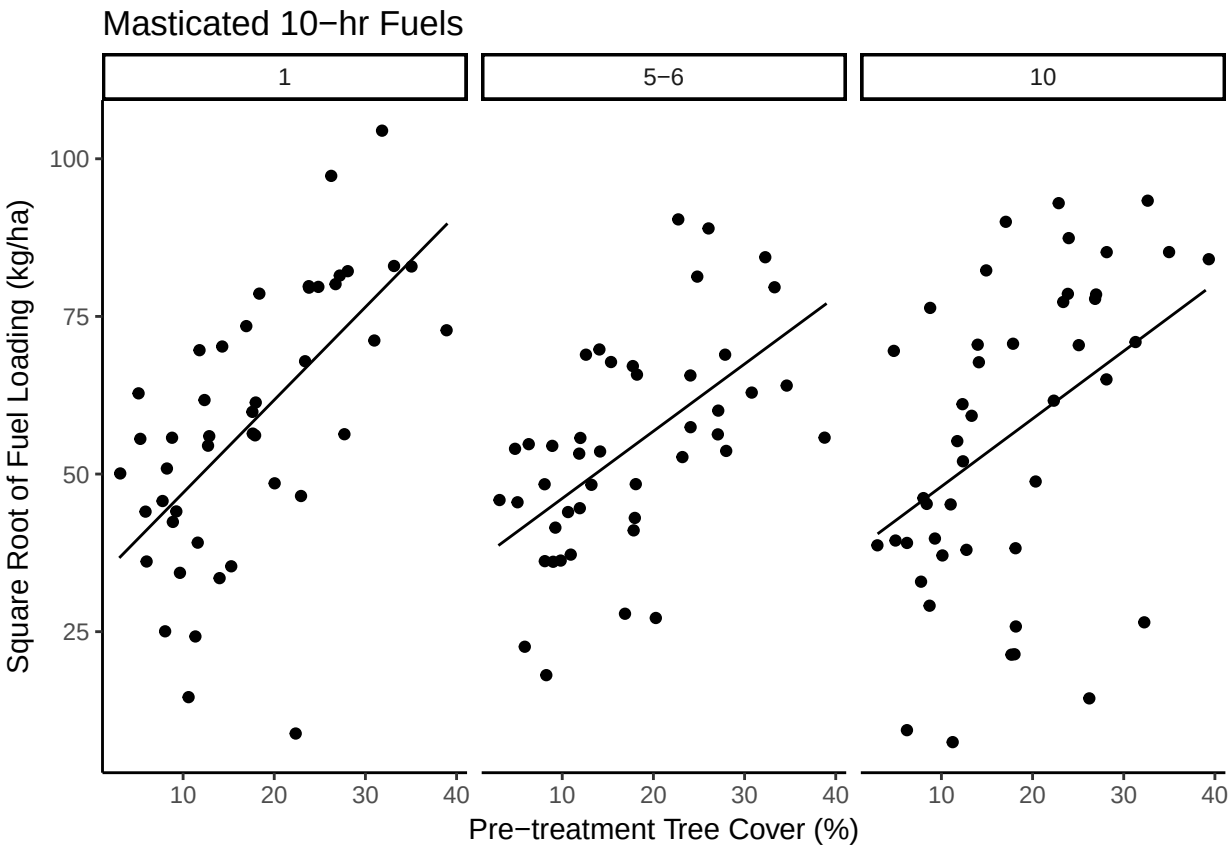
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(kgha_10h) ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 1117.4
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.2461 -0.7109  0.1677  0.6879  2.0467
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  12.66    3.558
##           yst5-6       66.17    8.134   -0.76
##           yst10       305.70   17.484   -0.96  0.55
##  Residual             258.05   16.064
```

```
## Number of obs: 134, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  32.2832     5.6102   5.754
## TC            1.4731     0.2651   5.556
## yst5-6        3.1837     8.8033   0.362
## yst10         5.0027    12.5591   0.398
## TC:yst5-6    -0.4069     0.3785  -1.075
## TC:yst10     -0.3993     0.3794  -1.052
##
## Correlation of Fixed Effects:
##           (Intr) TC     yst5-6 yst10  TC:5-6
## TC        -0.827
## yst5-6    -0.704  0.530
## yst10     -0.672  0.373  0.485
## TC:yst5-6  0.583 -0.704 -0.752 -0.262
## TC:yst10   0.583 -0.704 -0.374 -0.530  0.496
```

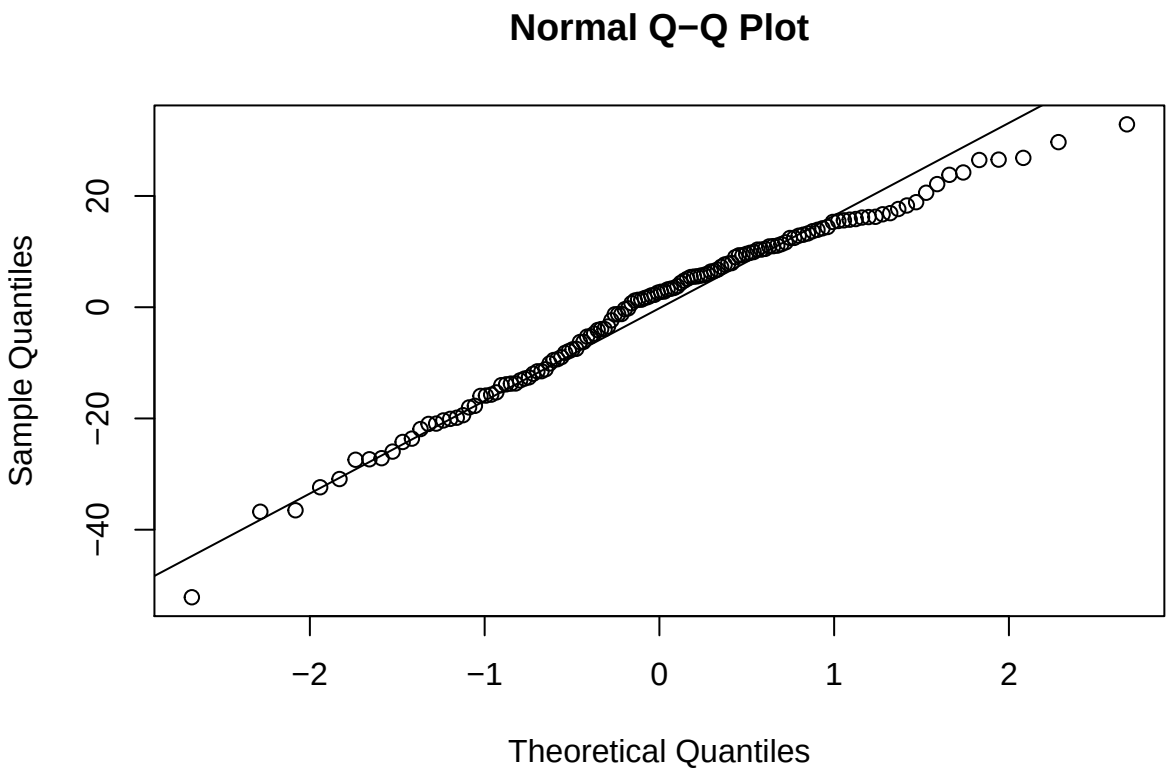
```
lincon(m)
```

```
##                estimate         se       lower      upper     tvalue  df
## (Intercept) 32.2832081  5.6101907  21.2874364 43.2789798  5.7543870 Inf
## TC           1.4731435  0.2651489   0.9534613  1.9928258  5.5559107 Inf
## yst5-6       3.1836819  8.8032881 -14.0704458 20.4378096  0.3616469 Inf
## yst10        5.0026536 12.5590916 -19.6127137 29.6180209  0.3983293 Inf
## TC:yst5-6   -0.4068783  0.3785025  -1.1487295  0.3349729 -1.0749687 Inf
## TC:yst10    -0.3992553  0.3794335  -1.1429314  0.3444208 -1.0522405 Inf
##                    pvalue
## (Intercept) 8.695677e-09
## TC          2.761681e-08
## yst5-6      7.176159e-01
## yst10       6.903875e-01
## TC:yst5-6   2.823888e-01
## TC:yst10    2.926892e-01
```

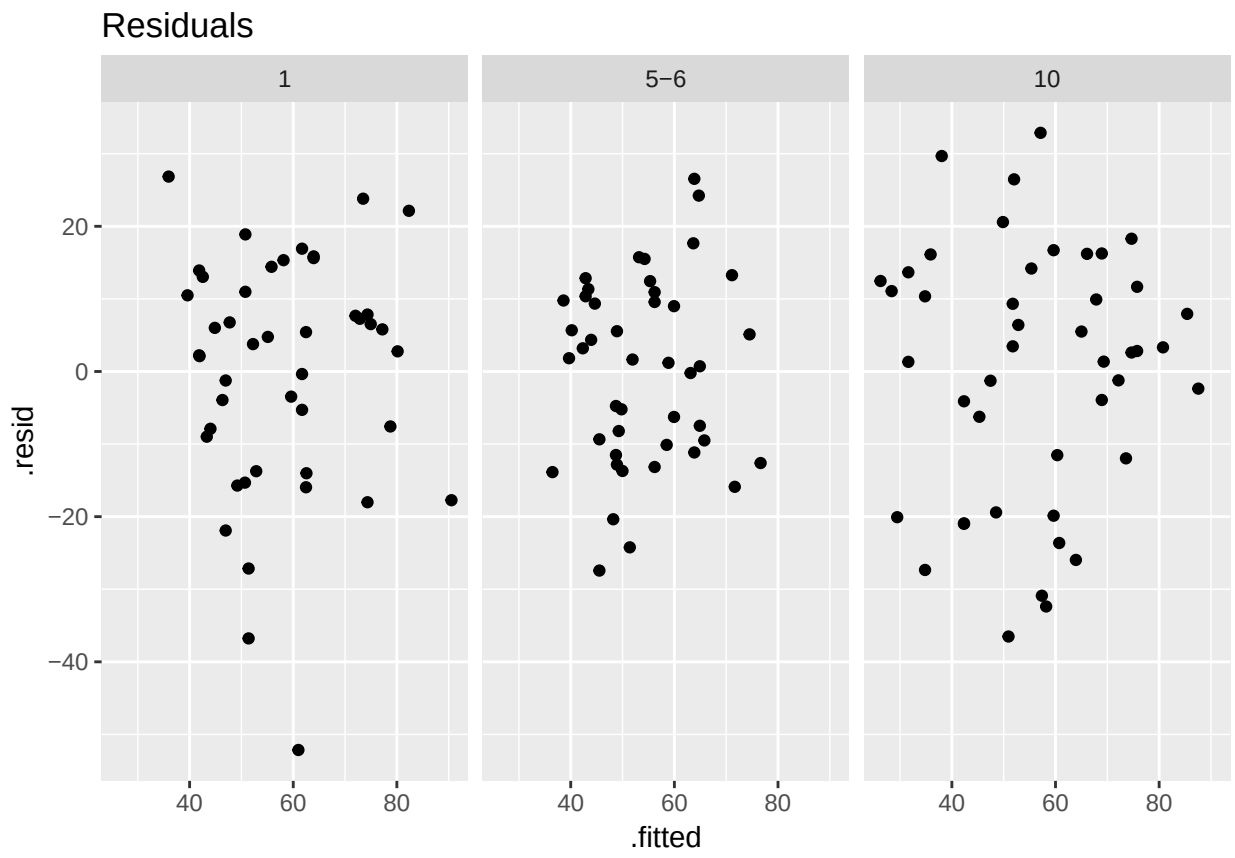
```
#by yst; averaged across scode (sites)
d$yhat10 <- predict(m, re.form = NA)

p <- ggplot(data = d, aes(x = TC, y = sqrt(kgha_10h)))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat10))
p <- p + theme_classic()
p <- p + labs(title = 'Masticated 10-hr Fuels',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)')
p <- p + facet_wrap(~yst)
plot(p)
```



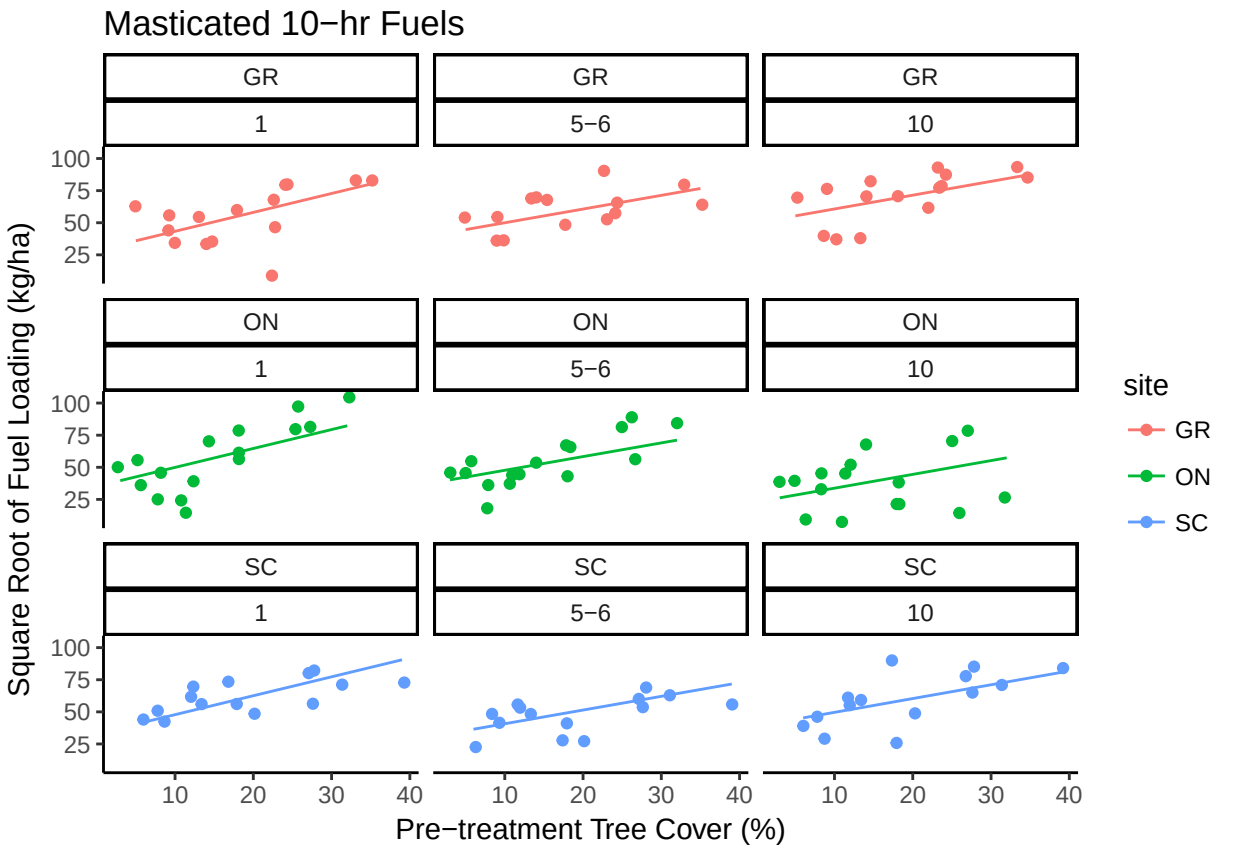

```
qqnorm(resid(m)); qqline(resid(m))
```



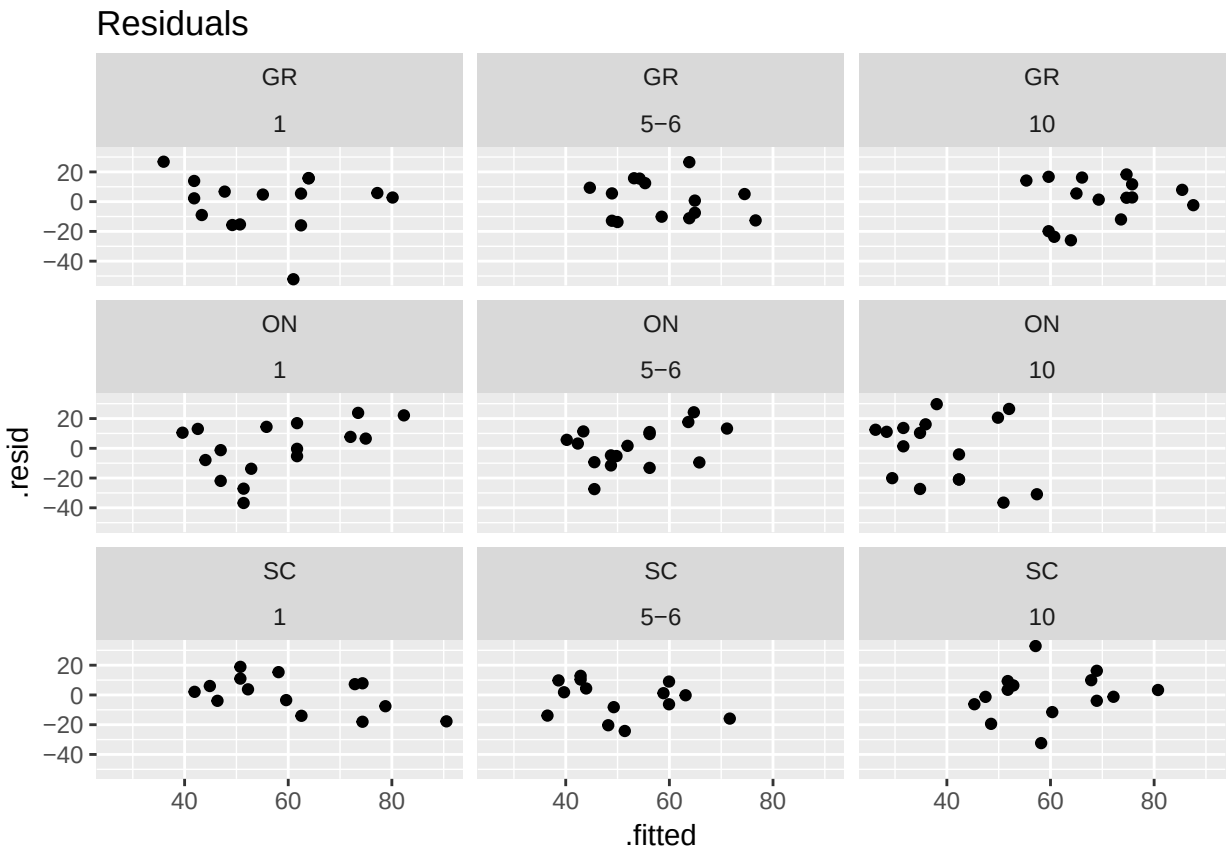

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst) + labs(title = 'Residuals')
```




```
#by yst and scode
d$yhat10 <- predict(m)
p <- ggplot(data = d, aes(x = TC, y = sqrt(kgha_10h), color = scode))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat10))
p <- p + theme_classic()
p <- p + labs(title = 'Masticated 10-hr Fuels',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)',
              color = 'site')
p <- p + facet_wrap(scode~yst)
plot(p)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst) + labs(title = 'Residuals
```



Masticated 100 + 1000-hr fuels

Need to check zero values for year 1

```
m <- lmer(sqrt(kgha_100_1000h) ~ TC + yst + TC:yst + (1 + yst|scode), data = d)
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : unable to evaluate scaled gradient
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : Model failed to converge: degenerate Hessian with 1 negative
## eigenvalues
```

```
summary(m)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(kgha_100_1000h) ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 1166.8
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.94202 -0.58616 -0.00832  0.62887  2.76563
##
## Random effects:
```

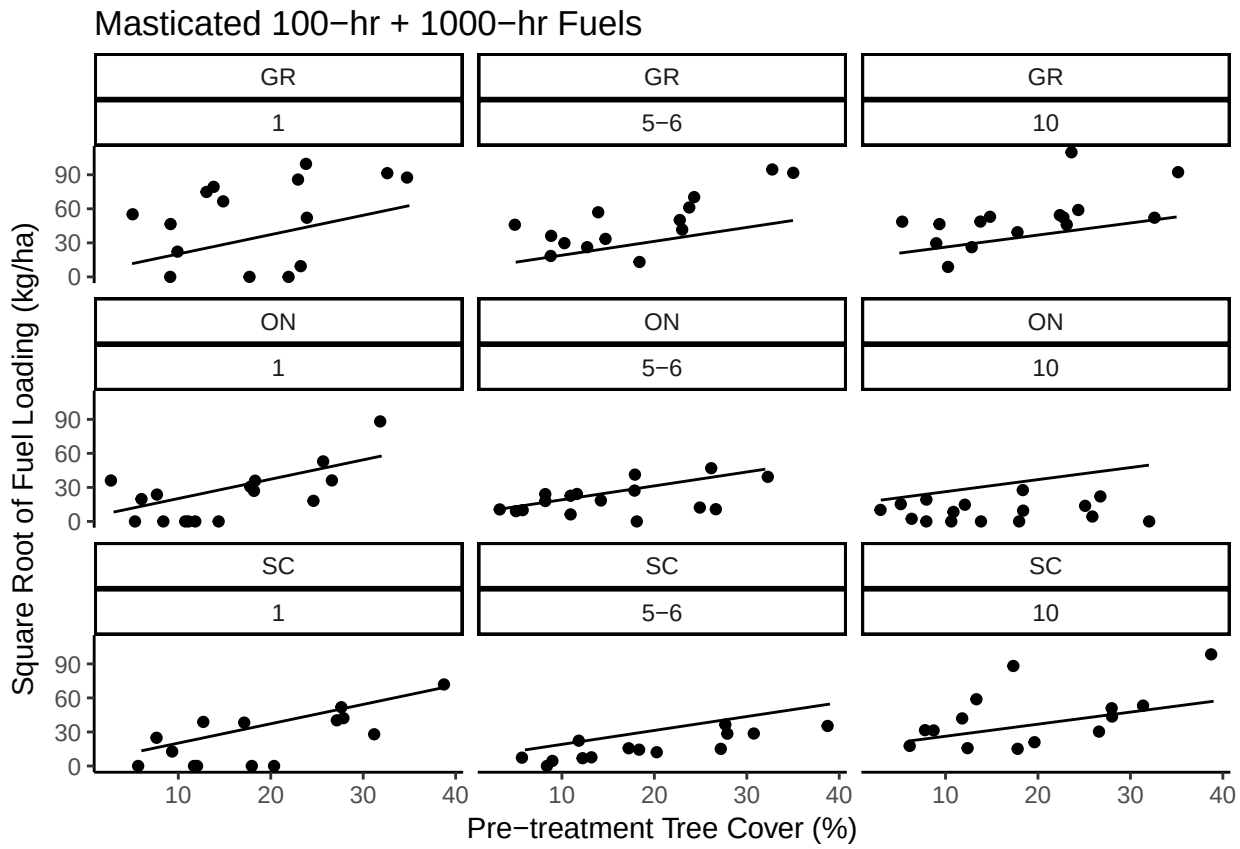
```
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 206.146  14.358
##           yst5-6        3.468   1.862    1.00
##           yst10       279.634  16.722   -0.22 -0.22
##  Residual             369.263  19.216
## Number of obs: 134, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   3.1160    10.4043   0.299
## TC            1.7058     0.3193   5.342
## yst5-6        3.6810     8.8848   0.414
## yst10        12.4675    13.1529   0.948
## TC:yst5-6    -0.4792     0.4486  -1.068
## TC:yst10     -0.6419     0.4536  -1.415
##
## Correlation of Fixed Effects:
##           (Intr) TC     yst5-6 yst10  TC:5-6
## TC        -0.538
## yst5-6    -0.323  0.617
## yst10     -0.419  0.425  0.312
## TC:yst5-6  0.375 -0.699 -0.880 -0.297
## TC:yst10   0.378 -0.703 -0.434 -0.605  0.492
## convergence code: 0
## unable to evaluate scaled gradient
## Model failed to converge: degenerate  Hessian with 1 negative eigenvalues
```

```
lincon(m)
```

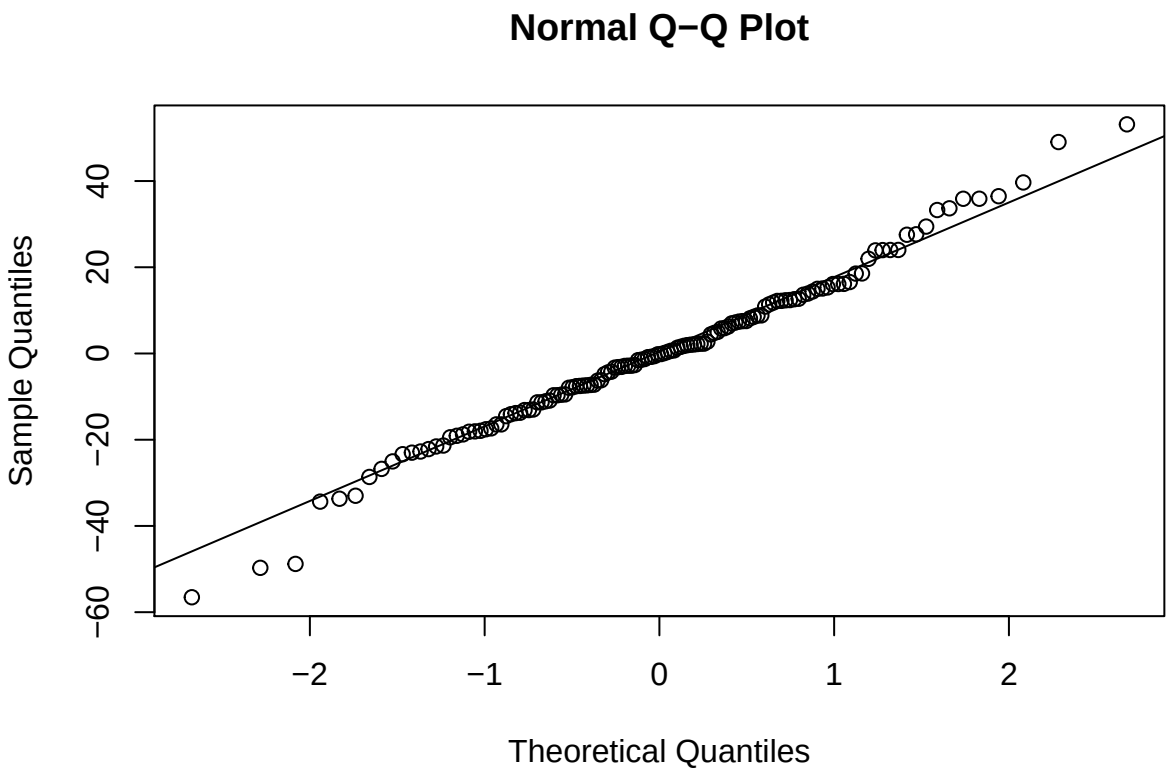
```
##                estimate         se      lower      upper     tvalue  df
## (Intercept)  3.1159661 10.4043343 -17.276155 23.5080867  0.2994873 Inf
## TC           1.7057506  0.3193123   1.079910  2.3315911  5.3419517 Inf
## yst5-6       3.6809936  8.8848367 -13.732966 21.0949535  0.4143007 Inf
## yst10       12.4674511 13.1528905 -13.311741 38.2466427  0.9478868 Inf
## TC:yst5-6   -0.4791706  0.4485722  -1.358356  0.4000147 -1.0682130 Inf
## TC:yst10    -0.6419318  0.4535916  -1.530955  0.2470914 -1.4152197 Inf
##                    pvalue
## (Intercept) 7.645683e-01
## TC          9.195117e-08
## yst5-6      6.786539e-01
## yst10       3.431871e-01
## TC:yst5-6   2.854244e-01
## TC:yst10    1.570041e-01
```

```
#by yst; averaged across scode (sites)
d$yhat100_1000 <- predict(m, re.form = NA)

p <- ggplot(data = d, aes(x = TC, y = sqrt(kgha_100_1000h)))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat100_1000))
p <- p + theme_classic()
p <- p + facet_wrap(scode~yst)
p <- p + labs(title = 'Masticated 100-hr + 1000-hr Fuels',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)')
```

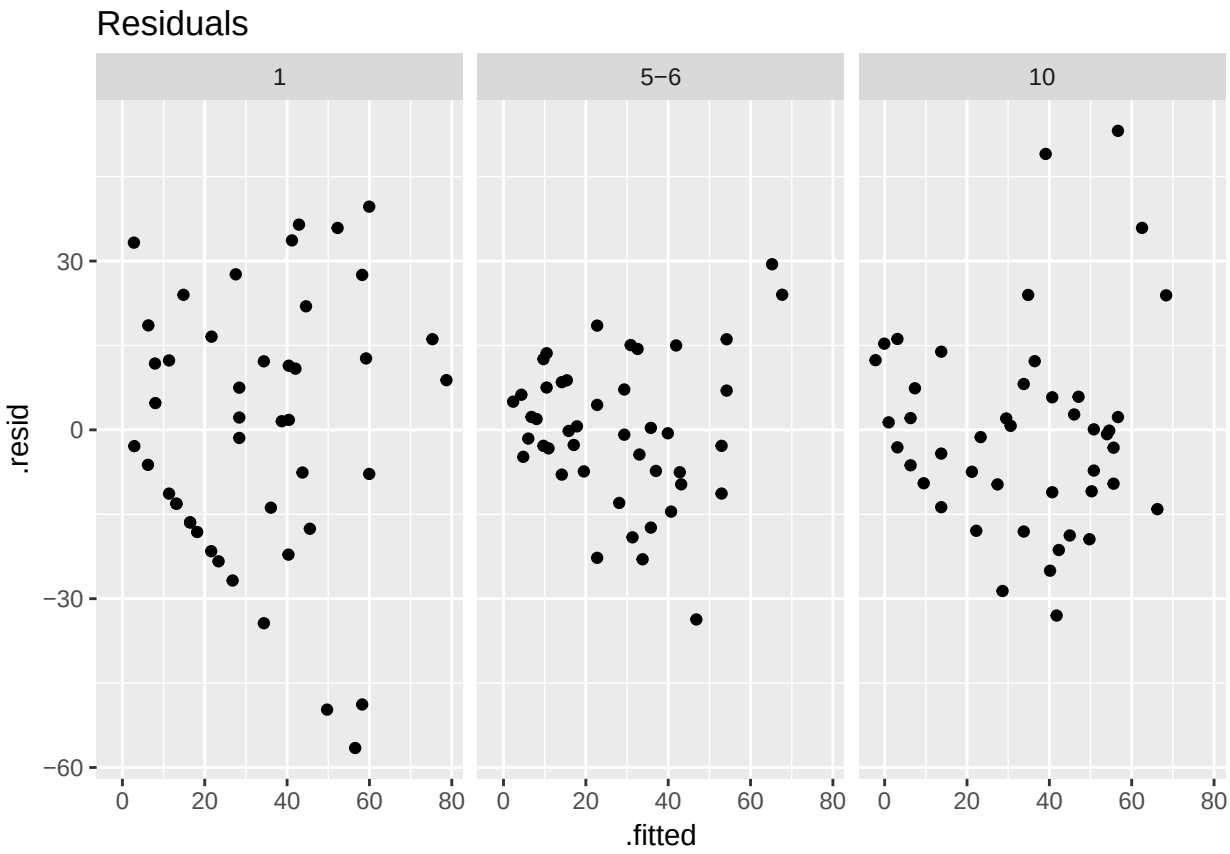
```
plot(p)
```



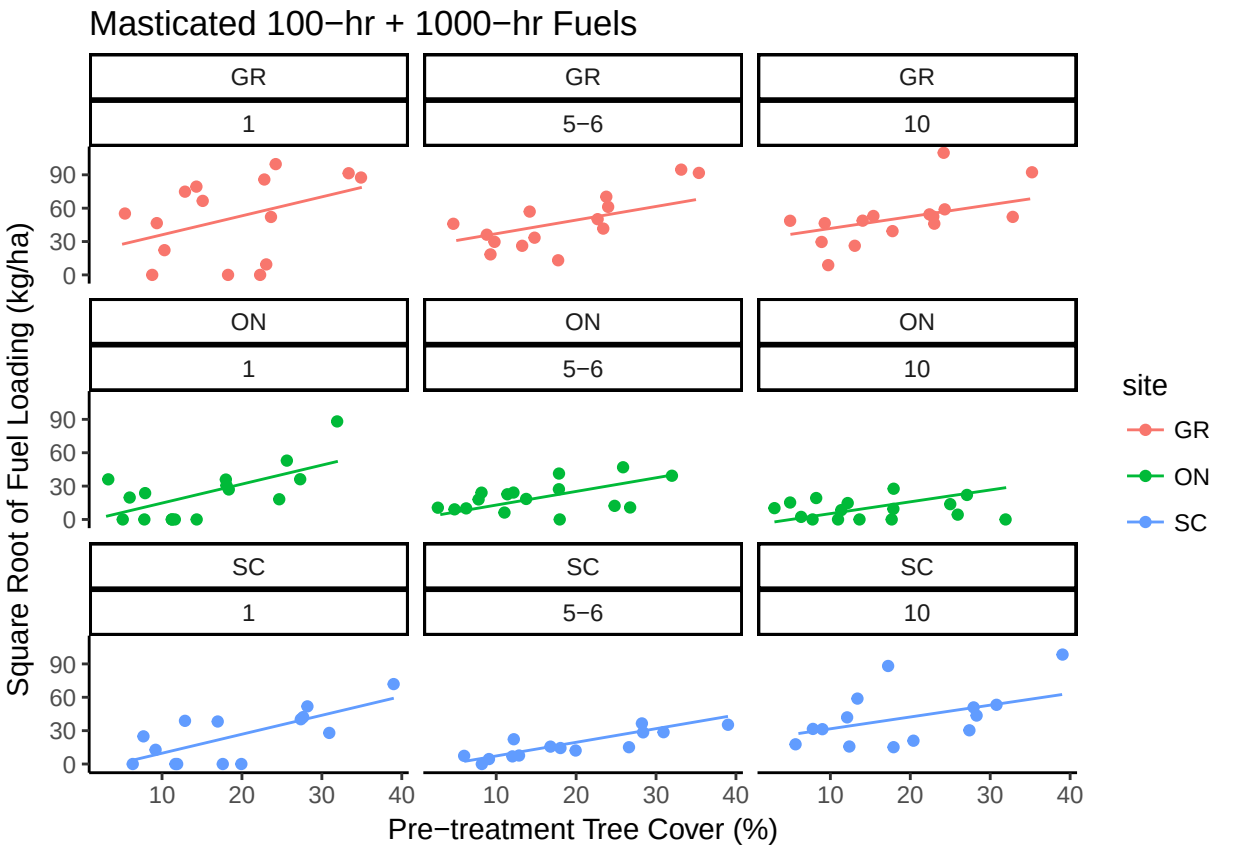

```
qqnorm(resid(m)); qqline(resid(m))
```



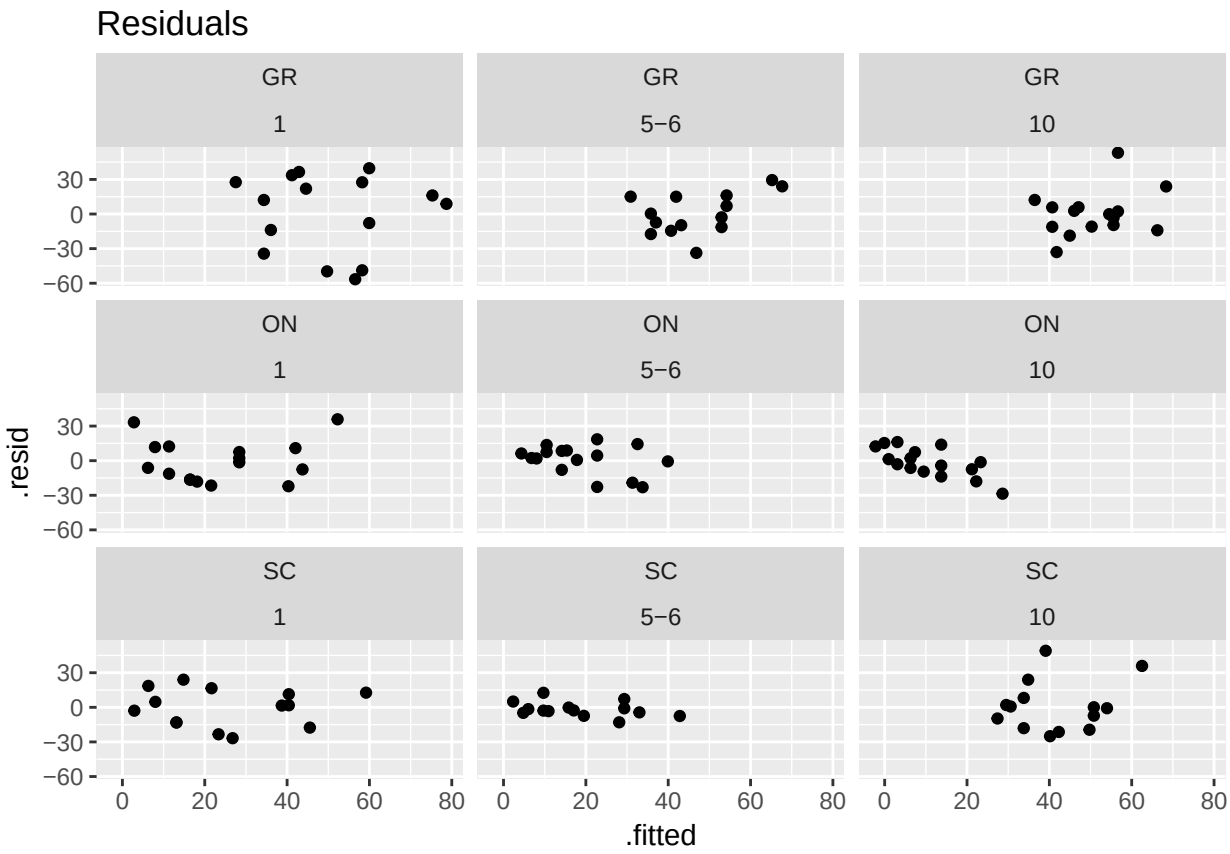

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst) + labs(title = 'Residuals')
```




```
#by yst and scode
d$yhat100_1000 <- predict(m)

p <- ggplot(data = d, aes(x = TC, y = sqrt(kgha_100_1000h), color = scode))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat100_1000))
p <- p + theme_classic()
p <- p + facet_wrap(scode~yst)
p <- p + labs(title = 'Masticated 100-hr + 1000-hr Fuels',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)',
              color = 'site')
plot(p)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst) + labs(title = 'Residuals
```



Tree Litter + Duff Fuels

```
#model, inferences, and residuals
m <- lmer(sqrt(duff) ~ yst + pre_tc + yst:pre_tc + (1 + yst|scode), data = d)
summary(m)
```

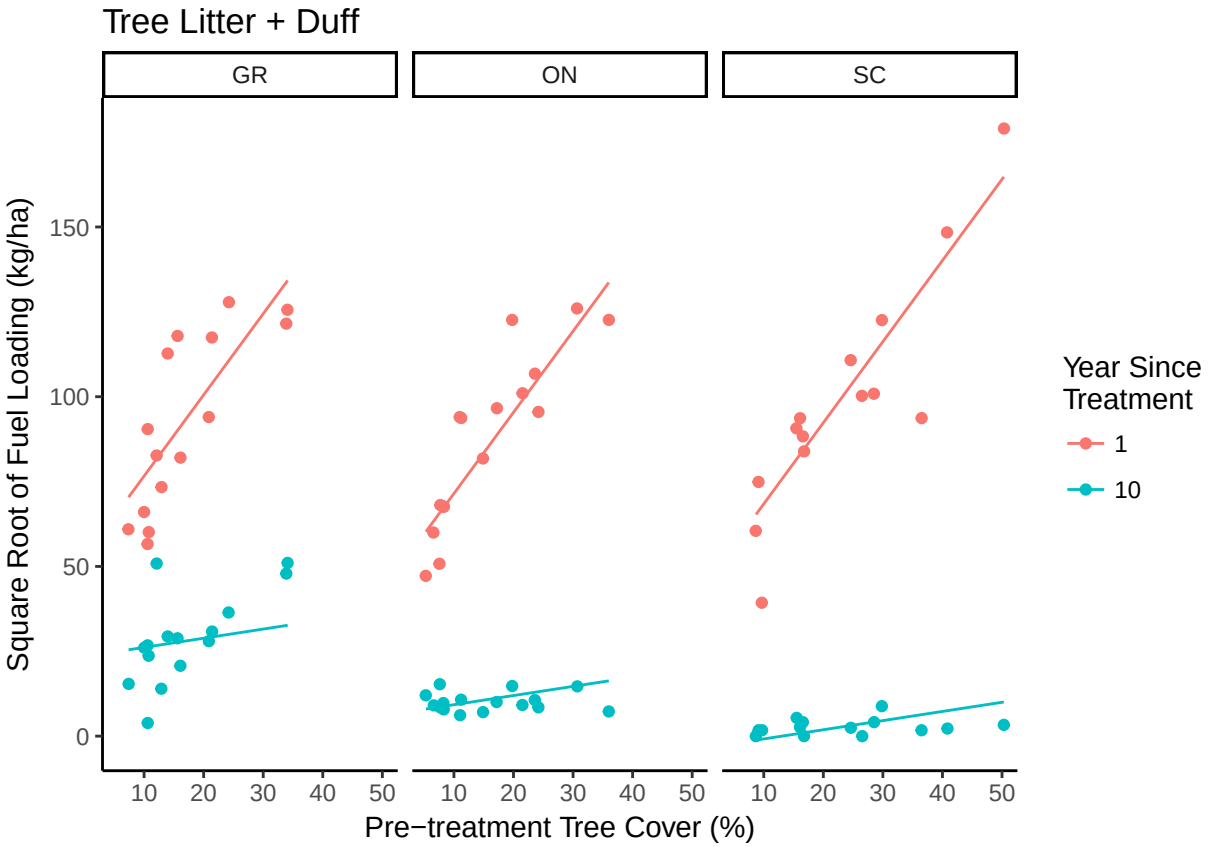
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(duff) ~ yst + pre_tc + yst:pre_tc + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 697.4
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.2668 -0.5465  0.0049  0.3963  2.3929
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  17.99    4.242
##           yst10        93.88    9.689   1.00
##  Residual             135.92   11.658
## Number of obs: 90, groups:  scode, 3
##
## Fixed effects:
```

```
##              Estimate Std. Error t value
## (Intercept)   48.2608     4.3365  11.129
## yst10        -39.4352     7.5666  -5.212
## pre_tc         2.3910     0.1679  14.242
## yst10:pre_tc  -2.1209     0.2392  -8.868
##
## Correlation of Fixed Effects:
##             (Intr) yst10  pre_tc
## yst10        0.038
## pre_tc      -0.721  0.400
## yst10:pr_tc  0.490 -0.590 -0.681
```

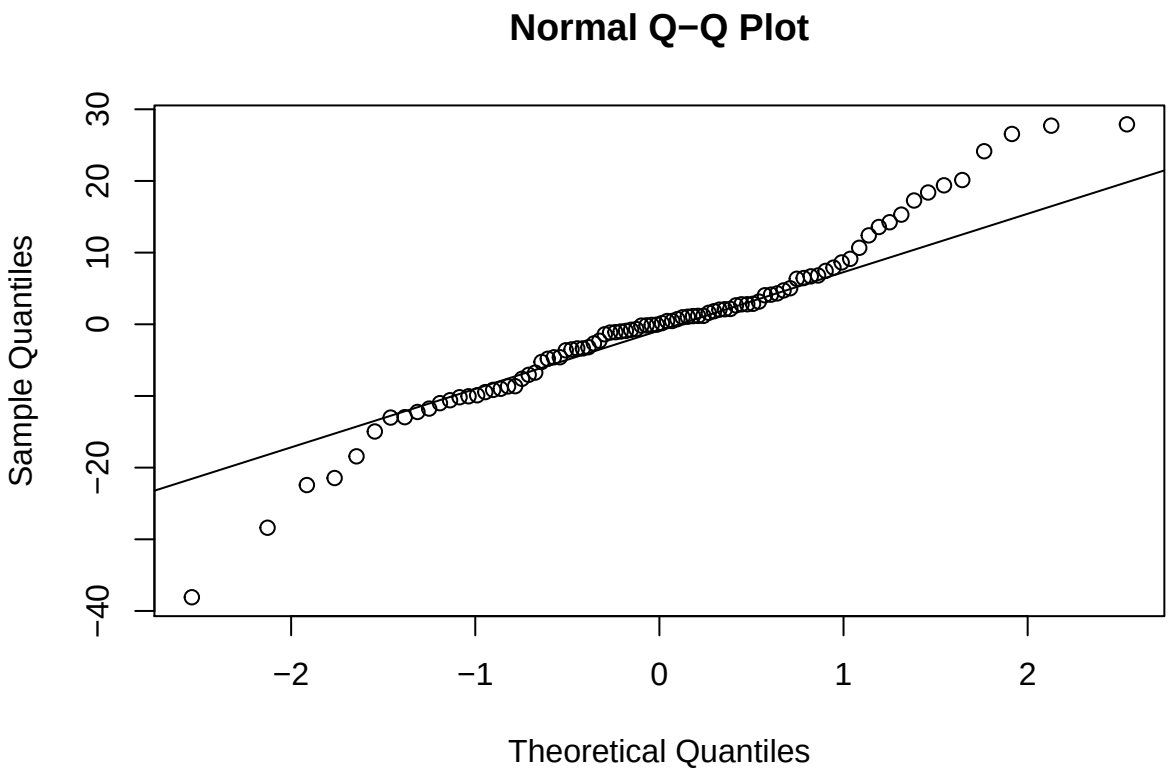
```
lincon(m)
```

```
##                estimate        se      lower      upper    tvalue  df
## (Intercept)   48.260752 4.3365105  39.761348  56.760157 11.128937 Inf
## yst10        -39.435246 7.5665734 -54.265457 -24.605034 -5.211771 Inf
## pre_tc         2.390954 0.1678787   2.061918   2.719990 14.242155 Inf
## yst10:pre_tc  -2.120931 0.2391646  -2.589685  -1.652177 -8.868080 Inf
##                    pvalue
## (Intercept)  9.071079e-29
## yst10        1.870467e-07
## pre_tc       5.015599e-46
## yst10:pre_tc 7.441802e-19
```

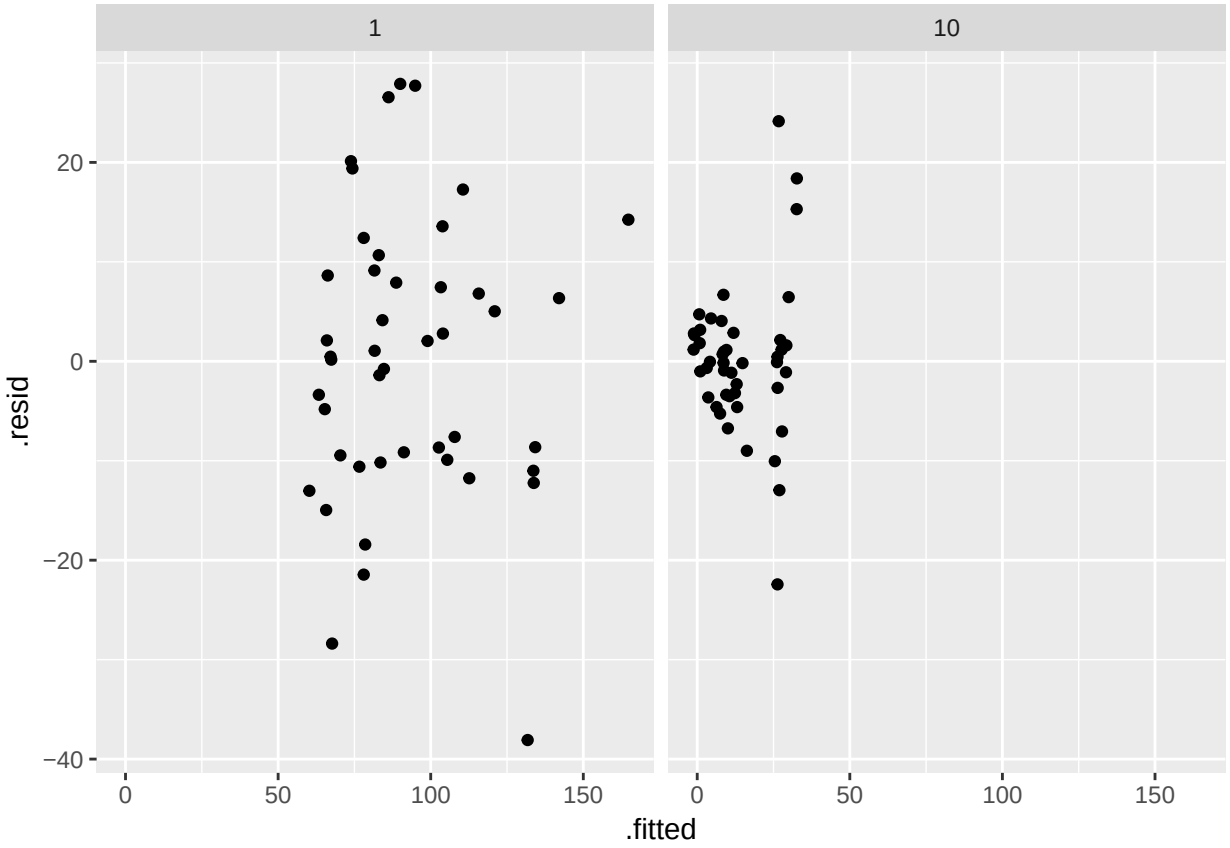
```
d$yhat_duff <- predict(m)
p <- ggplot(data = d, aes(x = pre_tc, y = sqrt(duff), color = yst))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat_duff))
p <- p + theme_classic() + facet_wrap(~scode)
p <- p + labs(title = 'Tree Litter + Duff',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)',
              color = 'Year Since \nTreatment')
plot(p)
```



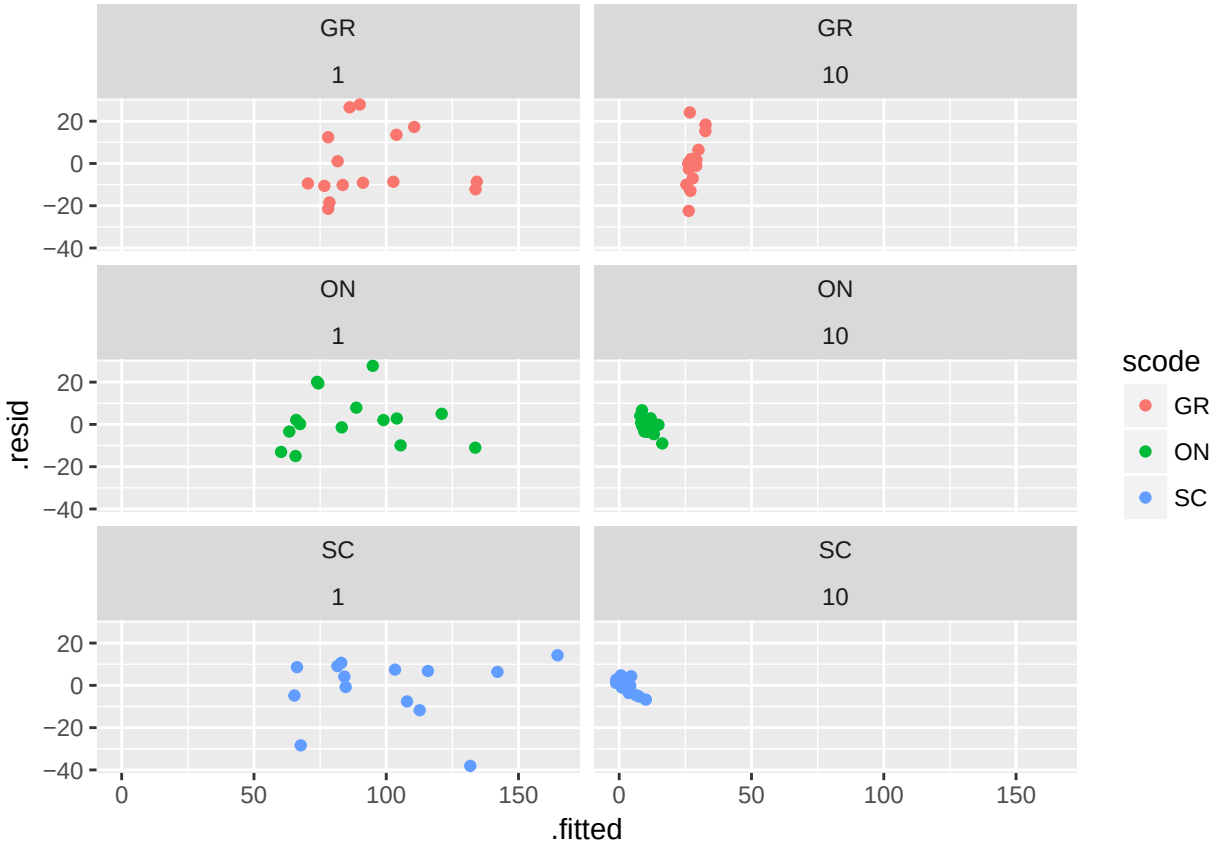

```
qqnorm(resid(m)); qqline(resid(m))
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
ggplot(m, aes(x = .fitted, y = .resid, color = scode)) + geom_point() + facet_wrap(scode~yst, nrow = 3)
```



For shrub and Herbaceous biomass and cover, use tree dominance index (TDI) instead of pre-treatment tree cover.

Tree Dominance Index (TDI) = (pre-treatment tree cover)/(pre-treatment tree cover + grass cover + shrub cover)

Herbaceous Fuels

yst = years since treatment

scode = site

herb_ttl = herbaceous fuel loading

**Investigate value of zero at Onaqui, yst = 10

```
precipitation <- read.csv('C:\\Users\\User\\Documents\\GitHub\\thesis\\Bruce\\edited\\precip_b_and_pris
precip <- precipitation %>%
  select(scode, yst, OJprecip, source) %>%
  filter(yst %in% c(0,1,2,3,6,10))
l <- left_join(l, precip, by = c('scode', 'yst'))
```

```
#m <- lmer(sqrt(herb_ttl) ~ TDI + yst + yst:TDI + (scode|yst), data = l)
m <- lmer(herb_ttl ~ TDI + yst + yst:TDI + (1 + yst|scode) + (1|OJprecip), data = l)
summary(m)
```

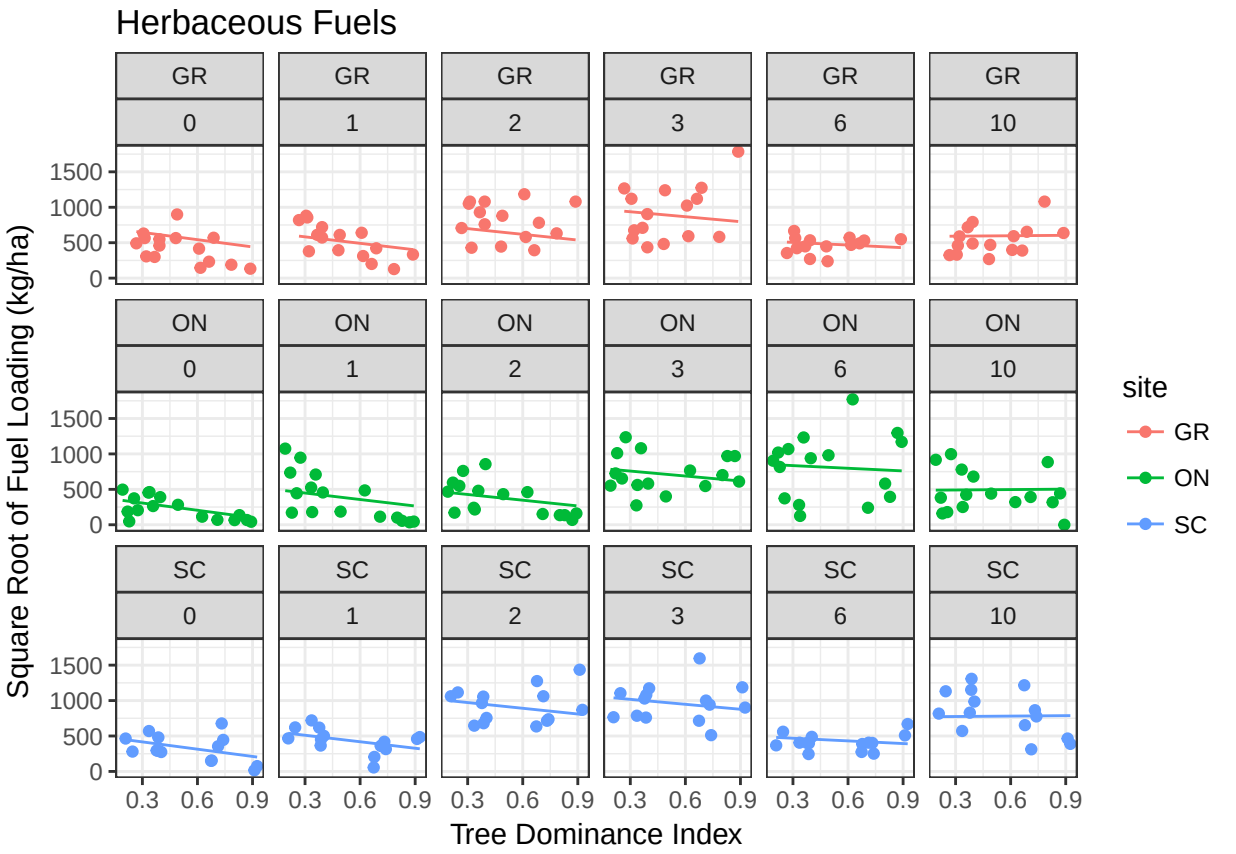
```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## herb_ttl ~ TDI + yst + yst:TDI + (1 + yst | scode) + (1 | OJprecip)
##    Data: l
##
## REML criterion at convergence: 3765.7
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.6624 -0.7147 -0.0646  0.5501  3.7205
##
## Random effects:
##  Groups   Name        Variance  Std.Dev. Corr
##  OJprecip (Intercept) 58117.706 241.076
##  scode    (Intercept)     6.902   2.627
##           yst           194.890  13.960  -1.00
##  Residual             70152.325 264.863
## Number of obs: 269, groups:  OJprecip, 14; scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   595.82     109.72   5.430
## TDI          -341.76     105.41  -3.242
## yst            22.64      22.80   0.993
## TDI:yst        36.16      21.13   1.712
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.499
## yst     -0.678  0.356
## TDI:yst  0.365 -0.731 -0.481
```

```
lincon(m)
```

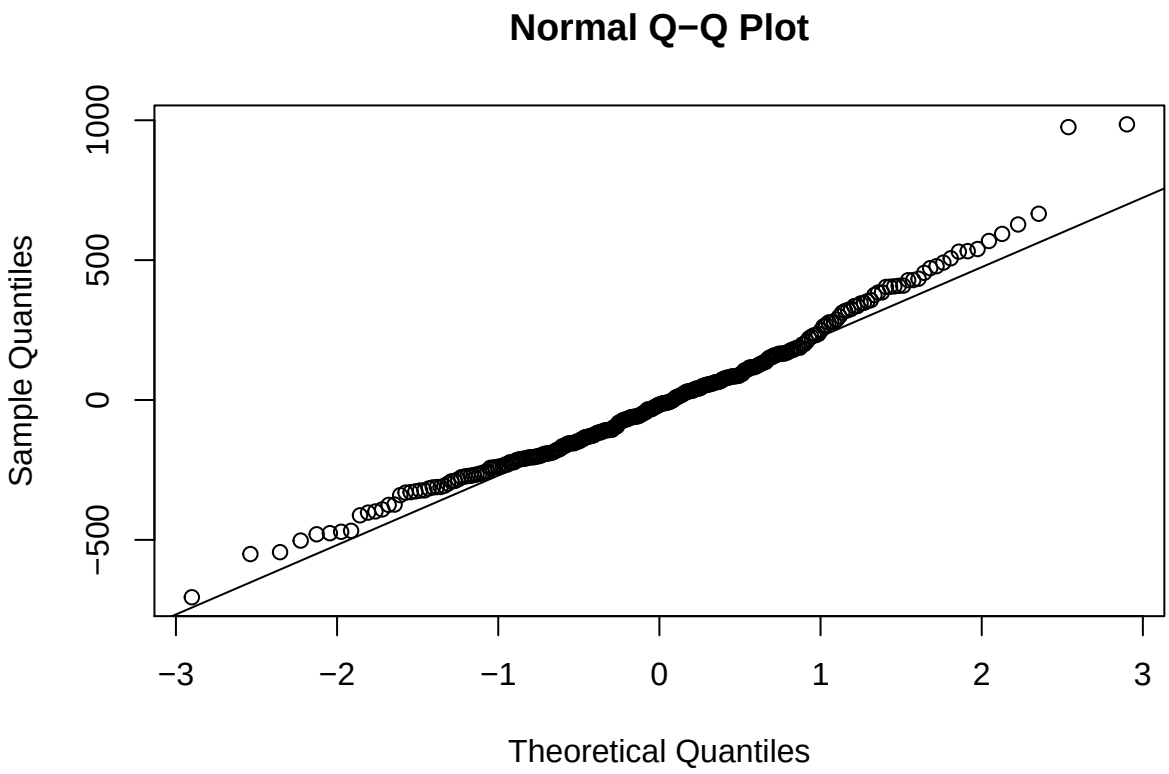
```
##               estimate        se       lower      upper     tvalue  df
## (Intercept)  595.82096 109.71884  380.775976  810.86594  5.4304341 Inf
## TDI         -341.76217 105.40896 -548.359934 -135.16440 -3.2422496 Inf
## yst           22.64326  22.79559  -22.035273   67.32180  0.9933177 Inf
## TDI:yst       36.15945  21.12652   -5.247758   77.56666  1.7115672 Inf
##                   pvalue
## (Intercept) 5.621712e-08
## TDI         1.185901e-03
## yst         3.205551e-01
## TDI:yst     8.697646e-02
```

```
l$yhat_herb <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = herb_ttl, color = scode))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_herb))
p <- p + theme_bw()
p <- p + labs(title = 'Herbaceous Fuels',
```

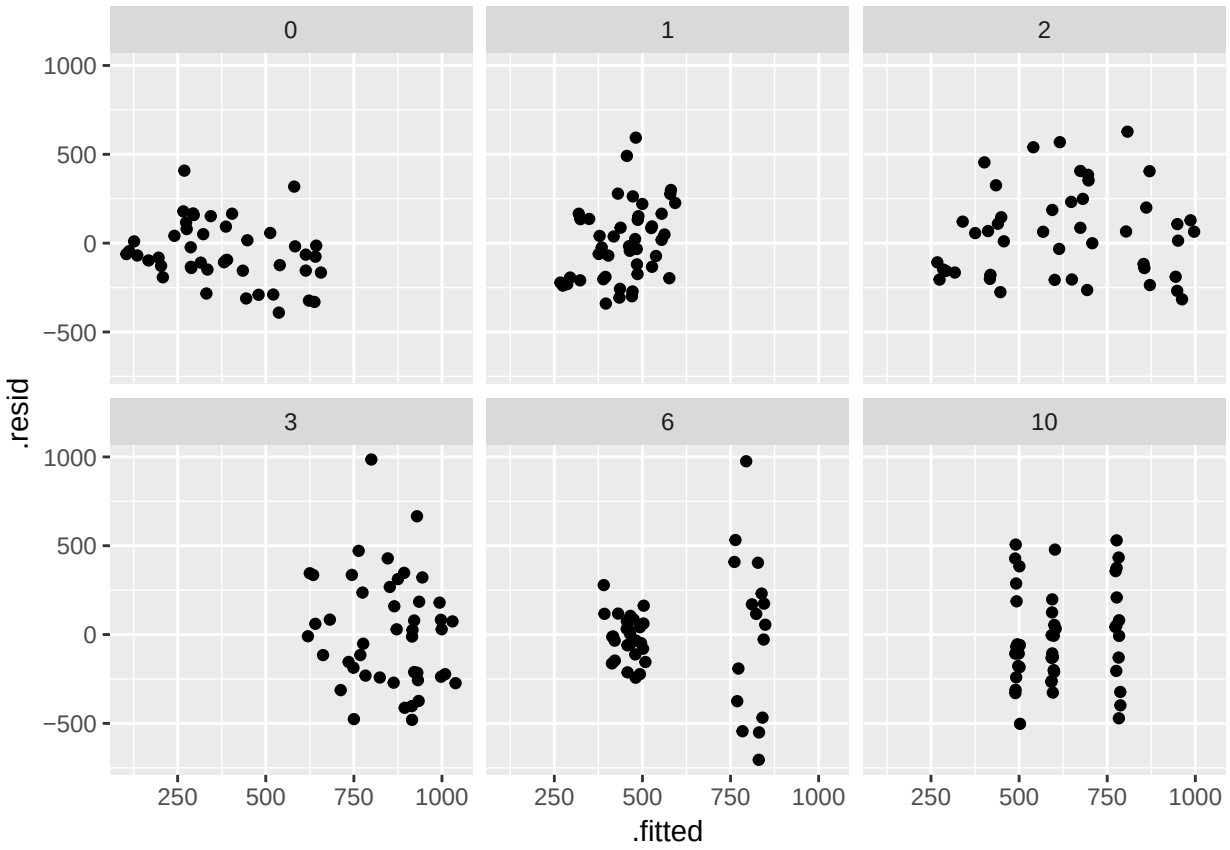
```
                x = 'Tree Dominance Index',
                y = 'Square Root of Fuel Loading (kg/ha)',
                color = 'site')
p <- p + scale_x_continuous(breaks = seq(0,1, by = 0.3))
p <- p + facet_wrap(scode~yst, ncol = 6, nrow = 3)
plot(p)
```



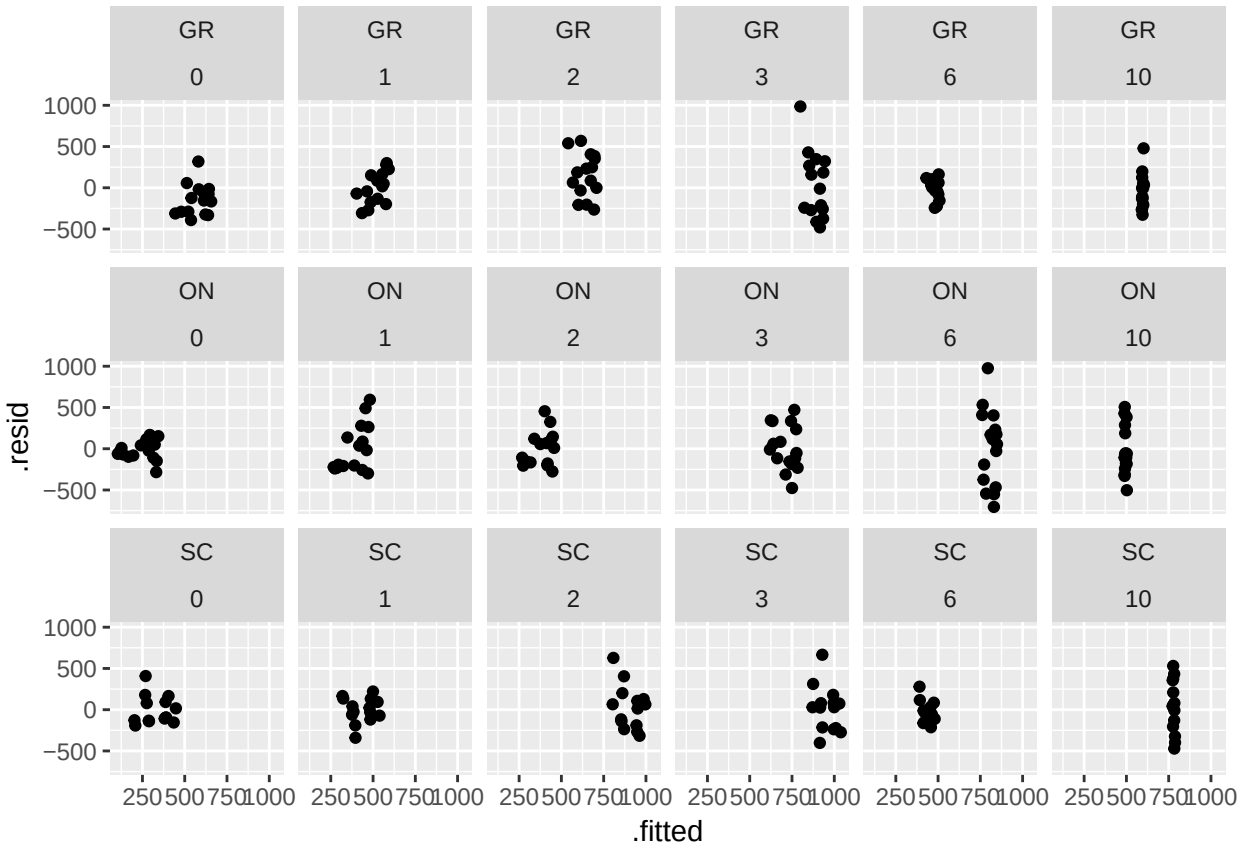

```
qqnorm(resid(m)); qqline(resid(m))
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst, nrow = 3, ncol = 6)
```



Shrub Fuels

**Data errors: Onaqui year 6, zero values are incorrect (JP-ON-GC-006, JP-ON-GC-010 have high shrub volumes but zero biomass)

**Missing data: no shrub data for Onaqui when YST = 0 (calendar year = 2006)

shrub_fuel = shrub fuel loading

TDI = tree dominance index

yst = years since treatment

scode = site

```
l$shrub_fuel <- abs(l$shrub_bio_ttl)

m <- lmer(sqrt(shrub_fuel) ~ TDI + yst + yst:TDI + (1 + yst|scode), data = l)
summary(m)
```

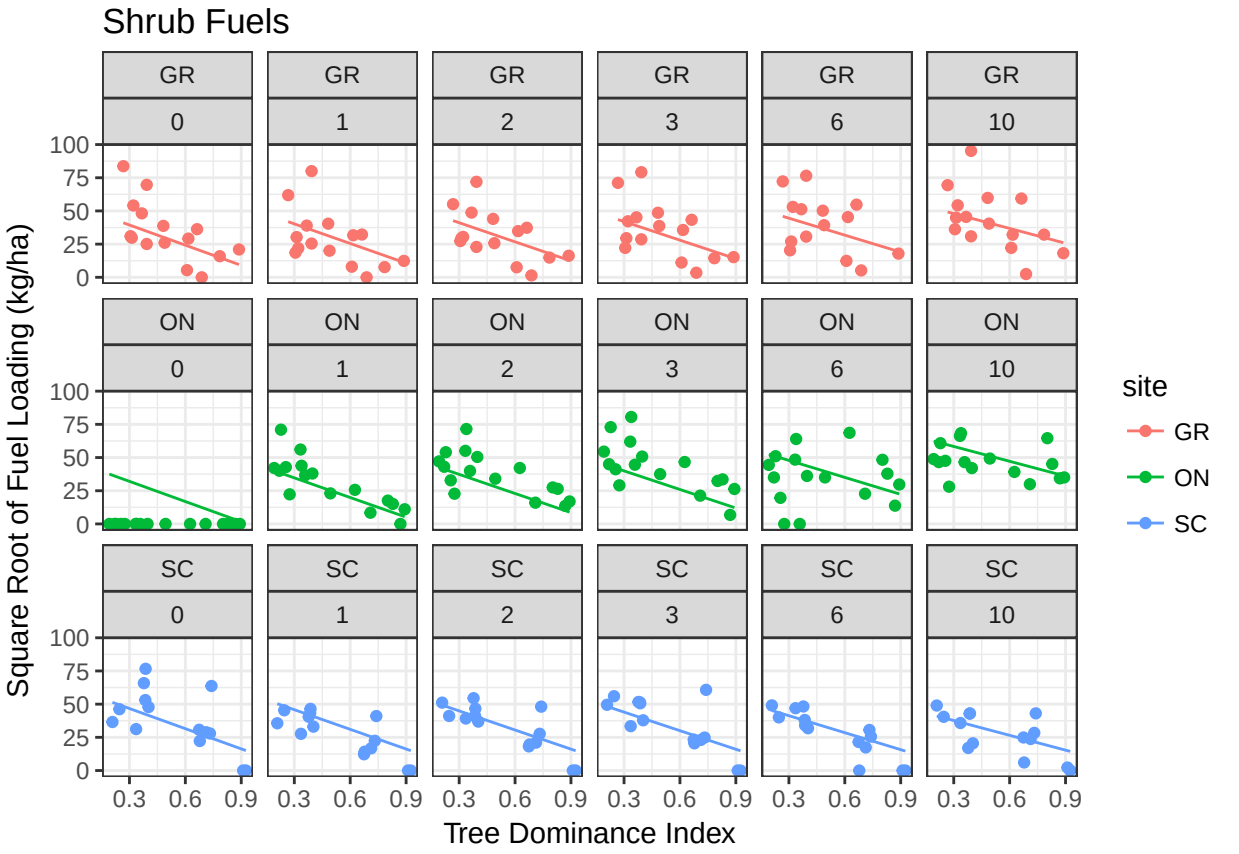
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(shrub_fuel) ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
## REML criterion at convergence: 2272.4
##
## Scaled residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -2.91834 -0.68826 -0.01133  0.56192  3.02800
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  57.985   7.615
##           yst           3.366   1.835   -1.00
##  Residual             280.626  16.752
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   54.594      5.774   9.455
## TDI          -50.675      6.665  -7.602
## yst            0.457      1.298   0.352
## TDI:yst        1.345      1.337   1.005
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.594
## yst     -0.897  0.390
## TDI:yst  0.437 -0.734 -0.530
```

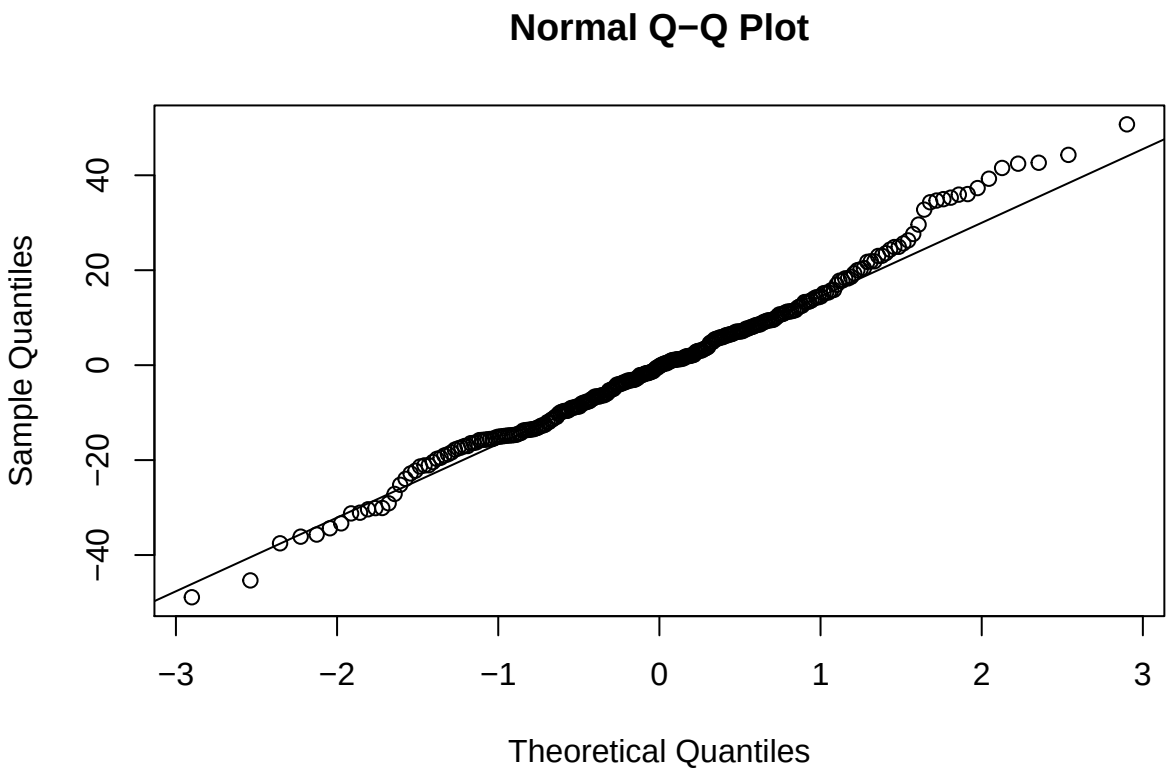
```
lincon(m)
```

```
##                 estimate       se      lower      upper     tvalue  df
## (Intercept)  54.5939092 5.774094  43.276894  65.910925  9.4549748 Inf
## TDI         -50.6745812 6.665541 -63.738801 -37.610362 -7.6024714 Inf
## yst           0.4569984 1.298245  -2.087516   3.001513  0.3520123 Inf
## TDI:yst       1.3446039 1.337326  -1.276508   3.965715  1.0054418 Inf
##                    pvalue
## (Intercept) 3.230998e-21
## TDI         2.905282e-14
## yst         7.248290e-01
## TDI:yst     3.146841e-01
```

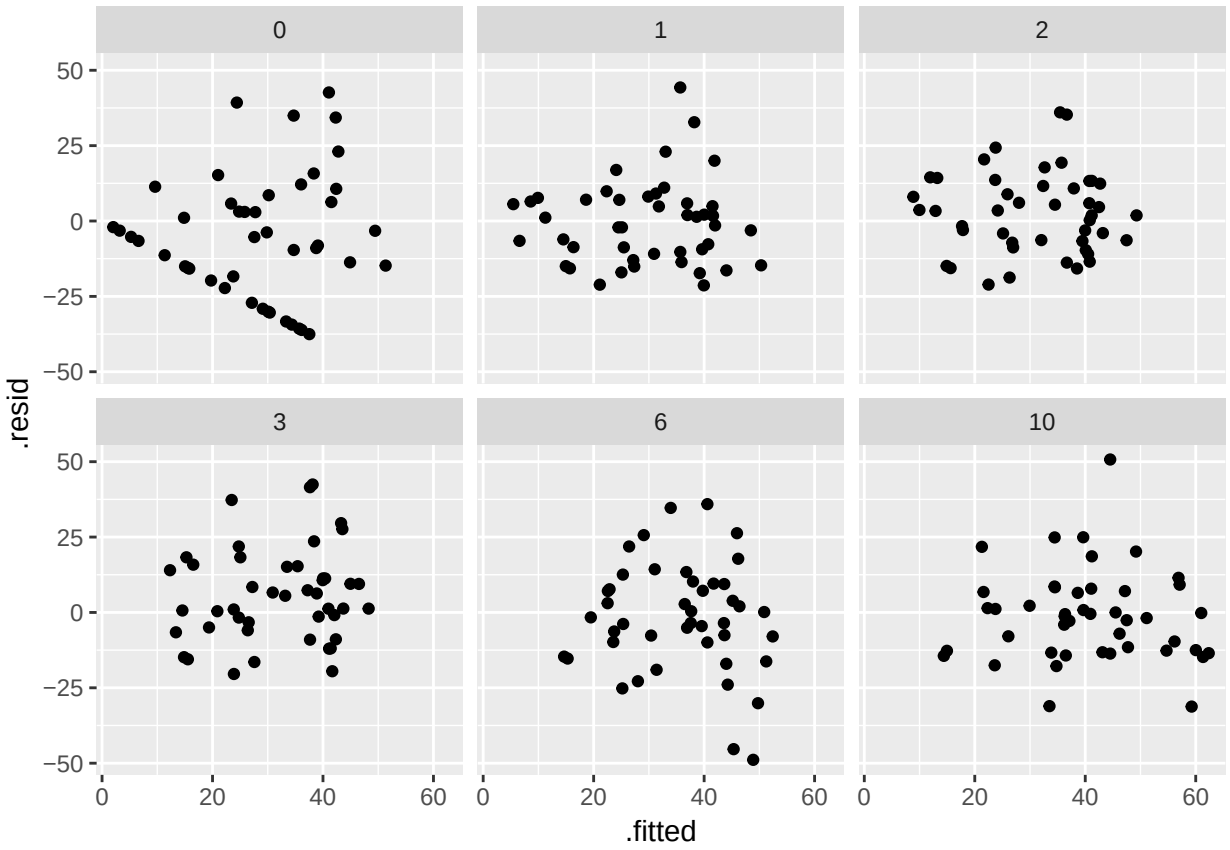
```
l$yhat_shrub <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = sqrt(shrub_fuel), color = scode))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_shrub))
p <- p + theme_bw()
p <- p + labs(title = 'Shrub Fuels',
              x = 'Tree Dominance Index',
              y = 'Square Root of Fuel Loading (kg/ha)',
              color = 'site')
p <- p + scale_x_continuous(breaks = seq(0,1, by = .3))
p <- p + facet_wrap(scode~yst, ncol = 6, nrow = 3)
plot(p)
```



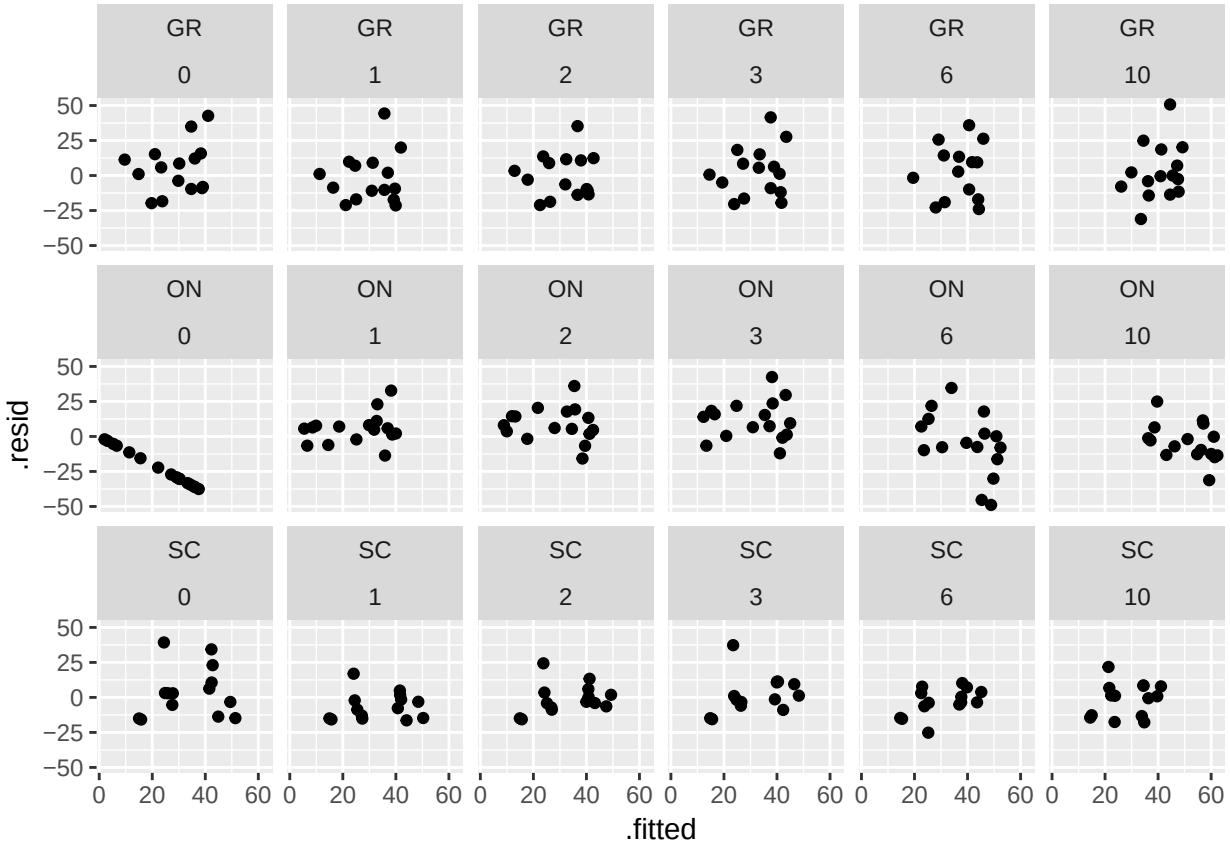

```
qqnorm(resid(m)); qqline(resid(m))
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst, ncol = 6, nrow = 3)
```



Shrub Cover

Note: Shrub cover increase when yst = 6 for scode = SC & GR but decrease in herb biomass

```
m <- lmer(can_cover_pt_shrub ~ TDI + yst + yst:TDI + (1 + yst|scode), data = l)
summary(m)
```

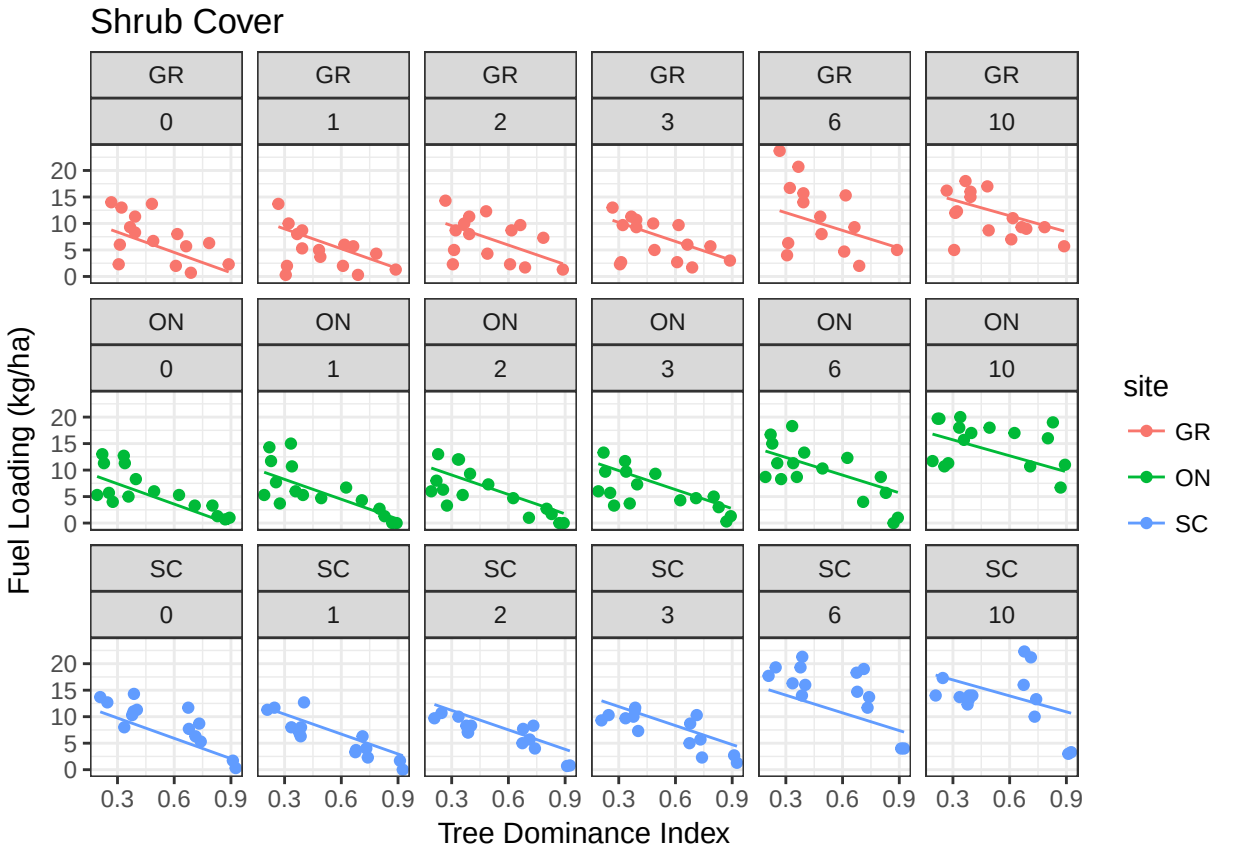
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: can_cover_pt_shrub ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
## REML criterion at convergence: 1474
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.53769 -0.71474 -0.07823  0.66138  3.05012
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  1.62781 1.2759
##           yst          0.02012 0.1419   -0.46
##  Residual             13.73500 3.7061
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
```

```
## (Intercept)  12.3467     1.1089  11.134
## TDI         -12.7825     1.4758  -8.661
## yst           0.6372     0.1848   3.448
## TDI:yst       0.2740     0.2952   0.928
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.685
## yst     -0.626  0.601
## TDI:yst  0.501 -0.731 -0.821
```

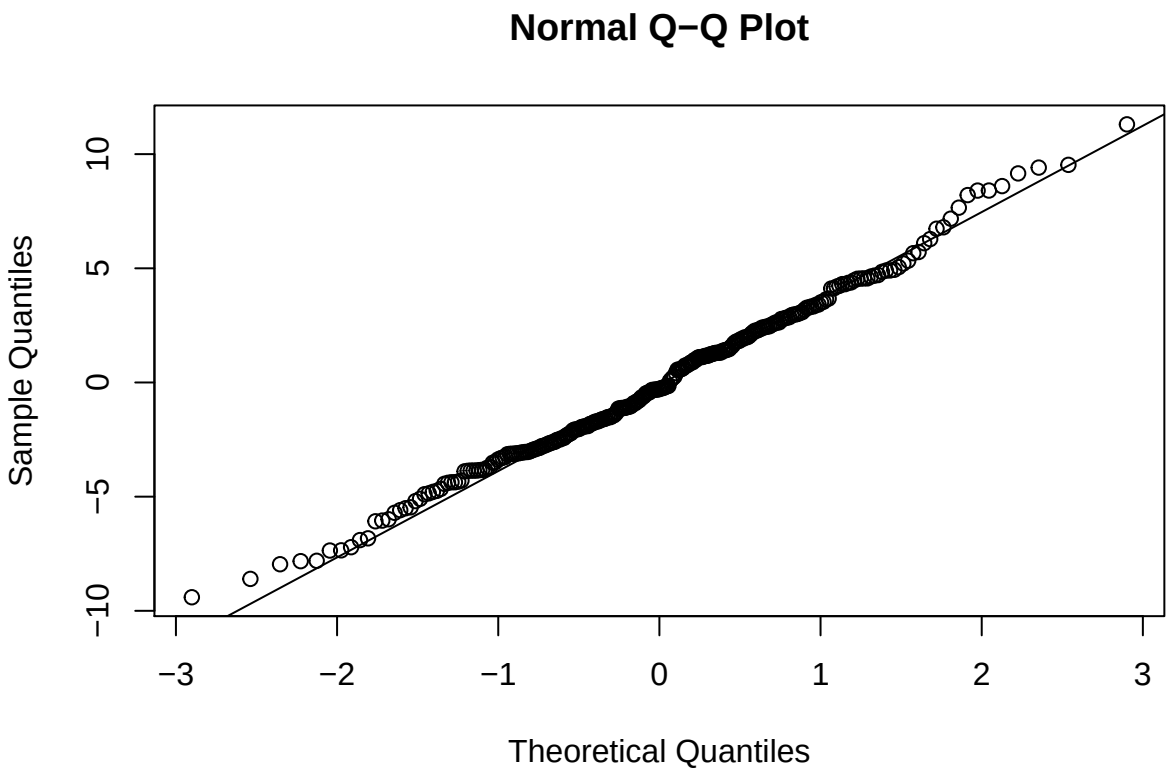
```
lincon(m)
```

```
##                estimate        se       lower      upper     tvalue  df
## (Intercept)  12.3466772 1.1089261  10.1732219 14.5201325 11.1339039 Inf
## TDI         -12.7825215 1.4758273 -15.6750899 -9.8899532 -8.6612585 Inf
## yst           0.6371933 0.1847986   0.2749947  0.9993920  3.4480415 Inf
## TDI:yst       0.2739555 0.2952431  -0.3047105  0.8526214  0.9278978 Inf
##                    pvalue
## (Intercept) 8.579394e-29
## TDI         4.665842e-18
## yst         5.646673e-04
## TDI:yst     3.534606e-01
```

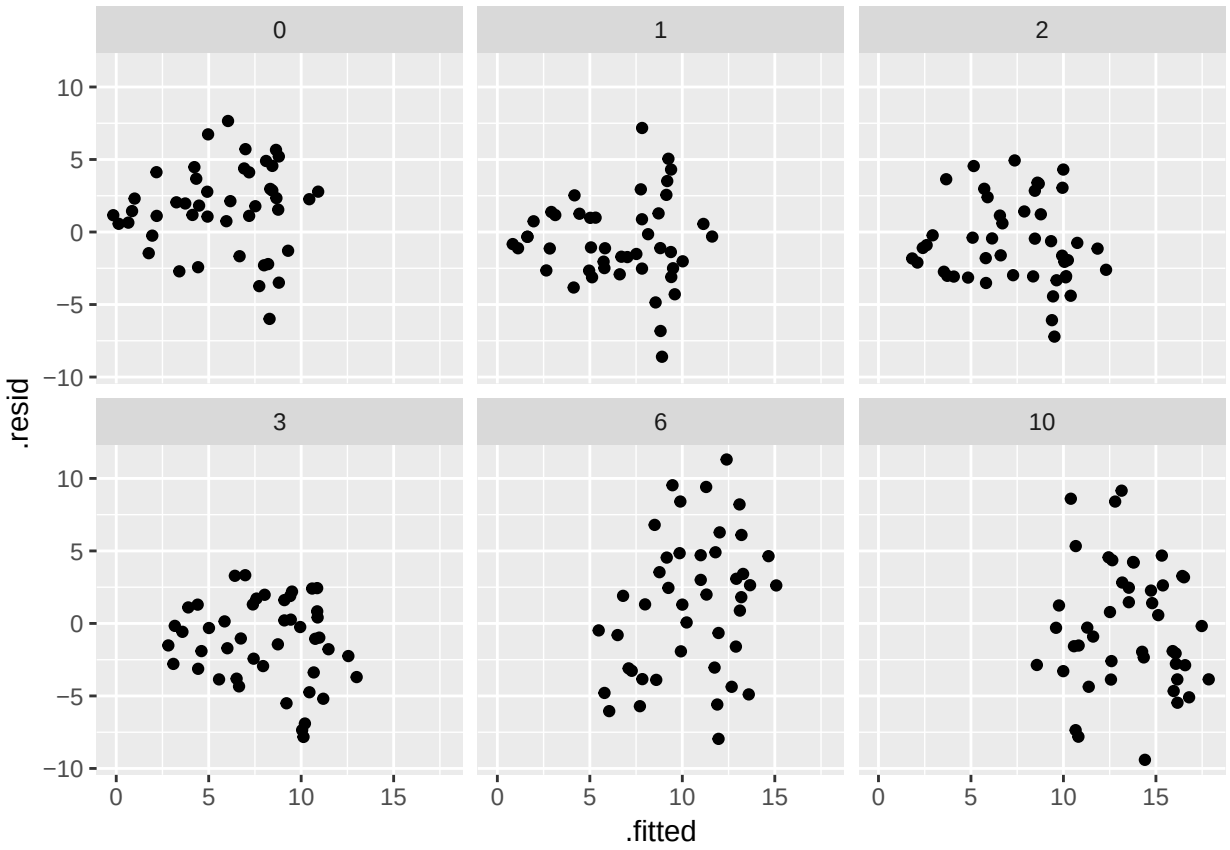
```
l$yhat_sh_cvr <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = can_cover_pt_shrub, color = scode))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_sh_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Shrub Cover',
              x = 'Tree Dominance Index',
              y = 'Fuel Loading (kg/ha)',
              color = 'site')
p <- p + scale_x_continuous(breaks = seq(0,1, by = 0.3))
p <- p + facet_wrap(scode~yst, ncol = 6, nrow = 3)
plot(p)
```



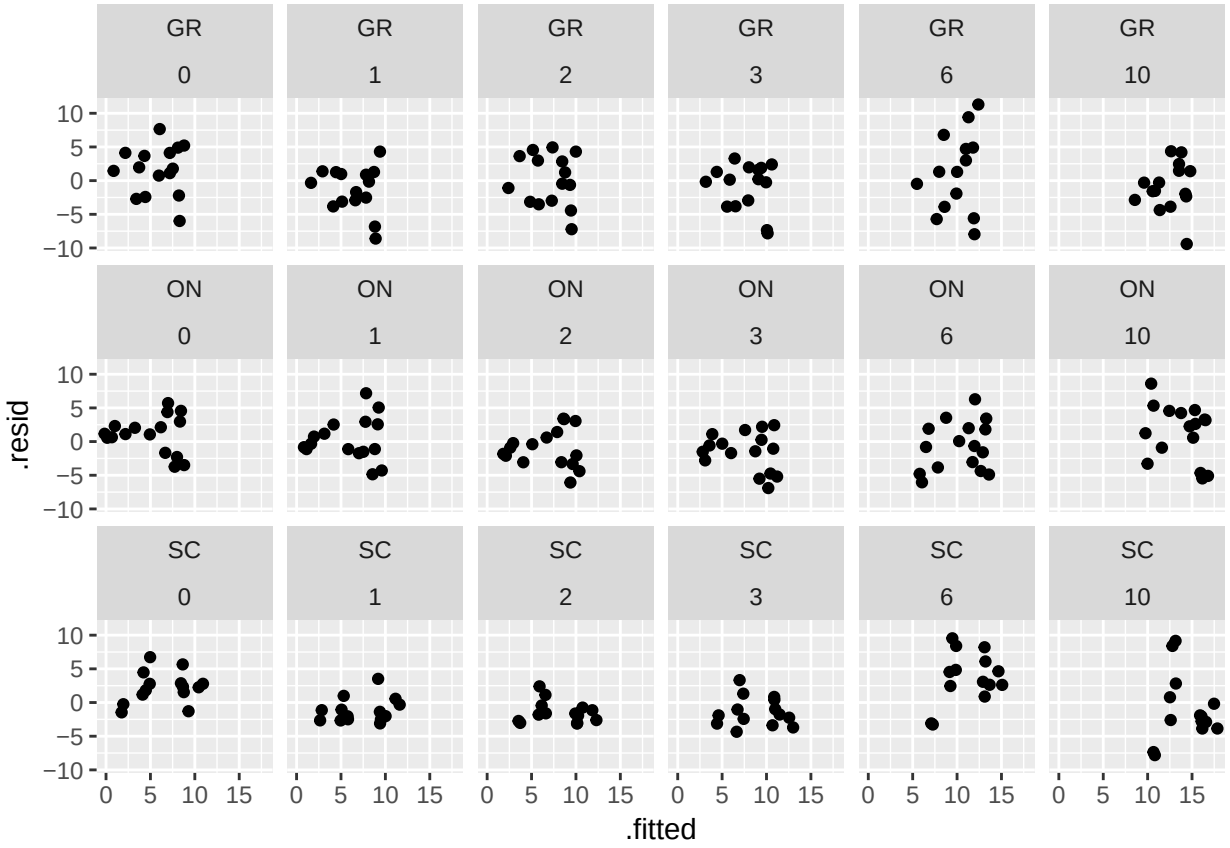

```
qqnorm(resid(m)); qqline(resid(m))
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst, ncol = 6, nrow = 3)
```



Perennial Grass Cover

```
m <- lmer(sqrt(can_cover_pt_pgrass) ~ TDI + yst + yst:TDI + (1 + yst|scode), data = l)
summary(m)
```

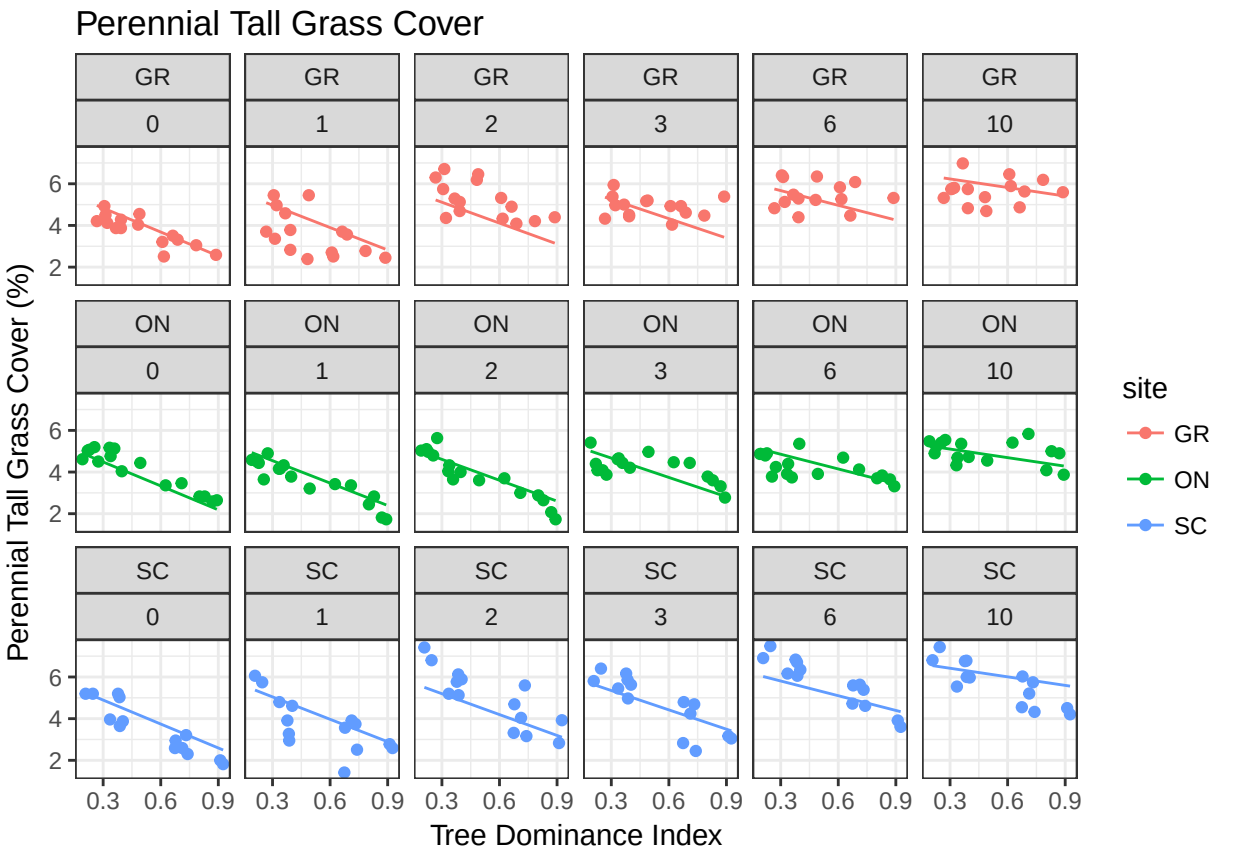
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(can_cover_pt_pgrass) ~ TDI + yst + yst:TDI + (1 + yst |
##     scode)
##    Data: l
##
## REML criterion at convergence: 627.4
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.05327 -0.61396 -0.02505  0.70445  2.63632
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 0.050221 0.22410
##           yst         0.002495 0.04995  1.00
##  Residual             0.561591 0.74939
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
```

```
## (Intercept)  5.88650    0.21107  27.889
## TDI         -3.83306    0.29717 -12.898
## yst          0.04423    0.04411   1.003
## TDI:yst      0.24627    0.05952   4.138
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.723
## yst     -0.035  0.505
## TDI:yst  0.527 -0.729 -0.693
```

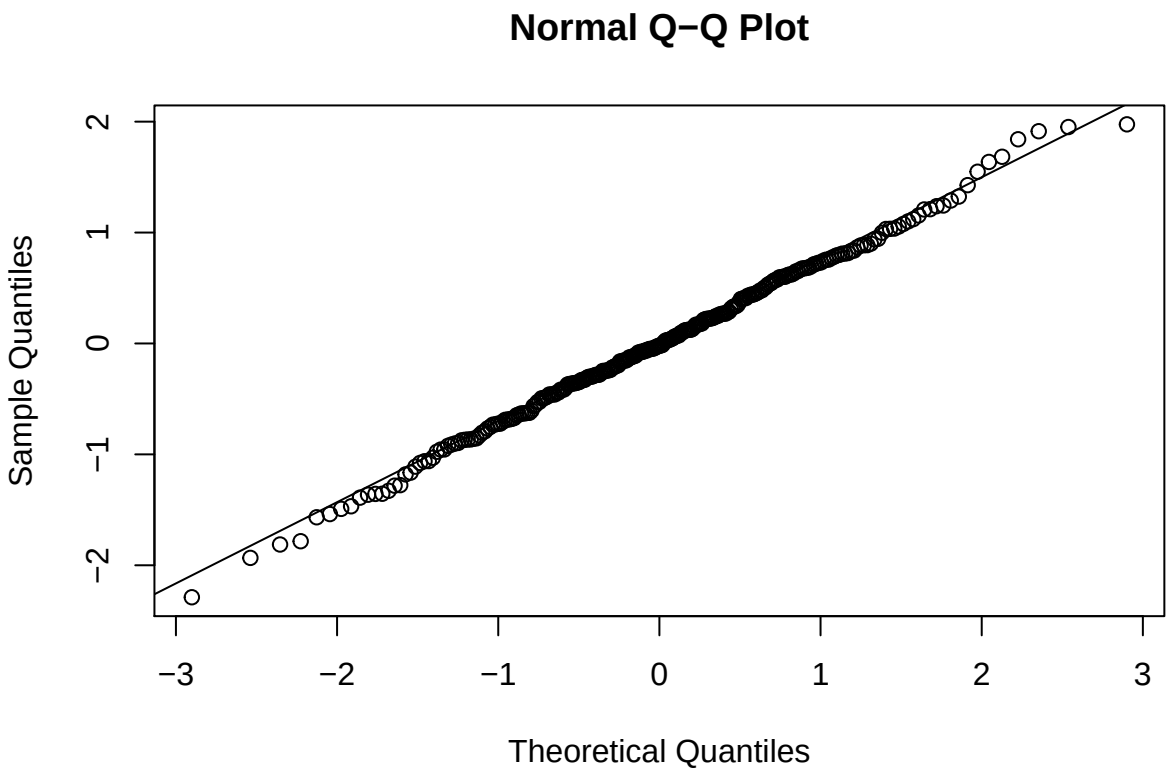
```
lincon(m)
```

```
##                estimate         se       lower      upper     tvalue  df
## (Intercept)  5.88649898 0.21106888  5.47281157  6.3001864  27.888995 Inf
## TDI         -3.83305891 0.29717257 -4.41550644 -3.2506114 -12.898428 Inf
## yst          0.04423219 0.04410908 -0.04222001  0.1306844   1.002791 Inf
## TDI:yst      0.24626761 0.05952036  0.12960984  0.3629254   4.137535 Inf
##                    pvalue
## (Intercept) 3.628195e-171
## TDI          4.593735e-38
## yst          3.159616e-01
## TDI:yst      3.510563e-05
```

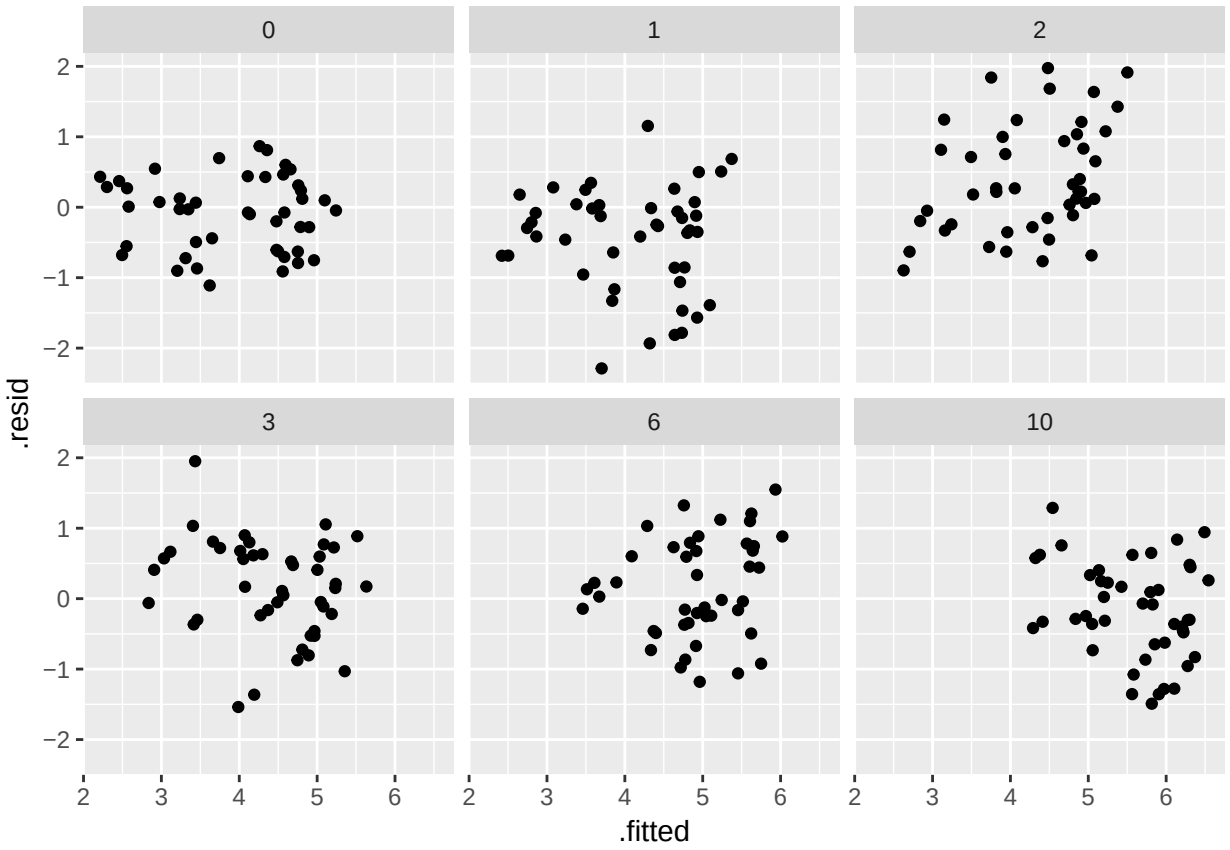
```
l$yhat_pgrass_cvr <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = sqrt(can_cover_pt_pgrass), color = scode))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_pgrass_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Perennial Tall Grass Cover',
              x = 'Tree Dominance Index',
              y = 'Perennial Tall Grass Cover (%)',
              color = 'site')
p <- p + scale_x_continuous(breaks = seq(0,1, by = 0.3))
p <- p + facet_wrap(scode~yst, ncol = 6, nrow = 3)
plot(p)
```



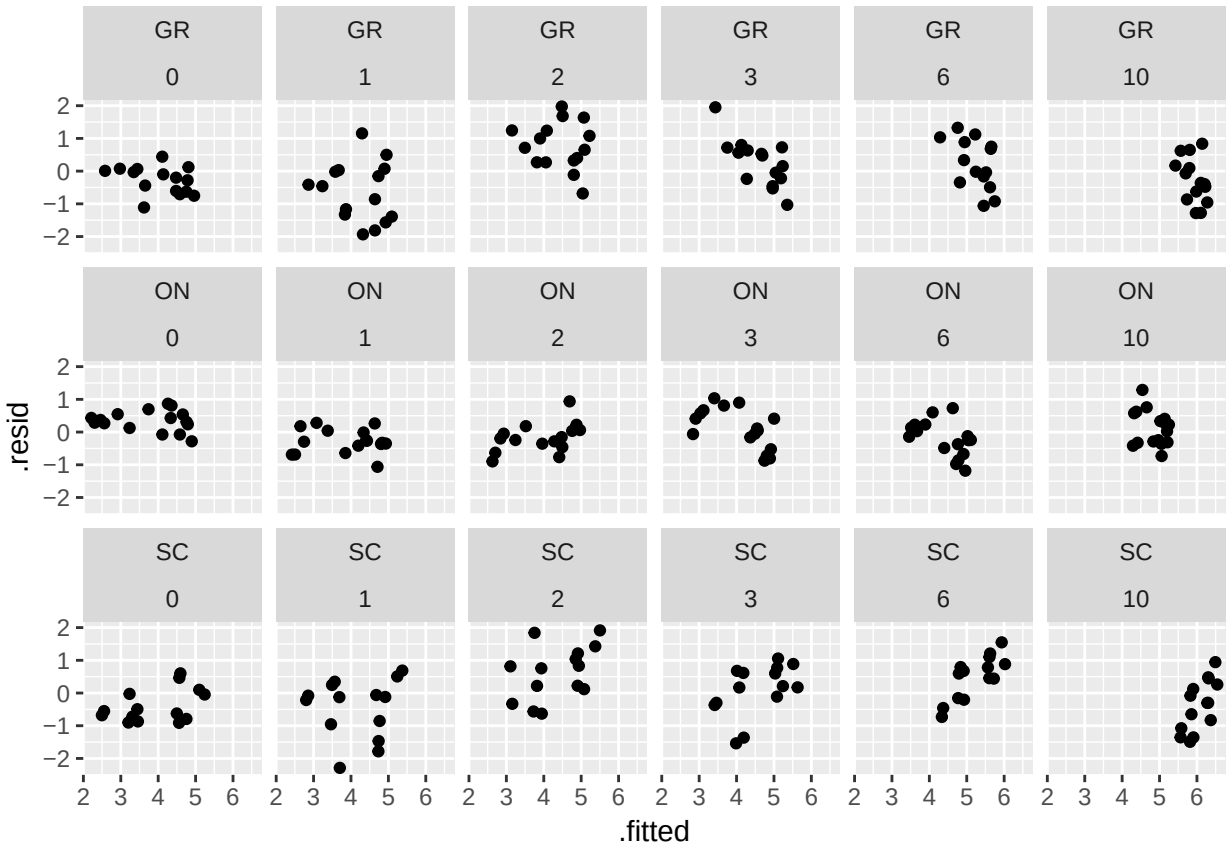

```
qqnorm(resid(m)); qqline(resid(m))
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst, ncol = 6, nrow = 3)
```



Annual Grass Cover

Note: what is going on at Scipio in yst = 6,10? Decrease in annual grass cover

```
m <- lmer(sqrt(can_cover_pt_agrass) ~ TDI + yst + yst:TDI + (1|scode), data = l)
summary(m)
```

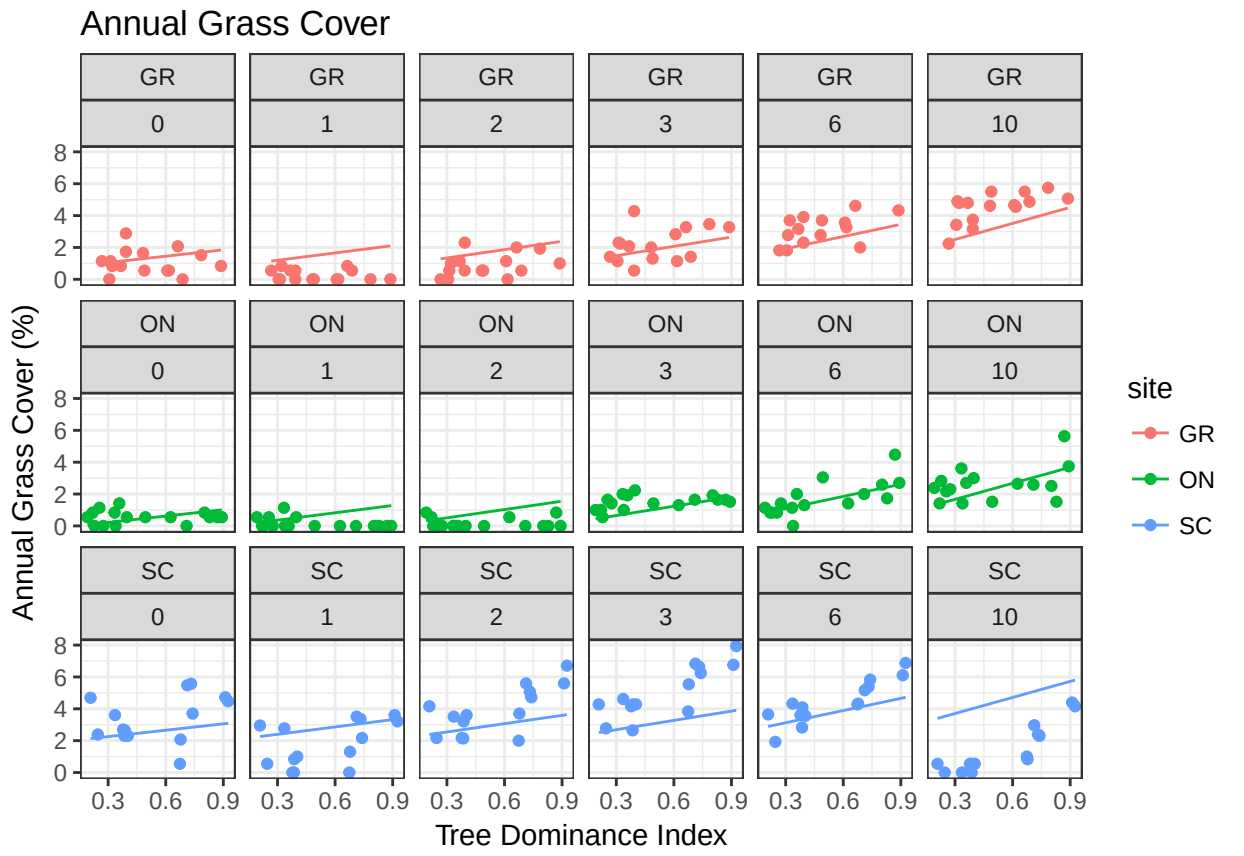
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(can_cover_pt_agrass) ~ TDI + yst + yst:TDI + (1 | scode)
##    Data: l
##
## REML criterion at convergence: 956.3
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.97289 -0.58525  0.01227  0.61552  2.89876
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  scode    (Intercept) 1.071    1.035
##  Residual             1.936    1.391
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  0.77343    0.67337   1.149
```

```
## TDI          1.33501    0.55304   2.414
## yst          0.08431    0.06189   1.362
## TDI:yst      0.20234    0.11040   1.833
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.422
## yst     -0.337  0.668
## TDI:yst  0.308 -0.729 -0.915
```

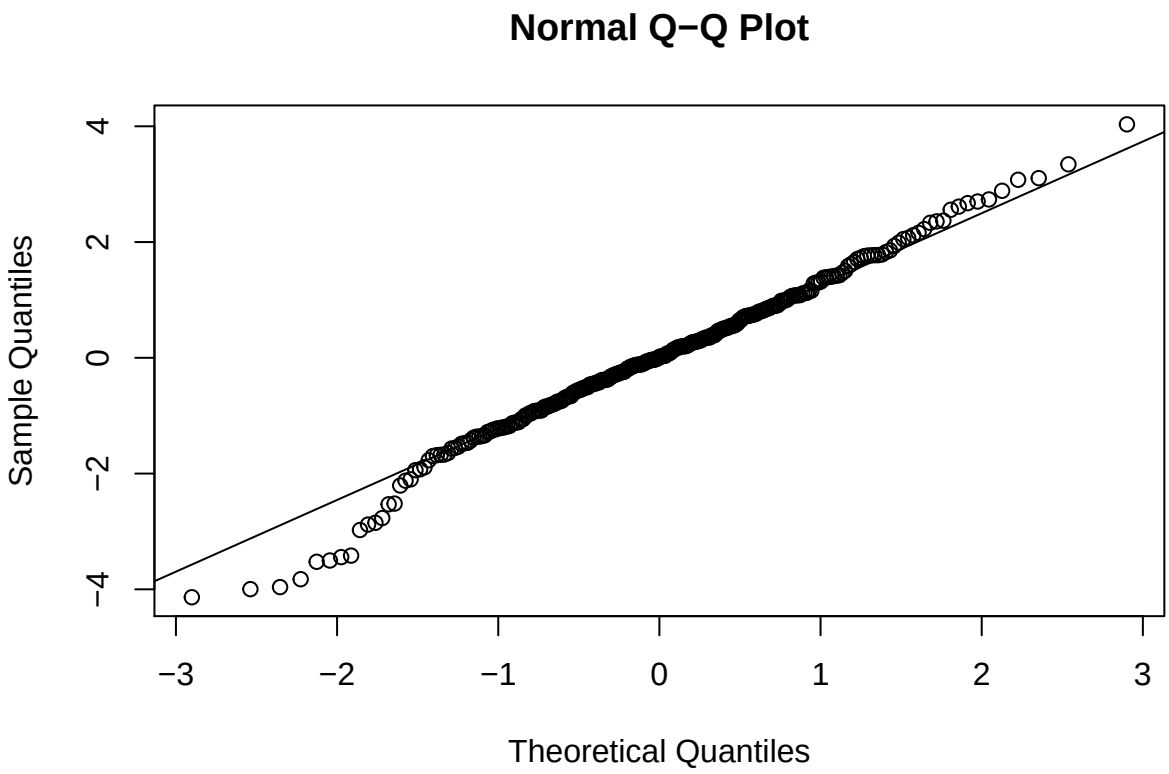
```
lincon(m)
```

```
##                estimate         se       lower     upper   tvalue  df
## (Intercept) 0.77342931 0.67336808 -0.54634787 2.0932065 1.148598 Inf
## TDI         1.33501430 0.55303675  0.25108218 2.4189464 2.413970 Inf
## yst         0.08431402 0.06189289 -0.03699380 0.2056218 1.362257 Inf
## TDI:yst     0.20233553 0.11039882 -0.01404218 0.4187132 1.832769 Inf
##                   pvalue
## (Intercept) 0.25072173
## TDI         0.01577975
## yst         0.17311675
## TDI:yst     0.06683693
```

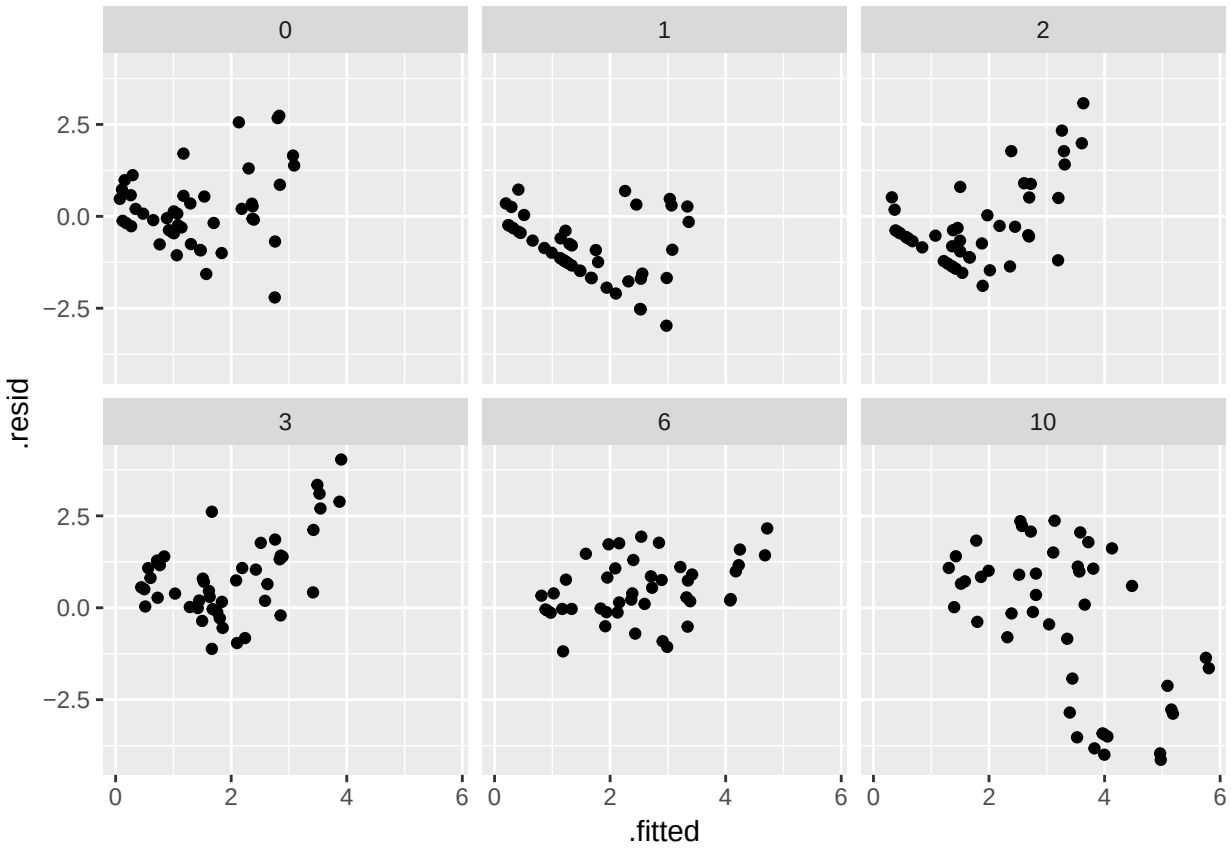
```
l$yhat_agrass_cvr <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = sqrt(can_cover_pt_agrass), color = scode))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_agrass_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Annual Grass Cover',
                x = 'Tree Dominance Index',
                y = 'Annual Grass Cover (%)',
                color = 'site')
p <- p + scale_x_continuous(breaks = seq(0,1, by = 0.3))
p <- p + facet_wrap(scode~yst, ncol = 6, nrow = 3)
plot(p)
```



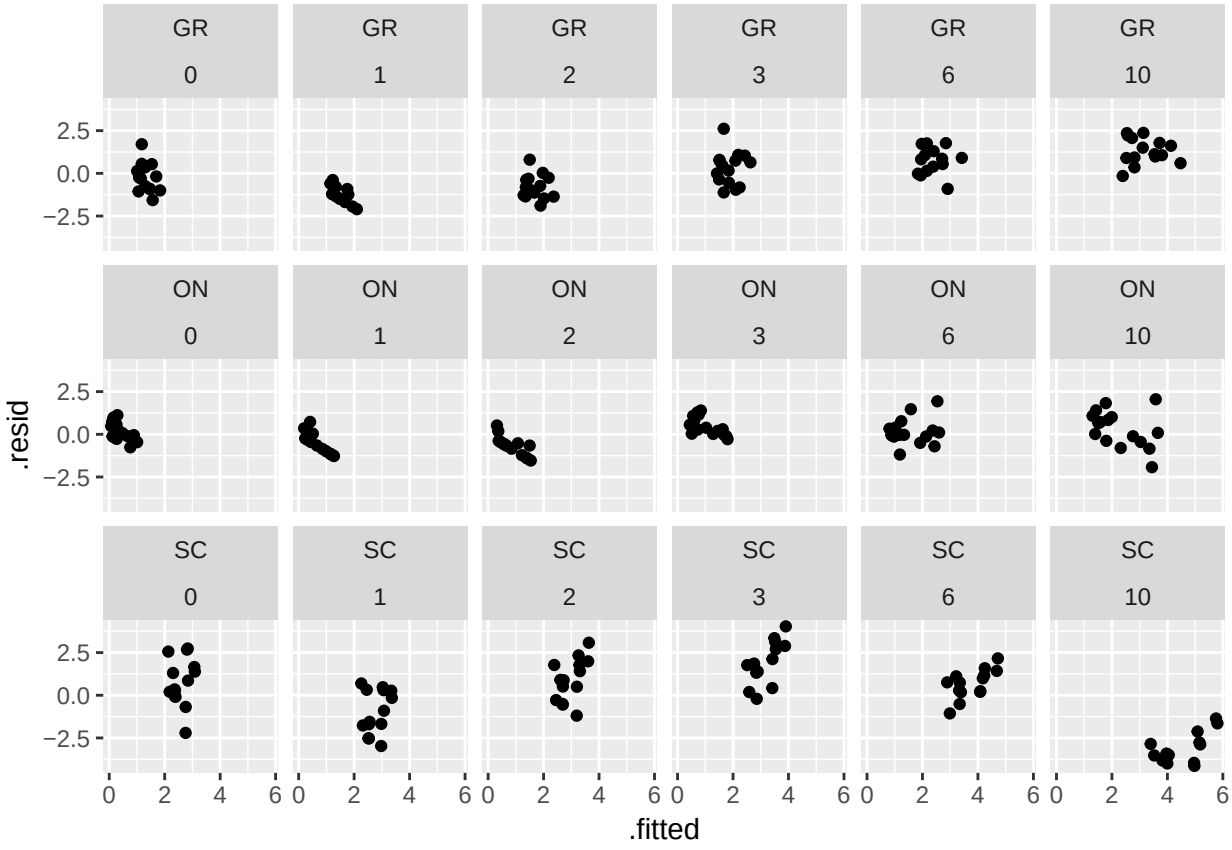

```
qqnorm(resid(m)); qqline(resid(m))
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst, ncol = 6, nrow = 3)
```



Tree Density >5 cm

```
td$tree_density <- td$tree_dns_5_50_JUOS + td$tree_dns_gt50_JUOS + td$tree_dns_5_50_PIED + td$tree_dns_g
td <- filter(td, (yst %in% c(-1,1,2,3,6,10) & scode %in% c('SC', 'GR')) | (yst %in% c(0,1,2,3,6,10) & sc
td$yst[td$yst == -1] <- 0  #so that all pre-treatment years are grouped together
```

MODEL FAILS TO CONVERGE UNLESS I TREAT YST AS FACTOR

```
m <- lmer(sqrt(tree_dns_gt50_JUOS + tree_dns_gt50_PIED) ~ TC + factor(yst) + factor(yst):TC + (1 + facto
summary(m)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## sqrt(tree_dns_gt50_JUOS + tree_dns_gt50_PIED) ~ TC + factor(yst) +
##     factor(yst):TC + (1 + factor(yst) | scode)
##    Data: td
##
## REML criterion at convergence: 924.9
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -4.404  0.000  0.000  0.000  3.279
##
## Random effects:
##  Groups   Name          Variance Std.Dev. Corr
```

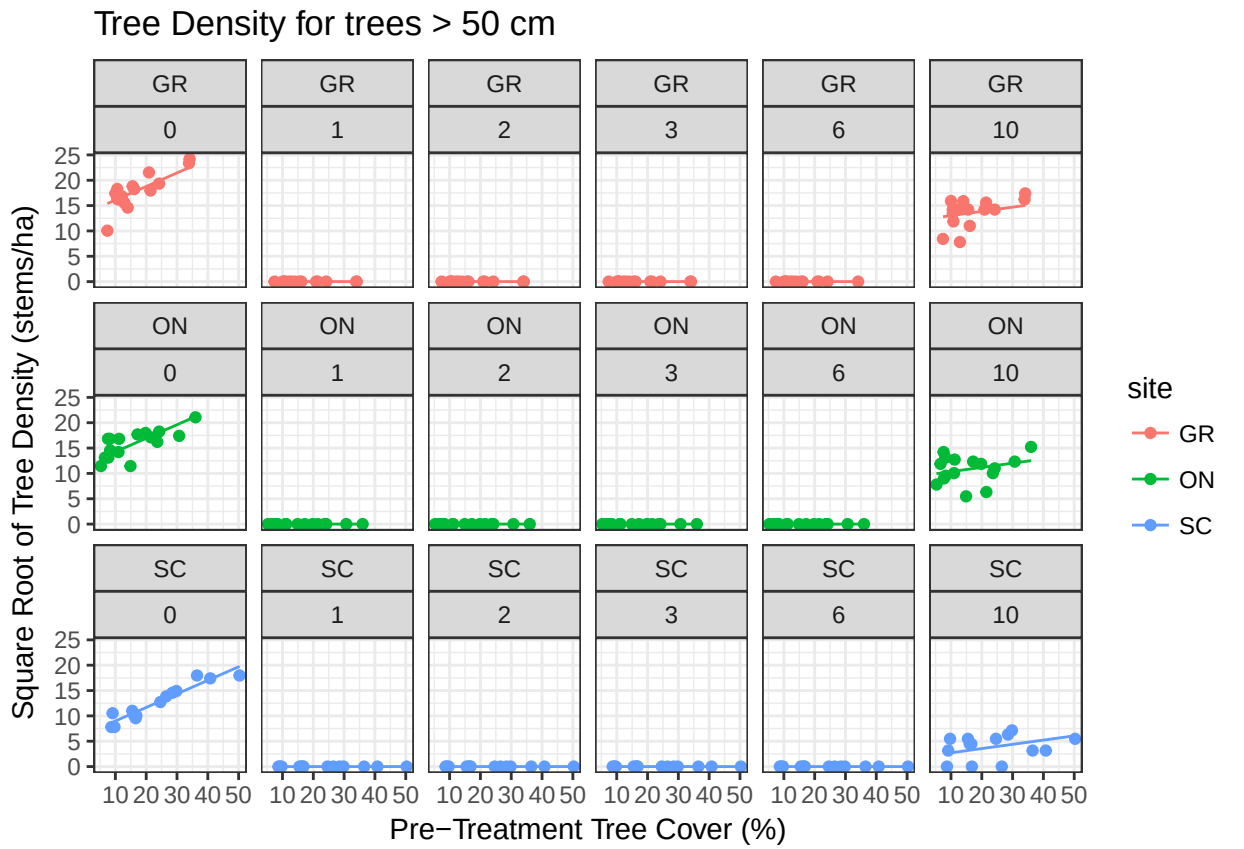
```
##  scode    (Intercept)   13.638   3.693
##           factor(yst)1  13.638   3.693    -1.00
##           factor(yst)2  13.638   3.693    -1.00  1.00
##           factor(yst)3  13.638   3.693    -1.00  1.00  1.00
##           factor(yst)6  13.638   3.693    -1.00  1.00  1.00  1.00
##           factor(yst)10  2.761   1.662     1.00 -1.00 -1.00 -1.00 -1.00
##  Residual                1.534   1.239
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##                    Estimate Std. Error t value
## (Intercept)       10.44257    2.16661   4.820
## TC                 0.26737    0.01808  14.791
## factor(yst)1     -10.44257    2.19944  -4.748
## factor(yst)2     -10.44257    2.19944  -4.748
## factor(yst)3     -10.44257    2.19944  -4.748
## factor(yst)6     -10.44257    2.19993  -4.747
## factor(yst)10     -2.57926    1.09906  -2.347
## TC:factor(yst)1   -0.26737    0.02534 -10.553
## TC:factor(yst)2   -0.26737    0.02534 -10.553
## TC:factor(yst)3   -0.26737    0.02534 -10.553
## TC:factor(yst)6   -0.26737    0.02565 -10.422
## TC:factor(yst)10  -0.18392    0.02515  -7.312
##
## Correlation of Fixed Effects:
##             (Intr) TC     fct()1 fct()2 fct()3 fct()6 fc()10 TC:f()1
## TC          -0.156
## factr(yst)1 -0.985  0.154
## factr(yst)2 -0.985  0.154  0.970
## factr(yst)3 -0.985  0.154  0.970  0.970
## factr(yst)6 -0.985  0.153  0.970  0.970  0.970
## fctr(yst)10  0.800  0.290 -0.788 -0.788 -0.788 -0.788
## TC:fctr(y)1  0.111 -0.713 -0.215 -0.110 -0.110 -0.110 -0.207
## TC:fctr(y)2  0.111 -0.713 -0.110 -0.215 -0.110 -0.110 -0.207  0.509
## TC:fctr(y)3  0.111 -0.713 -0.110 -0.110 -0.215 -0.110 -0.207  0.509
## TC:fctr(y)6  0.110 -0.705 -0.108 -0.108 -0.108 -0.215 -0.204  0.503
## TC:fctr()10  0.106 -0.682 -0.104 -0.104 -0.104 -0.104 -0.426  0.486
##             TC:()2 TC:()3 TC:()6
## TC
## factr(yst)1
## factr(yst)2
## factr(yst)3
## factr(yst)6
## fctr(yst)10
## TC:fctr(y)1
## TC:fctr(y)2
## TC:fctr(y)3  0.509
## TC:fctr(y)6  0.503  0.503
## TC:fctr()10  0.486  0.486  0.480
```

```
lincon(m)
```

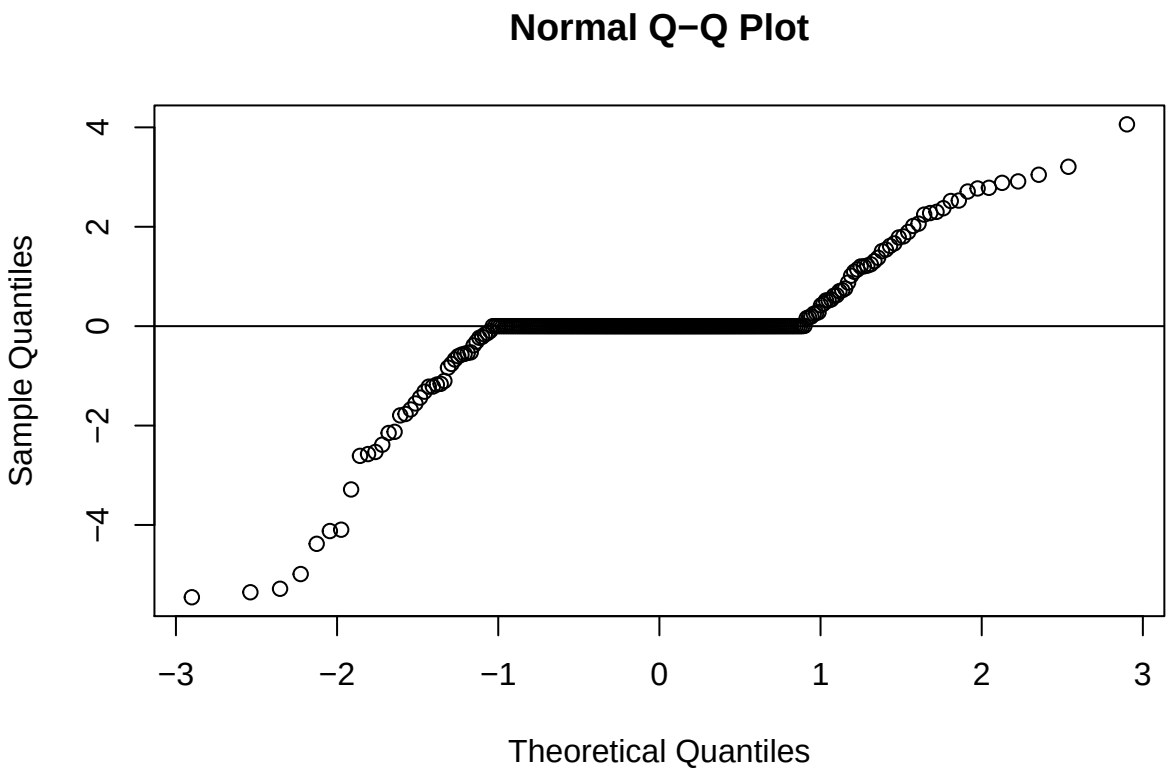
```
##                    estimate         se       lower      upper     tvalue
## (Intercept)       10.4425653 2.16660680   6.1960940 14.6890366   4.819779
## TC                 0.2673729 0.01807667   0.2319433  0.3028026  14.791048
```

```
## factor(yst)1     -10.4425653 2.19944008 -14.7533887 -6.1317420  -4.747829
## factor(yst)2     -10.4425654 2.19944002 -14.7533886 -6.1317421  -4.747829
## factor(yst)3     -10.4425653 2.19944013 -14.7533887 -6.1317418  -4.747829
## factor(yst)6     -10.4425653 2.19993239 -14.7543535 -6.1307770  -4.746766
## factor(yst)10     -2.5792637 1.09906011  -4.7333820 -0.4251455  -2.346790
## TC:factor(yst)1   -0.2673729 0.02533609  -0.3170308 -0.2177151 -10.553046
## TC:factor(yst)2   -0.2673729 0.02533609  -0.3170308 -0.2177151 -10.553046
## TC:factor(yst)3   -0.2673729 0.02533609  -0.3170308 -0.2177151 -10.553046
## TC:factor(yst)6   -0.2673729 0.02565495  -0.3176557 -0.2170902 -10.421887
## TC:factor(yst)10  -0.1839193 0.02515262  -0.2332176 -0.1346211  -7.312136
##                    df       pvalue
## (Intercept)       Inf 1.437175e-06
## TC                Inf 1.673278e-49
## factor(yst)1      Inf 2.056118e-06
## factor(yst)2      Inf 2.056116e-06
## factor(yst)3      Inf 2.056119e-06
## factor(yst)6      Inf 2.066944e-06
## factor(yst)10     Inf 1.893590e-02
## TC:factor(yst)1   Inf 4.917652e-26
## TC:factor(yst)2   Inf 4.917657e-26
## TC:factor(yst)3   Inf 4.917649e-26
## TC:factor(yst)6   Inf 1.970062e-25
## TC:factor(yst)10  Inf 2.629289e-13
```

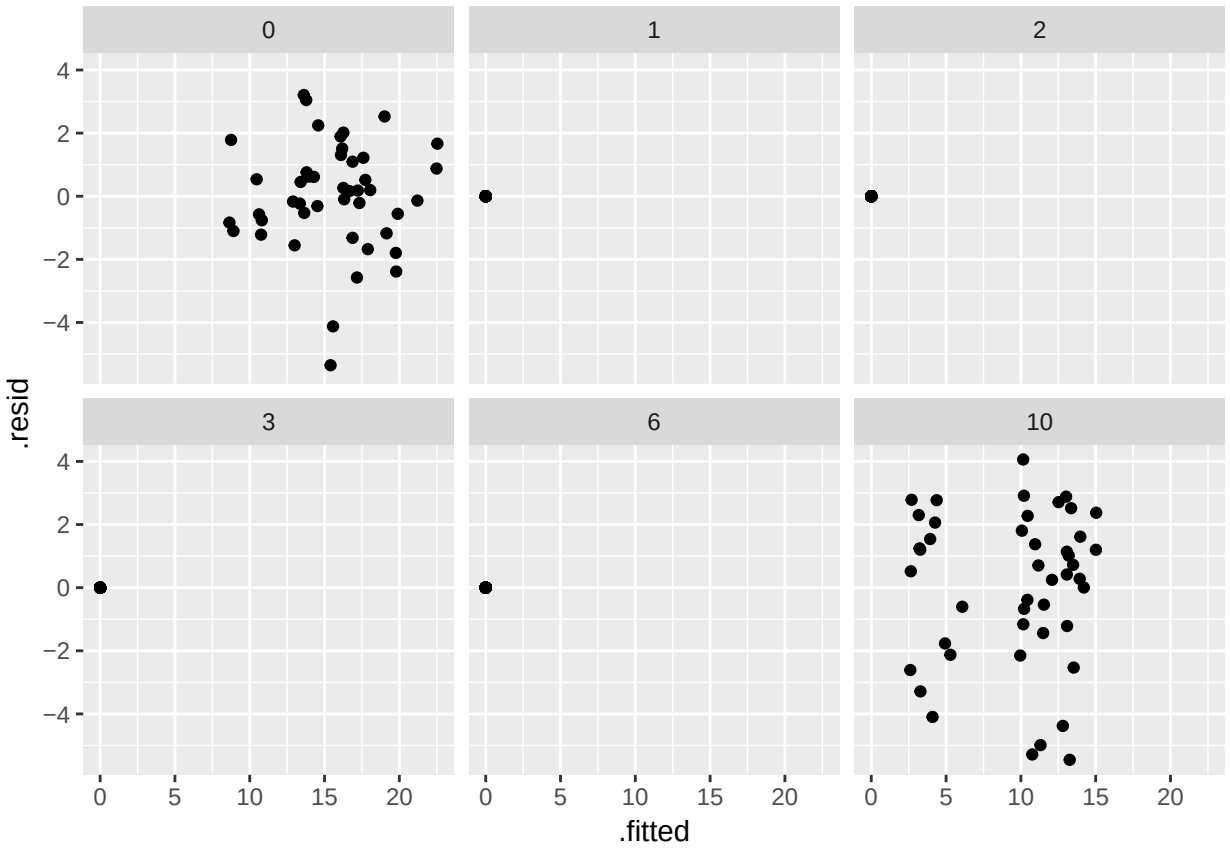
```
td$yhat_tree_dens <- predict(m)
p <- ggplot(data = td, aes(x = TC, y = sqrt(tree_dns_gt50_JUOS + tree_dns_gt50_PIED), color = scode))
p <- p + geom_point()
p <- p + theme_bw()
p <- p + geom_line(aes(y = yhat_tree_dens))
p <- p + labs(title = 'Tree Density for trees > 50 cm',
              x = 'Pre-Treatment Tree Cover (%)',
              y = 'Square Root of Tree Density (stems/ha)',
              color = 'site')
#p <- p + scale_x_continuous(breaks = seq(0,10, by = 2))
p <- p + facet_wrap(scode~yst, ncol = 6, nrow = 3)
plot(p)
```



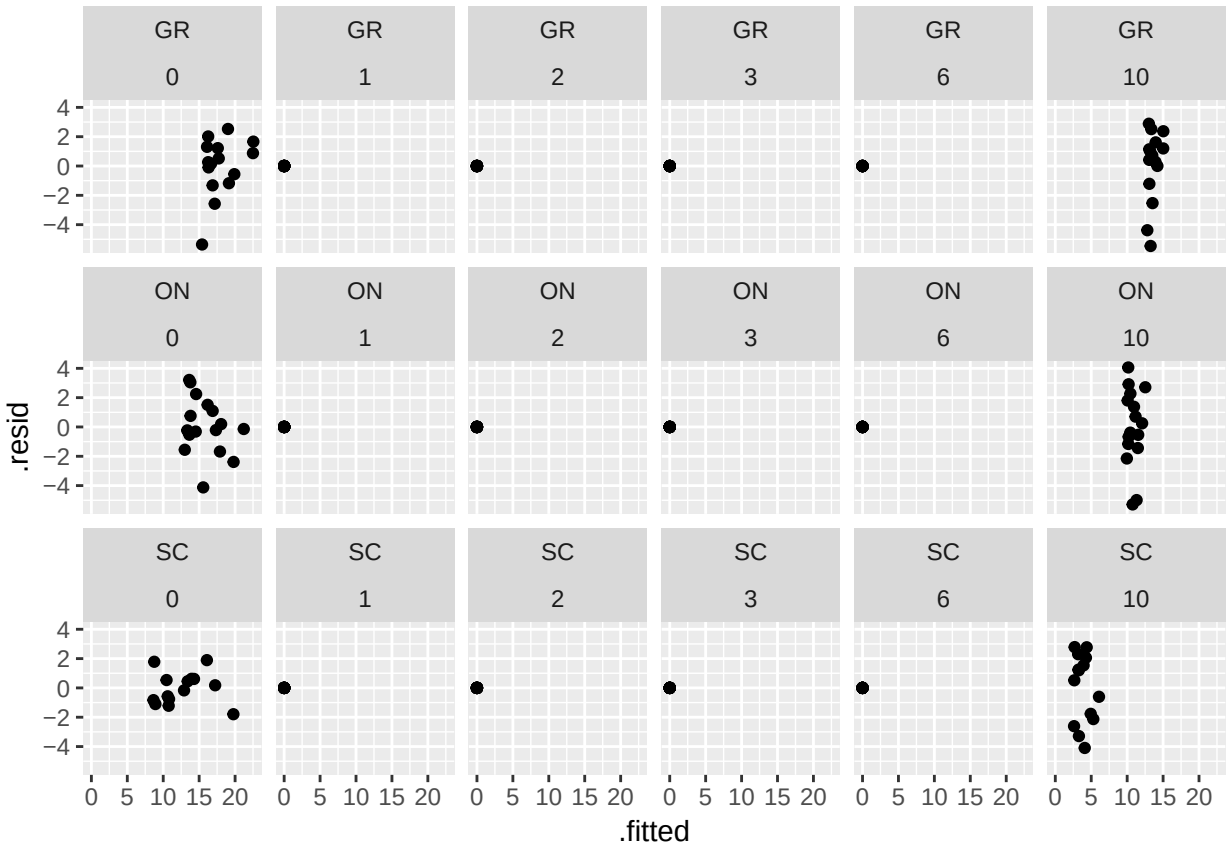

```
qqnorm(resid(m)); qqline(resid(m))
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(scode~yst, nrow = 3)
```



Tree Cover (trees > 50cm)

```
tcover <- filter(td, scode == 'ON' & year %in% c(6,16)|scode == 'GR' & year %in% c(6,17)|scode == 'SC' &
tcover$tree_cover_ttl[tcover$subplot_id %in% c('JP-SC-GC002', 'JP-SC-GC004', 'JP-SC-GC007') & tcover$yst
tcover$tree_cvr_PIED[tcover$subplot_id %in% c('JP-SC-GC002', 'JP-SC-GC004', 'JP-SC-GC007') & tcover$yst
tcover$tree_cvr_JUOS[tcover$subplot_id %in% c('JP-SC-GC002', 'JP-SC-GC004', 'JP-SC-GC007') & tcover$yst

m <- lmer(sqrt(tree_cover_ttl) ~ TC + yst + yst:TC + (1 + yst|scode), data = tcover)
summary(m)
lincon(m)


tcover$yhat_tree_cover <- predict(m)
p <- ggplot(data = tcover, aes(x = TC, y = sqrt(tree_cover_ttl), color = scode))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat_tree_cover))
p <- p + theme_bw()
p <- p + labs(title = 'Tree Cover',
              x = 'Pre-Treatment Tree Cover (%)',
              y = 'Square Root of Tree Cover (%)')
p <- p + scale_x_continuous(breaks = seq(0,1, by = 0.3))
p <- p + facet_wrap(scode~yst, ncol = 2, nrow = 3)
plot(p)
```

```
qqnorm(resid(m)); qqline(resid(m))
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point(aes(color = scode)) + facet_wrap(scode~yst, ncol =
```