Masticated Fuels Analyses

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Masticated 1-hr fuels

TC = pre-treatment tree cover (%)

yst = years since treatment; 0 represents pre-treatment; yst is a factor for masticated fuels

scode = site

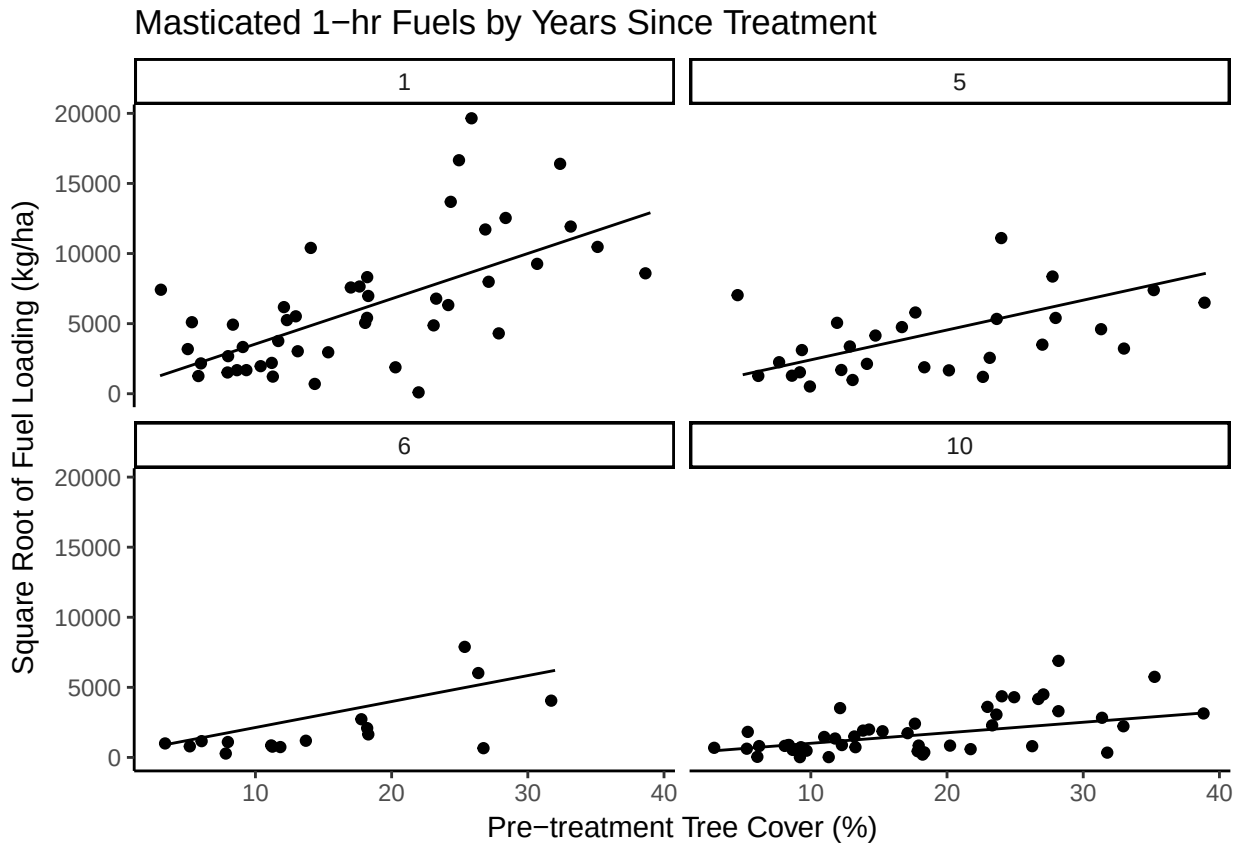
```
m <- lmer(kgha_1h ~ TC + yst + TC:yst + (1 + yst|scode), data = d)
summary(m)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: kgha_1h ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 2430
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -2.682 -0.562 -0.103  0.419  3.823
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 3618823  1902
##           yst           74413   273     -1.00
##  Residual             5731678  2394
## Number of obs: 134, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   318.79    1367.34    0.23
## TC            350.59      41.34    8.48
## yst            -6.19     200.12   -0.03
## TC:yst        -27.55       6.28   -4.39
##
## Correlation of Fixed Effects:
##        (Intr) TC     yst
## TC     -0.531
## yst    -0.939  0.460
## TC:yst  0.442 -0.833 -0.550
```

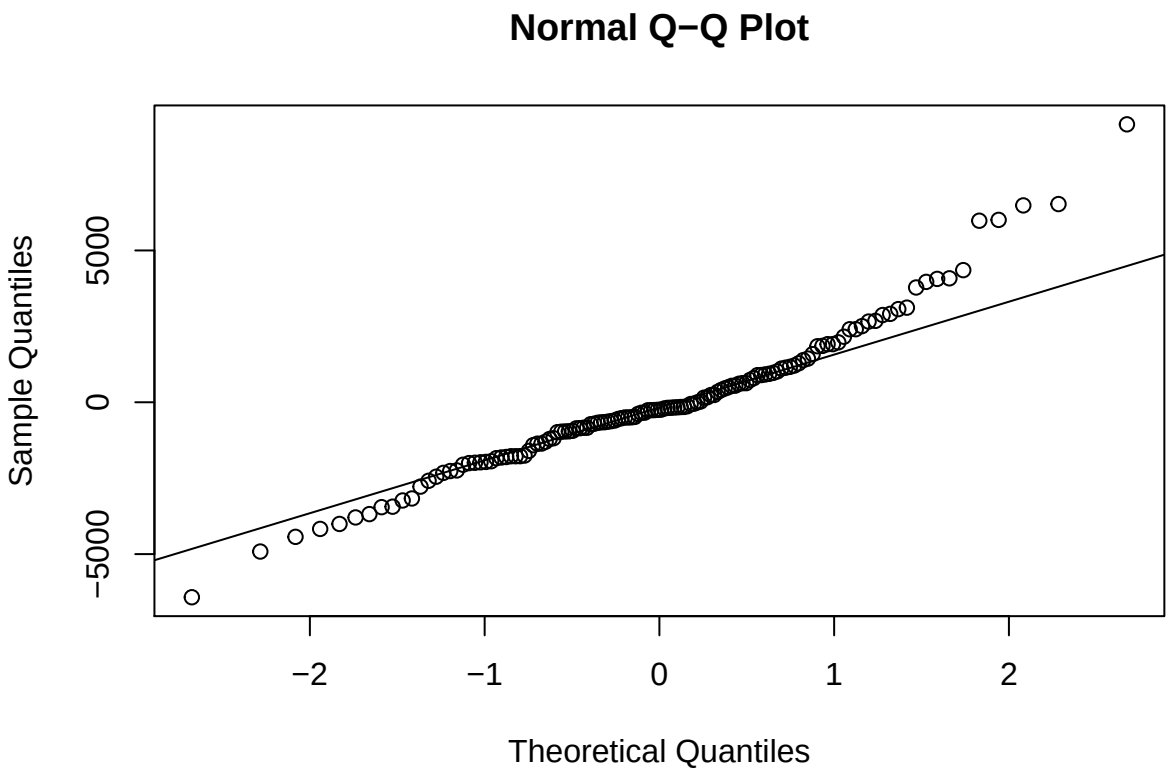
```
lincon(m)
```

```
##             estimate      se   lower  upper  tvalue  df   pvalue
## (Intercept)   318.79 1367.34 -2361.2 2998.7  0.2331 Inf 8.16e-01
## TC            350.59   41.34   269.6  431.6  8.4808 Inf 2.24e-17
## yst            -6.19  200.12  -398.4  386.0 -0.0309 Inf 9.75e-01
## TC:yst        -27.55    6.28   -39.9  -15.3 -4.3899 Inf 1.13e-05
```

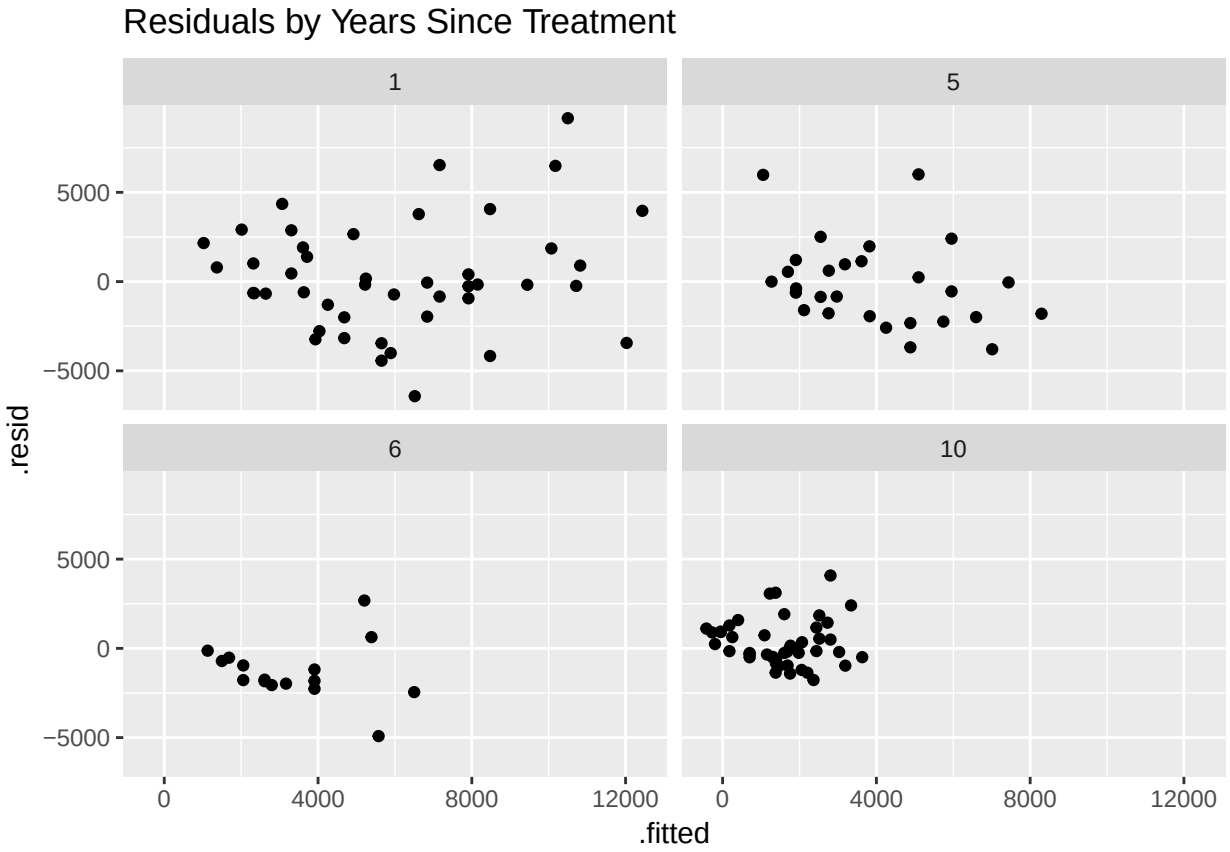
```r
#by yst; averaged across scode (sites)
d$yhat1 <- predict(m, re.form = NA)

p <- ggplot(data = d, aes(x = TC, y = 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 by Years Since Treatment',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)')
p <- p + facet_wrap(~yst, ncol = 2)
plot(p)
```



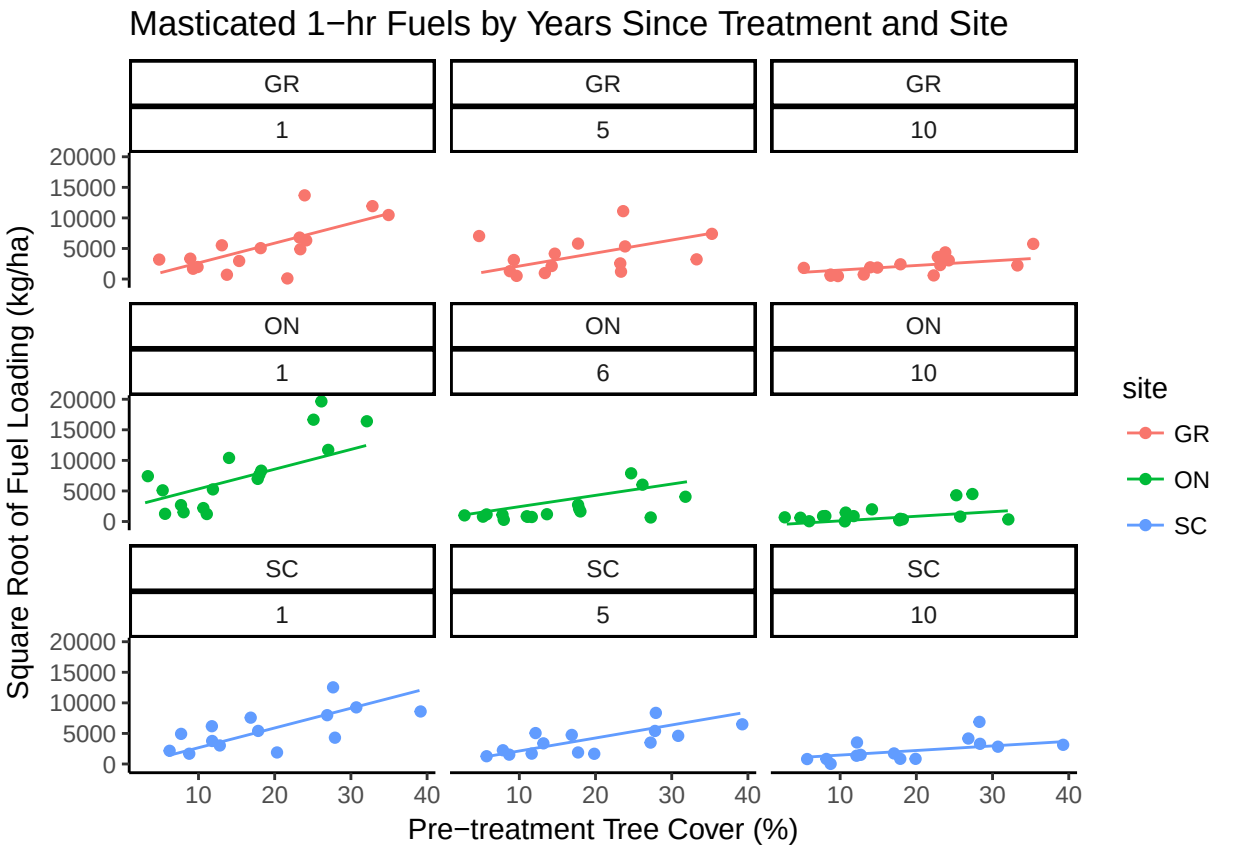

```r
qqnorm(resid(m)); qqline(resid(m))
```



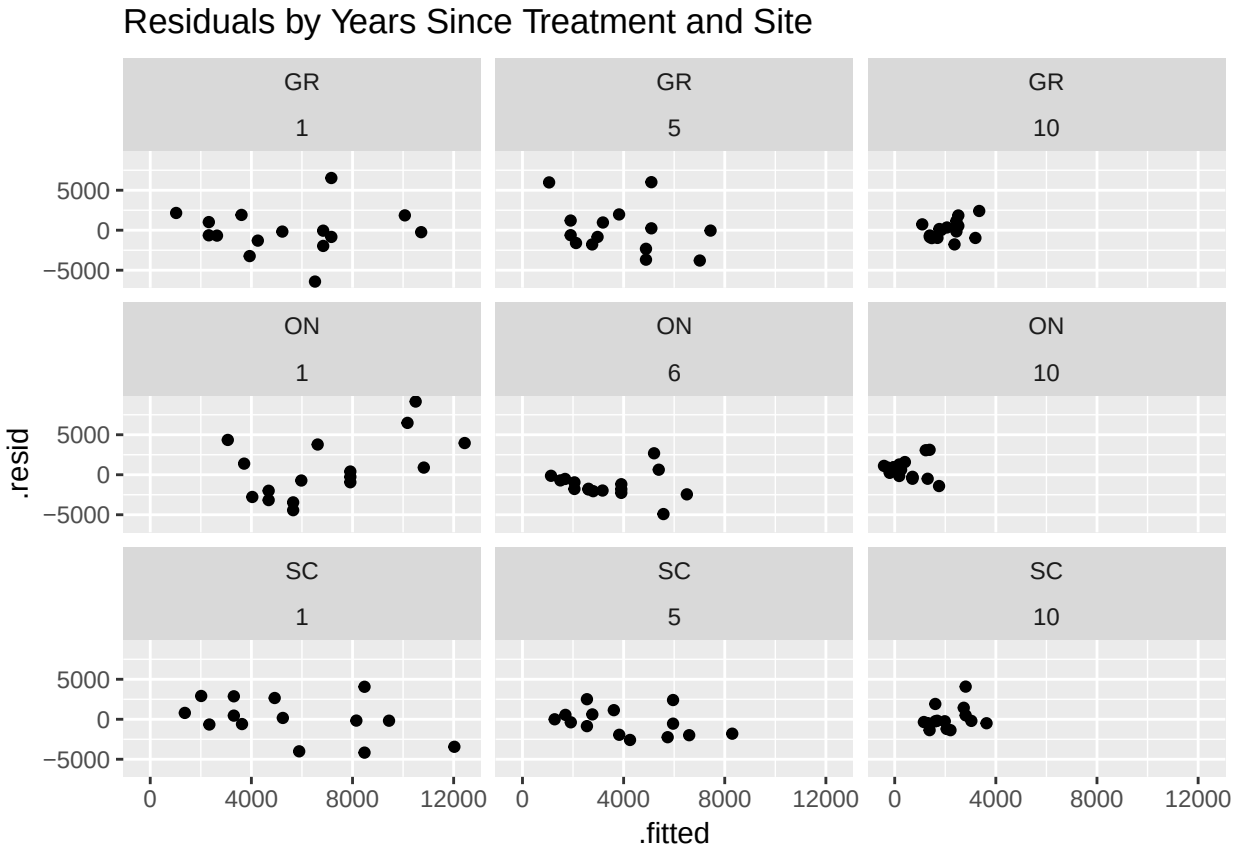

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() +
  facet_wrap(~yst, ncol = 2) + labs(title = 'Residuals by Years Since Treatment')
```




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

#by yst and scode
p <- ggplot(data = d, aes(x = TC, y = 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 by Years Since Treatment and Site',
              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 by Years Since Treatment and Site')
```



Masticated 10-hr fuels

TC = pre-treatment tree cover (%)

yst = years since treatment

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

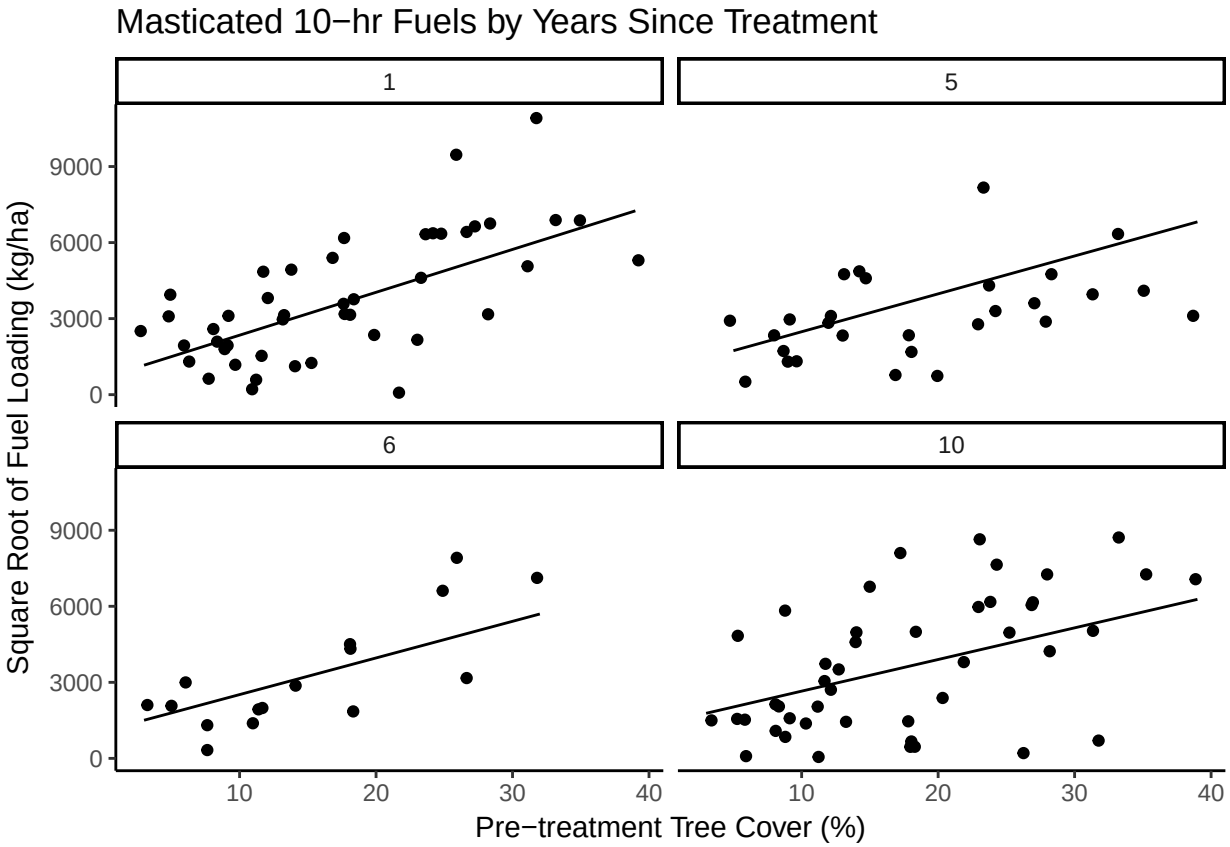
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: kgha_10h ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 2354
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1186 -0.8018  0.0942  0.6472  2.6521
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  739266   860
##           yst           46166   215     -0.97
##  Residual             3165429  1779
## Number of obs: 134, groups:  scode, 3
```

```
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   571.40     779.92    0.73
## TC            174.08      30.49    5.71
## yst            83.18     154.46    0.54
## TC:yst         -4.92       4.67   -1.05
##
## Correlation of Fixed Effects:
##        (Intr) TC     yst
## TC     -0.687
## yst    -0.879  0.440
## TC:yst  0.569 -0.828 -0.531
```

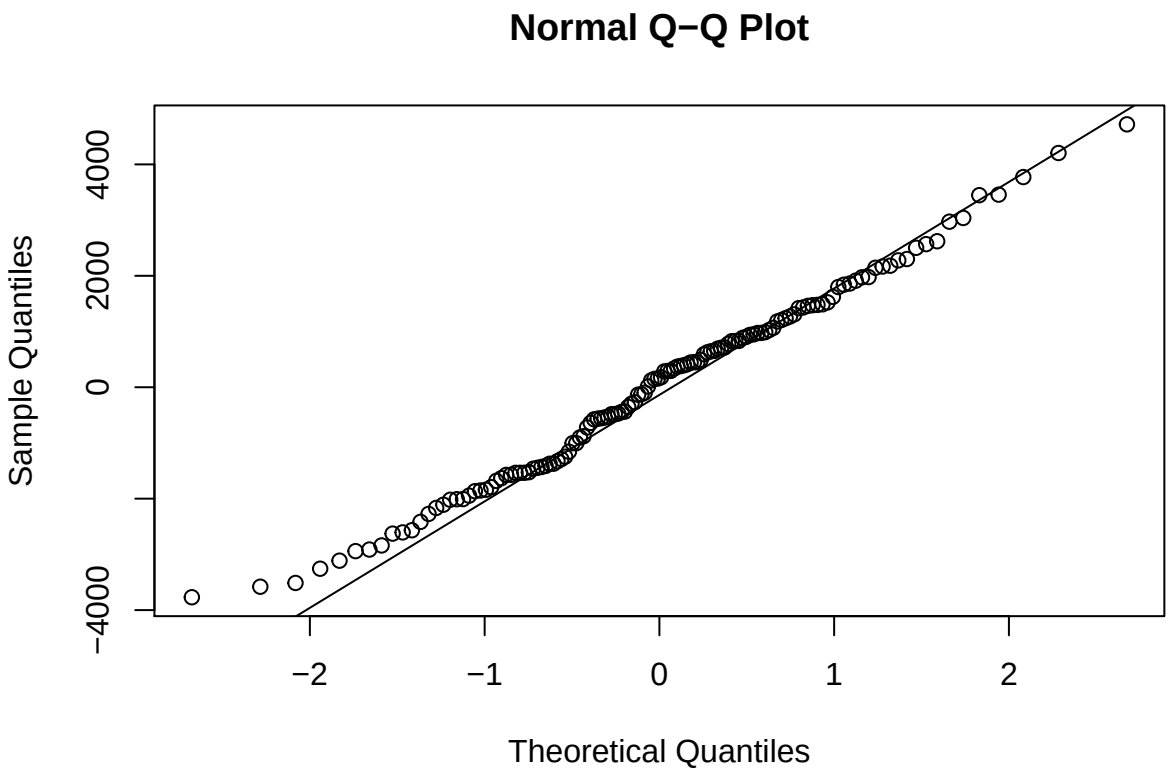
```
lincon(m)
```

```
##             estimate     se  lower   upper tvalue  df   pvalue
## (Intercept)   571.40 779.92 -957.2 2100.01  0.733 Inf 4.64e-01
## TC            174.08  30.49  114.3  233.85  5.709 Inf 1.14e-08
## yst            83.18 154.46 -219.5  385.92  0.539 Inf 5.90e-01
## TC:yst         -4.92   4.67  -14.1    4.23 -1.054 Inf 2.92e-01
```

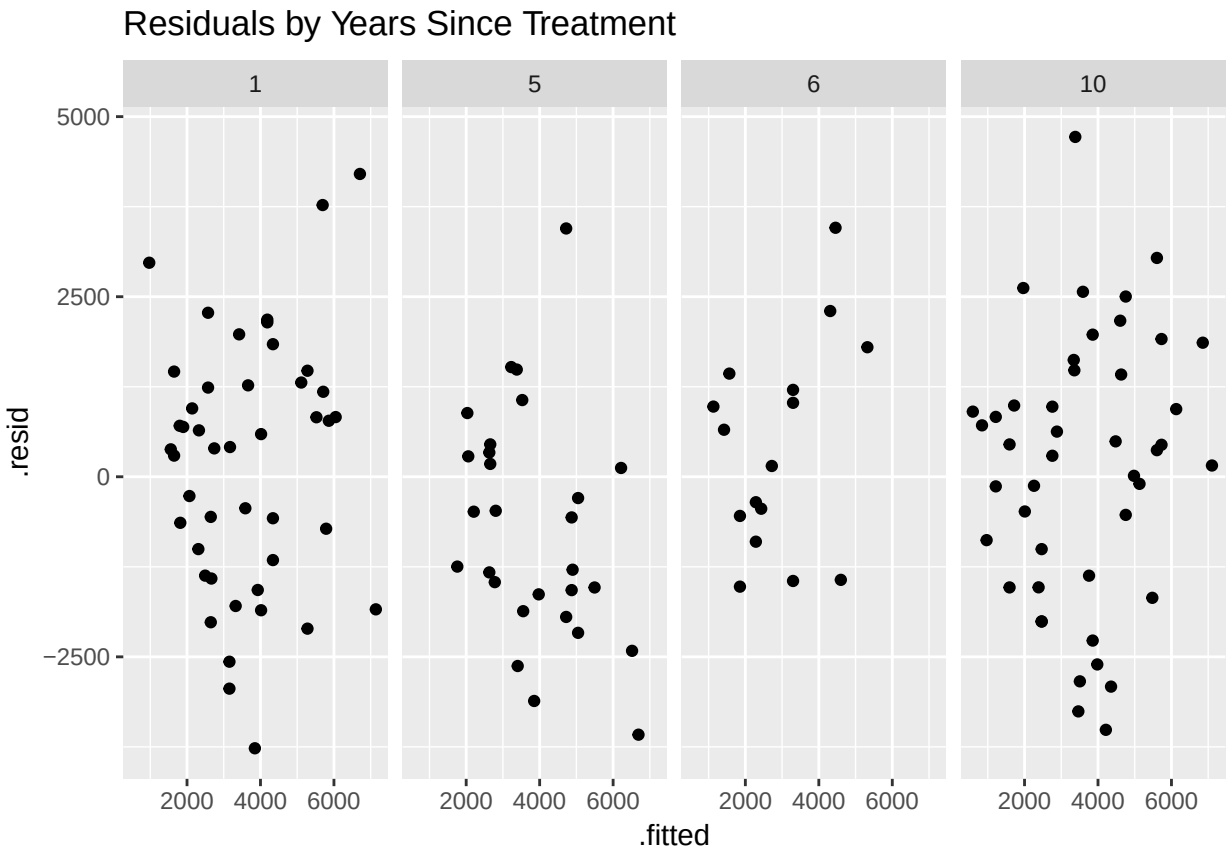
```
#by yst; averaged across scode (sites)
d$yhat10 <- predict(m, re.form = NA)

p <- ggplot(data = d, aes(x = TC, y = 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 by Years Since Treatment',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)')
p <- p + facet_wrap(~yst)
plot(p)
```



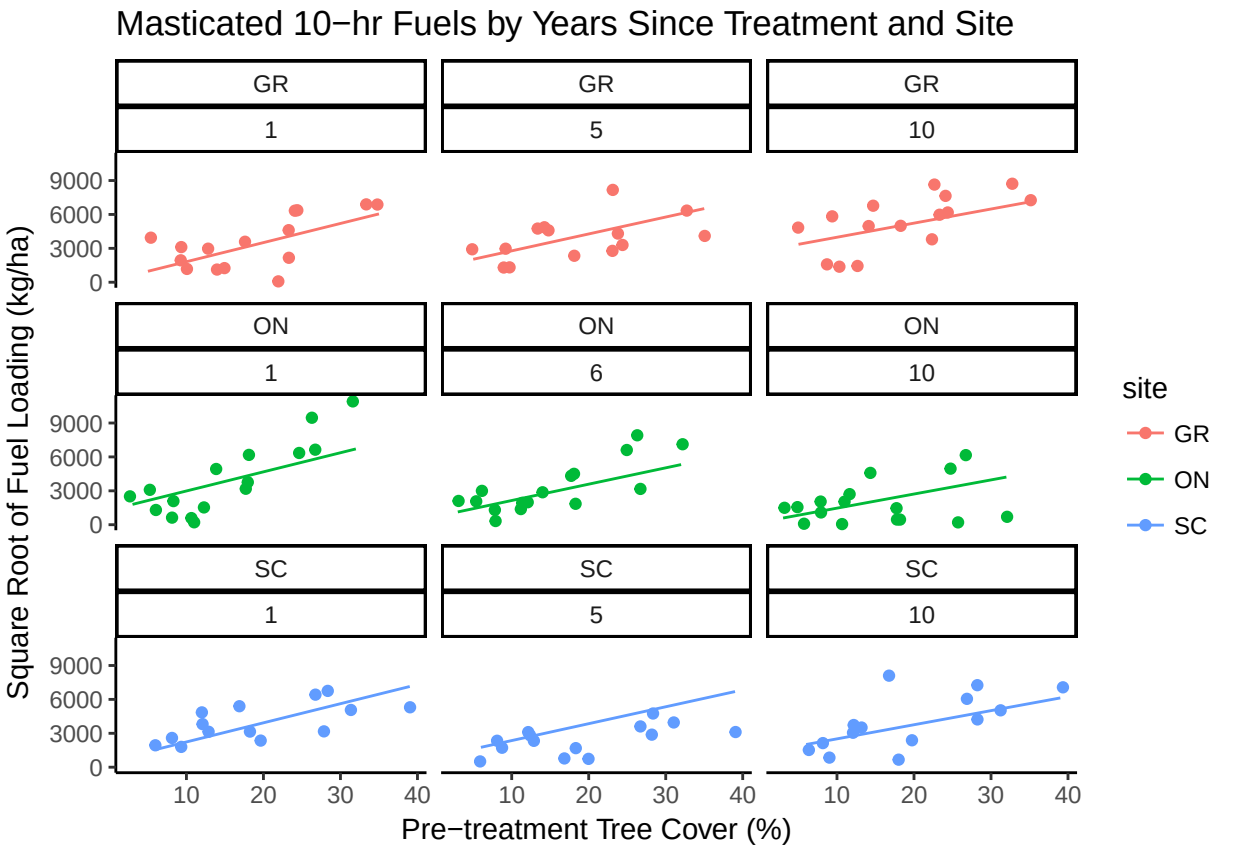

```
qqnorm(resid(m)); qqline(resid(m))
```



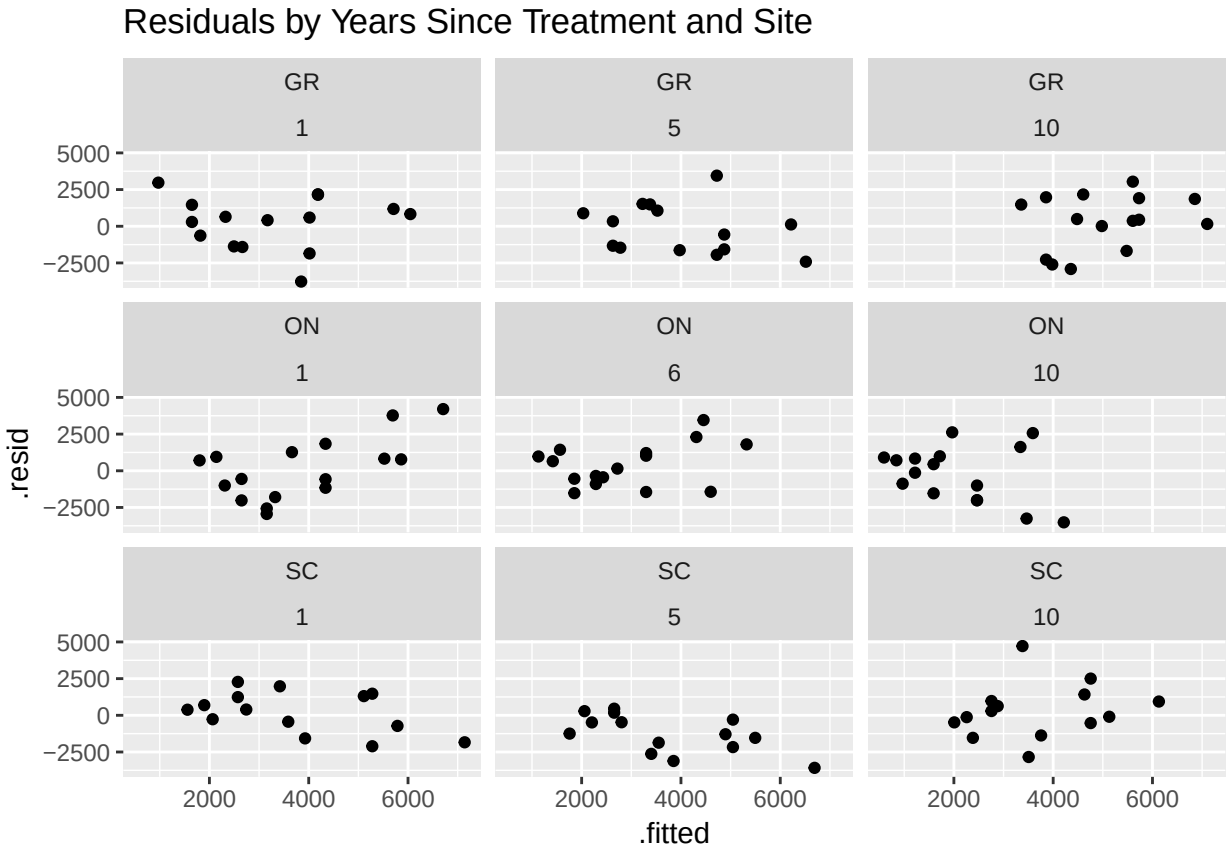

```
ggplot(m, aes(x = .fitted, y = .resid)) +
  geom_point() +
  facet_wrap(~yst, ncol = 4) +
  labs(title = 'Residuals by Years Since Treatment')
```




```
#by yst and scode
d$yhat10 <- predict(m)
p <- ggplot(data = d, aes(x = TC, y = 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 by Years Since Treatment and Site',
              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 by Years Since Treatment and Site')
```



Masticated 100 + 1000-hr fuels

Need to check zero values for year 1

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

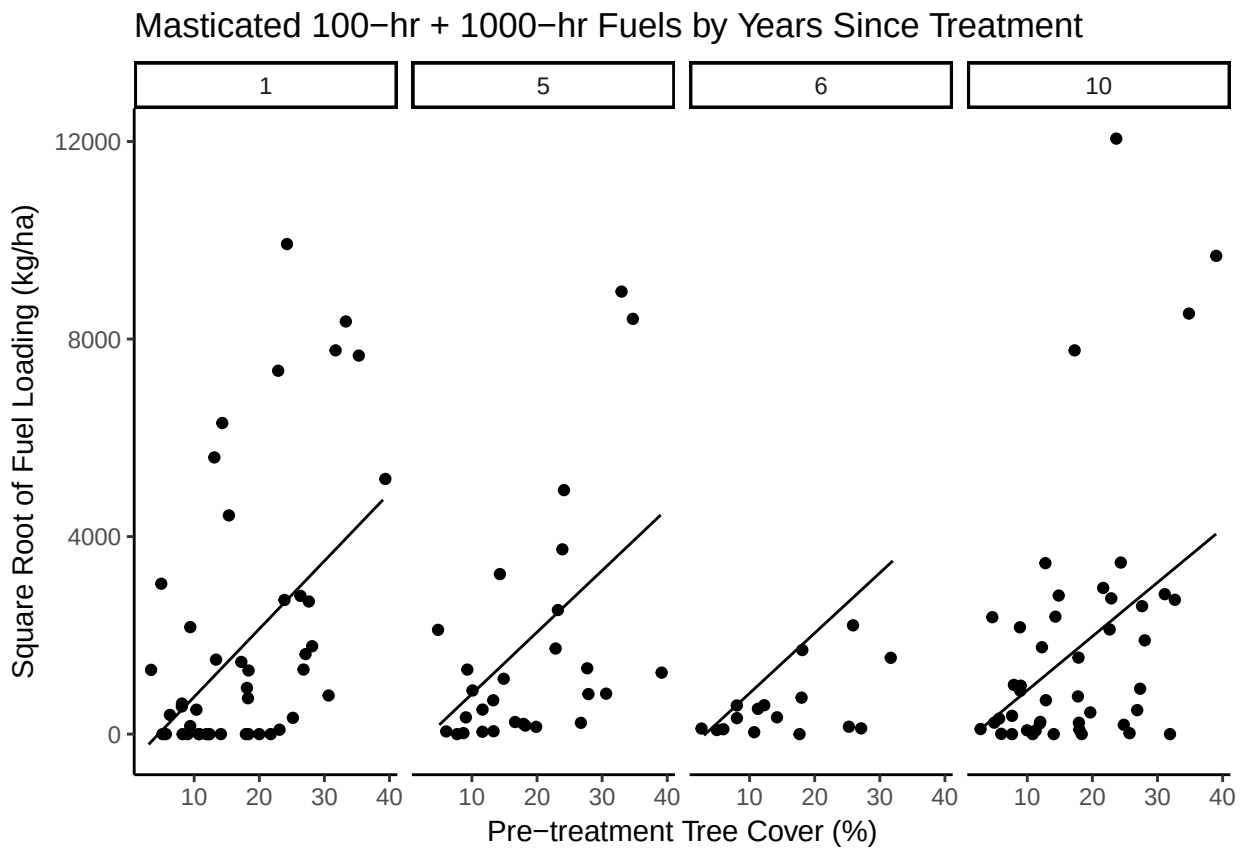
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: kgha_100_1000h ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 2377
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -2.125 -0.646 -0.050  0.343  4.436
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 2536664  1593
##           yst           15532   125     -0.69
##  Residual             3697736  1923
## Number of obs: 134, groups:  scode, 3
##
## Fixed effects:
```

```
##             Estimate Std. Error t value
## (Intercept)  -667.56    1127.98   -0.59
## TC            140.75      33.16    4.24
## yst            46.20     122.50    0.38
## TC:yst         -3.16       5.03   -0.63
##
## Correlation of Fixed Effects:
##        (Intr) TC     yst
## TC     -0.516
## yst    -0.718  0.596
## TC:yst  0.427 -0.827 -0.721
```

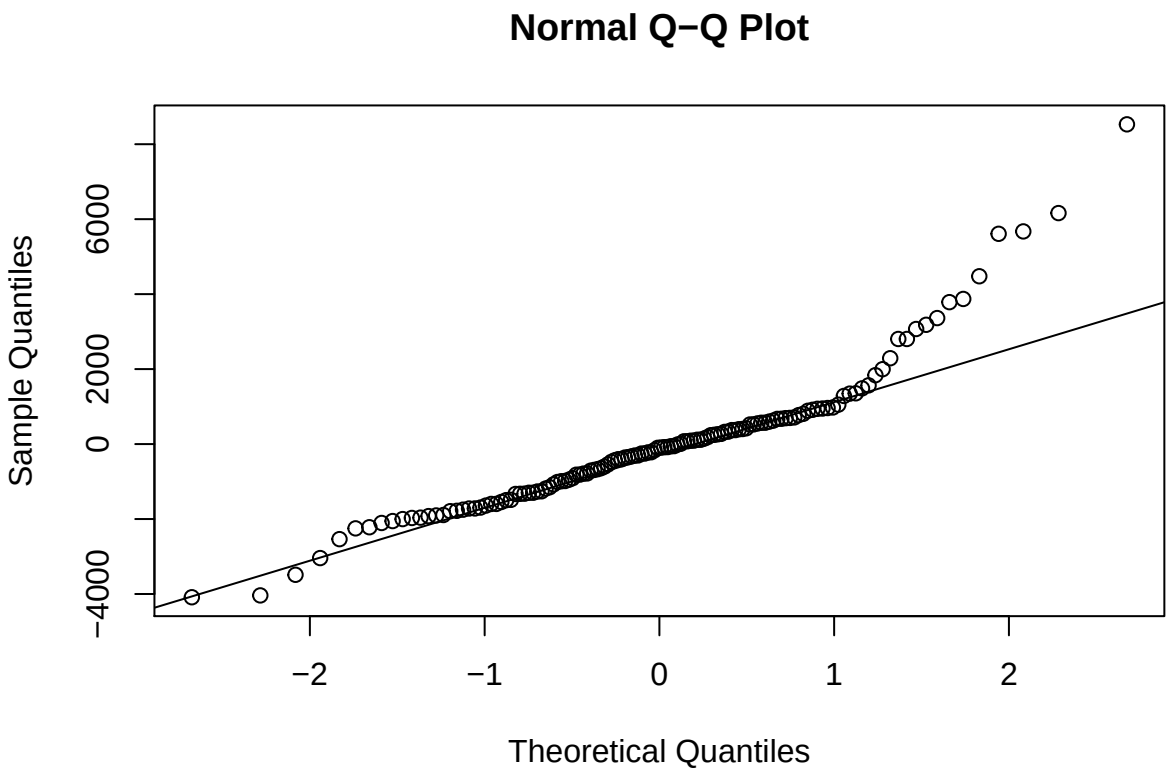
```
lincon(m)
```

```
##             estimate      se   lower   upper tvalue  df   pvalue
## (Intercept)  -667.56 1127.98 -2878.4 1543.24 -0.592 Inf 5.54e-01
## TC            140.75   33.16    75.8  205.75  4.244 Inf 2.19e-05
## yst            46.20  122.50  -193.9  286.29  0.377 Inf 7.06e-01
## TC:yst         -3.16    5.03   -13.0    6.71 -0.627 Inf 5.31e-01
```

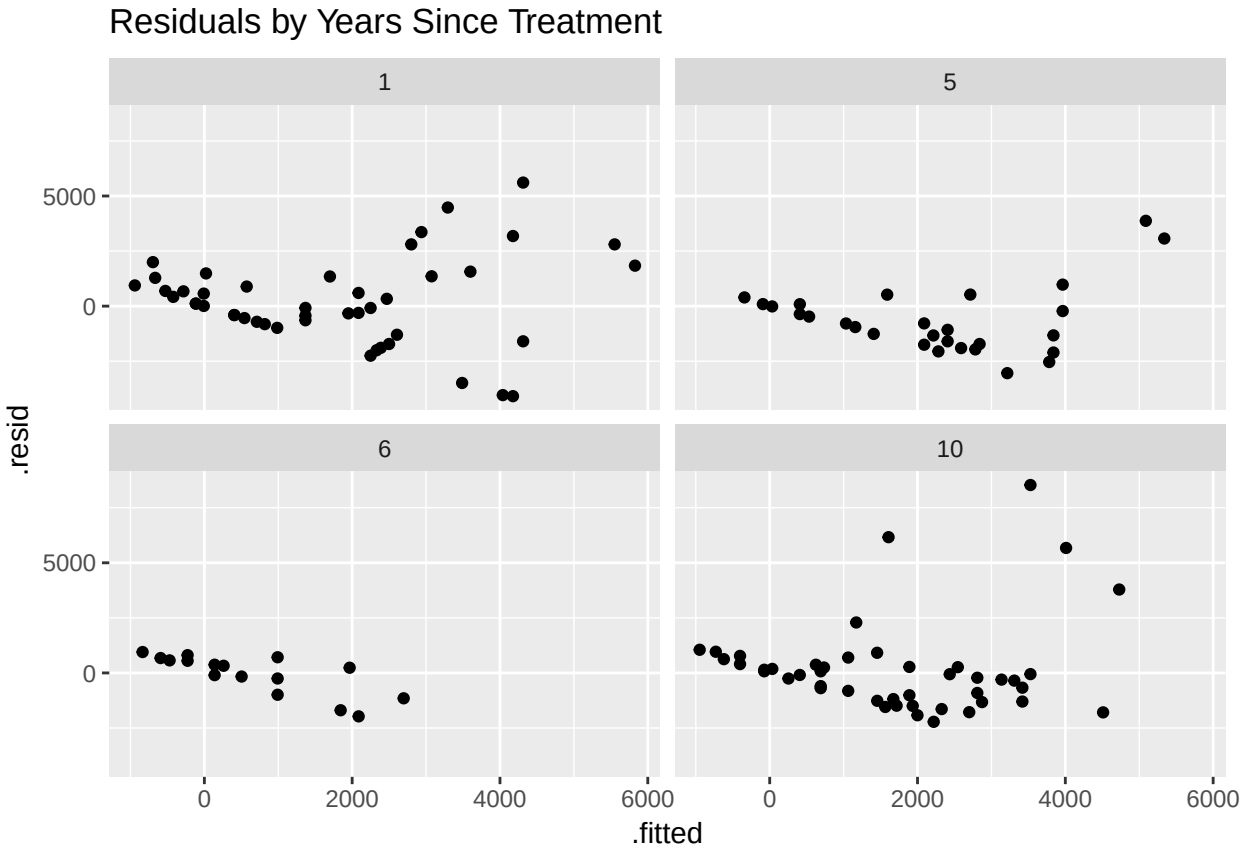
```
#by yst; averaged across scode (sites)
d$yhat100_1000 <- predict(m, re.form = NA)

p <- ggplot(data = d, aes(x = TC, y = kgha_100_1000h))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat100_1000))
p <- p + theme_classic()
p <- p + facet_wrap(~yst, ncol = 4)
p <- p + labs(title = 'Masticated 100-hr + 1000-hr Fuels by Years Since Treatment',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)')
plot(p)
```



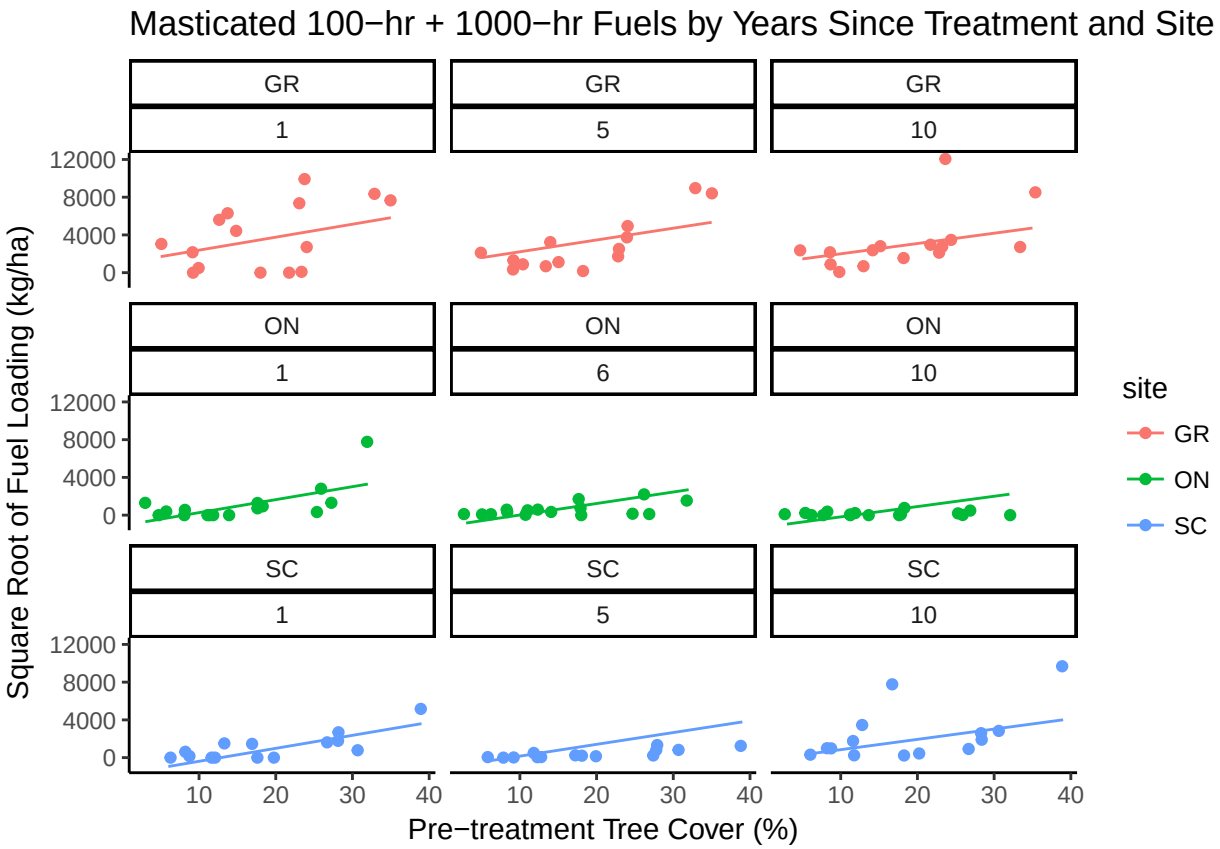

```
qqnorm(resid(m)); qqline(resid(m))
```



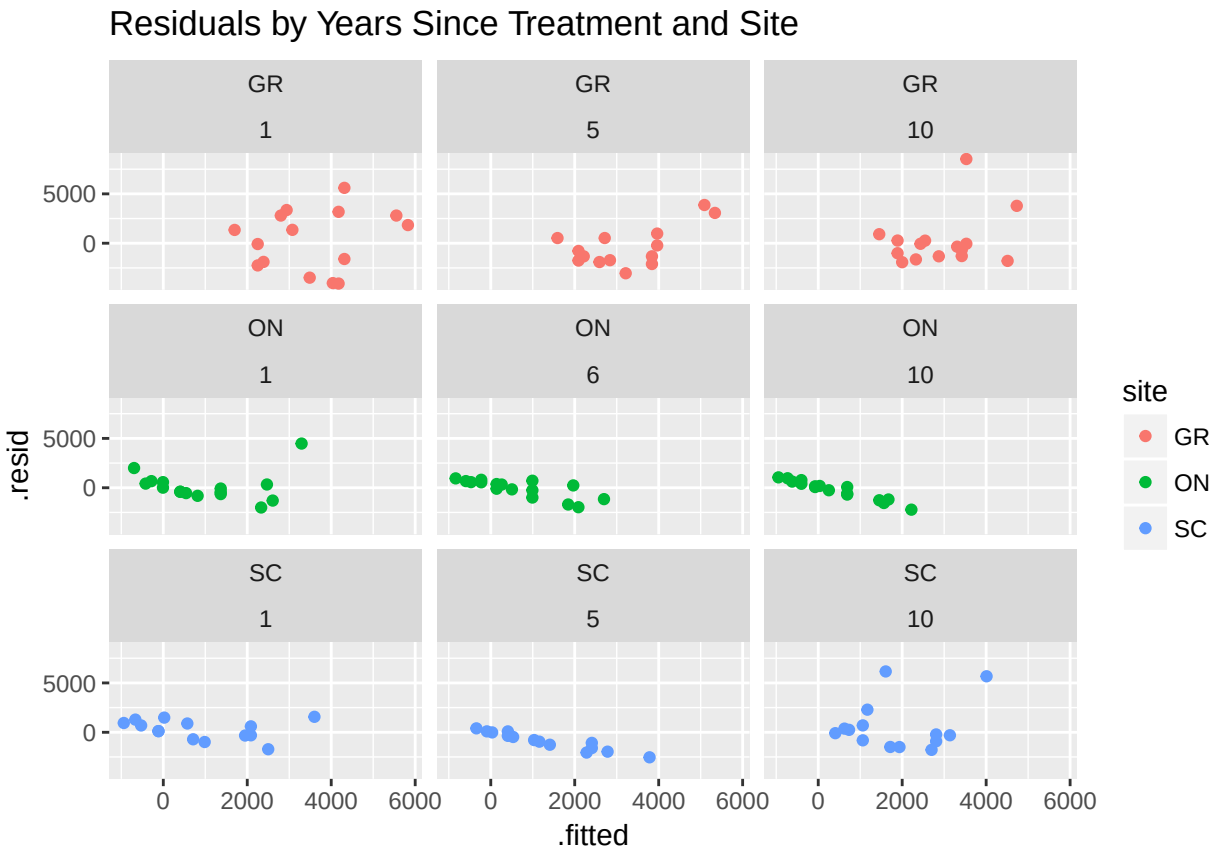

```
ggplot(m, aes(x = .fitted, y = .resid)) +
  geom_point() +
  facet_wrap(~yst, ncol = 2) +
  labs(title = 'Residuals by Years Since Treatment')
```




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

p <- ggplot(data = d, aes(x = TC, y = 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 by Years Since Treatment and Site',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)',
              color = 'site')
plot(p)
```




```
ggplot(m, aes(x = .fitted, y = .resid, color = scode)) +
  geom_point() +
  facet_wrap(scode~yst) +
  labs(title = 'Residuals by Years Since Treatment and Site',
       color = 'site')
```



Tree Litter + Duff Fuels

```
#model, inferences, and residuals
m <- lmer(duff ~ yst + pre_tc + yst:pre_tc + (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)
```

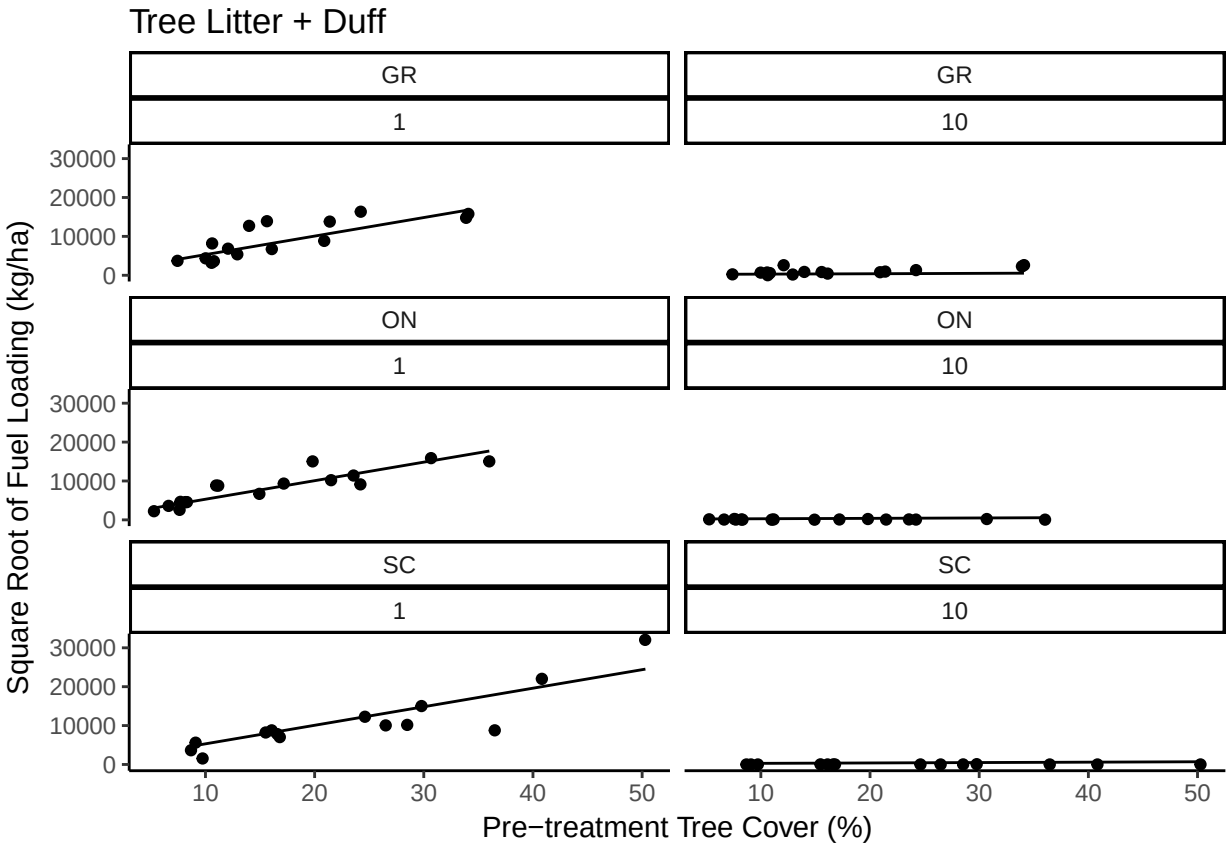
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: duff ~ yst + pre_tc + yst:pre_tc + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 1596
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -4.294 -0.223 -0.085  0.149  3.533
##
## Random effects:
```

```
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)       0     0.0
##           yst             934    30.6    NaN
##  Residual             4544992  2131.9
## Number of obs: 90, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   574.75     727.75    0.79
## yst           -38.63     104.36   -0.37
## pre_tc        528.72      34.12   15.49
## yst:pre_tc    -51.86       4.83  -10.75
##
## Correlation of Fixed Effects:
##            (Intr) yst    pre_tc
## yst        -0.759
## pre_tc     -0.873  0.663
## yst:pre_tc  0.672 -0.862 -0.770
## convergence code: 0
## unable to evaluate scaled gradient
## Model failed to converge: degenerate  Hessian with 1 negative eigenvalues
```

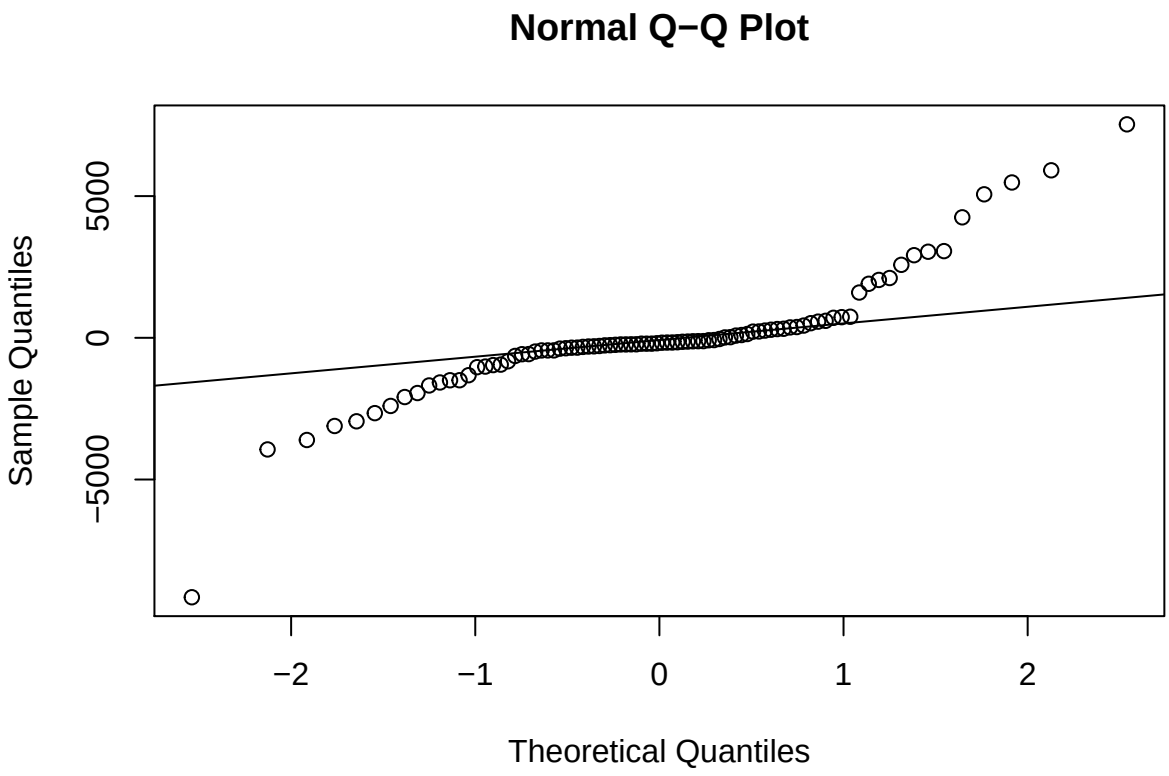
```
lincon(m)
```

```
##             estimate     se  lower  upper tvalue  df   pvalue
## (Intercept)    574.8 727.75 -851.6 2001.1   0.79 Inf 4.30e-01
## yst            -38.6 104.36 -243.2  165.9  -0.37 Inf 7.11e-01
## pre_tc         528.7  34.12  461.8  595.6  15.49 Inf 3.77e-54
## yst:pre_tc     -51.9   4.83  -61.3  -42.4 -10.75 Inf 6.05e-27
```

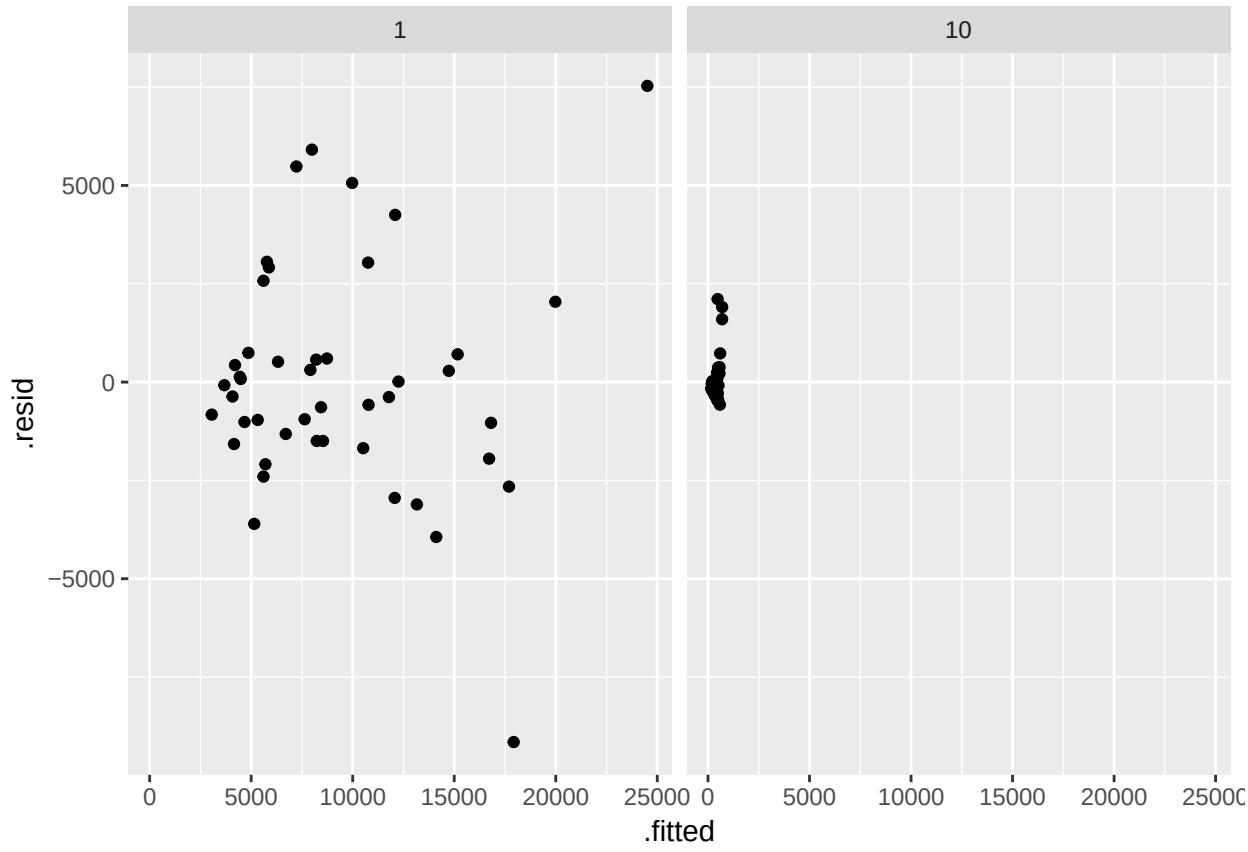
```
#by yst
d$yhat_duff <- predict(m, re.form = NA)
p <- ggplot(data = d, aes(x = pre_tc, y = duff))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat_duff))
p <- p + theme_classic() + facet_wrap(scode~yst, ncol = 2)
p <- p + labs(title = 'Tree Litter + Duff',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)')
plot(p)
```



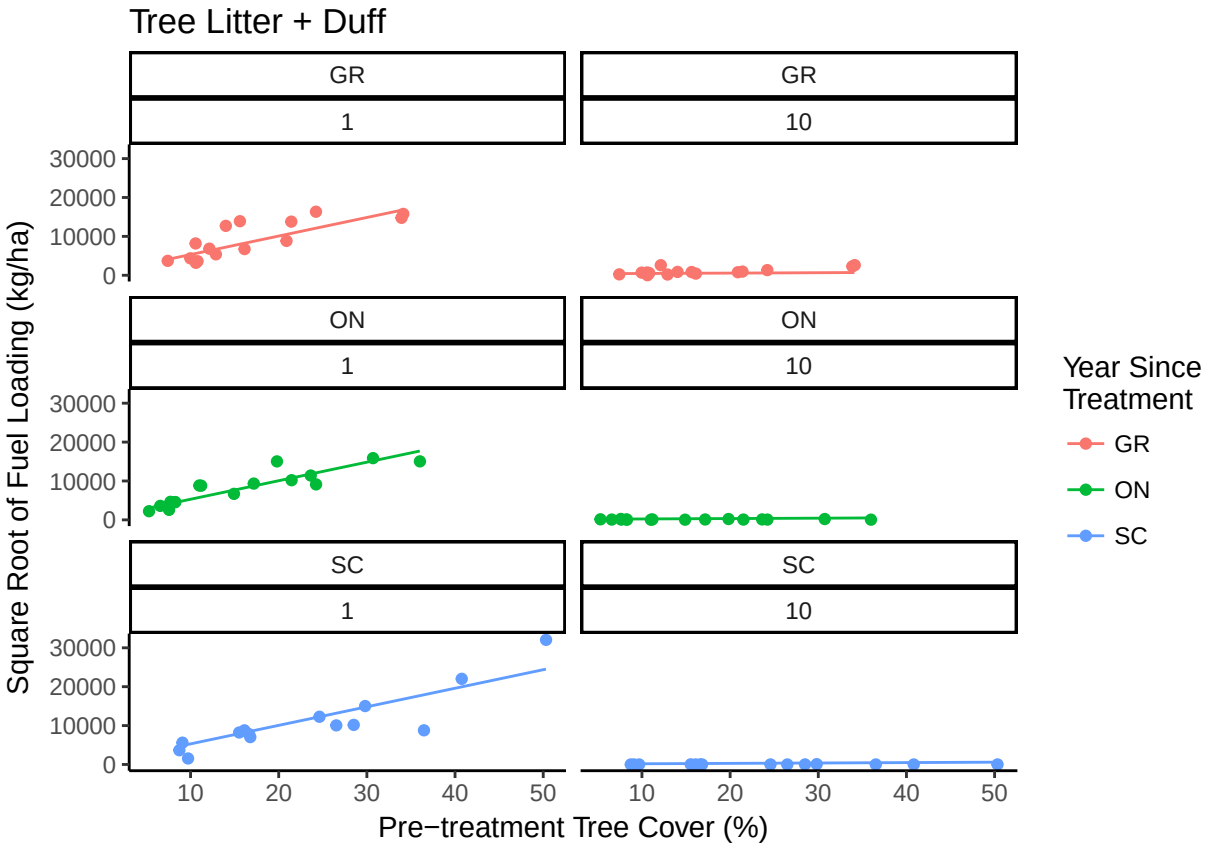

```
qqnorm(resid(m)); qqline(resid(m))
```



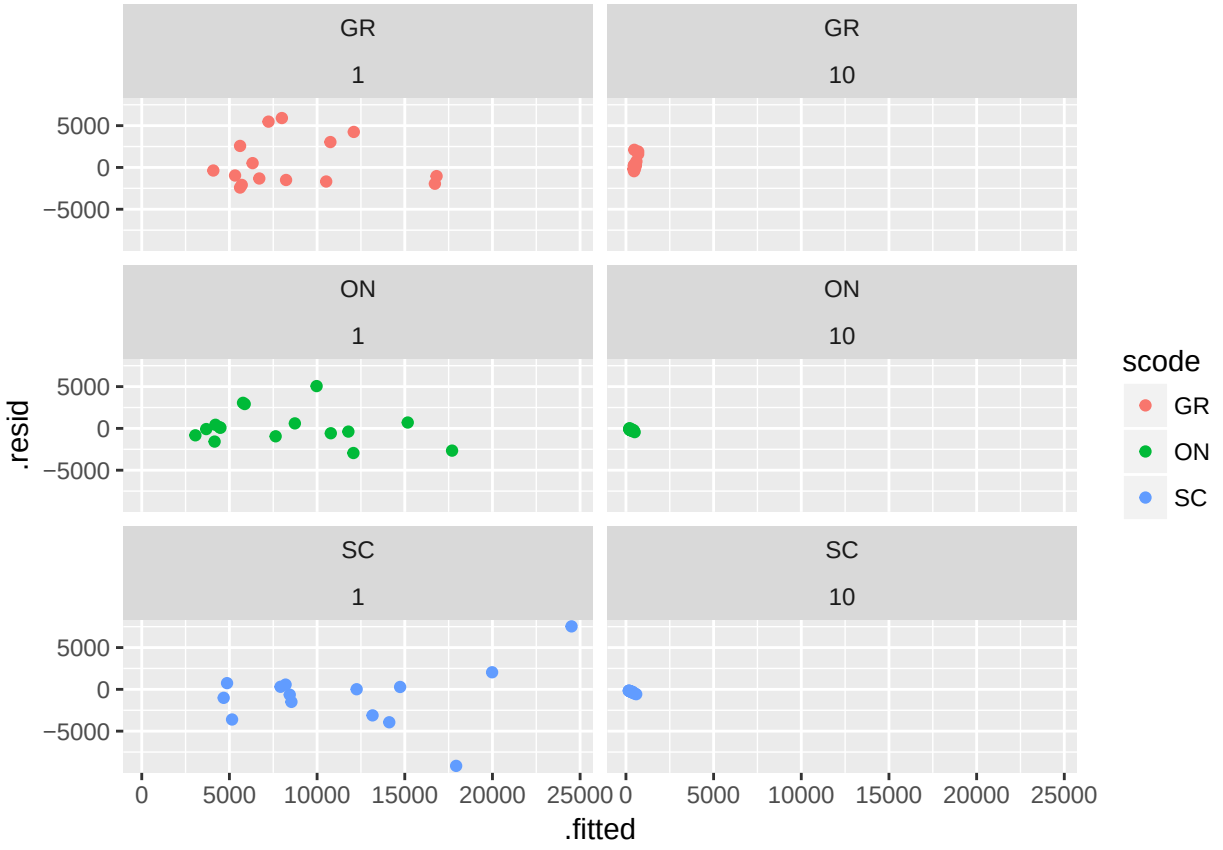

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
d$yhat_duff <- predict(m)
p <- ggplot(data = d, aes(x = pre_tc, y = duff, color = scode))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat_duff))
p <- p + theme_classic() + facet_wrap(scode~yst, ncol = 2)
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)
```




```
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

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

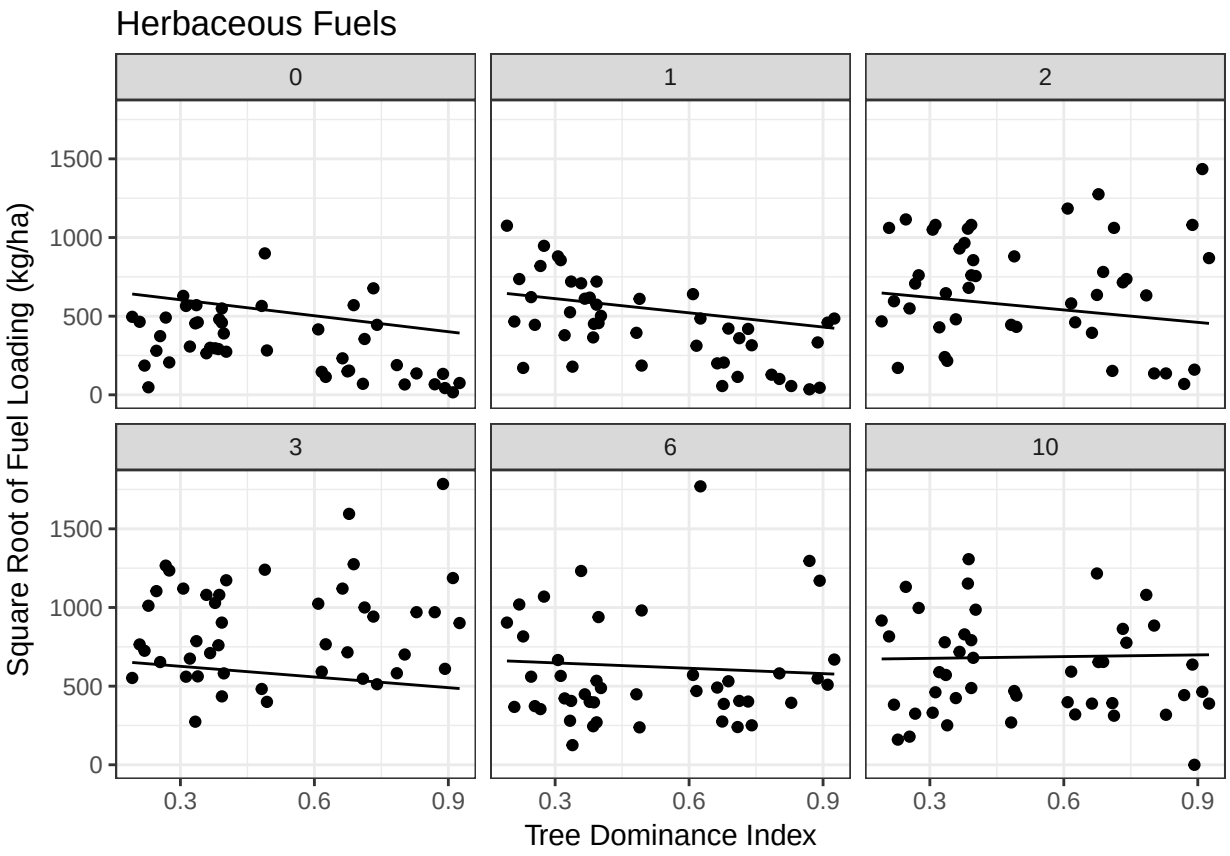
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: herb_ttl ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
```

```
## REML criterion at convergence: 3852
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -2.109 -0.767 -0.165  0.581  3.795
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  13418   115.8
##           yst            211    14.5    -0.87
##  Residual             109015   330.2
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   705.78      99.66    7.08
## TDI          -338.43     131.54   -2.57
## yst            -3.98      16.97   -0.23
## TDI:yst        37.46      26.30    1.42
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.679
## yst     -0.761  0.584
## TDI:yst  0.497 -0.732 -0.796
```

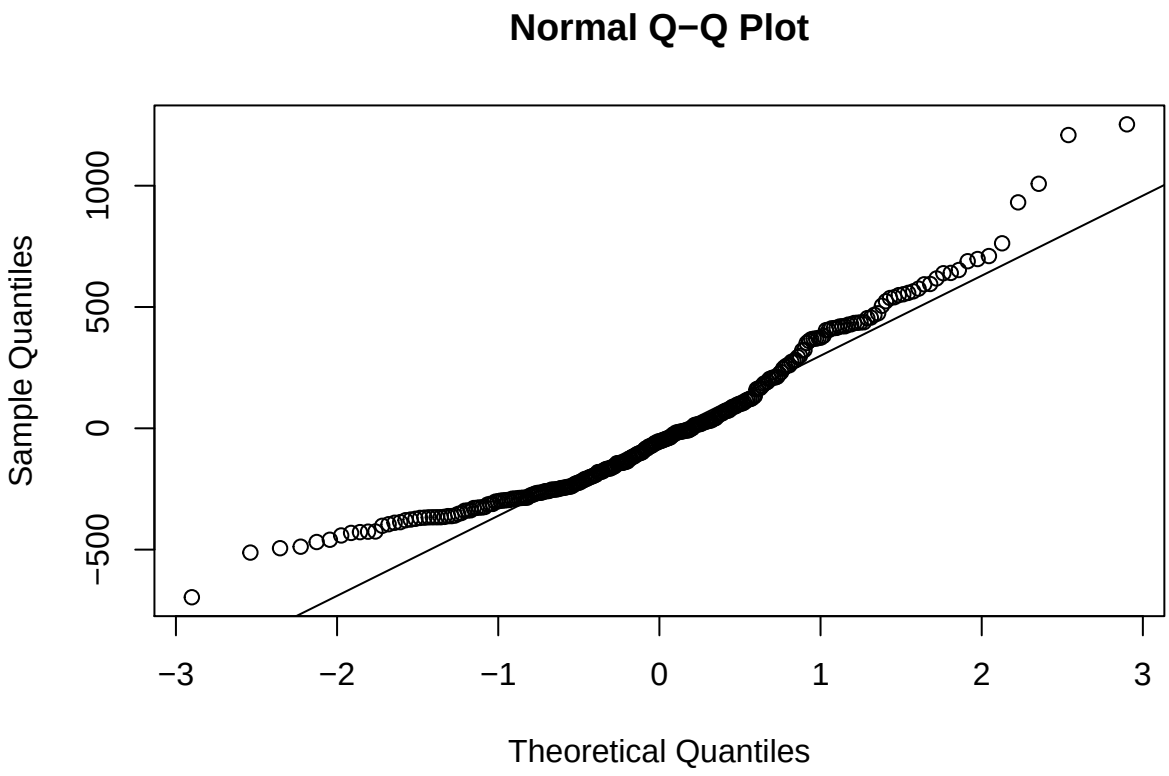
```
lincon(m)
```

```
##             estimate    se  lower upper tvalue  df   pvalue
## (Intercept)   705.78  99.7  510.5 901.1  7.082 Inf 1.42e-12
## TDI          -338.43 131.5 -596.2 -80.6 -2.573 Inf 1.01e-02
## yst            -3.98  17.0  -37.2  29.3 -0.234 Inf 8.15e-01
## TDI:yst        37.46  26.3  -14.1  89.0  1.425 Inf 1.54e-01
```

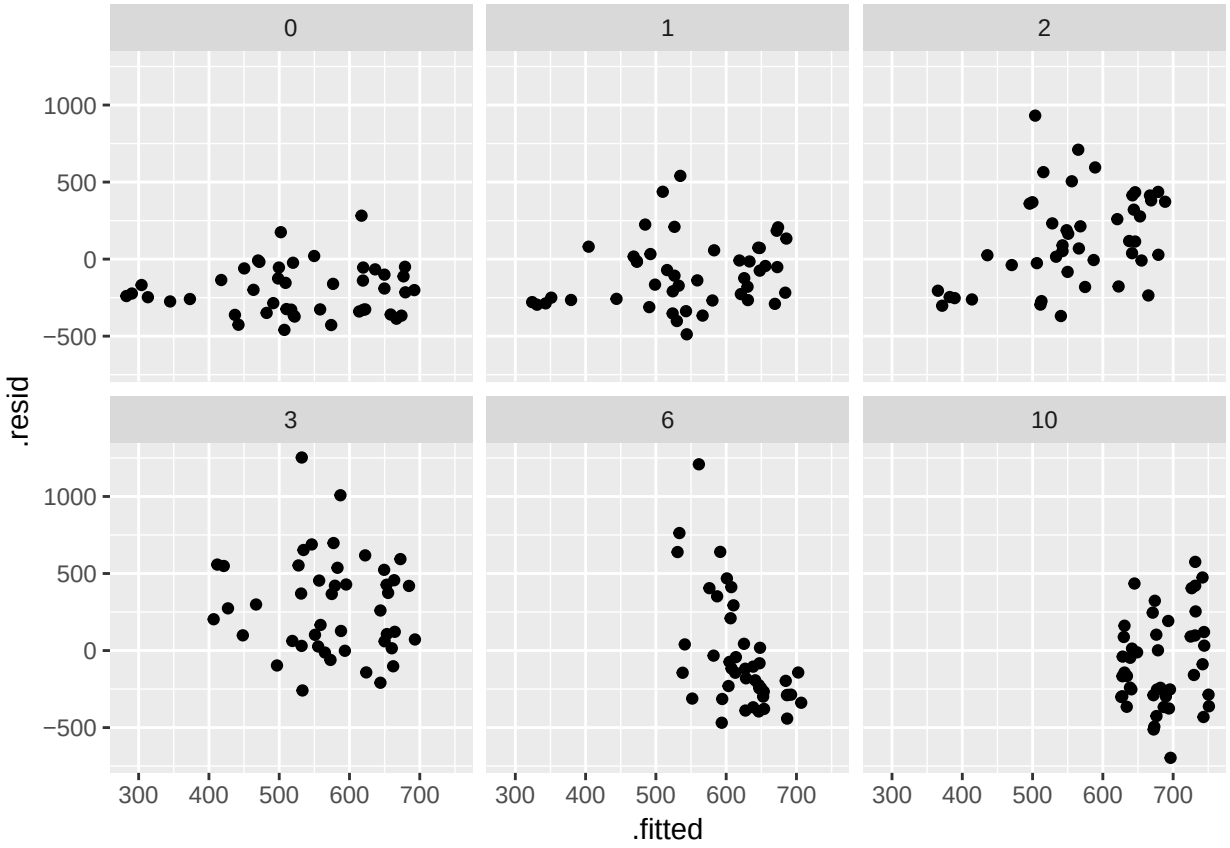
```
#by yst
l$yhat_herb <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = herb_ttl))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_herb))
p <- p + theme_bw()
p <- p + labs(title = 'Herbaceous Fuels',
              x = 'Tree Dominance Index',
              y = 'Square Root of Fuel Loading (kg/ha)')
p <- p + scale_x_continuous(breaks = seq(0,1, by = 0.3))
p <- p + facet_wrap(~yst, ncol = 3)
plot(p)
```



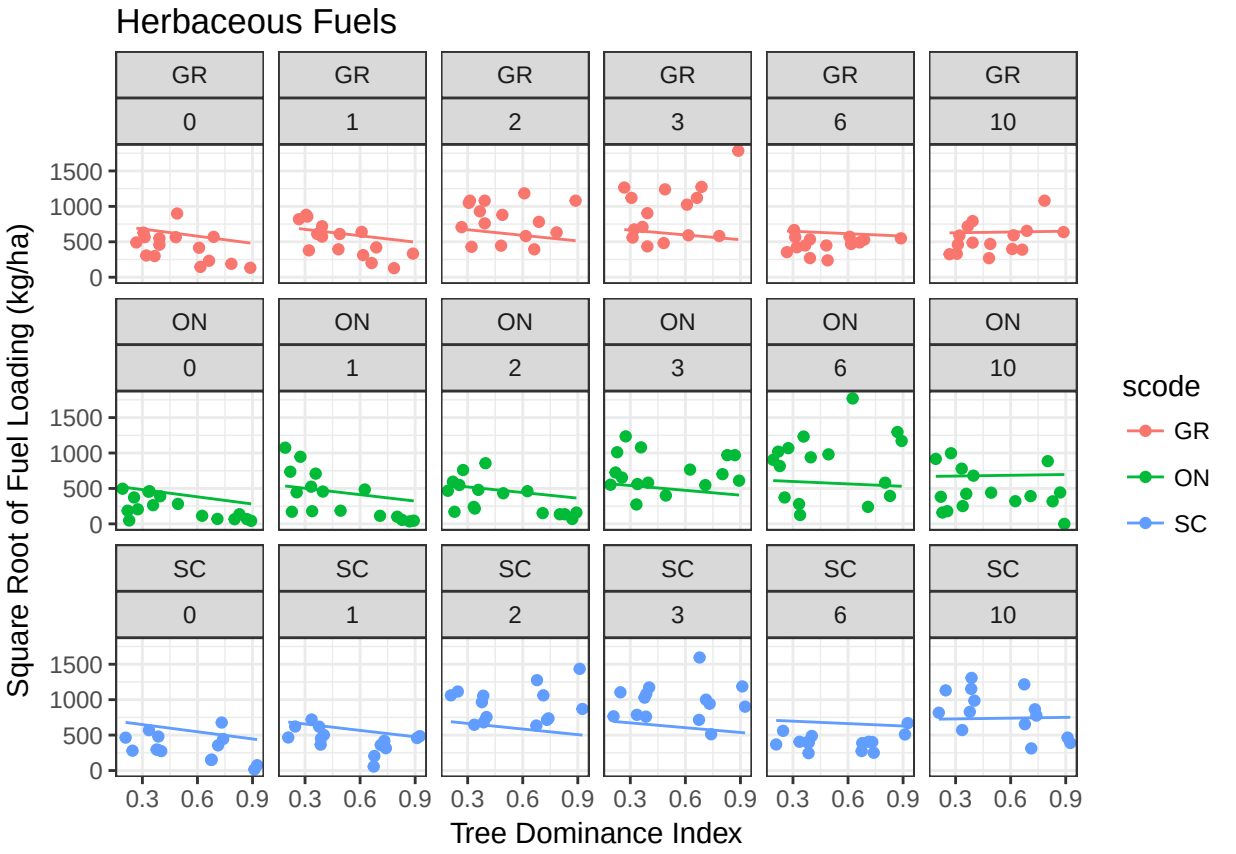

```
qqnorm(resid(m)); qqline(resid(m))
```



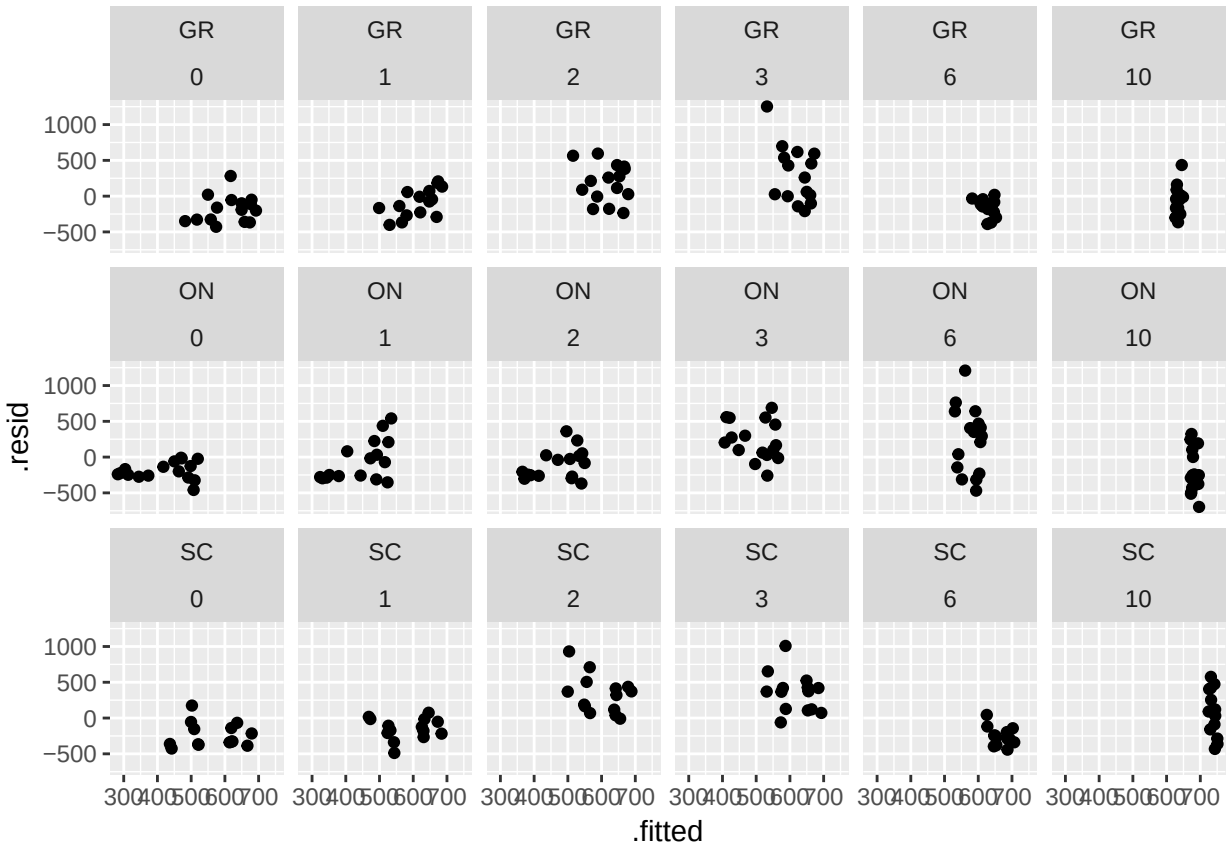

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
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)')
p <- p + scale_x_continuous(breaks = seq(0,1, by = 0.3))
p <- p + facet_wrap(scode~yst, ncol = 6, nrow = 3)
plot(p)
```




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

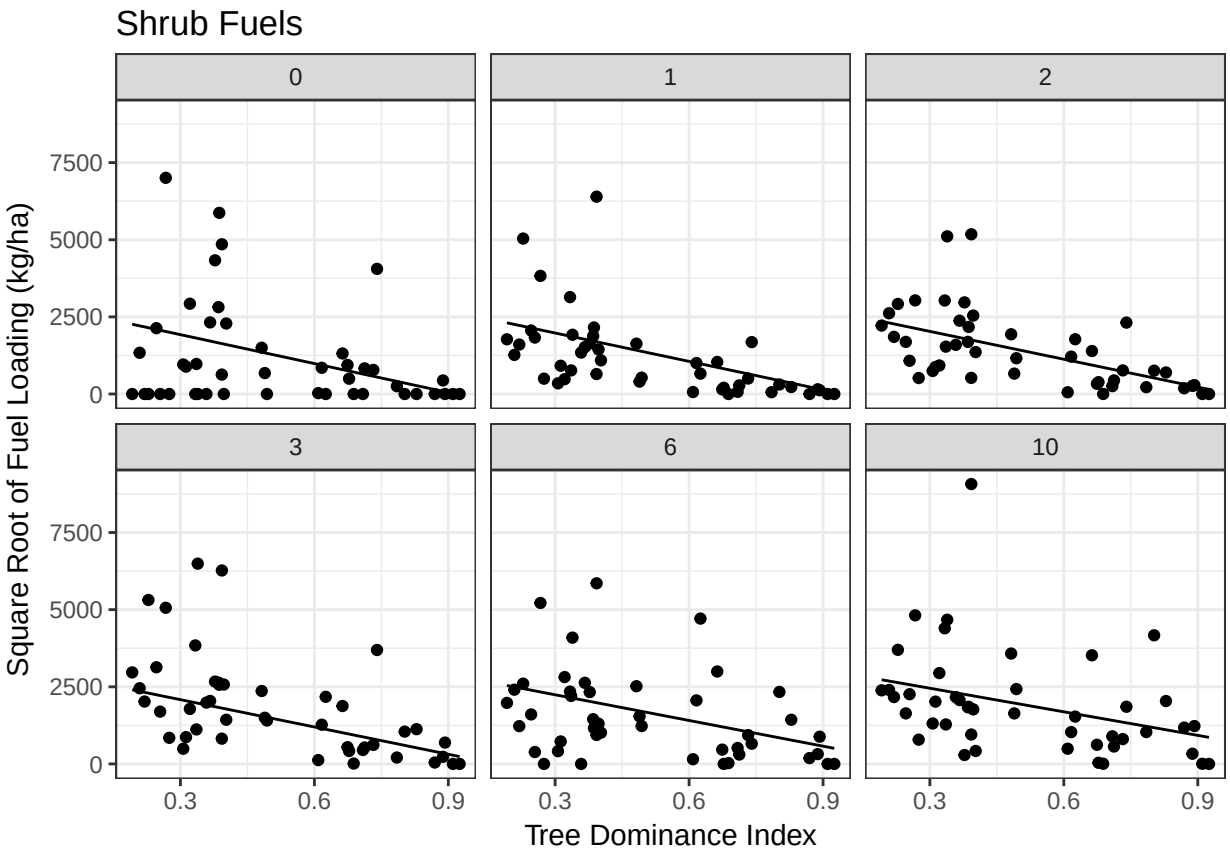
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: shrub_fuel ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
## REML criterion at convergence: 4589
##
## Scaled residuals:
```

```
##    Min     1Q Median     3Q    Max
## -1.907 -0.617 -0.178  0.288  5.000
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  124620   353
##           yst           11689   108     -1.00
##  Residual             1763595  1328
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   2860.7      359.5    7.96
## TDI          -3123.1      527.5   -5.92
## yst             35.6       86.2    0.41
## TDI:yst         57.7      106.0    0.54
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.754
## yst     -0.828  0.464
## TDI:yst  0.554 -0.733 -0.632
```

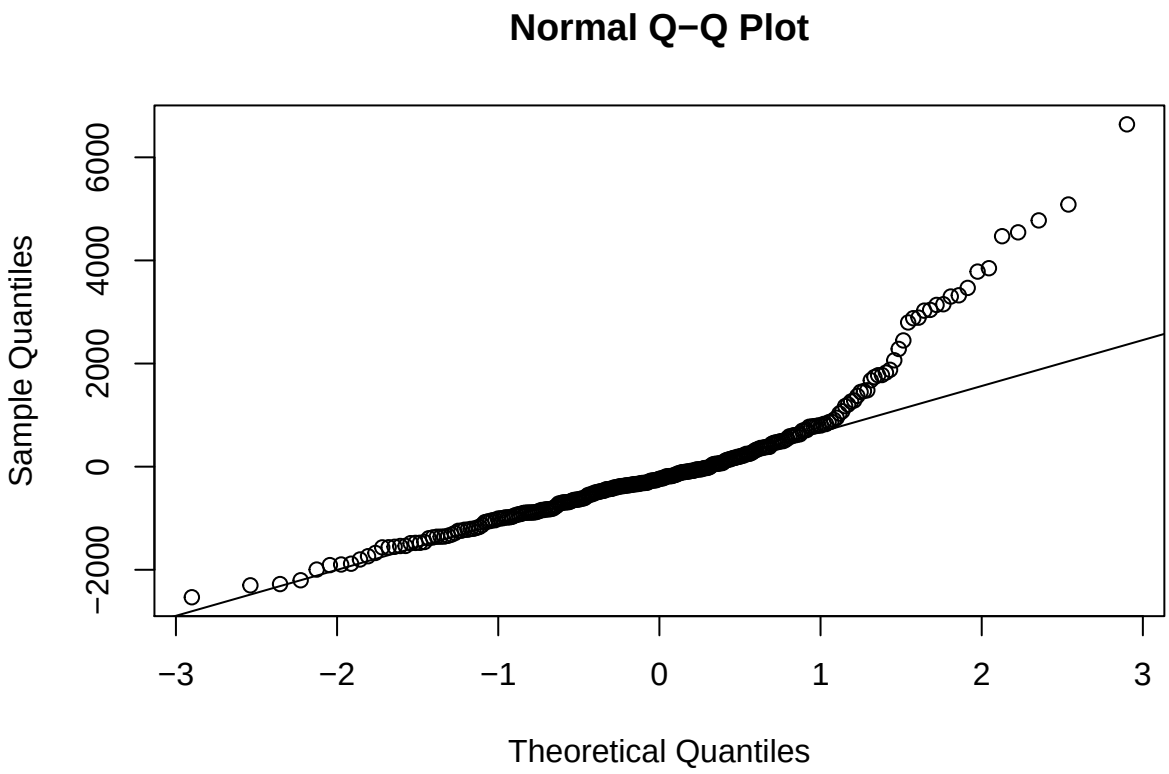
```
lincon(m)
```

```
##             estimate    se lower upper tvalue  df   pvalue
## (Intercept)   2860.7 359.5  2156  3565  7.958 Inf 1.75e-15
## TDI          -3123.1 527.5 -4157 -2089 -5.921 Inf 3.21e-09
## yst             35.6  86.2  -133   205  0.413 Inf 6.80e-01
## TDI:yst         57.7 106.0  -150   265  0.544 Inf 5.86e-01
```

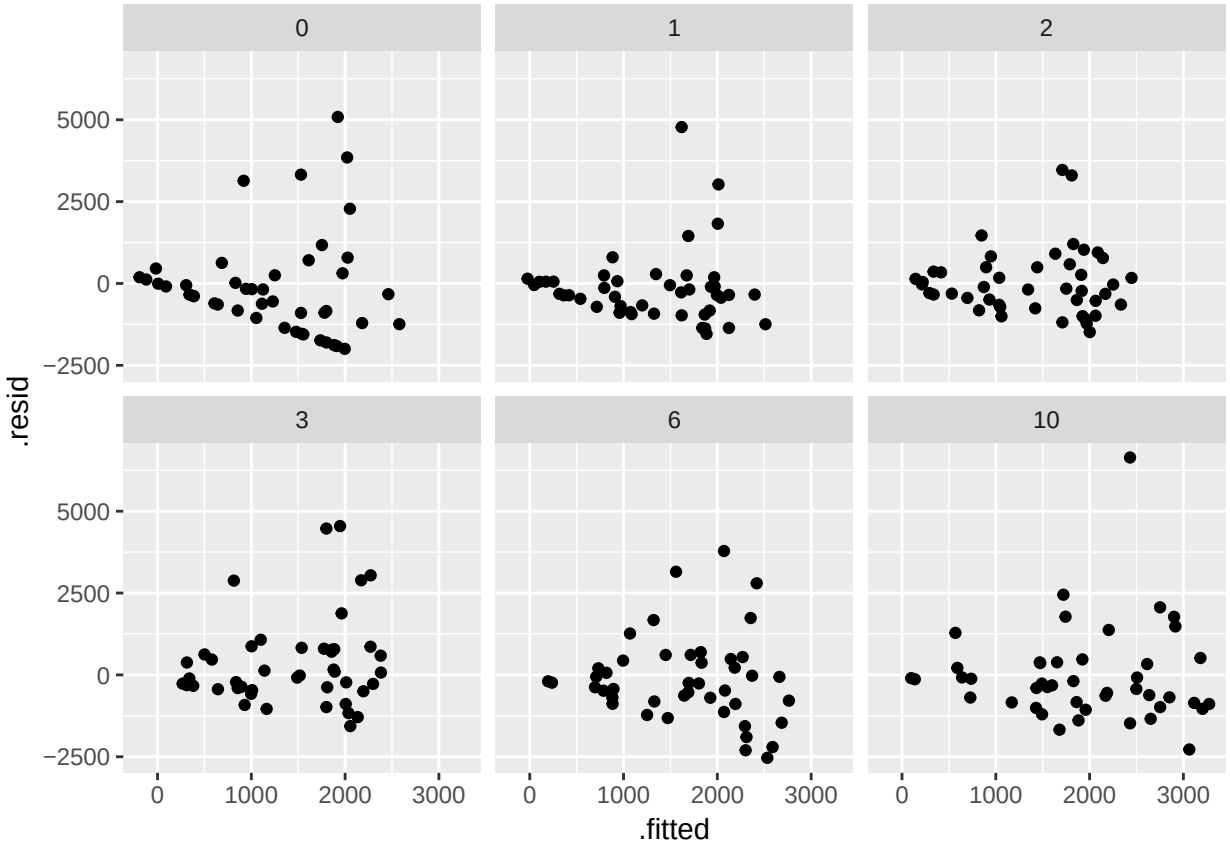
```
#by yst
l$yhat_shrub <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = shrub_fuel))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_shrub))
p <- p + theme_bw()
p <- p + labs(title = 'Shrub Fuels',
              x = 'Tree Dominance Index',
              y = 'Square Root of Fuel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



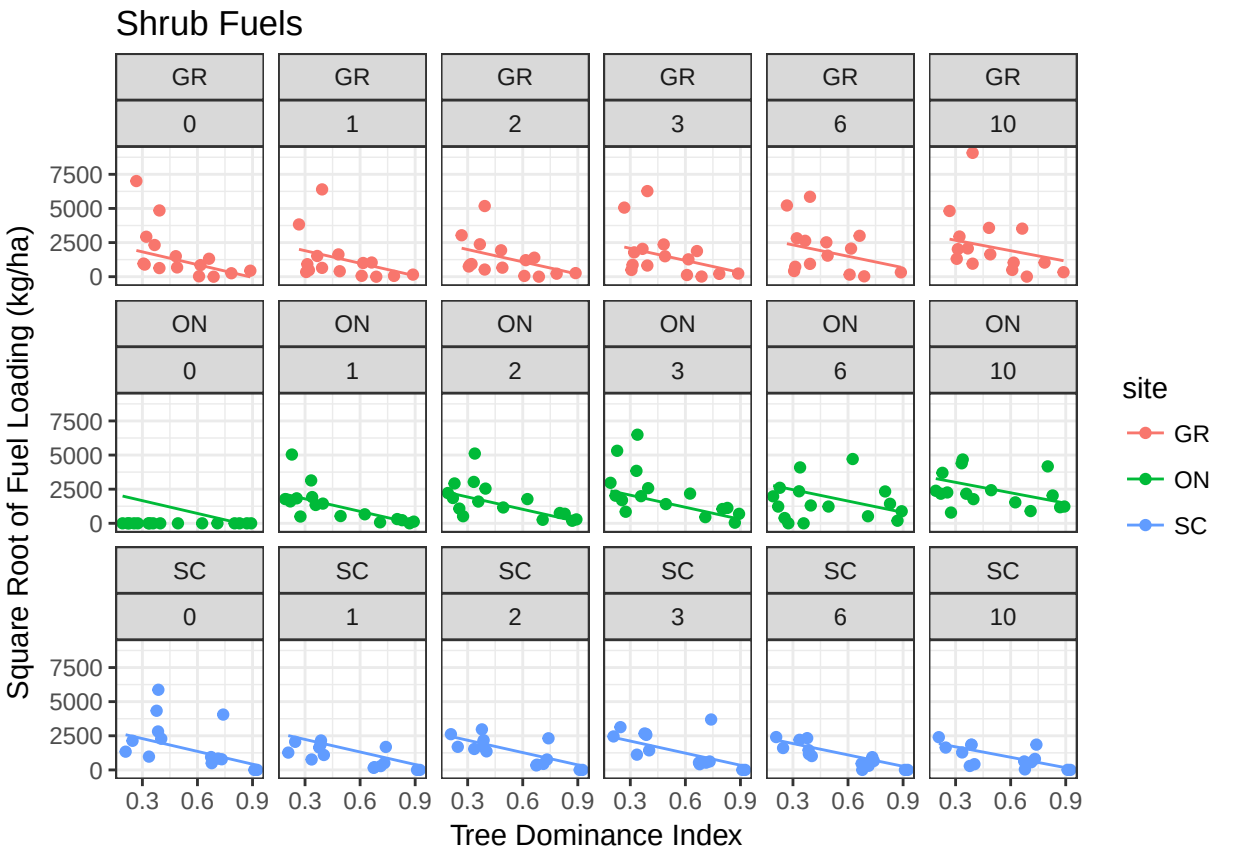

```
qqnorm(resid(m)); qqline(resid(m))
```



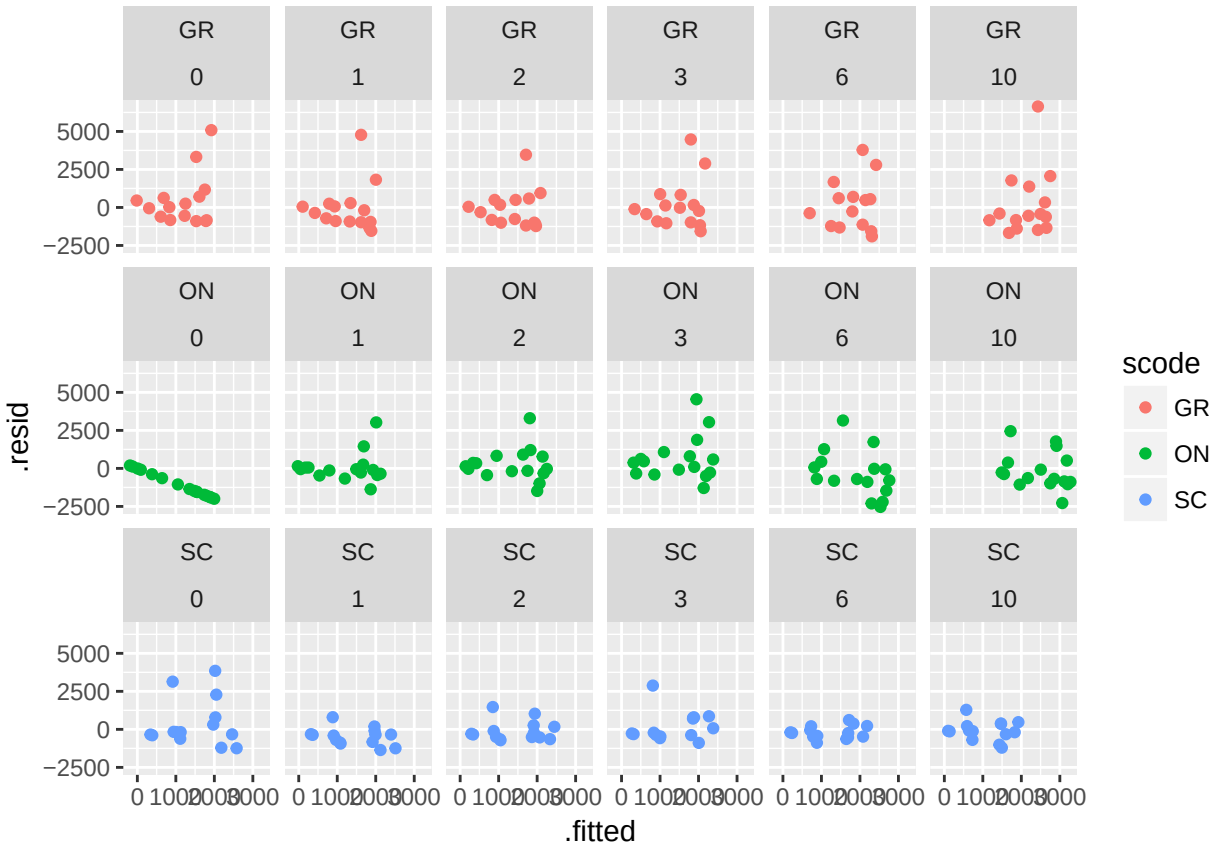

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
l$yhat_shrub <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = 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)
```




```
ggplot(m, aes(x = .fitted, y = .resid, color = scode)) +
  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)
```

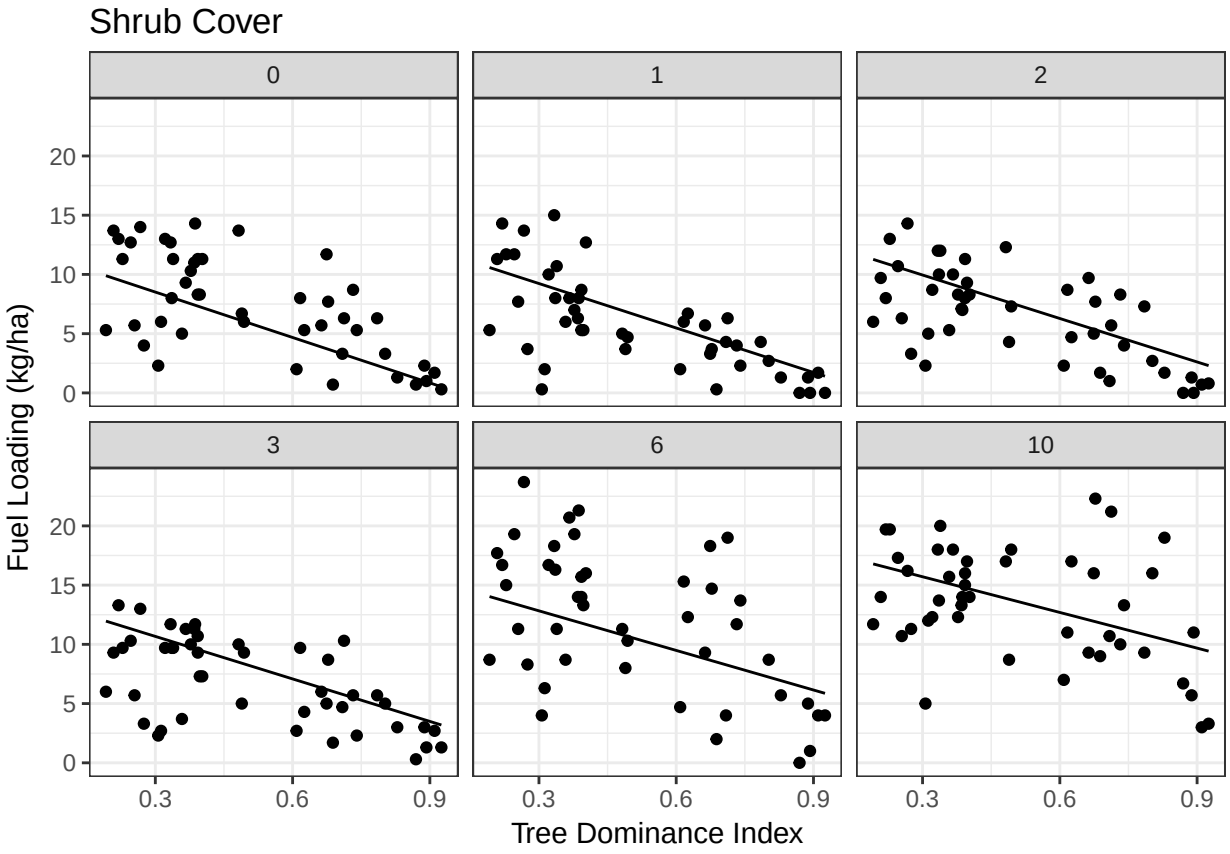
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: can_cover_pt_shrub ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
## REML criterion at convergence: 1474
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.5377 -0.7147 -0.0782  0.6614  3.0501
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  1.6278  1.276
##           yst          0.0201  0.142    -0.46
##  Residual             13.7350  3.706
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
```

```
## (Intercept)   12.347      1.109   11.13
## TDI          -12.783      1.476   -8.66
## yst            0.637      0.185    3.45
## TDI:yst        0.274      0.295    0.93
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.685
## yst     -0.626  0.601
## TDI:yst  0.501 -0.731 -0.821
```

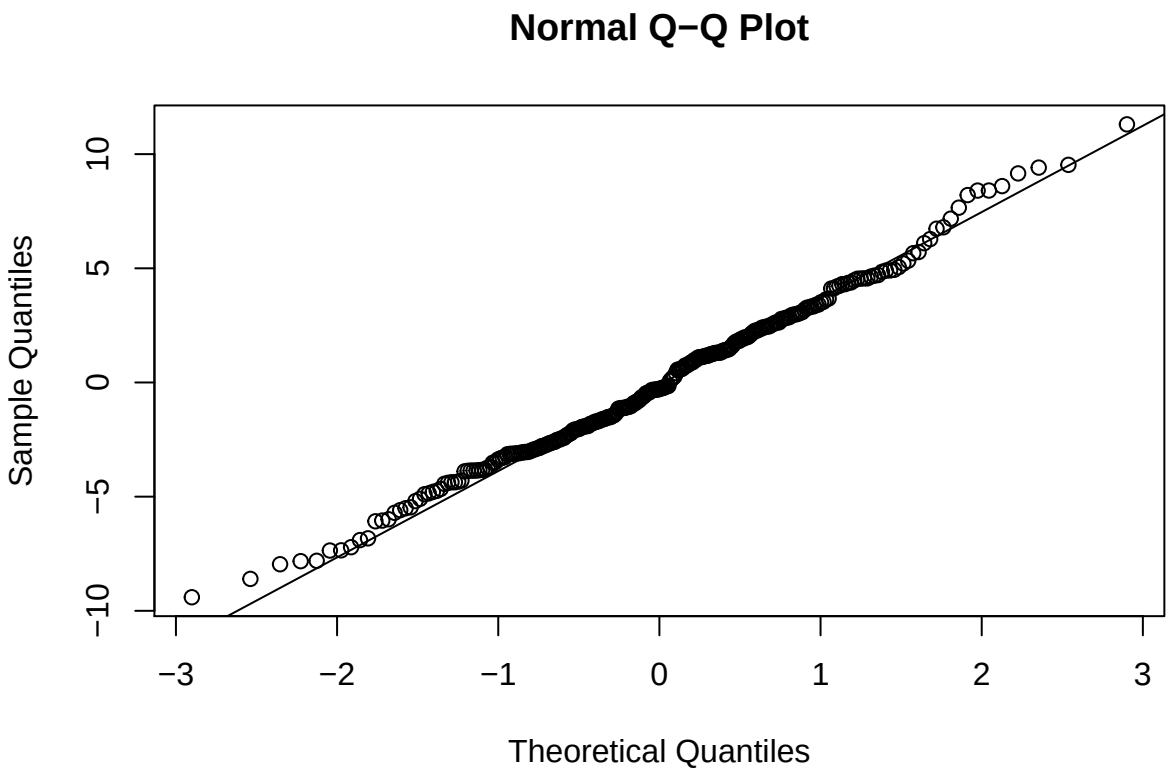
```
lincon(m)
```

```
##             estimate    se   lower  upper tvalue  df   pvalue
## (Intercept)   12.347 1.109  10.173 14.520 11.134 Inf 8.58e-29
## TDI          -12.783 1.476 -15.675 -9.890 -8.661 Inf 4.67e-18
## yst            0.637 0.185   0.275  0.999  3.448 Inf 5.65e-04
## TDI:yst        0.274 0.295  -0.305  0.853  0.928 Inf 3.53e-01
```

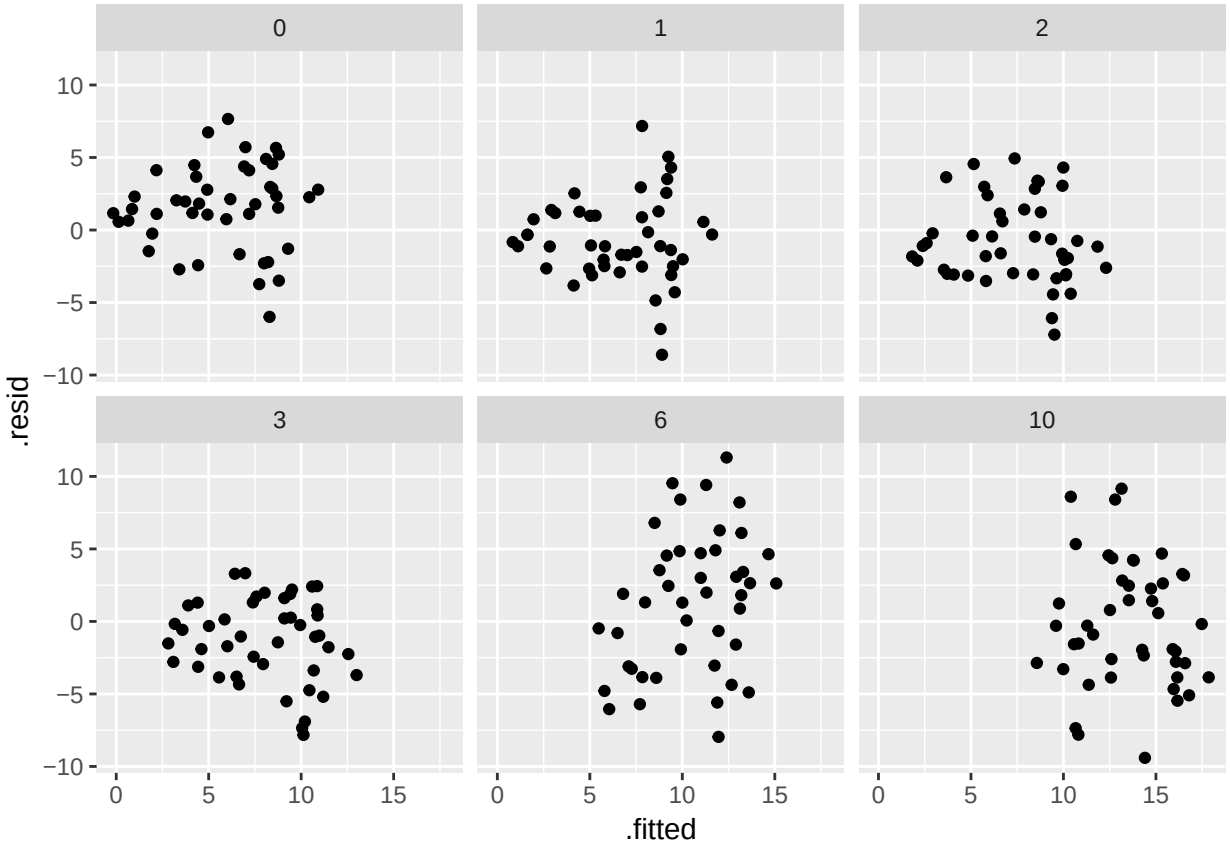
```
#by yst
l$yhat_sh_cvr <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = can_cover_pt_shrub))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_sh_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Shrub Cover',
              x = 'Tree Dominance Index',
              y = 'Fuel Loading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



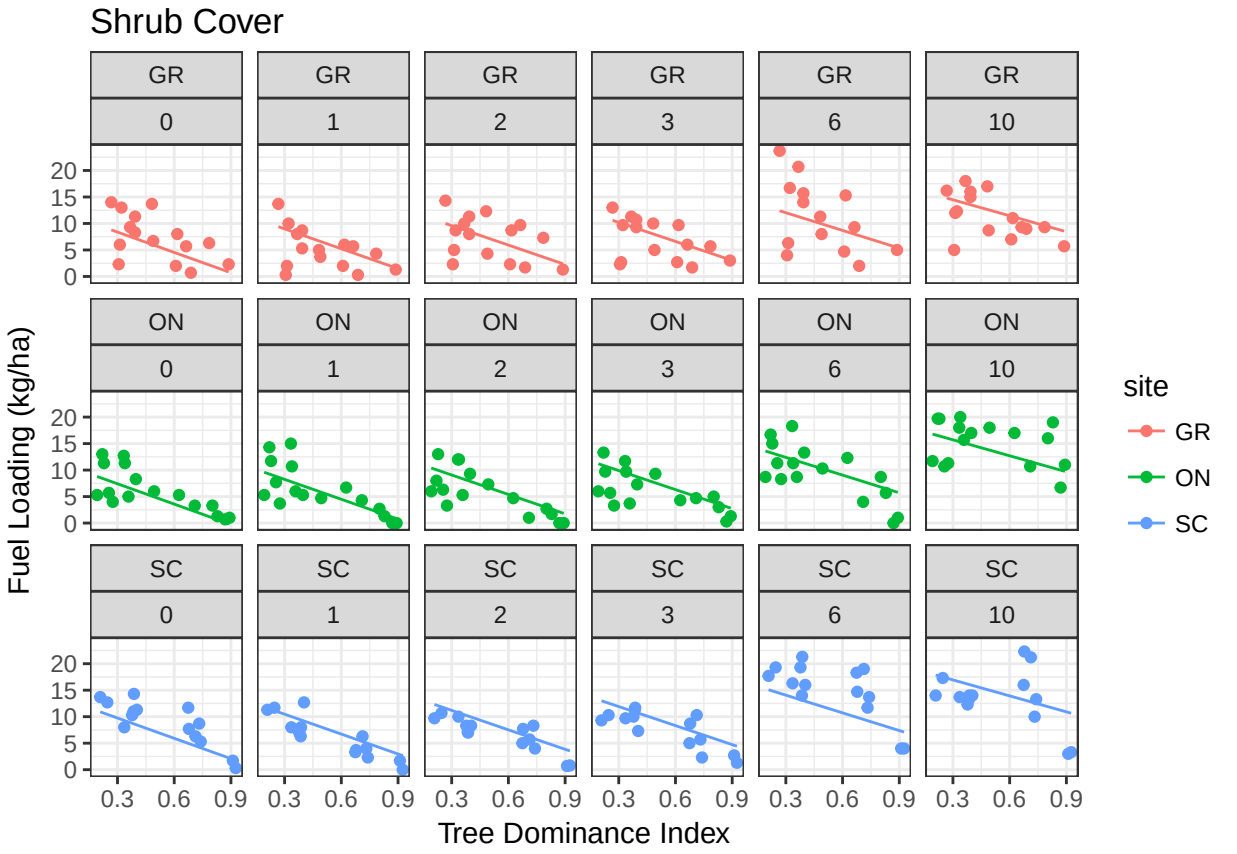

```
qqnorm(resid(m)); qqline(resid(m))
```



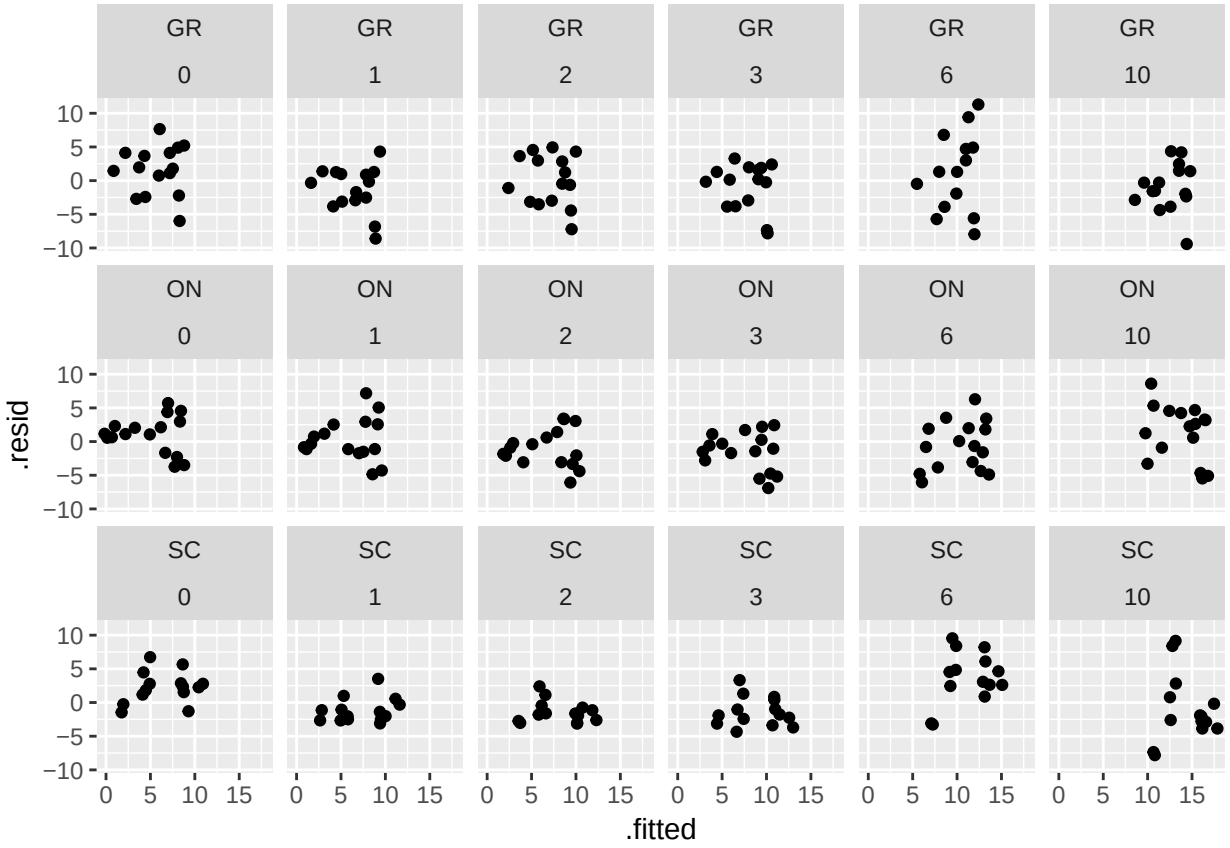

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
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)
```




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



Perennial Grass Cover

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

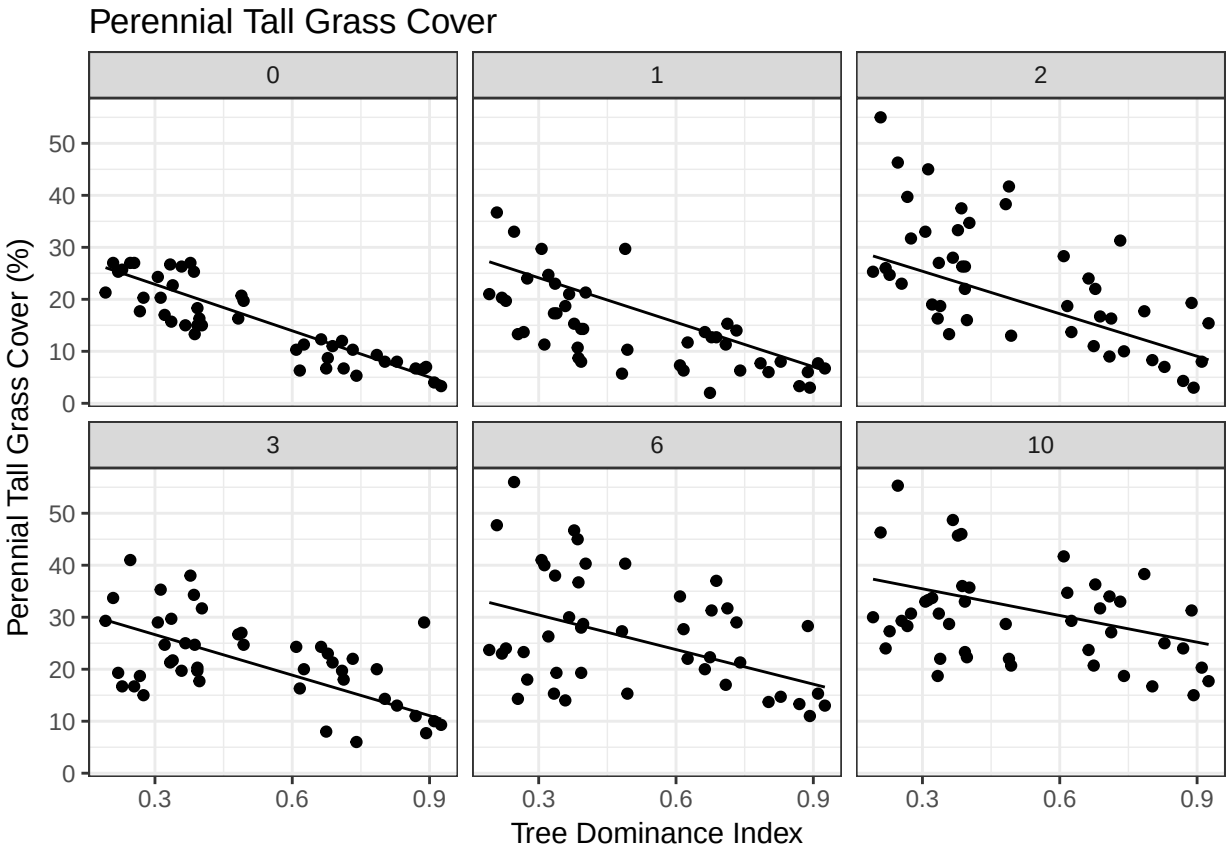
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: can_cover_pt_pgrass ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
## REML criterion at convergence: 1817
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -2.145 -0.593 -0.069  0.579  3.488
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  4.370   2.090
##           yst          0.316   0.562    1.00
##  Residual             49.927   7.066
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   31.813      1.982   16.05
```

```
## TDI          -29.782      2.802  -10.63
## yst            0.879      0.452    1.94
## TDI:yst        1.267      0.561    2.26
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.726
## yst      0.035  0.464
## TDI:yst  0.529 -0.729 -0.637
```

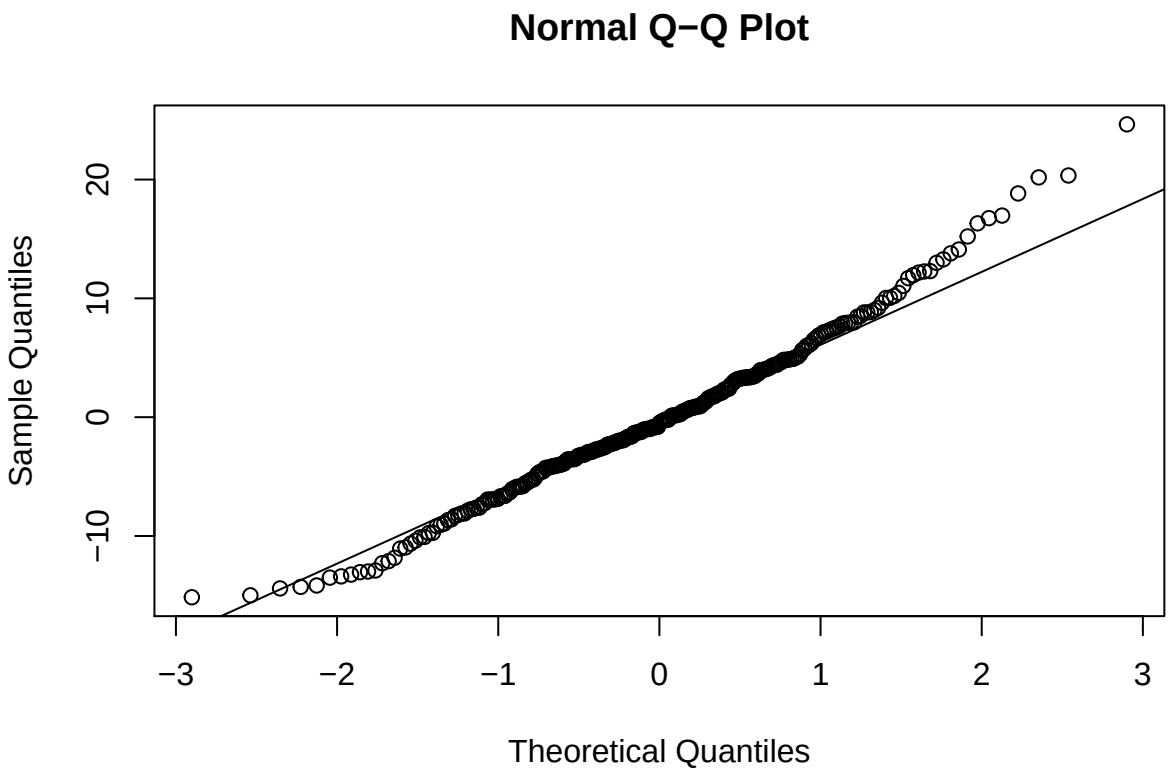
```
lincon(m)
```

```
##             estimate    se     lower  upper tvalue  df   pvalue
## (Intercept)   31.813 1.982  27.92841  35.70  16.05 Inf 5.61e-58
## TDI          -29.782 2.802 -35.27301 -24.29 -10.63 Inf 2.15e-26
## yst            0.879 0.452  -0.00739   1.77   1.94 Inf 5.19e-02
## TDI:yst        1.267 0.561   0.16683   2.37   2.26 Inf 2.40e-02
```

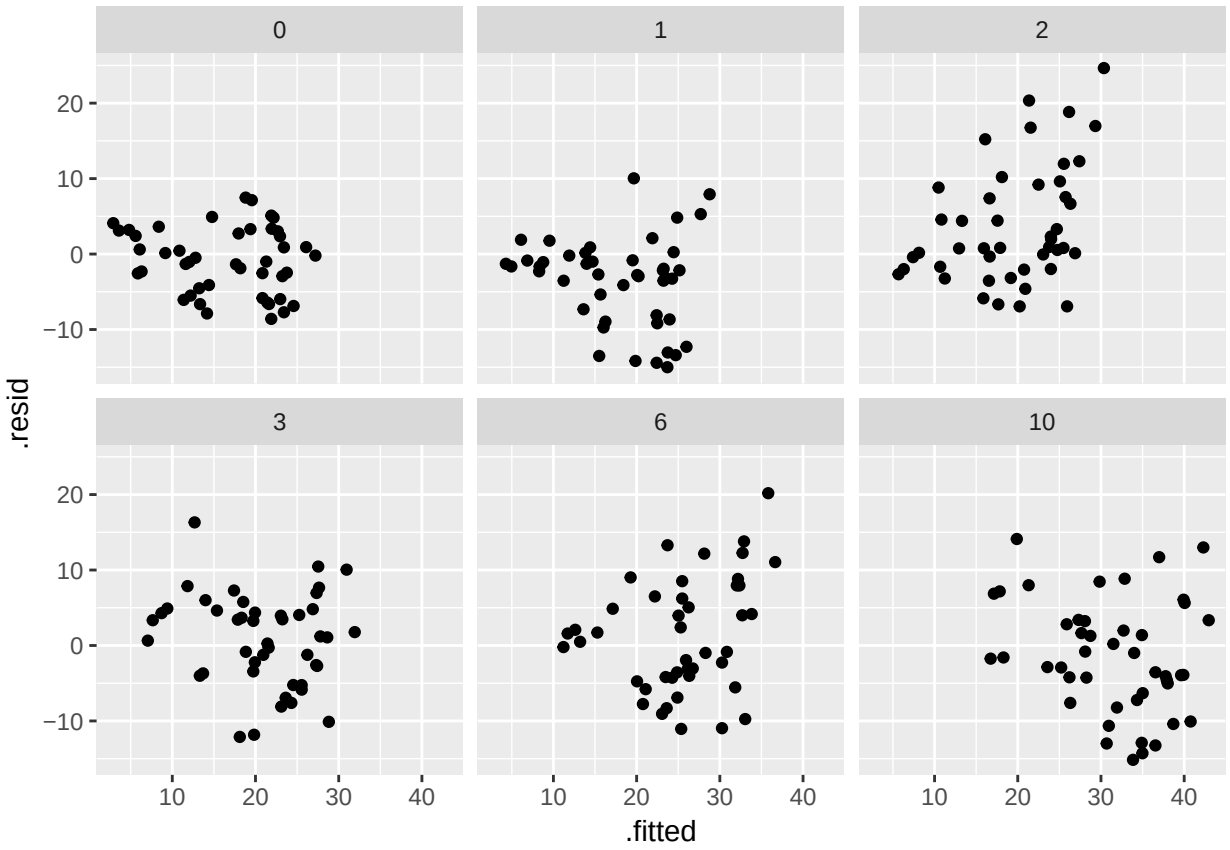
```
#by yst
l$yhat_pgrass_cvr <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = can_cover_pt_pgrass))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_pgrass_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Perennial Tall Grass Cover',
               x = 'Tree Dominance Index',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



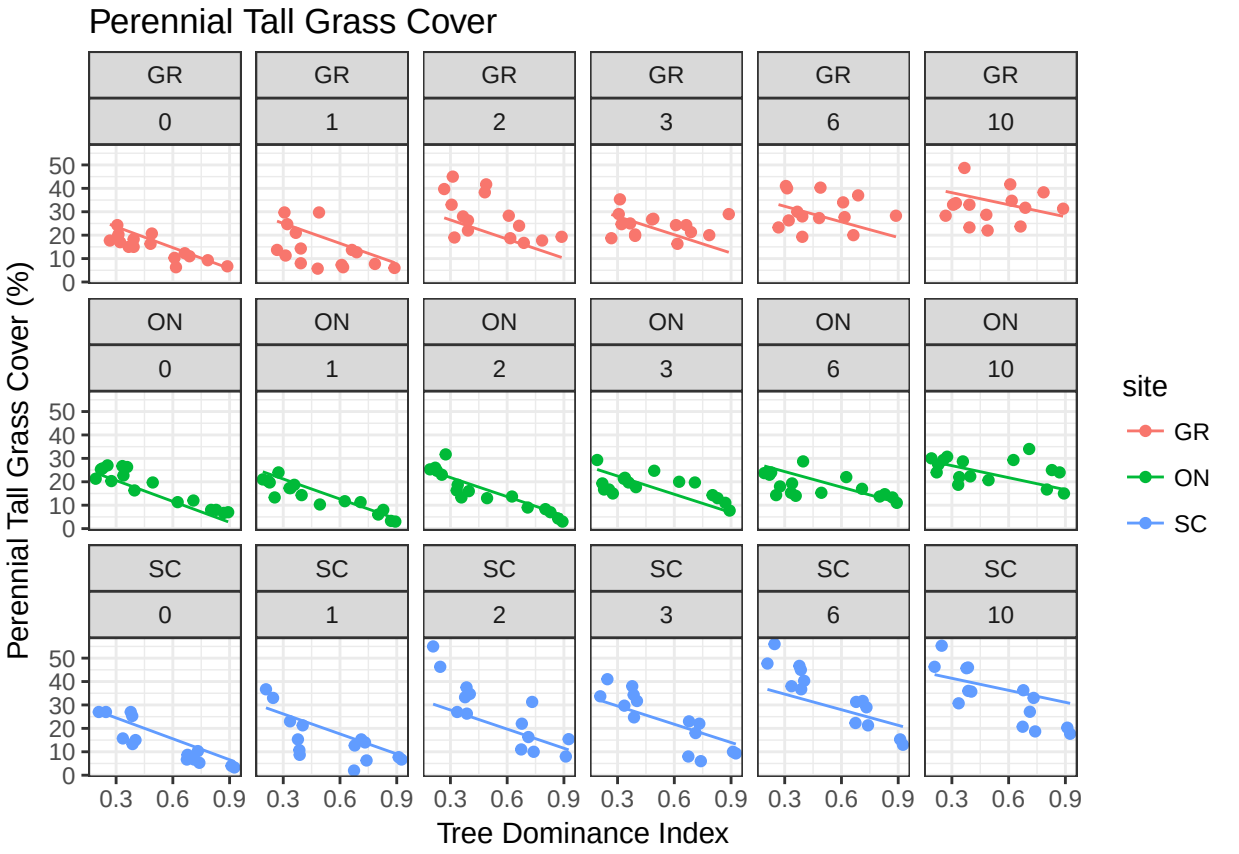

```
qqnorm(resid(m)); qqline(resid(m))
```



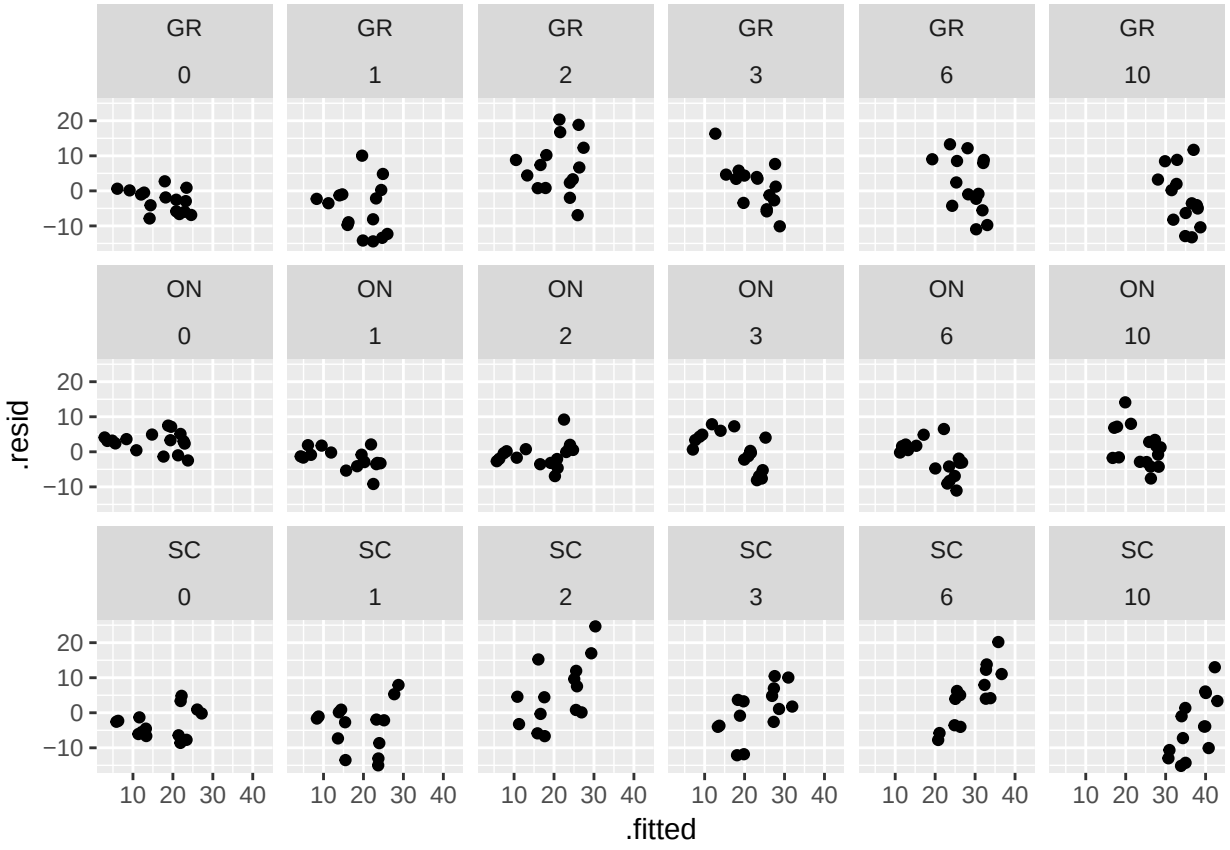

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
l$yhat_pgrass_cvr <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = 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)
```




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

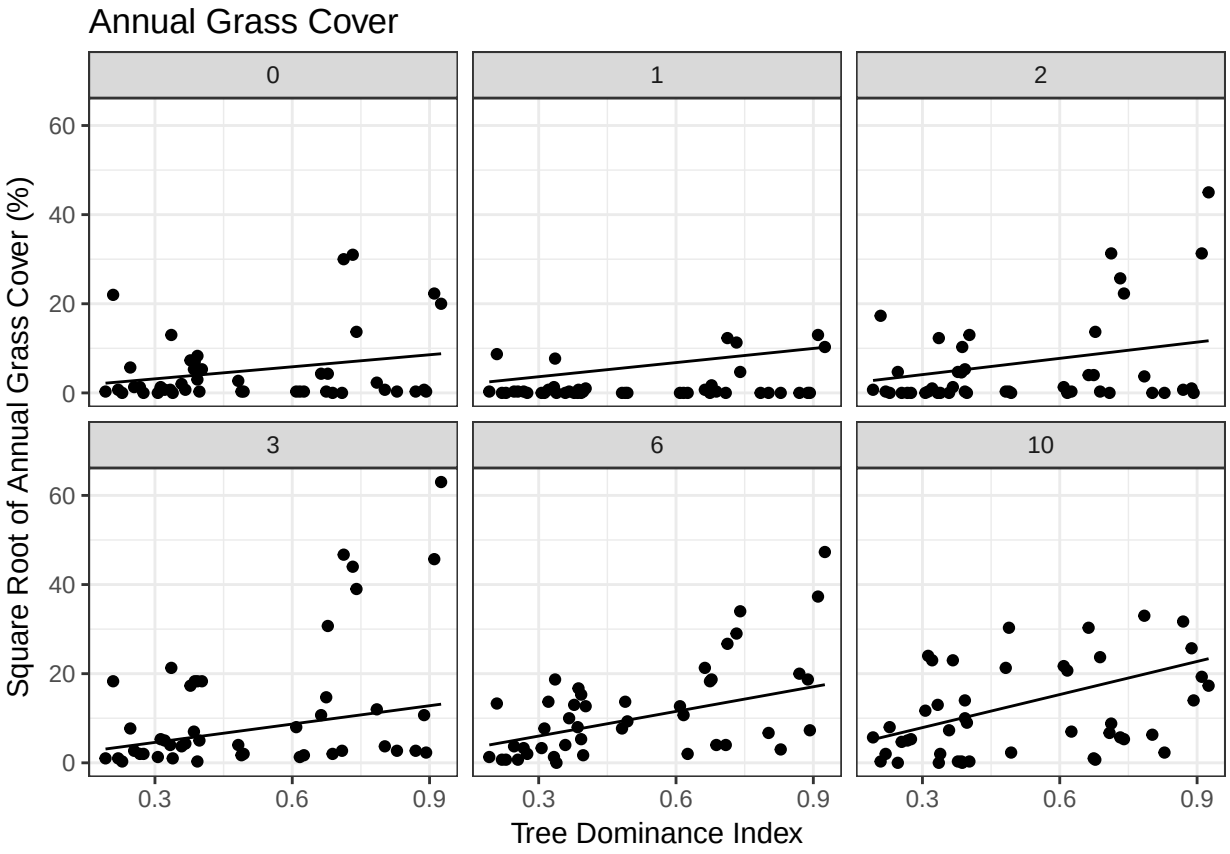
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: can_cover_pt_agrass ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
## REML criterion at convergence: 1871
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -2.238 -0.529 -0.046  0.357  5.538
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 92.79    9.63
##           yst          1.73    1.31     -0.90
##  Residual             59.72    7.73
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
```

```
## (Intercept)   0.4513     5.8248    0.08
## TDI           9.0081     3.0823    2.92
## yst           0.0026     0.8339    0.00
## TDI:yst       1.5726     0.6171    2.55
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.272
## yst     -0.869  0.279
## TDI:yst  0.199 -0.732 -0.381
```

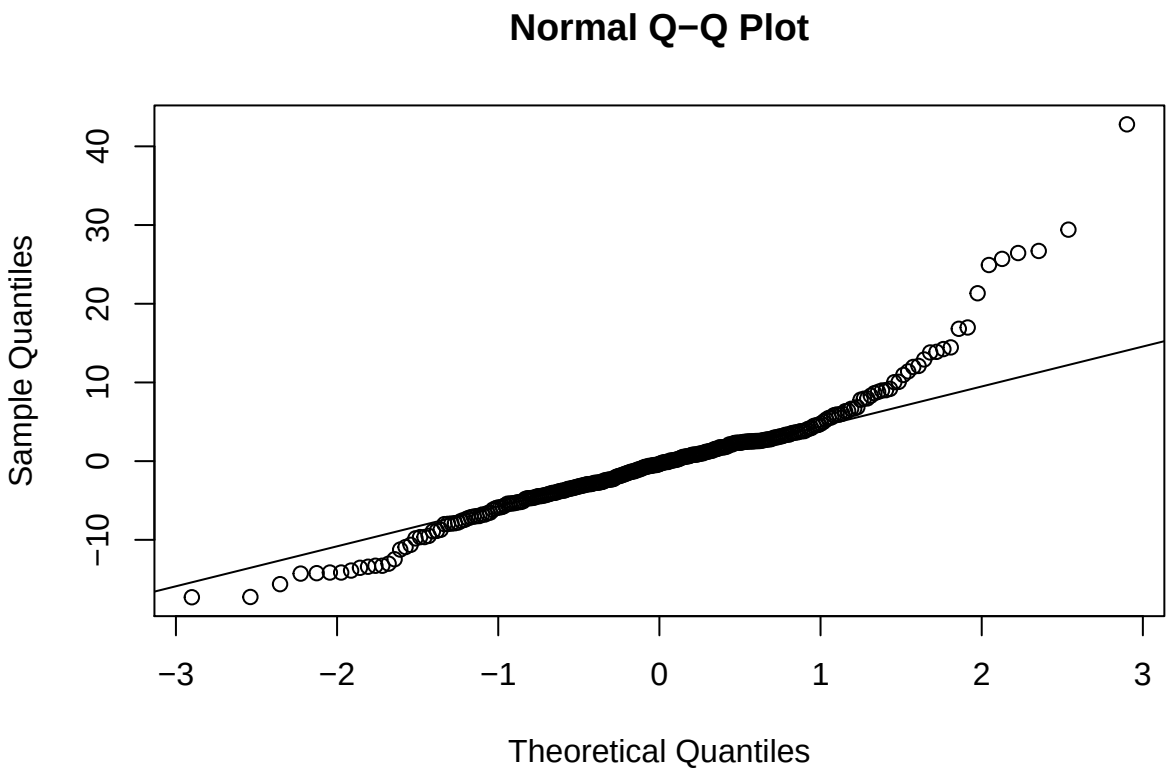
```
lincon(m)
```

```
##             estimate    se   lower upper  tvalue  df  pvalue
## (Intercept)   0.4513 5.825 -10.965 11.87 0.07747 Inf 0.93825
## TDI           9.0081 3.082   2.967 15.05 2.92254 Inf 0.00347
## yst           0.0026 0.834  -1.632  1.64 0.00312 Inf 0.99751
## TDI:yst       1.5726 0.617   0.363  2.78 2.54841 Inf 0.01082
```

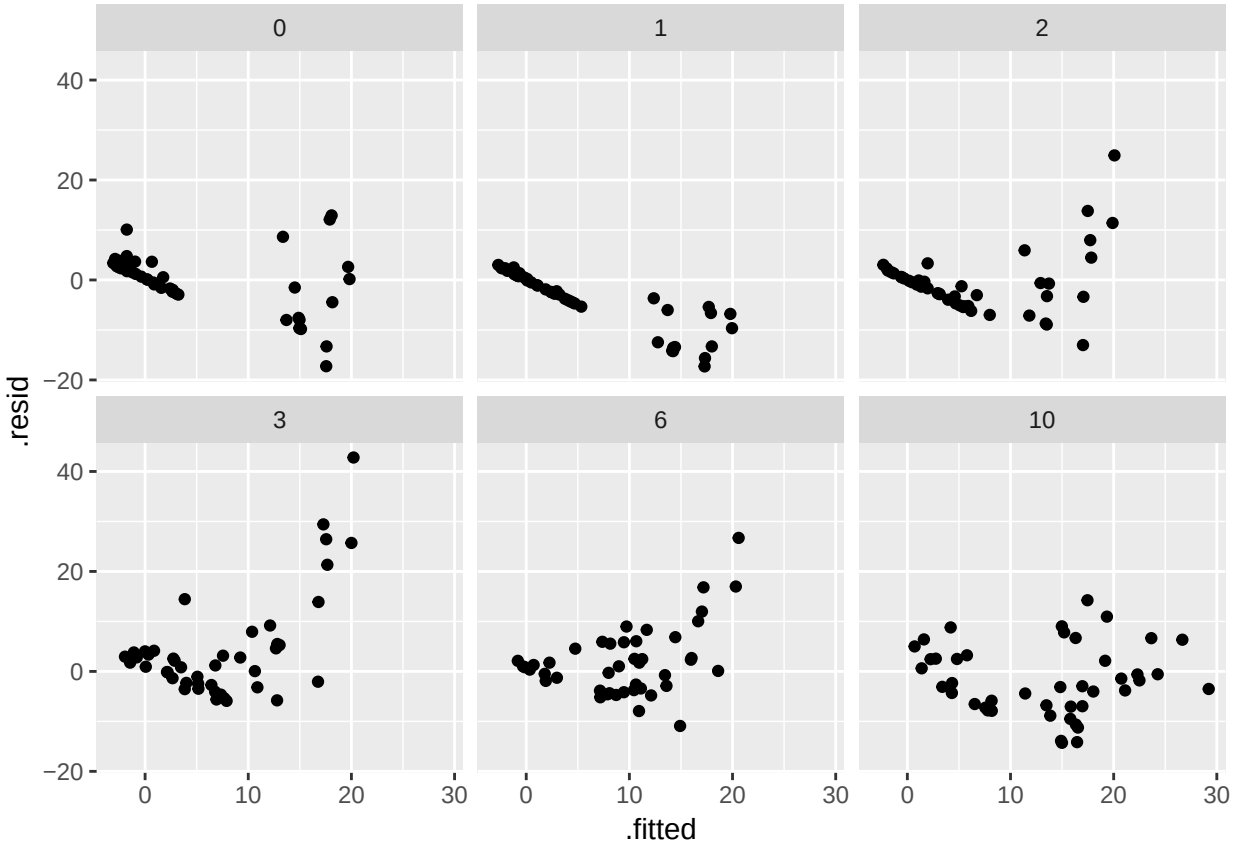
```
#by yst
l$yhat_agrass_cvr <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = can_cover_pt_agrass))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_agrass_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Annual Grass Cover',
               x = 'Tree Dominance Index',
               y = 'Square Root of Annual Grass Cover (%)')
p <- p + scale_x_continuous(breaks = seq(0,1, by = 0.3))
p <- p + facet_wrap(~yst, ncol = 3)
plot(p)
```



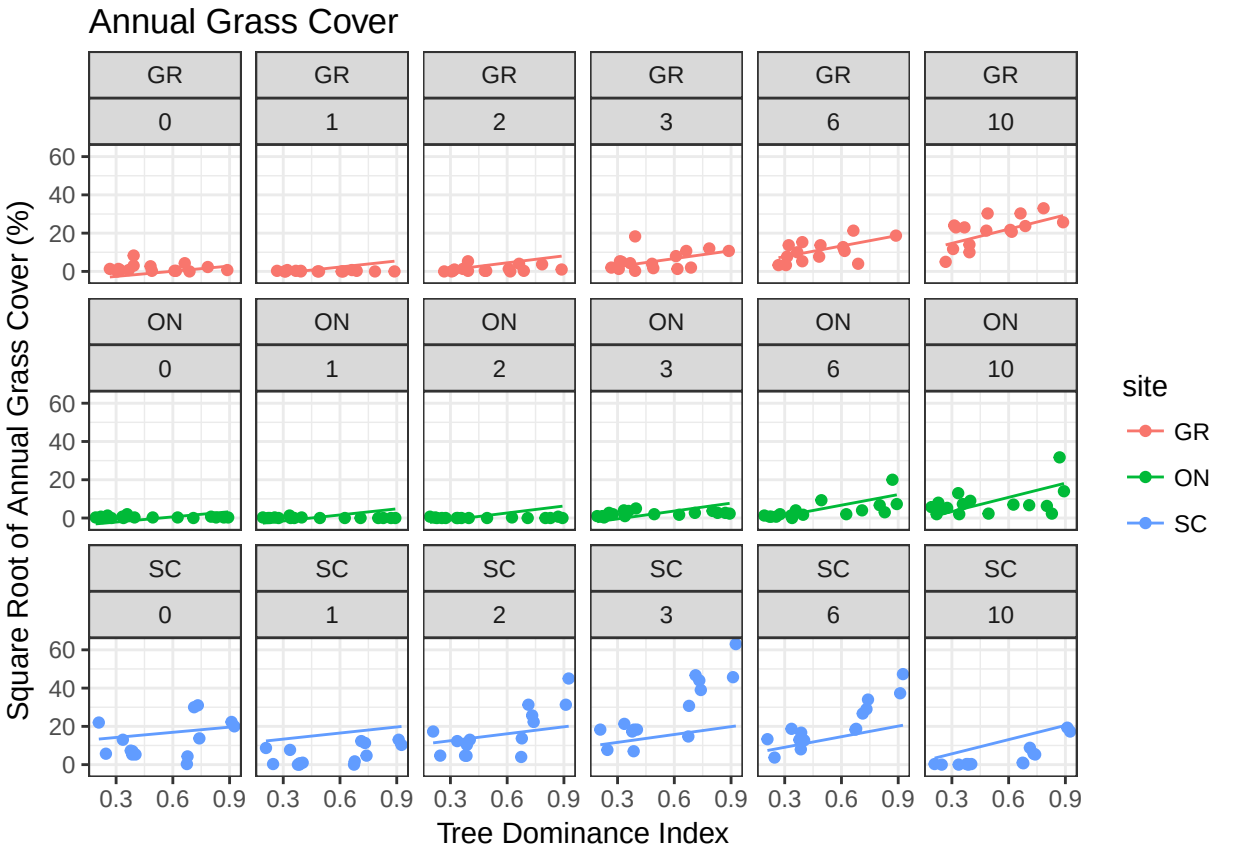

```
qqnorm(resid(m)); qqline(resid(m))
```



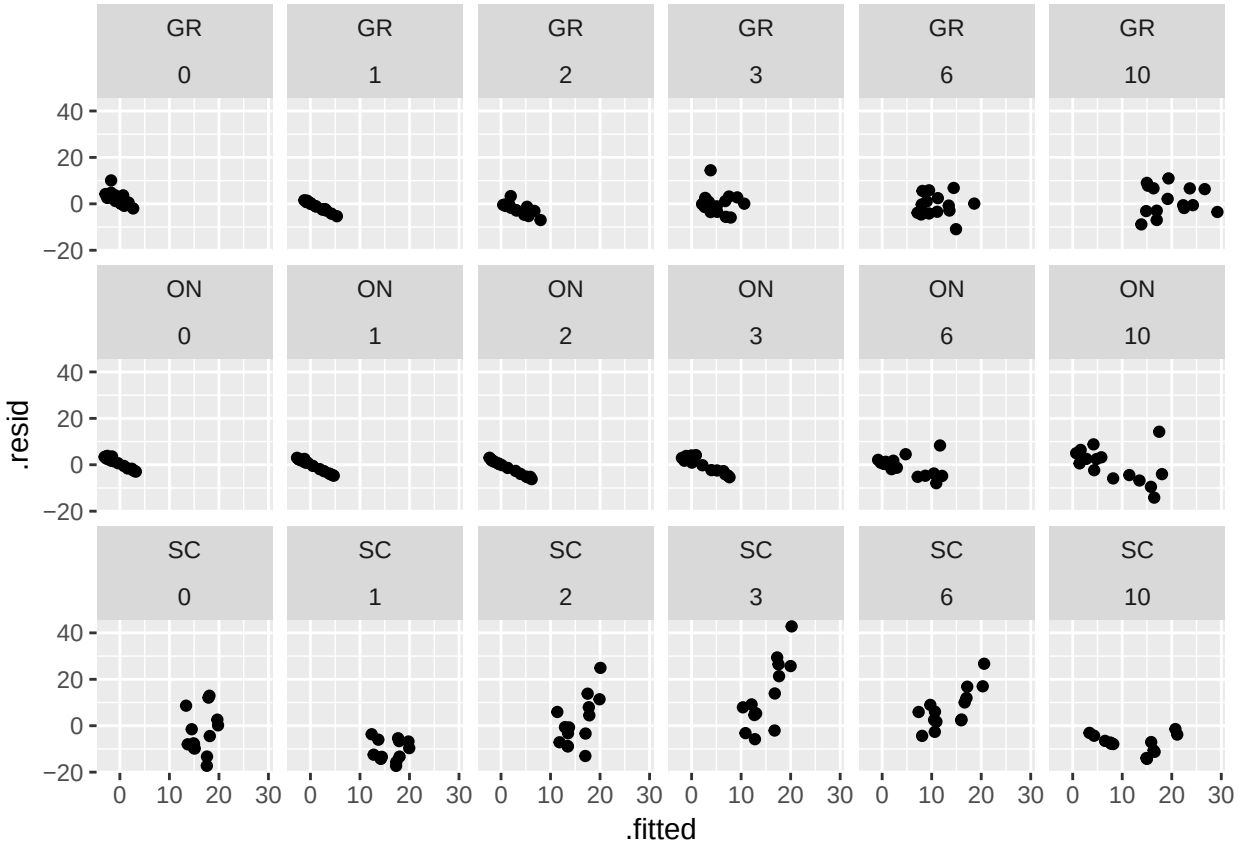

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
l$yhat_agrass_cvr <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = 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 = 'Square Root of 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)
```




```
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$tree_dns_
td <- filter(td, (yst %in% c(-1,1,2,3,6,10) & scode %in% c('SC', 'GR')) |
               (yst %in% c(0,1,2,3,6,10) & scode == 'ON'))
td$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(tree_dns_gt50_JUOS + tree_dns_gt50_PIED ~
            TC + factor(yst) + factor(yst):TC + (1 + factor(yst)|scode), data = td)
summary(m)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: tree_dns_gt50_JUOS + tree_dns_gt50_PIED ~ TC + factor(yst) +
##     factor(yst):TC + (1 + factor(yst) | scode)
##    Data: td
##
## REML criterion at convergence: 2573
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
##  -5.06   0.00   0.00   0.00   3.55
##
## Random effects:
```

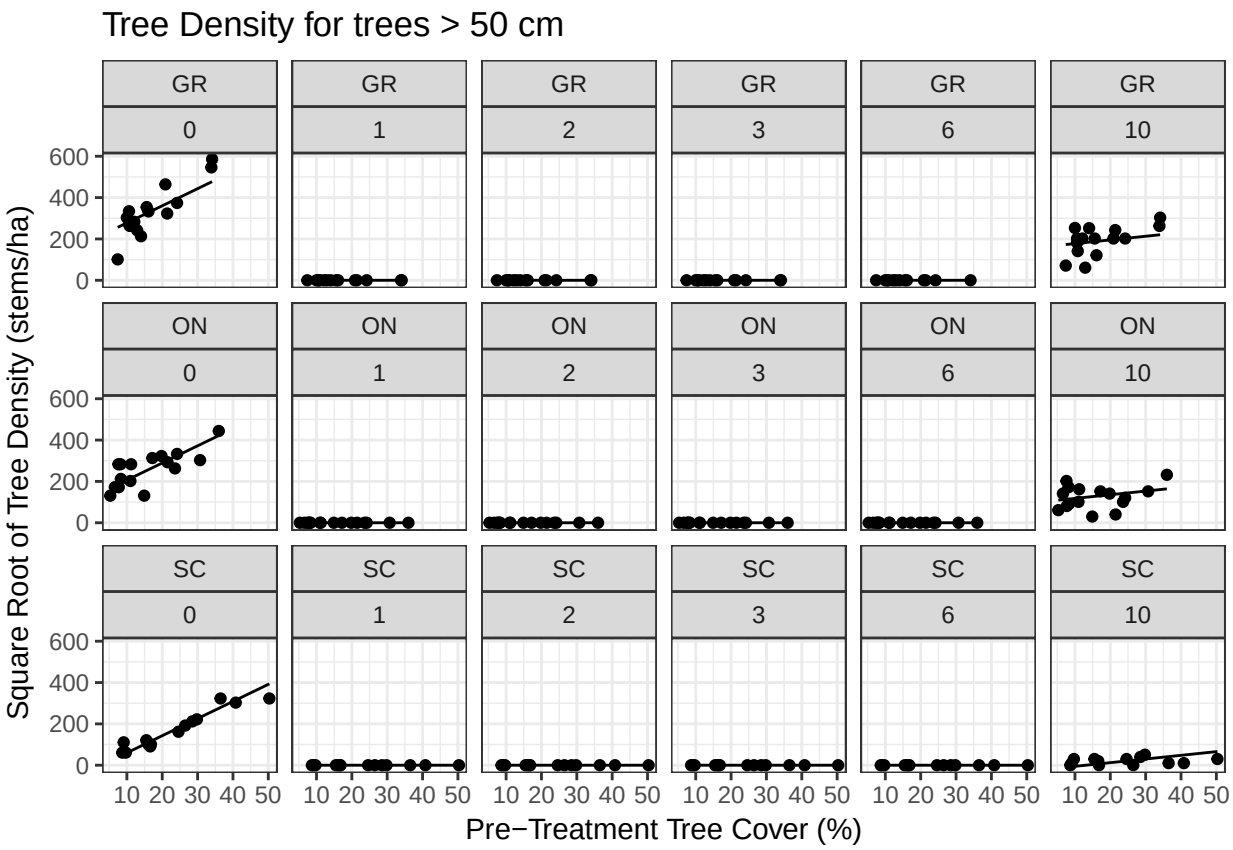
```
##  Groups   Name          Variance Std.Dev. Corr
##  scode    (Intercept)   12342    111.1
##           factor(yst)1  12342    111.1    -1.00
##           factor(yst)2  12342    111.1    -1.00  1.00
##           factor(yst)3  12342    111.1    -1.00  1.00  1.00
##           factor(yst)6  12342    111.1    -1.00  1.00  1.00  1.00
##           factor(yst)10   315     17.7    -1.00  1.00  1.00  1.00  1.00
##  Residual                 938     30.6
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##                  Estimate Std. Error t value
## (Intercept)        98.376     64.861    1.52
## TC                  8.287      0.453   18.28
## factor(yst)1      -98.376     65.534   -1.50
## factor(yst)2      -98.376     65.534   -1.50
## factor(yst)3      -98.376     65.534   -1.50
## factor(yst)6      -98.376     65.544   -1.50
## factor(yst)10     -19.481     16.742   -1.16
## TC:factor(yst)1    -8.287      0.631  -13.13
## TC:factor(yst)2    -8.287      0.631  -13.13
## TC:factor(yst)3    -8.287      0.631  -13.13
## TC:factor(yst)6    -8.287      0.639  -12.97
## TC:factor(yst)10   -6.511      0.621  -10.48
##
## Correlation of Fixed Effects:
##             (Intr) TC     fct()1 fct()2 fct()3 fct()6 fc()10 TC:f()1
## TC          -0.131
## factr(yst)1 -0.990  0.130
## factr(yst)2 -0.990  0.130  0.980
## factr(yst)3 -0.990  0.130  0.980  0.980
## factr(yst)6 -0.990  0.130  0.979  0.979  0.979
## fctr(yst)10 -0.686  0.478  0.679  0.679  0.679  0.679
## TC:fctr(y)1  0.094 -0.718 -0.180 -0.093 -0.093 -0.093 -0.344
## TC:fctr(y)2  0.094 -0.718 -0.093 -0.180 -0.093 -0.093 -0.344  0.516
## TC:fctr(y)3  0.094 -0.718 -0.093 -0.093 -0.180 -0.093 -0.344  0.516
## TC:fctr(y)6  0.093 -0.710 -0.092 -0.092 -0.092 -0.180 -0.339  0.510
## TC:fctr()10  0.090 -0.692 -0.089 -0.089 -0.089 -0.089 -0.691  0.497
##             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  0.516
## TC:fctr(y)6  0.510  0.510
## TC:fctr()10  0.497  0.497  0.491
```

```
lincon(m)
```

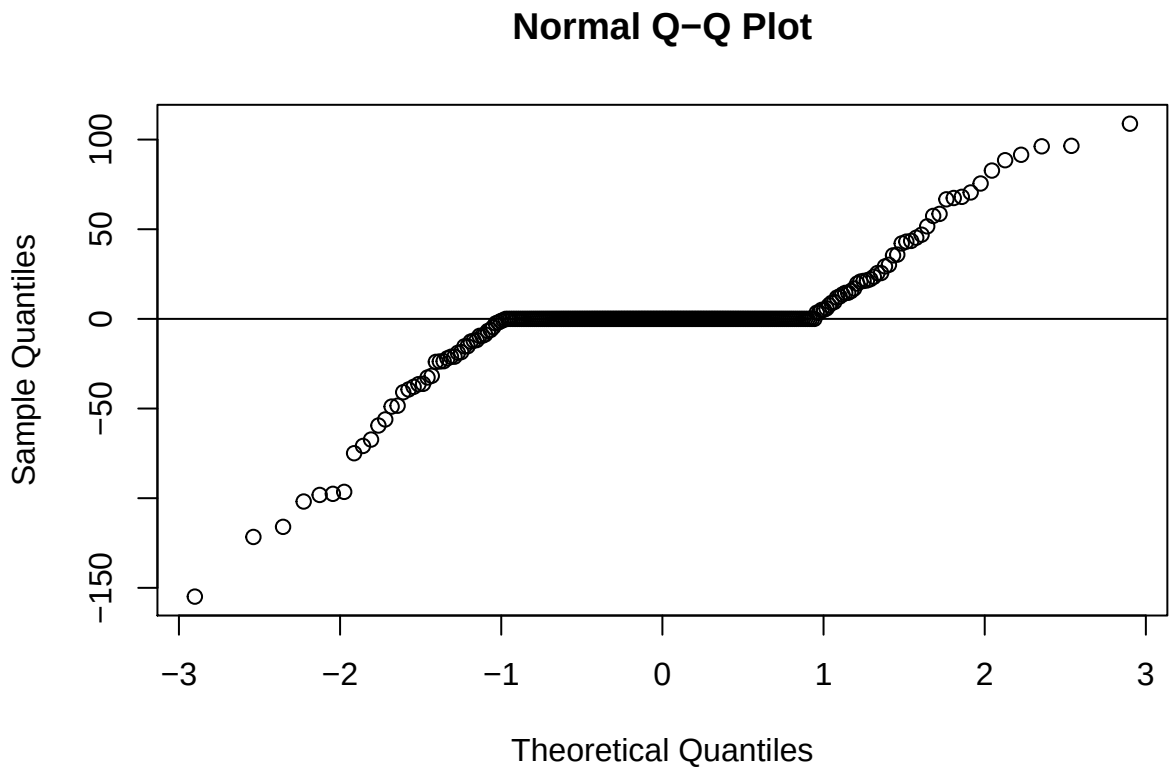
```
##                  estimate     se   lower  upper tvalue  df   pvalue
## (Intercept)         98.38 64.861  -28.75 225.50   1.52 Inf 1.29e-01
```

```
## TC                   8.29  0.453    7.40   9.18  18.28 Inf 1.30e-74
## factor(yst)1       -98.38 65.534 -226.82  30.07  -1.50 Inf 1.33e-01
## factor(yst)2       -98.38 65.534 -226.82  30.07  -1.50 Inf 1.33e-01
## factor(yst)3       -98.38 65.534 -226.82  30.07  -1.50 Inf 1.33e-01
## factor(yst)6       -98.38 65.544 -226.84  30.09  -1.50 Inf 1.33e-01
## factor(yst)10      -19.48 16.742  -52.30  13.33  -1.16 Inf 2.45e-01
## TC:factor(yst)1     -8.29  0.631   -9.52  -7.05 -13.13 Inf 2.21e-39
## TC:factor(yst)2     -8.29  0.631   -9.52  -7.05 -13.13 Inf 2.21e-39
## TC:factor(yst)3     -8.29  0.631   -9.52  -7.05 -13.13 Inf 2.21e-39
## TC:factor(yst)6     -8.29  0.639   -9.54  -7.03 -12.97 Inf 1.82e-38
## TC:factor(yst)10    -6.51  0.621   -7.73  -5.29 -10.48 Inf 1.02e-25
```

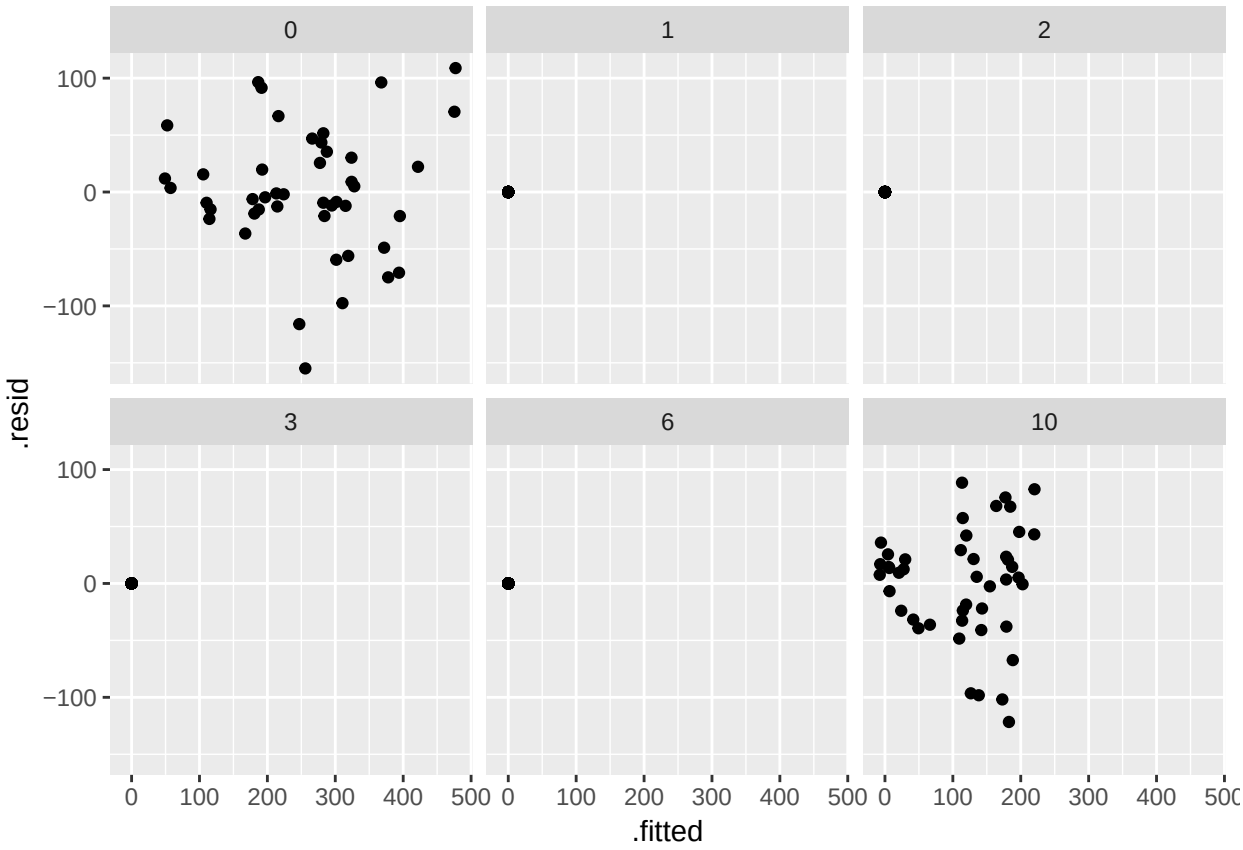
```r
#by yst
td$yhat_tree_dens <- predict(m)
p <- ggplot(data = td, aes(x = TC,
                           y = tree_dns_gt50_JUOS + tree_dns_gt50_PIED))
p <- p + geom_point()
p <- p + theme_bw()
p <- p + geom_line(aes(y = yhat_tree_dens))
p <- p + labs(title = 'Tree Density for trees > 50 cm',
     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



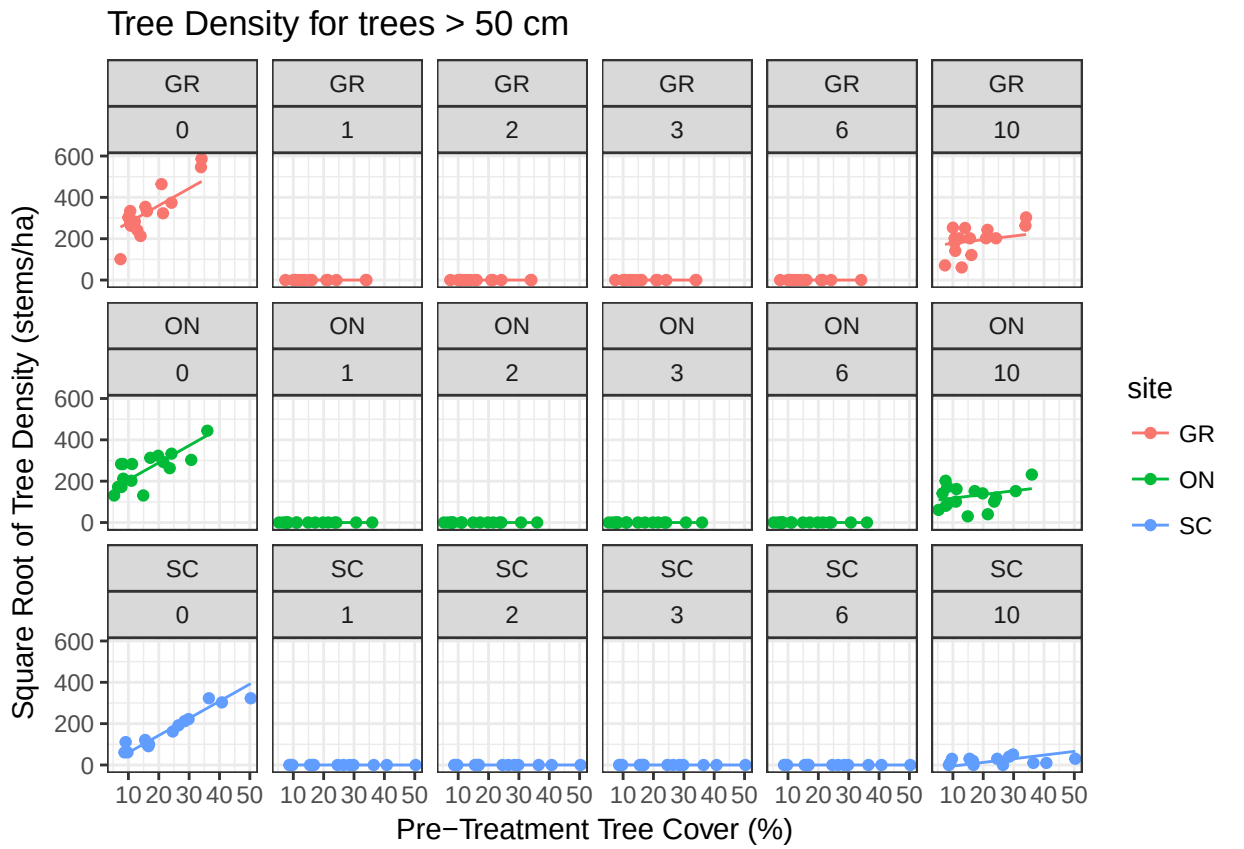
```
qqnorm(resid(m)); qqline(resid(m))
```



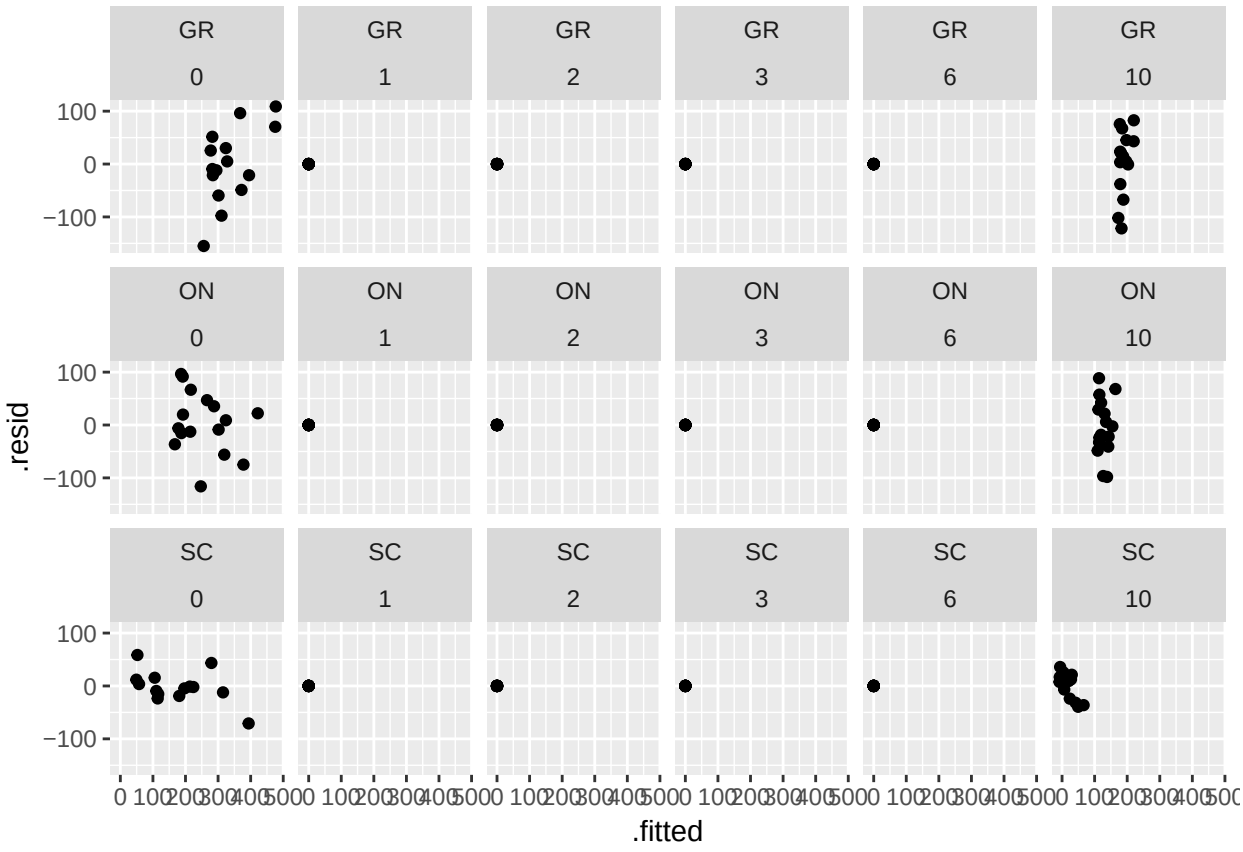

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
td$yhat_tree_dens <- predict(m)
p <- ggplot(data = td, aes(x = TC,
                           y = 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)
```




```
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(tree_cover_ttl ~ TC + yst + yst:TC + (1 + yst|scode), data = tcover)
summary(m)
lincon(m)

#by yst
tcover$yhat_tree_cover <- predict(m)
p <- ggplot(data = tcover, aes(x = TC, y = tree_cover_ttl))
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(0,60, by = 10))
p <- p + facet_wrap(scode~yst, ncol = 2)
plot(p)
```

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

#by yst and site
tcover$yhat_tree_cover <- predict(m)
p <- ggplot(data = tcover, aes(x = TC, y = 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(0,60, by = 10))
p <- p + facet_wrap(scode~yst, ncol = 2, nrow = 3)
plot(p)

ggplot(m, aes(x = .fitted, y = .resid)) +
  geom_point(aes(color = scode)) +
  facet_wrap(scode~yst, ncol = 2)
```