Masticated Fuels Analyses

Sam Wozniak

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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

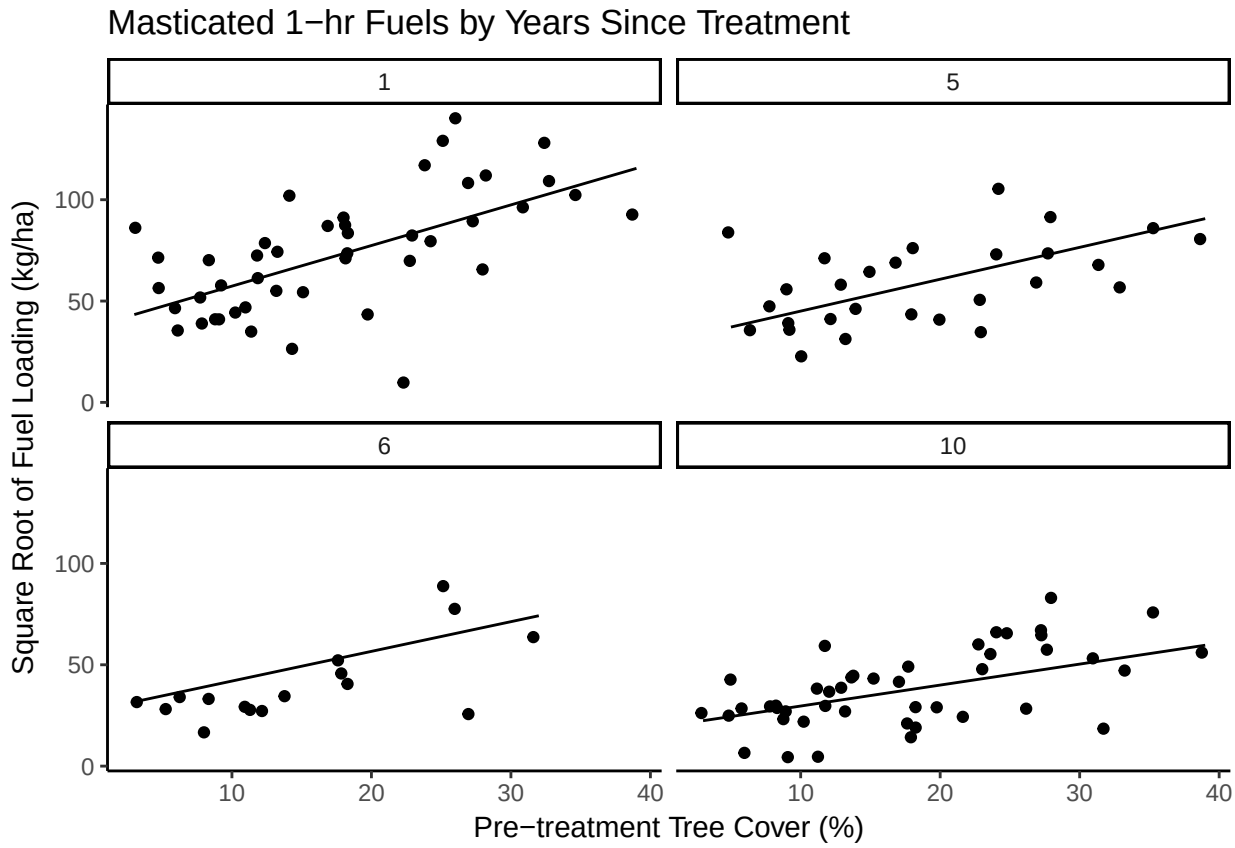
```
m <- lmer(sqrt(kgha_1h) ~ TC + yst + TC:yst + (1 + yst|scode), data = d)
summary(m)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(kgha_1h) ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 1161
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -3.618 -0.613  0.025  0.668  2.613
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 113.92   10.67
##           yst           3.57    1.89    -1.00
##  Residual             330.44   18.18
## Number of obs: 134, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  39.3290     8.7153    4.51
## TC            2.1115     0.3125    6.76
## yst          -2.0033     1.4400   -1.39
## TC:yst       -0.1077     0.0477   -2.26
##
## Correlation of Fixed Effects:
##        (Intr) TC     yst
## TC     -0.630
## yst    -0.920  0.486
## TC:yst  0.525 -0.833 -0.582
```

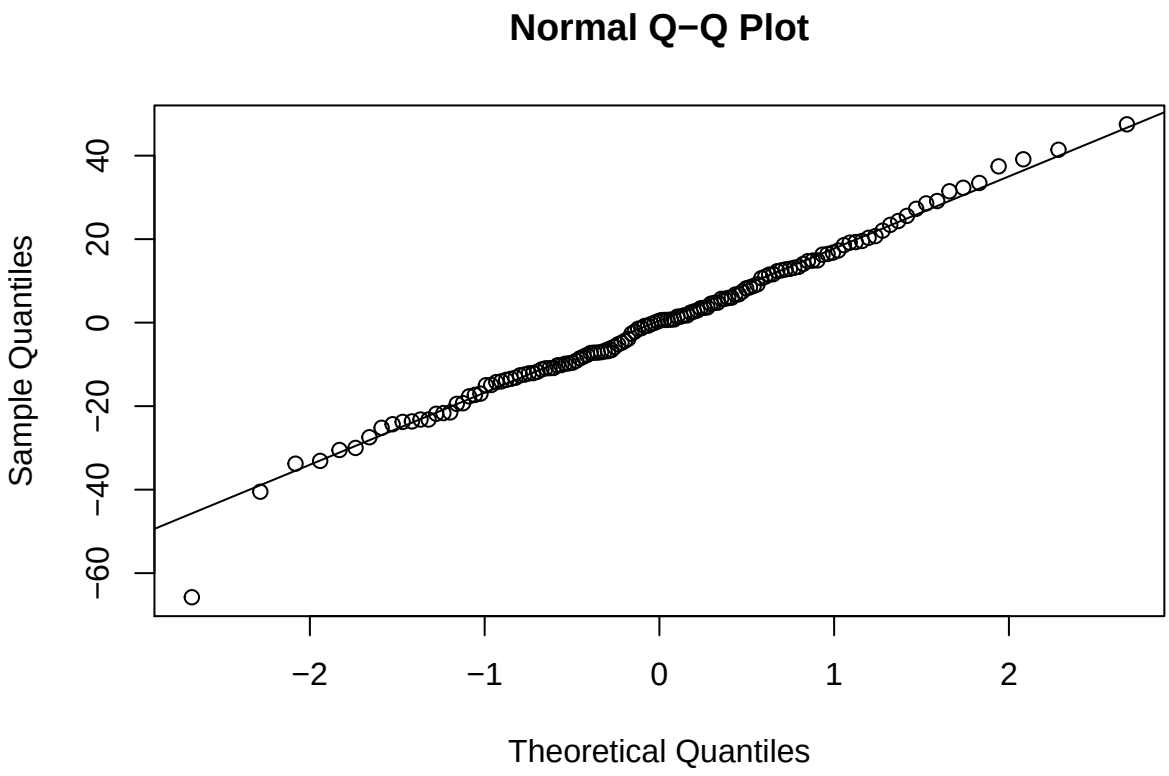
```
lincon(m)
```

```
##             estimate     se  lower   upper tvalue  df   pvalue
## (Intercept)   39.329 8.7153 22.247 56.4105   4.51 Inf 6.40e-06
## TC             2.111 0.3125  1.499  2.7240   6.76 Inf 1.42e-11
## yst           -2.003 1.4400 -4.826  0.8191  -1.39 Inf 1.64e-01
## TC:yst        -0.108 0.0477 -0.201 -0.0141  -2.26 Inf 2.41e-02
```

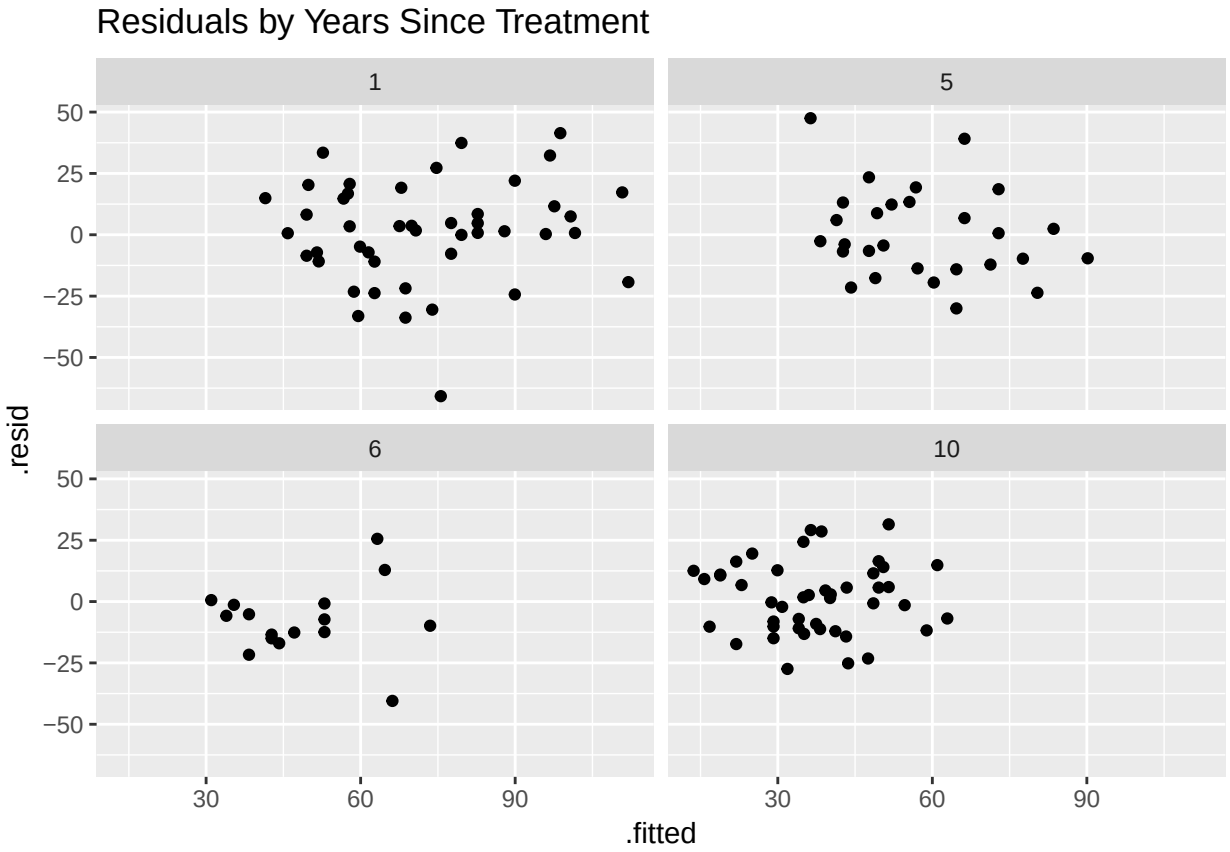
```r
#by yst; averaged across scode (sites)
d$yhat1 <- predict(m, re.form = NA)

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 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)
```



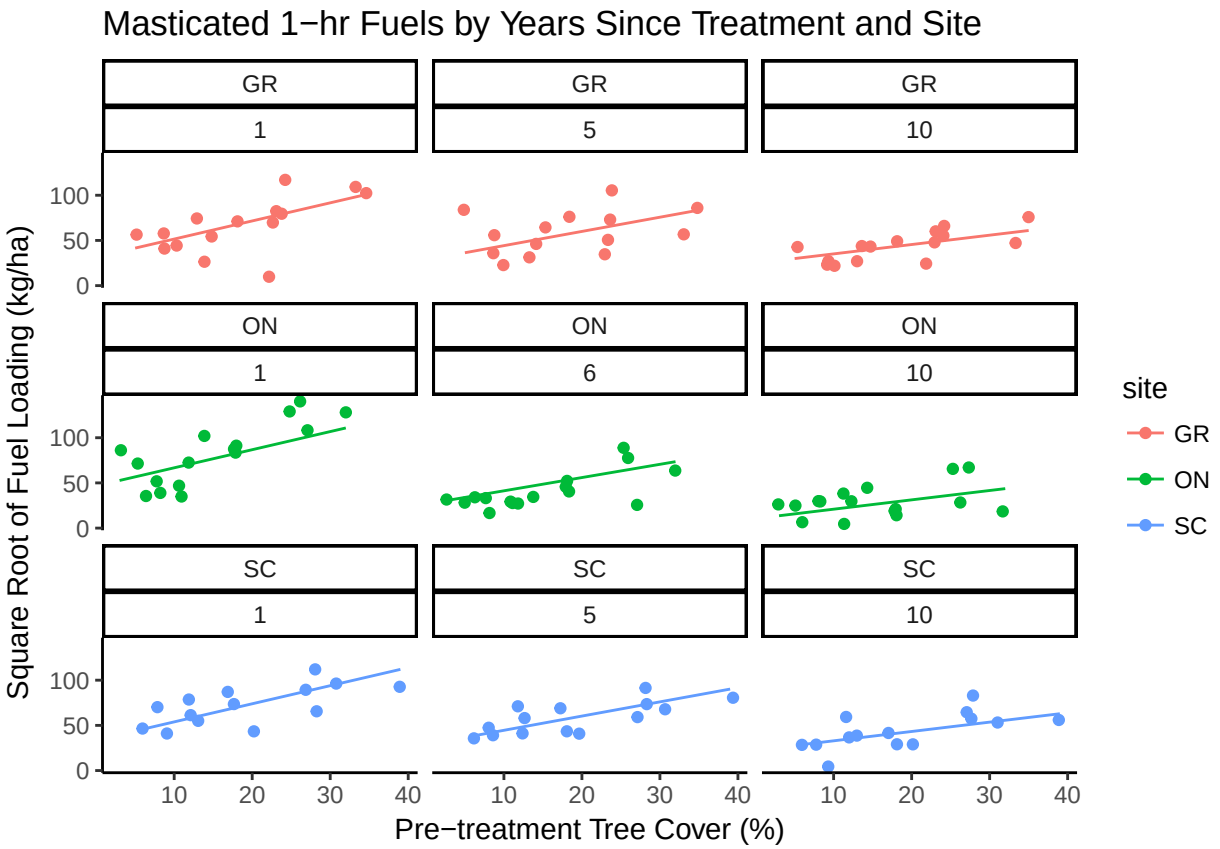

```r
qqnorm(resid(m)); qqline(resid(m))
```



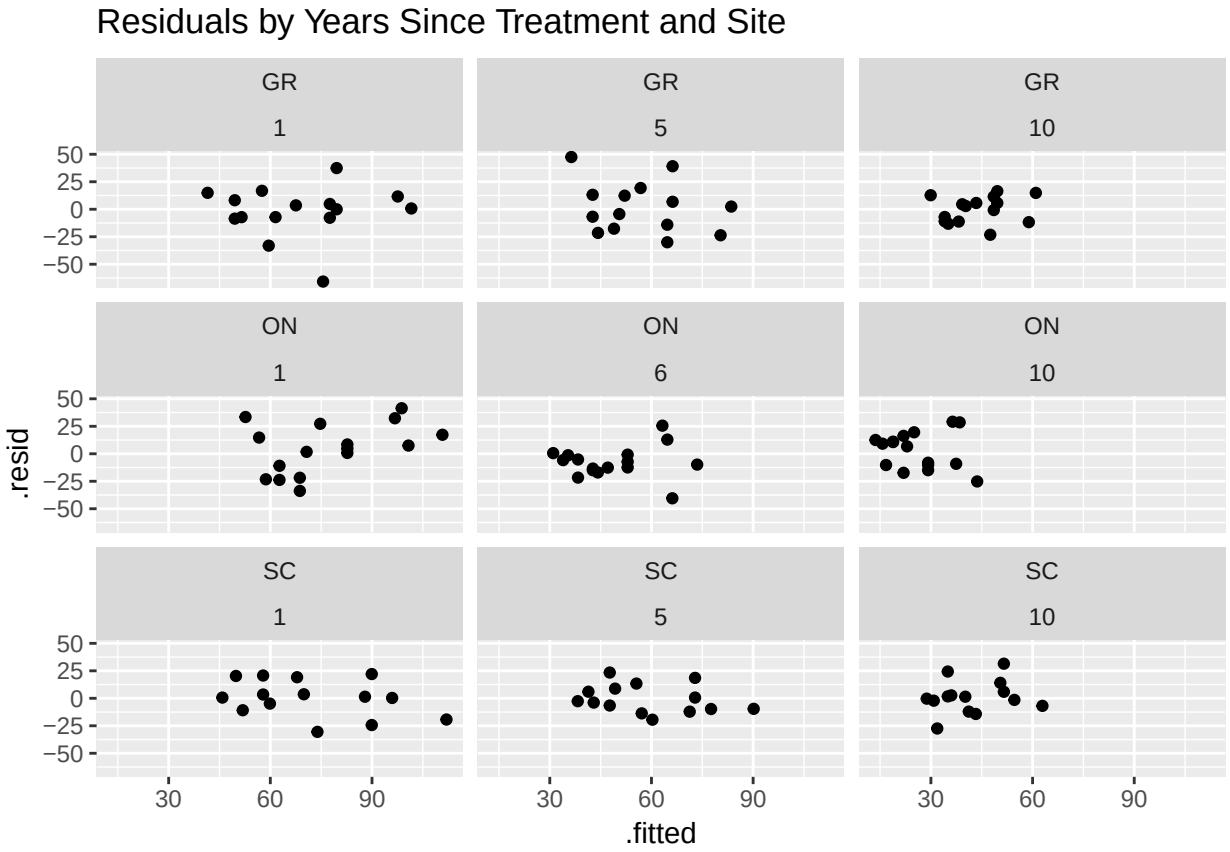

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() +
  facet_wrap(~yst, ncol = 2) + labs(title = 'Residuals by Years Since Treatment')
```




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

#by yst and scode
p <- ggplot(data = d, aes(x = TC, y = 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 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(sqrt(kgha_10h) ~ 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)
```

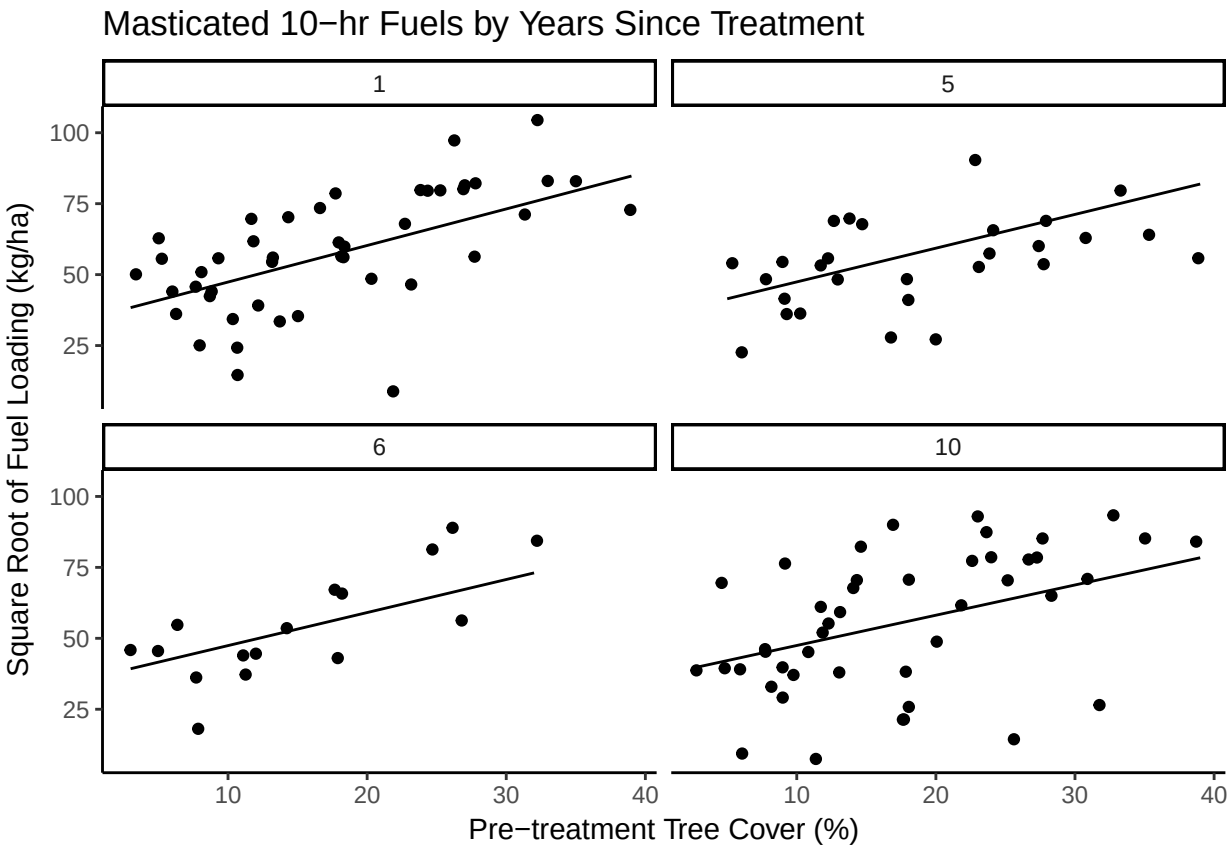
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(kgha_10h) ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 1139
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -3.295 -0.700  0.143  0.726  2.200
##
```

```
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)   0.00    0.00
##           yst           1.18    1.09     NaN
##  Residual             279.50   16.72
## Number of obs: 134, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  34.2345     5.6073    6.11
## TC            1.3129     0.2840    4.62
## yst           0.2581     1.0614    0.24
## TC:yst       -0.0247     0.0434   -0.57
##
## Correlation of Fixed Effects:
##        (Intr) TC     yst
## TC     -0.888
## yst    -0.665  0.591
## TC:yst  0.732 -0.823 -0.718
## convergence code: 0
## unable to evaluate scaled gradient
## Model failed to converge: degenerate  Hessian with 1 negative eigenvalues
```

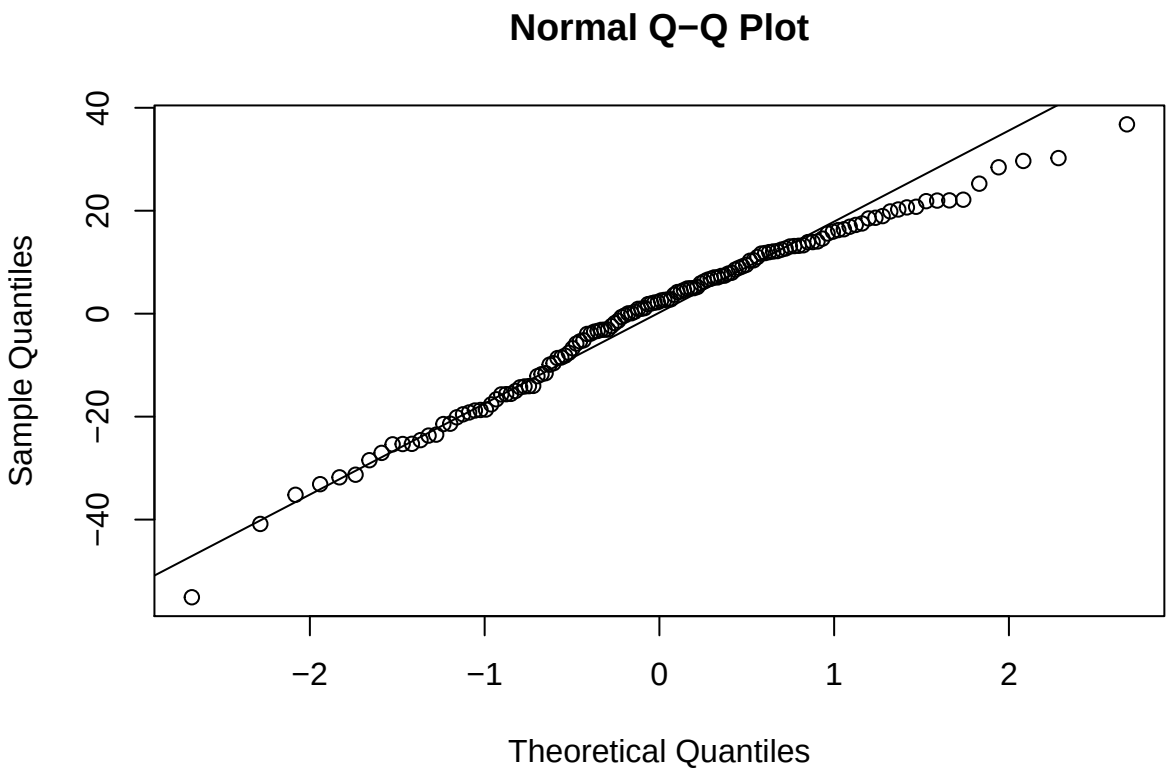
```
lincon(m)
```

```
##             estimate     se  lower   upper tvalue  df   pvalue
## (Intercept)  34.2345 5.6073 23.244 45.2247  6.105 Inf 1.03e-09
## TC            1.3129 0.2840  0.756  1.8695  4.624 Inf 3.77e-06
## yst           0.2581 1.0614 -1.822  2.3384  0.243 Inf 8.08e-01
## TC:yst       -0.0247 0.0434 -0.110  0.0604 -0.568 Inf 5.70e-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 by Years Since Treatment',
              x = 'Pre-treatment Tree Cover (%)',
              y = 'Square Root of Fuel Loading (kg/ha)')
p <- p + facet_wrap(~yst)
plot(p)
```

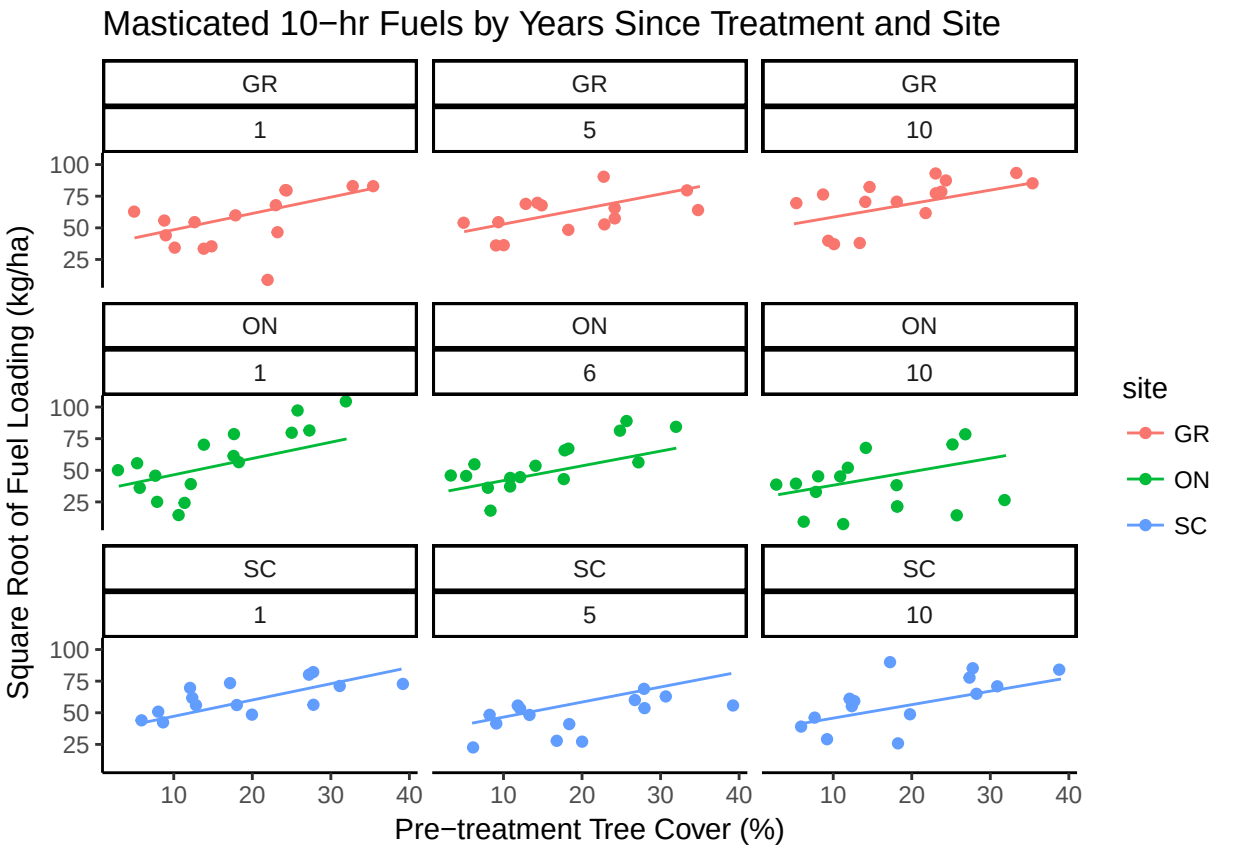



```
qqnorm(resid(m)); qqline(resid(m))
```

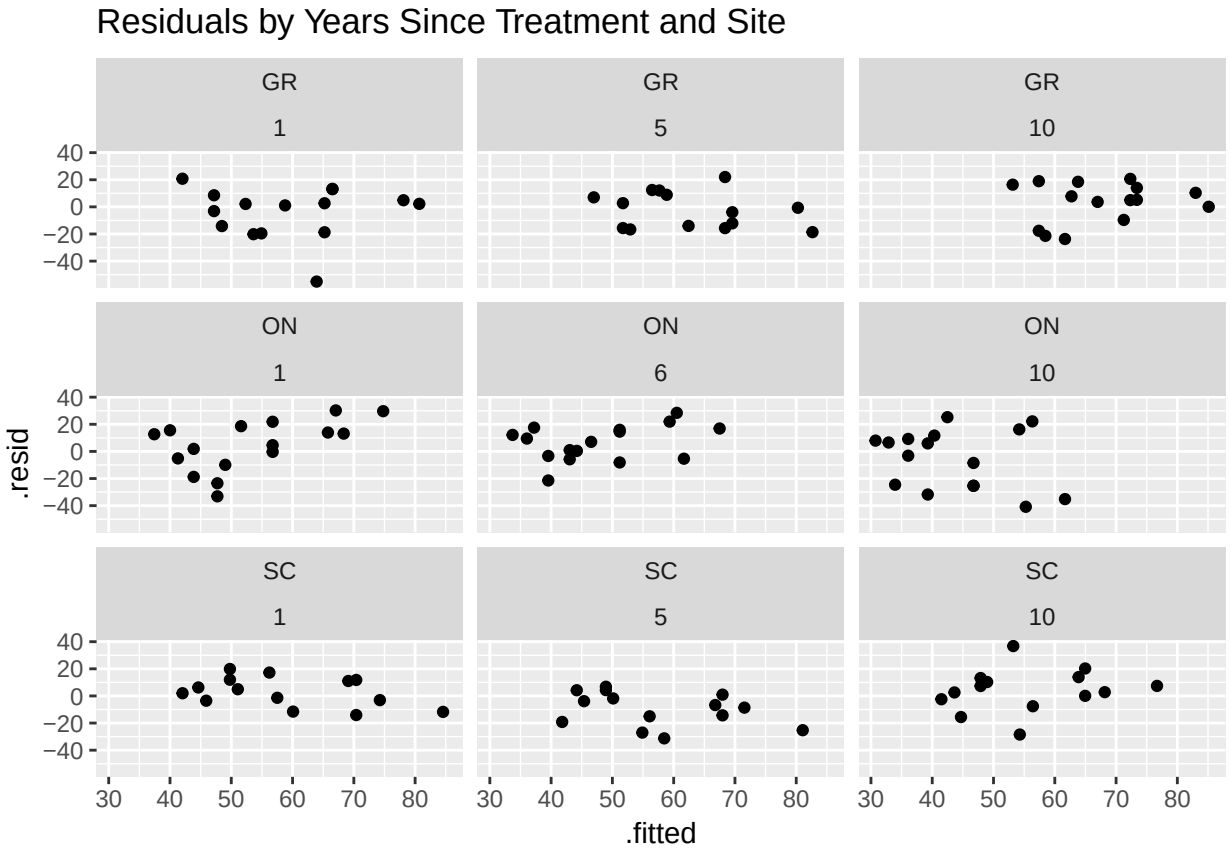



```
ggplot(m, aes(x = .fitted, y = .resid)) +
  geom_point() +
  facet_wrap(~yst, ncol = 4) +
  labs(title = 'Residuals by Years Since Treatment')
```


```
#by yst and scode
d$yhat10 <- predict(m)
p <- ggplot(data = d, aes(x = TC, y = 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 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(sqrt(kgha_100_1000h) ~ TC + yst + TC:yst + (1 + yst|scode), data = d)
summary(m)
```

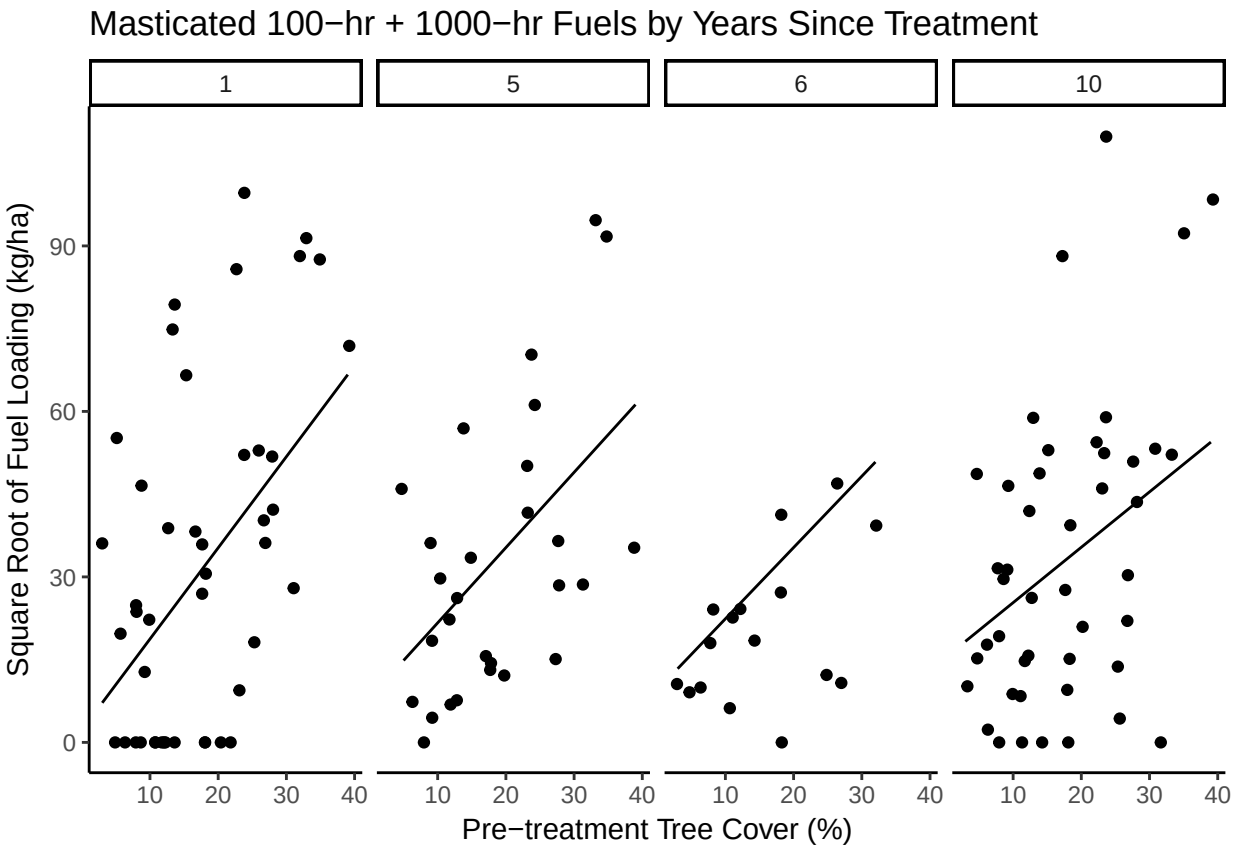
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(kgha_100_1000h) ~ TC + yst + TC:yst + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 1186
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.8143 -0.6377 -0.0376  0.6017  2.7742
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 271.34   16.47
##           yst           3.19    1.79    -0.47
##  Residual             384.42   19.61
## Number of obs: 134, groups:  scode, 3
##
## Fixed effects:
```

```
##             Estimate Std. Error t value
## (Intercept)   0.7641    11.6150    0.07
## TC            1.7247     0.3385    5.09
## yst           1.4532     1.4457    1.01
## TC:yst       -0.0721     0.0515   -1.40
##
## Correlation of Fixed Effects:
##        (Intr) TC     yst
## TC     -0.512
## yst    -0.608  0.517
## TC:yst  0.424 -0.827 -0.625
```

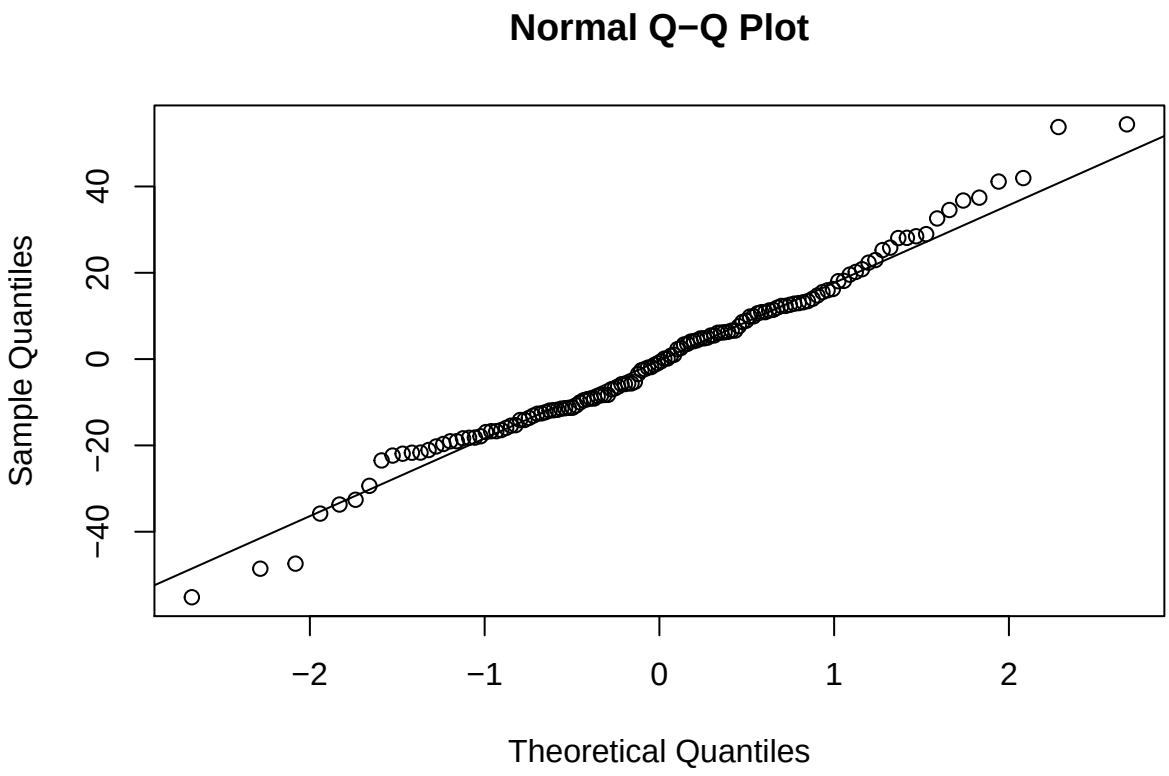
```
lincon(m)
```

```
##             estimate      se   lower   upper  tvalue  df   pvalue
## (Intercept)   0.7641 11.6150 -22.001 23.5290  0.0658 Inf 9.48e-01
## TC            1.7247  0.3385   1.061  2.3881  5.0947 Inf 3.49e-07
## yst           1.4532  1.4457  -1.380  4.2866  1.0052 Inf 3.15e-01
## TC:yst       -0.0721  0.0515  -0.173  0.0288 -1.4007 Inf 1.61e-01
```

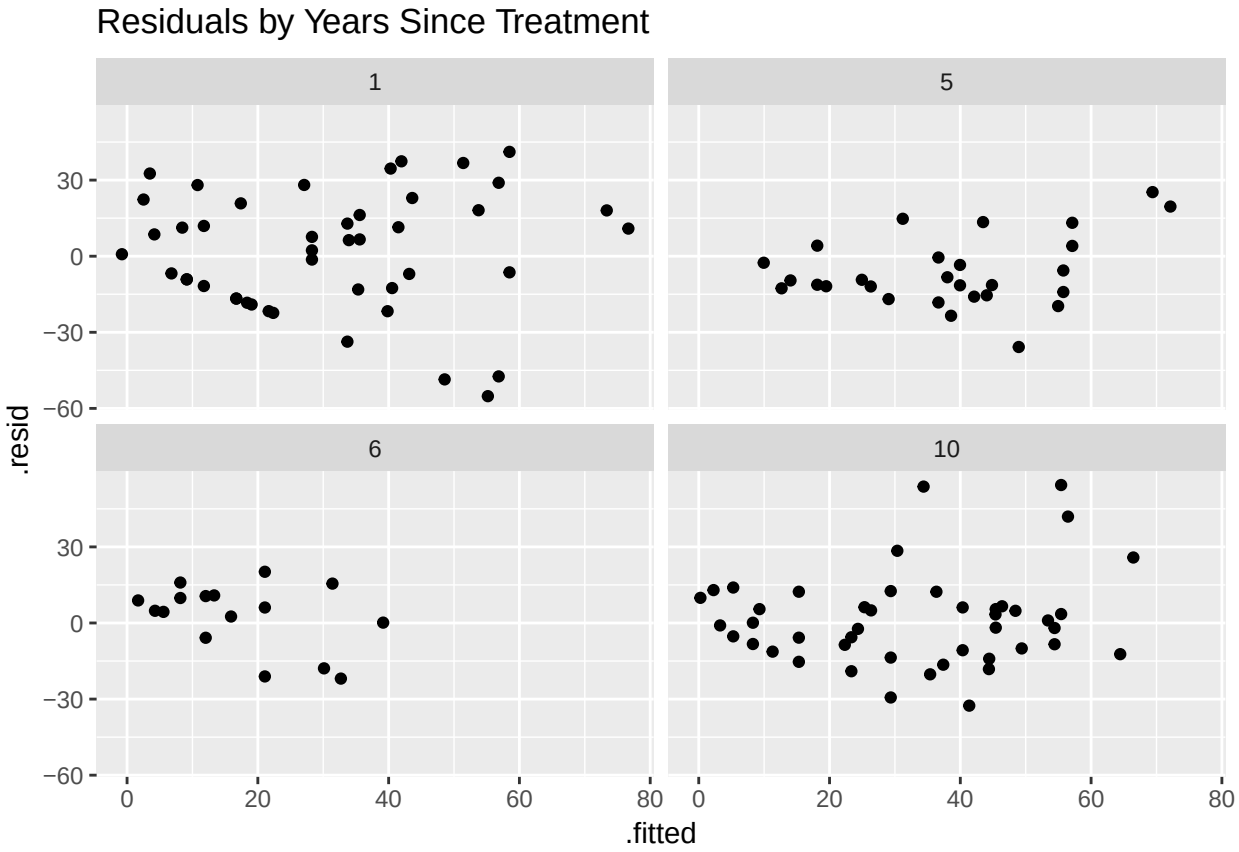
```
#by yst; averaged across scode (sites)
d$yhat100_1000 <- predict(m, re.form = NA)

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(~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)
```



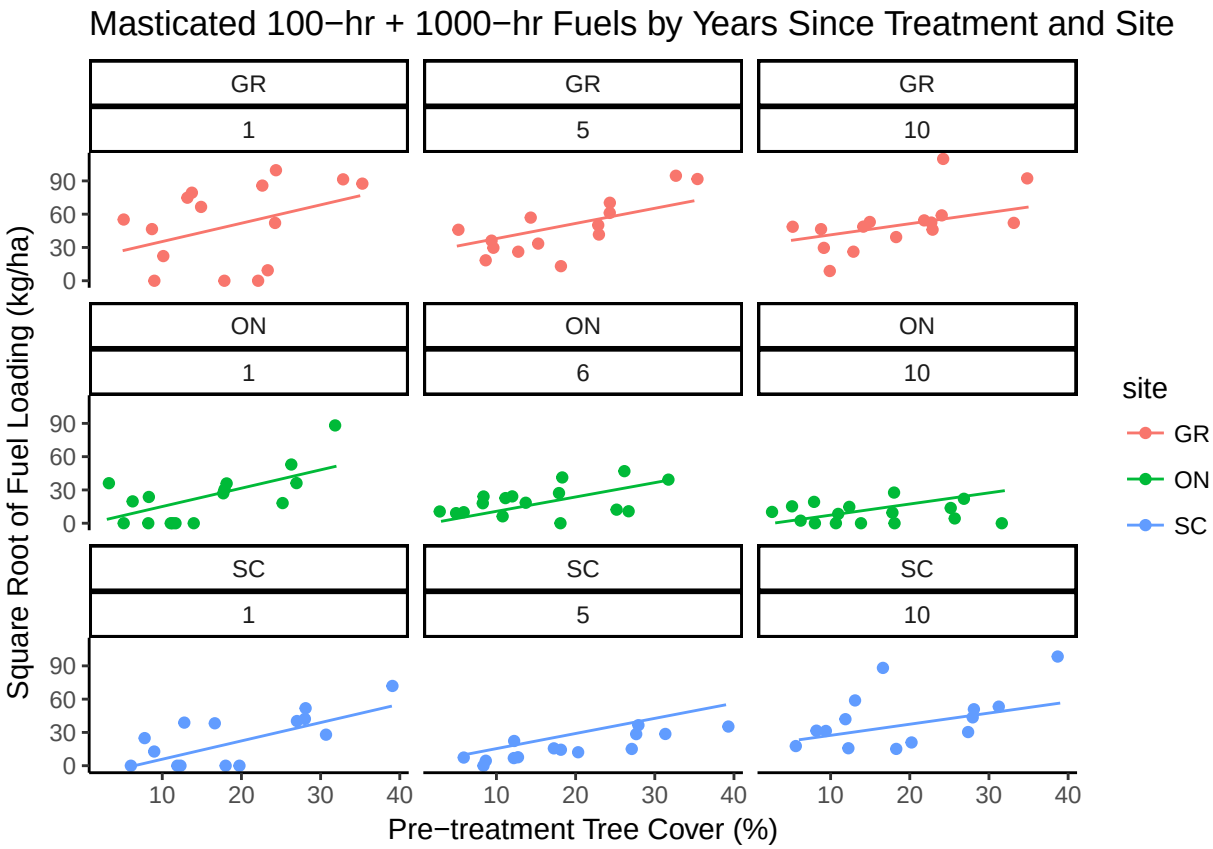

```
qqnorm(resid(m)); qqline(resid(m))
```



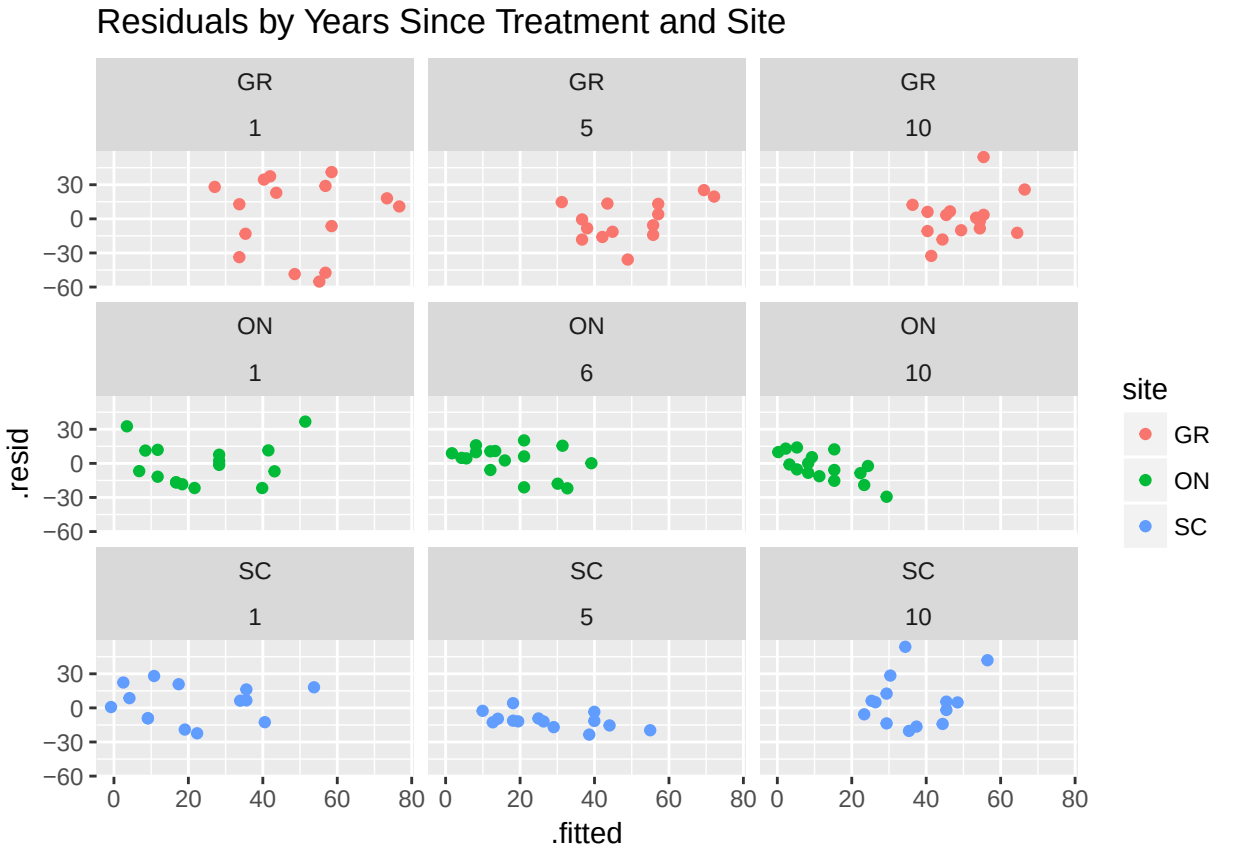

```
ggplot(m, aes(x = .fitted, y = .resid)) +
  geom_point() +
  facet_wrap(~yst, ncol = 2) +
  labs(title = 'Residuals by Years Since Treatment')
```




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

p <- ggplot(data = d, aes(x = TC, y = 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 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(sqrt(duff) ~ yst + pre_tc + yst:pre_tc + (1 + yst|scode), data = d)
summary(m)
```

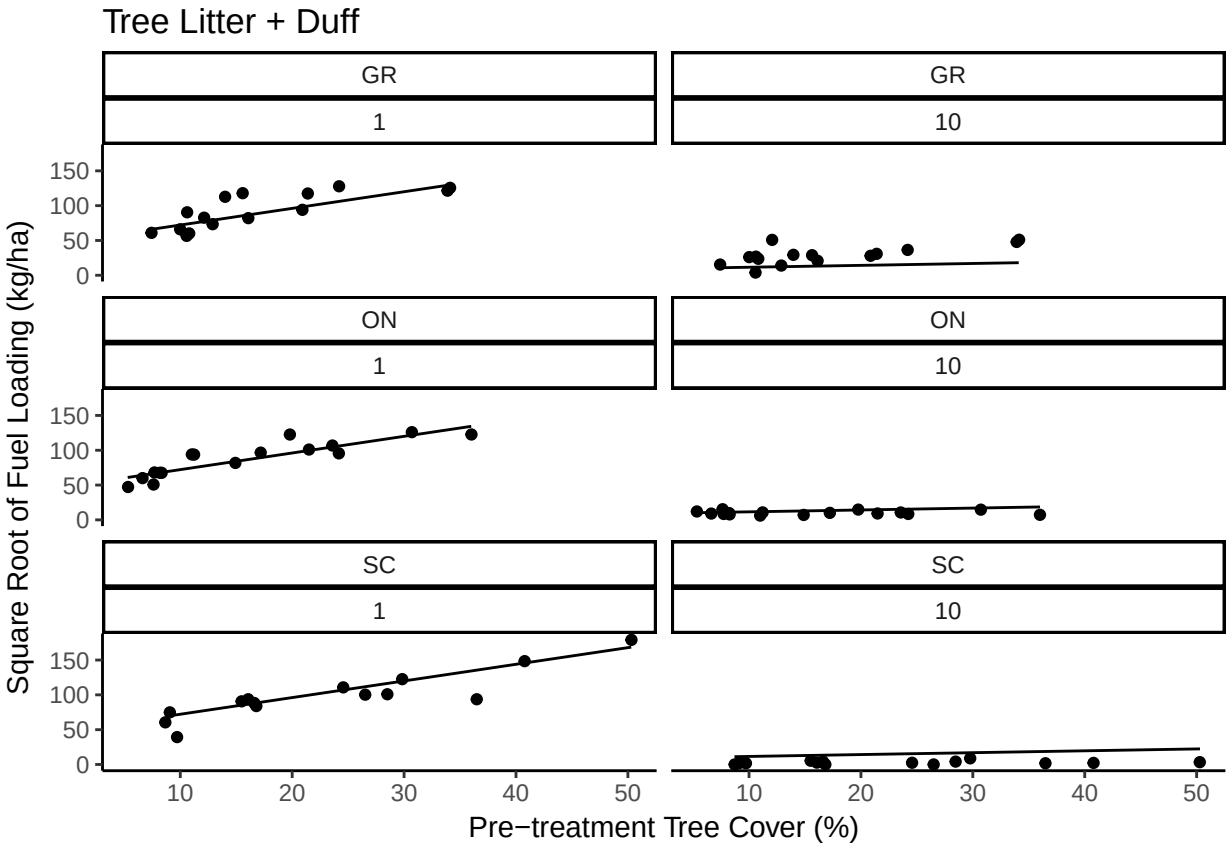
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(duff) ~ yst + pre_tc + yst:pre_tc + (1 + yst | scode)
##    Data: d
##
## REML criterion at convergence: 706
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -3.267 -0.546  0.005  0.396  2.393
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  10.02    3.16
##           yst           1.16    1.08    1.00
##  Residual             135.92   11.66
## Number of obs: 90, groups:  scode, 3
##
## Fixed effects:
```

```
##             Estimate Std. Error t value
## (Intercept)  52.6424     4.3859   12.00
## yst          -4.3817     0.8407   -5.21
## pre_tc        2.6266     0.1870   14.05
## yst:pre_tc   -0.2357     0.0266   -8.87
##
## Correlation of Fixed Effects:
##             (Intr) yst    pre_tc
## yst         -0.154
## pre_tc      -0.794  0.443
## yst:pre_tc  0.597 -0.590 -0.753
```

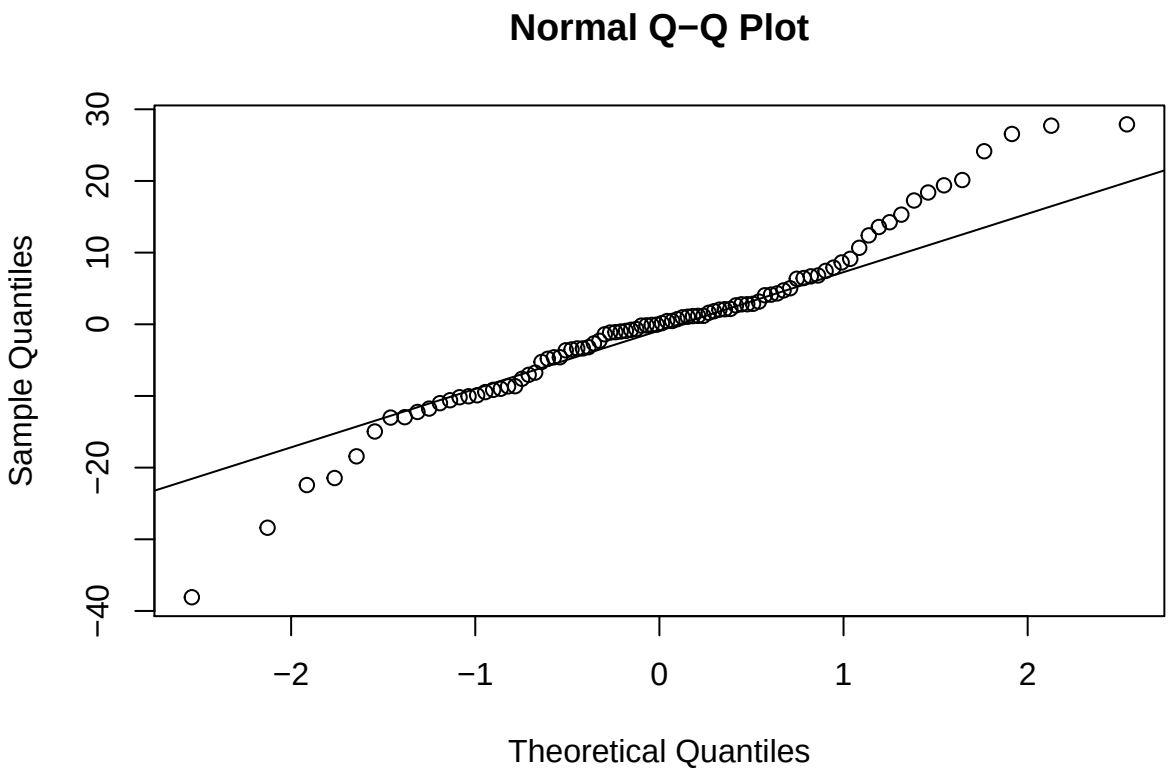
```
lincon(m)
```

```
##             estimate     se  lower  upper tvalue  df   pvalue
## (Intercept)   52.642 4.3859 44.046 61.239  12.00 Inf 3.44e-33
## yst           -4.382 0.8407 -6.029 -2.734  -5.21 Inf 1.87e-07
## pre_tc         2.627 0.1870  2.260  2.993  14.05 Inf 8.02e-45
## yst:pre_tc    -0.236 0.0266 -0.288 -0.184  -8.87 Inf 7.44e-19
```

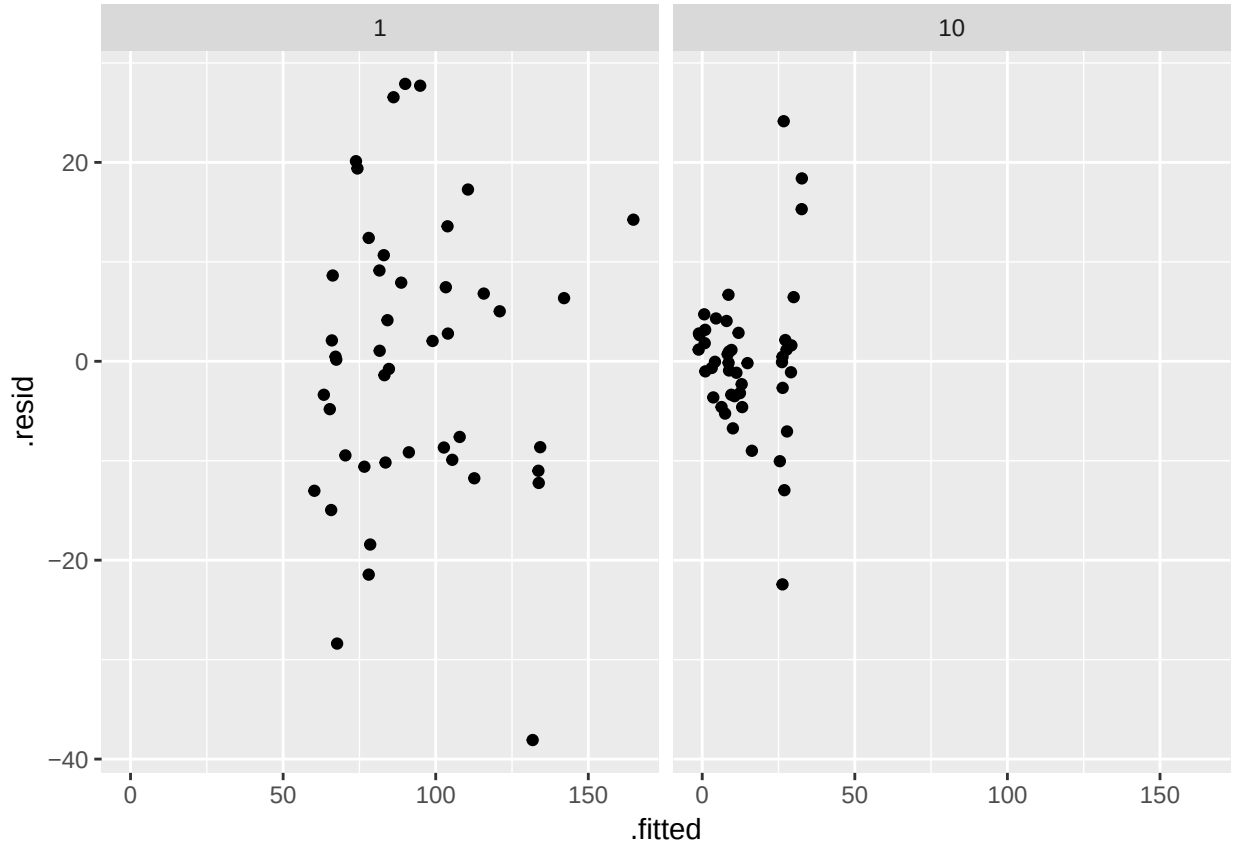
```
#by yst
d$yhat_duff <- predict(m, re.form = NA)
p <- ggplot(data = d, aes(x = pre_tc, y = sqrt(duff)))
p <- p + geom_jitter()
p <- p + geom_line(aes(y = yhat_duff))
p <- p + theme_classic() + facet_wrap(scode~yst, ncol = 2)
p <- p + labs(title = 'Tree Litter + Duff',
              x = 'Pre-treatment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



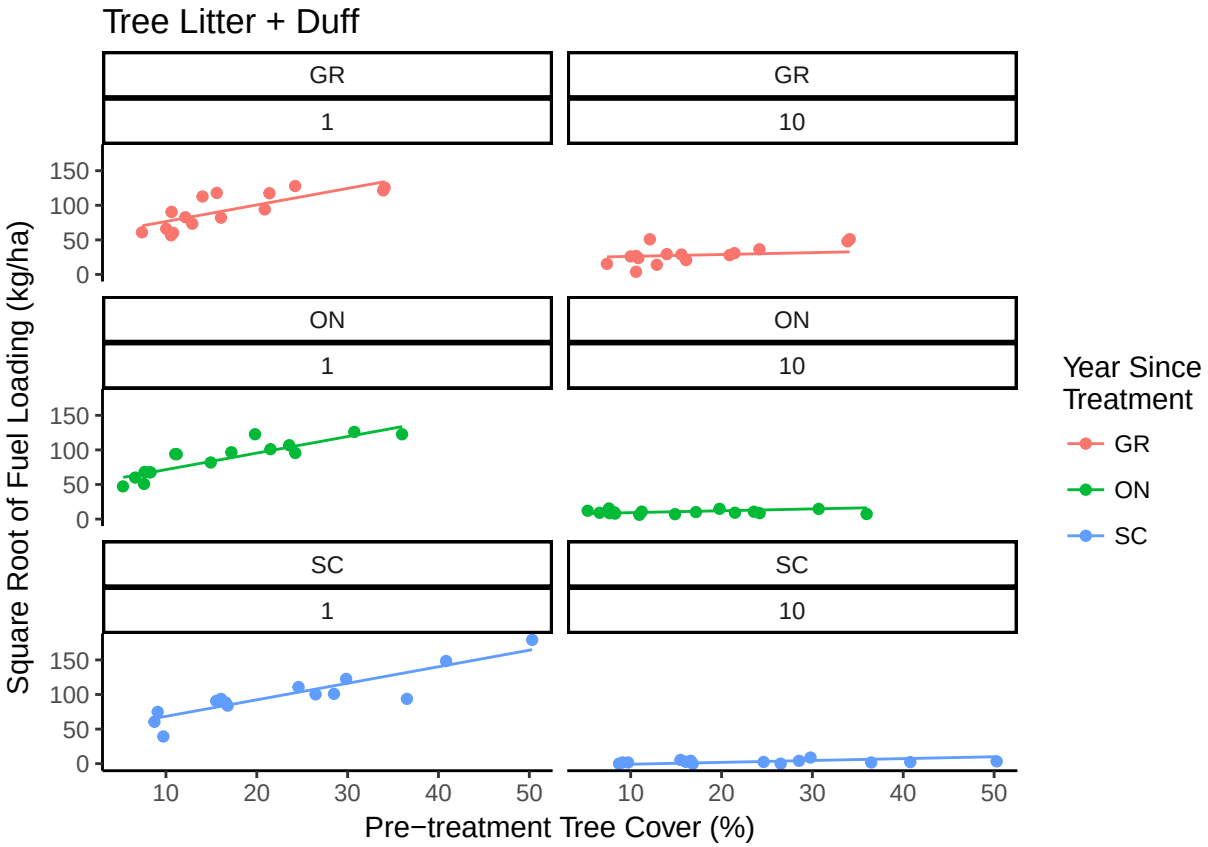

```
qqnorm(resid(m)); qqline(resid(m))
```



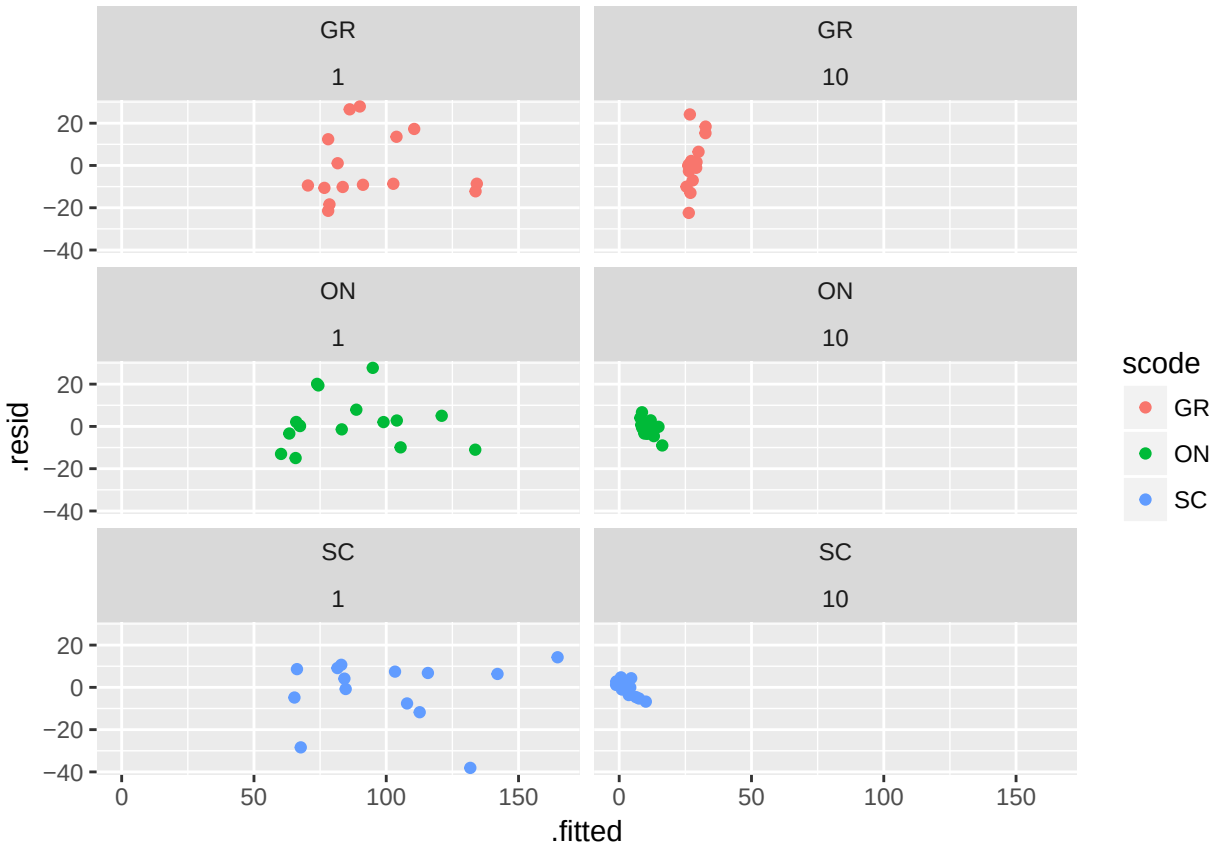

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
d$yhat_duff <- predict(m)
p <- ggplot(data = d, aes(x = pre_tc, y = sqrt(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(sqrt(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)
```

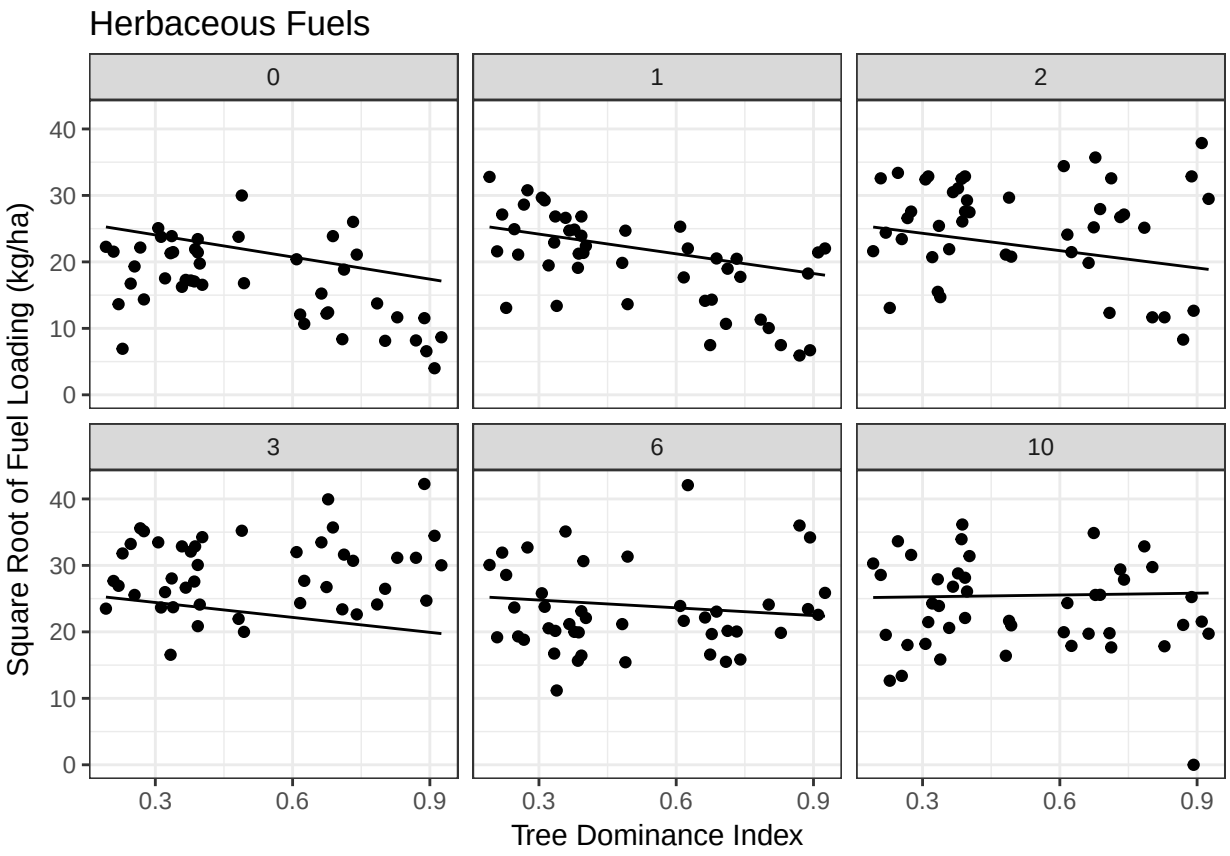
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(herb_ttl) ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
```

```
## REML criterion at convergence: 1810
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -3.624 -0.766 -0.072  0.722  3.004
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  9.3175  3.052
##           yst          0.0944  0.307    -0.91
##  Residual             48.9327  6.995
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   27.388      2.357   11.62
## TDI          -11.091      2.787   -3.98
## yst           -0.239      0.359   -0.67
## TDI:yst        1.201      0.557    2.16
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.609
## yst     -0.759  0.584
## TDI:yst  0.445 -0.732 -0.796
```

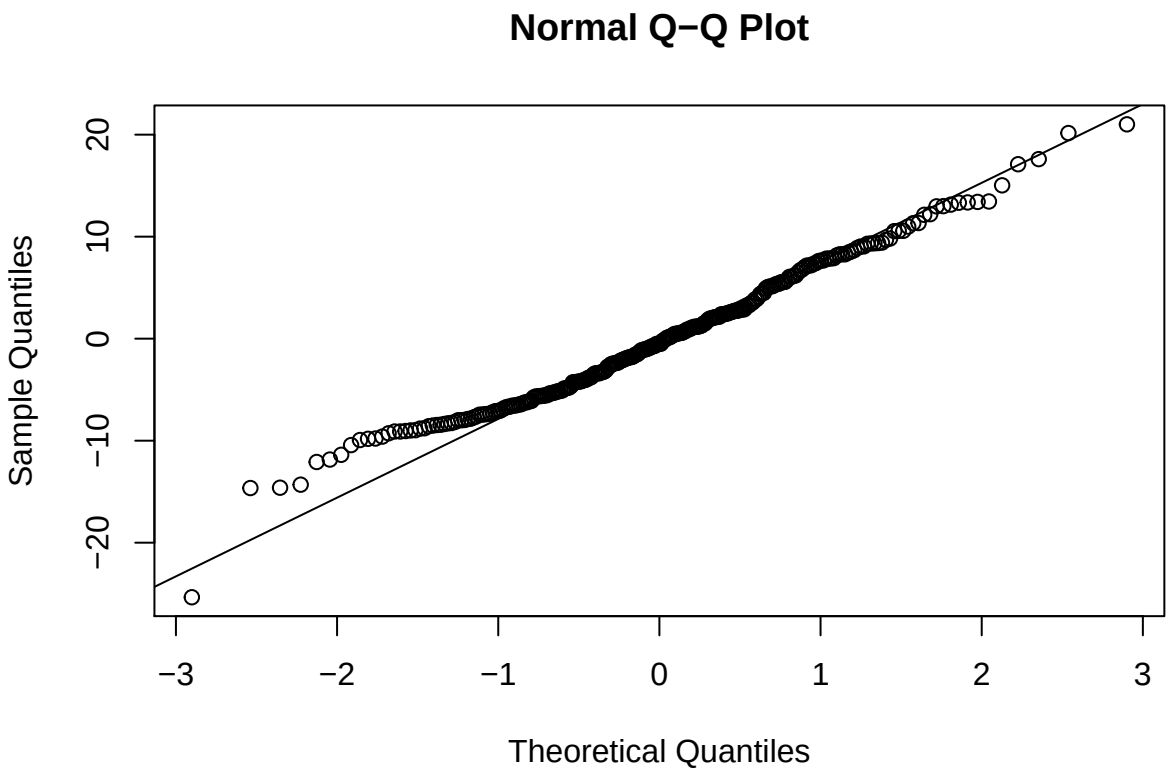
```
lincon(m)
```

```
##             estimate    se   lower  upper tvalue  df   pvalue
## (Intercept)   27.388 2.357  22.768 32.008 11.618 Inf 3.32e-31
## TDI          -11.091 2.787 -16.554 -5.629 -3.980 Inf 6.90e-05
## yst           -0.239 0.359  -0.943  0.465 -0.666 Inf 5.05e-01
## TDI:yst        1.201 0.557   0.110  2.292  2.157 Inf 3.10e-02
```

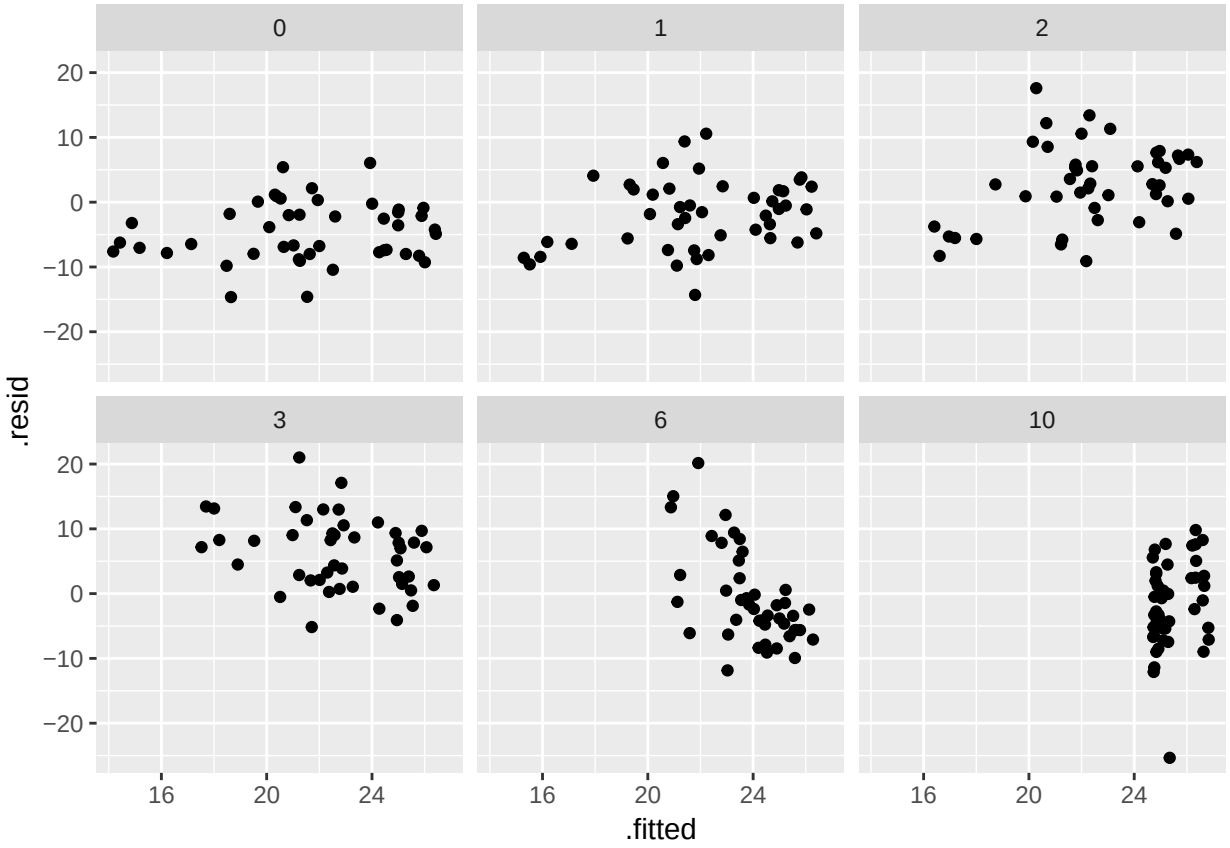
```
#by yst
l$yhat_herb <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = sqrt(herb_ttl)))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_herb))
p <- p + theme_bw()
p <- p + labs(title = 'Herbaceous Fuels',
               x = 'Tree Dominance Index',
               y = 'Square 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)
```



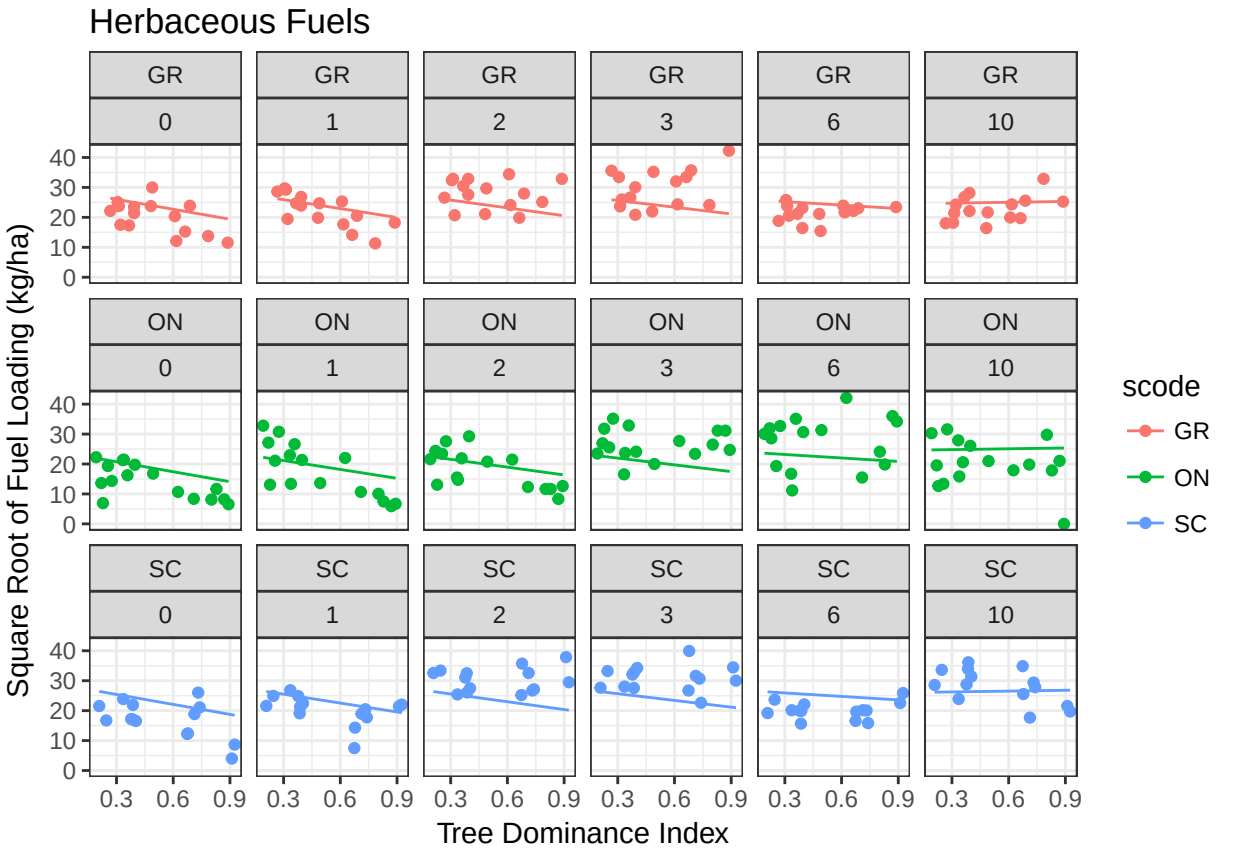

```
qqnorm(resid(m)); qqline(resid(m))
```



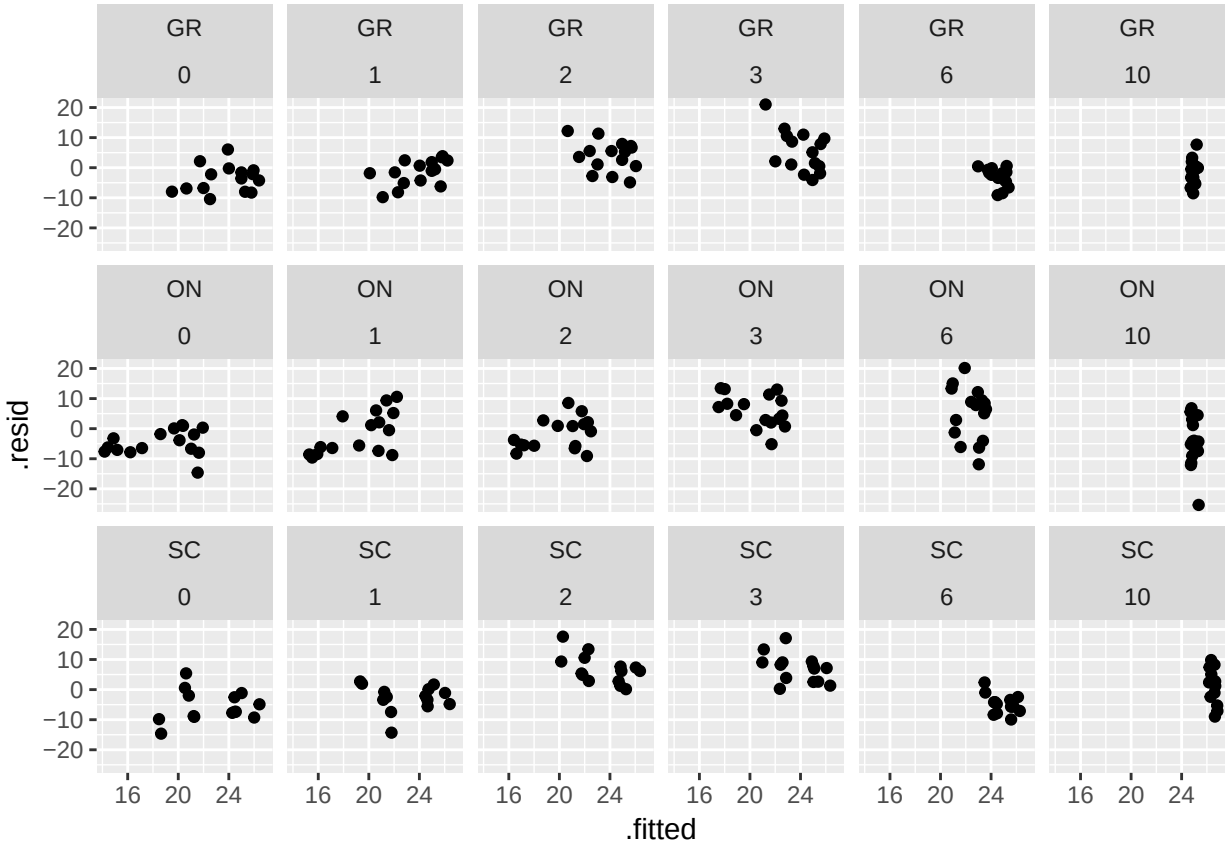

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
l$yhat_herb <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = sqrt(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(sqrt(shrub_fuel) ~ TDI + yst + yst:TDI + (1 + yst|scode), data = l)
summary(m)
```

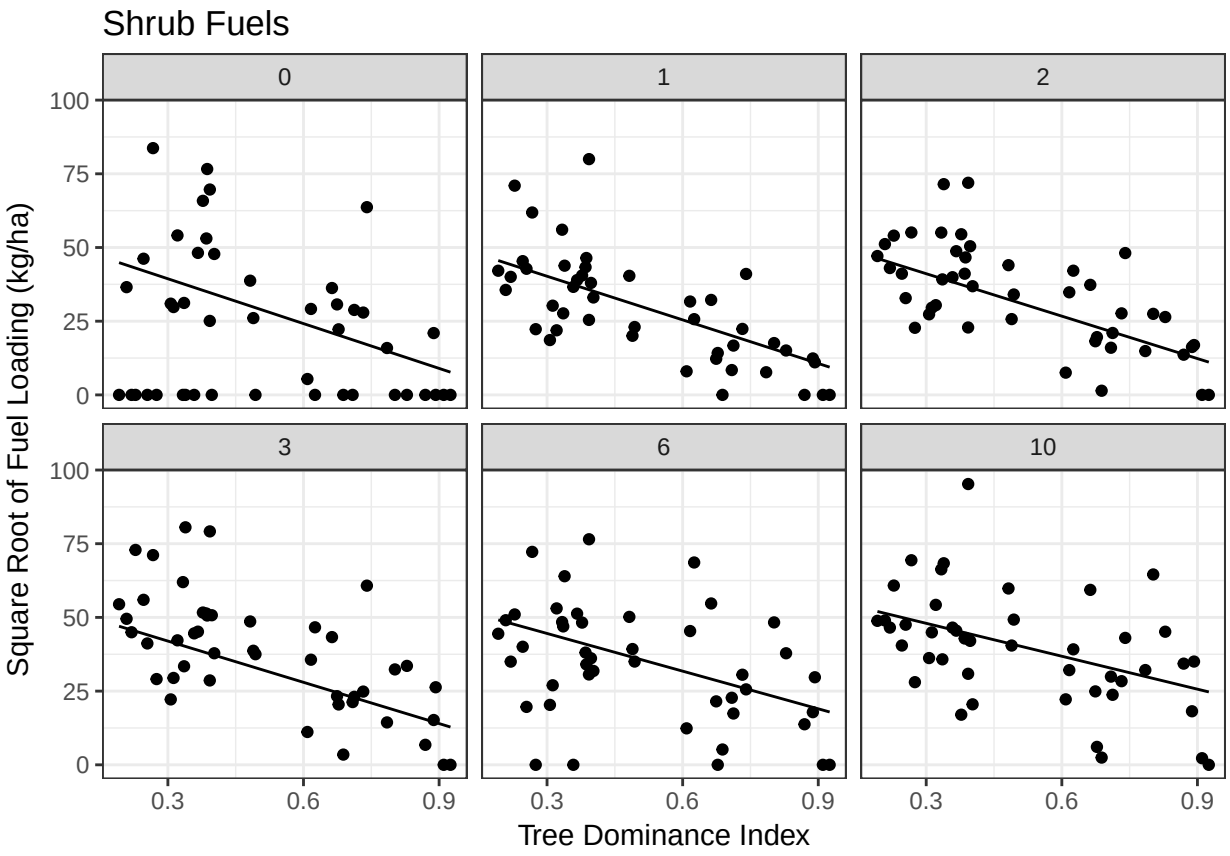
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(shrub_fuel) ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
## REML criterion at convergence: 2272
##
## Scaled residuals:
```

```
##     Min      1Q  Median      3Q     Max
## -2.9183 -0.6883 -0.0113  0.5619  3.0280
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept)  57.98    7.61
##           yst           3.37    1.83    -1.00
##  Residual             280.63   16.75
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   54.594      5.774    9.45
## TDI          -50.675      6.666   -7.60
## yst            0.457      1.298    0.35
## TDI:yst        1.345      1.337    1.01
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.594
## yst     -0.897  0.390
## TDI:yst  0.437 -0.734 -0.530
```

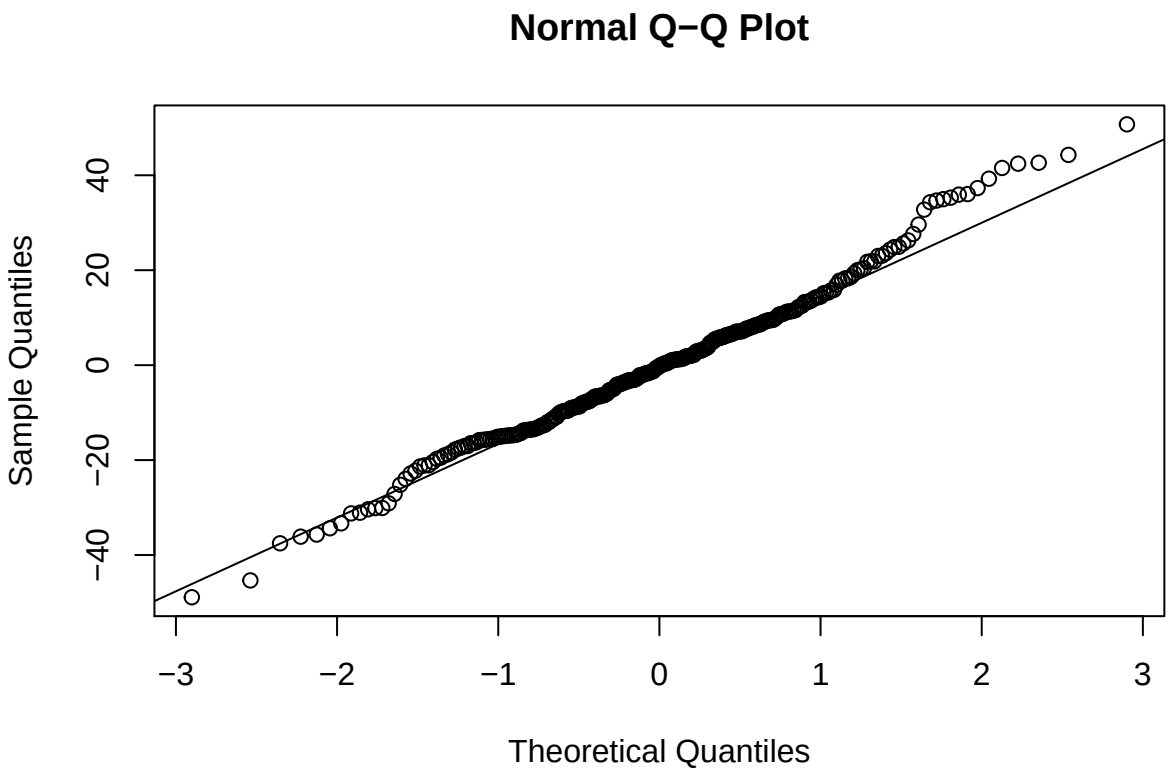
```
lincon(m)
```

```
##             estimate   se  lower  upper tvalue  df   pvalue
## (Intercept)   54.594 5.77  43.28  65.91  9.455 Inf 3.23e-21
## TDI          -50.675 6.67 -63.74 -37.61 -7.602 Inf 2.91e-14
## yst            0.457 1.30  -2.09   3.00  0.352 Inf 7.25e-01
## TDI:yst        1.345 1.34  -1.28   3.97  1.005 Inf 3.15e-01
```

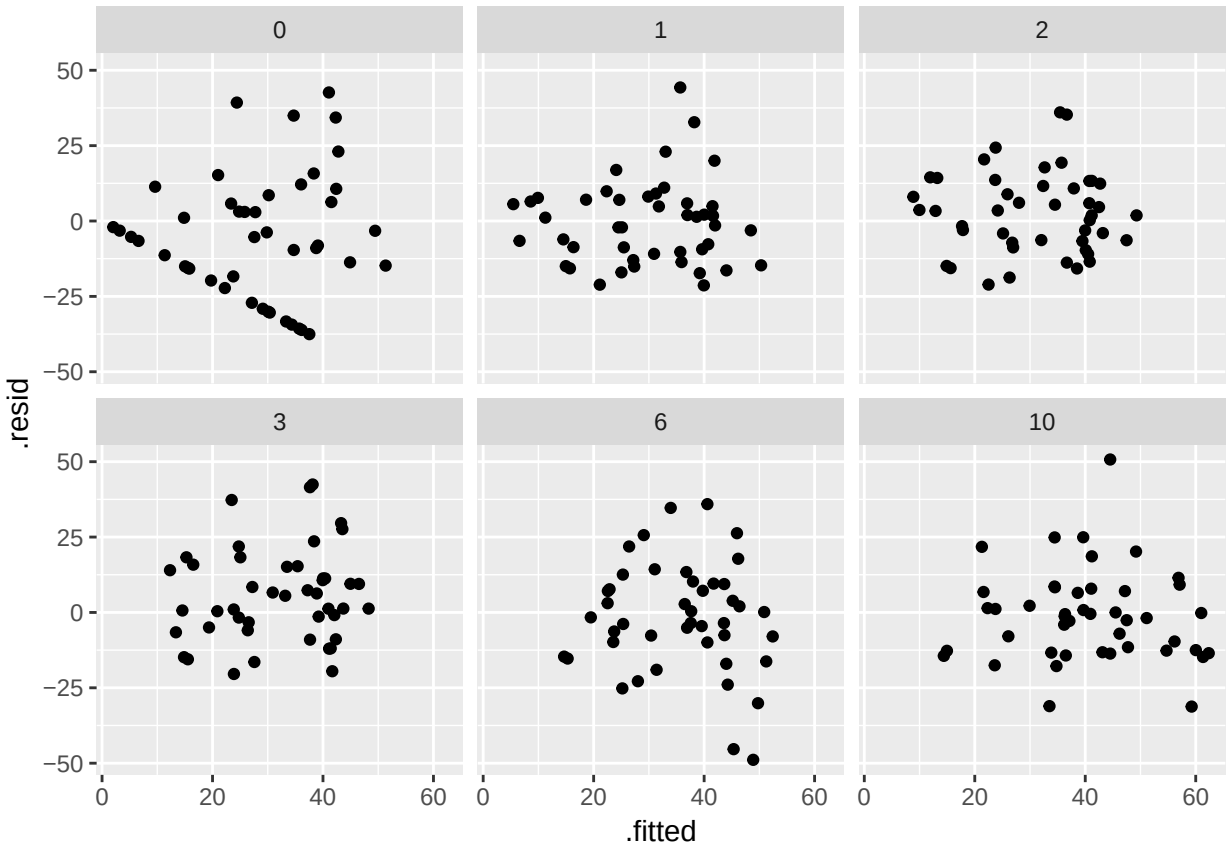
```
#by yst
l$yhat_shrub <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = sqrt(shrub_fuel)))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_shrub))
p <- p + theme_bw()
p <- p + labs(title = 'Shrub Fuels',
              x = 'Tree Dominance Index',
              y = 'Square Root 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)
```



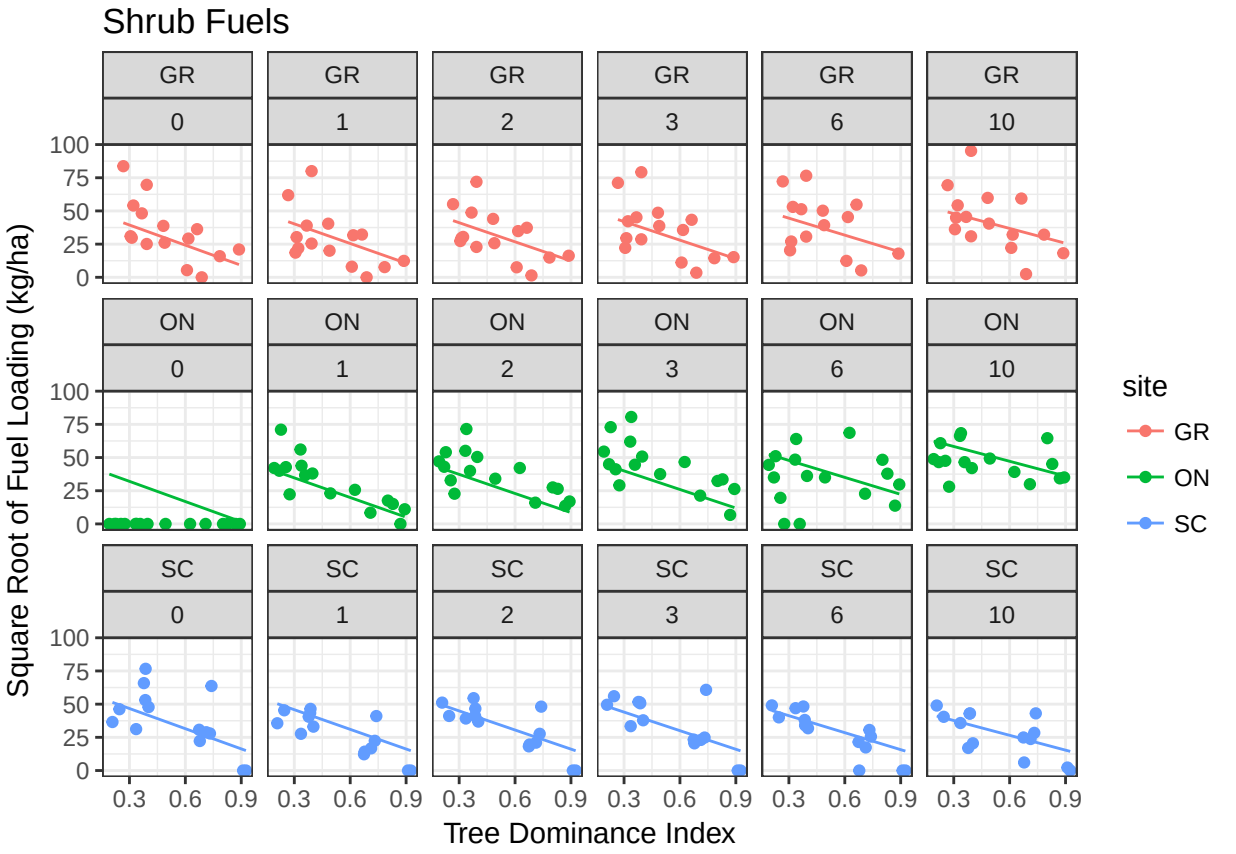

```
qqnorm(resid(m)); qqline(resid(m))
```



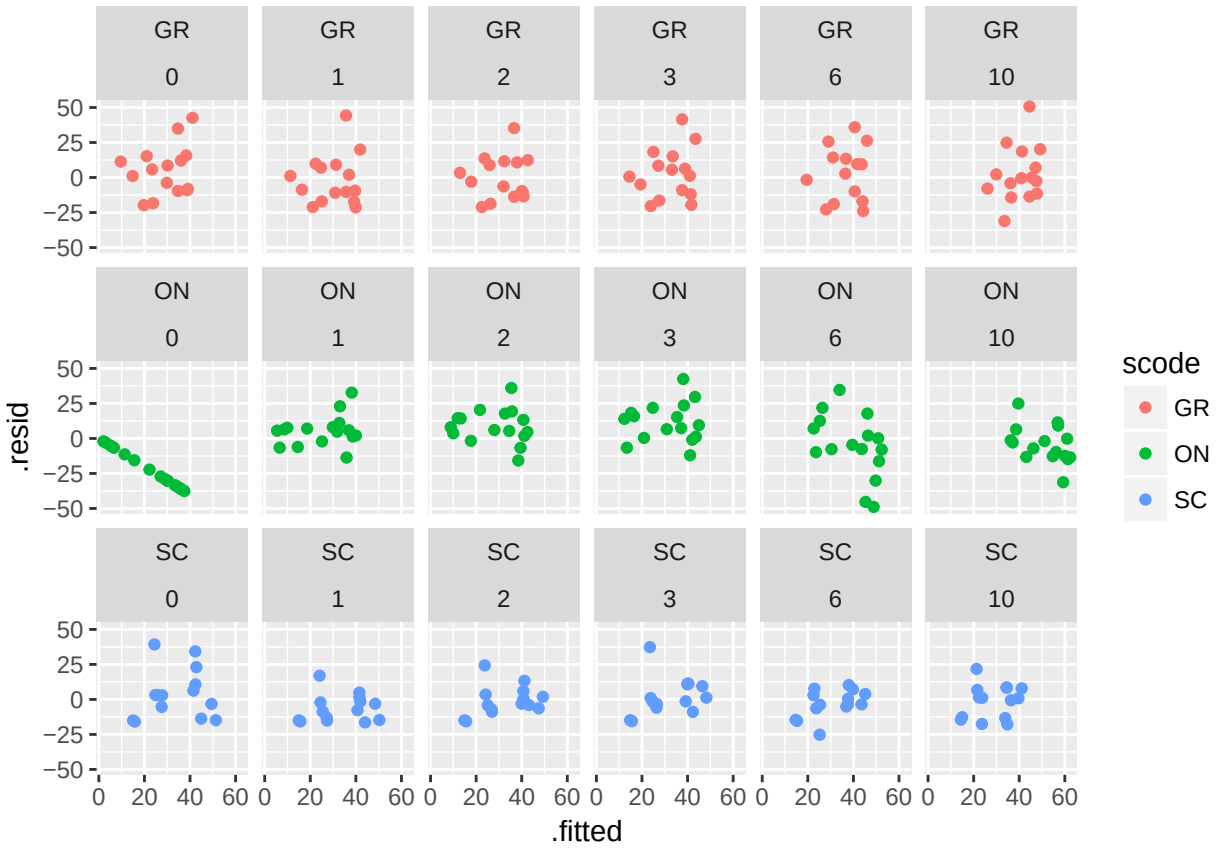

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




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




```
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)
```

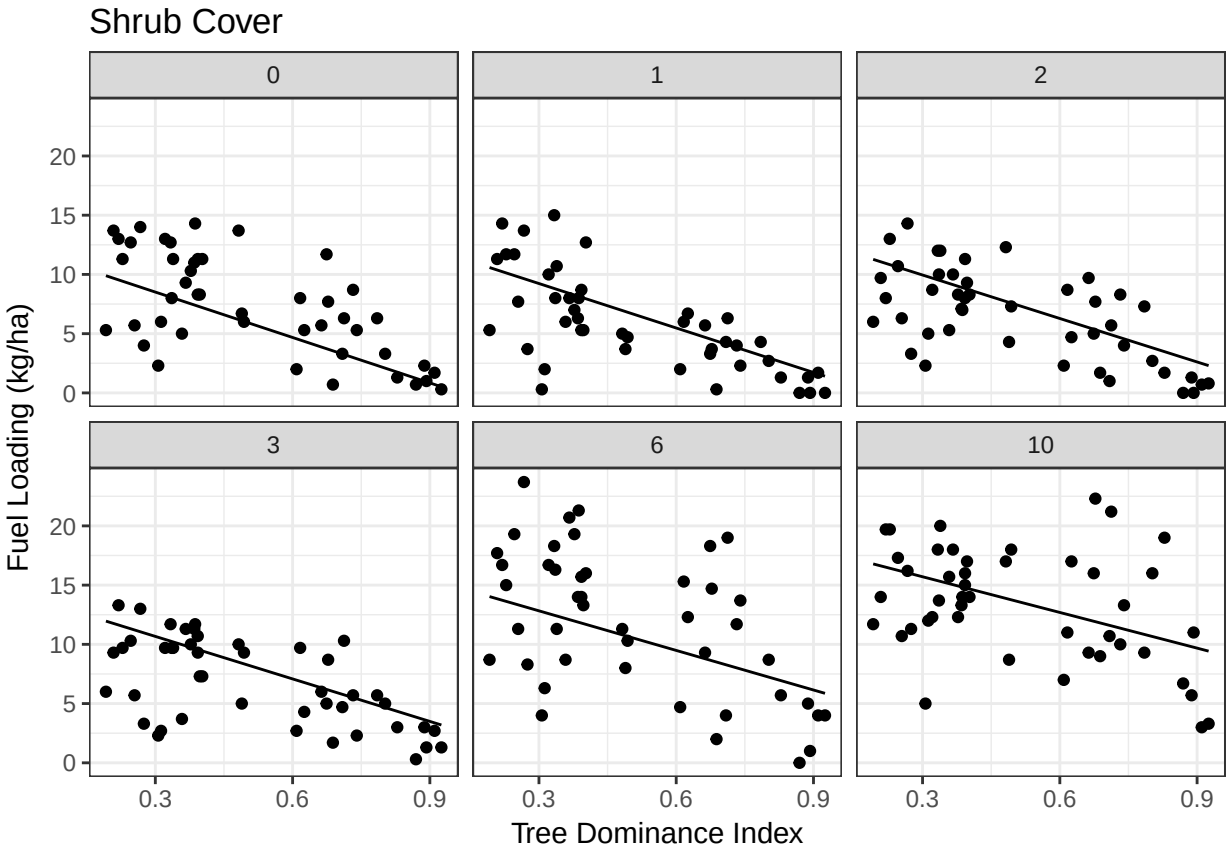
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: can_cover_pt_shrub ~ TDI + yst + yst:TDI + (1 + yst | scode)
##    Data: l
##
## REML criterion at convergence: 1474
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.5377 -0.7147 -0.0782  0.6614  3.0501
##
## Random 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
```

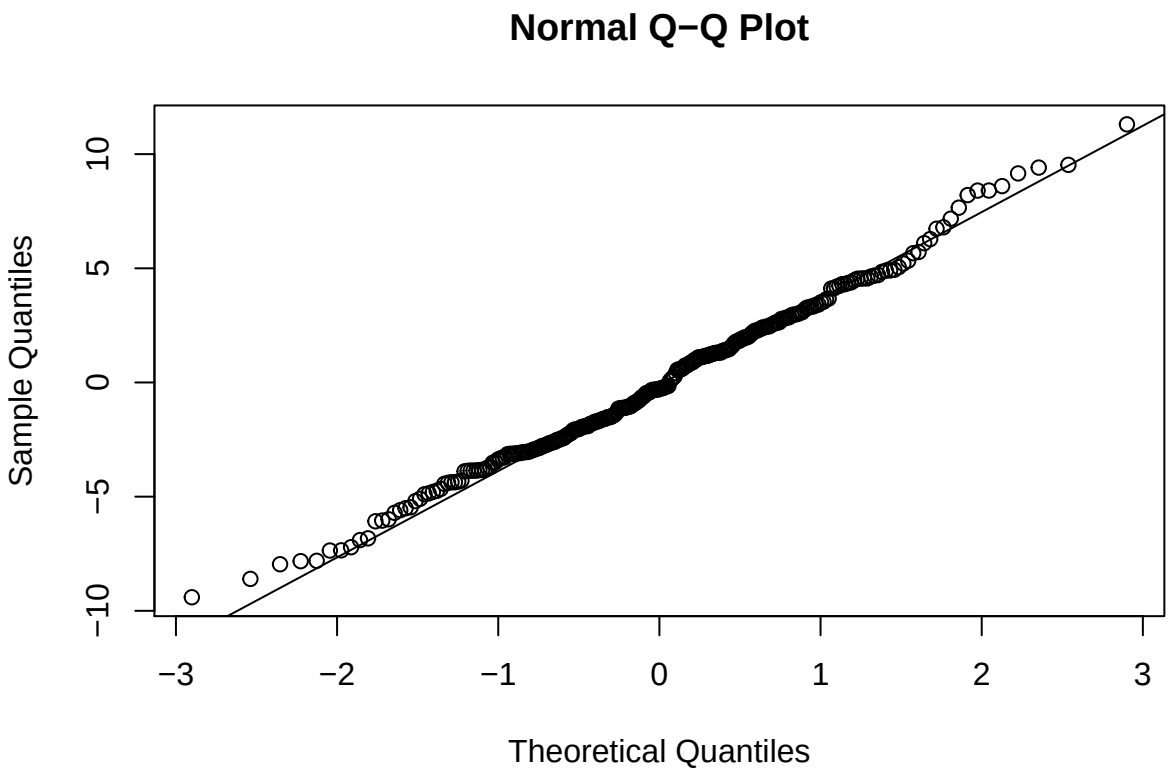
```
lincon(m)
```

```
##             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
```

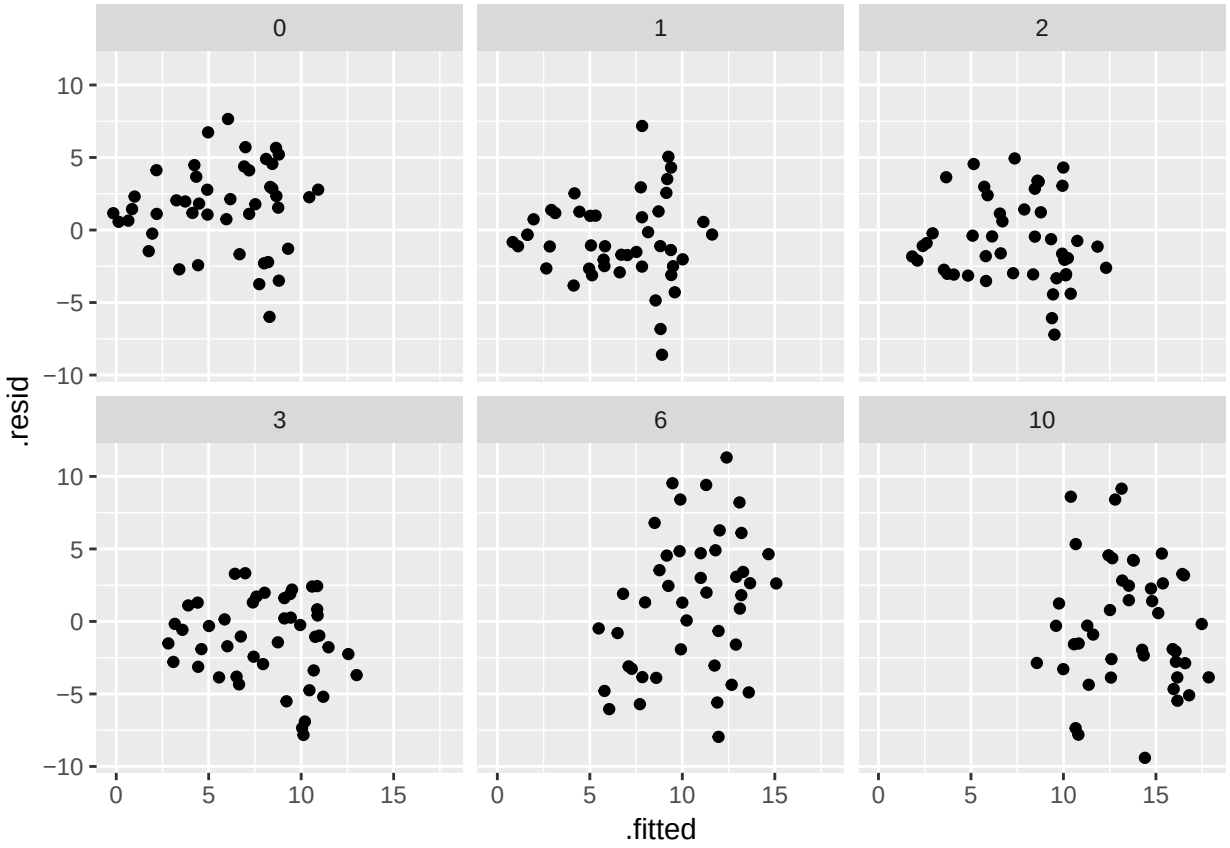
```
#by yst
l$yhat_sh_cvr <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = can_cover_pt_shrub))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_sh_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Shrub Cover',
              x = 'Tree Dominance Index',
              y = 'Fuel Loading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



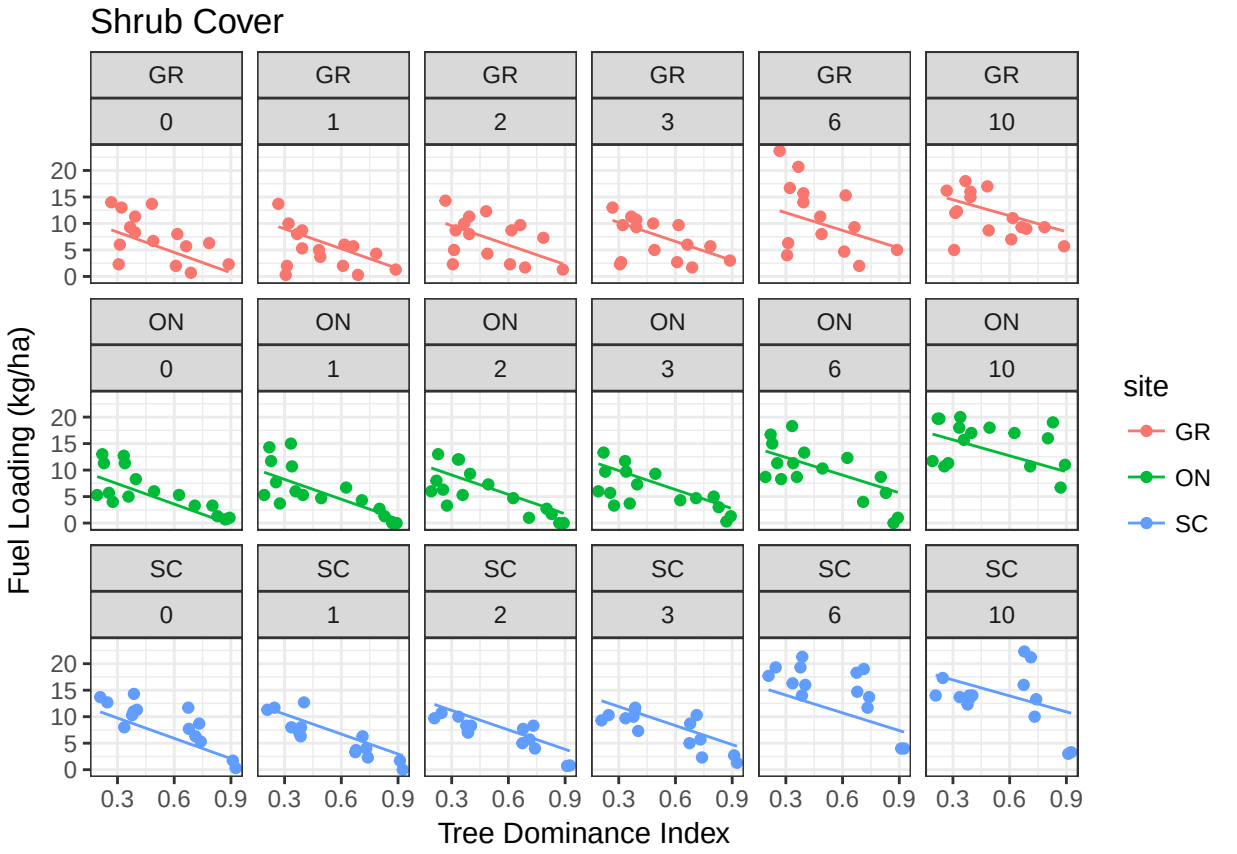

```
qqnorm(resid(m)); qqline(resid(m))
```



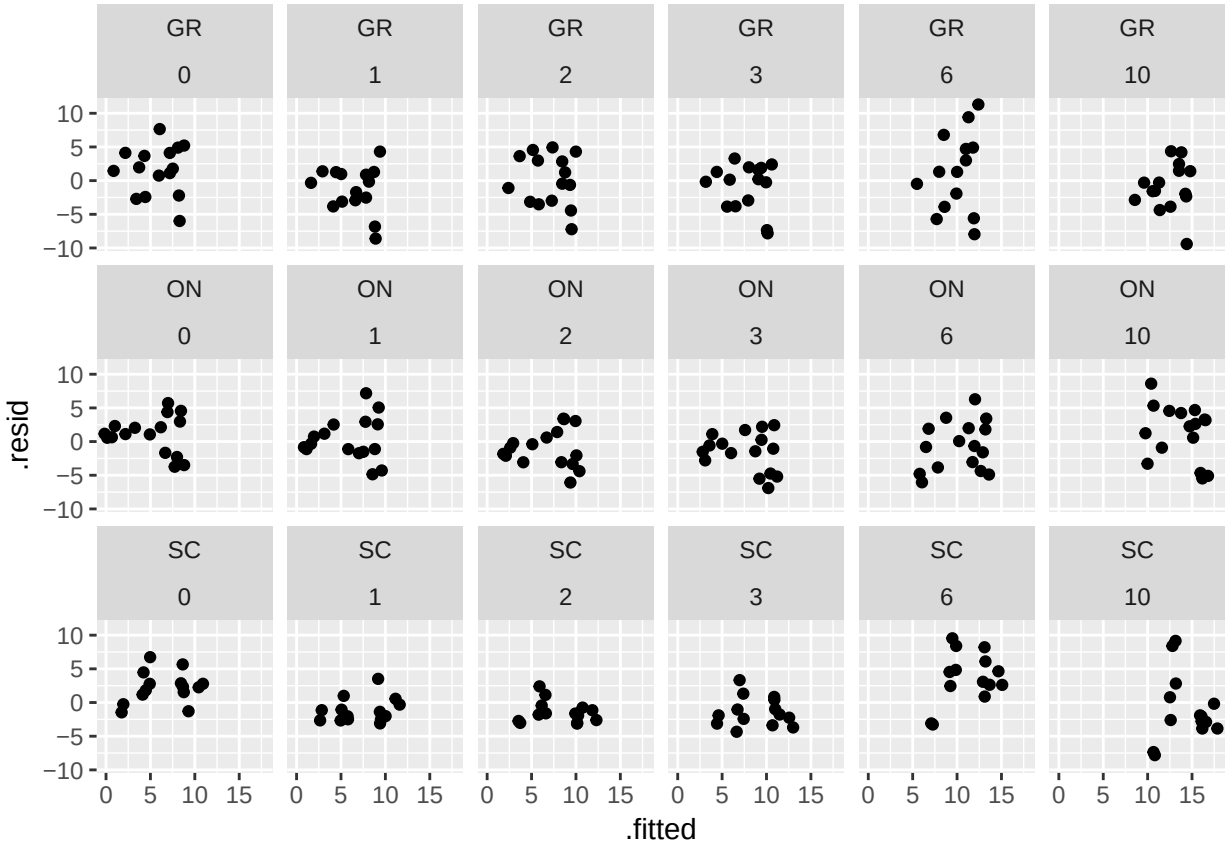

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




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

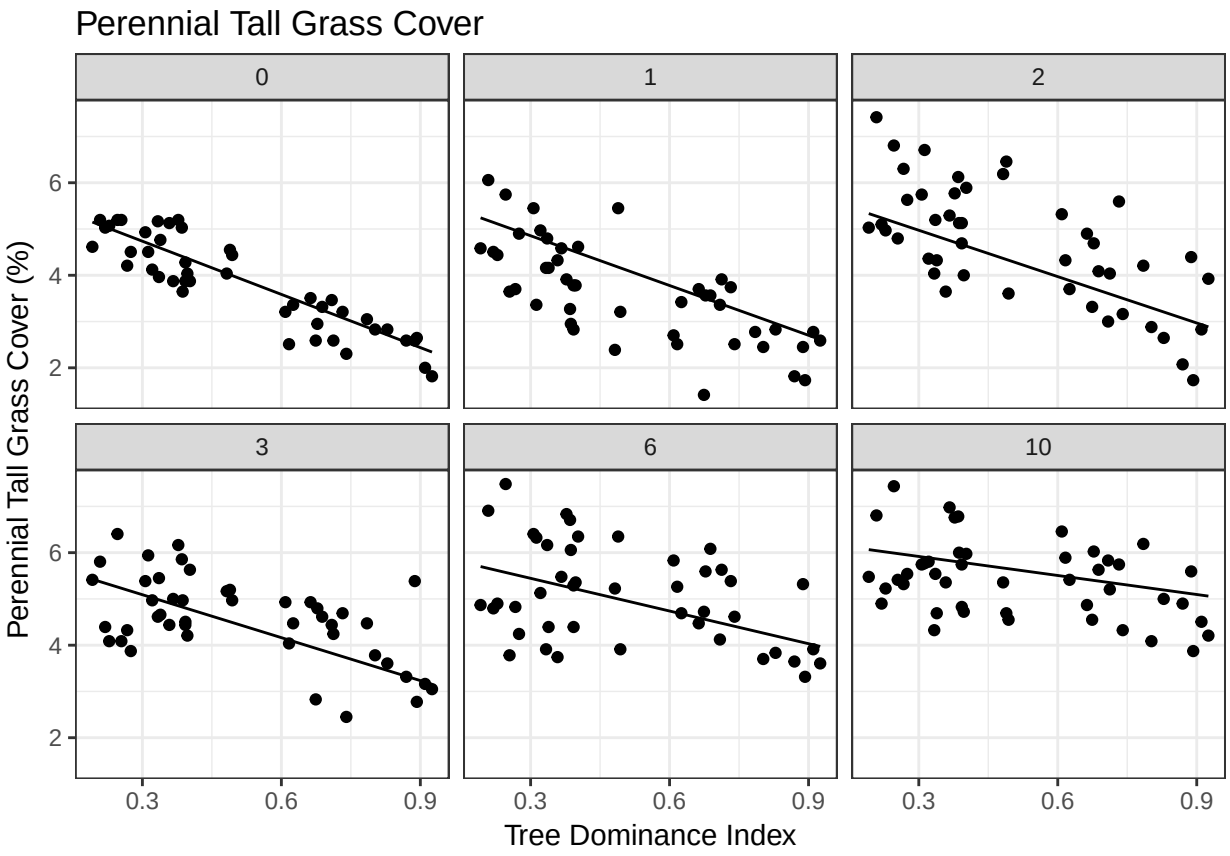
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(can_cover_pt_pgrass) ~ TDI + yst + yst:TDI + (1 + yst |
##     scode)
##    Data: l
##
## REML criterion at convergence: 627
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.0533 -0.6140 -0.0251  0.7044  2.6363
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 0.0502   0.224
##           yst         0.0025   0.050    1.00
##  Residual             0.5616   0.749
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##             Estimate Std. Error t value
```

```
## (Intercept)   5.8865     0.2111   27.89
## TDI          -3.8331     0.2972  -12.90
## yst           0.0442     0.0441    1.00
## TDI:yst       0.2463     0.0595    4.14
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.723
## yst     -0.035  0.505
## TDI:yst  0.527 -0.729 -0.693
```

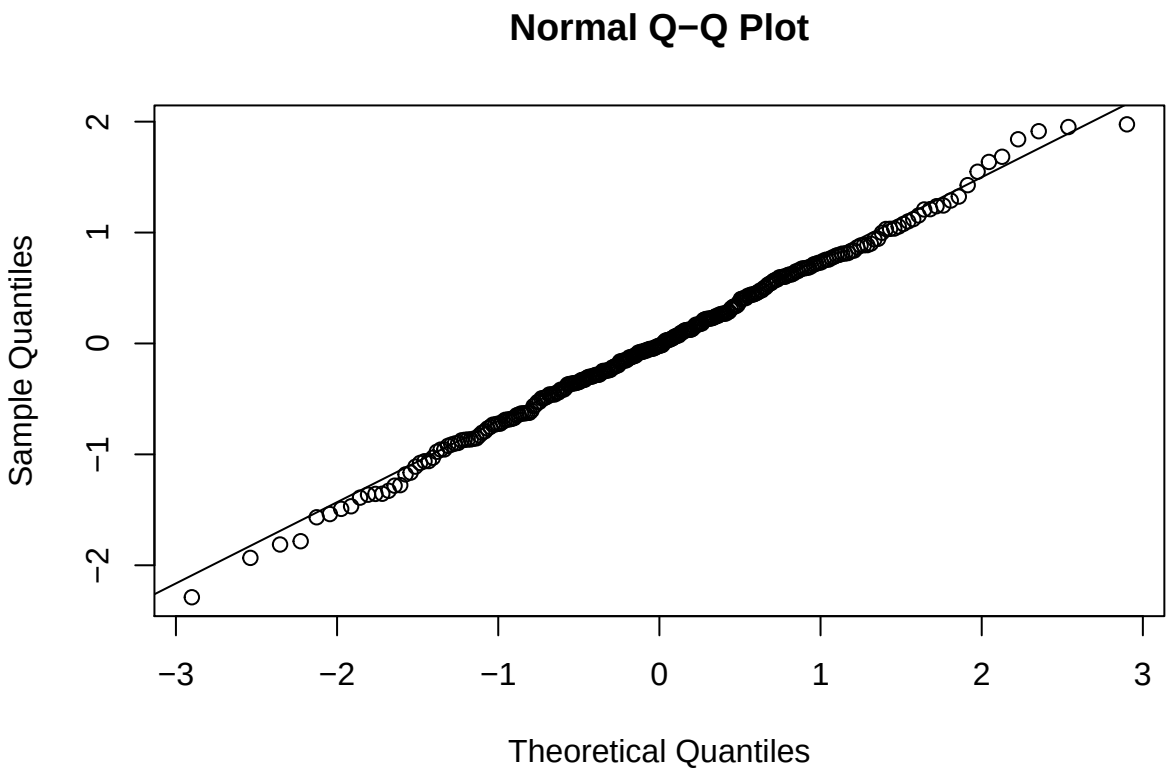
```
lincon(m)
```

```
##             estimate     se   lower  upper tvalue  df    pvalue
## (Intercept)   5.8865 0.2111  5.4728  6.300  27.89 Inf 3.63e-171
## TDI          -3.8331 0.2972 -4.4155 -3.251 -12.90 Inf  4.59e-38
## yst           0.0442 0.0441 -0.0422  0.131   1.00 Inf  3.16e-01
## TDI:yst       0.2463 0.0595  0.1296  0.363   4.14 Inf  3.51e-05
```

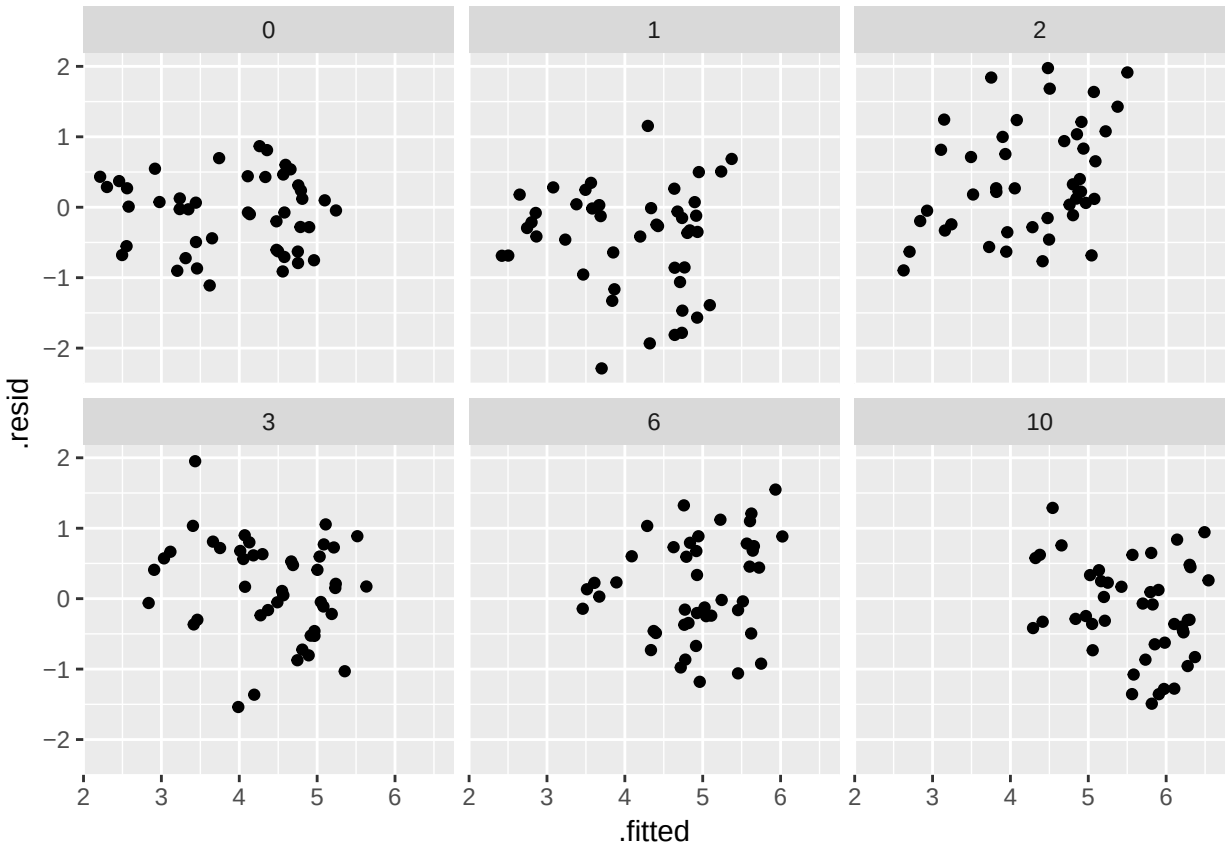
```
#by yst
l$yhat_pgrass_cvr <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = sqrt(can_cover_pt_pgrass)))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_pgrass_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Perennial Tall Grass Cover',
               x = 'Tree Dominance Index',
               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)
```



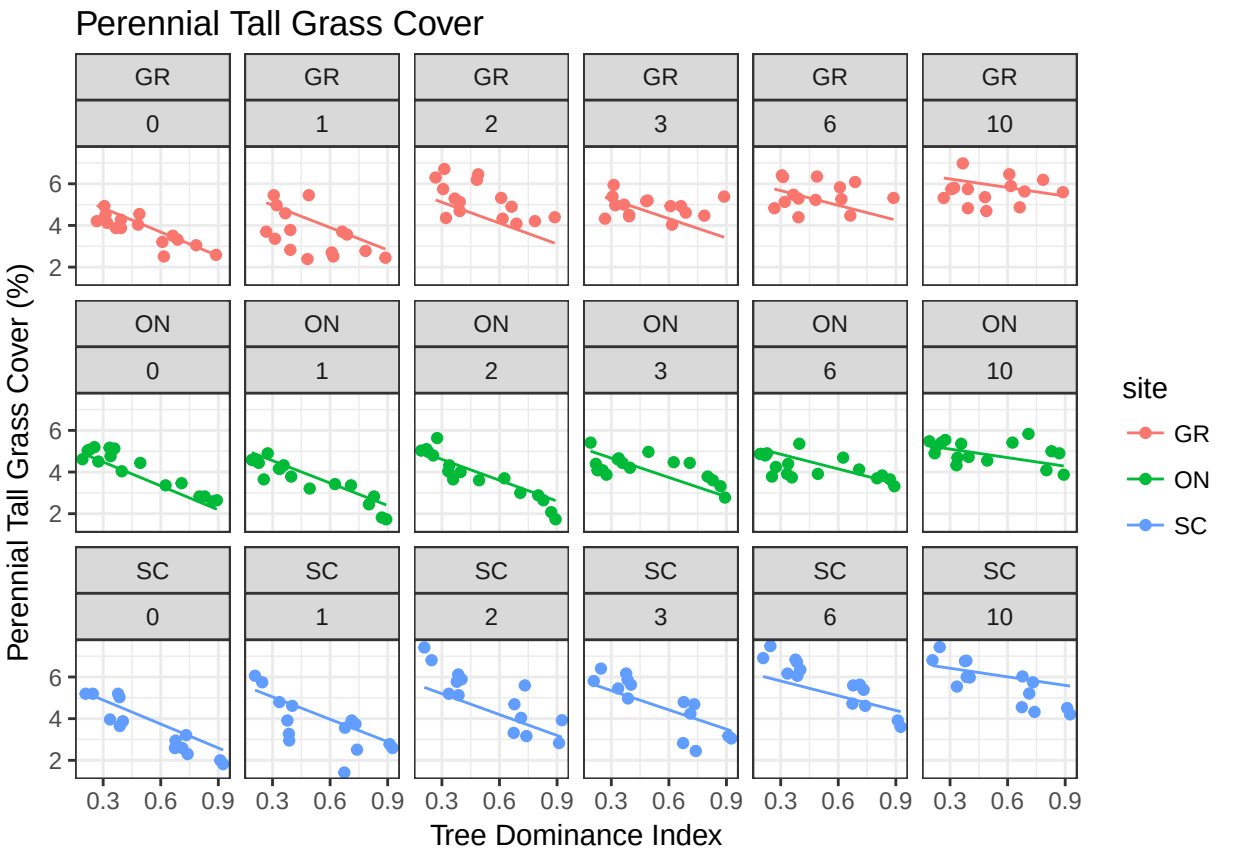

```
qqnorm(resid(m)); qqline(resid(m))
```



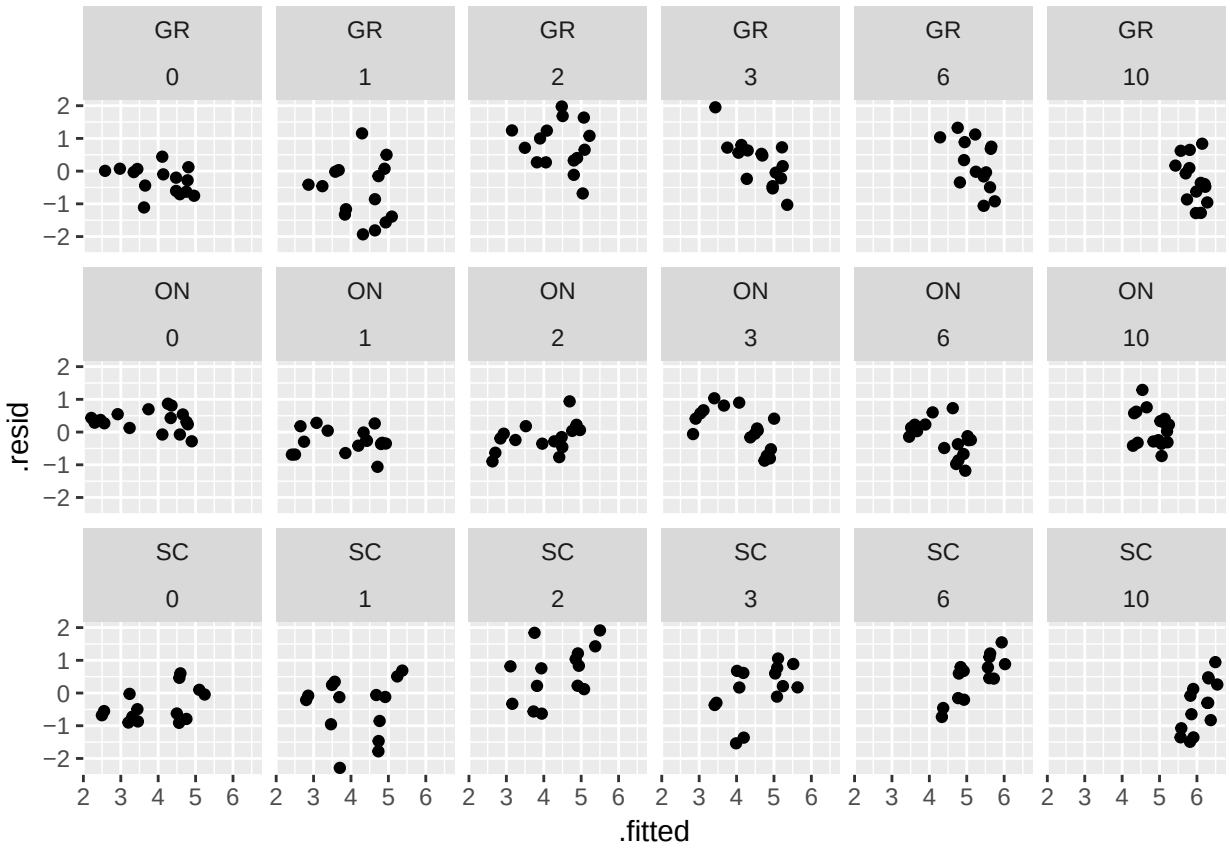

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




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




```
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 + yst|scode), data = l)
summary(m)
```

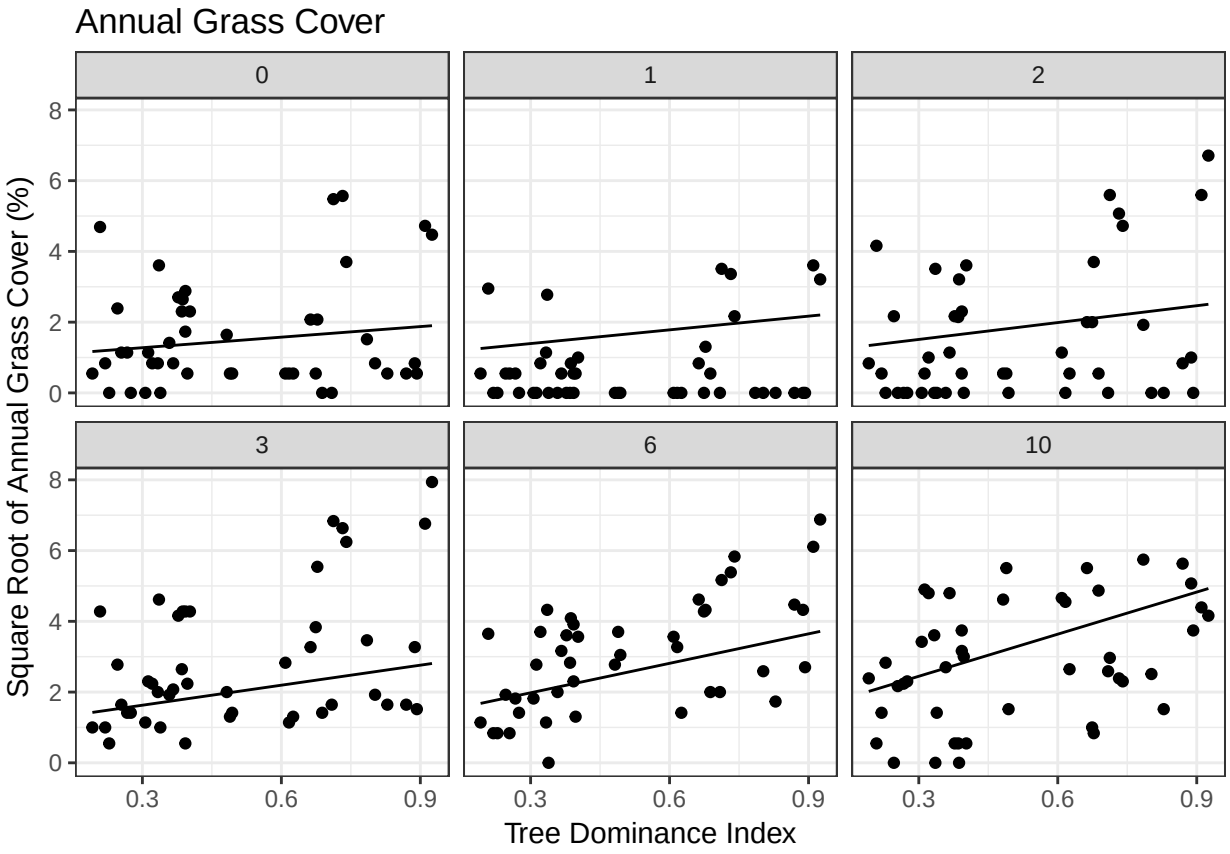
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: sqrt(can_cover_pt_agrass) ~ TDI + yst + yst:TDI + (1 + yst |
##     scode)
##    Data: l
##
## REML criterion at convergence: 876
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -3.190 -0.602 -0.061  0.695  3.255
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  scode    (Intercept) 3.6176   1.90
##           yst         0.0727   0.27     -0.94
##  Residual             1.3905   1.18
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
```

```
##             Estimate Std. Error t value
## (Intercept)   0.9791     1.1295    0.87
## TDI           0.9948     0.4704    2.12
## yst           0.0278     0.1644    0.17
## TDI:yst       0.2972     0.0942    3.16
##
## Correlation of Fixed Effects:
##         (Intr) TDI    yst
## TDI     -0.214
## yst     -0.916  0.216
## TDI:yst  0.157 -0.732 -0.295
```

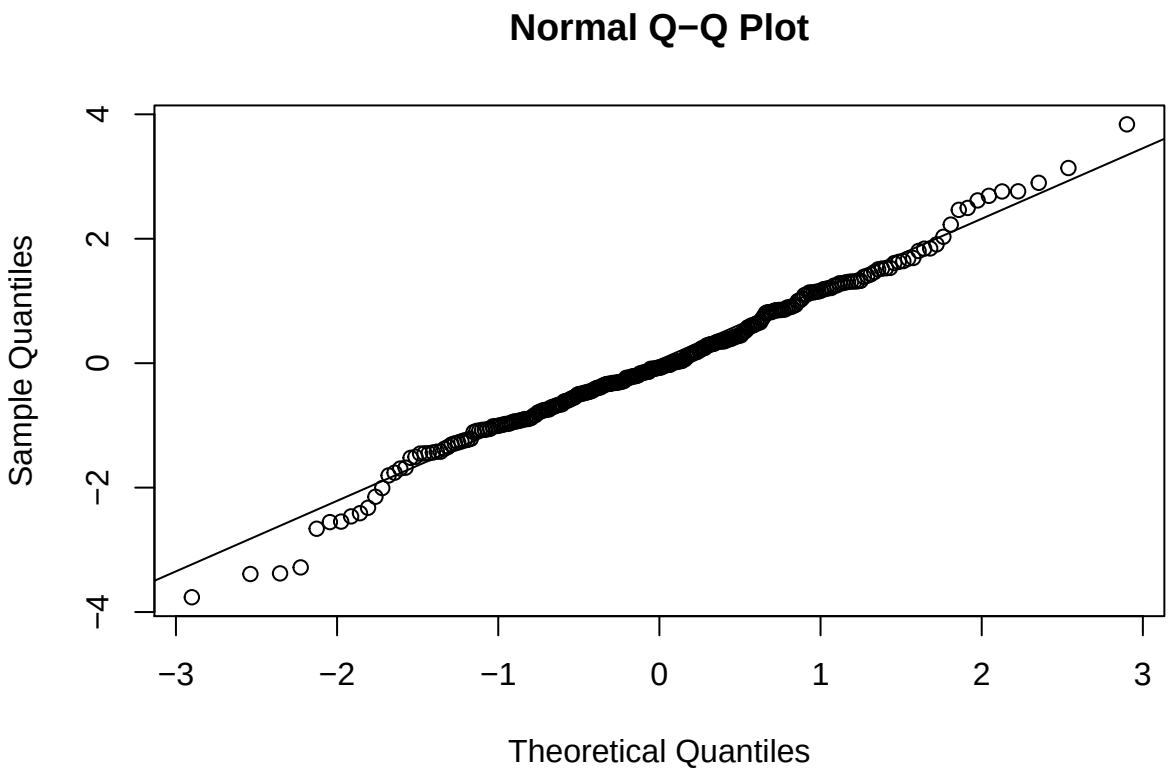
```
lincon(m)
```

```
##             estimate     se   lower upper tvalue  df pvalue
## (Intercept)   0.9791 1.1295 -1.2346 3.193  0.867 Inf 0.3860
## TDI           0.9948 0.4704  0.0729 1.917  2.115 Inf 0.0344
## yst           0.0278 0.1644 -0.2944 0.350  0.169 Inf 0.8659
## TDI:yst       0.2972 0.0942  0.1126 0.482  3.156 Inf 0.0016
```

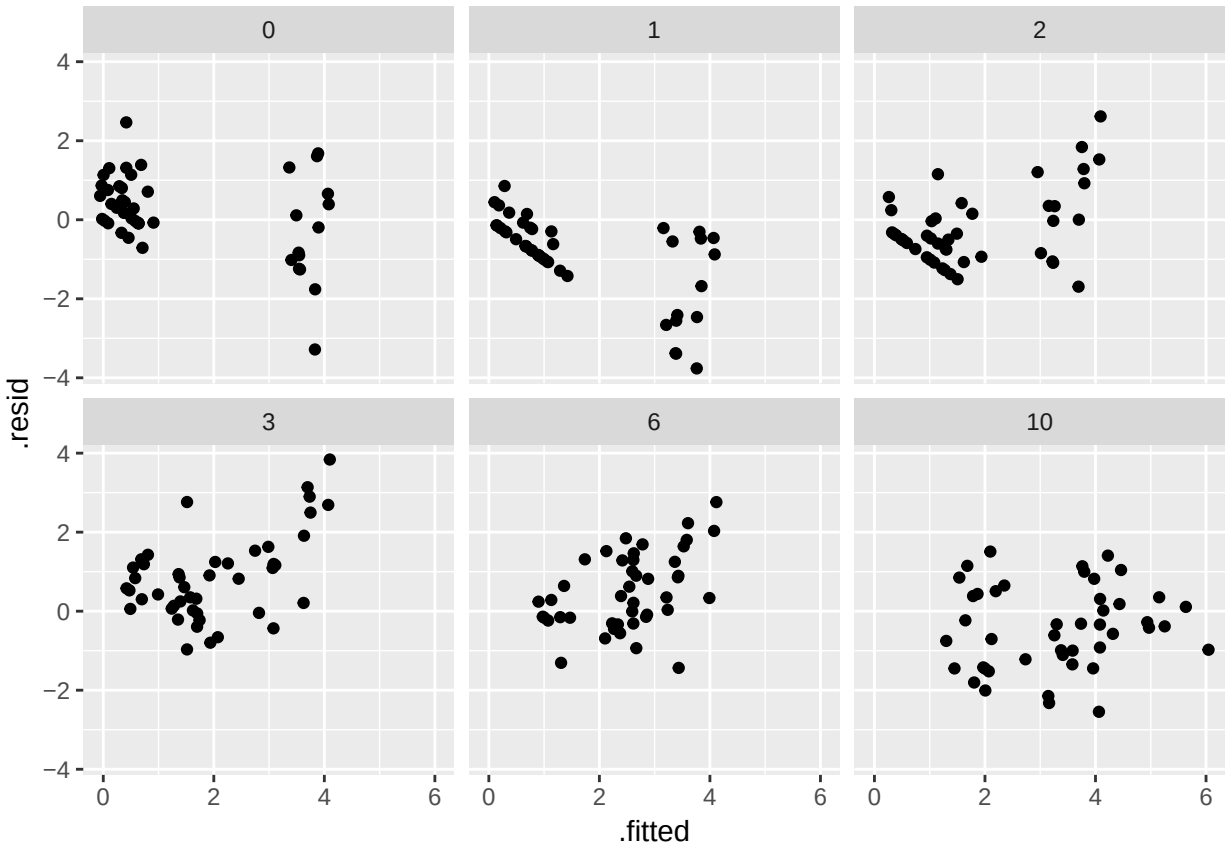
```
#by yst
l$yhat_agrass_cvr <- predict(m, re.form = NA)
p <- ggplot(data = l, aes(x = TDI, y = sqrt(can_cover_pt_agrass)))
p <- p + geom_point()
p <- p + geom_line(aes(y = yhat_agrass_cvr))
p <- p + theme_bw()
p <- p + labs(title = 'Annual Grass Cover',
               x = 'Tree Dominance Index',
               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)
```



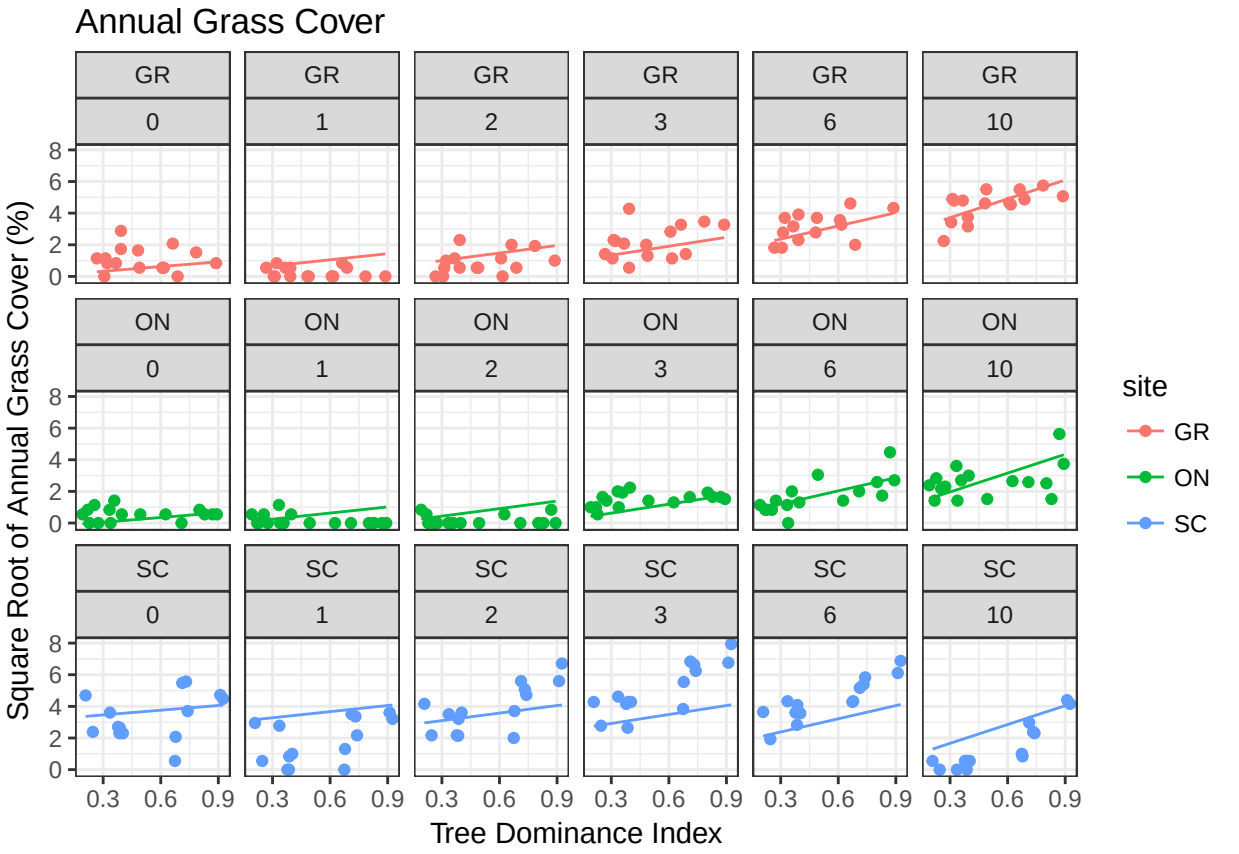

```
qqnorm(resid(m)); qqline(resid(m))
```



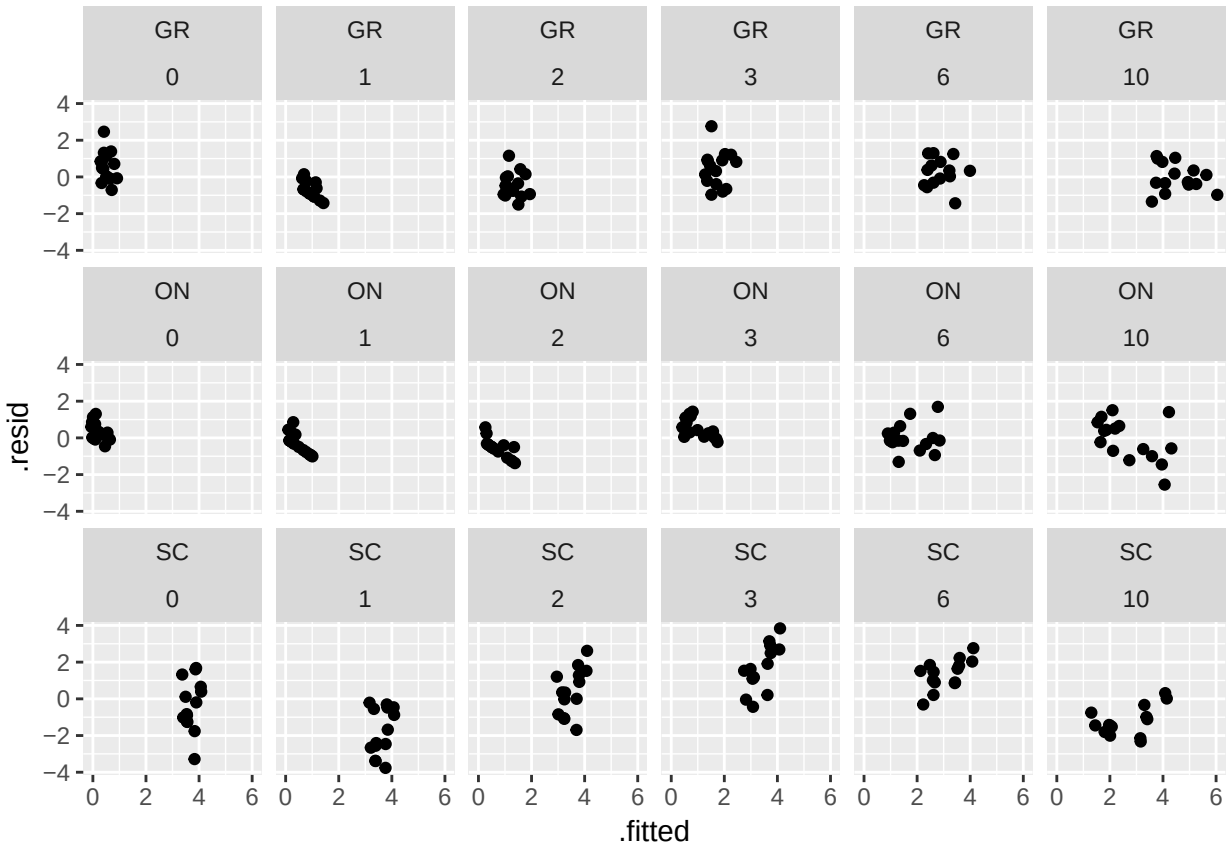

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




```
#by yst and site
l$yhat_agrass_cvr <- predict(m)
p <- ggplot(data = l, aes(x = TDI, y = 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 = '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(sqrt(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:
## 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: 925
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
##  -4.40   0.00   0.00   0.00   3.28
##
```

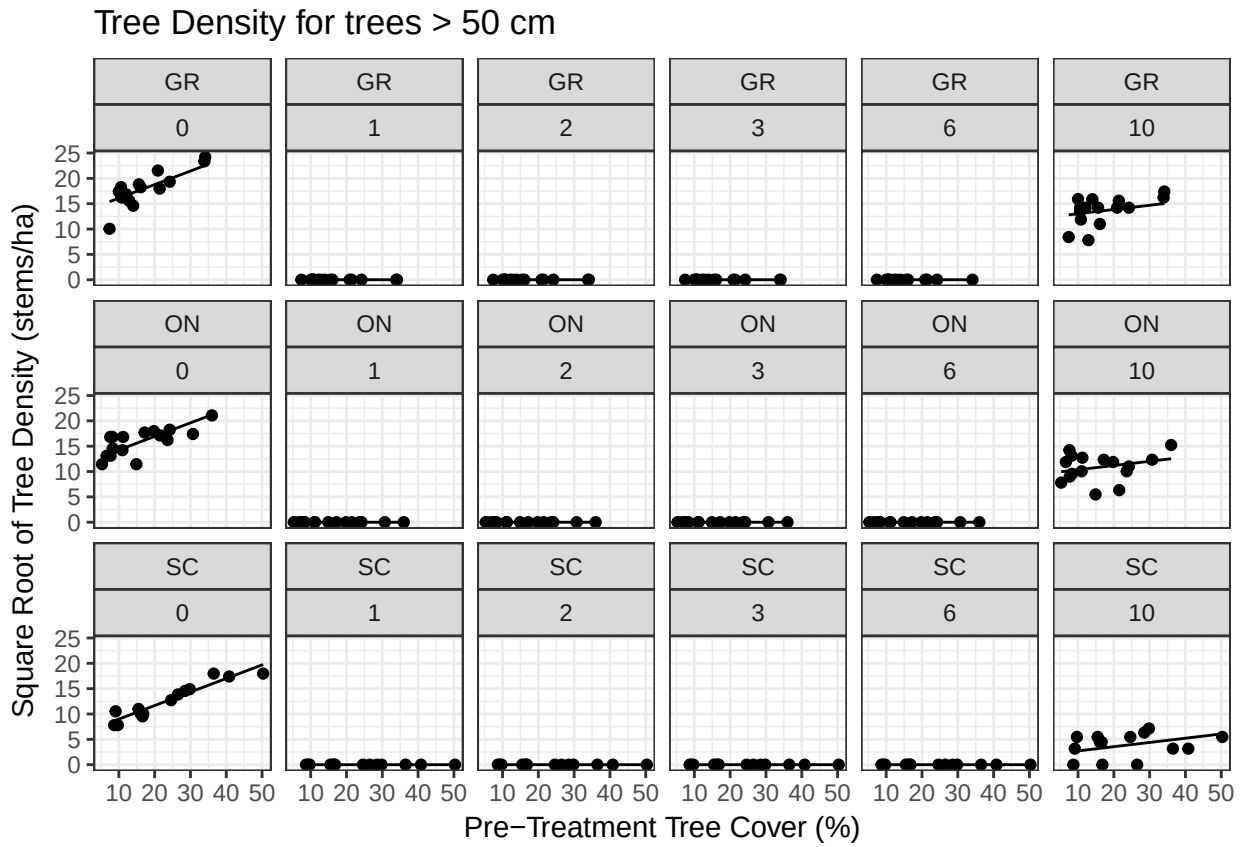
```
## Random effects:
##  Groups   Name          Variance Std.Dev. Corr
##  scode    (Intercept)   13.64    3.69
##           factor(yst)1  13.64    3.69     -1.00
##           factor(yst)2  13.64    3.69     -1.00  1.00
##           factor(yst)3  13.64    3.69     -1.00  1.00  1.00
##           factor(yst)6  13.64    3.69     -1.00  1.00  1.00  1.00
##           factor(yst)10  2.76    1.66      1.00 -1.00 -1.00 -1.00 -1.00
##  Residual                1.53    1.24
## Number of obs: 269, groups:  scode, 3
##
## Fixed effects:
##                   Estimate Std. Error t value
## (Intercept)        10.4426     2.1666    4.82
## TC                  0.2674     0.0181   14.79
## factor(yst)1      -10.4426     2.1994   -4.75
## factor(yst)2      -10.4426     2.1994   -4.75
## factor(yst)3      -10.4426     2.1994   -4.75
## factor(yst)6      -10.4426     2.1999   -4.75
## factor(yst)10      -2.5793     1.0991   -2.35
## TC:factor(yst)1    -0.2674     0.0253  -10.55
## TC:factor(yst)2    -0.2674     0.0253  -10.55
## TC:factor(yst)3    -0.2674     0.0253  -10.55
## TC:factor(yst)6    -0.2674     0.0257  -10.42
## TC:factor(yst)10   -0.1839     0.0252   -7.31
##
## 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)
```

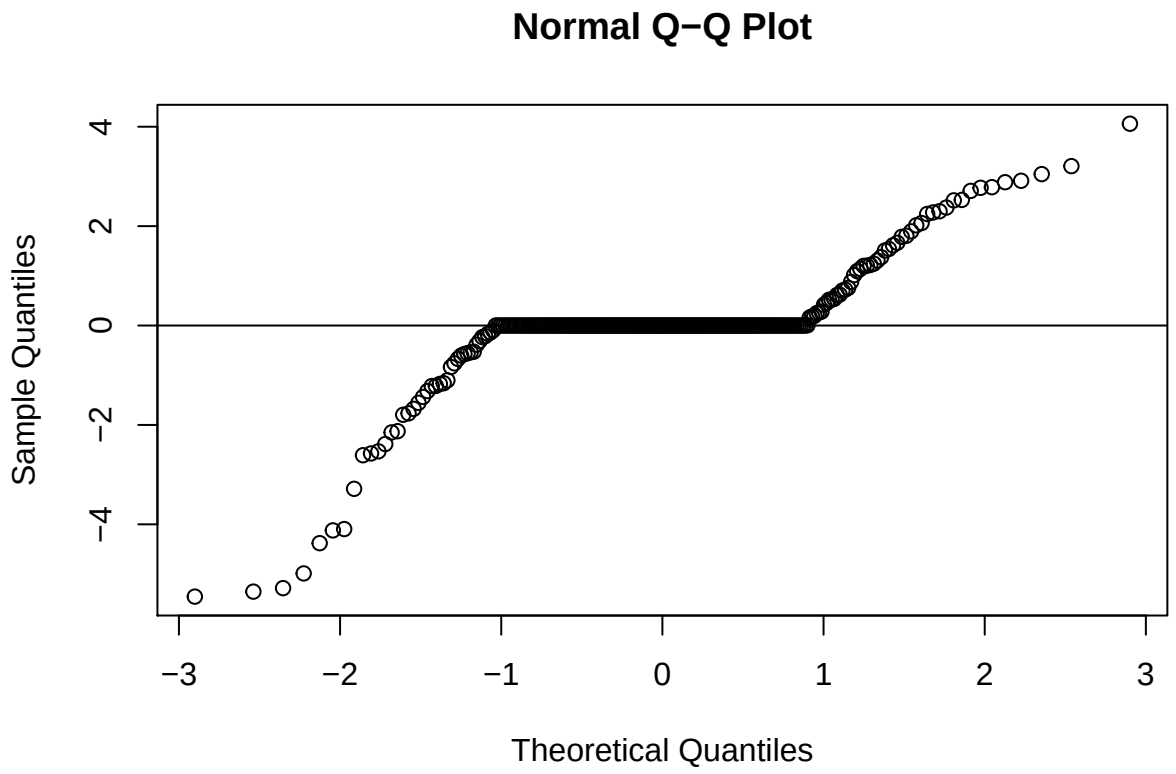
```
##                  estimate     se   lower  upper tvalue  df   pvalue
```

```
## (Intercept)         10.443 2.1666   6.196 14.689   4.82 Inf 1.44e-06
## TC                   0.267 0.0181   0.232  0.303  14.79 Inf 1.67e-49
## factor(yst)1       -10.443 2.1994 -14.753 -6.132  -4.75 Inf 2.06e-06
## factor(yst)2       -10.443 2.1994 -14.753 -6.132  -4.75 Inf 2.06e-06
## factor(yst)3       -10.443 2.1994 -14.753 -6.132  -4.75 Inf 2.06e-06
## factor(yst)6       -10.443 2.1999 -14.754 -6.131  -4.75 Inf 2.07e-06
## factor(yst)10       -2.579 1.0991  -4.733 -0.425  -2.35 Inf 1.89e-02
## TC:factor(yst)1     -0.267 0.0253  -0.317 -0.218 -10.55 Inf 4.92e-26
## TC:factor(yst)2     -0.267 0.0253  -0.317 -0.218 -10.55 Inf 4.92e-26
## TC:factor(yst)3     -0.267 0.0253  -0.317 -0.218 -10.55 Inf 4.92e-26
## TC:factor(yst)6     -0.267 0.0257  -0.318 -0.217 -10.42 Inf 1.97e-25
## TC:factor(yst)10    -0.184 0.0252  -0.233 -0.135  -7.31 Inf 2.63e-13
```

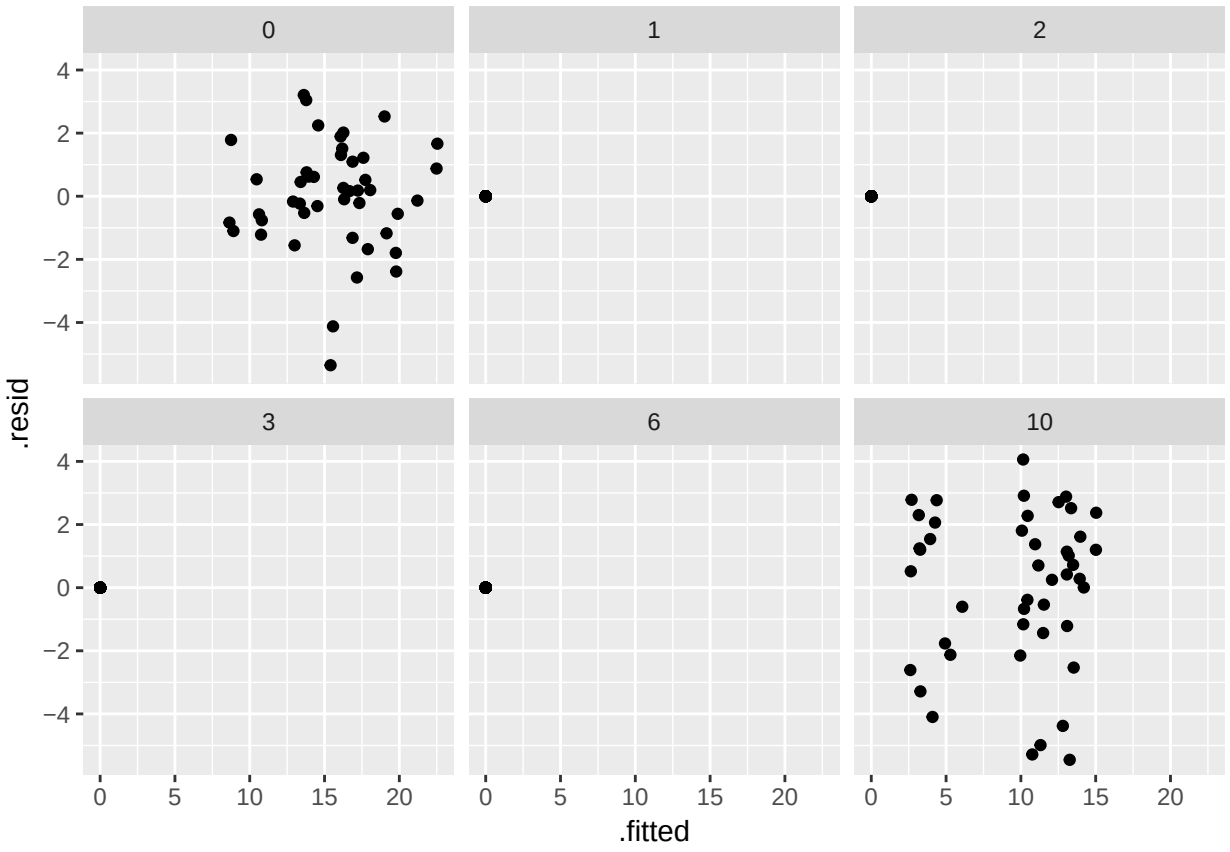
```r
#by yst
td$yhat_tree_dens <- predict(m)
p <- ggplot(data = td, aes(x = TC,
                           y = sqrt(tree_dns_gt50_JUOS + tree_dns_gt50_PIED)))
p <- p + geom_point()
p <- p + theme_bw()
p <- p + geom_line(aes(y = yhat_tree_dens))
p <- p + labs(title = 'Tree Density for trees > 50 cm',
              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)
```



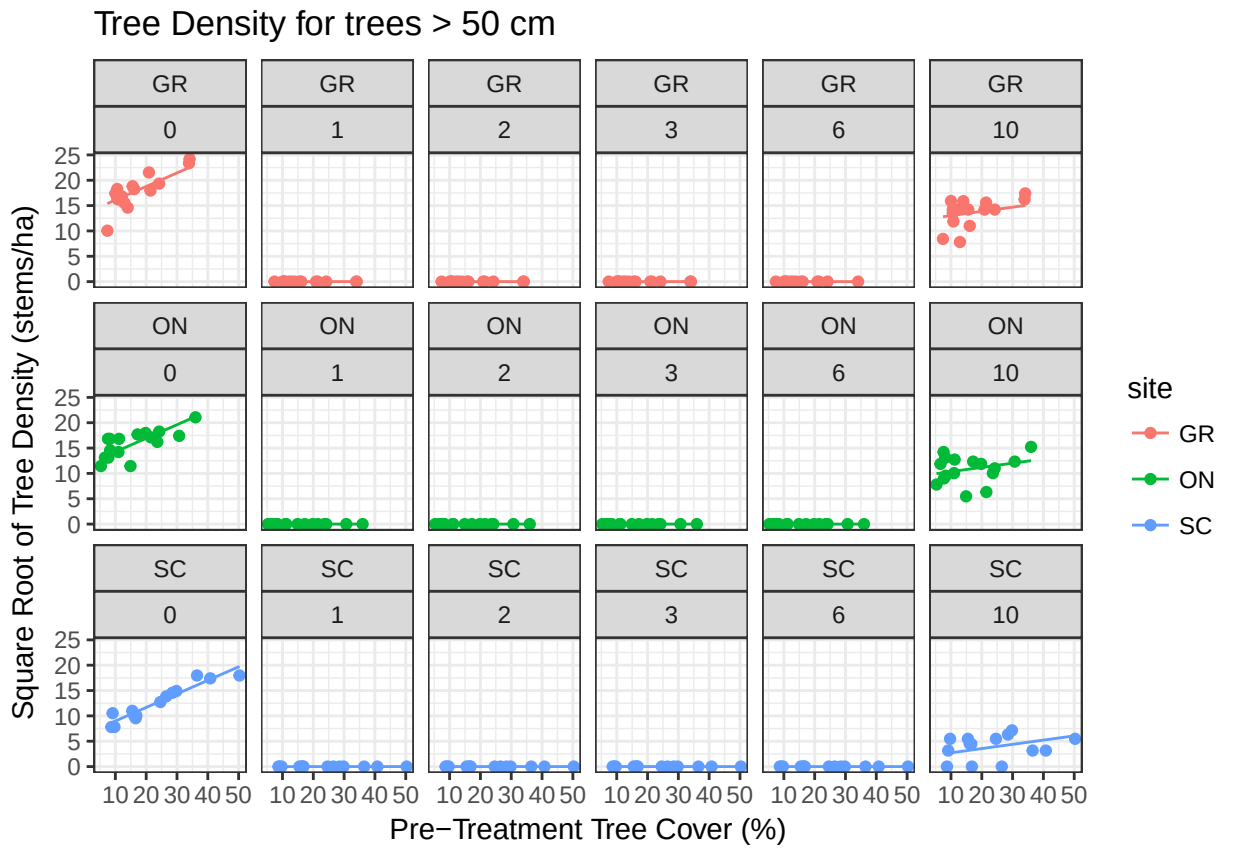
```
qqnorm(resid(m)); qqline(resid(m))
```



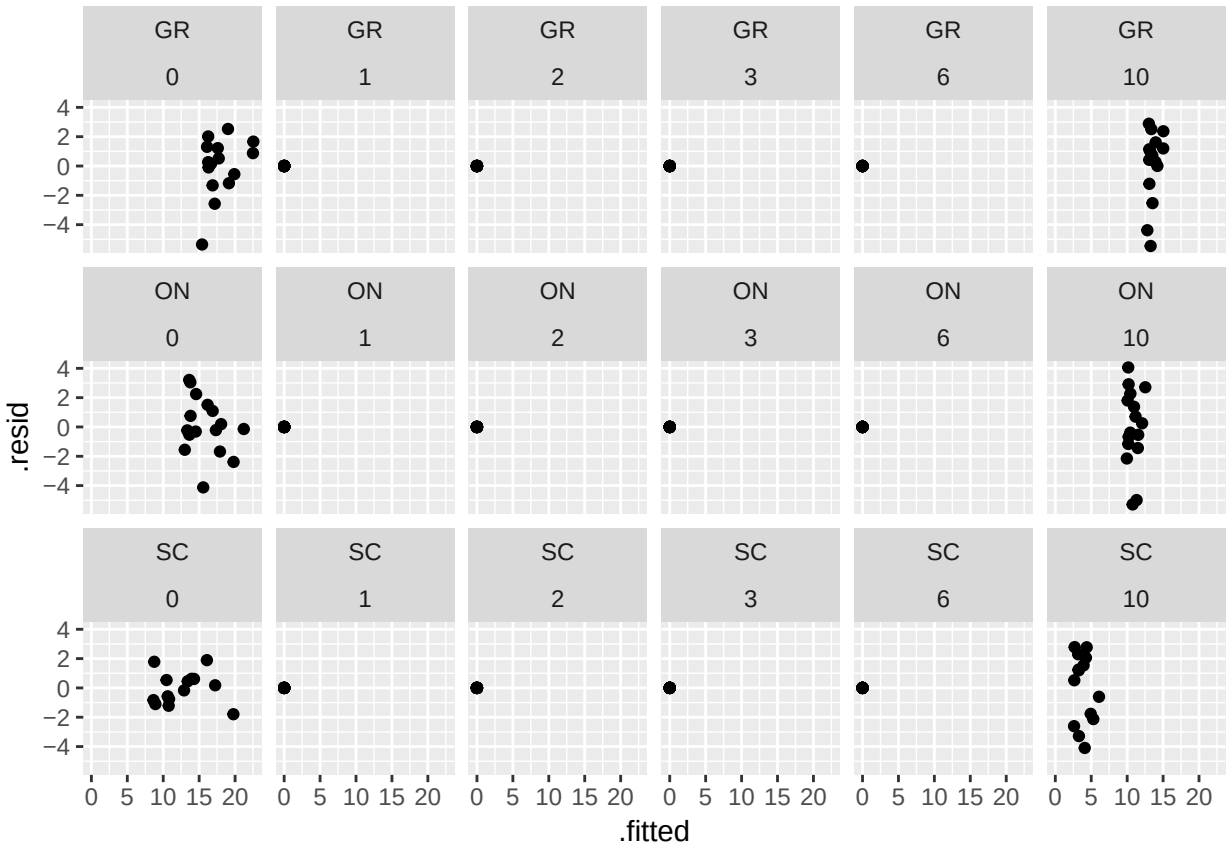

```
ggplot(m, aes(x = .fitted, y = .resid)) + geom_point() + facet_wrap(~yst)
```




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




```
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)

#by yst
tcover$yhat_tree_cover <- predict(m)
p <- ggplot(data = tcover, aes(x = TC, y = sqrt(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 = 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(0,60, 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)
```