Explore resilience evi

AJ Perez-Luque (@ajpelu)

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Prepare data

```
# Read data
raw_evires <- read.csv(file=paste(di, "/data/resilience/resiliences.csv", sep=""), header = TRUE, sep =

# add data of pop
anomalias <- read.csv(file=paste(di, "/data/anomalies/anomalias_evimean.csv", sep=""), header = TRUE, s

attr_iv_malla_modis_id <- anomalias %>% dplyr::select(iv_malla_modi_id,long,lat,pop) %>% unique()


raw_evires <- raw_evires %>% inner_join(attr_iv_malla_modis_id, by='iv_malla_modi_id')

# filter by pop and add new variable

evires <- raw_evires %>%
  mutate(
    clu_pop = as.factor(case_when(
      pop == 1 ~ "Camarate",
      pop %in% c(2,3,4,5) ~ 'Northern slope',
      pop %in% c(6,7,8) ~ 'Southern slope',
      pop == 9 ~ 'out')),
    clu_pop2 = as.factor(case_when(
      pop %in% c(1,2,3,4,5) ~ 'Northern slope',
      pop %in% c(6,7,8) ~ 'Southern slope',
      pop == 9 ~ 'out'))) %>%
  filter(clu_pop != 'out')

# Change name of clu_pop2 and disturb_year para los analisis anovas
evires <- evires %>% rename(site = clu_pop2) %>%
  mutate(disturb_year = as.factor(disturb_year))
```

ANOVAS

Recovery

Table 1: ANOVA table: rc

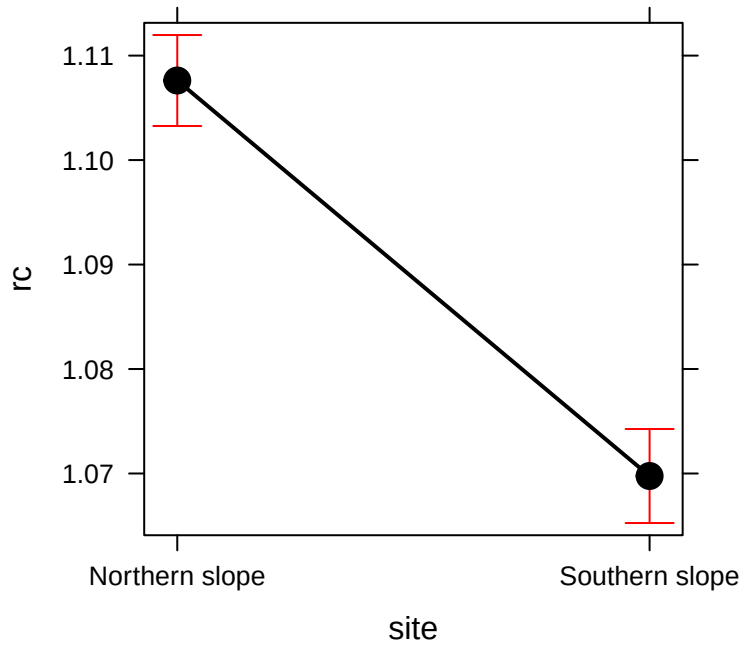
term	df	sumsq	meansq	statistic	p.value
disturb_year	1	1.951	1.951	420.3	**0**
site	1	0.6528	0.6528	140.6	**0**
disturb_year:site	1	1.969	1.969	424.1	**0**
Residuals	1820	8.45	0.00464		

	Statistic
R^2	0.35
adjR^2	0.35
σ_e	0.07
F	328.31
p	0.00
df_m	4.00
logLik	2313.52
AIC	-4617.05
BIC	-4589.50
dev	8.45
df_e	1820.00

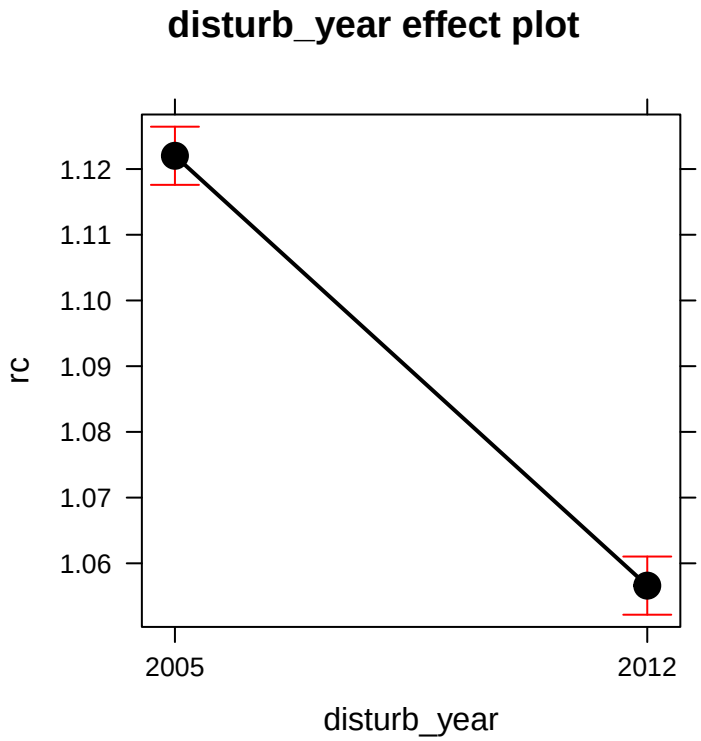
```
# Post hoc Define model
mymodel <- aov_rc$mymodel
postH_rc <- phc(mymodel = mymodel, resp_var = resp_var)
```

```
##
## ### Event ###
## $lsmeans
##  disturb_year   lsmean          SE   df lower.CL upper.CL
##  2005         1.120312 0.002257496 1820 1.115885 1.124740
##  2012         1.057062 0.002257496 1820 1.052634 1.061489
##
## Results are averaged over the levels of: site
## Confidence level used: 0.95
##
## $contrasts
##  contrast      estimate          SE   df t.ratio p.value
##  2005 - 2012 0.06325071 0.003192582 1820  19.812  <.0001
##
## Results are averaged over the levels of: site
##
##  disturb_year   lsmean          SE   df lower.CL upper.CL .group
##  2012         1.057062 0.002257496 1820 1.051998 1.062126  a
##  2005         1.120312 0.002257496 1820 1.115248 1.125377   b
##
## Results are averaged over the levels of: site
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## significance level used: alpha = 0.01
##
## ### Clu pop ###
## $lsmeans
##  site             lsmean          SE   df lower.CL upper.CL
##  Northern slope 1.107615 0.002220056 1820 1.103261 1.111969
##  Southern slope 1.069759 0.002294326 1820 1.065259 1.074259
##
## Results are averaged over the levels of: disturb_year
## Confidence level used: 0.95
##
## $contrasts
```

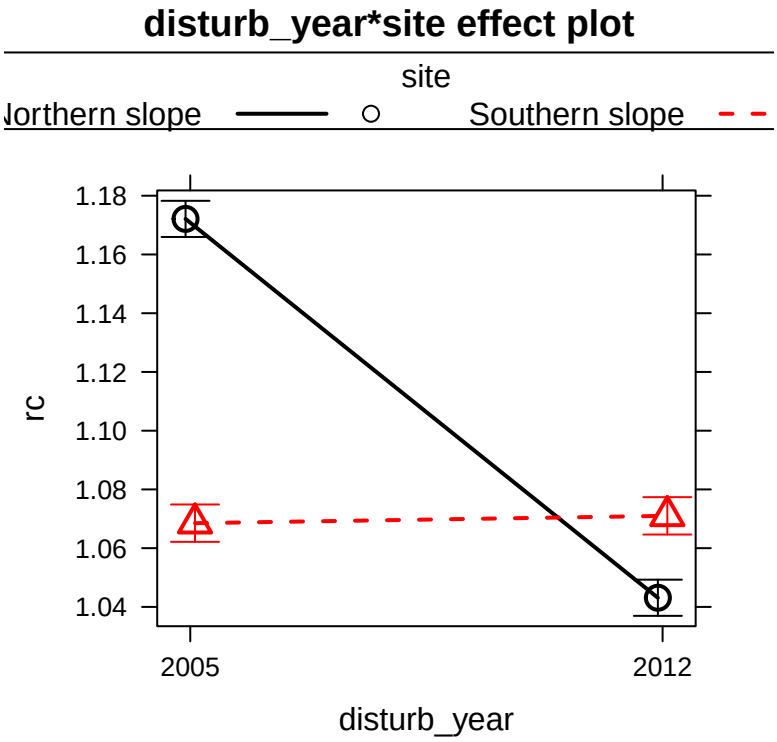
```
##  contrast                           estimate          SE   df t.ratio
##  Northern slope - Southern slope 0.03785579 0.003192582 1820  11.857
##  p.value
##   <.0001
##
## Results are averaged over the levels of: disturb_year
##
##  site             lsmean          SE   df lower.CL upper.CL .group
##  Southern slope 1.069759 0.002294326 1820 1.064612 1.074906  a
##  Northern slope 1.107615 0.002220056 1820 1.102635 1.112595   b
##
## Results are averaged over the levels of: disturb_year
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## significance level used: alpha = 0.01
##
## ### Event:Clu pop ###
## $lsmeans
##  disturb_year site             lsmean          SE   df lower.CL upper.CL
##  2005         Northern slope 1.172113 0.003139633 1820 1.165955 1.178271
##  2012         Northern slope 1.043117 0.003139633 1820 1.036959 1.049275
##  2005         Southern slope 1.068512 0.003244666 1820 1.062148 1.074876
##  2012         Southern slope 1.071007 0.003244666 1820 1.064643 1.077370
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast                                        estimate          SE   df
##  2005,Northern slope - 2012,Northern slope  0.128996090 0.004440112 1820
##  2005,Northern slope - 2005,Southern slope  0.103601172 0.004514992 1820
##  2005,Northern slope - 2012,Southern slope  0.101106495 0.004514992 1820
##  2012,Northern slope - 2005,Southern slope -0.025394918 0.004514992 1820
##  2012,Northern slope - 2012,Southern slope -0.027889595 0.004514992 1820
##  2005,Southern slope - 2012,Southern slope -0.002494677 0.004588651 1820
##  t.ratio p.value
##   29.052  <.0001
##   22.946  <.0001
##   22.394  <.0001
##   -5.625  <.0001
##   -6.177  <.0001
##   -0.544  1.0000
##
## P value adjustment: bonferroni method for 6 tests
ps
```



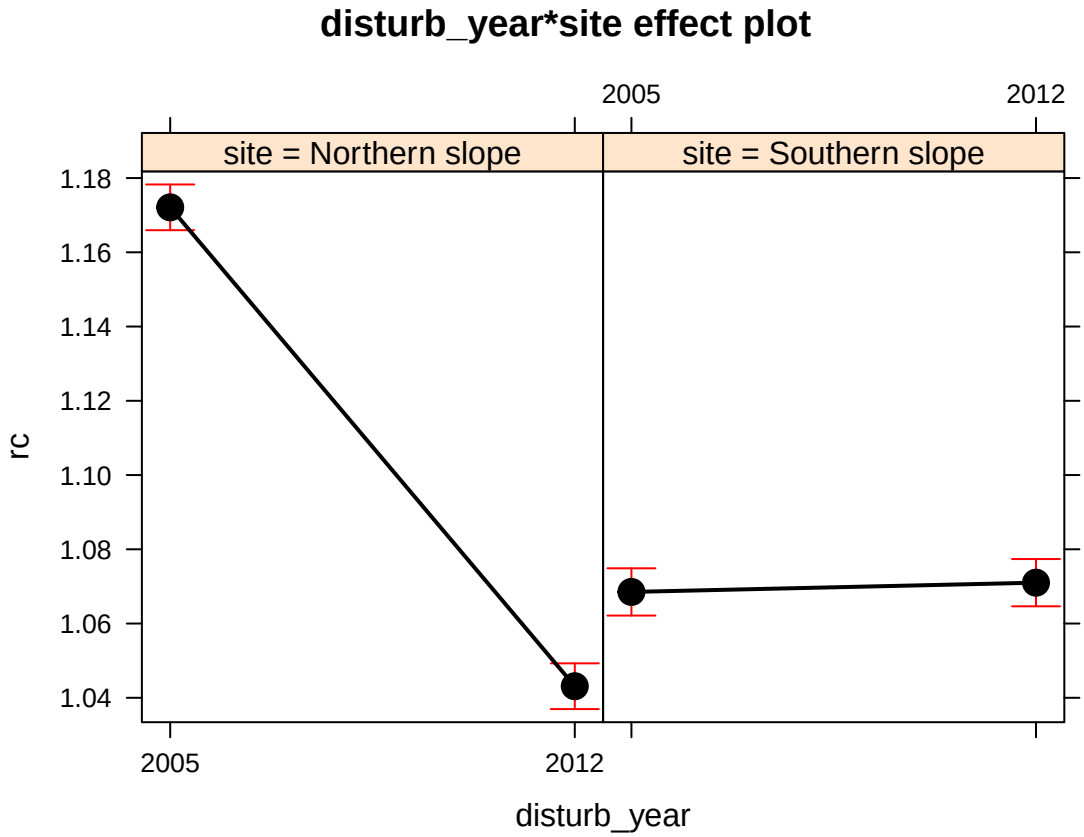

```
pd
```




```
picollapse
```


disturb_year*site effect plot
site
Northern slope
Southern slope
1.18
1.16
1.14
1.12
1.10
1.08
1.06
1.04
rc
2005
2012
disturb_year

```
pi
```


disturb_year*site effect plot
2005
2012
site = Northern slope
site = Southern slope
1.18
1.16
1.14
1.12
1.10
1.08
1.06
1.04
rc
2005
2012
disturb_year

Resistance

Table 3: ANOVA table: rt

term	df	sumsq	meansq	statistic	p.value
disturb_year	1	3.266	3.266	1079	**0**
site	1	0.6366	0.6366	210.2	**0**
disturb_year:site	1	0.9736	0.9736	321.5	**0**
Residuals	1820	5.511	0.00303		

	Statistic
R^2	0.47
adjR^2	0.47
σ_e	0.06
F	536.85
p	0.00
df_m	4.00
logLik	2703.33
AIC	-5396.66
BIC	-5369.12
dev	5.51
df_e	1820.00

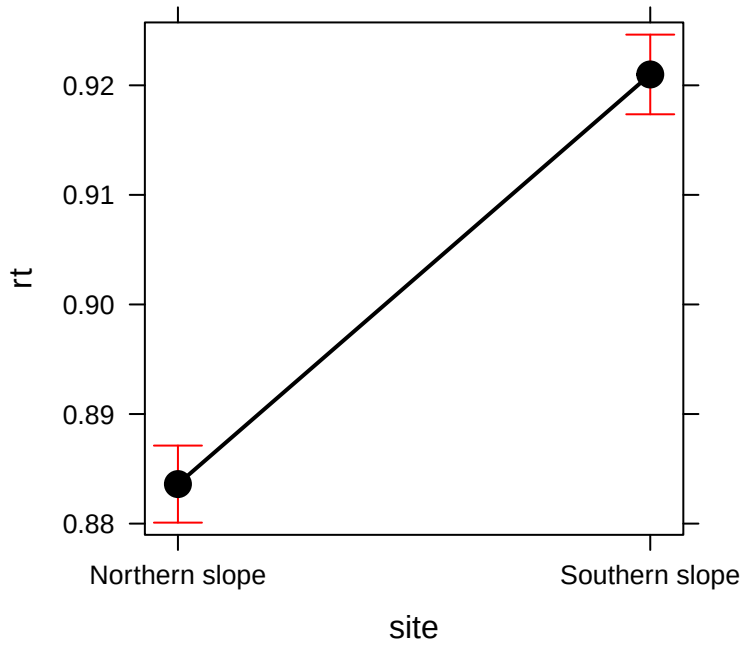
```
# Post hoc Define model
mymodel <- aov_rt$mymodel
postH_rt <- phc(mymodel = mymodel, resp_var = resp_var)
```

```
##
## ### Event ###
## $lsmeans
##  disturb_year    lsmean          SE   df  lower.CL  upper.CL
##  2005         0.8607403 0.001823114 1820 0.8571647 0.8643159
##  2012         0.9438559 0.001823114 1820 0.9402803 0.9474315
##
## Results are averaged over the levels of: site
## Confidence level used: 0.95
##
## $contrasts
##  contrast       estimate          SE   df t.ratio p.value
##  2005 - 2012 -0.08311557 0.002578272 1820 -32.237  <.0001
##
## Results are averaged over the levels of: site
##
##  disturb_year    lsmean          SE   df  lower.CL  upper.CL .group
##  2005         0.8607403 0.001823114 1820 0.8566506 0.8648300  a
##  2012         0.9438559 0.001823114 1820 0.9397662 0.9479456   b
##
## Results are averaged over the levels of: site
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
```

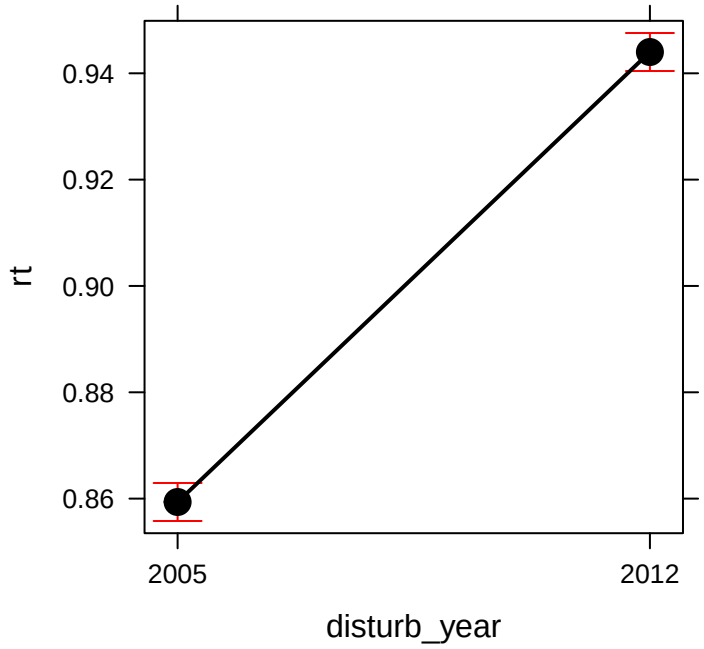
```
## significance level used: alpha = 0.01
##
## ### Clu pop ###
## $lsmeans
##  site              lsmean          SE   df  lower.CL  upper.CL
##  Northern slope 0.8836057 0.001792878 1820 0.8800894 0.8871220
##  Southern slope 0.9209905 0.001852856 1820 0.9173566 0.9246245
##
## Results are averaged over the levels of: disturb_year
## Confidence level used: 0.95
##
## $contrasts
##  contrast                           estimate          SE   df t.ratio
##  Northern slope - Southern slope -0.03738486 0.002578272 1820   -14.5
##  p.value
##   <.0001
##
## Results are averaged over the levels of: disturb_year
##
##  site              lsmean          SE   df  lower.CL  upper.CL .group
##  Northern slope 0.8836057 0.001792878 1820 0.8795838 0.8876276  a
##  Southern slope 0.9209905 0.001852856 1820 0.9168341 0.9251470   b
##
## Results are averaged over the levels of: disturb_year
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## significance level used: alpha = 0.01
##
## ### Event:Clu pop ###
## $lsmeans
##  disturb_year site              lsmean          SE   df  lower.CL
##  2005         Northern slope 0.8189321 0.002535512 1820 0.8139593
##  2012         Northern slope 0.9482792 0.002535512 1820 0.9433064
##  2005         Southern slope 0.9025485 0.002620335 1820 0.8974093
##  2012         Southern slope 0.9394325 0.002620335 1820 0.9342934
##   upper.CL
##  0.8239049
##  0.9532521
##  0.9076877
##  0.9445717
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast                                       estimate          SE   df
##  2005,Northern slope - 2012,Northern slope -0.12934712 0.003585755 1820
##  2005,Northern slope - 2005,Southern slope -0.08361641 0.003646227 1820
##  2005,Northern slope - 2012,Southern slope -0.12050043 0.003646227 1820
##  2012,Northern slope - 2005,Southern slope  0.04573071 0.003646227 1820
##  2012,Northern slope - 2012,Southern slope  0.00884669 0.003646227 1820
##  2005,Southern slope - 2012,Southern slope -0.03688402 0.003705713 1820
##  t.ratio p.value
##  -36.072  <.0001
##  -22.932  <.0001
```

```
##  -33.048  <.0001
##   12.542  <.0001
##    2.426  0.0921
##   -9.953  <.0001
##
## P value adjustment: bonferroni method for 6 tests
```

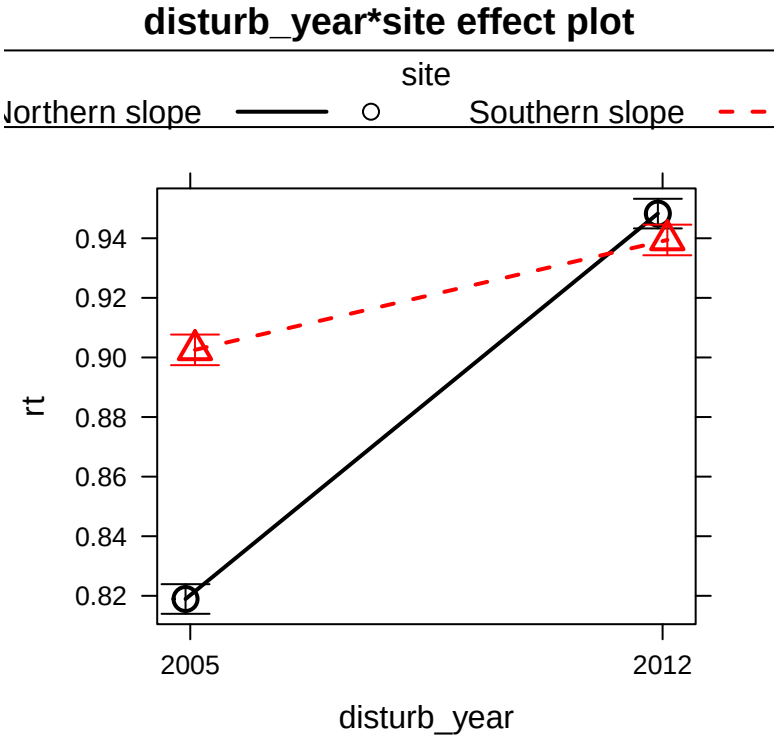
```
ps
```



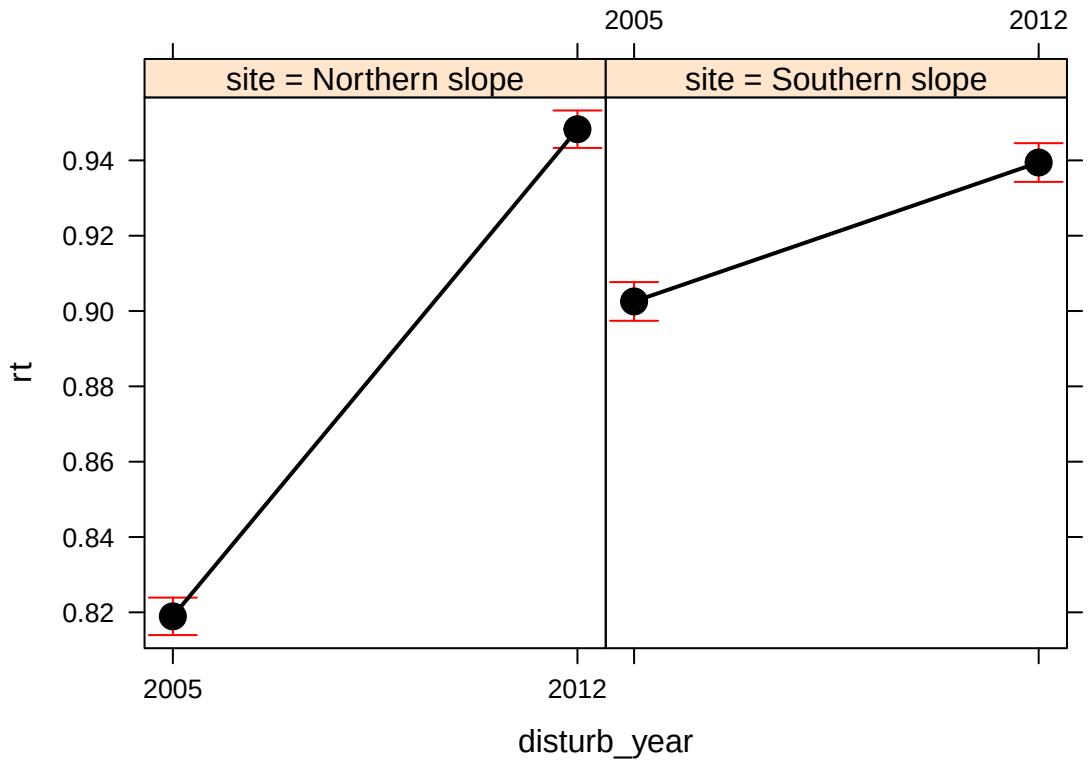

```
pd
```




```
picollapse
```




```
pi
```



Resilience

Table 5: ANOVA table: rs

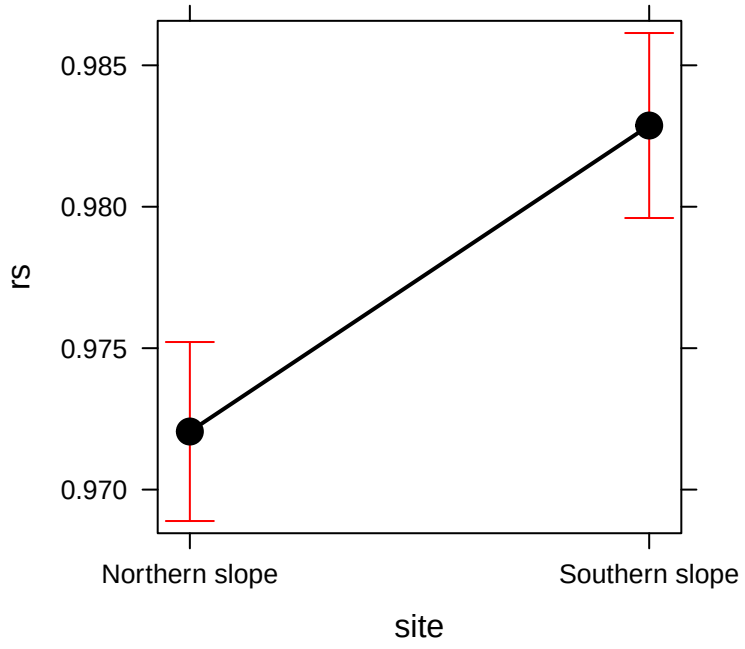
term	df	sumsq	meansq	statistic	p.value
disturb_year	1	0.6334	0.6334	258.4	**0**
site	1	0.0533	0.0533	21.74	**0**
disturb_year:site	1	0.01931	0.01931	7.875	**0.00507**
Residuals	1820	4.462	0.00245		

	Statistic
R^2	0.14
adjR^2	0.14
σ_e	0.05
F	96.00
p	0.00
df_m	4.00
logLik	2895.92
AIC	-5781.83
BIC	-5754.29
dev	4.46
df_e	1820.00

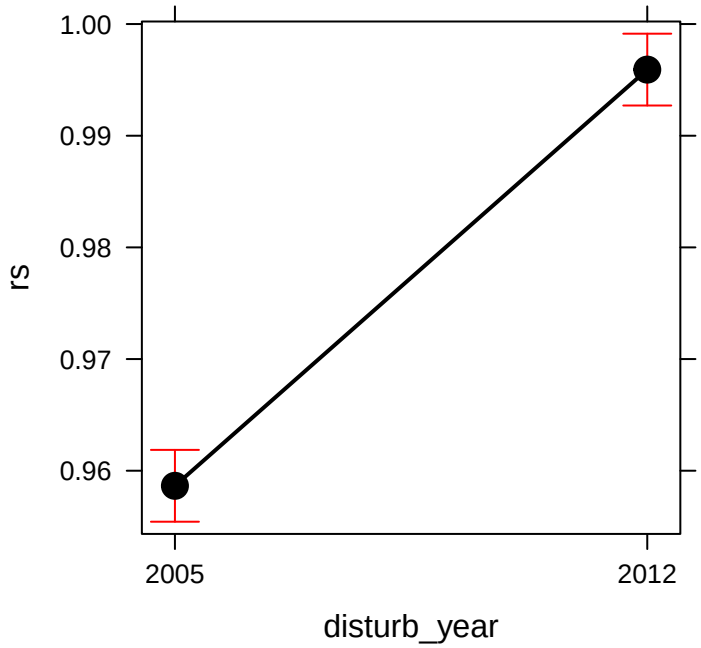
```r
# Post hoc Define model
mymodel <- aov_rs$mymodel
postH_rs <- phc(mymodel = mymodel, resp_var = resp_var)
```

```
##
## ### Event ###
## $lsmeans
##  disturb_year    lsmean          SE   df  lower.CL  upper.CL
##  2005         0.9587200 0.001640436 1820 0.9555027 0.9619373
##  2012         0.9962045 0.001640436 1820 0.9929872 0.9994219
##
## Results are averaged over the levels of: site
## Confidence level used: 0.95
##
## $contrasts
##  contrast       estimate          SE   df t.ratio p.value
##  2005 - 2012 -0.03748452 0.002319926 1820 -16.158  <.0001
##
## Results are averaged over the levels of: site
##
##  disturb_year    lsmean          SE   df  lower.CL  upper.CL .group
##  2005         0.9587200 0.001640436 1820 0.9550401 0.9623999  a
##  2012         0.9962045 0.001640436 1820 0.9925246 0.9998844   b
##
## Results are averaged over the levels of: site
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## significance level used: alpha = 0.01
##
## ### Clu pop ###
## $lsmeans
##  site              lsmean          SE   df  lower.CL  upper.CL
##  Northern slope 0.9720535 0.001613229 1820 0.9688896 0.9752175
##  Southern slope 0.9828710 0.001667198 1820 0.9796012 0.9861408
##
## Results are averaged over the levels of: disturb_year
## Confidence level used: 0.95
##
## $contrasts
##  contrast                           estimate          SE   df t.ratio
##  Northern slope - Southern slope -0.01081743 0.002319926 1820  -4.663
##  p.value
##   <.0001
##
## Results are averaged over the levels of: disturb_year
##
##  site              lsmean          SE   df  lower.CL  upper.CL .group
##  Northern slope 0.9720535 0.001613229 1820 0.9684347 0.9756724  a
##  Southern slope 0.9828710 0.001667198 1820 0.9791310 0.9866109   b
##
## Results are averaged over the levels of: disturb_year
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
```

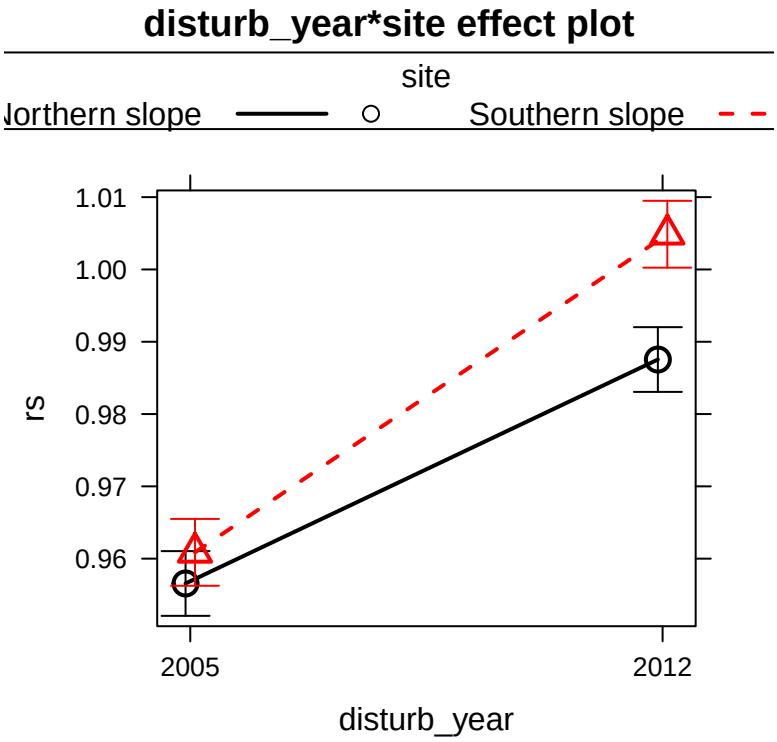
```
## significance level used: alpha = 0.01
##
## ### Event:Clu pop ###
## $lsmeans
##  disturb_year site              lsmean          SE   df  lower.CL
##  2005         Northern slope 0.9565664 0.002281451 1820 0.9520919
##  2012         Northern slope 0.9875407 0.002281451 1820 0.9830661
##  2005         Southern slope 0.9608736 0.002357774 1820 0.9562493
##  2012         Southern slope 1.0048684 0.002357774 1820 1.0002442
##   upper.CL
##  0.9610410
##  0.9920152
##  0.9654978
##  1.0094926
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast                                      estimate          SE   df
##  2005,Northern slope - 2012,Northern slope -0.030974221 0.003226458 1820
##  2005,Northern slope - 2005,Southern slope -0.004307134 0.003280871 1820
##  2005,Northern slope - 2012,Southern slope -0.048301950 0.003280871 1820
##  2012,Northern slope - 2005,Southern slope  0.026667087 0.003280871 1820
##  2012,Northern slope - 2012,Southern slope -0.017327728 0.003280871 1820
##  2005,Southern slope - 2012,Southern slope -0.043994816 0.003334396 1820
##  t.ratio p.value
##   -9.600  <.0001
##   -1.313  1.0000
##  -14.722  <.0001
##    8.128  <.0001
##   -5.281  <.0001
##  -13.194  <.0001
##
## P value adjustment: bonferroni method for 6 tests
ps
```



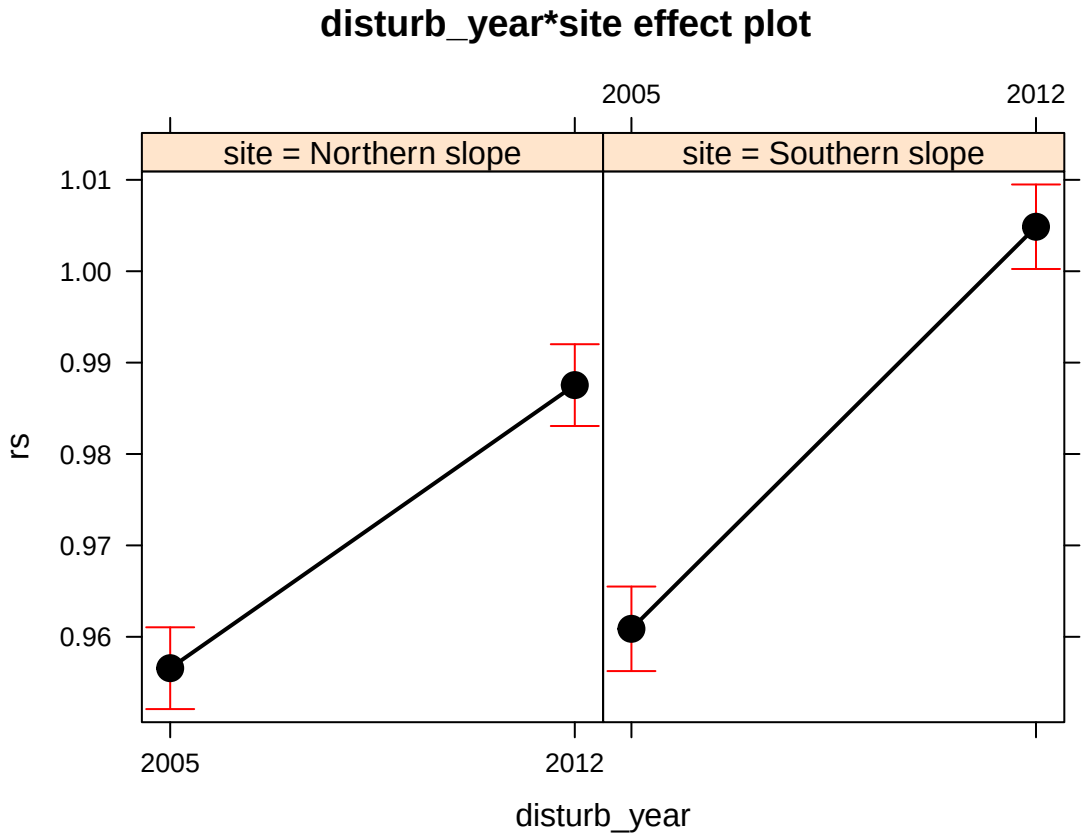

```
pd
```




```
picollapse
```


disturb_year*site effect plot
site
Northern slope
Southern slope
1.01
1.00
0.99
0.98
0.97
0.96
rs
2005
2012
disturb_year

```
pi
```


disturb_year*site effect plot
2005
2012
site = Northern slope
site = Southern slope
1.01
1.00
0.99
0.98
0.97
0.96
rs
2005
2012
disturb_year

Relative Resilience

Table 7: ANOVA table: rrs

term	df	sumsq	meansq	statistic	p.value
disturb_year	1	1.023	1.023	321.9	**0**
site	1	0.3215	0.3215	101.2	**0**
disturb_year:site	1	1.267	1.267	398.7	**0**
Residuals	1820	5.783	0.00318		

	Statistic
R^2	0.31
adjR^2	0.31
σ_e	0.06
F	273.95
p	0.00
df_m	4.00
logLik	2659.30
AIC	-5308.61
BIC	-5281.06
dev	5.78
df_e	1820.00

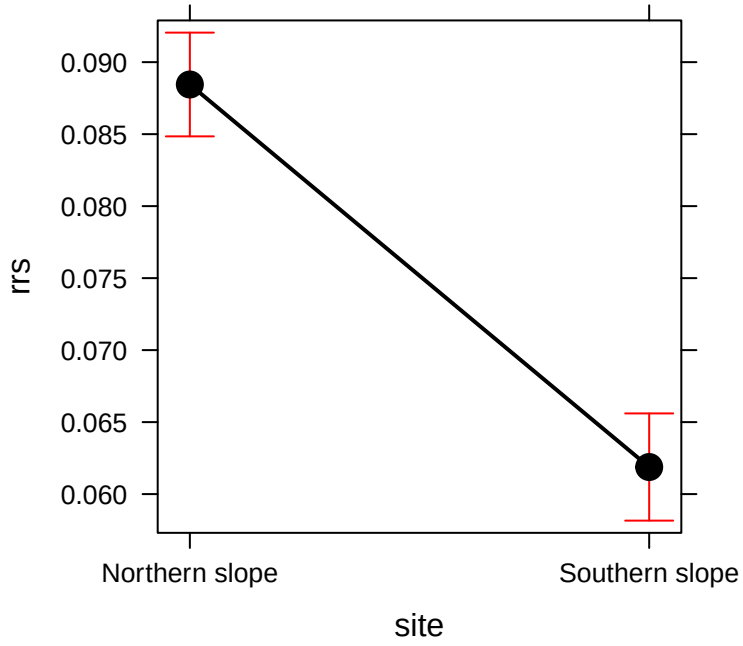
```
# Post hoc Define model
mymodel <- aov_rrs$mymodel
postH_rrs <- phc(mymodel = mymodel, resp_var = resp_var)
```

```
##
## ### Event ###
## $lsmeans
##  disturb_year     lsmean          SE   df   lower.CL  upper.CL
##  2005         0.09797968 0.001867656 1820 0.09431670 0.1016427
##  2012         0.05234863 0.001867656 1820 0.04868565 0.0560116
##
## Results are averaged over the levels of: site
## Confidence level used: 0.95
##
## $contrasts
##  contrast      estimate          SE   df t.ratio p.value
##  2005 - 2012 0.04563105 0.002641264 1820  17.276  <.0001
##
## Results are averaged over the levels of: site
##
##  disturb_year     lsmean          SE   df   lower.CL   upper.CL .group
##  2012         0.05234863 0.001867656 1820 0.04815899 0.05653826  a
##  2005         0.09797968 0.001867656 1820 0.09379004 0.10216931   b
##
## Results are averaged over the levels of: site
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
```

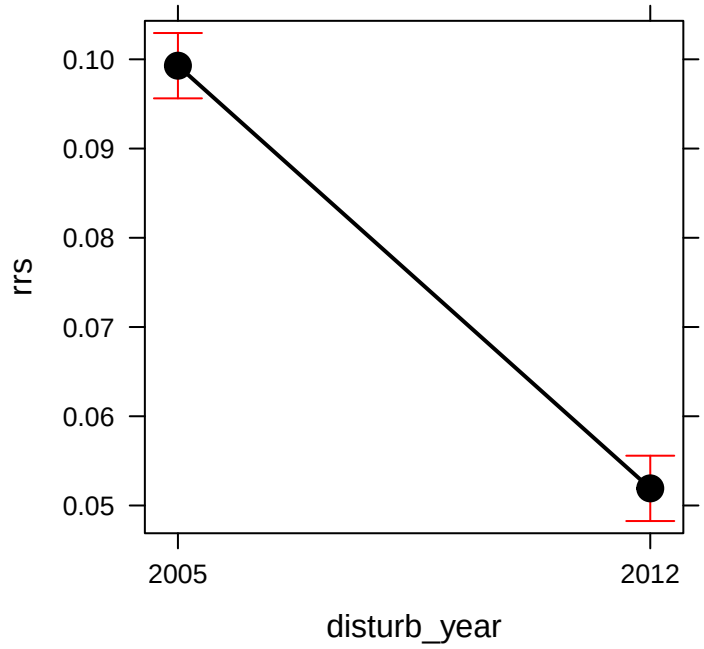
```
## significance level used: alpha = 0.01
##
## ### Clu pop ###
## $lsmeans
##  site               lsmean          SE   df   lower.CL   upper.CL
##  Northern slope 0.08844787 0.001836681 1820 0.08484564 0.09205009
##  Southern slope 0.06188044 0.001898125 1820 0.05815770 0.06560317
##
## Results are averaged over the levels of: disturb_year
## Confidence level used: 0.95
##
## $contrasts
##  contrast                           estimate          SE   df t.ratio
##  Northern slope - Southern slope 0.02656743 0.002641264 1820  10.059
##  p.value
##   <.0001
##
## Results are averaged over the levels of: disturb_year
##
##  site               lsmean          SE   df   lower.CL   upper.CL .group
##  Southern slope 0.06188044 0.001898125 1820 0.05762245 0.06613842  a
##  Northern slope 0.08844787 0.001836681 1820 0.08432772 0.09256802   b
##
## Results are averaged over the levels of: disturb_year
## Confidence level used: 0.95
## Conf-level adjustment: bonferroni method for 2 estimates
## significance level used: alpha = 0.01
##
## ### Event:Clu pop ###
## $lsmeans
##  disturb_year site               lsmean          SE   df  lower.CL
##  2005         Northern slope 0.13763432 0.002597459 1820 0.1325400
##  2012         Northern slope 0.03926142 0.002597459 1820 0.0341671
##  2005         Southern slope 0.05832504 0.002684355 1820 0.0530603
##  2012         Southern slope 0.06543584 0.002684355 1820 0.0601711
##    upper.CL
##  0.14272863
##  0.04435573
##  0.06358978
##  0.07070057
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast                                        estimate          SE   df
##  2005,Northern slope - 2012,Northern slope  0.098372900 0.003673362 1820
##  2005,Northern slope - 2005,Southern slope  0.079309278 0.003735312 1820
##  2005,Northern slope - 2012,Southern slope  0.072198481 0.003735312 1820
##  2012,Northern slope - 2005,Southern slope -0.019063621 0.003735312 1820
##  2012,Northern slope - 2012,Southern slope -0.026174419 0.003735312 1820
##  2005,Southern slope - 2012,Southern slope -0.007110797 0.003796251 1820
##  t.ratio p.value
##   26.780  <.0001
##   21.232  <.0001
```

```
##   19.329  <.0001
##   -5.104  <.0001
##   -7.007  <.0001
##   -1.873  0.3673
##
## P value adjustment: bonferroni method for 6 tests
```

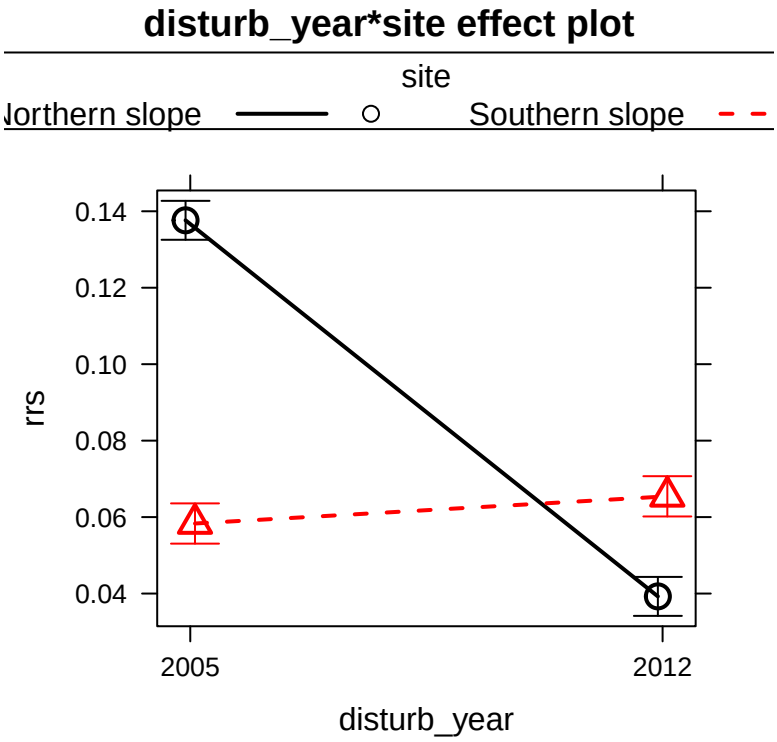
```
ps
```



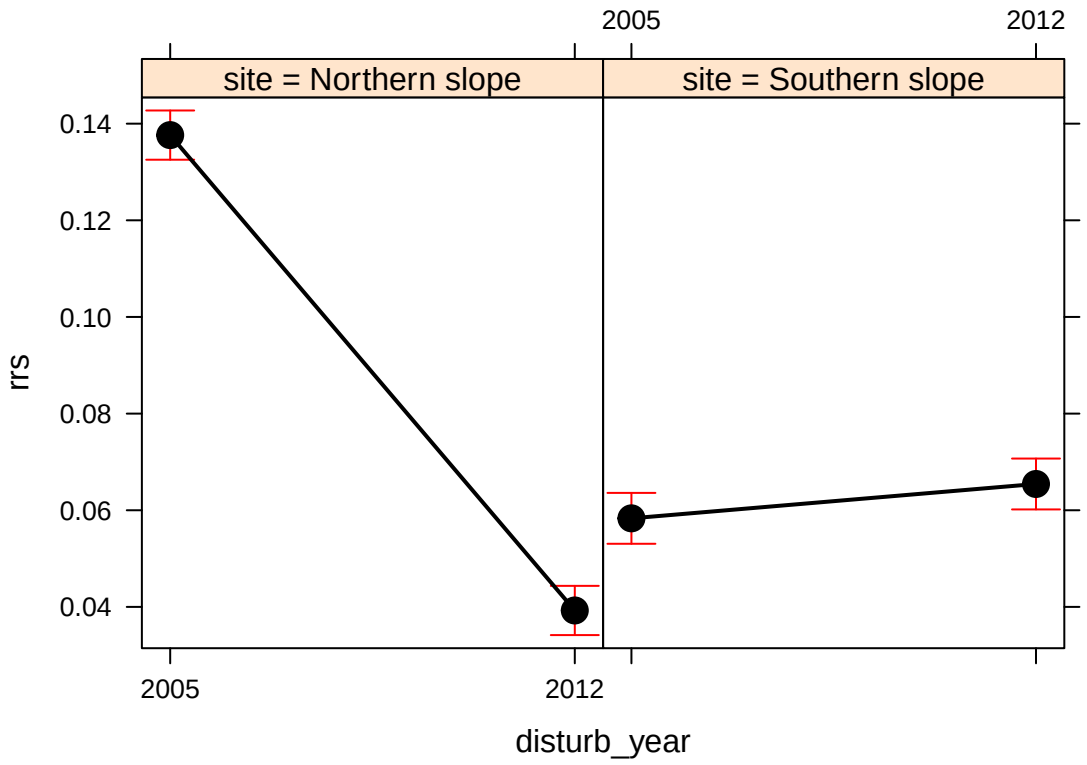

```
pd
```




```
picollapse
```

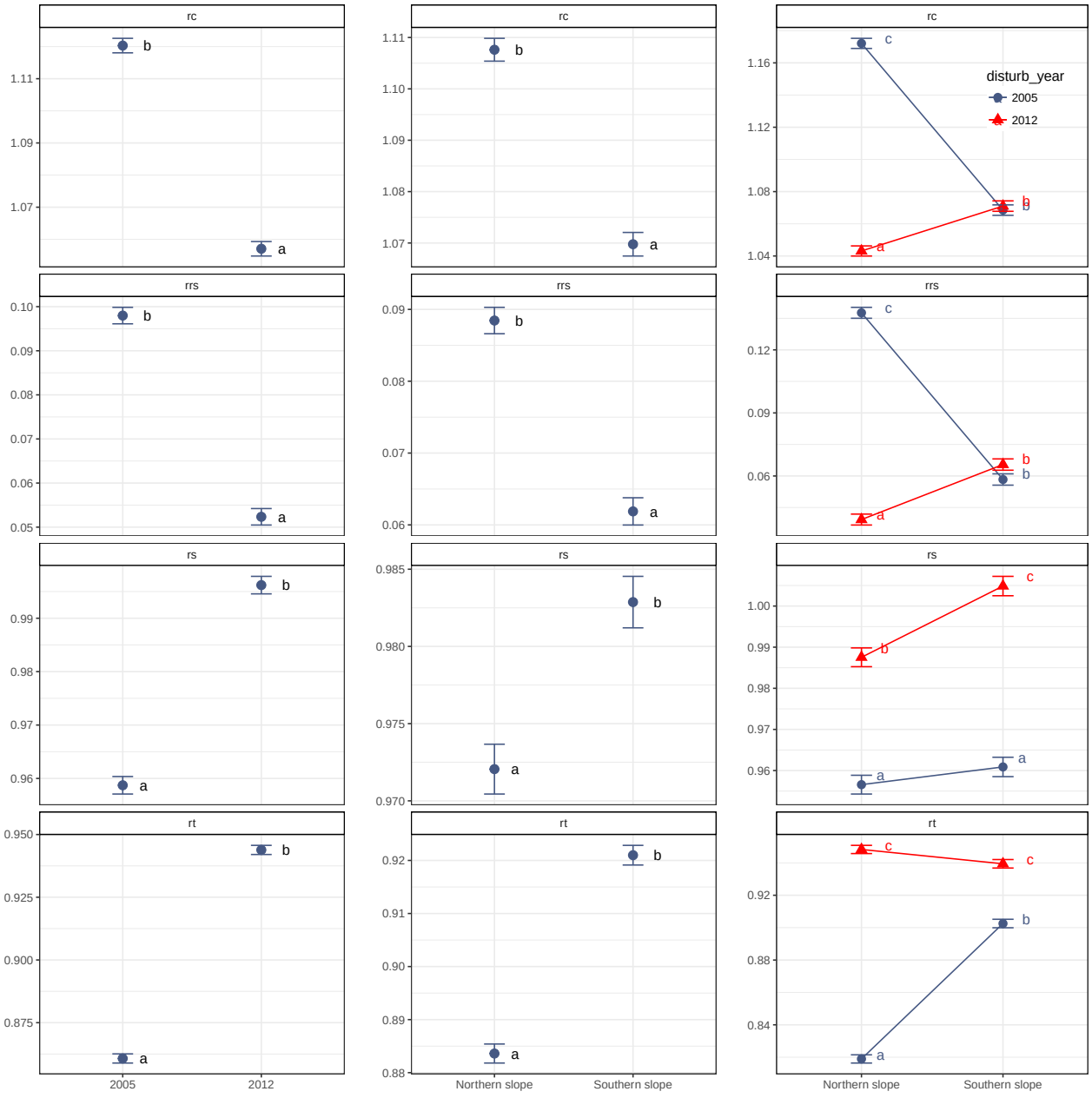



```
pi
```



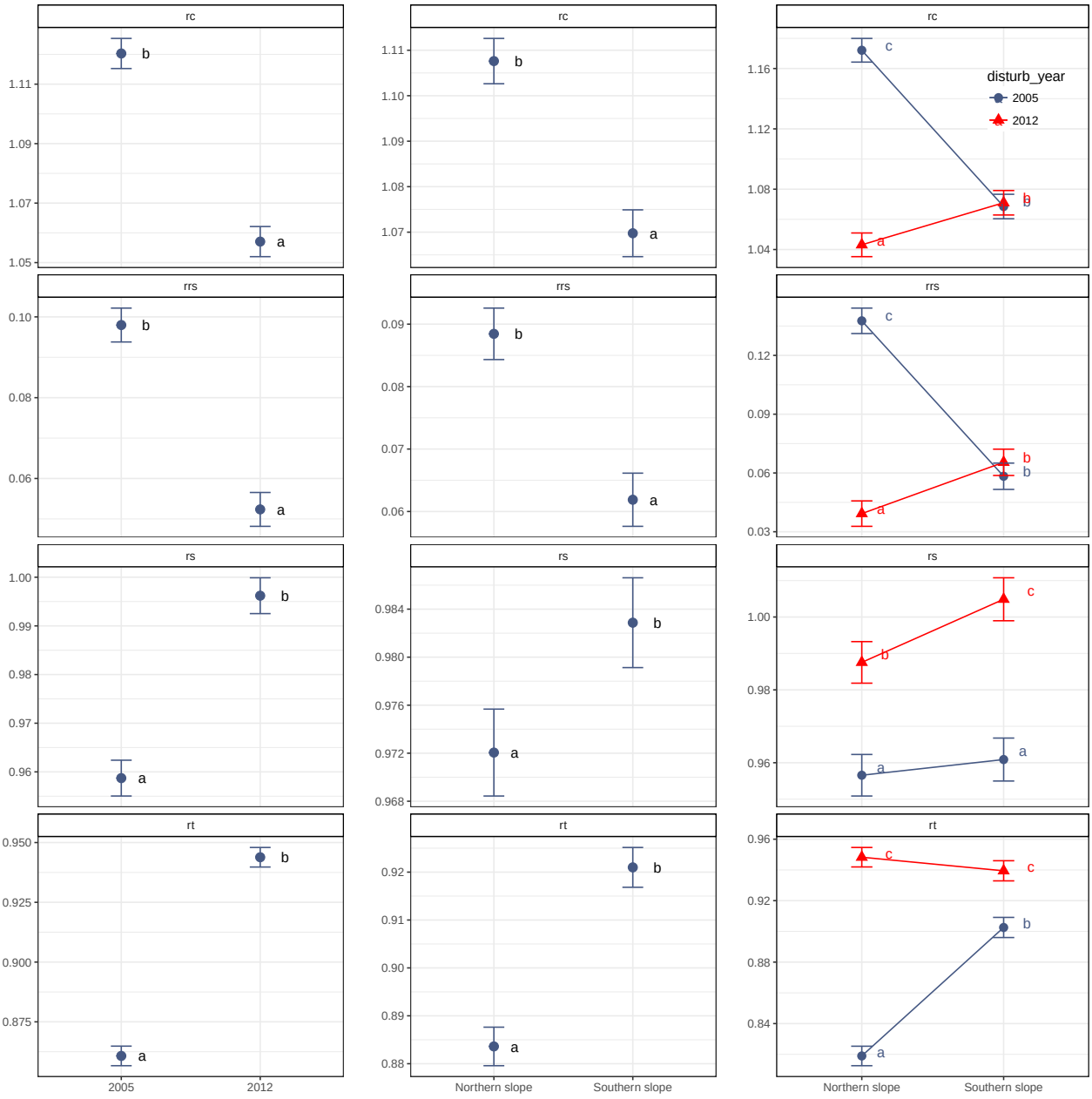
mean + sd

```
grid.arrange(plot_mdSE, plot_msSE, plot_mdsSE, ncol=3)
```



mean + ci

```
grid.arrange(plot_mdCI, plot_msCI, plot_mdsCI, ncol=3)
```




```
## pdf
##   2
```

```
## pdf
##   2
```

term	df	sumsq	meansq	statistic	p.value	var
disturb_year	1	1.951	1.951	420.3	3.368e-84	rc
site	1	0.6528	0.6528	140.6	2.706e-31	rc
disturb_year:site	1	1.969	1.969	424.1	7.127e-85	rc
Residuals	1820	8.45	0.004643	NA	NA	rc
disturb_year	1	3.266	3.266	1079	3.446e-186	rt
site	1	0.6366	0.6366	210.2	3.608e-45	rt
disturb_year:site	1	0.9736	0.9736	321.5	2.446e-66	rt

term	df	sumsq	meansq	statistic	p.value	var
Residuals	1820	5.511	0.003028	NA	NA	rt
disturb_year	1	0.6334	0.6334	258.4	1.817e-54	rs
site	1	0.0533	0.0533	21.74	3.346e-06	rs
disturb_year:site	1	0.01931	0.01931	7.875	0.005066	rs
Residuals	1820	4.462	0.002452	NA	NA	rs
disturb_year	1	1.023	1.023	321.9	2.05e-66	rrs
site	1	0.3215	0.3215	101.2	3.356e-23	rrs
disturb_year:site	1	1.267	1.267	398.7	2.249e-80	rrs
Residuals	1820	5.783	0.003178	NA	NA	rrs

	rc	rt	rs	rrs
R^2	0.3511444	0.4694715	0.1366188	0.3110905
adjR^2	0.3500749	0.4685970	0.1351956	0.3099549
σ_e	0.06813799	0.05502703	0.04951326	0.05637145
F	328.31282	536.84720	95.99708	273.95212
p	2.291209e-170	7.130860e-250	1.111125e-57	1.015581e-146
df_m	4	4	4	4
logLik	2313.524	2703.332	2895.917	2659.304
AIC	-4617.048	-5396.664	-5781.835	-5308.608
BIC	-4589.504	-5369.120	-5754.291	-5281.064
dev	8.449871	5.510913	4.461844	5.783487
df_e	1820	1820	1820	1820
variable	rc	rt	rs	rrs

Asumptions

- Explorar si se cumplen los supuestos de normalidad y homocedasticidad. Tenemos que comprobar que cada uno de los grupos son normales (2005 vs 2012; N vs S; e interactions)

```
shapirosNormal <- function(df, resp_var, factor_vars) {
  out <- df %>%
    group_by_(.dots=factor_vars) %>%
    summarise(statistic = round(shapiro.test(!!resp_var)$statistic,5),
              p_value = round(shapiro.test(!!resp_var)$p.value,5)) %>% data.frame()
  return(out)
}
```

Normalidad

```
### Resilience
nrsA <- shapirosNormal(evires, resp_var = quo(rs), 'disturb_year')
nrsA$var <- 'rs'
nrsB <- shapirosNormal(evires, resp_var = quo(rs), 'site')
nrsB$var <- 'rs'
nrsAB <- shapirosNormal(evires, resp_var = quo(rs), c('disturb_year','site'))
nrsAB$var <- 'rs'
```

```
### Recovery
nrcA <- shapirosNormal(evires, resp_var = quo(rc), 'disturb_year')
nrcA$var <- 'rc'
nrcB <- shapirosNormal(evires, resp_var = quo(rc), 'site')
nrcB$var <- 'rc'
nrcAB <- shapirosNormal(evires, resp_var = quo(rc), c('disturb_year','site'))
nrcAB$var <- 'rc'

### Resistance
nrtA <- shapirosNormal(evires, resp_var = quo(rt), 'disturb_year')
nrtA$var <- 'rt'
nrtB <- shapirosNormal(evires, resp_var = quo(rt), 'site')
nrtB$var <- 'rt'
nrtAB <- shapirosNormal(evires, resp_var = quo(rt), c('disturb_year','site'))
nrtAB$var <- 'rt'


### Relative Resilience
nrrsA <- shapirosNormal(evires, resp_var = quo(rrs), 'disturb_year')
nrrsA$var <- 'rrs'
nrrsB <- shapirosNormal(evires, resp_var = quo(rrs), 'site')
nrrsB$var <- 'rrs'
nrrsAB <- shapirosNormal(evires, resp_var = quo(rrs), c('disturb_year','site'))
nrrsAB$var <- 'rrs'
```

```
normtestA <- rbind(nrcA, nrtA, nrsA, nrrsA)
normtestA %>% pander()
```

disturb_year	statistic	p_value	var
2005	0.9937	0.00069	rc
2012	0.9952	0.00573	rc
2005	0.9962	0.0248	rt
2012	0.9976	0.2164	rt
2005	0.9989	0.8793	rs
2012	0.9938	8e-04	rs
2005	0.9977	0.2435	rrs
2012	0.9916	5e-05	rrs

```
write.csv(normtestA,
          file=paste0(di, '/out/anovas_resilience/normo_disturb_year.csv'), row.names = F)
```

```
normtestB <- rbind(nrcB, nrtB, nrsB, nrrsB)
normtestB %>% pander()
```

site	statistic	p_value	var
Northern slope	0.9768	0	rc
Southern slope	0.9889	0	rc
Northern slope	0.9909	1e-05	rt
Southern slope	0.9981	0.4341	rt
Northern slope	0.9901	1e-05	rs
Southern slope	0.9968	0.0752	rs
Northern slope	0.9942	0.00113	rrs

site	statistic	p_value	var
Southern slope	0.9905	2e-05	rrs

```
write.csv(normtestB,
          file=paste0(di, '/out/anovas_resilience/normo_site.csv'), row.names = F)
```

```
normtestAB <- rbind(nrcAB, nrtAB, nrsAB, nrrsAB)
normtestAB%>% pander()
```

disturb_year	site	statistic	p_value	var
2005	Northern slope	0.9873	0.00041	rc
2005	Southern slope	0.9922	0.02101	rc
2012	Northern slope	0.9907	0.0045	rc
2012	Southern slope	0.9905	0.00597	rc
2005	Northern slope	0.9932	0.03304	rt
2005	Southern slope	0.994	0.07917	rt
2012	Northern slope	0.9959	0.2602	rt
2012	Southern slope	0.9964	0.4178	rt
2005	Northern slope	0.9949	0.1252	rs
2005	Southern slope	0.9959	0.3181	rs
2012	Northern slope	0.9832	3e-05	rs
2012	Southern slope	0.9916	0.01349	rs
2005	Northern slope	0.994	0.05822	rrs
2005	Southern slope	0.9962	0.3659	rrs
2012	Northern slope	0.9961	0.3059	rrs
2012	Southern slope	0.9843	0.00011	rrs

```
write.csv(normtestAB,
          file=paste0(di, '/out/anovas_resilience/normo_disturb_year_site.csv'), row.names = F)
```

```
# rm(nrcA, nrcB, nrcAB,
#    nrsA, nrsB, nrsAB,
#    nrrsA, nrrsB, nrrsAB,
#    nrtA, nrtB, nrtAB)
```

- No se cumplen los requisitos de normalidad

Heterocedasticidad

```
homogetest <- function(resp_var, factores, df){
  require(car)

  out_factores <- c()

  for (f in factores){
    hv <- c()
    myformula <- as.formula(paste0(resp_var, "~", f))
    #tests
    fk <- fligner.test(myformula, data = df)
    lv <- leveneTest(myformula, data = df)
```

```
    # out
    hv$fk_stat <- round(fk$statistic,3)
    hv$fk_pvalue <- round(fk$p.value,7)
    hv$lev_stat <- round(lv$`F value`[1],3)
    hv$lev_pvalue <- round(lv$`Pr(>F)`[1],7)
    hv$factor <- f
    hv <- as.data.frame(hv)
    row.names(hv) <- NULL

    out_factores <- rbind(out_factores, hv)}
  return(out_factores)

}
```

```
factores <- c('disturb_year', 'site', 'interaction(disturb_year, site)')
responses <- c('rs', 'rc', 'rt', 'rrs')
homo <- c()


for (i in responses){
  ht <- homogetest(resp_var = i, factores = factores, df = evires)
  ht <- ht %>% mutate(response = i)
  homo <- rbind(homo, ht)
}

homo %>% pander()
```

fk_stat	fk_pvalue	lev_stat	lev_pvalue	factor	response
2.525	0.1121	2.648	0.1039	disturb_year	rs
3.839	0.05008	3.789	0.05174	site	rs
17.51	0.0005562	5.914	0.0005166	interaction(disturb_year, site)	rs
211.9	0	246.3	0	disturb_year	rc
141.3	0	150.6	0	site	rc
190.7	0	70.07	0	interaction(disturb_year, site)	rc
63.89	0	66.3	0	disturb_year	rt
125.1	0	131.9	0	site	rt
12.28	0.006492	4.056	0.006951	interaction(disturb_year, site)	rt
130.1	0	146.9	0	disturb_year	rrs
99.8	0	105.6	0	site	rrs
140.8	0	50.69	0	interaction(disturb_year, site)	rrs

```
write.csv(homo,
          file=paste0(di, '/out/anovas_resilience/homocedasticidad.csv'), row.names = F)
```

- Tampoco se cumplen los requisitos de homogeneidad de varianzas entre grupos

Transformación datos

Log

- Probamos a transformar los datos con log y reanalizar los supuestos de homocedasticidad

```
factores <- c('disturb_year', 'site', 'interaction(disturb_year, site)')
responses <- c('logrs', 'logrc', 'logrt', 'logrrs')
homo_log <- c()

evires <- evires %>%
  mutate(
    logrs = log(rs),
    logrc = log(rc),
    logrt = log(rc),
    logrrs = log(rrs)
)

for (i in responses){
  ht <- homogetest(resp_var = i, factores = factores, df = evires)
  ht <- ht %>% mutate(response = i)
  homo_log <- rbind(homo_log, ht)
}

homo_log %>% pander()
```

fk_stat	fk_pvalue	lev_stat	lev_pvalue	factor	response
0.286	0.5927	0.249	0.6176	disturb_year	logrs
4.653	0.031	4.631	0.03153	site	logrs
18.81	0.0002987	6.272	0.0003116	interaction(disturb_year, site)	logrs
181.4	0	208.7	0	disturb_year	logrc
127.8	0	136.2	0	site	logrc
165.2	0	60.48	0	interaction(disturb_year, site)	logrc
181.4	0	208.7	0	disturb_year	logrt
127.8	0	136.2	0	site	logrt
165.2	0	60.48	0	interaction(disturb_year, site)	logrt
2.26	0.1328	2.944	0.0864	disturb_year	logrrs
19.95	8e-06	16.68	4.64e-05	site	logrrs
116.2	0	32.45	0	interaction(disturb_year, site)	logrrs

```
write.csv(homo_log,
          file=paste0(di, '/out/anovas_resilience/homocedasticidad_log.csv'), row.names = F)
```

- Tampoco se cumplen

Log + 1

```
factores <- c('disturb_year', 'site', 'interaction(disturb_year, site)')
responses <- c('log1rs', 'log1rc', 'log1rt', 'log1rrs')
homo_log1 <- c()

evires <- evires %>%
  mutate(
    log1rs = log(rs + 1),
    log1rc = log(rc + 1),
    log1rt = log(rc + 1),
    log1rrs = log(rrs +1 )
)

for (i in responses){
  ht <- homogetest(resp_var = i, factores = factores, df = evires)
  ht <- ht %>% mutate(response = i)
  homo_log1 <- rbind(homo_log1, ht)
}

homo_log1 %>% pander()
```

fk_stat	fk_pvalue	lev_stat	lev_pvalue	factor	response
1.128	0.2883	1.152	0.2833	disturb_year	log1rs
4.259	0.03905	4.202	0.04052	site	log1rs
17.94	0.0004531	6.002	0.0004567	interaction(disturb_year, site)	log1rs
196.2	0	227.4	0	disturb_year	log1rc
134.3	0	143.7	0	site	log1rc
176.4	0	64.66	0	interaction(disturb_year, site)	log1rc
196.2	0	227.4	0	disturb_year	log1rt
134.3	0	143.7	0	site	log1rt
176.4	0	64.66	0	interaction(disturb_year, site)	log1rt
107.1	0	119.2	0	disturb_year	log1rrs
86.45	0	91.37	0	site	log1rrs
136.2	0	49.05	0	interaction(disturb_year, site)	log1rrs

```
write.csv(homo_log,
          file=paste0(di, '/out/anovas_resilience/homocedasticidad_log_plus_1.csv'), row.names = F)
```

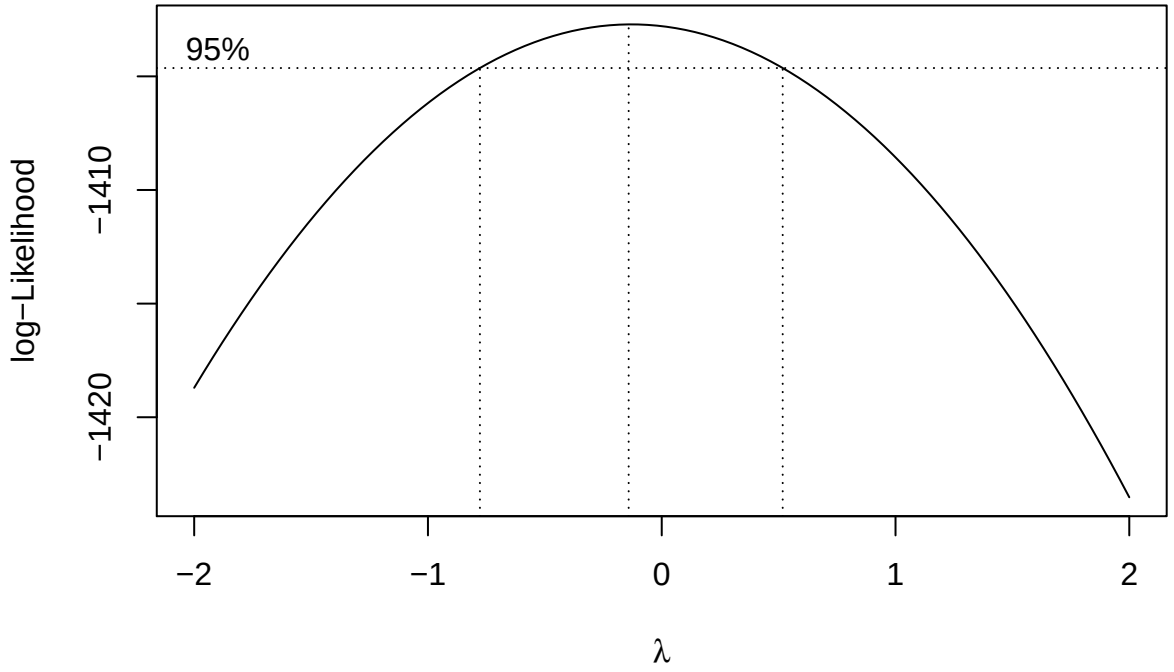
- Tampoco se cumplen

Buscar mejor transformación de Box-Cox

- Buscamos el mejor lambda para cada variable para estudiar posibles transformaciones

Lambda Resilience

```
m  <- lm(rs ~ disturb_year*site, evires)
b <- boxcox(m)
```

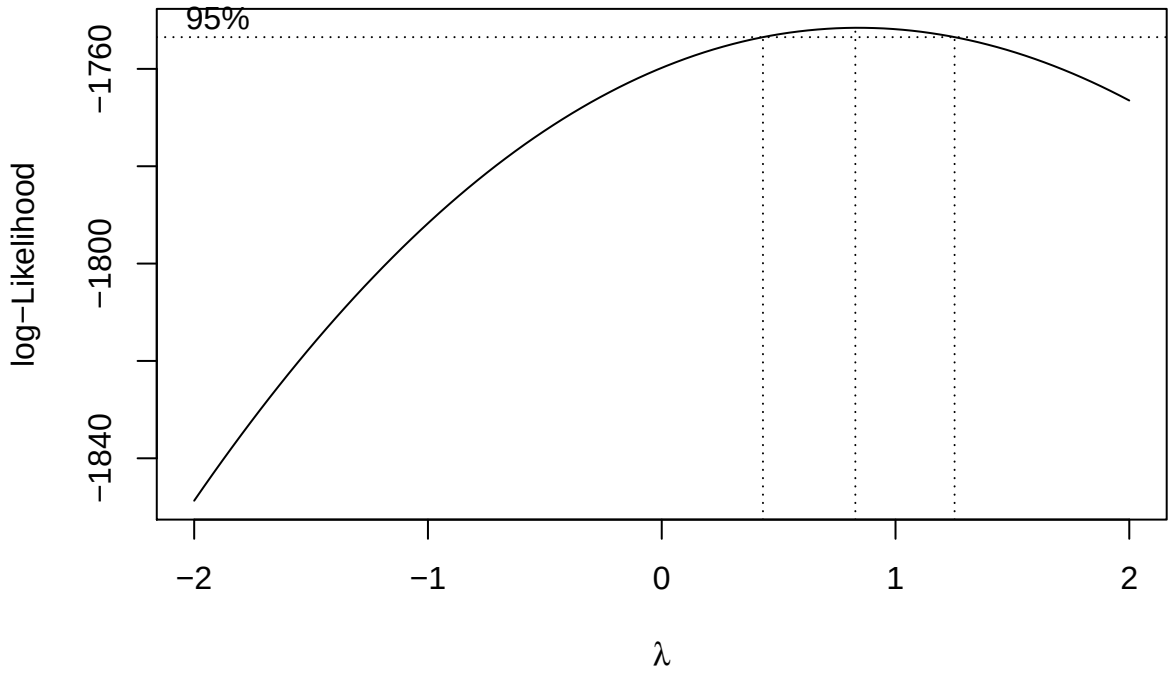



```
b$x[which.max(b$y)]
```

```
## [1] -0.1414141
```

Lambda Resistance

```
m  <- lm(rt ~ disturb_year*site, evires)
b <- boxcox(m)
```

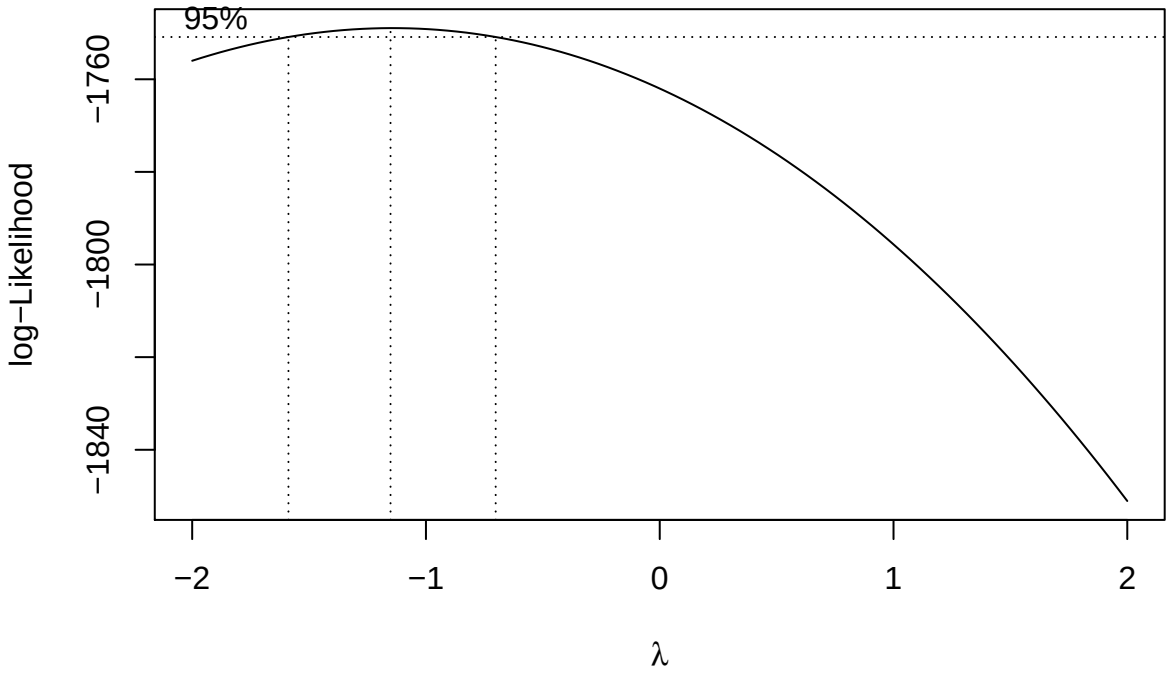


```
b$x[which.max(b$y)]
```

```
## [1] 0.8282828
```

Lambda Recovery

```
m  <- lm(rc ~ disturb_year*site, evires)
b <- boxcox(m)
```




```
b$x[which.max(b$y)]
```

```
## [1] -1.151515
```

Lambda Relative Resilience

```
m  <- lm(rrs ~ disturb_year*site, evires)
b <- boxcox(m)
b$x[which.max(b$y)]
```

Obtengo diferentes lambdas, lo cual complica las transformaciones. Por lo que opto por ROBUST ANOVA

ROBUST ANOVA

- Ver Wilcox (2005, 2012)
- Vamos a realizar un Robust factorial ANOVA. En concreto:
- Two-way robust factorial ANOVA on M-estimator
- pkg WRS2

Recovery

```
robustANOVA <- function(df, resp_var, factores,
         alpha, nboot, treshold) {
  # alpha: alpha ci for huber m-estimation
  # nboot: numer of iterations
  # treshoold for letter (posthoc)
  # See http://rcompanion.org/rcompanion/d_08a.html


  # Create interaction
  df$interaction <- interaction(df$disturb_year, df$site)

  # Formulas
  formulaFull <- as.formula(paste0(resp_var,  " ~ ",
                                   paste(factores, collapse = '+')))

  formula_A <- as.formula(paste0(resp_var,  " ~ ", factores[1]))
  formula_B <- as.formula(paste0(resp_var,  " ~ ", factores[2]))
  formula_AB <- as.formula(paste0(resp_var,  " ~ interaction"))


  # Produce Huber M-estimators and confidence intervals by group
  mest <- groupwiseHuber(formulaFull, data = df, ci.type = 'wald', conf.level = alpha)

  # Two-way robust analysis
  x <- pbad2way(formulaFull, data = df, est = "mom", nboot = nboot)

  out_ra <- data.frame(
    term = c(x$varnames[2],
             x$varnames[3],
             paste0(x$varnames[2], ':', x$varnames[3])),
    p_value = c(x$A.p.value, x$B.p.value, x$AB.p.value))

  # post-hoc
  ## factor A
  pha <- pairwiseRobustTest(formula_A, data = df, est = "mom",
                            nboot = nboot, method="bonferroni")
  ## factor B
  phb <- pairwiseRobustTest(formula_B, data = df, est = "mom",
                            nboot = nboot, method="bonferroni")
  ## interaction effect (AB)
  phab <- pairwiseRobustTest(formula_AB, data = df, est = "mom",
                            nboot = nboot, method="bonferroni")
  ## letters
  letters_ph <- rbind(
    cldList(comparison = pha$Comparison,
        p.value    = pha$p.adjust,
        threshold  = treshold),
    cldList(comparison = phb$Comparison,
        p.value    = phb$p.adjust,
        threshold  = treshold),
    cldList(comparison = phab$Comparison,
```

```
        p.value    = phab$p.adjust,
        threshold  = treshold))

  ph <- rbind(pha, phb, phab)

  phRWS2 <- mcp2a(formulaFull, data=df, est = "mom", nboot = nboot)

  out <- list()
  out$mest <- mest # Huber M-estimators and Confidence Intervals
  out$ra <- out_ra # Output for Two-way robust analysis (M-estimators)
  out$letters_ph <- letters_ph # Letters comparison posthoc
  out$ph <- ph # posthoc comparison usinng pairwiseRobustTest

  print(out_ra)
  print(phRWS2)
  return(out)
}
```

```
factores = c('disturb_year', 'site', 'disturb_year:site')
```

```
rars <- robustANOVA(df=evires, resp_var='rs', factores=factores,
              alpha = 0.95, nboot = 3000, treshold = 0.01)
```

```
## [1] "comparison 1 ..."
##
##
## [1] "comparison 1 ..."
##
##
## [1] "comparison 1 ..."
## [1] "comparison 2 ..."
## [1] "comparison 3 ..."
## [1] "comparison 4 ..."
## [1] "comparison 5 ..."
## [1] "comparison 6 ..."
##
##
##                term    p_value
## 1      disturb_year 0.00000000
## 2              site 0.00000000
## 3 disturb_year:site 0.04133333
## Call:
## mcp2a(formula = formulaFull, data = df, est = "mom", nboot = nboot)
##
##                       psihat ci.lower ci.upper p-value
## disturb_year1       -0.07125 -0.07928 -0.06284   0.000
## site1               -0.02635 -0.03517 -0.01822   0.000
## disturb_year1:site1  0.01036  0.00259  0.01971   0.015
```

```
rarc <- robustANOVA(df=evires, resp_var='rc', factores=factores,
              alpha = 0.95, nboot = 3000, treshold = 0.01)
```

```
## [1] "comparison 1 ..."
##
##
```

```
## [1] "comparison 1 ..."
##
##
## [1] "comparison 1 ..."
## [1] "comparison 2 ..."
## [1] "comparison 3 ..."
## [1] "comparison 4 ..."
## [1] "comparison 5 ..."
## [1] "comparison 6 ..."
##
##
##                term p_value
## 1      disturb_year       0
## 2              site       0
## 3 disturb_year:site       0
## Call:
## mcp2a(formula = formulaFull, data = df, est = "mom", nboot = nboot)
##
##                       psihat ci.lower ci.upper p-value
## disturb_year1       0.12129  0.11064  0.13384       0
## site1               0.07067  0.05845  0.08131       0
## disturb_year1:site1 0.13400  0.12236  0.14523       0
```

```
rart <- robustANOVA(df=evires, resp_var='rt', factores=factores,
             alpha = 0.95, nboot = 3000, treshold = 0.01)
```

```
## [1] "comparison 1 ..."
##
##
## [1] "comparison 1 ..."
##
##
## [1] "comparison 1 ..."
## [1] "comparison 2 ..."
## [1] "comparison 3 ..."
## [1] "comparison 4 ..."
## [1] "comparison 5 ..."
## [1] "comparison 6 ..."
##
##
##                term p_value
## 1      disturb_year       0
## 2              site       0
## 3 disturb_year:site       0
## Call:
## mcp2a(formula = formulaFull, data = df, est = "mom", nboot = nboot)
##
##                        psihat ci.lower ci.upper p-value
## disturb_year1       -0.16567 -0.17501 -0.15623       0
## site1               -0.07410 -0.08298 -0.06423       0
## disturb_year1:site1 -0.09022 -0.09976 -0.08079       0
```

```
rarrs <- robustANOVA(df=evires, resp_var='rrs', factores=factores,
             alpha = 0.95, nboot = 3000, treshold = 0.01)
```

```
## [1] "comparison 1 ..."
##
##
## [1] "comparison 1 ..."
##
##
## [1] "comparison 1 ..."
## [1] "comparison 2 ..."
## [1] "comparison 3 ..."
## [1] "comparison 4 ..."
## [1] "comparison 5 ..."
## [1] "comparison 6 ..."
##
##
##                term p_value
## 1      disturb_year       0
## 2              site       0
## 3 disturb_year:site       0
## Call:
## mcp2a(formula = formulaFull, data = df, est = "mom", nboot = nboot)
##
##                       psihat ci.lower ci.upper p-value
## disturb_year1        0.09017  0.08010  0.09900       0
## site1                0.04760  0.03810  0.05718       0
## disturb_year1:site1 0.10647  0.09695  0.11605       0
```

Estimadores de huber

```
rars$mest$var <- 'rs'
rarc$mest$var <- 'rc'
rart$mest$var <- 'rt'
rarrs$mest$var <- 'rrs'

mhuber <- rbind(rarc$mest, rart$mest, rars$mest, rarrs$mest)
mhuber %>% pander()
```

disturb_year	site	n	M.Huber	lower.ci	upper.ci	var
2005	Northern slope	471	1.169	1.161	1.177	rc
2005	Southern slope	441	1.066	1.058	1.074	rc
2012	Northern slope	471	1.042	1.036	1.047	rc
2012	Southern slope	441	1.071	1.067	1.075	rc
2005	Northern slope	471	0.819	0.8137	0.8243	rt
2005	Southern slope	441	0.9016	0.8958	0.9074	rt
2012	Northern slope	471	0.9472	0.9423	0.9521	rt
2012	Southern slope	441	0.9387	0.9336	0.9438	rt
2005	Northern slope	471	0.9553	0.9507	0.9599	rs
2005	Southern slope	441	0.9618	0.9573	0.9663	rs
2012	Northern slope	471	0.9855	0.9805	0.9905	rs
2012	Southern slope	441	1.004	0.9996	1.008	rs
2005	Northern slope	471	0.1362	0.1304	0.142	rrs
2005	Southern slope	441	0.05819	0.05141	0.06498	rrs
2012	Northern slope	471	0.03883	0.03396	0.0437	rrs

disturb_year	site	n	M.Huber	lower.ci	upper.ci	var
2012	Southern slope	441	0.06618	0.06291	0.06946	rrs

Pairwise comparison

```
rars$ph$var <- 'rs'
rarc$ph$var <- 'rc'
rart$ph$var <- 'rt'
rarrs$ph$var <- 'rrs'

pairwise <- rbind(rarc$ph, rart$ph, rars$ph, rarrs$ph)
pairwise %>% pander()
```

Comparison	Statistic	p.value	p.adjust	var
2005 - 2012 = 0	0.05994	0	0	rc
Northern slope - Southern slope = 0	0.03308	0	0	rc
2005.Northern slope - 2012.Northern slope = 0	0.1276	0	0	rc
2005.Northern slope - 2005.Southern slope = 0	0.1023	0	0	rc
2005.Northern slope - 2012.Southern slope = 0	0.09598	0	0	rc
2012.Northern slope - 2005.Southern slope = 0	-0.02531	0	0	rc
2012.Northern slope - 2012.Southern slope = 0	-0.03167	0	0	rc
2005.Southern slope - 2012.Southern slope = 0	-0.006357	0.21	1	rc
2005 - 2012 = 0	-0.0853	0	0	rt
Northern slope - Southern slope = 0	-0.03784	0	0	rt
2005.Northern slope - 2012.Northern slope = 0	-0.1279	0	0	rt
2005.Northern slope - 2005.Southern slope = 0	-0.08216	0	0	rt
2005.Northern slope - 2012.Southern slope = 0	-0.1199	0	0	rt
2012.Northern slope - 2005.Southern slope = 0	0.04579	0	0	rt
2012.Northern slope - 2012.Southern slope = 0	0.008059	0.02533	0.152	rt
2005.Southern slope - 2012.Southern slope = 0	-0.03773	0	0	rt
2005 - 2012 = 0	-0.03583	0	0	rs
Northern slope - Southern slope = 0	-0.01344	0	0	rs
2005.Northern slope - 2012.Northern slope = 0	-0.03045	0	0	rs
2005.Northern slope - 2005.Southern slope = 0	-0.007997	0.02867	0.172	rs

Comparison	Statistic	p.value	p.adjust	var
2005.Northern slope - 2012.Southern slope = 0	-0.0488	0	0	rs
2012.Northern slope - 2005.Southern slope = 0	0.02245	0	0	rs
2012.Northern slope - 2012.Southern slope = 0	-0.01835	0	0	rs
2005.Southern slope - 2012.Southern slope = 0	-0.0408	0	0	rs
2005 - 2012 = 0	0.04601	0	0	rrs
Northern slope - Southern slope = 0	0.02191	0	0	rrs
2005.Northern slope - 2012.Northern slope = 0	0.09832	0	0	rrs
2005.Northern slope - 2005.Southern slope = 0	0.07703	0	0	rrs
2005.Northern slope - 2012.Southern slope = 0	0.06889	0	0	rrs
2012.Northern slope - 2005.Southern slope = 0	-0.02129	0	0	rrs
2012.Northern slope - 2012.Southern slope = 0	-0.02943	0	0	rrs
2005.Southern slope - 2012.Southern slope = 0	-0.008148	0.046	0.276	rrs

Interaction plot

Response ~ (x=Drought)

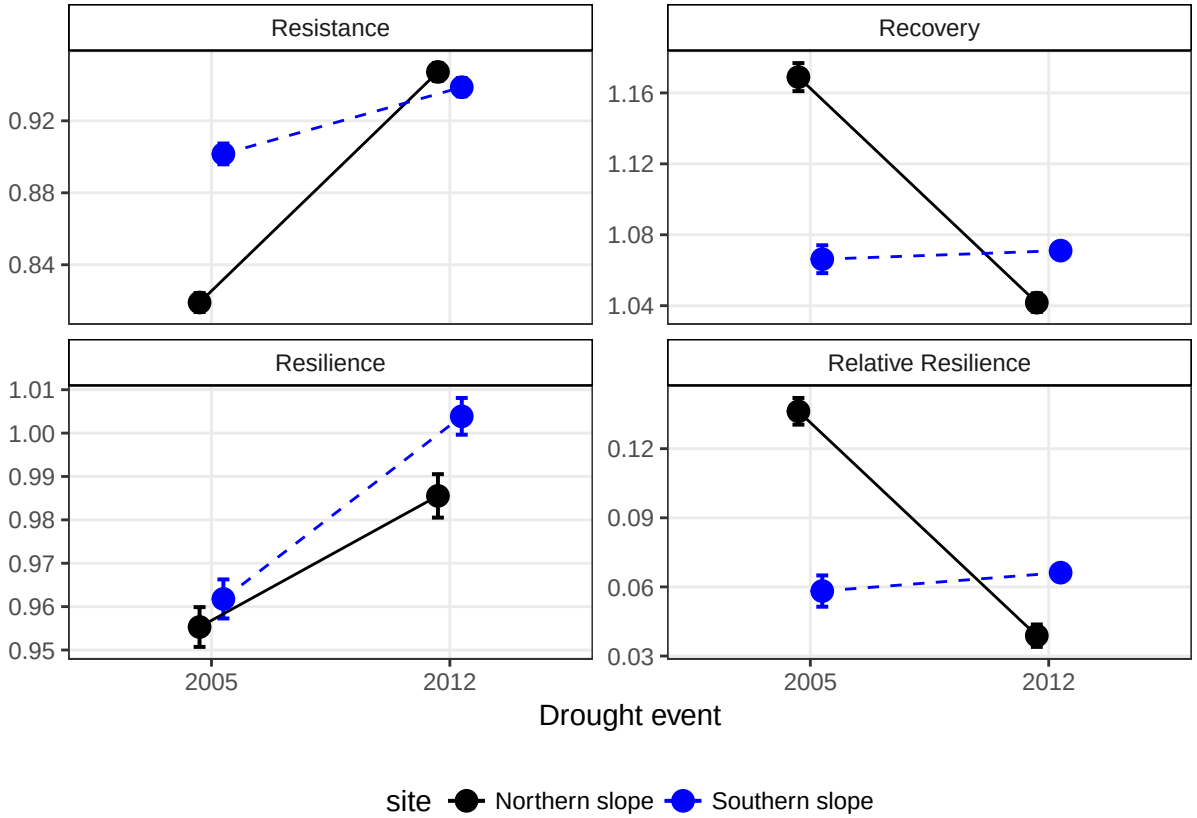
```
mhuber<- mhuber %>%
  mutate(var_sorted = case_when(var == "rc" ~ "1_rc",
                                var == "rt" ~ "0_rt",
                                var == "rs" ~ "2_rs",
                                var == "rrs" ~ "3_rrs"))

pd <- position_dodge(.2)

robust_plot_evi_drought <- ggplot(mhuber, aes(x=disturb_year, y=M.Huber, color = site, group=site, fill=
  geom_errorbar(aes(ymin=lower.ci, ymax=upper.ci),
                width=.1, size=0.7, position=pd) +
  geom_line(aes(group=site,color=site, linetype=site), position=pd) +
  geom_point(shape=21, size=3.5, position=pd) +
  facet_wrap(~var_sorted, nrow = 2, scales = 'free_y',
             labeller=as_labeller(c('0_rt' = 'Resistance',
                                    '1_rc' = 'Recovery',
                                    '2_rs' = 'Resilience',
                                    '3_rrs' = 'Relative Resilience'))) +
  scale_color_manual(values=c('black','blue')) +
  scale_fill_manual(values=c('black','blue')) + theme_bw() +
  scale_linetype_manual(values=c("solid", "dashed")) +
  theme(panel.grid.minor = element_blank(),
```

```
        strip.background = element_rect(colour='black',
                                        fill='white'),
        legend.position="bottom") +
  ylab('') + xlab('Drought event')

robust_plot_evi_drought
```




```
pdf(paste0(di, '/images/resilience/robust_plot_evi_drought.pdf'), width=9, height = 9)
robust_plot_evi_drought
dev.off()
```

```
## pdf
##   2
```

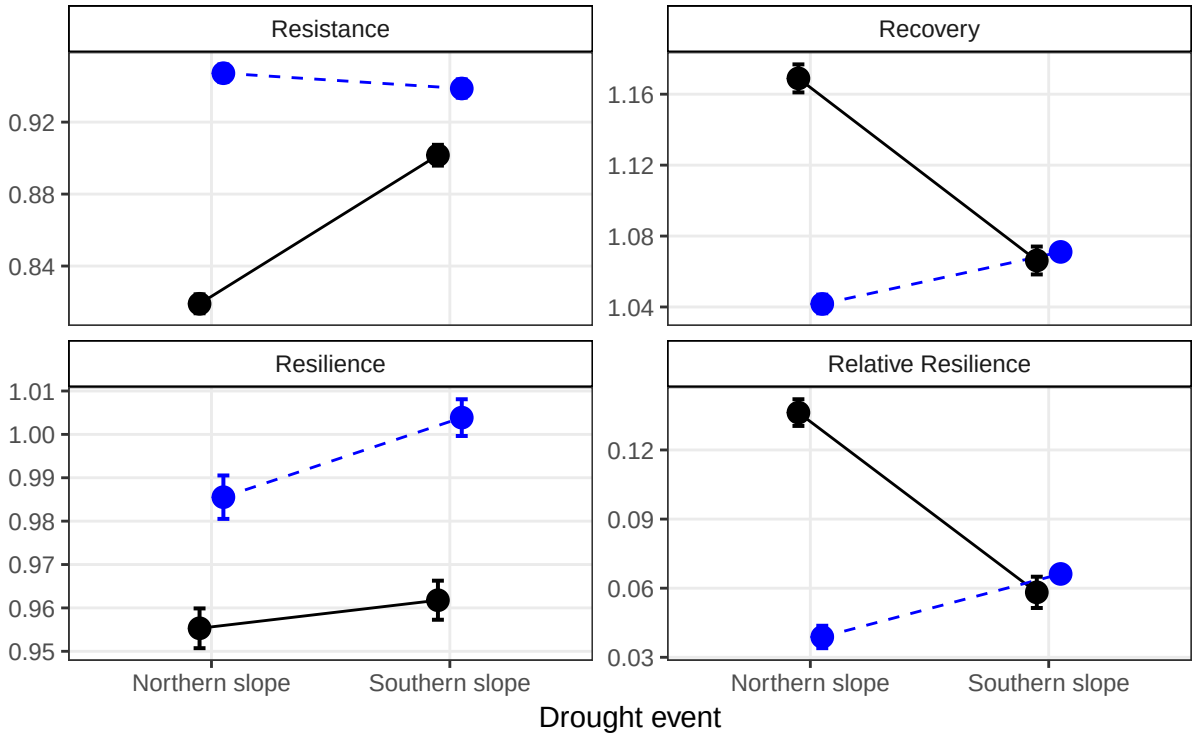
Response ~ (x=site)

```
pd <- position_dodge(.2)

robust_plot_evi_site <- ggplot(mhuber, aes(x=site, y=M.Huber, color = disturb_year, group=disturb_year,
  geom_errorbar(aes(ymin=lower.ci, ymax=upper.ci),
                width=.1, size=0.7, position=pd) +
  geom_line(aes(group=disturb_year,color=disturb_year, linetype=disturb_year), position=pd) +
  geom_point(shape=21, size=3.5, position=pd) +
  facet_wrap(~var_sorted, nrow = 2, scales = 'free_y',
             labeller=as_labeller(c('0_rt' = 'Resistance',
                                    '1_rc' = 'Recovery',
                                    '2_rs' = 'Resilience',
```

```
                                  '3_rrs' = 'Relative Resilience'))) +
  scale_color_manual(values=c('black','blue')) +
  scale_fill_manual(values=c('black','blue')) + theme_bw() +
  scale_linetype_manual(values=c("solid", "dashed")) +
  theme(panel.grid.minor = element_blank(),
        strip.background = element_rect(colour='black',
                                        fill='white'),
        legend.position="bottom") +
  ylab('') + xlab('Drought event')


robust_plot_evi_site
```




```
pdf(paste0(di, '/images/resilience/robust_plot_evi_site.pdf'), width=9, height = 9)
robust_plot_evi_site
dev.off()
```

```
## pdf
##   2
```

```
# Export data
write.csv(mhuber, file=paste0(di, '/out/anovas_resilience/robust_mhuber.csv'), row.names = F)
write.csv(pairwise, file=paste0(di, '/out/anovas_resilience/robust_pairwise.csv'), row.names = F)
```