Explore CBI

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```
library(ggplot2)
library(rlang)
```

```
## Warning: package 'rlang' was built under R version 3.4.3
```

```
library(sf)
```

```
## Linking to GEOS 3.6.2, GDAL 2.2.3, proj.4 4.9.3
```

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(mgcv)
```

```
## Loading required package: nlme
```

```
##
## Attaching package: 'nlme'
```

```
## The following object is masked from 'package:dplyr':
##
##     collapse
```

```
## This is mgcv 1.8-20. For overview type 'help("mgcv-package")'.
```

```
library(purrr)
```

```
##
## Attaching package: 'purrr'
```

```
## The following objects are masked from 'package:rlang':
##
##     %@%, %||%, as_function, flatten, flatten_chr, flatten_dbl,
##     flatten_int, flatten_lgl, invoke, list_along, modify, prepend,
##     rep_along, splice
```

```
library(broom)
library(modelr)
```

```
##
## Attaching package: 'modelr'
```

```
## The following object is masked from 'package:broom':
##
##     bootstrap
```

```r
library(tidyr)
library(lazyeval)
```

```
##
## Attaching package: 'lazyeval'
```

```
## The following objects are masked from 'package:purrr':
##
##     is_atomic, is_formula
```

```
## The following objects are masked from 'package:rlang':
##
##     expr_label, expr_text, f_env, f_env<-, f_label, f_lhs,
##     f_lhs<-, f_rhs, f_rhs<-, f_text, is_atomic, is_formula,
##     is_lang, is_pairlist, missing_arg
```

```r
library(lme4)
```

```
## Loading required package: Matrix
```

```
##
## Attaching package: 'Matrix'
```

```
## The following object is masked from 'package:tidyr':
##
##     expand
```

```
##
## Attaching package: 'lme4'
```

```
## The following object is masked from 'package:nlme':
##
##     lmList
```

```r
###
### Bilinear interpolation
###

# Get 16-day window, bilinear interpolation data
cbi_16_bilinear <- st_read("../data/cbi_calibration/cbi-calibration_16-day-window_L57_bilinear-interp.g
```

```
## Reading layer `cbi-calibration_16-day-window_L57_bilinear-interp' from data source `/Users/mikoontz/
## Simple feature collection with 401 features and 67 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: -119.7917 ymin: 35.55484 xmax: -117.9751 ymax: 37.88774
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```r
# Get 32-day window, bilinear interpolation data
cbi_32_bilinear <- st_read("../data/cbi_calibration/cbi-calibration_32-day-window_L57_bilinear-interp.g
```

```
## Reading layer `cbi-calibration_32-day-window_L57_bilinear-interp' from data source `/Users/mikoontz/
## Simple feature collection with 401 features and 67 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: -119.7917 ymin: 35.55484 xmax: -117.9751 ymax: 37.88774
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```r
# Get 48-day window, bilinear interpolation data
cbi_48_bilinear <- st_read("../data/cbi_calibration/cbi-calibration_48-day-window_L57_bilinear-interp.g
```

```
## Reading layer `cbi-calibration_48-day-window_L57_bilinear-interp' from data source `/Users/mikoontz/
## Simple feature collection with 401 features and 67 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: -119.7917 ymin: 35.55484 xmax: -117.9751 ymax: 37.88774
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```r
# Get 64-day window, bilinear interpolation data
cbi_64_bilinear <- st_read("../data/cbi_calibration/cbi-calibration_64-day-window_L57_bilinear-interp.g
```

```
## Reading layer `cbi-calibration_64-day-window_L57_bilinear-interp' from data source `/Users/mikoontz/
## Simple feature collection with 401 features and 67 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: -119.7917 ymin: 35.55484 xmax: -117.9751 ymax: 37.88774
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```r
###
### Bicubic interpolation
###

# Get 16-day window, bicubic interpolation data
cbi_16_bicubic <- st_read("../data/cbi_calibration/cbi-calibration_16-day-window_L57_bicubic-interp.geo
```

```
## Reading layer `cbi-calibration_16-day-window_L57_bicubic-interp' from data source `/Users/mikoontz/d
## Simple feature collection with 401 features and 67 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: -119.7917 ymin: 35.55484 xmax: -117.9751 ymax: 37.88774
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```r
# Get 32-day window, bicubic interpolation data
cbi_32_bicubic <- st_read("../data/cbi_calibration/cbi-calibration_32-day-window_L57_bicubic-interp.geo
```

```
## Reading layer `cbi-calibration_32-day-window_L57_bicubic-interp' from data source `/Users/mikoontz/d
## Simple feature collection with 401 features and 67 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: -119.7917 ymin: 35.55484 xmax: -117.9751 ymax: 37.88774
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```r
# Get 48-day window, bicubic interpolation data
cbi_48_bicubic <- st_read("../data/cbi_calibration/cbi-calibration_48-day-window_L57_bicubic-interp.geo
```

```
## Reading layer `cbi-calibration_48-day-window_L57_bicubic-interp' from data source `/Users/mikoontz/d
## Simple feature collection with 401 features and 67 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: -119.7917 ymin: 35.55484 xmax: -117.9751 ymax: 37.88774
## epsg (SRID):    4326
```

```
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```
# Get 64-day window, bicubic interpolation data
cbi_64_bicubic <- st_read("../data/cbi_calibration/cbi-calibration_64-day-window_L57_bicubic-interp.geo
```

```
## Reading layer `cbi-calibration_64-day-window_L57_bicubic-interp' from data source `/Users/mikoontz/d
## Simple feature collection with 401 features and 67 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: -119.7917 ymin: 35.55484 xmax: -117.9751 ymax: 37.88774
## epsg (SRID):    4326
## proj4string:    +proj=longlat +datum=WGS84 +no_defs
```

```
cbi_list <- list(bilinear_16 = cbi_16_bilinear,
                 bilinear_32 = cbi_32_bilinear,
                 bilinear_48 = cbi_48_bilinear,
                 bilinear_64 = cbi_64_bilinear,
                 bicubic_16 = cbi_16_bicubic,
                 bicubic_32 = cbi_32_bicubic,
                 bicubic_48 = cbi_48_bicubic,
                 bicubic_64 = cbi_64_bicubic)
```

How will we compare different response variables?

```
# Conveient function to get coefficient of determination from a non-linear model. Note this value (R^2)
# does NOT have the same meaning in a non-linear context as it does in a a linear context. Thus
# it shouldn't be used as an estimate of how much variation in the data is explained by the model.
# Here, I'm using it to at least have some comparison to severity models in the literature.

r2 <- function(m) {
  r2 <- 1 - (sum(residuals(m)^2)) / sum(((m$model[[1]]) - mean(m$model[[1]], na.rm = TRUE))^2, na.rm = 
  r2
}

# Non-linear models (of the form used by Miller and Thode (2007) and Parks et al. (2014))
### Example of overall R^2
m1a <- nls(RBR ~ a + b * exp(cbi_over * c),
           data = cbi_16_bicubic[cbi_16_bicubic$conifer_forest == 1, ],
           start = list(a = 0, b = 1, c = 1),
           model = TRUE)

r2(m1a)
```

```
## [1] 0.794671
```

```
glimpse(cbi_16_bicubic)
```

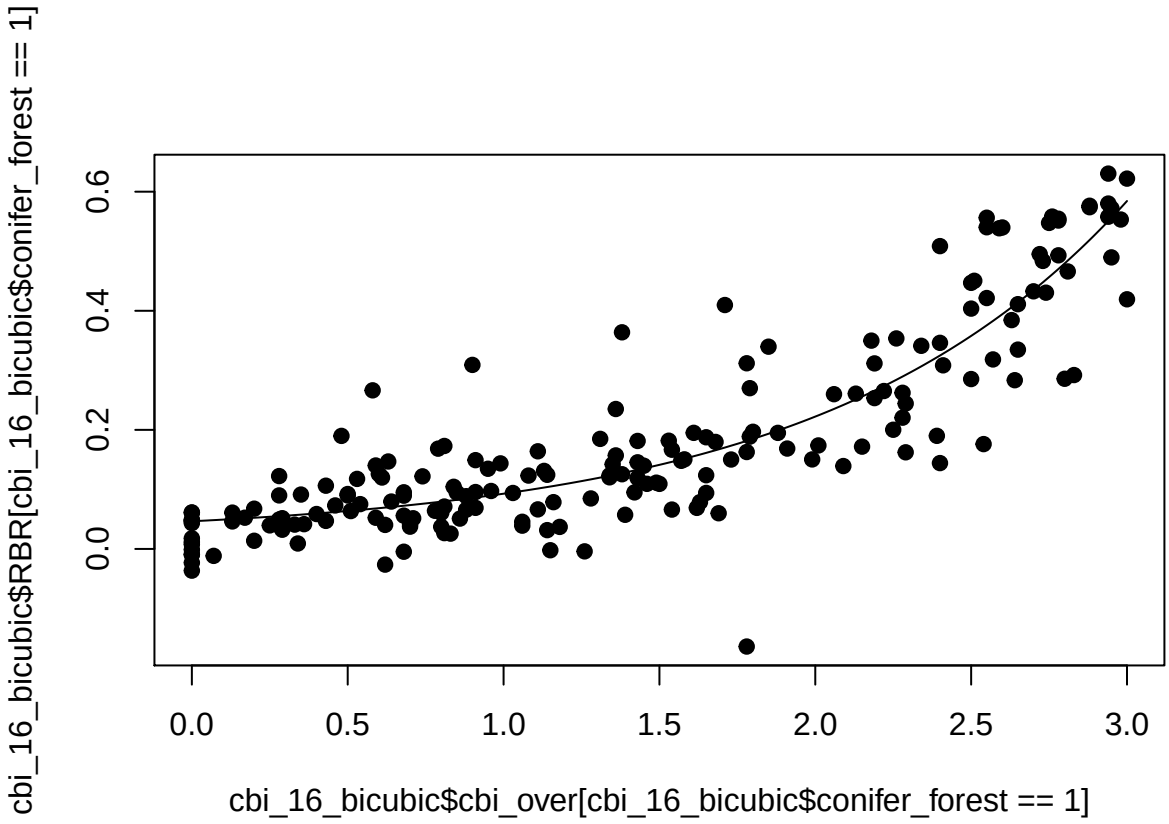
```
## Observations: 401
## Variables: 68
## $ RBR               <dbl> -0.004720859, 0.025714779, 0.047106579, 0.02...
## $ RdEVI             <dbl> 15.32710936, 10.16492795, -6.64124727, 26.83...
## $ RdNBR             <dbl> -0.30232033, 1.63727257, 3.00774977, 1.70791...
## $ RdNBR2            <dbl> -1.08521070, 1.71012993, 6.31019145, 2.03676...
## $ RdNDVI            <dbl> -0.2923872, 1.9495600, 1.6407096, 3.5045205,...
## $ alarm_date        <dbl> 1.033456e+12, 1.033456e+12, 1.033456e+12, 1....
## $ aspect            <dbl> 348, 277, 316, 300, 281, 271, 301, 249, 271,...
## $ cbi_over          <dbl> 0.68, 0.83, 0.43, 0.81, 1.36, 1.14, 0.00, 0....
```

```
## $ conifer_forest    <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0,...
## $ dEVI              <dbl> 0.936030367, 0.586792965, -0.430500539, 1.71...
## $ dNBR              <dbl> -0.008191228, 0.046338320, 0.083190024, 0.04...
## $ dNBR2             <dbl> -0.020249337, 0.033861905, 0.131865263, 0.03...
## $ dNDVI             <dbl> -0.007704794, 0.052078545, 0.042973697, 0.09...
## $ date              <dbl> 1.033456e+12, 1.033456e+12, 1.033456e+12, 1....
## $ elev              <dbl> 1820, 2213, 1859, 1836, 1730, 1663, 1625, 17...
## $ erc               <dbl> 77.30512, 77.30512, 77.30512, 77.30512, 77.3...
## $ fire_name         <chr> "Tar Gap", "Tar Gap", "Tar Gap", "Tar Gap", ...
## $ fm100             <dbl> 8.361945, 8.361945, 8.361945, 8.361945, 8.36...
## $ focal_mean_evi_1  <dbl> 2.9407766, 2.7348858, 3.2818728, 3.5927544, ...
## $ focal_mean_evi_2  <dbl> 2.893755, 3.234671, 3.334225, 3.209441, 2.48...
## $ focal_mean_evi_3  <dbl> 2.915415, 3.296022, 3.124283, 3.223561, 2.42...
## $ focal_mean_evi_4  <dbl> 2.9645081, 3.2969772, 3.0597345, 3.2872144, ...
## $ focal_mean_ndvi_1 <dbl> 0.6693925, 0.7099566, 0.6603786, 0.7100132, ...
## $ focal_mean_ndvi_2 <dbl> 0.6770165, 0.6850120, 0.6745226, 0.6978956, ...
## $ focal_mean_ndvi_3 <dbl> 0.6794191, 0.6712593, 0.6589357, 0.6907797, ...
## $ focal_mean_ndvi_4 <dbl> 0.6801584, 0.6646367, 0.6480628, 0.6814232, ...
## $ focal_mean_ndwi_1 <dbl> 0.52052706, 0.60418516, 0.51737964, 0.517637...
## $ focal_mean_ndwi_2 <dbl> 0.51405394, 0.57512772, 0.49334475, 0.518127...
## $ focal_mean_ndwi_3 <dbl> 0.51270872, 0.56245995, 0.46286649, 0.510480...
## $ focal_mean_ndwi_4 <dbl> 0.51096129, 0.55981469, 0.43435124, 0.497883...
## $ het_evi_1         <dbl> 0.36842275, 0.46440565, 0.44353512, 0.505305...
## $ het_evi_2         <dbl> 0.4861752, 0.9900468, 0.6806487, 0.5719009, ...
## $ het_evi_3         <dbl> 0.5582396, 1.3921863, 0.8888694, 0.5747776, ...
## $ het_evi_4         <dbl> 0.6344000, 1.1984415, 1.1167517, 0.9740762, ...
## $ het_ndvi_1        <dbl> 0.01842920, 0.01670047, 0.03249328, 0.013676...
## $ het_ndvi_2        <dbl> 0.02053086, 0.03069870, 0.02830280, 0.022365...
## $ het_ndvi_3        <dbl> 0.02073112, 0.03103883, 0.04368138, 0.023855...
## $ het_ndvi_4        <dbl> 0.02361636, 0.03404527, 0.05257702, 0.029497...
## $ het_ndwi_1        <dbl> 0.01846665, 0.03234043, 0.04114682, 0.033106...
## $ het_ndwi_2        <dbl> 0.02763174, 0.05554041, 0.06425933, 0.037826...
## $ het_ndwi_3        <dbl> 0.03389298, 0.05456992, 0.10321307, 0.040411...
## $ het_ndwi_4        <dbl> 0.03653562, 0.05710152, 0.12948399, 0.051834...
## $ id                <chr> "44", "62", "59", "56", "45", "51", "61", "4...
## $ lat               <dbl> 36.43769, 36.43365, 36.44200, 36.44119, 36.4...
## $ lon               <dbl> -118.6815, -118.6740, -118.6772, -118.6788, ...
## $ ordinal_day       <dbl> 273, 273, 273, 273, 273, 273, 273, 273, 151,...
## $ postFire_evi      <dbl> 2.7935448, 2.7456382, 4.6324236, 2.3770013, ...
## $ postFire_nbr      <dbl> 0.74230492, 0.75467288, 0.68180585, 0.649869...
## $ postFire_nbr2     <dbl> 0.368421048, 0.358208954, 0.304827243, 0.295...
## $ postFire_ndvi     <dbl> 0.7020979, 0.6615044, 0.6430545, 0.6097872, ...
## $ postFire_ndwi     <dbl> 0.514623523, 0.483456790, 0.475075543, 0.438...
## $ pr                <dbl> 0.000000, 0.000000, 0.000000, 0.000000, 0.00...
## $ preFire_evi       <dbl> 3.7295752, 3.3324312, 4.2019231, 4.0940171, ...
## $ preFire_nbr       <dbl> 0.7341137, 0.8010112, 0.7649959, 0.6948915, ...
## $ preFire_nbr2      <dbl> 0.3481717, 0.3920709, 0.4366925, 0.3323124, ...
## $ preFire_ndvi      <dbl> 0.6943931, 0.7135830, 0.6860282, 0.7026858, ...
## $ preFire_ndwi      <dbl> 0.52862704, 0.59065133, 0.53481692, 0.471445...
## $ slope             <dbl> 23, 15, 24, 24, 24, 17, 27, 20, 16, 11, 13, ...
## $ source            <chr> "zhu2006", "zhu2006", "zhu2006", "zhu2006", ...
## $ tmmx              <dbl> 744.9651, 744.9651, 744.9651, 744.9651, 744....
## $ topo_roughness_1  <dbl> 11.2354072, 5.8616870, 11.1775445, 10.222524...
## $ topo_roughness_2  <dbl> 20.686105, 12.641903, 18.025012, 18.438901, ...
```

```
## $ topo_roughness_3  <dbl> 29.649222, 18.524746, 23.729231, 25.790792, ...
## $ topo_roughness_4  <dbl> 37.452094, 24.888049, 29.045414, 33.850766, ...
## $ cbi_over_t        <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ...
## $ cbi_tot           <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ...
## $ cbi_tot_t         <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ...
## $ geometry          <simple_feature> POINT (-118.681525632691 36..., P...
```

Basic plot of where these CBI plots are...

```
plot(cbi_16_bicubic$cbi_over[cbi_16_bicubic$conifer_forest == 1],
     cbi_16_bicubic$RBR[cbi_16_bicubic$conifer_forest == 1],
     pch = 19)
lines(seq(0, 3, by = 0.01), predict(m1a, newdata = data.frame(cbi_over = seq(0, 3, by = 0.01))))
```




```
# Where would the cutoff for "high severity" be? CBI of 2.25 or greater translates to an RdNBR of...
severity_thresholds <- predict(m1a, newdata = data.frame(cbi_over = c(0, 0.1, 1.25, 2.25)))
severity_thresholds
```

```
## [1] 0.04644322 0.04923689 0.11390926 0.28137144
```

```
# How many missing values for each set of data?
nrow(cbi_16_bicubic) # 401 total points
```

```
## [1] 401
```

```
nrow(cbi_16_bicubic[is.na(cbi_16_bicubic$RBR), ]) # 44 missing points
```

```
## [1] 44
```

```
nrow(cbi_16_bicubic[is.na(cbi_16_bicubic$RBR), ]) / nrow(cbi_16_bicubic)
```

```
## [1] 0.1097257
```

```r
# Just a check, should be the same regardless of interpolation method
nrow(cbi_16_bilinear[is.na(cbi_16_bilinear$RBR), ])
```

```
## [1] 44
```

```r
nrow(cbi_32_bicubic[is.na(cbi_32_bicubic$RBR), ]) / nrow(cbi_32_bicubic)
```

```
## [1] 0.01995012
```

```r
nrow(cbi_48_bicubic[is.na(cbi_48_bicubic$RBR), ]) / nrow(cbi_48_bicubic)
```

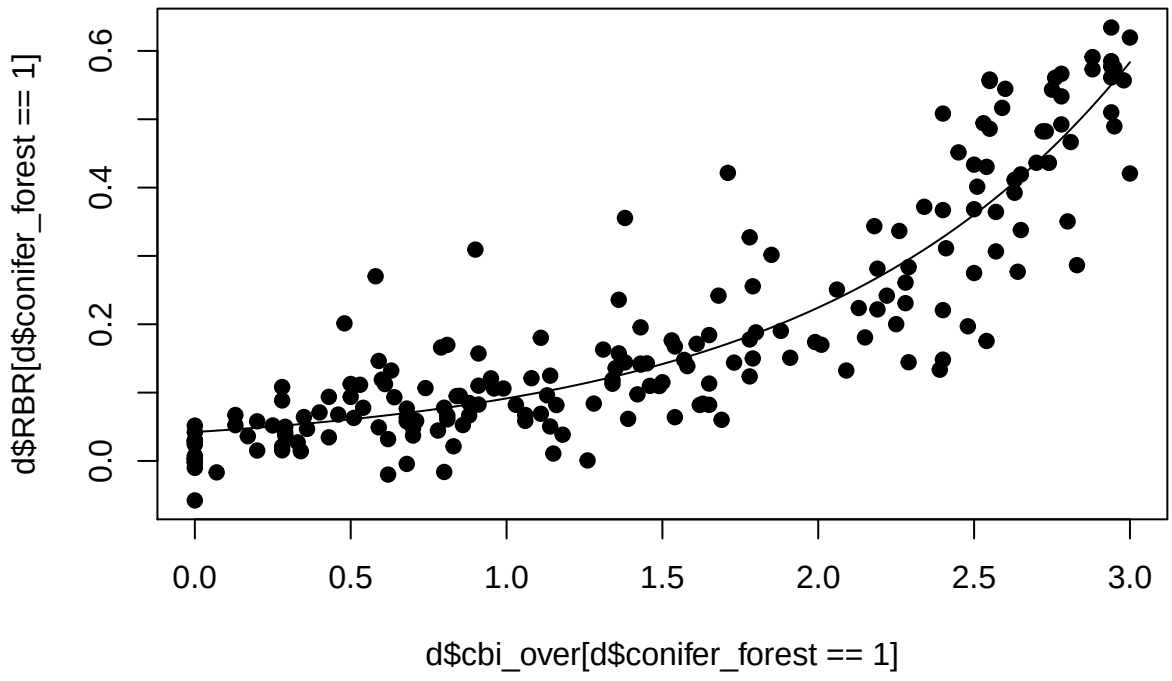
```
## [1] 0.01995012
```

```r
nrow(cbi_64_bicubic[is.na(cbi_64_bicubic$RBR), ]) / nrow(cbi_64_bicubic)
```

```
## [1] 0.01995012
```

```r
d <- cbi_32_bicubic

plot(d$cbi_over[d$conifer_forest == 1], d$RBR[d$conifer_forest == 1], pch = 19)
m1 <- nls(RBR ~ a + b * exp(cbi_over * c),
                data = subset(d, conifer_forest == 1),
                start = list(a = 0, b = 1, c = 1),
                model = TRUE)
lines(seq(0, 3, by = 0.01), predict(m1, newdata = data.frame(cbi_over = seq(0, 3, by = 0.01))))
```




```r
summary(m1)
```

```
##
## Formula: RBR ~ a + b * exp(cbi_over * c)
##
## Parameters:
##   Estimate Std. Error t value Pr(>|t|)
## a 0.013375   0.018686   0.716  0.47496
## b 0.028939   0.009684   2.988  0.00316 **
## c 0.993517   0.109057   9.110  < 2e-16 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.07427 on 199 degrees of freedom
##
## Number of iterations to convergence: 4
## Achieved convergence tolerance: 5.364e-07
##   (6 observations deleted due to missingness)
```

```
r2(m1)
```

```
## [1] 0.81999
```