Assignment 6: Using Sobol with an ODE

Colleen McCamy

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Establishing the Carbon Model

```
# loading the function
source("calculate_forest_growth.R")

calculate_forest_growth
```

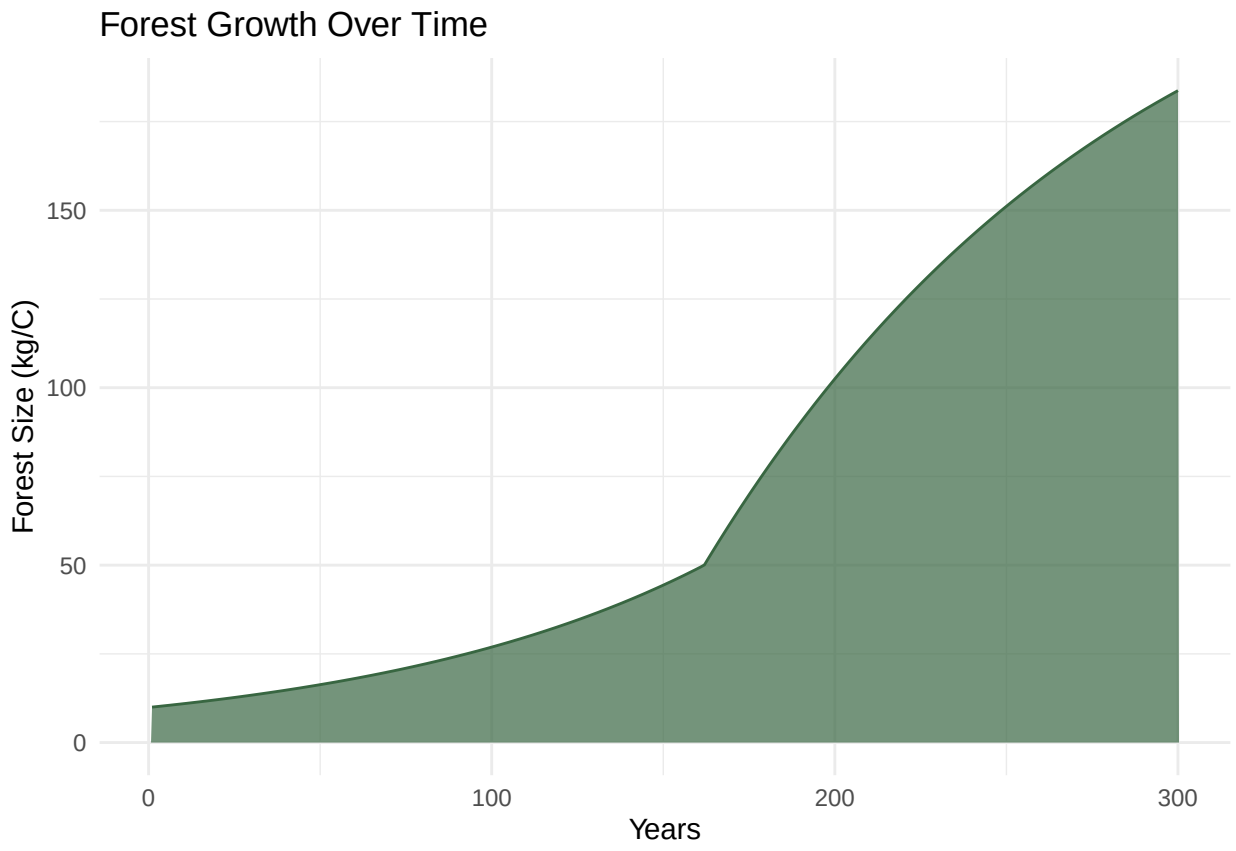
```
## function (time, C, params)
## {
##     if (C < params$thresh) {
##         carbon_change = params$r * C
##     }
##     else {
##         carbon_change = params$g * (1 - C/params$k)
##     }
##     return(list(carbon_change))
## }
```

Running the Model without Sobel

```
# storing parameters
time <- seq(1, 300, 1)
C_initial <- 10

# storing params as a dataframe
params <- list(k = 250,
                r = 0.01,
                g = 2,
                thresh = 50)

# running the model
results <- ode(y = C_initial,
               times = time,
               func = calculate_forest_growth,
               parms = params)

# storing as dataframe
results_df <- as.data.frame(results) |>
  rename("forest_growth" = 2)
```

Graphing the Results

```
# creating an area chart
results_df |>
  ggplot(aes(x = time, y =  forest_growth)) +
  geom_area(fill = "#386641",
            alpha = 0.7) +
  geom_line(color = "#386641") +
  theme_minimal() +
  labs(title = "Forest Growth Over Time",
       y = "Forest Size (kg/C)",
       x = "Years")
```



Running Model with Sobol Sensitivity Analysis

Initiating parameters

```
# setting sobel inputs
num_params <- 1500
sd_percent <- 0.10

### ----------------
### parameter values
```

```
### ----------------

### first parameter set

# carrying capacity
k <- rnorm(mean = params$k,
           sd = (params$k * sd_percent),
           n = num_params)

# exponential growth rate (before canopy closure)
r <- rnorm(mean = params$r,
           sd = (params$r * sd_percent),
           n = num_params)

# linear growth rate (after canopy closure)
g <- rnorm(mean = params$g,
           sd = (params$g * sd_percent),
           n = num_params)

# canopy closure threshold
thresh <- rnorm(mean = params$thresh,
           sd = (params$thresh * sd_percent),
           n = num_params)

# putting all params into one dataframe
sample1 = cbind.data.frame(k = k,
                      r = r,
                      g = g,
                      thresh = thresh)

### second parameter set

# carrying capacity
k <- rnorm(mean = params$k,
           sd = (params$k * sd_percent),
           n = num_params)

# exponential growth rate (before canopy closure)
r <- rnorm(mean = params$r,
           sd = (params$r * sd_percent),
           n = num_params)

# linear growth rate (after canopy closure)
g <- rnorm(mean = params$g,
           sd = (params$g * sd_percent),
           n = num_params)

# canopy closure threshold
thresh <- rnorm(mean = params$thresh,
           sd = (params$thresh * sd_percent),
           n = num_params)

# putting all params into one dataframe
```

```
sample2 = cbind.data.frame(k = k,
                      r = r,
                      g = g,
                      thresh = thresh)
```

```
# changing any negative values to zero in both samples
sample1 <- sample1 |>
  map_df(pmax, 0.0)

sample2 <- sample2 |>
  map_df(pmax, 0.0)
```

Creating sobol parameter object

```
# creating our sobel obejct and get sets of parameters for running the model
sens_params <- sobolSalt(model = NULL,
                         sample1,
                         sample2,
                         nboot = 350)

# adding column names
colnames(sens_params$X) <- c("k", "r", "g", "thresh")

# turning into dataframe for sensitivity analysis iteration
sens_params_df <- as.data.frame(sens_params$X)

# looking at just one parameter set
# sens_params$X[1,]
```

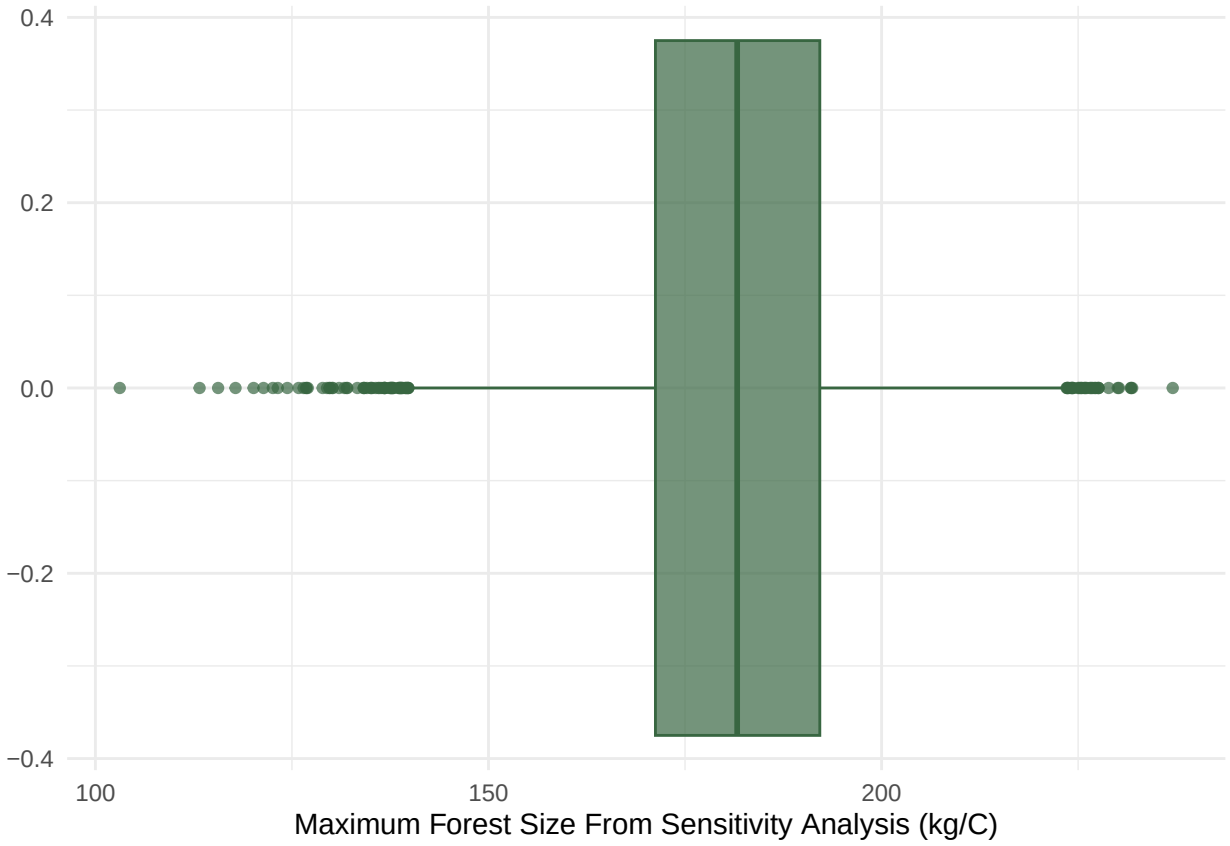
Conducting sensitivity analysis

```
# loading in the wrapper function
source("conduct_forest_sensitivity.R")

# running the analysis
results_sens <- sens_params_df |>
  pmap(conduct_forest_sensitivity,
       C_initial = C_initial,
       time = time,
       func = calculate_forest_growth)

# binding rows and turning results into a dataframe
results_sens <- do.call(rbind, results_sens)
results_sens <- as.data.frame(results_sens)

# renaming and adding parameter values
results_sens <- results_sens |>
  rename("max_growth" = 1) |>
  cbind(sens_params_df)
```

Sensitivity Analysis - Indices & Plot

Graphing the sensivitity results

```
# creating a boxplot
results_sens |>
  ggplot(aes(max_growth)) +
  geom_boxplot(fill = "#386641",
               alpha = 0.7,
               color = "#386641") +
  theme_minimal() +
  labs(x = "Maximum Forest Size From Sensitivity Analysis (kg/C)")
```



Reporting sobel indices

```
# getting analysis
max_growth <- tell(sens_params,
                   results_sens$max_growth)

# adding row names to first order
rownames(max_growth$S) <- c("k", "r", "g", "thresh")

print("First Order Indices")
```

```
## [1] "First Order Indices"
```

```
max_growth$S
```

```
##          original          bias std. error   min. c.i. max. c.i.
## k      0.35858225 -0.0036924134 0.02651246 0.309576342 0.4163448
## r      0.34102945 -0.0017966077 0.02462932 0.291323904 0.3886687
## g      0.19734455 -0.0023145924 0.02468385 0.150804583 0.2503948
## thresh 0.05872827 -0.0009866682 0.02635791 0.005379591 0.1060137
```

```
# adding row names to second order
rownames(max_growth$T) <- c("k", "r", "g", "thresh")

print("Second Order Indices")
```

```
## [1] "Second Order Indices"
```

```
max_growth$T
```

```
##          original          bias std. error  min. c.i.  max. c.i.
## k      0.37032319 -1.096166e-03 0.01857377 0.33168616 0.40524311
## r      0.38535542  1.256730e-03 0.02008718 0.34226370 0.42336110
## g      0.20945947  1.350349e-04 0.01078753 0.18738093 0.22846209
## thresh 0.06356204 -2.312842e-05 0.00373331 0.05586691 0.07096621
```

Discussion

Looking at the first order index, it appears that both carrying capacity and the exponential growth rate is most sensitive to the output of the model with a relatively small confidence interval that does not include 0. This could mean that the output from rate at which forest grow when below the threshold canopy closure is most sensitive to change and in the context of climate change, with more severe storms and heavy rain instances contrasted with extreme drought, this model will could not accurately portray forest growth and there could be a decrease in growth rate. Also, depending on the conditions, warming temperature could lead to more extreme growing rates when less than the threshold canopy. This rapid growth could have negative implications for understory flora and biodiversity.