Growth Model & Sensitivity Analysis - Sobol

Group I - Jake Eisaguirre, Yuitan Fang, Julia Parish

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Growth Model & Sobol Sensitivity Analysis

This environmental model was completed as an assignment for the course, Environmental Data Science 230 | Environmental Science & Management: Modeling Environmental Systems. The goal of this assignment was to code a function to compute forest growth and conduct a sobol sensitivity analysis that explores how the estimated maximum and mean forest size varies. This assignment focuses on developing skills to create a model of forest growth and conduct a sobol sensitivity analysis.

Parameters

- K = carrying capacity (C)
- r = pre-canopy closure rate
- g = post-canopy closure rate

Load Libraries

```
library(here)
library(tidyverse)
library(kableExtra)
library(deSolve)
library(sensitivity)
library(purrr)
```

1. Implement a forest growth rate model

Forest size is measured in units of carbon (C)

```
# source the function

source(here("R","forestgrowthrate.R"))

dgrowthrate
```

```
## function (time, C, parms)
## {
##     dC = parms$r * C
##     if (C >= parms$threshold) {
##         dC = parms$g * (1 - C/parms$K)
##     }
##     return(list(dC))
## }
```

2. Run the model for 300 years (with ODE solver) and plot the result

Parameters for model

- threshold = 50 kgC (canopy closure threshold)
- K = 250 kg C (carrying capacity)
- r = 0.01 (exponential growth rate before before canopy closure)
- g = 2 kg/year (linear growth rate after canopy closure)

```
# create parameter list and specify the initial size and years to run the model

# set parameters
K = 250
r = 0.01
g = 2
threshold = 50

initialsize <- 10
years <- seq(from = 1, to = 300, by = 5)
parms <- list(K = K, r = r, g = g,  threshold = threshold)

#apply solver
results <- ode(initialsize, years, dgrowthrate, parms)

# convert results to data frame
results <- as.data.frame(results)

#add meaningful names to columns of results
colnames(results) = c("year", "C")
```

```
# view sample of df
results_sample <- head(results)

results_table <- kable(results_sample,
                       caption = "Sample of Forest Growth ODE Model Results") %>%
  kable_styling(latex_options = "HOLD_position")

results_table
```

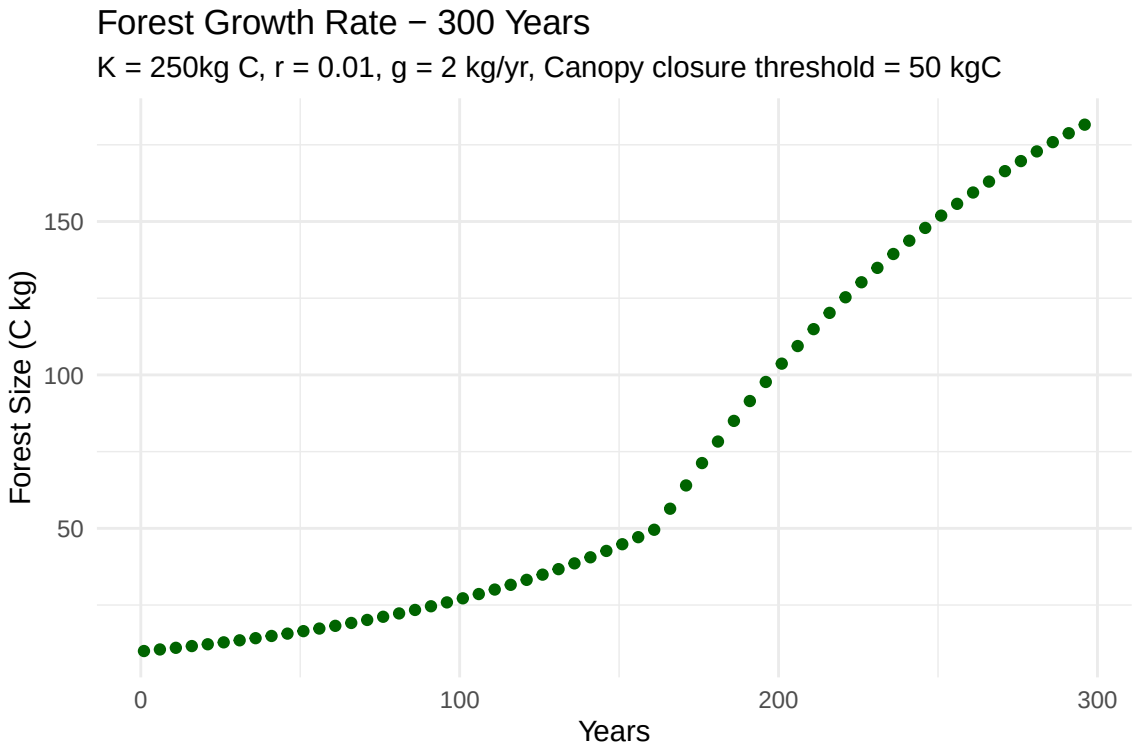
Table 1: Sample of Forest Growth ODE Model Results

year	C
1	10.00000
6	10.51272
11	11.05171
16	11.61834
21	12.21403
26	12.84026

```
# plot results
model01_plot <- results %>%
  ggplot(aes(x = year, y = C)) +
```

```
  geom_point(color = "darkgreen") +
  labs(x = "Years", y = "Forest Size (C kg)",
       title = "Forest Growth Rate - 300 Years",
       subtitle = "K = 250kg C, r = 0.01, g = 2 kg/yr, Canopy closure threshold = 50 kgC") +
  theme_minimal()

model01_plot
```



3.A. Run a sobol sensitivity analysis that explores how the estimated maximum and mean forest size (e.g maximum and mean values of C over the 300 years) varies with the pre canopy closure growth rate (r) and post-canopy closure growth rate (g) and canopy closure threshold and carrying capacity(K)

Assume that parameters are all normally distributed with means as given above and standard deviation of 10% of mean value

```
# set the number of parameters
np = 200

K = rnorm(mean = K, sd = K*0.01, n = np)
r = rnorm(mean = r, sd = r*0.01, n = np)
g = rnorm(mean = g, sd = g*0.01, n = np)
threshold = rnorm(mean = threshold, sd = threshold*0.01, n = np)

X1 = cbind.data.frame(r = r, K = K, g = g, threshold = threshold)
```

```r
# repeat to calculate second set of samples
np = 200

K = rnorm(mean = K, sd = K*0.01, n = np)
r = rnorm(mean = r, sd = r*0.01, n = np)
g = rnorm(mean = g, sd = g*0.01, n = np)
threshold = rnorm(mean = threshold, sd = threshold*0.01, n = np)

X2 = cbind.data.frame(r = r, K = K, g = g, threshold = threshold)
```

```r
# create sobol object and get parameters
sens_forest <- sobol(model = NULL, X1, X2, nboot = 300)

colnames(sens_forest$X) <- c("r", "K", "g", "threshold")

parameters <- list(r = sens_forest$X[1,1],
                   K = sens_forest$X[1,2],
                   g = sens_forest$X[1,3],
                   threshold = sens_forest$X[1,4])

forest_sensitivity <- ode(func = dgrowthrate, y = initialsize, times = years, parms = parameters)

forest_sens_df <- as.data.frame(forest_sensitivity)
colnames(forest_sens_df) = c("time","C")
```

```r
# ????????

# turn computing our metrics into a function

# compute_metrics = function(result) {
#   maxpop = max(result$P)
# idx = which.max(result$P)
# maxyear = result$time[idx]
# return(list(maxpop=maxpop, maxyear=maxyear))}
#
# # try it on our first parameter set
# compute_metrics(result)

# or

# https://naomitague.github.io/ESM232_course/lectures/lecture12_growth.html#(5)
# use a wrapper function to just return the carbon trajectories
# p_wrapper = function(r,harv, K, Pinitial, simtimes, func) {
#     parms = list(r=r, K=K, harv=harv)
#     result = ode(y=Pinitial, times=simtimes, func=func, parms=parms)
#     result=as.data.frame(result)
#    colnames(result)=c("time","C")
#   # get metrics
#   metrics=compute_metrics(result$C)
#   return(metrics)
# }
```

3.B. Graph the results of the sensitivity analysis as a box plot of maximum forest size and a plot of the two Sobol indices (S and T).

3.C. Discuss what the results of your simulation might mean for climate change impacts on forest growth