Dynamic Growth

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1. Implement forest growth model in R

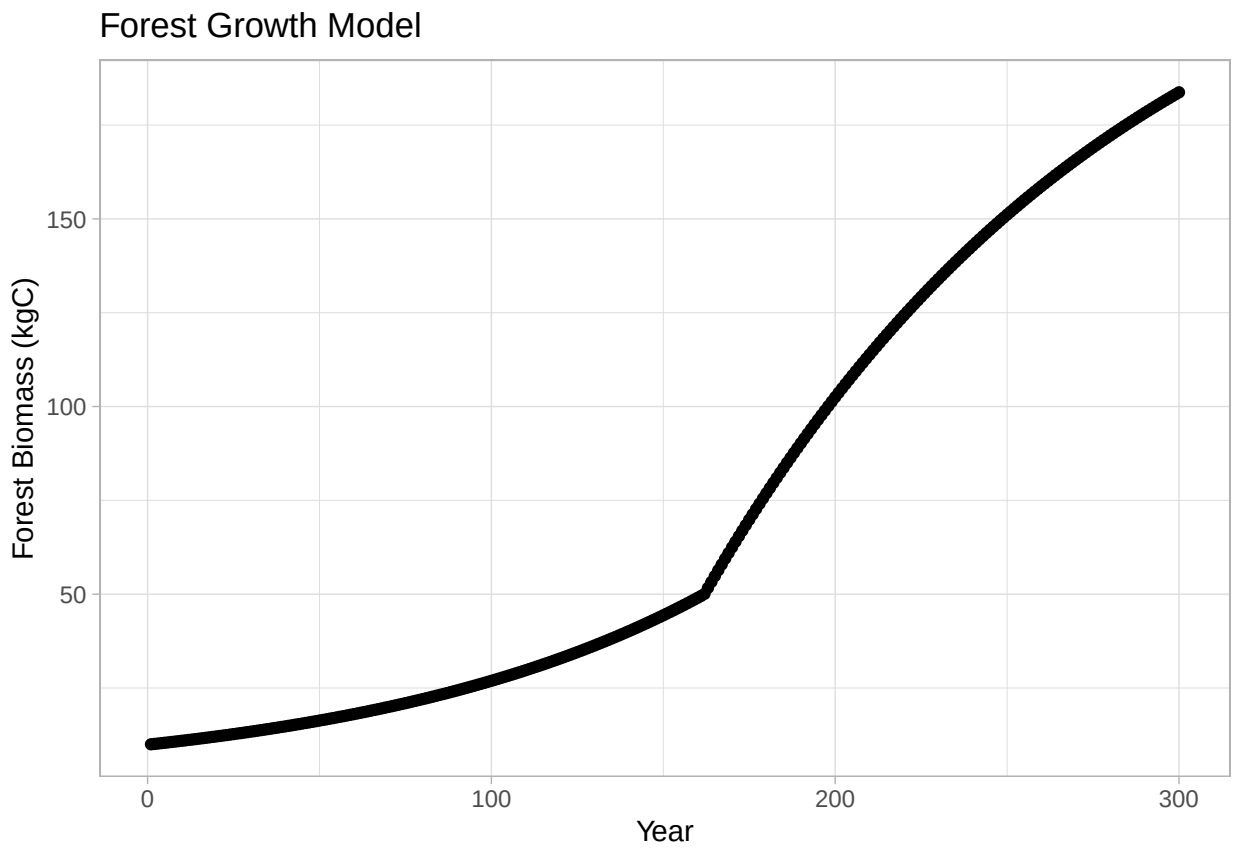
```
source('R/forest_growth.R')
```

2. Run model for 300 years

- Initial forest size: 10 kg/C
- Canopy closure threshold: 50 kgC
- K: 250 kgC
- r: 0.01
- g: 2 kg/year

```
# Set time range of 300 years
time = seq(from=1, to=300)

# Set parameters and initial population
parms = list(r=0.01, g=2, thresh=50, K=250)
C_initial = 10

# Run ode solver
growth = ode(C_initial, time, forest_growth, parms)

# Clean column names
colnames(growth) = c("Time", "Carbon")
```

```
ggplot(as.data.frame(growth), aes(Time, Carbon)) +
  geom_point() +
  labs(y="Forest Biomass (kgC)", x="Year", title="Forest Growth Model") +
  theme_light()
```



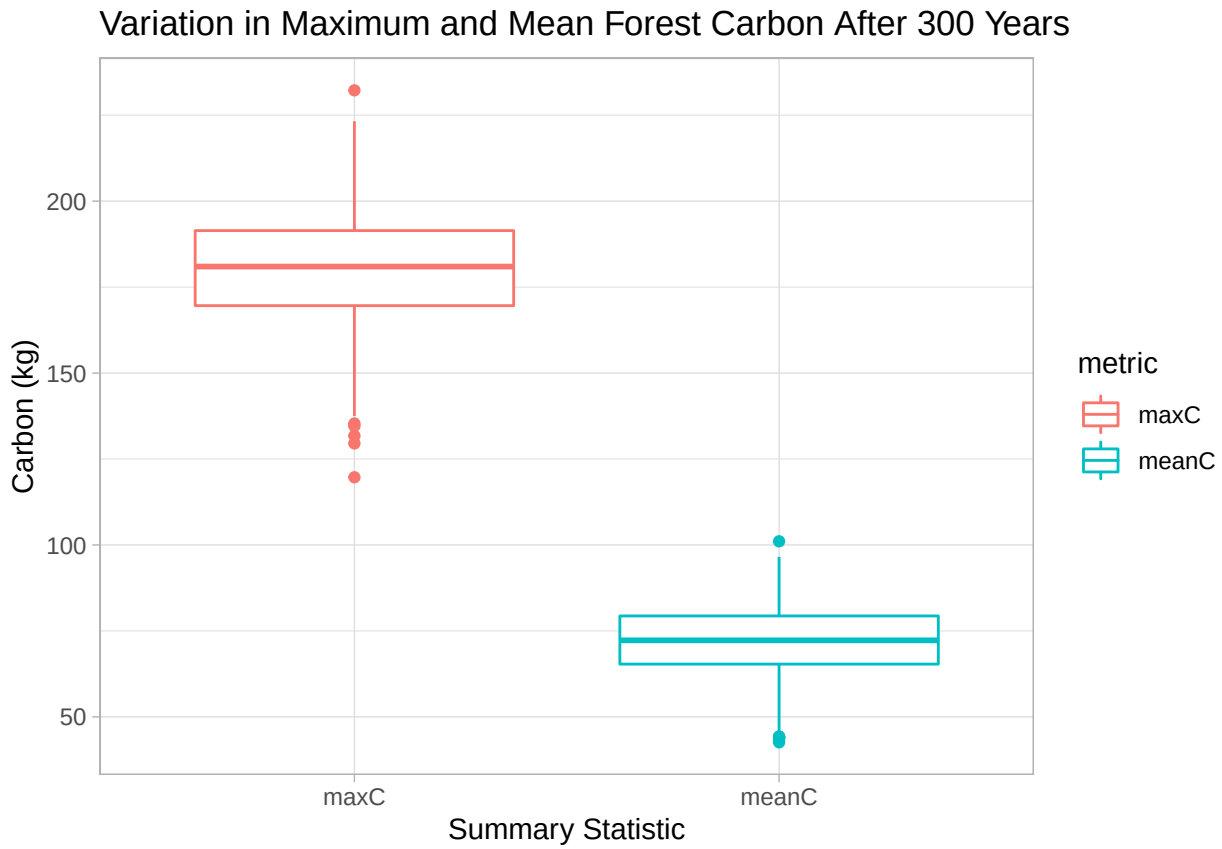
3. Sobol sensitivity analysis

- Parameters (r, g, thresh, K) are all normally distributed with means as given and standard deviation of 10% of mean

```
# Set number of parameters
np = 100

# Set parameter mean values
r_mean = 0.01
g_mean = 2
K_mean = 250
thresh_mean = 50

# Create parameter distributions
r = rnorm(mean=r_mean, sd=r_mean*0.1, n=np)
g = rnorm(mean=g_mean, sd=g_mean*0.1, n=np)
K = rnorm(mean=K_mean, sd=K_mean*0.1, n=np)
thresh = rnorm(mean=thresh_mean, sd=thresh_mean*0.1, n=np)

# Create dataframe
X1 = cbind.data.frame(r=r, g=g, K=K, thresh=thresh)

# Repeat to get second set of samples
```

```
r = rnorm(mean=r_mean, sd=r_mean*0.1, n=np)
g = rnorm(mean=g_mean, sd=g_mean*0.1, n=np)
K = rnorm(mean=K_mean, sd=K_mean*0.1, n=np)
thresh = rnorm(mean=thresh_mean, sd=thresh_mean*0.1, n=np)

# Create dataframe
X2 = cbind.data.frame(r=r, g=g, K=K, thresh=thresh)

# Create Sobel object and get sets of parameters for running the model
sens_C = sobolSalt(model=NULL, X1, X2, nboot=300)

# Add names to parameter sets
colnames(sens_C$X) = c("r", "g", "K", "thresh")

# Get functions to compute metrics for each parameter set
source('R/compute_metrics.R')
source('R/p_wrapper.R')

# Compute results
all_results = as.data.frame(sens_C$X) %>%
  pmap(p_wrapper, C_initial=C_initial, time=time, func=forest_growth)

# Extract results into dataframe
all_results_df = all_results %>%
  map_dfr(`[`, c("maxC", "meanC"))
```

```
plot_df = all_results_df %>%
  gather(key="metric", value="value")

ggplot(plot_df, aes(metric, value, col=metric)) +
  geom_boxplot() +
  theme_light() +
  labs(title = "Variation in Maximum and Mean Forest Carbon After 300 Years") + ylab("Carbon (kg)") + xl
```



Sobol Indices for Max Carbon

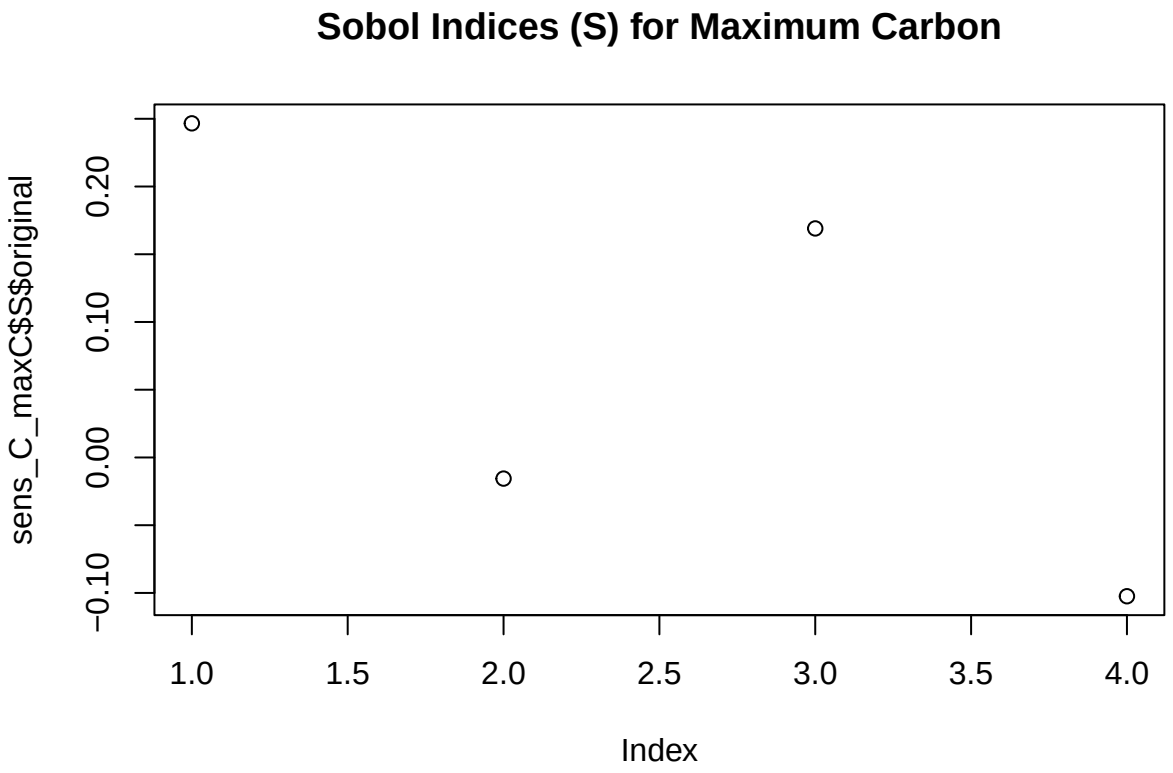
```
# Get indices for max carbon
sens_C_maxC = sensitivity::tell(sens_C, all_results_df$maxC)

# rename
rownames(sens_C_maxC$T) <- c("r", "g", "K", "thresh")
rownames(sens_C_maxC$S) <- c("r", "g", "K", "thresh")

# Get first-order indices (main effect without covariance)
sens_C_maxC$S
```

```
##           original          bias std. error   min. c.i.  max. c.i.
## r       0.24661908 -0.0010712162 0.09558241  0.06559489 0.44864436
## g      -0.01559488 -0.0030443480 0.10074560 -0.20946535 0.18293012
## K       0.16904899 -0.0005204443 0.09243230 -0.00164899 0.34886753
## thresh -0.10243314  0.0010343527 0.09309134 -0.29019353 0.09035945
```

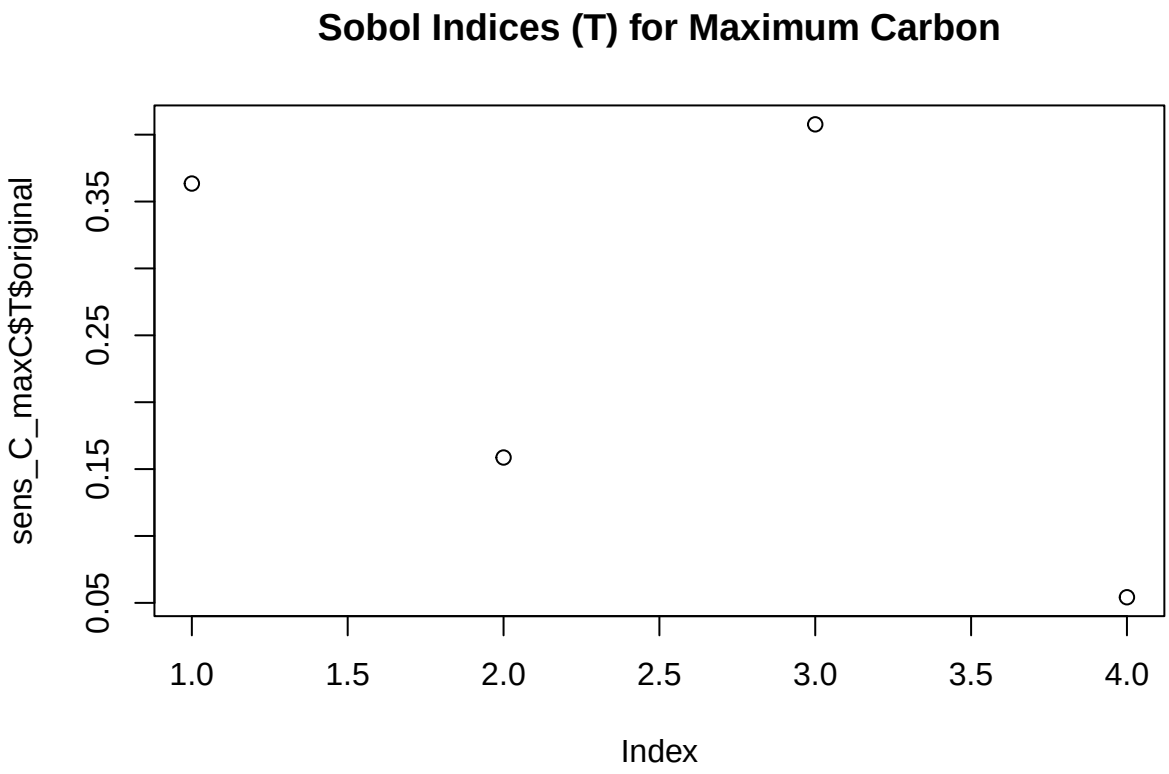
```
# Get total sensitivity index
sens_C_maxC$T
```

```
##           original        bias std. error  min. c.i.  max. c.i.
## r       0.36344590 0.005645936 0.06508779 0.21558400 0.47677205
## g       0.15865753 0.004597064 0.03534634 0.07620258 0.21318566
## K       0.40770015 0.009253824 0.07328804 0.24541091 0.52917890
## thresh 0.05420642 0.001716744 0.01162864 0.02430590 0.07087283
```

```r
# Plot

plot(sens_C_maxC$S$original, main = "Sobol Indices (S) for Maximum Carbon")
```




```r
plot(sens_C_maxC$T$original, main = "Sobol Indices (T) for Maximum Carbon")
```



Sobol Indices for Mean Carbon

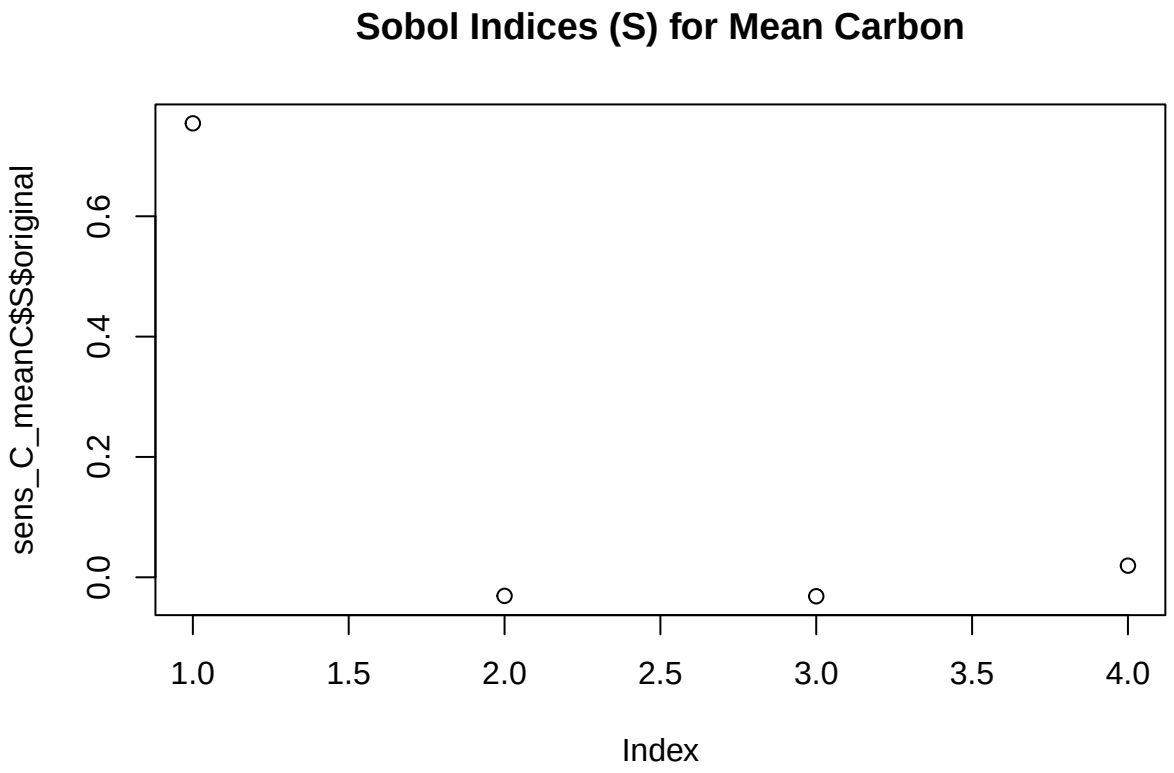
```
# Repeat for mean carbon
sens_C_meanC = sensitivity::tell(sens_C, all_results_df$meanC)

# rename
rownames(sens_C_meanC$T) <- c("r", "g", "K", "thresh")
rownames(sens_C_meanC$S) <- c("r", "g", "K", "thresh")

# Get first-order indices (main effect without covariance)
sens_C_meanC$S
```

```
##           original         bias std. error  min. c.i. max. c.i.
## r       0.75444902 -0.007984711 0.04753657  0.6821955 0.8744046
## g      -0.03090427 -0.004095027 0.08083707 -0.1930653 0.1266832
## K      -0.03149364 -0.003162285 0.07151275 -0.1613588 0.1234070
## thresh  0.01933957 -0.008859851 0.07559614 -0.1416420 0.1796599
```

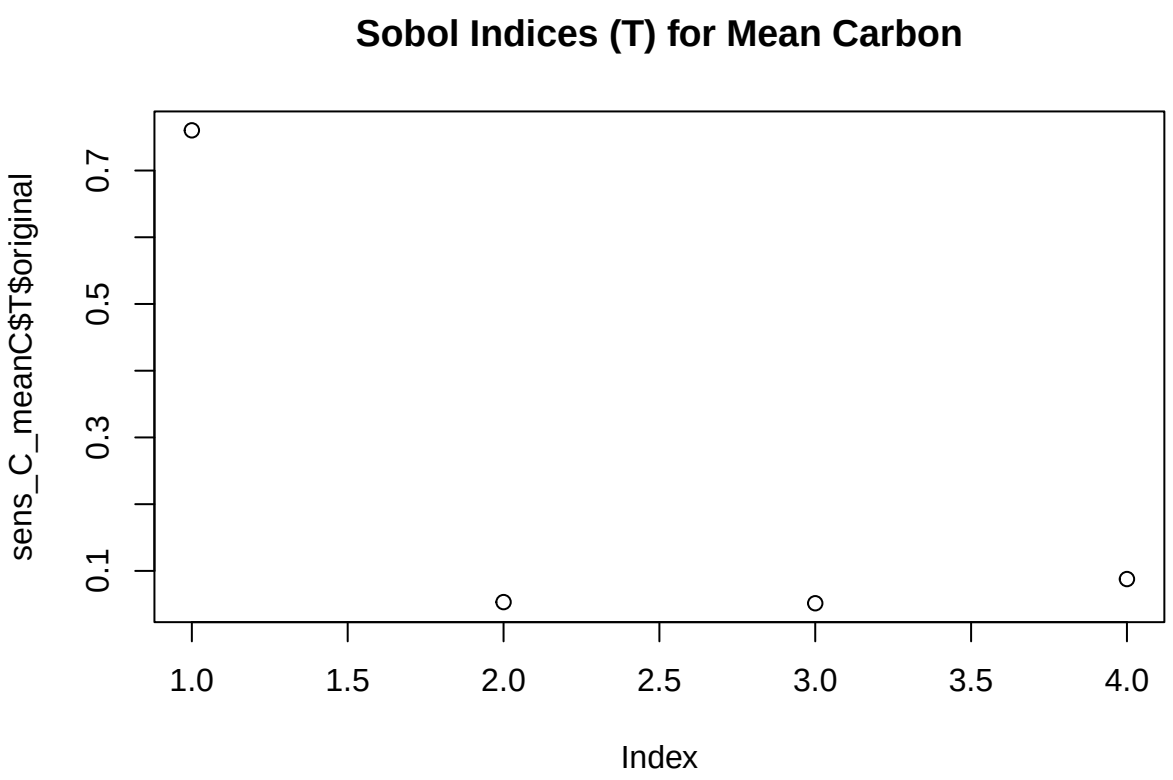
```
# Get total sensitivity index
sens_C_meanC$T
```

```
##          original         bias std. error  min. c.i.  max. c.i.
## r      0.76019448 0.0045874120 0.08083519 0.58400036 0.91314601
## g      0.05325050 0.0013094868 0.01017588 0.02897026 0.06870427
## K      0.05153692 0.0018915412 0.01245560 0.02085725 0.07021818
## thresh 0.08775183 0.0006670407 0.01737982 0.05047881 0.11587180
```

```r
# Plot

plot(sens_C_meanC$S$original, main = "Sobol Indices (S) for Mean Carbon")
```




```r
plot(sens_C_meanC$T$original, main = "Sobol Indices (T) for Mean Carbon")
```



In 2-3 sentences, discuss what the results of your simulation might mean for climate change impacts on forest growth (e.g think about what parameters climate change might influence).

Our sobol sensitivity analysis shows us that for `max_C` *the parameter with the highest sensitivity is carrying capacity, and for* `mean_C`*, the parameter with the highest sensitivity is the exponential growth rate. Both of these parameters can be highly affected by climate change due to the reduction in precipitation and water supply. On top of that climate change will also cause an increase in drought and forest fires which can have affects on both carrying capacity and exponential growth rate.*