ESM232_FinalProject

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Assigment Description:

*** Next to items that are done/assignment requirements that our model meets.

1. Identify a question for which the use of a model would help you to answer it. Select a question that has the following characteristics. The model should involve at least 3 sub models:

- *** a. It would be interesting to perform sensitivity analysis for at least two parameters
  - Both population models: Beetle - r and K. Pine tree: Initial conditions, growth rates, fecundity, etc.
- *** b. At least one sub-model should include either an ODE or a spatial model
  - The beetle model will contain an ODE
- c. Provide some rationale for why this is an important question to answer and why a model is needed (1-2 paragraphs)

2. Develop a conceptual model of your approach *** a. Identify the characteristics of submodels that you will use - spatial or lumped, dynamic or static, deterministic or stochastic, physically based/abstract?

- b. Identify the goal of your model - ***what is the question that it will be used to answer; for which types of users
- *** c. Design a figure to illustrate your conceptual model
  - Below
- *** d. Determine the inputs, outputs that will be used for each submodels
  - Code chunks below You will complete a draft version of I and II and submit as an Rmarkdown document or text file by May 1. ###############################

Overarching Question:

How will climate change impacts on bark beetle populations and tree populations influence forest carbon sequestration?

- Goal of model: Create a model that can used to estimate how climate change and bark beetle simultaneously impact the carbon sequestration of pine trees in a given area. We will choose a particular species of pine and particular species of bark beetle, but those can be exchanged for other species by future users.
- Approach: This larger model relies on three submodels: 1) a bark beetle population growth model, 2) a tree population projection model, and 3) tree volume burned.
- Expectations: We expect temperature increases to decrease bark beetle mortality rates and thus increase the population growth rate. Temperature is expected to a have mixed effect on the pine population – Increased temperature can increase the length of a growing season which increases net primary productivity (NPP). However, increased temperature also decreases soil moisture which has been shown to decrease primary producticity. Therefore, the effect of temperature on trees will be linked to water availability. Water availability has been show to be positively influential in tree defense

from bark beetles. Carbon sequestration will incorporate the volume of dead trees and forest NPP to provide information about how much carbon is sequestered in the forest following a fire.

- Extra component: The probility of fire and the fire's severity will be a user controlled input. Three fire severity levels will be pre-defined and selected by the user (high, medium, and low).

Rationale for Model Importance:

According to the US Forest Service, an estimated 129 million trees have dies in California's national forests since 2010, due to the interactions of climate change, drought, and bark beetle infestations. Our model seeks to illistrate the potential impact these factors can have on climate sequestration. Typically, forests are considered carbon sinks, yet as tree mortality rises from increased beetle infestation and drought, there is a threat of converting these sinks to sources.

The rate of carbon release from a forest is strongly linked to net primary productivity (NPP) and tree mortality. With the increasing threat of wildfires to California's forests, this model will calculate to "stock" of dead trees likely to be burnt, releasing carbon, across a set of three fire types (low, moderate, and high severity fires). Understanding the interplay between fire, NPP, bark beetles, forests, and climate change can illuminate the possible magnitude of this growing problem and incentivize new solutions.

Beginning Model Inputs:

1. Bark beetle population growth model

- Lumped
- Static (Will potentially make dynamic to then also make the pine model more dynamic)
- Deterministic
- Physically-based
- Will include an ODE

```
# Variables
N_0=10000 # Initial population size

# Paramters
r=0.75 # Intrinsic growth rate
K=100000 # Carrying capacity

# Model -- Logistic growth model. Once we've chosen a particular beetle and tree species, we hope to fi
```

2. Pine population projection model

- Lumped
- Static
- Hopefully stochastic, dependent on available information
- Physically-based

```
# Variables
# Survival terms in matrix model
# Initial population structure

# Paramters
# All inputs into matrix model except survival will be parameters, defined by published information


# Matrix population model based on size/stage classes, depending on availability of published matrix mo
```

```r
n_pine <- c("n_1","n_2","n_3") # Initial population size

A_pine <- as.matrix(0.5, 1, 4,
                    0.3, 0, 0,
                    0, 0.5, 0,
                    0,  0, 0.8) # Matrix model with 3 stage classes

# Can use this type of model to make state predictions about demographic structure of population & esti
```

3. Model of forest volume burned

- Lumped
- Static
- Deterministic
- Physically-based

```r
# Variables
n_pine <- c("n_1","n_2","n_3")
fire_severity <- c("low","medium","high")
prob_fire <- 0.3

# Parameters
dbh_1 = 10 # DBH as defined by stages in matrix population model
dbh_2 = 20
dbh_3 = 30
H = 10 # Height at each stage
b_0 = 0.1 # Tree specific volume coefficient
b_1 = 2 # Tree specific volume coefficient - Cylinder factor form ratio

# Combined variable model -- Commonly used by the U.S. Forest Service
forest_biomass <- b_0 + b_1*dbh_1^2*H

# volume_burned <- forest_biomass*prob_fire*fire_severity
# Conversion of volume burned to a volume of carbon
```

Bringing it all together

$$Change\ in\ carbon\ sequestration\ due\ to\ bark\ beetle\ and\ climate\ impact = NPP - carbon\ released\ during\ forest\ fire$$

Estimating the combined effect of bark beetle and climate change on forest carbon sequestration