Data Meagre Models: The Case of Flooded Vegetation in the Amazons

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Outline

1 The Environmental System
   - Flooded Regions
   - Germination and vegetation growth
   - Model Data

2 The models
   - The model $M_1$
   - Numerical results $M_1$
   - The model $M_2$
   - Numerical results $M_2$

3 Considerations about the models
The Environmental System

1. Flooded Regions
2. Germination and vegetation growth
3. Model Data

2. The models
   1. The model $M_1$
   2. Numerical results $M_1$
   3. The model $M_2$
   4. Numerical results $M_2$

3. Considerations about the models
Tropical forests have distinctive layers of vegetation, which elements belong to species that are characterized by the mean height of their adult individuals.

Tropical forests are also dynamic and variagated entities, possessing different ecosystems in distinct stages of maturation.

The Amazon Forest distinguishes itself by the annual flood, that is considered as the most important factor affecting plant settlement.
The Flood

The annual variation of rivers height that distinguishes the Amazon Forest floods part of its area.

Flooded Regions

- The annual flood of the várzeas depend on climate and the variation between high and low waters height may reach 18m.
- According to the latest estimates, the extension of the annually flooded lands is around 20% of the total landscape area.
- Trees of some species may stay with the roots and the lower trunk submersed for up to 7 months per year.

Figura: Image: www.google.com
Trees of the same species have quite different growth rates at distinct levels of inundation.

The annual flood not only varies the density of tree populations, but also affects their life cycle and trophic relations.

The species present in flooded areas vary according to soil humidity and the submersion time, showing generally a good adaptation to the flood sazonality.

**Figura:** Image: www.google.com
For some species, the mortality varies is high, varying from 70% to 90% after being inundated for 12 weeks.

**Figura:** Image: www.google.com
Germination and vegetation growth

- Trees of some species release their seeds during the terrestrial phase but, for the majority of species, seeds are released during the higher waters period.
- Floating or submerged seeds may be transported far away by rivers’ currents.
- The contact of seeds with the water favors germination because the water induces the penetration of oxygen in the seeds and allow for nutrients to be transferred to all its parts.
- Light incidence affects the time till germination and vegetation dynamics.
- In *terra firme* forests the time needed for a plant to attain canopy condition is of the order of years for pioneer trees and of decades for species of the climax stage.
- A great variety of complex process is occurring simultaneously.
Germination and vegetation growth

**Figura:** a) *Pseudobombax munguba* trees during aquatic phase; b) branch close-up: open fruit spreading seeds; c) ripe closed fruits; d) floating tuft of seed cotton (kapok) drifting over water; e) seed cotton amid aquatic macrophytes. Image: M. T. F. Piedade.
About the employed data

- Information about germination and tree growth in flooded areas are deficient.
- Gathering data in flooded regions is difficult due to severe access constrains.
- Data is mostly gathered in regions that remain flooded for short periods.
- Some data were obtained in casas de vegetação, artificial settings that emulate forest conditions.
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The model $M_1$

The model considers a two dimensional region subdivided into cells.

The model considers Moore type neighborhoods.

The state updates used in these cells is homogeneous and all the cells use the same update rules.
Growth Stages

1. Germinating-seeds represent the seeds that had been dispersed and germinated but not yet established;
2. Young-trees represent plants that had been established until growth trees and are still incapable of producing seeds;
3. Mature-trees represent the trees that are capable of producing seeds.
Transition hypothesis

1. The transition from the young-trees stage to the mature-trees stage occurs once a years in average for each individual.
2. We initially consider that germinating-seeds become young-trees if they do not die.
3. Germinating-seeds take only one time step to grow, to establish and to become young-trees,
4. The mature-trees produce seeds once each year.
Correction Factor

The correction factor represents the mean time that an young-tree takes to became a mature-tree. The $a$ time lag is introduced in the model as a correction factor applied to the transition between the young-trees and mature-trees stage at each iteration.
Seed distribution

Let $A$ and $B$ be distinct points of co-ordinates $(i, j)$ and $(a, b)$, in a region that contains initially only one mature tree. Let:

- $d_{ij}$ is the distance between $A$ and $B$;
- $p_{ij}$ is the probability of a seed from the mature tree at point $A$ falls at $B$;

$$p_{ij} = \alpha e^{-d_{ij}},$$

Adding the probabilities of a seed falling at $B$ in all cells of the neighborhood $\Omega_\beta$ of $A$, we have:

$$\sum_{l=g}^{h} \sum_{k=r}^{s} \alpha e^{-d_{lk}} = 1,$$

where $g = \max\{1, i - alc\}$, $h = \min\{alc + i, n\}$, $r = \max\{1, j - alc\}$, $s = \min\{alc + j, n\}$ and $n$ is the matrix dimension of the cellular space.
Seed production and distribution

Then, if

$$\alpha = \frac{1}{h \sum_{s} \sum_{l=g}^{h} e^{-d_{lk}}},$$

$$\sum_{l=g}^{h} \sum_{k=r}^{s} e^{-d_{lk}},$$

the probability that a seed will fall at point $B$ in the neighborhood $\Omega_\beta$ of a mature tree at $A$ is:

$$p_{ij} = \frac{e^{-d_{ij}}}{h \sum_{s} \sum_{l=g}^{h} e^{-d_{lk}}},$$

$$\sum_{l=g}^{h} \sum_{k=r}^{s} e^{-d_{lk}}.$$
Numerical results $M_1$

$\mu_n = 10\%$

$\mu_n = 40\%$

$\mu_n = 80\%$
Numerical results of $M_1$

**Tabela:** Mortality by natural factors variation

<table>
<thead>
<tr>
<th>Variation of mortalities by natural factors $\mu_n$</th>
<th>$T_1$</th>
<th>$T_2$</th>
<th>$T_3$</th>
<th>...</th>
<th>$T_{30}$</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_n$</td>
<td>$T_1$</td>
<td>$T_2$</td>
<td>$T_3$</td>
<td>...</td>
<td>$T_{30}$</td>
<td>Mean</td>
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<tr>
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<td>129</td>
<td>119</td>
<td>...</td>
<td>166</td>
<td>156.3667</td>
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</tbody>
</table>
Numerical results of $M_1$

a) $\mu_n = 10\%$.

b) $\mu_n = 40\%$.

c) $\mu_n = 80\%$.

Figura: Variability of results of the parameter set $S_3$
The model $M_2$

The model introduces the influence of flood gradient in mature trees mortality.
Consider water column high variation $h_{inund.}$:

$$h_{inund.} = h_{max} - k_1(x - a)^2 + k_2(y - b)^2. \tag{5}$$

where $h_{max} = 10 \text{ m}$ is the maximum high of water column and $a, b, k_1, k_2 \in \mathbb{R}$.

Moreover, let
- $\mu_n$ is the mortality by natural factors;
- $\mu_I$ is the flood pulse influence in the mortality.

Then, germinating seeds mortality $\mu_{gs}$ is given by

$$\mu_{gs} = \mu_n + \mu_I \frac{h_{inund.}}{h_{max}}. \tag{6}$$
The model $M_2$

- $\mu_L$ is the term that represents the mortality by competition between mature trees and young trees;
- $q_m$ is the amount of mature trees in a neighborhood of the cell space;
- $alc_L$ is the radius of the region where competition between mature trees and young trees occurs.

The mortality of young trees is given by the competition function:

$$\mu_y = \mu_n + \mu_L (1 - \mu_{gs}) \left( \frac{q_m}{(2alc_L + 1)^2} \right).$$

(7)
Numerical results $M_2$

\[ \mu_n = 10\% \quad \mu_n = 40\% \quad \mu_n = 80\% \]
Numerical results $M_2$

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<th>$T_{30}$</th>
<th>Mean</th>
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<tbody>
<tr>
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<td>24</td>
<td>...</td>
<td>42</td>
<td>34</td>
</tr>
</tbody>
</table>
The models | Numerical results $M_2$

**Numerical results of $M_2$**

![Graph](image1.png)

**a)** $\mu_n = 10\%$.

![Graph](image2.png)

**b)** $\mu_n = 40\%$.

![Graph](image3.png)

**c)** $\mu_n = 80\%$.
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3. Considerations about the models
Considerations about the models

1. The flood effect is considered only implicitly, by the hypotheses adopted and the data used.

2. Includes the density population effect

3. A more direct treatment of flood effects, including the region topography and the time that the vegetation remains submersed would be of great utility and would help to study the influence of the flood gradient in the growth of the trees and changes in the population.

4. A more direct treatment of flood effects will facilitate the study of species distribution along different flood gradients.
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2. Maria Teresa F. Piedade;
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4. Astrid Wittmann;
5. Auristela Conserva;
6. Cezar Welter.
The parameter \( alc \) represents the neighborhood size of dispersion seeds.
Considerations about the models

100 years, $\mu_n = 10\%$, alc=7

100 years, $\mu_n = 80\%$, alc=7

20 years, $\mu_n = 10\%$, alc=5, ci=01

20 years, $\mu_n = 10\%$, alc=5, ci=12