Climate Sensitive Ingrowth Based on Swiss National Forest Inventory Data

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Research Context

Forests provide a wide range of ecosystem services, such as carbon sequestration, promoting biodiversity, protection against natural hazards, wood supply, space for recreation, etc. Climate change threatens forests' health and therewith its various services. Hence, it is paramount to investigate climate-adaptive management strategies to mitigate climate-change effects. Using data from the Swiss National Forest Inventory (NFI), the forest model MASSIMO is used to simulate the effects of different management strategies considering various climate scenarios. Among MASSIMO's ecological and economic modeled processes, ingrowth determines part of the future forest species composition.

This project aims at (1) statistically modeling attributes driving ingrowth and (2) developing an adaptive plantation module.

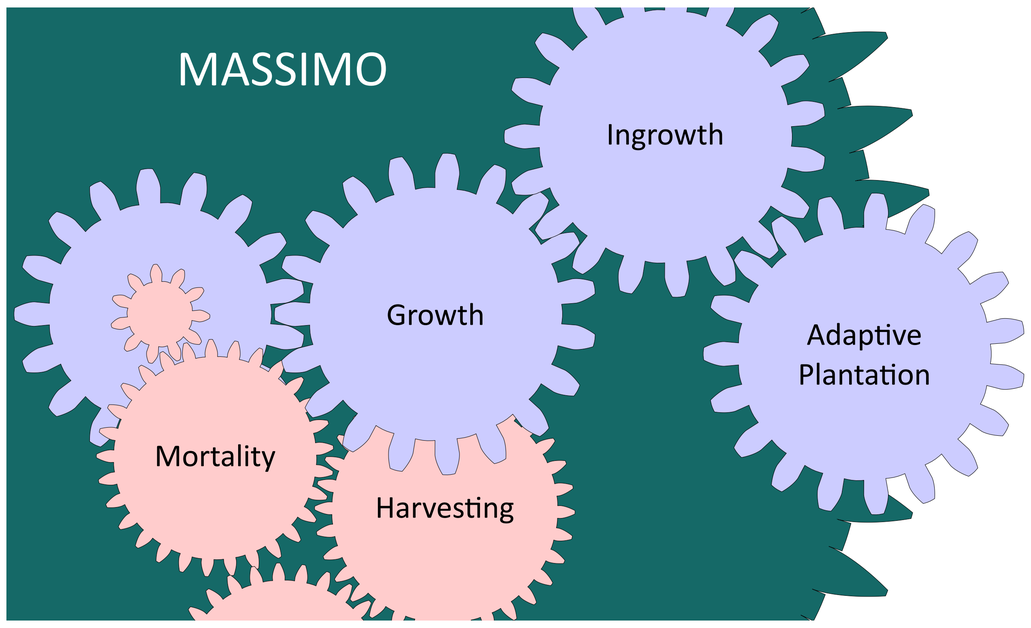

Figure 1: Conceptual simulation-gears from the Management Scenario SImulation MOdel (MASSIMO).

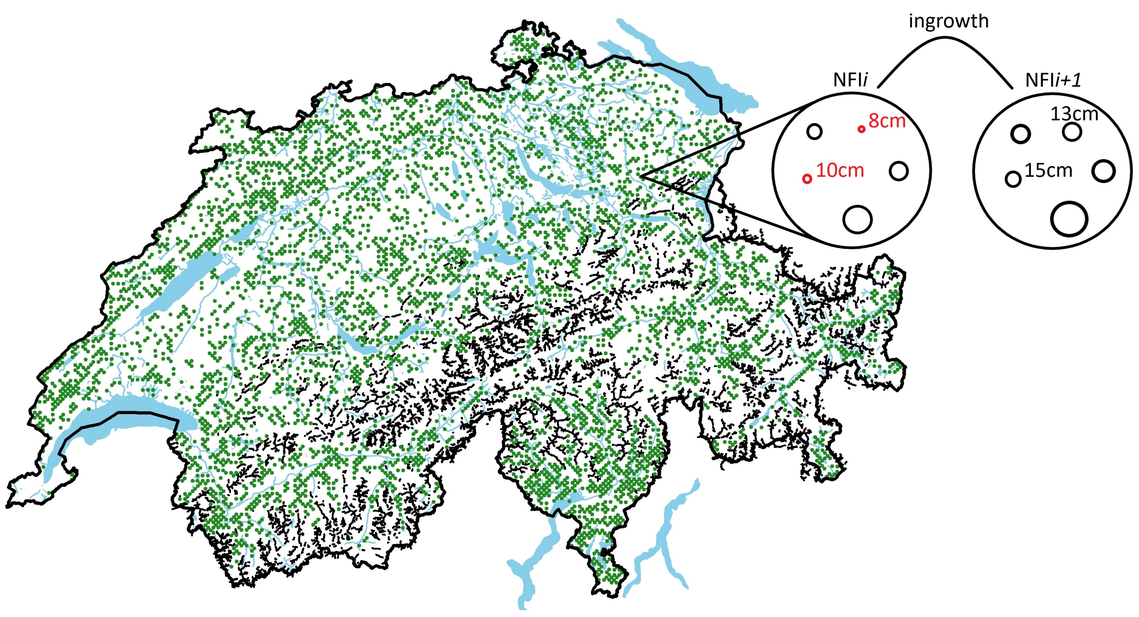

Figure 2: Ingrowth measurements in Swiss national forest inventory plots.

Data

Climate effects e.g. temperature, precipitation, radiation, n-deposition.

Stand-level characteristics e.g. number of stems per ha (nph), basal area per ha, site-type (timber, pole, selection, coppice, regeneration), dominant species, beers aspect.

Soil effects e.g. carbon-, pH-, sand-, clay-, gravel-content.

Previous stand-state e.g. number of vegetation years since NFIi ($nvegper$), number of ingrowth between NFIi-1 and NFIi.

Anthropogenic effects e.g. public or private forest owner.

Tree species douglas fir, fir, pine, spruce, stone pine, other conifers, ash, beech, chestnut, larch, maple, oak & other broadleaves.

Ingrowth

We investigate three different aspects of ingrowth

- the **number of ingrown trees** per plot between two consecutive NFIs (ni), i.e. between NFIi and NFIi+1. In the context of Swiss NFIs, a stem is considered as ingrowth if it has at least $12cm$ dbh (caliper threshold).
- the **species** of the ingrowth trees (s).
- the **diameter at breast height** of the ingrowth trees (dbh) in centimeters.

Statistical Models for

Number of ingrowth trees (ni) a zero inflated Poisson model. With probability p it is 0 and with $p-1$ it follows the Poisson random variable Y_i for $i \in \{1, \dots, n\}$, where n is the number of plots over all NFI's:

$$Y_i = \begin{cases} 0 & \text{with probability } p + (1-p)\exp(-\lambda) \\ k & \text{with probability } (1-p)\dfrac{\lambda^k \exp(-\lambda)}{k!} \end{cases} \qquad \text{for } k \in \mathbb{N}^+.$$

Species of ingrowth trees using a multinomial regression model for thirteen tree species categories.

Diameter at breast height per species and ingrowth trees using maximum likelihood estimates of a Weibull probability density function (f_W).

$$\ell_s(x_{1:n} - 12; \rho, \lambda) = \sum_{i=1}^{n} \log(f_W(x_i - 12; \rho, \lambda).$$

Such that ρ and λ are reparametrized by $\rho = \exp(\boldsymbol{\alpha X})$ and $\lambda = \exp(\boldsymbol{\beta X})$, where the design matrix $\boldsymbol{X}$ contains explanatory variables.

Preliminary Results

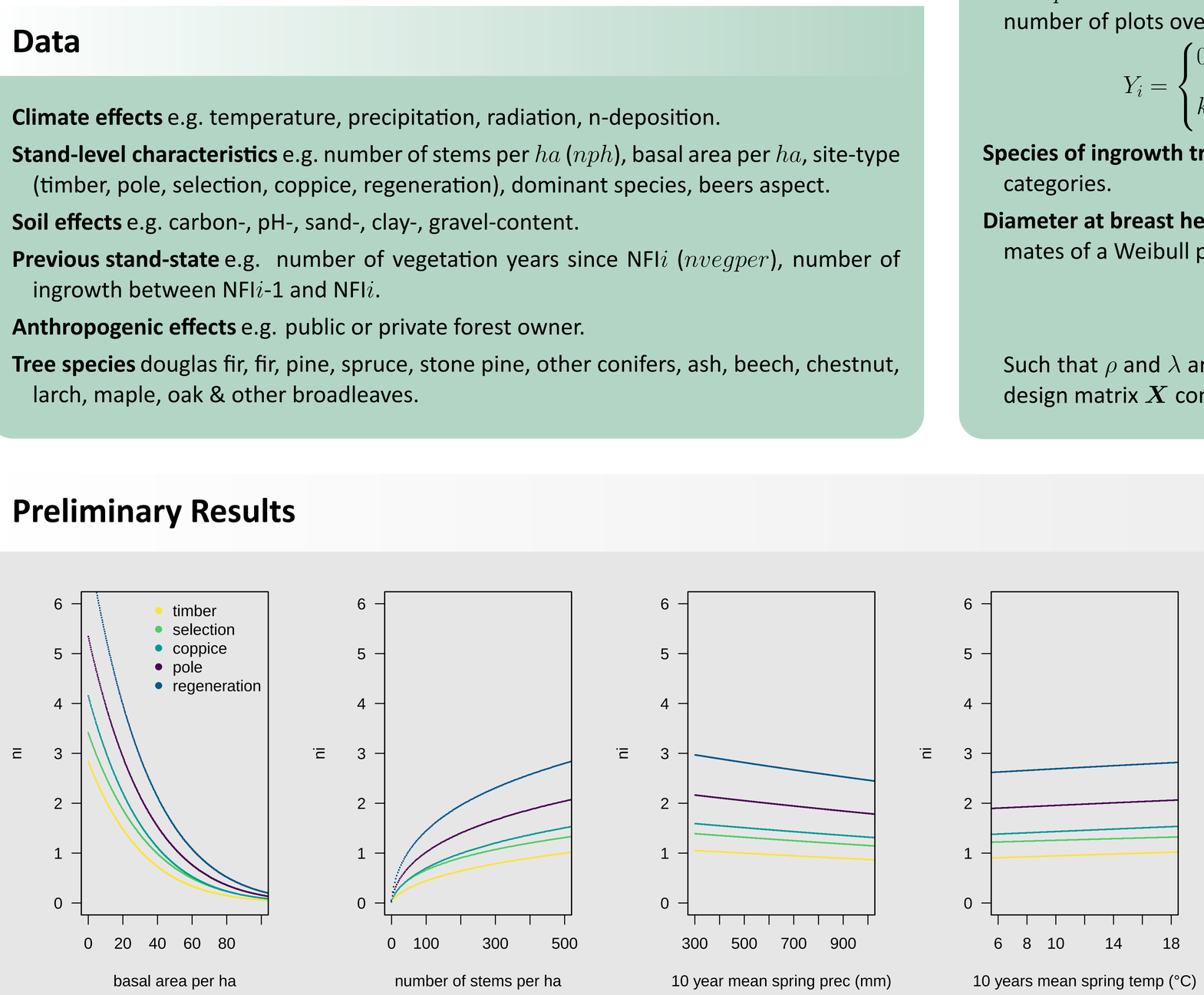

Figure 3: Effects on number of ingrowth trees per plot of: basal area per ha, ten year average of mean spring precipitation, ten year average of mean spring temperature, number of stems per ha; stratified by different site-types. In general, the number of ingrowth trees is higher in young site-types and the higher the basal area per hectar, the lower the ingrowth. Dryer and warmer growth conditions in spring also lead to higher ingrowth.

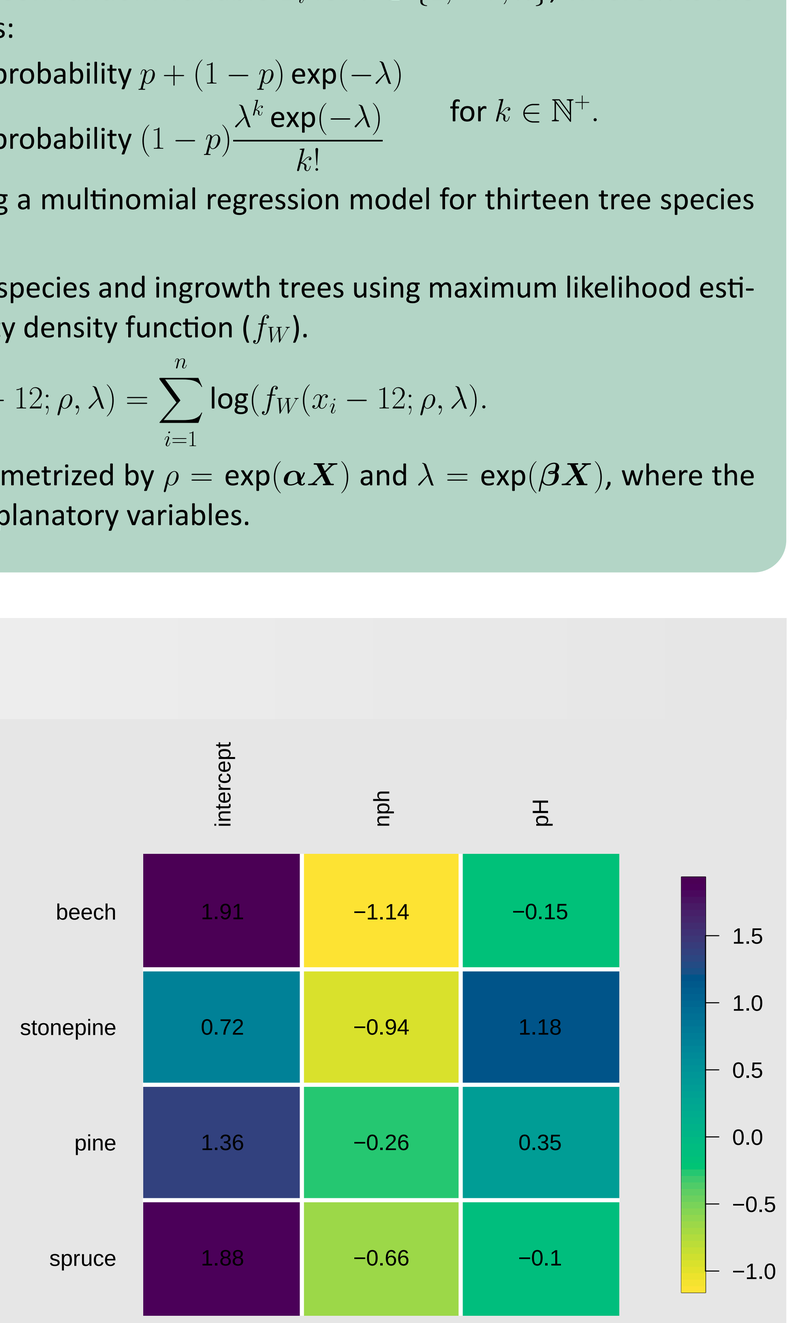

Figure 4: Effects of different variables on dbh of ingrowth trees for different species. The effect directions and values show how the dbh of the average ingrowth of the respective species are associated with the different variables.