Developing regional G4M model to support wildlife management in Sweden

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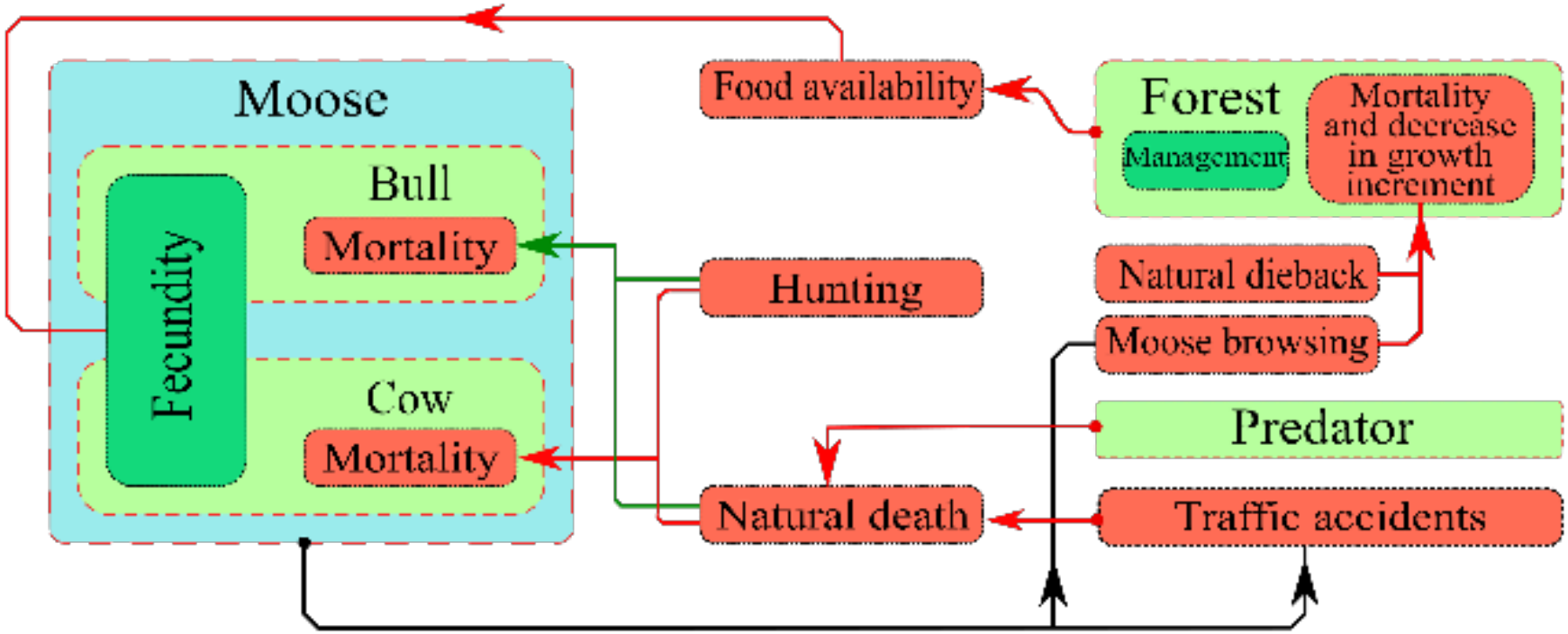
Main goals

To develop modeling framework including

- spatial forest dynamics
- moose dynamics
- linkage of moose population with forest growth

Scheme of the model dynamics



Moose dynamics

Let $j = 0, \ldots, A_\dagger$, $n = 0, \ldots, N$, where $N, A_\dagger \in \mathbb{N}$.
Here n – time period, j – age group.
$M_c(n, j)$ – number of cows in period n, j's age group.
$M_b(n, j)$ – number of bulls in period n, j's age group.
Discrete-time dynamics of **cow**:

$$M_c(n+1, j+1) = M_c(n, j) - \mu_c(n, j) M_c(n, j),$$

$$\{\text{num. of c. in period } n+1\} = \{\text{num. of c. in period } n\} - \{\text{num. of dead c. in period } n\}$$

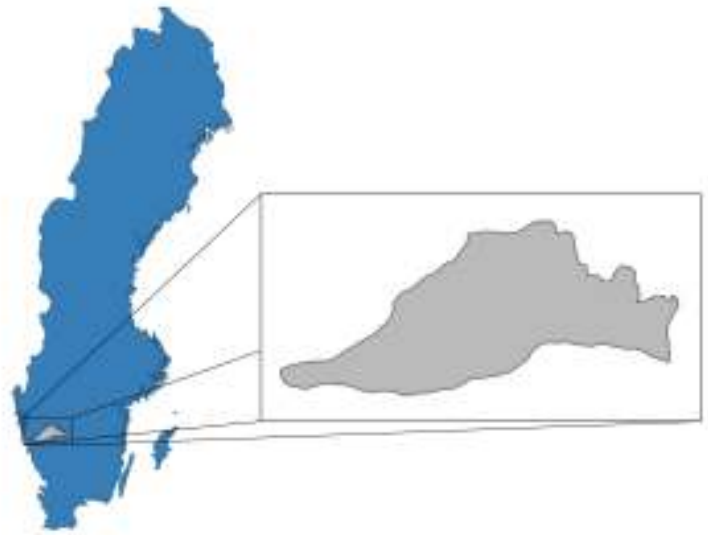
$$M_c(n+1, 0) = \sum_{i=1}^{A_\dagger} (\mathrm{P}_c(M_c(n, i), M_b(n, i)) \cdot \mathrm{fec}_c(\text{Forage}, i))$$

$$\{\text{num. of c. born at period } n+1\} = \{\text{pairing function}\} \cdot \{\text{fec. rate of cow}\}.$$

$M_c(0, j) = M_c^0(j)$ — initial distribution of c.

Bull dynamics is described by analogy.

Initial data for Swedish forest



SLU Forest Map with 25×25 m^2 resolution
A shape for the County of Västra Götaland.
Dimension is 2339416 rows x 13 columns
Number of cells is 2682

	Area_ha	age	birch_vol	biomassl	deciduous_vol	ID_Grid	height	oak_vol	pine_vol	spruce_vol	total_vol
0	0.0625	16	4	11	2	2	3	4	5	0	15
1	0.0625	15	3	11	0	2	2	4	8	0	15
2	0.0625	20	15	43	24	2	4	0	6	12	57
3	0.0625	31	34	51	0	2	7	0	18	15	67
4	0.0625	68	45	144	0	2	15	0	87	72	204

Each grid cell contains five species: birch, deciduous, oak, pine, spruce.

Data prerpocessing

- For each grid cell and each species the dominant height, growth curves and site index were identified

To fit the height (total volume and growing stock) curves we used the following model:

$$X^i = c_1^i \left(1 - \exp\left(-c_2^i \cdot \text{Age}\right)\right)^{c_3^i} \tag{1}$$

where

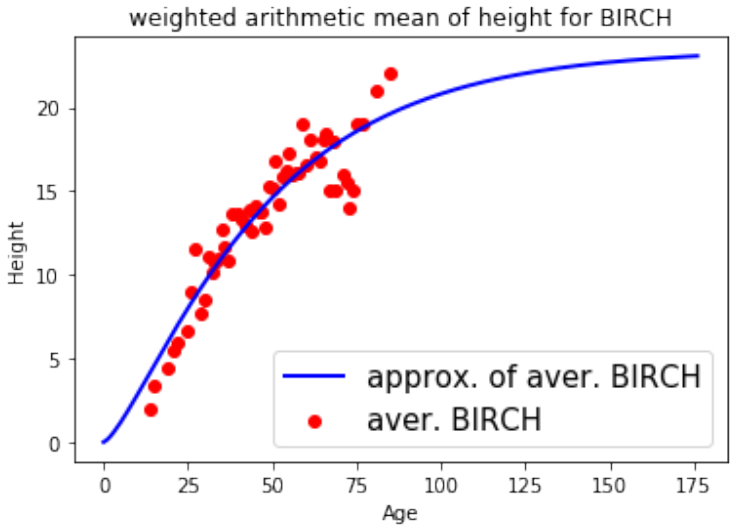
$$\begin{cases} c_1^i = C_{11}^i + C_{12}^i \cdot \text{SI} + C_{13}^i \cdot \text{SI}^2 \\ c_2^i = C_{21}^i + C_{22}^i \cdot \text{SI} + C_{23}^i \cdot \text{SI}^2 \\ c_3^i = C_{31}^i + C_{32}^i \cdot \text{SI} + C_{33}^i \cdot \text{SI}^2 \end{cases}$$

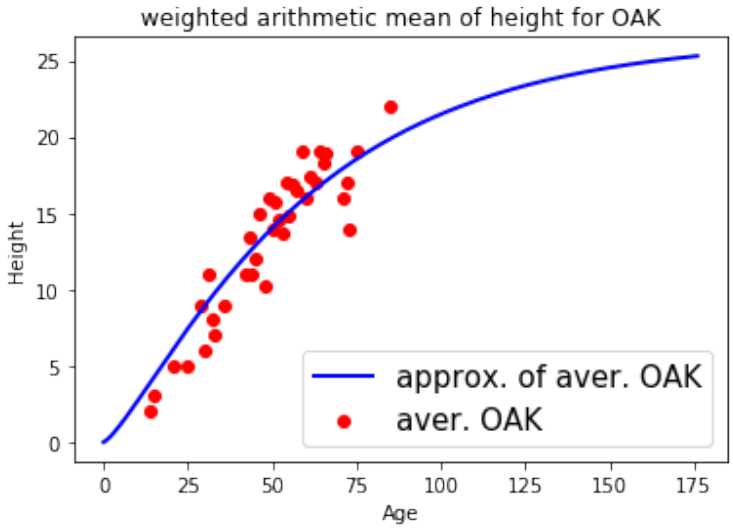
Here X_i is height for $(i = 1)$, growing stock for $(i = 2)$ and total volume for $(i = 3)$; SI is site index. Coefficients C_{jk}^i are taken from Shvidenko et al. "Tables and Models of Growth and Productivity of Forests for Major Species of Northern Eurasia", 2008.

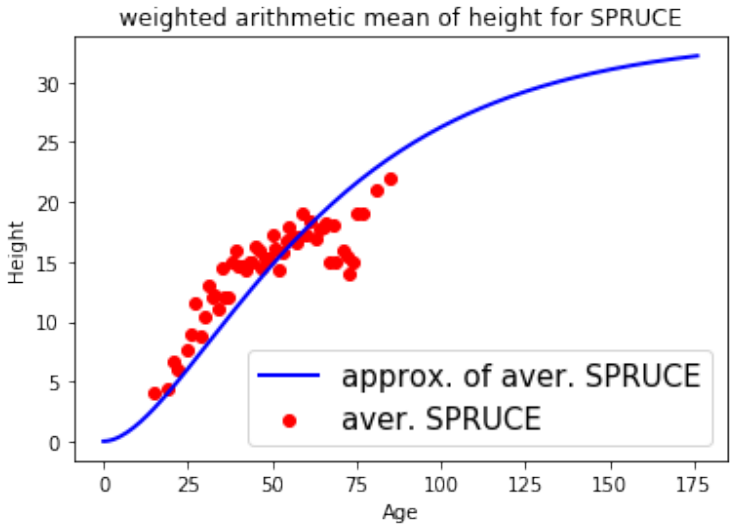
- Constructed curves allowed to model spatial forest dynamics at 25 m^2 resolution

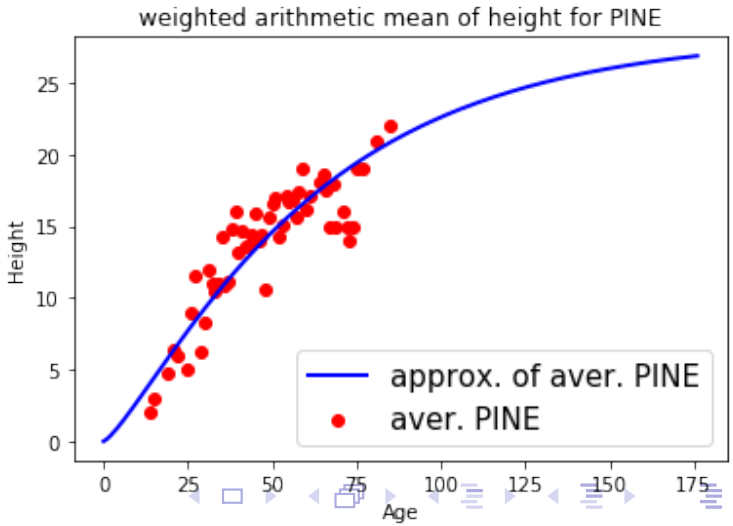
Calibration

Cell with id=2. The cell contains the following species: oak (SI_{oak}=3.94), birch (SI_{birch}=3.14), spruce (SI_{spruce}=2.67) and pine (SI_{pine}=3.61).









Productivity of real (non full stocked) forest

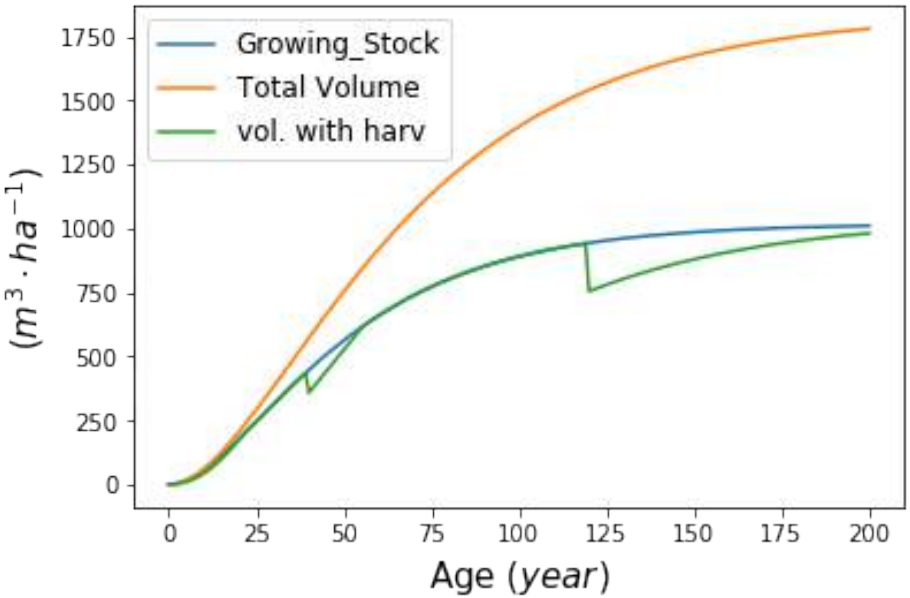


Figure: harv. = 20 perc.

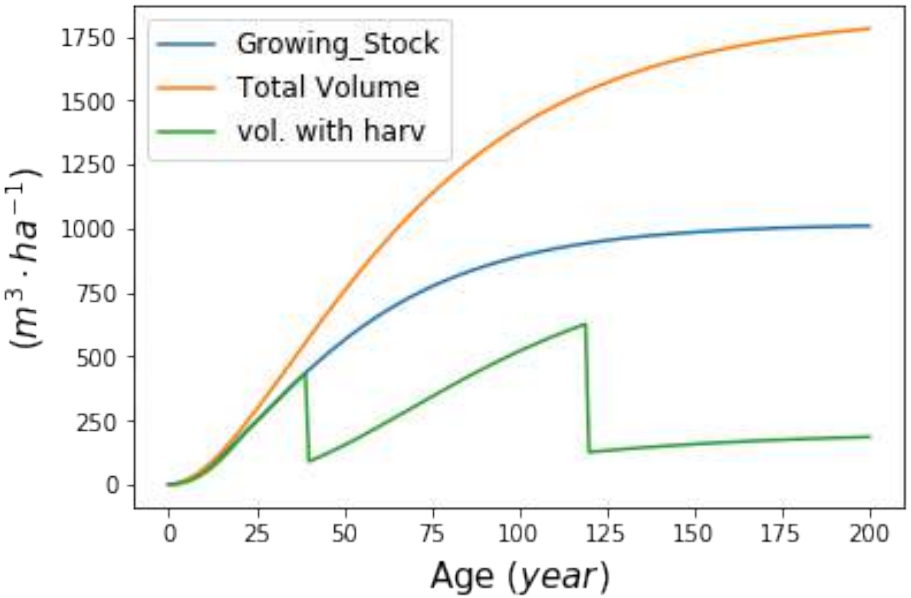
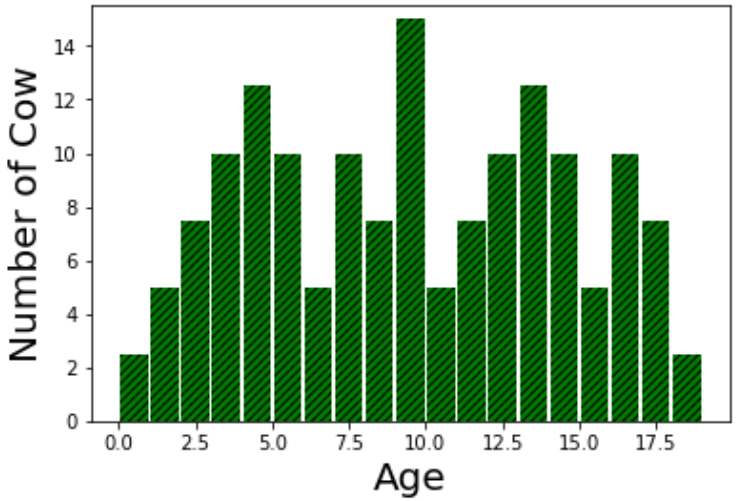


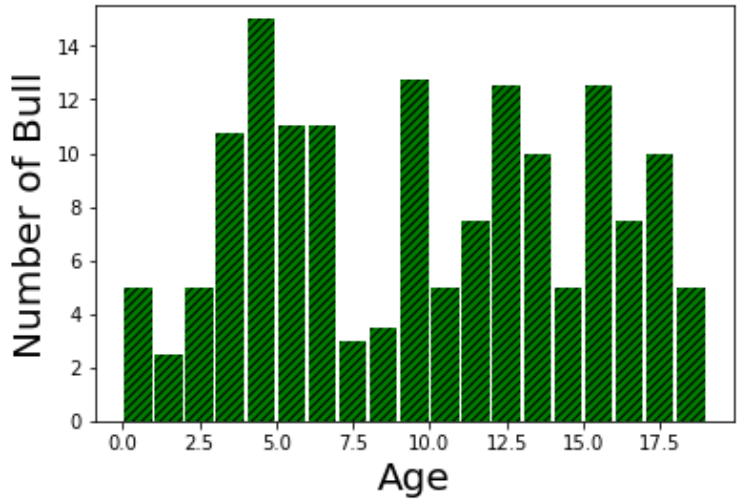
Figure: harv. = 80 perc.

To model productivity of real (non full stocked) forest we used Gerkhard's equation.

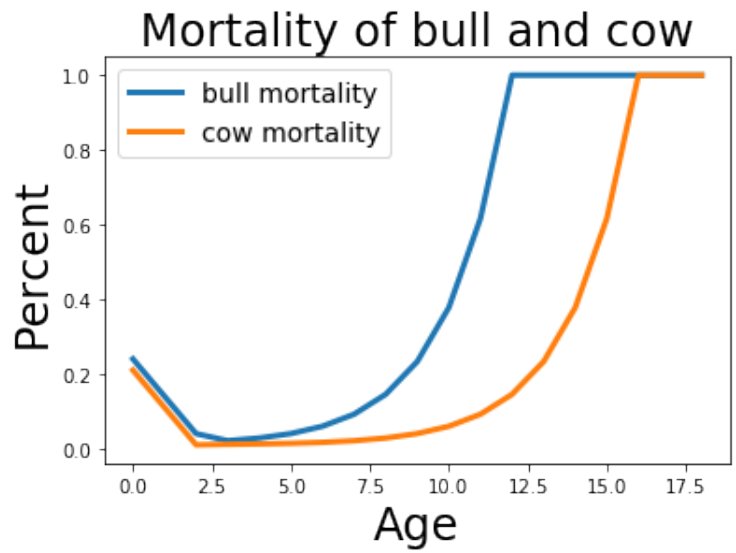
Setup for moose model

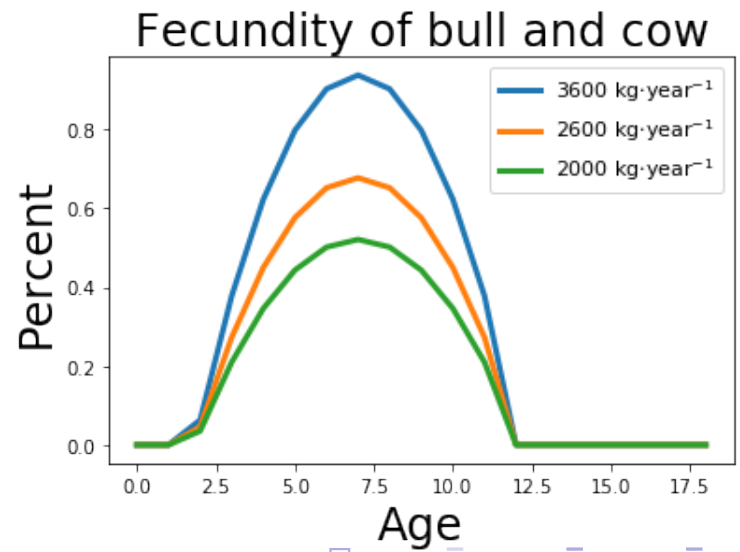
Initial distributions of moose population was taken randomly





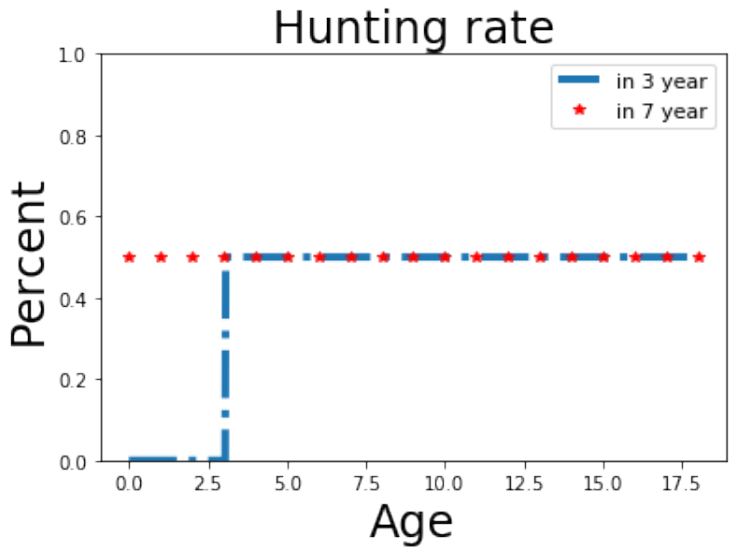
Characteristics of moose





Example 1 (Hunting!)

- Time horizon = 10 years.
- Forage comprises two type:
  type 1 biomass of trees up to 3 m height;
  type 2 biomass of trees from 3 up to 6 m height;
- 3600 kg of forage per year is normal intake of moose.
- Hunting:



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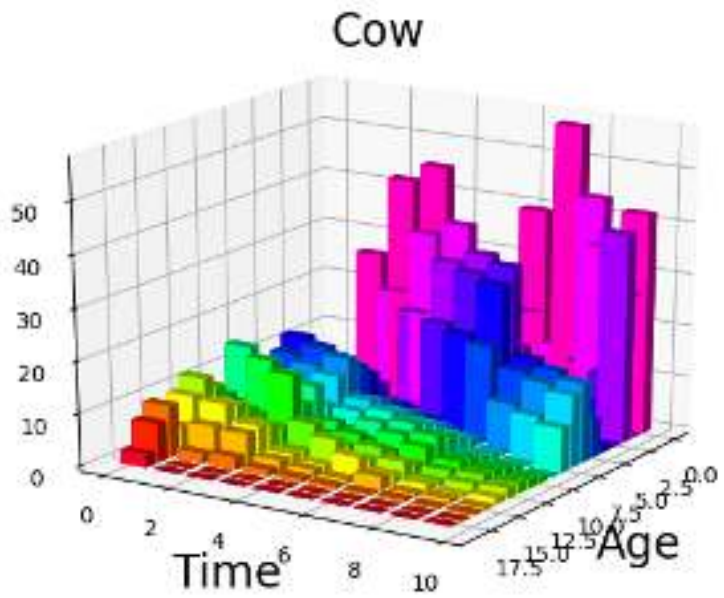
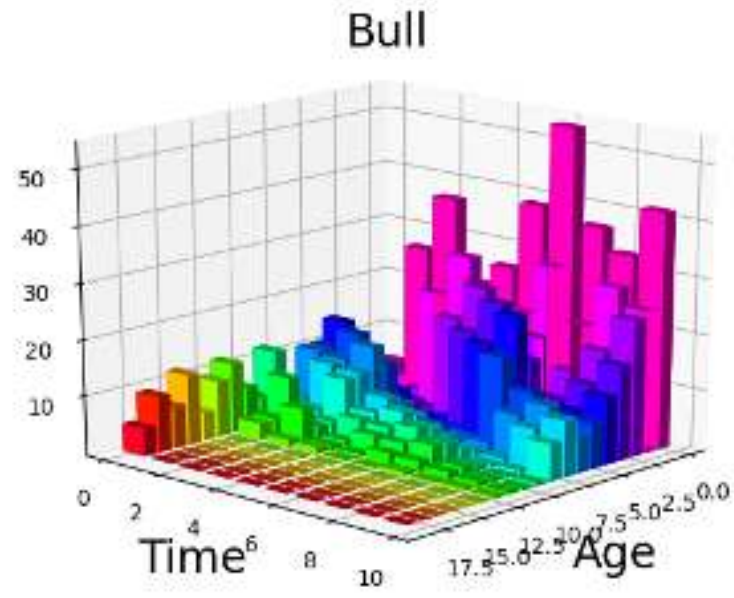
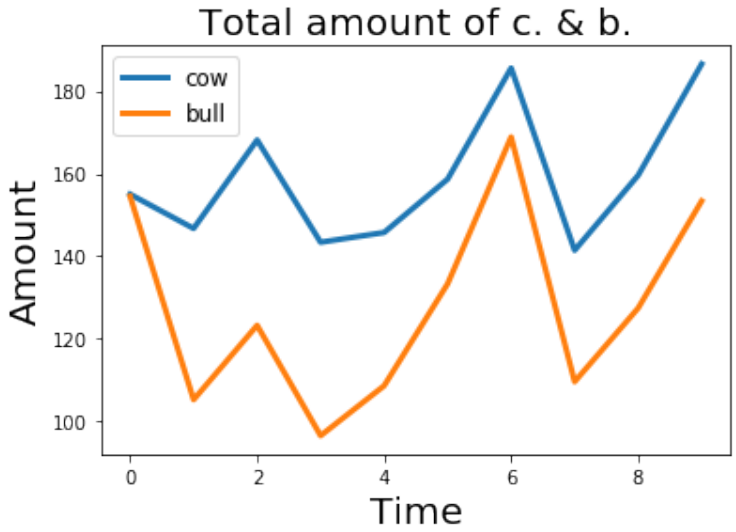
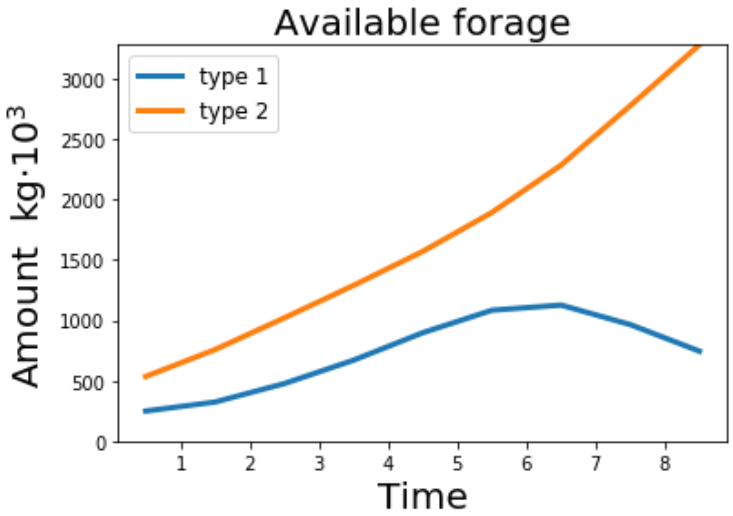


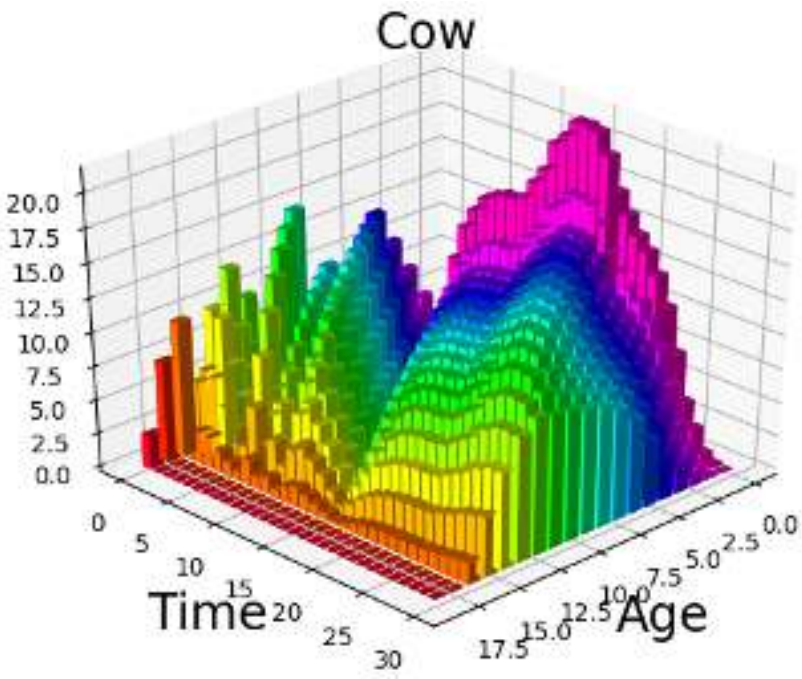


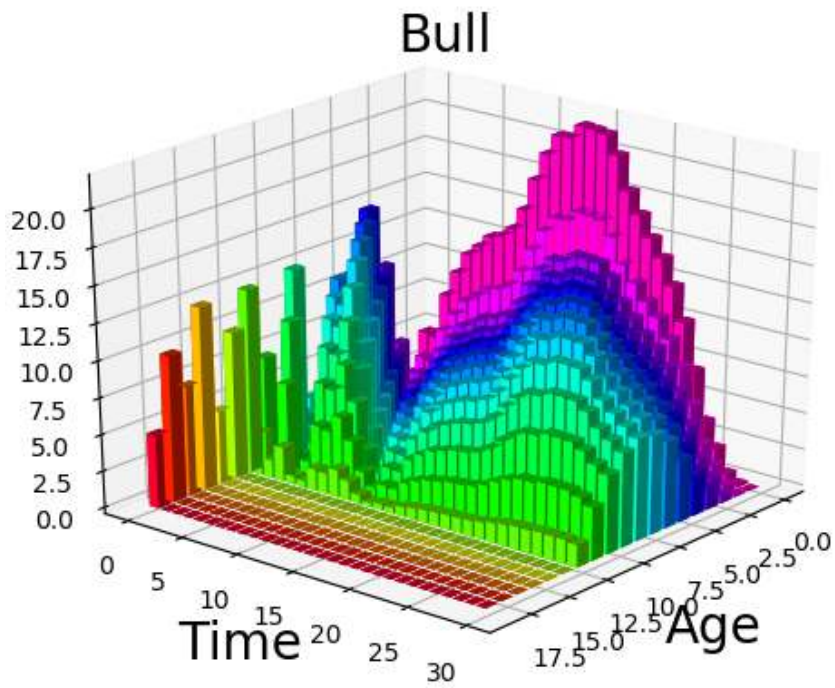




Example 2 (Lack of forage)

- No hunting
- 50 grid cells
- Time horizont = 30 years





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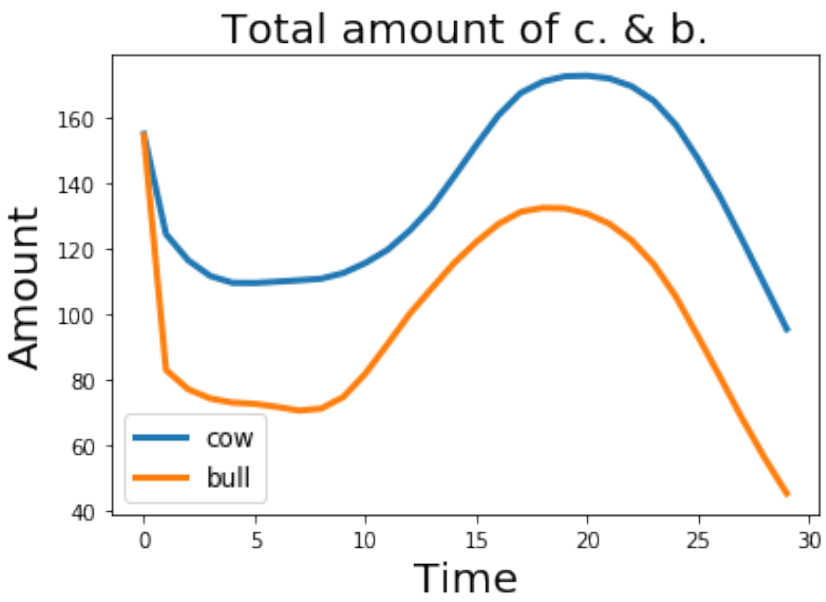
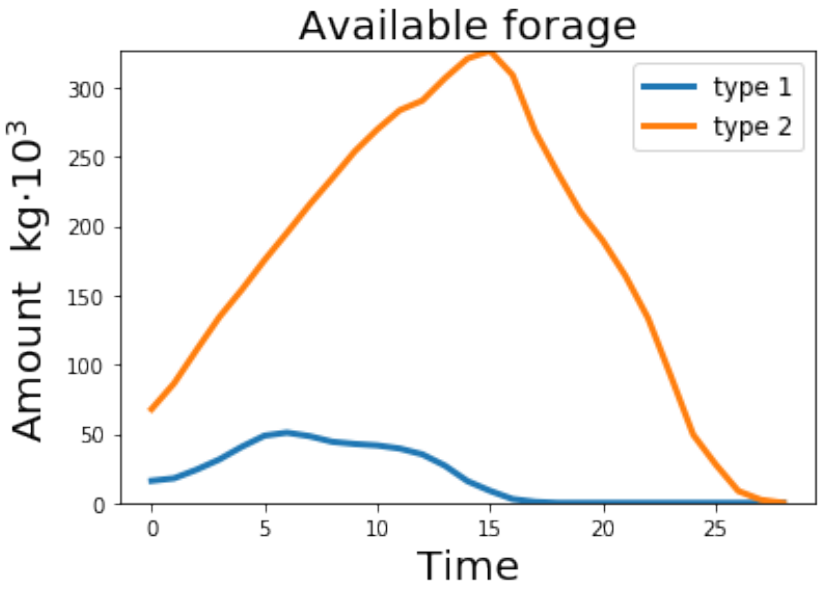


Decline of total moose amount is caused by decrease of forage.



type 1: forage obtained from trees up to 3 m height.

type 2: forage obtained from trees from 3 m and up to 6 m height.

Further modification of model and researches

- Calibration of functions modeling forage and damage from browsing
- Spatial statistics on traffic accidents in the region
- Economic assessments of different scenarios for moose and forest management

Thank you for your attention!

Any questions?