GROWTH-RATE OF PERENNIAL SPECIES AND SUSTAINABLE SUPPLY OF BIOMASS

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The limits of available land area require paying attention to optimization of sustainable supply of biomass to substitute the fossil resources by materials and goods from natural renewable supplies of wood and other biomass. Attempts are made to assess conditions for efficient sustainable annual supply of wood biomass minimizing the required land area.

The model of growth-rate

Available experimental data available experimental data on the rates of growth of grey alder (Alnus incana) [1] reveal a substantial increase of the annual increment of biomass up to certain age before reaching a maximum or starting to slow down (Figure 1).

Assuming a linear decrease with time of the annual biomass increment after reaching the maximum the amount of accumulated biomass (the stock) at cutting age xo can be presented as

\[ S(x_0) = S + \int_1^x y(x)dx = S + \frac{x_o - l}{2}[2b + a(x_o + l)] \]  

where \( S \) is stock at the age of maximum growth-rate \( x = 1 \), \( a \) and \( b \) – constants defining the growth-rate \( y(x) \) at time \( x \geq 1 \), it is – after reaching the maximum annual increment:

\[ y(x) = b + a \cdot x \]  

Fig. 1. Diagram of 5-year increments of stock in grey alder growths from experimental data [1]. The average annual increment over 5 years is assumed as the actual growth-rate at midway of the relevant period.

Constant \( b \) is related to constant \( a \) by normalizing the age with respect to the age at maximum growth-rate (which is 10 years in case of grey alder):

\[ b = 1 - a \]

Normalization the stock with respect to the amount accumulated at constant growth-rate \( y = 1 \) by the age accepted as unit, stock \( S \) in equation (1) is set to \( S = 0.5 \) meaning that biomass is stored at average constant rate between \( y = 0 \) and \( y = 1 \).

Results

For sustainable annual supply of a certain amount biomass the total area under growth would be proportional to cutting age and to reciprocal of the stock (biomass per unit area) at the cutting age. In terms of normalized stock and with account of (2) it is presented by:

\[ A(x_o) = const \frac{x_o}{a x_o^2 + 2(l-a)x_o -(l-a)} \]  

wherefrom the minimum of required total area for sustainable annual supply of biomass is attained at cutting age determined by

\[ x_o = \sqrt[3]{\frac{l-a}{a}} \]  

As seen from (4), the function \( A(x_o) \) has a real minimum only under condition of growth-rate declining after reaching the maximum, it is – at negative values of \( a < 0 \). At \( a = -0.5 \) the optimum cutting age of grey alder would be 18 years with annual supply of wood biomass from 120 to 200 m³/ha depending on the site quality.

References