Příloha 6

Globální model tvaru kmene pro hlavní dřeviny ČR
IFER 2010 (interní materiál, připravuje se k tisku)
(popis způsobu implementace modelu a parametry modelu)

## Stem profile model

For the modeling of stem profile of individual trees the exponential model of Riemer et al. (1995) was used:

$$d_h = 2\left(\frac{i}{1-e^{q(1.3-H)}} + \left(\frac{d_{1.3}}{2} - i\right)\left(1 - \frac{1}{1-e^{p(1.3-H)}}\right) + \frac{\left(\frac{d_{1.3}}{2} - i\right)e^{1.3p}}{1-e^{p(1.3-H)}}e^{-ph} - \frac{ie^{-qH}}{1-e^{q(1.3-H)}}e^{qh}\right) \quad \text{(Eq. 1)}$$

where $d_h$ – stem diameter at height h

*H* – total height

$d_{1.3}$ – diameter at breast height

*i, p, q* – model parameters

This model is very robust, can be relatively easily parameterized if required to reflect regional of site specific requirements. The model parameters have logical meaning; parameter *i* represents the common asymptote of lower and upper parts of the stem, *p* is the parameter characterizing the lower part of the stem, and *q* is the parameter characterizing the upper part of the stem. In contrast to various other models this model is flexible and able to describe very different types of tree shapes (Cerny 1997, unpublished report for the Czech State Forests).

Initially, the model was parameterized individually for each of the 38 391 sample stems using the non-linear least squares method. This procedure resulted in the set of parameters of stem profile (Eq. 1) for every sample tree.

A species specific generalization of the model was then carried out by relating stem profile parameters to the basic dendrometric characteristics used in forestry practice:

$$i = p_1 d_{1.3}^{p_2} H^{p_3} \quad \text{(Eq. 2)}$$

$$q = p_1 d_{1.3}^{p_2} H^{p_3} \quad \text{(Eq. 3)}$$

Parameter *p* does not have a clear relation to the basic dendrometric characteristics and therefore it was modeled indirectly by the diameter at stump height ($d_{stump}$):

$$d_{stump} = p_1 d_{1.3}^{p_2} \quad \text{(Eq. 4)}$$

By default the stump height was assumed to be 1 % of the tree height.

The parameterization of the above models (Eqs. 2, 3, 4) was carried out using the non-linear least squares method. The empirical data were originally collected for other purposes than modeling covered by this study. Therefore, instead of there being a normal distribution of diameter classes, the data reflected more typical diameter distributions of forest stands where there is a larger proportion of smaller trees. In order to ensure a proper behavior of resulting models for all tree sizes, the mean values for 1 cm diameter classes were used for parameterization of the models of Eqs. 2, 3, 4. All trees with a DBH <10 cm were excluded from the parameterization for two reasons; a) these do not have well formed and well measurable stem shapes and b) pre-harvest assement are not carried out on trees with no merchantable volume . Regardless of the specific approach to parameterization, the statistical evaluation of the resulting model included the complete set of empirical data.

Additional computational effort was necessary for the calculation of parameter *p*. Among various alternatives for optimization, the following procedure represents a simple but sufficiently robust and fast approach and was therefore used in this study:

```
// first approximation of parameter p
Parameter_p = 1.6
// step of change of parameter p
Step = 16
// stem diameter [cm] at stump height calculated from stem profile model
StemDiameter = equation 1(StumpHeight, DBH, TreeHeight; Parameters i,p,q)
//sign indicating direction of current stem diameter to target stump diameter
Sign = (StumpDiameter-StemDiameter)/abs(StumpDiameter-StemDiameter)
// change parameter p until difference between calculated stem diameter [cm] and stump diameter [cm] are very close
REPEAT
 Parameter_p = max(1e-10, Parameter_p + Sign*Step)
 StemDiameter = equation 1(StumpHeight, DBH, TreeHeight; Parameters i,p,q)
 Step = Step/2
 Sign = (StumpDiameter-StemDiameter)/abs(StumpDiameter-StemDiameter)
UNTIL abs(StumpDiameter-StemDiameter)<1e-3
```

Using iterative optimization it is possible to find the value of parameter *p* which guarantees that the stem profile curve passes through the point of height and diameter of the stump.

Analogical iterative optimization can also be used for further improvement of the stem profile curve in case of availability of an extended set of dendrometric characteristics. The modeled stump diameter value can be replaced by its direct measurement. The accuracy of the upper part of the stem profile can be reasonably improved using an additional measurement of upper stem diameter. Diameter at any relative or fixed height can be used under the condition that both the diameter and height values are known. Most commonly, the upper stem diameter is taken at approximately 1/3 (from the base) of the tree height. This explanatory variable was therefore also alternatively used to parameterize the stem shape models.

Stem and partial stem volumes were calculated using a spatial finite integral of the stem profile curve. The volume of any stem segment can be calculated where the measurements from the ground of the lower and upper ends of the segment are known.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<!--
Field-Map Stem Profiler
(Global Models of Stem Profile)
Method developed by IFER - Institute of Forest Ecosystem Research Ltd.
Implemented by IFER - Monitoring and Mapping Solutions Ltd.
2008-2010
http://www.ifer.cz
http://www.field-map.com
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