***Height and Bole Volume estimation for Permanent Trees and Saplings***

*Lixi updated 10/01/2012*

# *HT estimation*

* Step1: canopy height was calculated as mean height of co-dominant trees for each plot in each census year of 1986, 1987, 1998, and 2010. Because no crown position data was collected in 1986, crown position collected in 1988 was used for 1986. And plot 16 sampled in 1987 didn’t have any co-dominant trees, so data from 1998 for plot 16 were used, in other words, plot 16 has the same canopy height in 1987 and 1998. (Be careful about 0s! there isn’t any trees with co-dominant crown position and ht recorded as 0s). Then for plants which had heights measured, if height is less than canopy height, we defined canopy level as “Below”, and if height is greater or equal to canopy height, we define canopy level as “Above”.
* Step2: canopy DBH was calculated as mean DBH (excluding 0 values) of trees at or above canopy height in each plot in each census year of 1986, 1987, 1998, and 2010.
* Step3: For trees which only had DBH but no height measured, we compare DBH with canopy DBH to decide it’s canopy position,
* Step4: Use data for plants which have both DBH and heights from different years, and fit a power function (using least square) as below for each species, elevation class, and canopy position separately to find values for the coefficients. If one plant has DBH and height data from more than one year, then only data from the first census year (when both DBH and height were greater than 0) would be included. For FAGR, PRPE, ACSP, ACSA, and ACPE, only data from L elevation were used for power function fitting (sometimes only L elevation data were available anyway).
* Step5: Then for plants which had only DBH no height measured, we use the power function and relevant coefficient to estimate heights.

## *Questions:*

* When calculate canopy height, we didn’t exclude trees which were dead in 1986 or 1987? Should we exclude them?
* The power function of fitting HT on DBH would also include 1986/1987 dead plants. Should we exclude them?
* Some 86 tagged plants, heights were first measured in 87, but in the power model fitting, they were treated as heights in 1986.
* Plants with DBH measured but height <=1.37 were excluded first, and then we decided to include them in power function fitting.
* After estimating heights, there are some plants which have decrease in heights over a period, which might lead to decrease in bole volume.
* We haven’t fixed decrease in DBH in master file, which could be the reason of decrease in bole volume too.
* For bole volume estimation, 1988 tagged saplings were excluded. They only had height measured in 1988, but we can use the HT/DBH power function derived from data in other years to estimate DBH, and then estimate bole volume basing on HT or/and DBH.

*Power function:*

*HEIGHT (m) = A \* DBH (cm) ^ B*

*A, B: coefficients, details see file “coefsDBHtoHT.csv”*

# *BV estimation*

# *1. Estimation for bigger trees.*

## *1. 1ABBA and PIRU*

ABBA with DBH greater than 1.3cm height greater than 1.3m and PIRU with DBH greater than 1.5cm and height greater than 1.3m, each tree was divided into 10 cylindrical sections, and to estimate diameter outside bark for each section, using model 2 from Kozak (2004):



d: diameter inside bark or diameter outside bark at section height (cm)

D: DBH (cm)

H: total tree height from ground (m)

h=section height from ground (m) (starting with 0 in the calculation).

z=h/H

p=1.3/H (relative breast height)

X= (1-z1/3)/(1-p1/3),

Q=1-z1/3

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | a0 | a1 | a2 | b1 | b2 | b3 | b4 | b5 | b6 |
| ABBA | 0.911 | 1.026 | -0.005 | 0.368 | -0.645 | 0.502 | 1.780 | 0.096 | -0.487 |
| PIRU | 0.940 | 0.998 | 0.010 | 0.508 | -0.636 | 0.355 | 1.687 | 0.078 | -0.242 |

Starting with height equal to 0, we will get 10 diameters from using Kozak’s equation, and the 11th would be 0. So area (m2) for each diameter calculated is:

*Area=0.00007854\*d2*

Then volume form each section was calculated with Smalian’s formula as follows:

*V= (A1+A2)\*L/2*

A1/A2:area of the small and large end of the log (m2).

L: length of the log (m).

Then the volume of each section was summed up to get a bole volume for each tree, in other words, bole volume for each tree was calculated as:

*BV= (A1+2\*A2+2\*A3+2\*A4+2\*A5+2\*A6+2\*A7+2\*A8+2\*A9+2\*A10+10)\*(H/10)/2*

## *1.2. FAGR*

No FAGR has enough height (5.28m) to use Clark’s formula, so Honer’s formula was used. The original form of Honer’s formula is:



V= Total volume in ft3

D = diameter outside bark (inches) measured at breast height (4.5 ft)

H = total height (ft)

b0 =0.959; b1=334.829 for beech.

We’ll have to convert DBH and Height, and then calculate with this equation.

To use DBH in cm and HT in m, we can use the following equation:



V: bole volume in m3

D: diameter measured at 1.3m height outside bard in cm

H: total tree height in m

A0=0.959; a1=102.056, a2=0.004334 for beech.

To convert diameter measured at 1.37 m to 1.3 m, Honer’s taper function:

*D1.37= (1-0.04365\*c1)\*D1.3*

*So D1.3=D1.37/ (1-0.04365\*c1)*

*c1=0.145 for beech.*

## *1.3. Other species*

For all species other than ABBA, PIRU, and FAGR with height bigger than or equal to 5.28m (regardless of DBH) Clark’s formula was used.

Bole volume between any two heights is calculated as:

BV=0.005454154\*(I1\*D2\*((1-G\*W)\*(U1-L1)+W\*((1-L1/H)r\*(H-L1) -

(1-U1/H)r\*(H-U1))/(r+1))

+ I2\*I3\*(T\*(U2-L2)+Z\*((1-L2/H)p\*(H-L2) -

(1-U2/H)p\*(H-U2))/(p+1))

+ I4\*F2\*(b\*(U3-L3)-b\*((U3-17.3)2-(L3-17.3)2)/(H-17.3) +

(b/3)\*((U3-17.3)3-(L3-17.3)3)/(H-17.3)2 +

I5\*(1/3)\*((1-b)/a2)\*(a\*(H-17.3)-(L3-17.3))3/(H-17.3)2 -

I6\*(1/3)\*((1-b)/a2)\*(a\*(H-17.3)-(U3-17.3))3/(H-17.3)2))

*Basic symbols:*

D: diameter at breast height (4.5 feet/1.3716m) in inches. To convert our DBH in cm to inches: D=DBH\*0.393700787

H: total tree height in feet. To convert our HT in m to feet: H=HT\*3.2808399

F: diameter at 17.3 feet/5.273m above ground in inches. F=D(a1+b1(17.3/H)2), where a1 and b1 are species coefficients

L: lower height of interest in feet, which is 0

U: upper height of interest in feet, which is total tree height H.

*Combined variables:*

G: (1-4.5/H)r

W: (c+e/D3)/ (1-G)

X: (1-4.5/H) p

Y: (1-17.3/H) p

Z: (D2-F2)/(X-Y)

T: D2-ZX

r, c, e: regression coefficient for stem section below 4.5 feet

p: regression coefficients for stem section between 4.5 and 17.3 feet

b, a: regression coefficients for stem section above 17.3 feet.

L1-L3: maximum of L and 0, 4.5, and 17.3 feet. They equal to 0, 4.5, and 17.3 feet in our calculation because L=0

U1-U3: minimum of 4.5, 17.3 feet and H

*Indicator variables:*

I1: I1=1 if L<4.5 feet; I1=0 otherwise. I1=1 in our calculation

I2: I2=1 if L<17.3 feet; I1=0 otherwise. I2=1 in our calculation

I3: I3=1 if U>4.5 feet; I3=0 otherwise.

I4: I4=1 if U>17.3; I4=0 otherwise

I5: I5=1 if (L3-17.3)<a\*(H-17.3); I5=0 otherwise.

I6: I6=1 if (U3-17.3)<a(H-17.3); I6=0 otherwaise

*Coefficients for Clark’s equation*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species | a1 | b1 | r | c | e | p | b | a |
| PRPE or SOAM(cherry in Clark’s table) | 0.92487 | -0.89867 | 37.12714 | 0.48776 | 1.50579 | 6.18866 | 1.64261 | 0.55071 |
| ACPE, ACSA, or ACSP (red maple in Clark’s table) | 0.93991 | -1.62226 | 22.00135 | 0.45472 | 166.1 | 7.31546 | 1.17064 | 0.27213 |
| FAGR(beech in Clark’s table) | 0.91141 | -0.6673 | 44.36826 | 1.22158 | 79.44636 | 6.36236 | 1.11382 | 0.14312 |
| BEAL, BECO, or BEPA (birch in Clark’s table) | 0.85516 | -0.00134 | 49.41385 | 1.01241 | -91.82769 | 11.23179 | 1.19704 | 0.23928 |

# *2 Smaller trees*

ABBA trees with DBH <= 1.3cm or HT <=1.3m; PIRU trees with DBH <=1.5cm or HT<=1.3m; and species other than ABBA, PIRU, and FAGR and have heights <5.28m, a power function was used to estimate bole volume.

*BV=A\*heightB*

BV: bole volume in m3

Height: height in m.

A/B: coefficient, which we got from fitting a power function of estimated bole volume on height from bigger trees. The same thing as fitting for height and DBH, data from different years would be pooled, but if a plant has data from more than one year, only data from the first year would be included. For ACSP, and ACSA, some outliers were excluded in model fitting. Values see “coefs\_HT.to.BV.csv”

# *3. BEPA*

BEPA was not estimated for bole volume, because there might not even be BEPA on Moosilauke

# *Recoding and checking Lixi did*

Lixi recoded bole volume estimating in SAS and checked for difference than Noah’s estimated bole volume for 1998 data. Power function fitting to estimate heights were also reran in SAS, power function fitting to estimate bole volume for small plants were not though, coefficients from Noah were used. Till 09/12/2012, besides some real small difference for small plants caused by how many digits we keep for coefficients, all the problems (eg. Coefficients not updated in documentation, errors in codes, etc) caused differences were fixed.