i-Tree Eco Biogenic Emissions Model Descriptions

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Version 1.0

August 24, 2012

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1. Introduction

Employing field-surveyed urban forest information, location specific data, weather data, and air pollutant measurements, i-Tree Eco assesses the structure of community trees and quantifies the environmental services that trees provide. i-Tree Eco was developed based on the Urban Forest Effects (UFORE) model. With its biogenic emission component (UFORE-B) integrated into i-Tree Eco, volatile organic compounds (VOCs) emissions from vegetation can be estimated with i-Tree Eco version 5. This document provides detailed i-Tree Eco biogenic emission model descriptions.

2. Model Descriptions

The amount of VOC emissions depends on vegetation genus, leaf dry weight biomass, air and leaf temperature and other environmental factors. Based on field sampling of vegetation (deciduous/evergreen trees and shrubs) on various land use types, i-Tree Eco estimates the hourly emission of isoprene (C_5H_8) and monoterpene (C_{10} terpenoids) by genus for each land use. The hourly estimates are summed for the year, leaf-on period, each month, daytime in each month, and averaged for the entire year, depending on tree or shrub types (deciduous or evergreen). Among these, yearly sum of VOCs emissions by genus and for each land use are further summarized for individual trees, species in the analysis domain and species in land use types.

2.1. Isoprene emission

Hourly isoprene emission $I_{g,l}$ (μgC tree^{-1} hr^{-1}) by genera g in land use l at temperature T(K) and PAR flux L (μmol m^{-2} s^{-1}), can be estimated as (Geron et al. 1994)

$$I_{g,l} = I_g \cdot LB_{g,l} \cdot C_L \cdot C_{T.l} \quad (1)$$

I_g = isoprene base emission rate in μgC (g leaf dry weight)$^{-1}$ hr^{-1} by genera g at the standard temperature T_s (30 °C = 303K) and PAR flux of 1000 μmol m^{-2} s^{-1}

$LB_{g,l}$ = leaf dry weight biomass (g) for genera g in land use l

C_L = hourly light correction factor

$$C_L = \frac{\sum_{j=1}^{N} C_{L,j}}{N} \quad (2)$$

$C_{L,j}$ = hourly light correction factor in j^{th} layer of canopy that is vertically divided into N (=30) layers

$$C_{L,j} = \frac{\Delta F_j^{\,*}}{\Delta F} \cdot C_{L,sunlit} + \left(1 - \frac{\Delta F_j^{\,*}}{\Delta F}\right) \cdot C_{L,shaded} \quad (3)$$

ΔF = leaf area index in each layer
ΔF_j^* = sunlit leaf area index in the j^{th} layer assuming a spherical leaf distribution
$C_{L,sunlit}$ = hourly light correction factor on sunlit leaves
$C_{L,shaded}$ = hourly light correction factor on shaded leaves

$C_{L,sunlit}$, $C_{L,shaded}$ can be estimated as

$$C_{L,shulit} = \frac{\alpha \cdot C_{L1} \cdot L_{sunlit}}{\left(1+\alpha^2 \cdot L_{sunlit}{}^2\right)^{1/2}} \quad (4)$$

$$C_{L,shaded} = \frac{\alpha \cdot C_{L1} \cdot L_{shaded}}{\left(1+\alpha^2 \cdot L_{shaded}{}^2\right)^{1/2}} \quad (5)$$

α = 0.0027
C_{L1} = 1.066
L_{sunlit} = hourly PAR on sunlit leaves (Hirabayashi et al. 2012)
L_{shaded} = hourly PAR on shaded leaves (Hirabayashi et al. 2012)

$C_{T,l}$ is hourly leaf temperature correction factor for land use type l and estimated as (Geron et al. 1994; Guenther et al. 1995; Guenther 1997)

$$C_{T,l} = \frac{exp\left[\frac{CT_1(T_l - T_S)}{R \cdot T_S \cdot T_l}\right]}{0.96 + exp\left[\frac{CT_2(T_l - T_M)}{R \cdot T_S \cdot T_l}\right]} \quad (6)$$

R = ideal gas constant (=8.314 K^{-1} mol^{-1})
CT_1 = 95,000 J mol^{-1}

CT_2 = 230,000 J mol^{-1}
T_l = leaf temperature for land use l (K)
T_s = standard temperature (30°C=303K)
T_M = 314K

T_l can be calculated by correcting the air temperature T with transpiration rate, leaf area index and percentage tree cover.

$$T_l = T - \frac{TR}{TR_s} \cdot \frac{F_l}{F_s} \cdot C \cdot TC_l \quad (7)$$

T = air temperature (K)
TR = transpiration rate
TR_s = standard transpiration rate (=80 g m^{-2} hr^{-1}) (Kramer 1983)
F_l = leaf area index for land use l
F_s = standard leaf area index (=6) (McPherson et al. 1994)
C = conversion factor for the lowest maximum midday temperature reduction effect (Simpson 1998)
TC_l = percentage tree cover for land use l

2.2. Monoterpene emission

Hourly monoterpene emission $M_{g,l}$ (µgC tree^{-1} hr^{-1}) by genera g in land use l at temperature T(K) can be estimated as (Geron et al. 1994)

$$M_{g,l} = M_g \cdot C_{T.l} \quad (8)$$

M_g = monoterpene base emission rate in µgC (g leaf dry weight)$^{-1}$ hr^{-1} by genera g at the standard temperature T_s (30 °C = 303K)
$LB_{g,l}$ = leaf dry weight biomass (g) for genera g in land use l
$C_{T,l}$ = hourly leaf temperature correction factor for land use l

$$C_{T.l} = exp[\beta(T_l - T_s)] \quad (9)$$

β = 0.09
T_l = leaf temperature on land use l, calculated with Eqn. 7

T_s = standard temperature (30°C=303K)

2.3. Summation and average of emissions

Both hourly estimates of isoprene and monoterpene emissions are summed for the year, leaf-on periods in the year, each month, daytime in each month, and averaged for the year. The yearly sums are further summarized on a genera- and land use-basis. To calculate these summaries, hourly estimates only in leaf-on periods are used for deciduous trees/shrubs, while year-round hourly estimates are used for evergreen trees/shrubs.

3. Project Summary of Biogenic VOCs Emissions

The annual results of biogenic VOCs emissions are further converted into more detailed summaries such as those per individual trees, per species across an analysis domain and per species in land use types depending on project types (full inventory or sampling project). Figure 1 illustrates the structure of this section, in which sub sections explaining the methodology to calculate more detailed summaries for each project are presented.

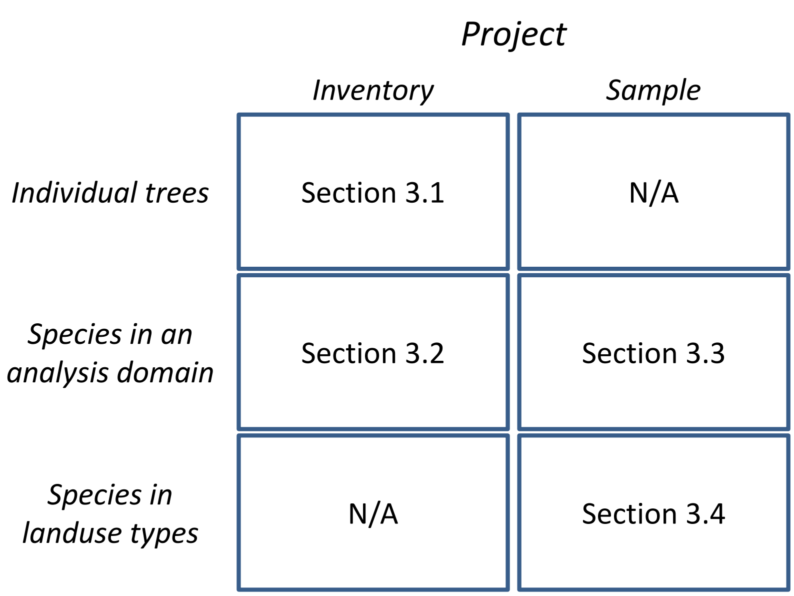

Figure 1 Structure of Section 3 explaining more detailed summarizing methods

3.1. Individual tree summary for inventory projects

Biogenic emission ($E_{i(g,s)}$) for individual tree *i* of genera *g* and species *s* is estimated as

$$E_{i(g,s)} = E_g \times \frac{LB_{i(g,s)}}{\sum LB_g} \tag{10}$$

E_g	=	yearly bio-emission for genera *g*
$LB_{i(g,s)}$	=	leaf biomass for tree *i* of genera *g* and species *s*
$\sum LB_g$	=	leaf biomass for genera g (sum of leaf dry weight biomass for genera *g*)

3.2. Species-based summary in an analysis domain for inventory projects

Biogenic emission (E_s) summarized for species *s* is estimated as

$$E_s = \sum E_{i(g,s)} \tag{11}$$

3.3. Species-based summary in an analysis domain for sample projects

Biogenic emission (E_s) summarized for species *s* is estimated as

$$E_s = E_g \times \frac{LB_{g,s}}{\sum LB_g} \tag{12}$$

E_g	=	yearly bio-emission for genera *g*
$LB_{g,s}$	=	leaf biomass for genera *g* and species *s* across a city
$\sum LB_g$	=	leaf dry weight biomass for genera g across a city (sum of leaf dry weight biomass for genera *g*)

3.4. Species-based summary in landuse types for sample projects

Biogenic emission ($E_{l,s}$) summarized for landuse type *l* and species *s* is estimated as

$$E_{l,s} = E_l \times \frac{LB_{l,s}}{\sum LB_l} \tag{13}$$

E_g	=	yearly bio-emission for land use *l*

$LB_{l,s}$ = leaf biomass for species *s* across land use *l*

$\sum LB_l$ = leaf dry weight biomass across land use *l* (sum of leaf dry weight biomass for land use *l*)

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