i-Tree Eco (UFORE) and Forecast Integration Specification

Satoshi Hirabayashi[1]

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[1] The Davey Tree Expert Company, Syracuse, New York 13210, USA

Contents

1. Introduction

Using local environmental data in 2010, i-Tree Eco simulations were performed in rural and urban areas of counties across the conterminous United States. In the simulations air pollutant removal and associated monetary values, biogenic emission of volatile organic compounds, and avoided runoff for deciduous or evergreen trees with LAI ranging from 0 to 18 were estimated. The results were then divided by the tree cover area (m^2) in each modeling domain and these multipliers were stored in a national database.

Using the national multiplier database, i-Tree Forecast estimates ecosystem services provided by trees from the current year (year-1) through the future years of a user's choice. The current year and a weather station could be picked by a user, while pre-assigned upper air (radiosonde) station and air pollutant monitors are employed based on a user's study area. Theoretically, the ecosystem service estimated for the year-1 by Forecast should be equivalent to those estimated by Eco for the same year, though this is not always true as the multipliers used by Forecast were derived using 2010 monitor data closest to the center of the rural and urban area in each county. Hence, an adjustment to the multipliers is necessary to match the results for the year-1 estimated by Forecast and for the same year estimated by Eco.

This document specifies the national multipliers, adjustment to multipliers, and calculation of each ecosystem service in i-Tree Forecast.

2. Multipliers

Table 1 presents an example of the multipliers for the urban area of Baltimore, MD extracted from the national county-basis multiplier database. PrimaryPartitionID and SecondaryPartitionID define county, LAI has values from 0 to 18 with 0.5 increments, LeafType is either "Evergreen" or "Deciduous", Parameter specifies ecosystem services (pollutant removal/value for CO, NO_2, $PM_{10}{}^*$, $PM_{2.5}$ and SO_2 are not listed). OVOCCorrFactor was created for the future use as the other VOC is currently not reported in Eco. Multiplier represents annual value for a unit tree cover area (m^2). IsopreneCorrFactor and MonoterpeneCorrFactor are correction factors to which light and temperature correction factor and carbon to isoprene or monoterpene conversion factor combined. Note that the

structure in Table 1 is in a database with no normalization considered. The structure of the final database for the i-Tree product may be different from this.

Table 1 Example of multipliers

Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier
24	510	5	Evergreen	O3 Removal (g/m2/year)	5.74454
24	510	5	Evergreen	O3 Value ($/m2/year)	0.08056
24	510	5	Evergreen	IsopreneCorrFactor	647.75
24	510	5	Evergreen	MonoterpeneCorrFactor	3626.06
24	510	5	Evergreen	OVOCCorrFactor	3798.58
24	510	5	Evergreen	AvoidedRunoff (m3/m2/yr)	0.01766
24	510	5	Deciduous	O3 Removal (g/m2/year)	3.95044
24	510	5	Deciduous	O3 Value ($/m2/year)	0.05355
24	510	5	Deciduous	IsopreneCorrFactor	617.553
24	510	5	Deciduous	MonoterpeneCorrFactor	3135.88
24	510	5	Deciduous	OVOCCorrFactor	3285.07
24	510	5	Deciduous	AvoidedRunoff (m3/m2/yr)	0.01166

3. Adjustment to multipliers and calculation of ecosystem services

Adjustments to multipliers to match the results for the same year produced by i-Tree Eco and Forecast (typically the first year of forecasted results) as well as the calculations of each ecosystem service are explained in this section. Adjustments and ecosystem service calculations are generally completed in four steps; 1) run i-Tree Eco using the same study area, year, and weather station as Forecast, 2) divide Eco's results for the total forest area into deciduous and evergreen portion of the forest and derive ecosystem services per unit tree cover area (multipliers), 3) compare the multipliers from the step 2 with those in the national multiplier database to derive an adjustment factor, and 4) apply the multiplier and adjustment factor to compute the ecosystem services for the future forest structure. In the following subsections, the whole process will be explained using an example project in Baltimore, MD (urban area), in which the year-1 of Forecast is 2013 and the adjustment of the multipliers is

performed with the Eco's results for 2013 created with the same weather station as Forecast.

3.1. Pollutant removal

3.1.1. Step 1 (Eco run)

Table 2 presents an example of O_3 results from i-Tree Eco (08_DomainYearlySums table in UFOREDTree.mdb) for Baltimore, MD in 2013. CumFlux (g/m^2) represents the annual pollutant removal mass per unit tree cover area. The rows denoted "Deciduous" and "Evergreen" are a breakdown of the total values into each leaf type for multiplier adjustments. Comparing these values with corresponding multipliers in the national database, the adjustment to the multipliers will be made for Forecast .The detailed derivations are explained in the following sections.

Table 2 Example of Eco-D output for Baltimore, MD in 2013

Year	Pollutant	TerPart	CumFlux (g/m2)	FluxDomain (m-tons)
2013	O3	Baltimore	4.800	120.00
		Deciduous	3.936	78.72
		Evergreen	8.256	41.28

3.1.2. Step 2 (Eco results divided into deciduous/evergreen)

Table 3 shows forest parameters for the total area, deciduous and evergreen forests. LAI, Evergreen% and TrCovArea (m2) for the total area can be derived from ENVIRON.OUT file created by Eco version 5 (there should be an equivalent output from Eco version 6). Leaf Area (m2) can be derived by multiplying LAI and TrCovArea (m2). The parameters for the total area in Table 3 can be divided into deciduous and evergreen portion of forests.

Table 3 Forest parameters for Baltimore 2013 Eco project

TerPart	LAI	Evergreen %	TrCovArea (m2)	Leaf Area (m2)
Baltimore	5	20	25000000	125000000
Deciduous	4.1		20000000	82000000
Evergreen	8.6		5000000	43000000

Tree cover area for deciduous and evergreen can be calculated as follows:

$$TrCovArea_{De} = TrCovArea_{Total} \times Deciduous\ (\%) = 25{,}000{,}000 \times 80(\%)$$
$$= 20{,}000{,}000\ (m^2)$$

$$TrCovArea_{Ev} = TrCovArea_{Total} \times Evergreen\ (\%) = 25{,}000{,}000 \times 20(\%)$$
$$= 5{,}000{,}000\ (m^2)$$

Assuming that Leaf Area (m^2) for each leaf type are provided by UFORE-ACE or calculated within the Eco shell based on data provided by UFORE-ACE, LAI for each leaf type can be calculated as:

$$LAI_{De} = \frac{LeafArea_{Dec}}{TrCovArea_{De}} = \frac{82{,}000{,}000\ (m^2)}{20{,}000{,}000\ (m^2)} = 4.1$$

$$LAI_{Ev} = \frac{LeafArea_{Ev}}{TrCovArea_{Ev}} = \frac{43{,}000{,}000\ (m^2)}{5{,}000{,}000\ (m^2)} = 8.6$$

Note that LAI for each leaf type may also be provided by UFORE-ACE.

FluxDomain (m-tons) in Table 2 represents total annual O_3 removal in the study area. This value could be proportionally divided into each leaf type based on leaf area:

$$FluxDomain_{De} = FluxDomain_{Total} \times \frac{LeafArea_{De}}{LeafArea_{Total}}$$
$$= 120\ (m-tons) \times \frac{82{,}000{,}000\ (m^2)}{125{,}000{,}000\ (m^2)} = 78.72\ (m-tons)$$

$$FluxDomain_{Ev} = FluxDomain_{Total} \times \frac{LeafArea_{Ev}}{LeafArea_{Total}}$$
$$= 120\ (m-tons) \times \frac{43{,}000{,}000\ (m^2)}{125{,}000{,}000\ (m^2)} = 41.28\ (m-tons)$$

Pollutant removal per unit tree cover area for deciduous and evergreen forests can then be derived as (see Table 2):

$$CumFlux_{De} = \frac{FluxDomain_{De}}{TrCovArea_{De}} = \frac{78.72\ (m-tons)}{20{,}000{,}000\ (m^2)} = 3.936\ (g/m^2)$$

$$CumFlux_{Ev} = \frac{FluxDomain_{Ev}}{TrCovArea_{Ev}} = \frac{41.28\ (m-tons)}{5{,}000{,}000\ (m^2)} = 8.256\ (g/m^2)$$

3.1.3. Step 3 (derivation of adjustment factor)

LAIs for deciduous and evergreen forests were calculated as 4.1 and 8.6, respectively. Look up the multiplier database for these LAI values (rounded to 4 and 8.5, respectively) to locate the O_3 removal multipliers (Table 4). Adjustment factors can be derived as:

$$AdjFactor_{De} = \frac{Multiplier_{Eco-De}}{Multiplier_{De}} = \frac{3.936\ (g/m^2)}{3.663\ (g/m^2)} = 1.074$$

$$AdjFactor_{Ev} = \frac{Multiplier_{Eco-Ev}}{Multiplier_{Ev}} = \frac{8.256\ (g/m^2)}{7.028\ (g/m^2)} = 1.175$$

Table 4 Multiplier in national database and adjustment factor

Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adjustment Factor
24	510	4	Deciduous	O3 Removal (g/m2/year)	3.663	1.074
24	510	8.5	Evergreen	O3 Removal (g/m2/year)	7.028	1.175

3.1.4. Step 4 (calculation of ecosystem services)

For a given year, i-Tree Forecast can estimate the annual O_3 removals for Baltimore, MD based on leaf type, LAI, canopy cover area, multiplier and adjustment factor. Table 5 shows multipliers from the national database along with the adjustment factor derived in the previous section. For deciduous tree cover of 20,000,000 (m^2) with LAI 5.5, annual removal of O_3 can be calculated as:

$$R_{O_3} = 4.079 \left(\frac{\frac{g}{m^2}}{year}\right) \times 1.074 \times 20{,}000{,}000\ (m^2) = 87654543.879\ (g)$$
$$= 87.65\ (m-ton)$$

For evergreen tree cover of 5,000,000 (m^2) with LAI 7.5, annual removal of O_3 can be calculated as:

$$R_{O_3} = 6.689 \left(\frac{\frac{g}{m^2}}{year}\right) \times 1.175 \times 5{,}000{,}000\ (m^2) = 39285823.463\ (g)$$
$$= 39.29\ (m-ton)$$

Table 5 Multipliers from the national database

Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adjustment Factor
24	510	5.5	Deciduous	O3 Removal (g/m2/year)	4.079	1.074
24	510	7.5	Evergreen	O3 Removal (g/m2/year)	6.689	1.175

3.2. Pollutant removal monetary value

3.2.1. Step 1 (Eco run)

Table 6 presents an example of O_3 results from i-Tree Eco (08_DomainYearlySums table in UFOREDTree.mdb) for Baltimore, MD in 2013. CumVal ($/m2) represents the annual pollutant removal monetary value per unit tree cover area.

Table 6 Example of Eco-D output for Baltimore, MD in 2013

Year	Pollutant	TerPart	CumVal ($/m2)	ValDomain ($1000)
2013	O3	Baltimore	0.0426	1019.74
		Deciduous	0.0334	668.95

		Evergreen	0.0702	350.79

3.2.2. Step 2 (Eco results divided into deciduous/evergreen)

Forest parameters presented in Table 3 will be used to divide total monetary values into each leaf type. ValDomain (m-tons) in Table 6 represents the annual monetary values associated with O_3 removal in the study area. This value could be proportionally divided into each leaf type based on leaf area:

$$ValDomain_{De} = ValDomain_{Total} \times \frac{LeafArea_{De}}{LeafArea_{Total}}$$
$$= 1019.74\ (\$1000) \times \frac{82{,}000{,}000\ (m^2)}{125{,}000{,}000\ (m^2)} = 668.95\ (\$1000)$$

$$ValDomain_{Ev} = ValDomain_{Total} \times \frac{LeafArea_{Ev}}{LeafArea_{Total}}$$
$$= 1019.74\ (\$1000) \times \frac{43{,}000{,}000\ (m^2)}{125{,}000{,}000\ (m^2)} = 350.79\ (\$1000)$$

Monetary value per unit tree cover area for deciduous and evergreen forests can then be derived as (see Table 6):

$$CumValue_{De} = \frac{ValDomain_{De}}{TrCovArea_{De}} = \frac{668.95\ (\$1000)}{20{,}000{,}000\ (m^2)} = 0.0334\ (\$/m^2)$$

$$CumValue_{Ev} = \frac{ValDomain_{Ev}}{TrCovArea_{Ev}} = \frac{350.79\ (\$1000)}{5{,}000{,}000\ (m^2)} = 0.0702\ (\$/m^2)$$

3.2.3. Step 3 (derivation of adjustment factor)

LAIs for deciduous and evergreen forests were calculated as 4.1 and 8.6,. Look up the multiplier database for these LAI values (rounded to 4 and 8.5, respectively) to locate the O_3 value multipliers (Table 7). Adjustment factors can be derived as:

$$AdjFactor_{De} = \frac{Multiplier_{Eco-De}}{Multiplier_{De}} = \frac{0.0334\ (\$/m^2)}{0.050\ (\$/m^2)} = 0.673$$

$$AdjFactor_{Ev} = \frac{Multiplier_{Eco-Ev}}{Multiplier_{Ev}} = \frac{0.0702(\$/m^2)}{0.097\ (\$/m^2)} = 0.723$$

Table 7 Multiplier in national database and adjustment factor

Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adjustment Factor
24	510	4	Deciduous	O3 Value ($/m2/year)	0.050	0.673
24	510	8.5	Evergreen	O3 Value ($/m2/year)	0.097	0.723

3.2.4. Step 4 (calculation of ecosystem services)

For a given year, i-Tree Forecast can estimate the annual O_3 removal monetary values for Baltimore, MD based on LAI, canopy cover area, multiplier and adjustment factor. Table 8 shows multipliers from the national database along with the adjustment factor. For deciduous tree cover of 20,000,000 (m^2) with LAI 5.5, annual monetary value of O_3 removal can be calculated as:

$$V_{O_3} = 0.0552 \left(\frac{\$}{\frac{m^2}{year}}\right) \times 0.673 \times 20{,}000{,}000\ (m^2) = 742{,}820\ (\$)$$

Evergreen tree cover of 5,000,000 (m^2) with LAI 7.5, annual monetary value of O_3 removal can be calculated as:

$$V_{O_3} = 0.0928 \left(\frac{\$}{\frac{m^2}{year}}\right) \times 0.723 \times 5{,}000{,}000\ (m^2) = 335{,}273\ (\$)$$

Table 8 Multipliers from national database

Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adjustment Factor

24	510	5.5	Deciduous	O3 Value ($/m2/year)	0.0552	0.673
24	510	7.5	Evergreen	O3 Value ($/m2/year)	0.0928	0.723

3.3. Biogenic pollutant emission

3.3.1. Step 1 (Eco run)

Tables 9 and 10 present an example of yearly correction factor for isoprene and monoterpene, respectively, for deciduous trees in each landuse type (this table, YearlyCorrectionFactor, is newly added to B's output database, UFOREBTree.mdb in version 6). LAI for each landuse type estimated by UFORE-ACE are also listed in the table. Note that those for evergreen trees are also available in the database.

Table 9 Example of Eco-B output for Baltimore, MD in 2013

Landuse	LanduseDesc	CorrFactor	Deciduous	Pollutant	LAI
B	Barren	492.10	-1	Isoprene	1.93
C	Commercial/Ind.	474.68	-1	Isoprene	4.86
F	Forest	394.70	-1	Isoprene	6.68
I	Institutional	456.01	-1	Isoprene	7.71
OU	Urban Open	420.25	-1	Isoprene	7.84
RH	Hi Dens. Resid.	470.60	-1	Isoprene	3.08
RM	Md/Lw Den. Res.	448.94	-1	Isoprene	3.78
T	Transportation	477.10	-1	Isoprene	3.92

Table 10 Example of Eco-B output for Baltimore, MD in 2013

Landuse	LanduseDesc	CorrFactor	Deciduous	Pollutant	LAI
B	Barren	2514.29	-1	Monoterpene	1.93
C	Commercial/Ind.	2478.13	-1	Monoterpene	4.86
F	Forest	2311.82	-1	Monoterpene	6.68
I	Institutional	2439.46	-1	Monoterpene	7.71
OU	Urban Open	2365.23	-1	Monoterpene	7.84
RH	Hi Dens. Resid.	2469.67	-1	Monoterpene	3.08

RM	Md/Lw Den. Res.	2424.80	-1	Monoterpene	3.78
T	Transportation	2483.15	-1	Monoterpene	3.92

3.3.2. Step 2 (Eco results divided into deciduous/evergreen)

As correction factors are originally derived for deciduous and evergreen trees by the Eco-B function, this step is not necessary.

3.3.3. Step 3 (derivation of adjustment factor)

Tables 11 and 12 present correction factors extracted from the multiplier database. LAI for each landuse type in Tables 9 and 10 are rounded and corresponding correction factors are listed for each Landuse. Adjustments can be made based on the correction factors for each landuse type in Tables 9 and 11 for isoprene and Tables 10 and 12 for monoterpene. Correction factors are determined for each landuse type based on its LAI and tree cover percent. The national run ideally creates correction factors in rural and urban areas in counties with LAI and tree cover percentage varied within their possible range (i.e., LAI ranging from 0 to 18 or so, and tree cover ranging from 0 to 100%), however, to avoid complexity only LAI was varied and the tree cover percentage was fixed with the estimated tree cover percentage in each rural/urban area. Therefore, biogenic pollutant emissions estimated in Forecast is an approximation and the accuracy may be limited. The isoprene's adjustment factor for each landuse type are calculated as:

$$AdjFactor_{De-B} = \frac{Multiplier_{Eco-De-B}}{Multiplier_{De-B}} = \frac{492.10}{1075.52} = 0.458$$

$$AdjFactor_{De-C} = \frac{Multiplier_{Eco-De-C}}{Multiplier_{De-C}} = \frac{474.68}{617.55} = 0.769$$

$$AdjFactor_{De-F} = \frac{Multiplier_{Eco-De-F}}{Multiplier_{De-F}} = \frac{394.70}{500.76} = 0.788$$

$$AdjFactor_{De-I} = \frac{Multiplier_{Eco-De-I}}{Multiplier_{De-I}} = \frac{456.01}{418.84} = 1.089$$

$$AdjFactor_{De-OU} = \frac{Multiplier_{Eco-De-OU}}{Multiplier_{De-OU}} = \frac{420.25}{418.84} = 1.003$$

$$AdjFactor_{De-RH} = \frac{Multiplier_{Eco-De-RH}}{Multiplier_{De-RH}} = \frac{470.60}{874.72} = 0.538$$

$$AdjFactor_{De-RM} = \frac{Multiplier_{Eco-De-RM}}{Multiplier_{De-RM}} = \frac{448.94}{728.03} = 0.617$$

$$AdjFactor_{De-T} = \frac{Multiplier_{Eco-De-T}}{Multiplier_{De-T}} = \frac{477.10}{728.03} = 0.655$$

Table 11 Multiplier in national database and adjustment factor

Landuse	Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adj. Factor
B	24	510	2	Deciduous	IsopreneCorrFactor	1075.52	0.458
C	24	510	5	Deciduous	IsopreneCorrFactor	617.55	0.769
F	24	510	7	Deciduous	IsopreneCorrFactor	500.76	0.788
I	24	510	8	Deciduous	IsopreneCorrFactor	418.84	1.089
OU	24	510	8	Deciduous	IsopreneCorrFactor	418.84	1.003
RH	24	510	3	Deciduous	IsopreneCorrFactor	874.72	0.538
RM	24	510	4	Deciduous	IsopreneCorrFactor	728.03	0.617
T	24	510	4	Deciduous	IsopreneCorrFactor	728.03	0.655

The monoterpene's adjustment factor for each landuse type are calculated as:

$$AdjFactor_{De-B} = \frac{Multiplier_{Eco-De-B}}{Multiplier_{De-B}} = \frac{2514.29}{3175.25} = 0.792$$

$$AdjFactor_{De-C} = \frac{Multiplier_{Eco-De-C}}{Multiplier_{De-C}} = \frac{2478.13}{3135.88} = 0.790$$

$$AdjFactor_{De-F} = \frac{Multiplier_{Eco-De-F}}{Multiplier_{De-F}} = \frac{2311.82}{3125.37} = 0.740$$

$$AdjFactor_{De-I} = \frac{Multiplier_{Eco-De-I}}{Multiplier_{De-I}} = \frac{2439.46}{3116.01} = 0.783$$

$$AdjFactor_{De-OU} = \frac{Multiplier_{Eco-De-OU}}{Multiplier_{De-OU}} = \frac{2365.23}{3116.01} = 0.759$$

$$AdjFactor_{De-RH} = \frac{Multiplier_{Eco-De-RH}}{Multiplier_{De-RH}} = \frac{2469.67}{3156.11} = 0.783$$

$$AdjFactor_{De-RM} = \frac{Multiplier_{Eco-De-RM}}{Multiplier_{De-RM}} = \frac{2424.80}{31444.3} = 0.771$$

$$AdjFactor_{De-T} = \frac{Multiplier_{Eco-De-T}}{Multiplier_{De-T}} = \frac{2483.15}{3144.3} = 0.790$$

Table 12 Multiplier in national database and adjustment factor

Landuse	Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adj. Factor
B	24	510	2	Deciduous	MonoterpeneCorrFactor	3175.25	0.792
C	24	510	5	Deciduous	MonoterpeneCorrFactor	3135.88	0.790
F	24	510	7	Deciduous	MonoterpeneCorrFactor	3125.37	0.740
I	24	510	8	Deciduous	MonoterpeneCorrFactor	3116.01	0.783
OU	24	510	8	Deciduous	MonoterpeneCorrFactor	3116.01	0.759
RH	24	510	3	Deciduous	MonoterpeneCorrFactor	3156.11	0.783
RM	24	510	4	Deciduous	MonoterpeneCorrFactor	3144.3	0.771
T	24	510	4	Deciduous	MonoterpeneCorrFactor	3144.3	0.790

3.3.4. Step 4 (calculation of ecosystem services)

For a given year, i-Tree Forecast can estimate the annual isoprene or monoterpene emissions for each genus in each landuse type in Baltimore, MD based on genus, leaf type, LAI, correction factor (multiplier) and adjustment factor as:

$$E_{poll} = BE_{poll} \times LB \times CF \times AF$$

where E_{poll} is the pollutant emission (µg); BE_{poll} is base emission for a genera, obtained from the species database (µgC/g leaf dry weight); *LB* is leaf biomass (g) *CF* is annual correction factor, and AF is adjustment factor. Here, an example of annual bio-emission by Acer

(deciduous) with LAI=4.5 and leaf biomass=10,000,000 (g) in the Forest landuse type is provided. Table 13 presents correction factors extracted from the national multiplier database along with the adjustment factor for Forest landuse derived in the previous section. Table 14 presents examples in the species database. Annual isoprene emission can be calculated as:

$$E_{isoprene} = 0.1\ \left(\frac{\mu gC}{g} leaf\ dry\ weight\right) \times 10{,}000{,}000 \times 669.05 \times 0.788 =$$

$$527{,}211{,}400\ (\mu g) =\ 527\ (g)$$

Annual monoterpene emission can be calculated as:

$$E_{monoterpene} = 1.60\ \left(\frac{\mu gC}{g} leaf\ dry\ weight\right) \times 10{,}000{,}000 \times 3139.81 \times 0.740 =$$

$$37{,}175{,}350{,}400\ (\mu g) =\ 37.18\ (kg)$$

Table 13 Multipliers from national database

Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adjustment Factor
24	510	4.5	Deciduous	IsopreneCorrFactor	669.05	0.788
24	510	4.5	Deciduous	MonoterpeneCorrFactor	3139.81	0.740

Table 14 Base emission in species database

GenusBioemissionsID	GenusID	BioemissionTypeID	GenusBioemissionValue
5	Acer	Isoprene	0.10
66	Acer	Monoterpene	1.60

3.4. Avoided runoff

3.4.1. Step 1 (Eco run)

For Baltimore, MD in 2013, annual avoided runoff was estimated as 318,443.98 m^3 by Eco (VegIntercept (m3/yr) field in 01_InterceptYearlySums table in WaterInterceptTree.mdb.)

3.4.2. Step 2 (Eco results divided into deciduous/evergreen)

Table 15 shows forest parameters for the total area, deciduous and evergreen forests same as Table 3.

Table 15 Forest parameters for Baltimore 2013 Eco project

TerPart	LAI	Evergreen %	TrCovArea (m2)	Leaf Area (m2)
Baltimore	5	20	25000000	125000000
Deciduous	4.1		20000000	82000000
Evergreen	8.6		5000000	43000000

The total annual avoided runoff, 318,443.98 m^3 could be proportionally divided into each leaf type based on leaf area:

$$AvoidedRunoff_{De} = AvoidedRunoff_{Total} \times \frac{LeafArea_{De}}{LeafArea_{Total}}$$

$$= 318{,}443.98\ (m^3) \times \frac{82{,}000{,}000\ (m^2)}{125{,}000{,}000\ (m^2)} = 208{,}899.25\ (m^3)$$

$$AvoidedRunoff_{Ev} = AvoidedRunoff_{Total} \times \frac{LeafArea_{Ev}}{LeafArea_{Total}}$$

$$= 318{,}443.98\ (m^3) \times \frac{43{,}000{,}000\ (m^2)}{125{,}000{,}000\ (m^2)} = 109{,}544.73\ (m^3)$$

Avoided runoff per unit tree cover area for deciduous and evergreen forests can then be derived as:

$$Multiplier_{De} = \frac{AvoidedRunoff_{De}}{TrCovArea_{De}} = \frac{208{,}899.25\ (m^3)}{20{,}000{,}000\ (m^2)} = 0.0104\ (m^3/m^2)$$

$$Multiplier_{Ev} = \frac{AvoidedRunoff_{Ev}}{TrCovArea_{Ev}} = \frac{109{,}544.73\ (m^3)}{5{,}000{,}000\ (m^2)} = 0.0219\ (m^3/m^2)$$

3.4.3. Step 3 (derivation of adjustment factor)

LAIs for deciduous and evergreen forests were calculated as 4.1 and 8.6. Look up the multiplier database for these LAI values (rounded to 4 and 8.5, respectively) to locate the avoided runoff multipliers (Table 16). Adjustment factors can be derived as:

$$AdjFactor_{De} = \frac{Multiplier_{Eco-De}}{Multiplier_{De}} = \frac{0.0104\ (m^3/m^2)}{0.0099\ (m^3/m^2)} = 1.052$$

$$AdjFactor_{Ev} = \frac{Multiplier_{Eco-Ev}}{Multiplier_{Ev}} = \frac{0.0219\ (m^3/m^2)}{0.0257\ (m^3/m^2)} = 0.853$$

Table 16 Multiplier in national database and adjustment factor

Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adjustment Factor
24	510	4	Deciduous	AvoidedRunoff (m3/m2/yr)	0.010	1.052
24	510	8.5	Evergreen	AvoidedRunoff (m3/m2/yr)	0.026	0.853

3.4.4. Step 4 (calculation of ecosystem services)

For a given year, i-Tree Forecast can estimate the annual avoided runoff for Baltimore, MD based on LAI, canopy cover area, multiplier and adjustment factor. Table 17 shows multipliers from the national database. For deciduous tree cover of 20,000,000 (m^2) with LAI 5.5, annual avoided runoff can be calculated as:

$$S = 0.013 \left(\frac{\frac{m^3}{m^2}}{year} \right) \times 20{,}000{,}000\ (m^2) \times 1.052 = 263{,}602\ (m^3)$$

For evergreen tree cover of 5,000,000 (m^2) with LAI 7.5, removal of O_3 can be calculated as:

$$S = 0.024 \left(\frac{\frac{m^3}{m^2}}{year} \right) \times 5{,}000{,}000\ (m^2) \times 0.853 = 100{,}308\ (m^3)$$

Table 17 Multipliers from the national database

Primary Partition ID	Secondary Partition ID	LAI	LeafType	Parameter	Multiplier	Adjustment Factor
24	510	5.5	Deciduous	AvoidedRunoff (m3/m2/yr)	0.013	1.052
24	510	7.5	Evergreen	AvoidedRunoff (m3/m2/yr)	0.024	0.853