Air Pollutant Removals, Biogenic Emissions and Hydrologic Estimates for i-Tree Applications

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1 Introduction

i-Tree Eco version 6.0 supports the United States including Alaska and Hawaii, Puerto Rico, Australia, Canada and The United Kingdom as a study area to estimate air pollutant removals, biogenic emissions of volatile organic compounds (VOCs) as well as hydrologic variables such as potential evaporation, potential transpiration, evaporation, transpiration, rainfall interception, and avoided runoff by trees and shrubs. For other i-Tree applications (i.e., Canopy, Design, Forecast and Landscape), batch processes of i-Tree Eco were performed to pre-calculate these ecosystem services per unit tree cover (m^2), from which ecosystem services for analysis domains in each application can be estimated. Supported countries/areas vary across the i-Tree Canopy, Design, Forecast and Landscape applications, depending on the progress of the batch runs. This document presents detail information about data and process to estimate the aforementioned ecosystem services in the supported countries/areas in each of i-Tree applications.

Section 2 provides counties/areas information supported by each of i-Tree applications. Section 3 summarizes the data available for i-Tree Eco as well as those employed in each i-Tree Eco batch process to derive estimates for each supported country/area. Section 4 further provides the data details, such as source, the number of available measurement sites, locations on maps, and derivation of forest data to run batch processes for each supported country/area for available data year. Section 5 provides tables and their contents created by the batch processes.

2 Supported Countries/Areas

2.1 Air Pollutant Removals

Removal of six criteria air pollutants (CO, NO_2, O_3, $PM_{2.5}$ and SO_2) by trees/shrubs and associated monetary values are estimated and reported in i-Tree Eco for the supported countries/areas (Table 1). Based on batch i-Tree Eco runs, air pollutant removals are estimated and reported in other i-Tree applications in supported countries/areas (Table 1). Valuation for CO is calculated based on the median externality value and producer price index in each supported country. Valuation for NO_2, O_3, $PM_{2.5}$ and SO_2 is calculated using US EPA's BenMAP (US EPA, 2015a) for the conterminous United

States. For other countries and areas regression equations constructed based on the county-based BenMAP results for the conterminous United States are used (Nowak et al., 2014). In addition to the monetary costs avoided due to reduced air pollutant concentration, avoided adverse health incidences are also estimated by BenMAP.

Table 1 Supported countries/area in i-Tree applications for air pollutant removals

Supported countries/areas	Eco	Eco batch run for			
		Canopy	Landscape	Design	Forecast
Conterminous US	x	x	x	x[c]	x
Alaska[ad]	x	x[b]	x[b]	x[c]	x
Hawaii[a]	x			x[c]	x
Puerto Rico[a]	x			x[c]	x
Australia[a]	x				
Canada[a]	x	x[b]	x[b]	x[c]	x
UK[a]	x			x[c]	x

x: Currently supported
[a]: BenMAP valuation based on US national regression equations
[b]: Run completed but table not created
[c]: Run and tables (_LocationPollutant, _LocationPollutantRegression) completed but not implemented in application
[d]: Alaska has no NO_2 estimate as there is no measurement available

2.2 Biogenic VOC Emissions

Biogenic emission of volatile organic compound (isoprene and monoterpenes) from trees/shrubs are estimated and reported in i-Tree applications for the supported countries/areas (Table 2).

Table 2 Supported countries/area in i-Tree applications for biogenic VOC emissions

Supported countries/areas	Eco	Eco batch run for			
		Canopy	Landscape	Design	Forecast
Conterminous US	x			x[a]	x[a]
Alaska[a]	x			x[a]	x[a]
Hawaii[a]	x				
Puerto Rico[a]	x				
Australia[a]	x				
Canada[a]	x			x[a]	x[a]
UK[a]	x				

x: Currently supported
[a]: Run completed but table not completed

2.3 Hydrologic Variables

Six hydrologic variables (potential evaporation, potential transpiration, evaporation, transpiration, rainfall interception, and avoided runoff) provided by trees/shrubs are estimated and reported in i-Tree applications for the supported countries/areas (Table 3).

Table 3 Supported countries/area in i-Tree applications for hydrologic variables

Supported countries/areas	Eco	Eco batch run for			
		Canopy	Landscape	Design	Forecast
Conterminous US	x[a]	x[b]	x[c]	x[d]	x[d]
Alaska	x[a]				
Hawaii	x[a]				
Puerto Rico	x[a]				
Australia	x[a]				
Canada	x[a]				
UK	x[a]				

x: Currently supported
[a]: Based on US urban area national average of impervious cover (=25.5%) (Nowak and Greenfield 2012)
[b]: Table (_LocationHydro) created but not implemented in application
[c]: Based on county rural/urban area average of impervious cover (2011 NLCD)
[d]: Run completed but table not created

3 Data Summary for Eco Processes

For i-Tree Canopy, Design, Forecast and Landscape, air pollutant removals, biogenic emissions and hydrologic services provided by 1 m^2 of tree cover were calculated by running internal models of i-Tree Eco in a batch process. In the conterminous United States, for instance, rural and urban areas in the counties were used as analysis domains for a batch process, and a database was created to store the data for each domain (e.g., tree cover, LAI, monitor information, population, etc.) required to run the models. i-Tree Eco's internal models were ran for each analysis domain repeatedly and the final results were stored in the LocationSpecies or other databases (Fig. 1). Two types of batch processes needed to run to pre-calculate the ecosystem services: 1) for i-Tree Canopy/Landscape with the actual LAI and evergreen% and 2) for i-Tree Design/Forecast with varied LAI (from 0

to 18) and evergreen% (0 or 100) . This section summarizes data employed to estimate each ecosystem service by i-Tree Eco and the batch processes for each supported country/area.

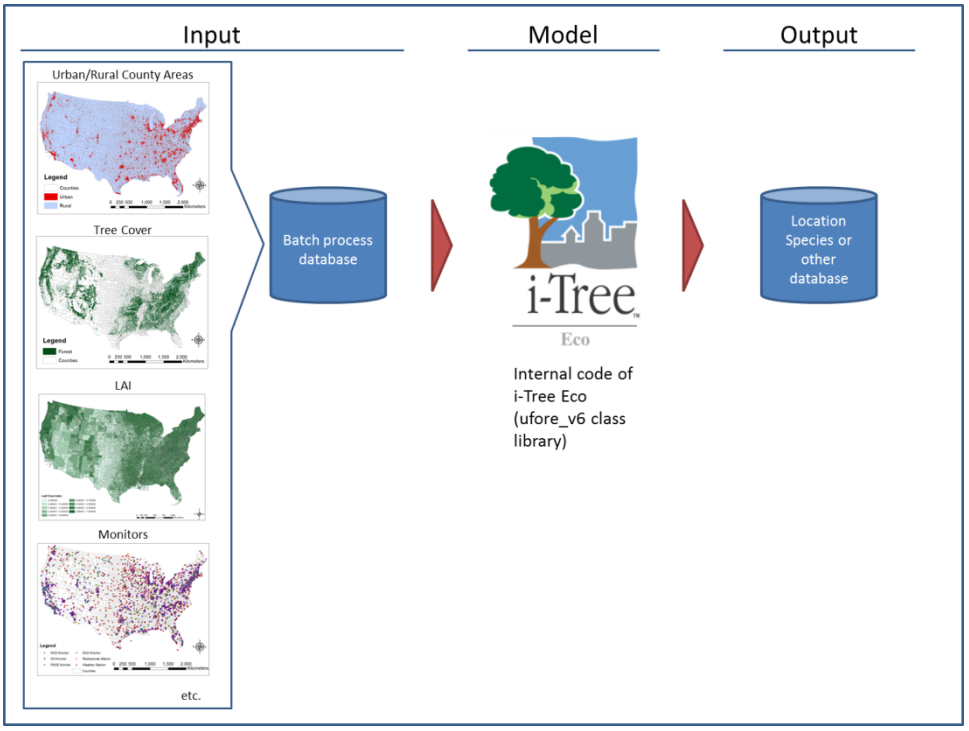

Figure 1 Process diagram of the batch process to estimate ecosystem service per 1 m^2 tree cover in the conterminous United States

3.1 Air Pollutant Removals

As presented in Table 1, the air pollutant removal analysis was supported for the conterminous United States, Alaska, Hawaii, Puerto Rico, Australia, Canada, and the UK. Eco batch runs were completed for the conterminous United States except for Design. Forecast batch was completed for the seven countries/areas. Other batch runs were partially completed. The following subsections summarize the data available and employed for each of supported countries/areas.

3.1.1 Conterminous United States

Table 4 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate air pollutant removals for i-Tree Canopy/Landscape,

Design/Forecast and US EPA's EnviroAtlas for the conterminous United States

		Model/Process			
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/ Forecast	Eco batch runs for EnviroAtlas
Analysis Domain		Primary/ Secondary/Tertiary partitions	Rural and urban areas in secondary partitions	Rural and urban areas in secondary partitions	Census block group
Year		2005-2013	2010	2010	2008
Air Pollutant		US EPA AQS[a]	US EPA AQS[a]	US EPA AQS[a]	EPA fused[b] ($PM_{2.5}$) US EPA AQS[a] (other pollutants)
Weather		NCDC[c]	NCDC[c]	NCDC[c]	NCDC[c]
Radiosonde		NOAA/ESRL[d]	NOAA/ESRL[d]	NOAA/ESRL[d]	NOAA/ESRL[d]
Forest	LAI	Plot-based estimate	MODIS 2007[e]	0-18 (0.5 increment)	4.5
	Tree Cover (%)	Plot-based estimate	NLCD 2001[f] adjusted[g]	NLCD 2001[f] adjusted[g]	EnviroAtlas-based estimate
	Evergreen (%)	Plot-based estimate	NLCD 2001[f] adjusted[g]	Evergreen 100% or Deciduous 100%	EnviroAtlas-based estimate
Area (m2)		Partition area	Partition area	Partition area	EnviroAtlas-based estimate
Population		2010 Census[h]	2010 Census[h]	2010 Census[h]	2010 Census[h]
Batch Process Completed?		N/A	Yes	Yes	Yes for pilot cities
Lookup Table Created		N/A	_LocationBenefits	_LocationCarbon _LocationPollutant, _LocationPollutantRegression	N/A

[a]: U.S. Environmental Protection Agency (US EPA), 2015b
[b]: U.S. Environmental Protection Agency (US EPA), 2015c
[c]: National Climatic Data Center (NCDC), 2015
[d]: Notional Oceanic and Atmospheric Administration (NOAA), 2015
[e]: U.S. Geological Survey (USGS), 2015a
[f]: U.S. Geological Survey (USGS), 2015c
[g]: Nowak and Greenfield, 2010
[h]: U.S. Census Bureau, 2015a

3.1.2 Alaska

Table 5 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate air pollutant removals for i-Tree Canopy/Landscape, Design/Forecast for Alaska

		Model/Process		
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2012-2013	2012	2012
Air Pollutant		EPA AQS[a]	EPA AQS[a]	EPA AQS[a]
Weather		NCDC[b]	NCDC[b]	NCDC[b]
Radiosonde		NOAA/ESRL[c]	NOAA/ESRL[c]	NOAA/ESRL[c]
Forest	LAI	Plot-based estimate	MODIS 2010[d]	0-18 (0.5 increment)
	Tree Cover (%)	Plot-based estimate	2005 North American Land Cover[e]	2005 North American Land Cover[e]
	Evergreen (%)	Plot-based estimate	2005 North American Land Cover[e]	Evergreen 100% or Deciduous 100%
Area (m2)		Partition area	Partition area	Partition area
Population		2010 Census[f]	2010 Census[f]	2010 Census[f]
Batch Process Completed?		N/A	Yes	Yes
Lookup Table Created		N/A	Not yet created	_LocationPollutant, _LocationPollutantRegression

[a]: U.S. Environmental Protection Agency (US EPA), 2015b
[b]: National Climatic Data Center (NCDC), 2015
[c]: Notional Oceanic and Atmospheric Administration (NOAA), 2015

[d]: U.S. Geological Survey (USGS), 2015a
[e]: U.S. Geological Survey (USGS), 2015b
[f]: U.S. Census Bureau, 2015a

3.1.3 Hawaii

Table 6 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate air pollutant removals for i-Tree Canopy/Landscape, Design/Forecast for Hawaii

		Model/Process		
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2005-09, 2011-13	2012	2012
Air Pollutant		EPA AQS[a]	EPA AQS[a]	EPA AQS[a]
Weather		NCDC[b]	NCDC[b]	NCDC[b]
Radiosonde		NOAA/ESRL[c]	NOAA/ESRL[c]	NOAA/ESRL[c]
Forest	LAI	Plot-based estimate	MODIS[d] (not yet processed)	0-18 (0.5 increment)
	Tree Cover (%)	Plot-based estimate	NLCD 2001[e]	NLCD 2001[e]
	Evergreen (%)	Plot-based estimate	NLCD 2001[e]	Evergreen 100% or Deciduous 100%
Area (m2)		Partition area	Partition area	Partition area
Population		2010 Census[f]	2010 Census[f]	2010 Census[f]
Batch Process Completed?		N/A	No	Yes
Lookup Table Created		N/A	Not yet created	_LocationPollutant, _LocationPollutantRegression

[a]: U.S. Environmental Protection Agency (US EPA), 2015b
[b]: National Climatic Data Center (NCDC), 2015
[c]: Notional Oceanic and Atmospheric Administration (NOAA), 2015
[d]: U.S. Geological Survey (USGS), 2015a

[e]: U.S. Geological Survey (USGS), 2015c
[f]: U.S. Census Bureau, 2015a

3.1.4 Puerto Rico

Table 7 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate air pollutant removals for i-Tree Canopy/Landscape, Design/Forecast for Puerto Rico

		Model/Process		
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2007, 2012	2012	2012
Air Pollutant		EPA AQS[a]	EPA AQS[a]	EPA AQS[a]
Weather		NCDC[b]	NCDC[b]	NCDC[b]
Radiosonde		NOAA/ESRL[c]	NOAA/ESRL[c]	NOAA/ESRL[c]
Forest	LAI	Plot-based estimate	MODIS[d] (not yet processed)	0-18 (0.5 increment)
	Tree Cover (%)	Plot-based estimate	NLCD 1992[e]	NLCD 1992 [e]
	Evergreen (%)	Plot-based estimate	NLCD 1992 [e]	Evergreen 100% or Deciduous 100%
Area (m2)		Partition area	Partition area	Partition area
Population		2010 Census[f]	2010 Census[f]	2010 Census[f]
Batch Process Completed?		N/A	No	Yes
Lookup Table Created		N/A	Not yet created	_LocationPollutant, _LocationPollutantRegression

[a]: U.S. Environmental Protection Agency (US EPA), 2015b
[b]: National Climatic Data Center (NCDC), 2015
[c]: Notional Oceanic and Atmospheric Administration (NOAA), 2015
[d]: U.S. Geological Survey (USGS), 2015a
[e]: U.S. Geological Survey (USGS), 2015c
[f]: U.S. Census Bureau, 2015a

3.1.5 Australia

Table 8 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate air pollutant removals for i-Tree Canopy/Landscape, Design/Forecast for Australia

		Model/Process		
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2010, 2011	2010, 2011	2010, 2011
Air Pollutant		Obtained from Australia	Obtained from Australia	Obtained from Australia
Weather		NCDC[a]	NCDC[a]	NCDC[a]
Radiosonde		NOAA/ESRL[b]	NOAA/ESRL[b]	NOAA/ESRL[b]
Forest	LAI	Plot-based estimate	MODIS[c] (not yet processed)	0-18 (0.5 increment)
	Tree Cover (%)	Plot-based estimate	Not obtained	Not obtained
	Evergreen (%)	Plot-based estimate	Not obtained	Evergreen 100% or Deciduous 100%
Area (m2)		Partition area	Partition area	Partition area
Population		Obtained from Australia	Obtained from Australia	Obtained from Australia
Batch Process Completed?		N/A	No	No
Lookup Table Created		N/A	Not yet created	Note yet created

[a]: National Climatic Data Center (NCDC), 2015
[b]: Notional Oceanic and Atmospheric Administration (NOAA), 2015
[c]: U.S. Geological Survey (USGS), 2015a

3.1.6 Canada

Table 9 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate air pollutant removals for i-Tree Canopy/Landscape,

Design/Forecast for Canada

		Model/Process		
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2010	2010	2010
Air Pollutant		NAPS[a]	NAPS[a]	NAPS[a]
Weather		NCDC[b]	NCDC[b]	NCDC[b]
Radiosonde		NOAA/ESRL[c]	NOAA/ESRL[c]	NOAA/ESRL[c]
Forest	LAI	Plot-based estimate	MODIS 2010[d]	0-18 (0.5 increment)
	Tree Cover (%)	Plot-based estimate	Earth Observation for Sustainable Development of forest (EOSD) land cover data[e] 2005 North American Land[f] for missing areas only	Earth Observation for Sustainable Development of forest (EOSD) land cover data[e] 2005 North American Land Cover[f] for missing areas only
	Evergreen (%)	Plot-based estimate	Earth Observation for Sustainable Development of forest (EOSD) land cover data[e] 2005 North American Land Cover[f] for missing areas only	Evergreen 100% or Deciduous 100%
Area (m2)		Partition area	Partition area	Partition area
Population		Obtained from Australia	Obtained from Australia	Obtained from Australia
Batch Process Completed?		N/A	Yes	Yes
Lookup Table Created		N/A	Not yet created	_LocationPollutant, _LocationPollutantRegression

[a]: Environment Canada, 2015
[b]: National Climatic Data Center (NCDC), 2015
[c]: Notional Oceanic and Atmospheric Administration (NOAA), 2015
[d]: U.S. Geological Survey (USGS), 2015a
[e]:Canadian Council of Forest Ministers, 2015
[f]: U.S. Geological Survey (USGS), 2015b

3.1.7 United Kingdom

Table 10 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate air pollutant removals for i-Tree Canopy/Landscape, Design/Forecast for the United Kingdom

		Model/Process		
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2013	2013	2013
Air Pollutant		Obtained from Forest Research of the UK	Obtained from Forest Research of the UK	Obtained from Forest Research of the UK
Weather		NCDC[a]	NCDC[a]	NCDC[a]
Radiosonde		NOAA/ESRL[b]	NOAA/ESRL[b]	NOAA/ESRL[b]
Forest	LAI	Plot-based estimate	MODIS[c] (not yet processed)	0-18 (0.5 increment)
	Tree Cover (%)	Plot-based estimate	Obtained from Forest Research of the UK	Obtained from Forest Research of the UK
	Evergreen (%)	Plot-based estimate	Obtained from Forest Research of the UK	Evergreen 100% or Deciduous 100%
Area (m2)		Partition area	Partition area	Partition area
Population		Obtained from Forest Research of the UK	Obtained from Forest Research of the UK	Obtained from Forest Research of the UK
Batch Process Completed?		N/A	No	Yes
Lookup Table Created		N/A	Not yet created	_LocationPollutant, _LocationPollutantRegres

				sion

[a]: National Climatic Data Center (NCDC), 2015
[b]: Notional Oceanic and Atmospheric Administration (NOAA), 2015
[c]: U.S. Geological Survey (USGS), 2015a

3.2 Biogenic VOC Emissions

As presented in Table 2, the biogenic VOC emission analysis was supported for the conterminous United States, Alaska, Hawaii, Puerto Rico, Australia, Canada, and the UK. Eco batch runs for Design/Forecast were completed for the conterminous US, Alaska and Canada; however, the final table was not created in the LocationSpecies or other databases. The following subsections summarize the data available and employed for each of supported countries/areas.

3.2.1 Conterminous United States

Table 11 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate biogenic VOC emissions for i-Tree Canopy/Landscape, Design/Forecast for the conterminous United States

		Model/Process		
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2005-2013	2010	2010
Weather		NCDC[a]	NCDC[a]	NCDC[a]
Forest	LAI	Plot-based estimate	MODIS 2007[b]	0-18 (0.5 increment)
	Evergreen (%)	Plot-based estimate	NLCD 2001 adjusted[c]	Evergreen 100% or Deciduous 100%
Batch Process Completed?		N/A	No	Yes
Lookup Table Created		N/A	Not yet created	Not yet created

[a]: National Climatic Data Center (NCDC), 2015
[b]: U.S. Geological Survey (USGS), 2015a
[c]: Nowak and Greenfield, 2010

3.2.2 Alaska

Table 12 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate biogenic VOC emissions for i-Tree Canopy/Landscape, Design/Forecast for Alaska

		Model/Process		
		Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2012-2013	2012	2012
Weather		NCDC[a]	NCDC[a]	NCDC[a]
Forest	LAI	Plot-based estimate	MODIS 2010[b]	0-18 (0.5 increment)
	Evergreen (%)	Plot-based estimate	2005 North American Land Cover[e]	Evergreen 100% or Deciduous 100%
Batch Process Completed?		N/A	No	Yes
Lookup Table Created		N/A	Not yet created	Not yet created

[a]: National Climatic Data Center (NCDC), 2015
[b]: U.S. Geological Survey (USGS), 2015a
[c]: U.S. Geological Survey (USGS), 2015b

3.2.3 Canada

Table 13 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate biogenic VOC emissions for i-Tree Canopy/Landscape, Design/Forecast for Canada

	Model/Process		
	Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast
Analysis Domain	Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year	2010	2010	2010
Weather	NCDC[a]	NCDC[a]	NCDC[a]

Forest	LAI	Plot-based estimate	MODIS 2010[b]	0-18 (0.5 increment)
	Evergreen (%)	Plot-based estimate	Canada's National Forest Information System[c] 2005 North American Land Cover[d] for missing areas only	Evergreen 100% or Deciduous 100%
Batch Process Completed?		N/A	No	Yes
Lookup Table Created		N/A	Not yet created	Not yet created

[a]: National Climatic Data Center (NCDC), 2015
[b]: U.S. Geological Survey (USGS), 2015a
[c]:Canadian Council of Forest Ministers, 2015
[f]: U.S. Geological Survey (USGS), 2015b

3.2.4 Other Countries/Areas

Biogenic VOC emission estimates are supported in i-Tree Eco for Hawaii, Puerto Rico, Australia, and the UK. The analysis domain, year, weather and forest data for these countries/areas to estimate biogenic VOC emissions are same as those listed in Tables 6, 7, 8 and 10, respectively.

3.3 Hydrologic Variables

As presented in Table 3, the hydrologic analysis was supported for the conterminous United States, Alaska, Hawaii, Puerto Rico, Australia, Canada, and the UK. Eco batch runs for the conterminous US was completed but not implemented in the i-Tree applications except Landscape. The following subsections summarize the data available and employed for each of supported countries/areas.

3.3.1 Conterminous United States

Table 14 Data summary for i-Tree Eco and i-Tree Eco batch runs to estimate hydrologic variables for i-Tree Canopy/Landscape, Design/Forecast for the conterminous United States

	Model/Process		
	Eco	Eco batch runs for Canopy/ Landscape	Eco batch runs for Design/Forecast

Analysis Domain		Primary/ Secondary/Tertiary partitions	Secondary partitions	Secondary partitions
Year		2005-2013	2010	2010
Weather		NCDC[a]	NCDC[a]	NCDC[a]
Forest	LAI	Plot-based estimate	MODIS 2007[b]	0-18 (0.5 increment)
	Tree Cover (%)	Plot-based estimate	NLCD 2001 adjusted[c]	NLCD 2001 adjusted[c]
	Evergreen (%)	Plot-based estimate	NLCD 2001 adjusted[c]	Evergreen 100% or Deciduous 100%
Area (m2)		Partition area	Partition area	Partition area
Impervious Cover (%)		National average – 25.5%[d]	County rural/urban average from NLCD 2011[e]	County rural/urban average from NLCD 2011[e]
Batch Process Completed?		N/A	Yes	Yes
Lookup Table Created		N/A	_LocationHydro	Not yet created

[a]: National Climatic Data Center (NCDC), 2015
[b]: U.S. Geological Survey (USGS), 2015a
[c]: Nowak and Greenfield, 2010
[d]: Nowak and Greenfield, 2012
[e]: U.S. Geological Survey (USGS), 2015c

3.3.2 Other Countries/Areas

Hydrologic variable estimates are supported in i-Tree Eco for Alaska, Hawaii, Puerto Rico, Australia, Canada and the UK. The analysis domain, year, weather, and forest and area data for these countries/areas to estimate hydrologic variables are same as those listed in Tables 5, 6, 7, 8, 9 and 10, respectively. National average for the impervious cover (25.5%) in the urban areas of the conterminous United States (Nowak and Greenfield, 2012) is used in these countries/areas.

4 Data Details

This section further details the data employed and available in each i-Tree application for the supported countries/areas.

4.1 County Rural and Urban Areas

For the conterminous US, Eco batch runs were performed on rural and urban areas in each county. These areas were delimited using 2010 Census data with rural land defined as land not classified as urban (U.S. Census Bureau, 2015b) (Fig. 1).

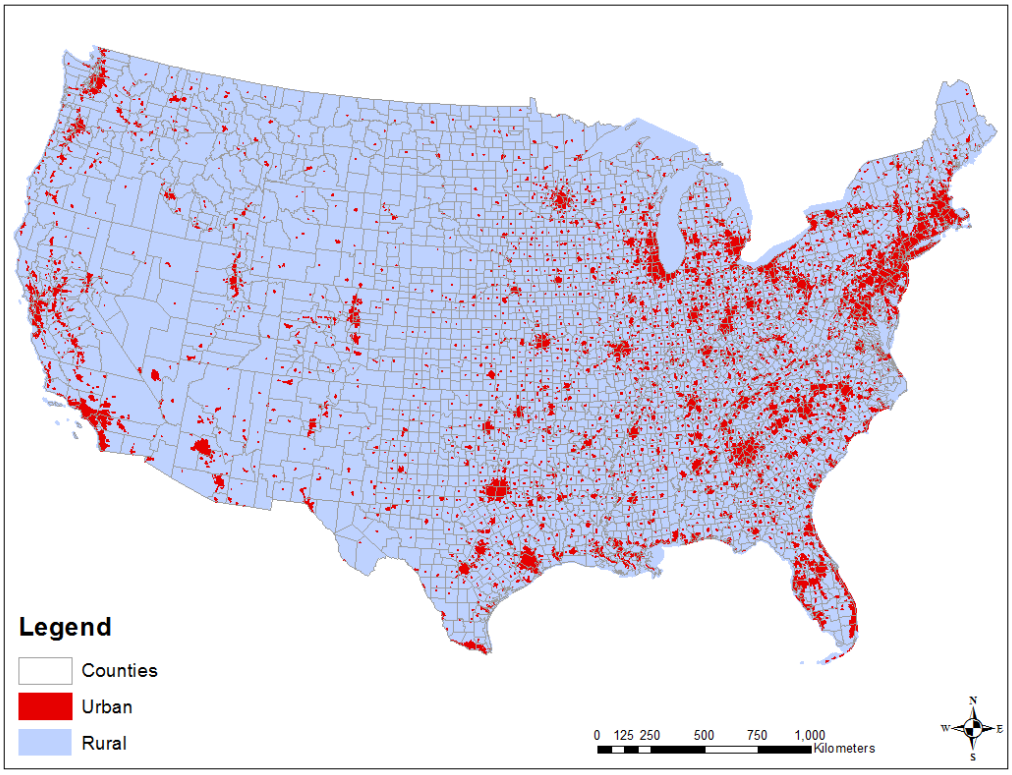

Figure 2 Rural and urban areas delimited for each county in the conterminous United States

4.2 Air Pollutant Concentration

Table 15 presents the number of air pollutant monitors from 2005 to 2013 in the supported countries/areas. In Alaska air pollutant data only for 2012 and 2013 could be used since monitors are insufficient in other years. In Puerto Rico, only 2007 and 2012 are usable as there are no missing monitors in these years. Air pollutant data for Virgin Islands

are available but not yet implemented in i-Tree Eco (monitor assignment was not recorded in _LocationAssignedPollutants table). In Australia, air pollutant data for 2010 (Australian Capital Territory, New South Wales, Tasmania, Victoria) and 2011 (Northern Territory, Queensland, South Australia, and Western Australia) are used in i-Tree Eco. In Canada, air pollutant data are available only for 2010 (PM10 is not available). In the UK, air pollutant data are available only for 2013.

Table 15 Number of air pollutant monitors

Year	Monitor	Conterminous US	Alaska	Hawaii	Puerto Rico	Virgin Islands	Australia	Canada	UK
2005	CO	415	0	2	1	0	0	0	0
	NO_2	421	0	2	0	0	0	0	0
	O_3	1183	1	1	0	0	0	0	0
	PM_{10}	995	1	5	5	0	0	0	0
	$PM_{2.5}$	1024	0	4	10	2	0	0	0
	SO_2	502	0	6	8	5	0	0	0
2006	CO	391	0	2	0	0	6	0	0
	NO_2	415	0	2	2	0	12	0	0
	O_3	1061	1	1	0	0	13	0	0
	PM_{10}	918	2	8	9	0	10	0	0
	$PM_{2.5}$	963	4	5	10	2	2	0	0
	SO_2	490	0	6	7	5	7	0	0
2007	CO	370	0	2	2	0	6	0	0
	NO_2	413	0	2	1	0	12	0	0
	O_3	1203	1	1	2	0	13	0	0
	PM_{10}	911	2	5	10	2	10	0	0
	$PM_{2.5}$	941	0	5	9	1	2	0	0
	SO_2	490	0	10	8	5	7	0	0
2008	CO	358	0	2	3	0	6	0	0
	NO_2	401	0	2	0	0	12	0	0
	O_3	1200	0	1	2	0	13	0	0
	PM_{10}	873	2	5	9	1	10	0	0

	$PM_{2.5}$	931	4	9	7	1	2	0	0
	SO_2	456	0	11	12	5	7	0	0
2009	CO	334	0	2	3	0	6	0	0
	NO_2	393	0	2	0	0	12	0	0
	O_3	1215	1	1	2	0	13	0	0
	PM_{10}	824	4	4	6	3	10	0	0
	$PM_{2.5}$	948	6	9	7	1	2	0	0
	SO_2	432	0	11	11	5	7	0	0
2010	CO	323	0	2	3	0	17	69	0
	NO_2	399	0	2	0	0	37	138	0
	O_3	1232	2	1	2	0	34	204	0
	PM_{10}	793	2	4	6	1	37	0	0
	$PM_{2.5}$	936	6	10	3	1	12	197	0
	SO_2	426	0	11	10	5	24	128	0
2011	CO	327	0	2	3	0	8	0	0
	NO_2	393	0	3	0	0	22	0	0
	O_3	1317	3	2	2	0	17	0	0
	PM_{10}	796	9	4	6	1	24	0	0
	$PM_{2.5}$	927	11	11	6	0	13	0	0
	SO_2	435	0	12	6	5	17	0	0
2012	CO	318	6	3	3	0	0	0	0
	NO_2	397	0	2	1	0	0	0	0
	O_3	1295	2	2	2	0	0	0	0
	PM_{10}	787	10	3	6	0	0	0	0
	$PM_{2.5}$	910	12	12	10	1	0	0	0
	SO_2	444	1	12	5	5	0	0	0
2013	CO	301	4	3	3	0	0	0	6
	NO_2	400	0	2	0	0	0	0	116
	O_3	1276	2	2	2	0	0	0	80
	PM_{10}	744	9	3	6	0	0	0	59
	$PM_{2.5}$	915	11	13	8	0	0	0	68
	SO_2	449	1	12	4	0	0	0	26

4.2.1 Conterminous United States

Hourly concentrations for six criteria air pollutants (CO, NO_2, O_3, PM_{10}, $PM_{2.5}$ and SO_2) for the conterminous United States were obtained from the U.S. EPA's Air Quality System national database for the year 2005 – 2013 (US EPA, 2015a). The missing values in the records were imputed based on week-of-year, day-of-week and hour-of-day means of data existing at a target site (Hirabayashi and Kroll, in preparation). Figures 3 presents air pollutant monitor locations in the United States.

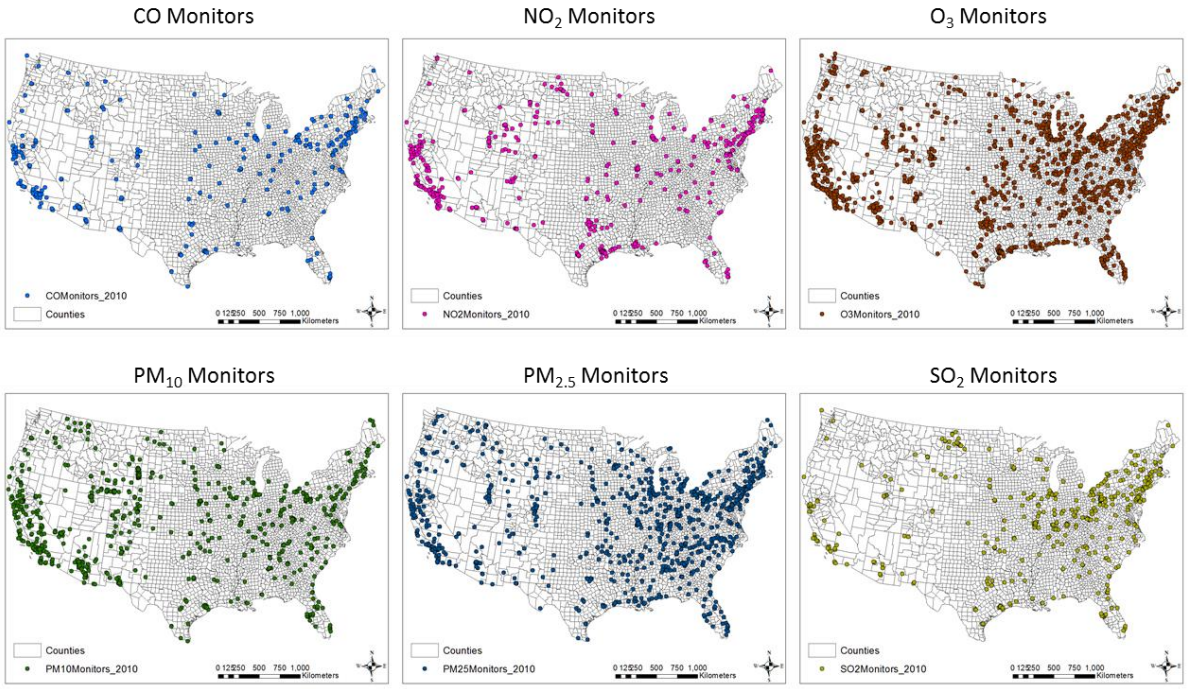

Figure 3 Air pollutant monitor locations for 2010 in the conterminous United States

4.2.2 Alaska

Hourly concentrations for five criteria air pollutants (CO, O_3, PM_{10}, $PM_{2.5}$ and SO_2) for Alaska were obtained from the U.S. EPA's Air Quality System national database for the year 2005 – 2013 (US EPA, 2015a). No NO_2 monitor is available for Alaska. Air pollutant data only for 2012 and 2013 could be used since monitors are insufficient in other years Missing values were linearly interpolated using the existing data measured right

before and after the missing values. Figure 4 presents air pollutant monitor locations in Alaska.

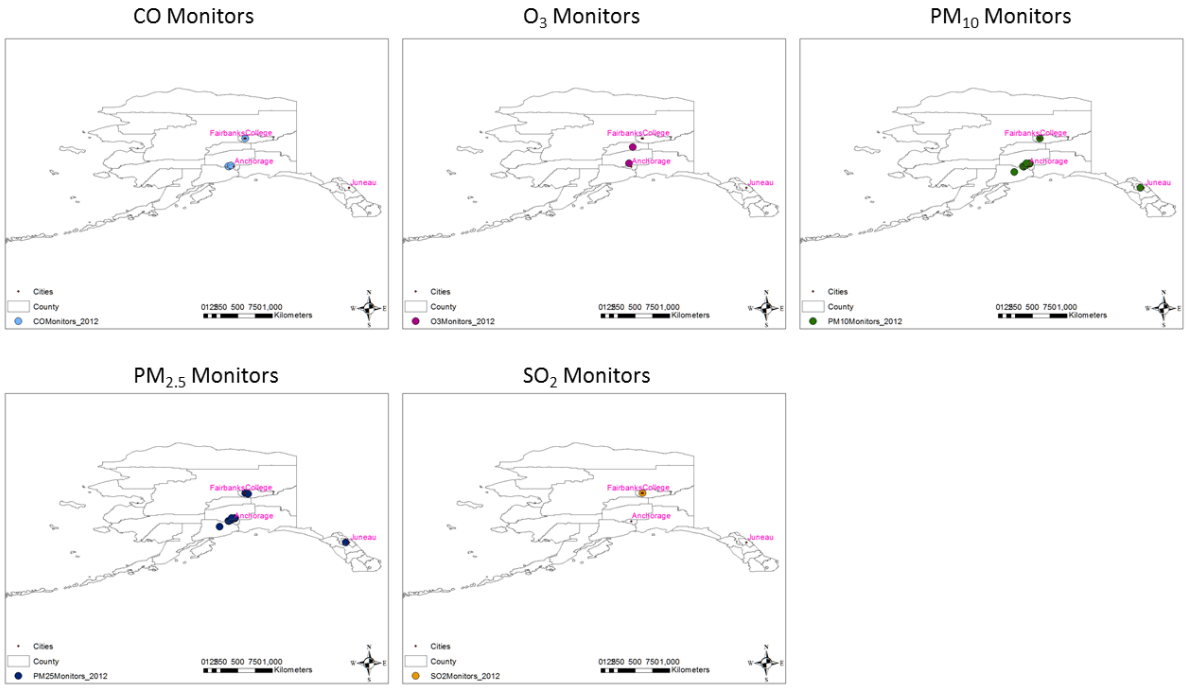

Figure 4 Air pollutant monitor locations for 2012 in Alaska

4.2.3 Hawaii

Hourly concentrations for six criteria air pollutants (CO, NO_2, O_3, PM_{10}, $PM_{2.5}$ and SO_2) for Hawaii were obtained from the U.S. EPA's Air Quality System national database for the year 2005 – 2013 (US EPA, 2015a). Missing values were linearly interpolated using the existing data measured right before and after the missing values. Figures 5 presents air pollutant monitor locations in Hawaii.

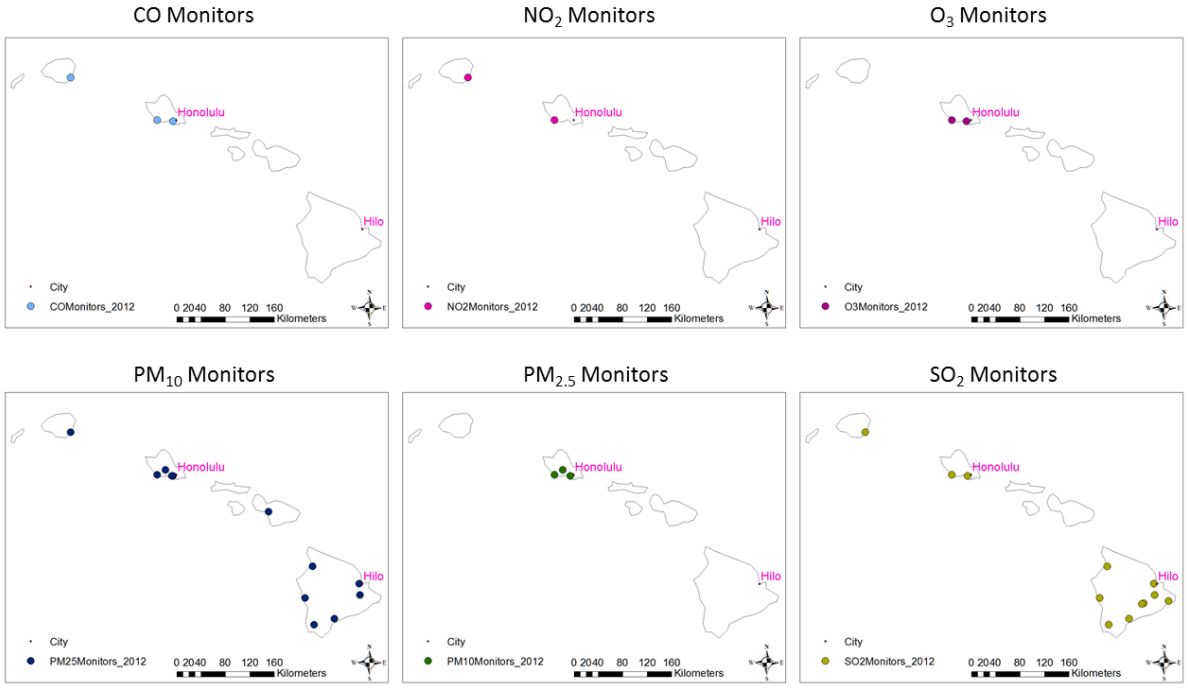

Figure 5 Air pollutant monitor locations for 2012 in Hawaii

4.2.4 Puerto Rico

Hourly concentrations for six criteria air pollutants (CO, NO_2, O_3, PM_{10}, $PM_{2.5}$ and SO_2) for the conterminous United States, Alaska, Hawaii, and Puerto Rico were obtained from the U.S. EPA's Air Quality System national database for the year 2005 – 2013 (US EPA, 2015a). Only 2007 and 2012 are usable as there are no missing monitors in these years. Missing values were linearly interpolated using the existing data measured right before and after the missing values. Figures 6 presents air pollutant monitor locations in Puerto Rico.

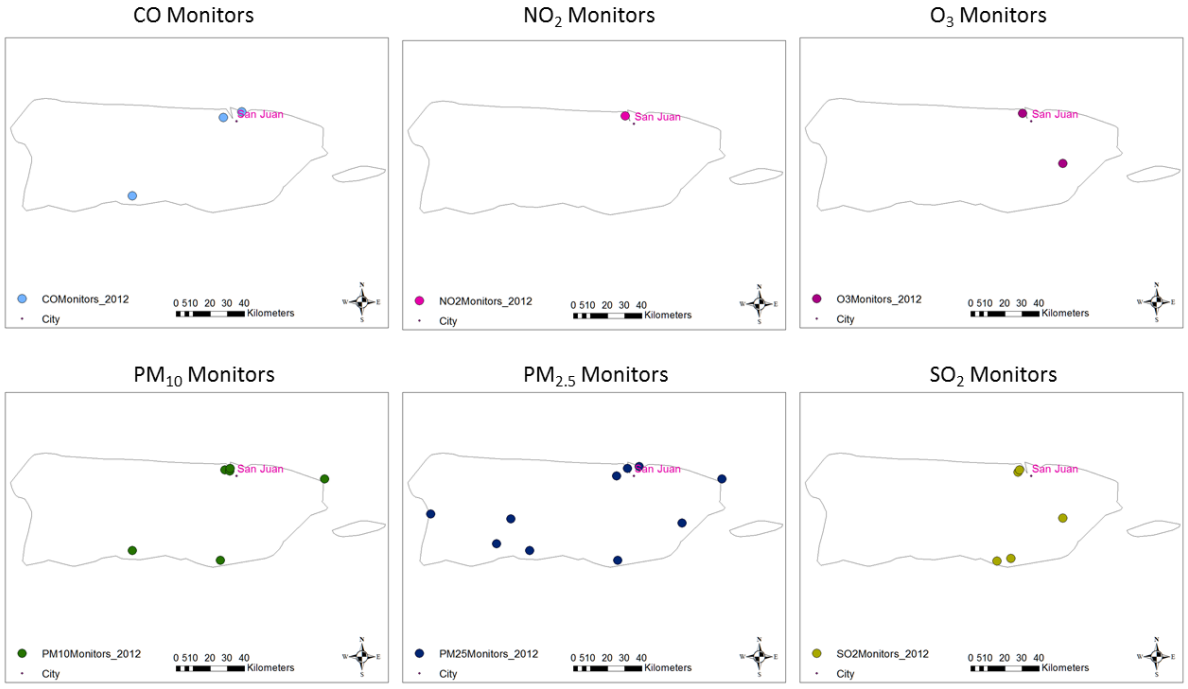

Figure 6 Air pollutant monitor locations for 2012 in Puerto Rico

4.2.5 Australia

Hourly air pollutant concentration data for Australia were obtained from ENSPEC in Australia. Figures 7 and 8 present air pollutant monitor locations in Australia. Missing values were linearly interpolated using the existing data measured right before and after the missing values.

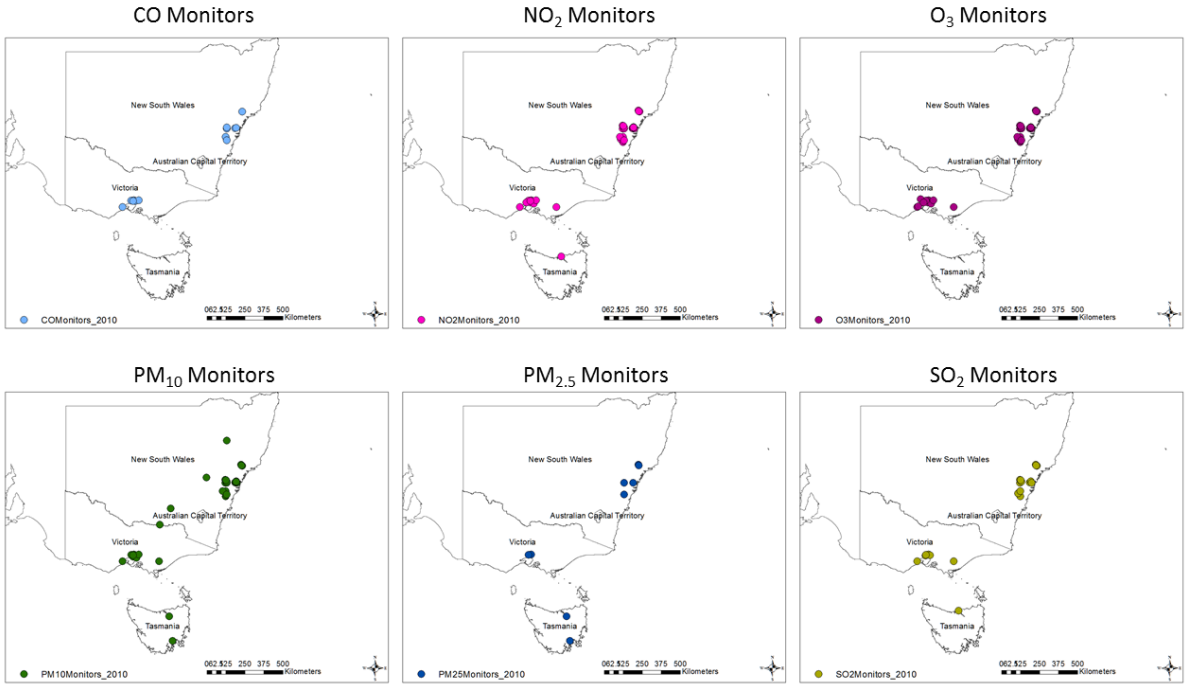

Figure 7 Air pollutant monitor locations for 2010 in Australian Capital Territory, New South Wales, Tasmania, and Victoria

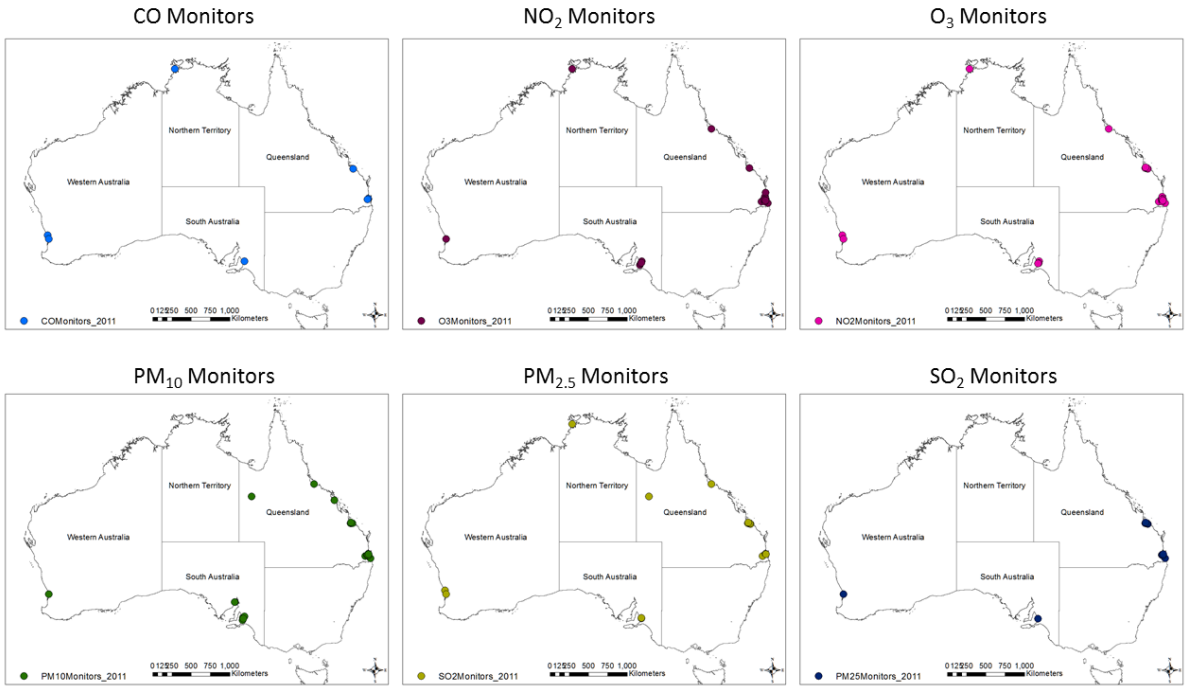

Figure 8 Air pollutant monitor locations for 2011 in Northern Territory, Queensland, South Australia, and Western Australia

4.2.6 Canada

Hourly air pollutant concentration data for Canada were obtained from NAPS (Environmental Canada, 2015). Currently only 2010 data are available in i-Tree Eco. Missing values were linearly interpolated using the existing data measured right before and after the missing values. Figure 9 presents air pollutant monitor locations in Canada.

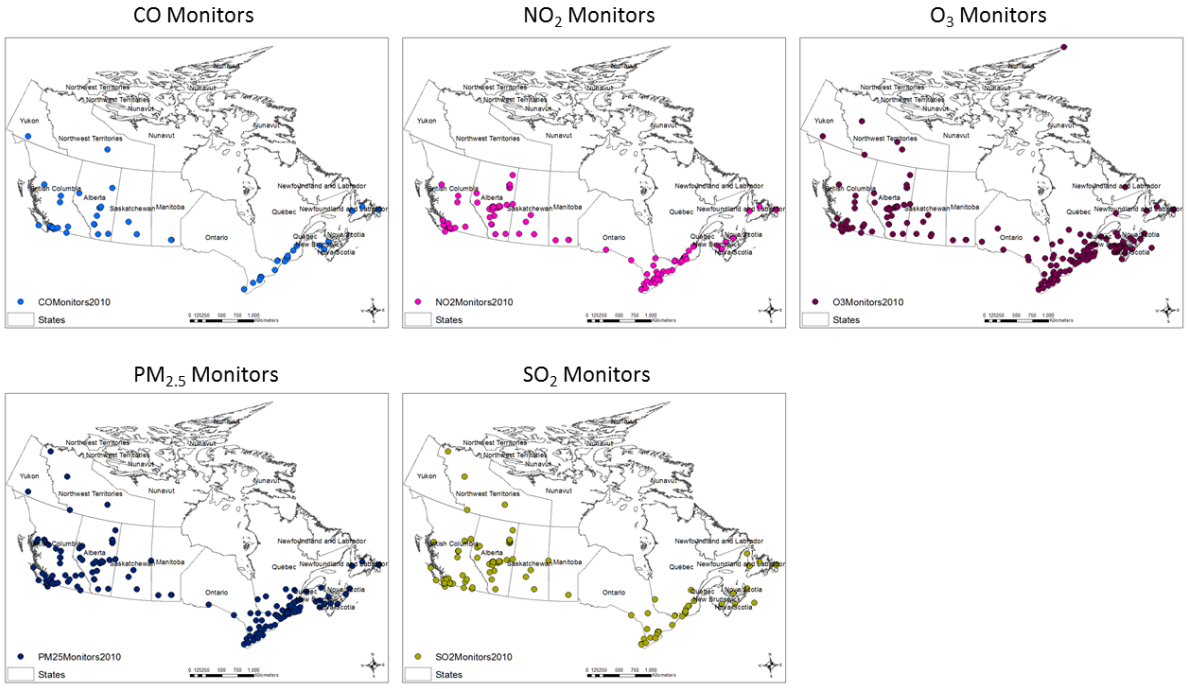

Figure 9 Air pollutant monitor locations for 2010 in Canada

4.2.7 United Kingdom

Figure 10 presents air pollutant monitor locations in the United Kingdom obtained from Forest Research agency of the UK. Missing values were linearly interpolated using the existing data measured right before and after the missing values.

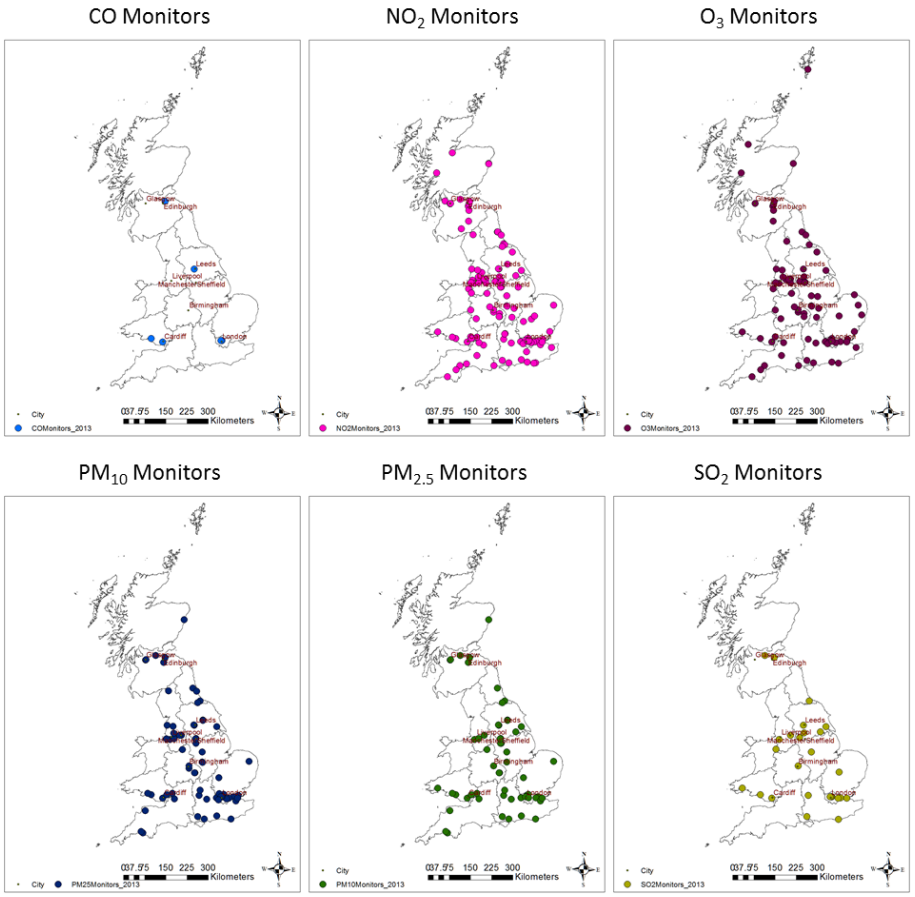

Figure 10 Air pollutant monitor locations for 2013 in the United Kingdom

4.3 Surface Weather

Table 16 presents the number of valid surface weather stations from 2005 to 2013 in the supported countries/areas as well as other international locations. Validation of weather stations is detailed in Hirabayashi (2015). Figures 11 and 12 presents valid weather station locations. Surface weather data in Canada, Australia and the UK generally lack hourly precipitation data (PCP01). 6-hour data (PCP06) were disaggregated into hourly data on the Eco server.

Table 16 Number of surface weather stations

Year	Conterminous US	Alaska	Hawaii	Puerto Rico	Virgin Islands	Australia	Canada	UK	Other Inter-national
2005	825	34	7	2	0	140	149	31	1911
2006	814	35	7	1	1	109	140	43	1942
2007	857	39	9	1	0	118	142	44	2185
2008	946	35	6	2	1	115	139	39	1985
2009	951	26	7	2	0	127	133	42	2165
2010	938	31	6	2	0	255	132	44	2113
2011	988	33	6	2	1	249	100	46	2305
2012	1069	30	9	1	2	93	104	42	2306
2013	228	16	8	1	1	21	125	25	370

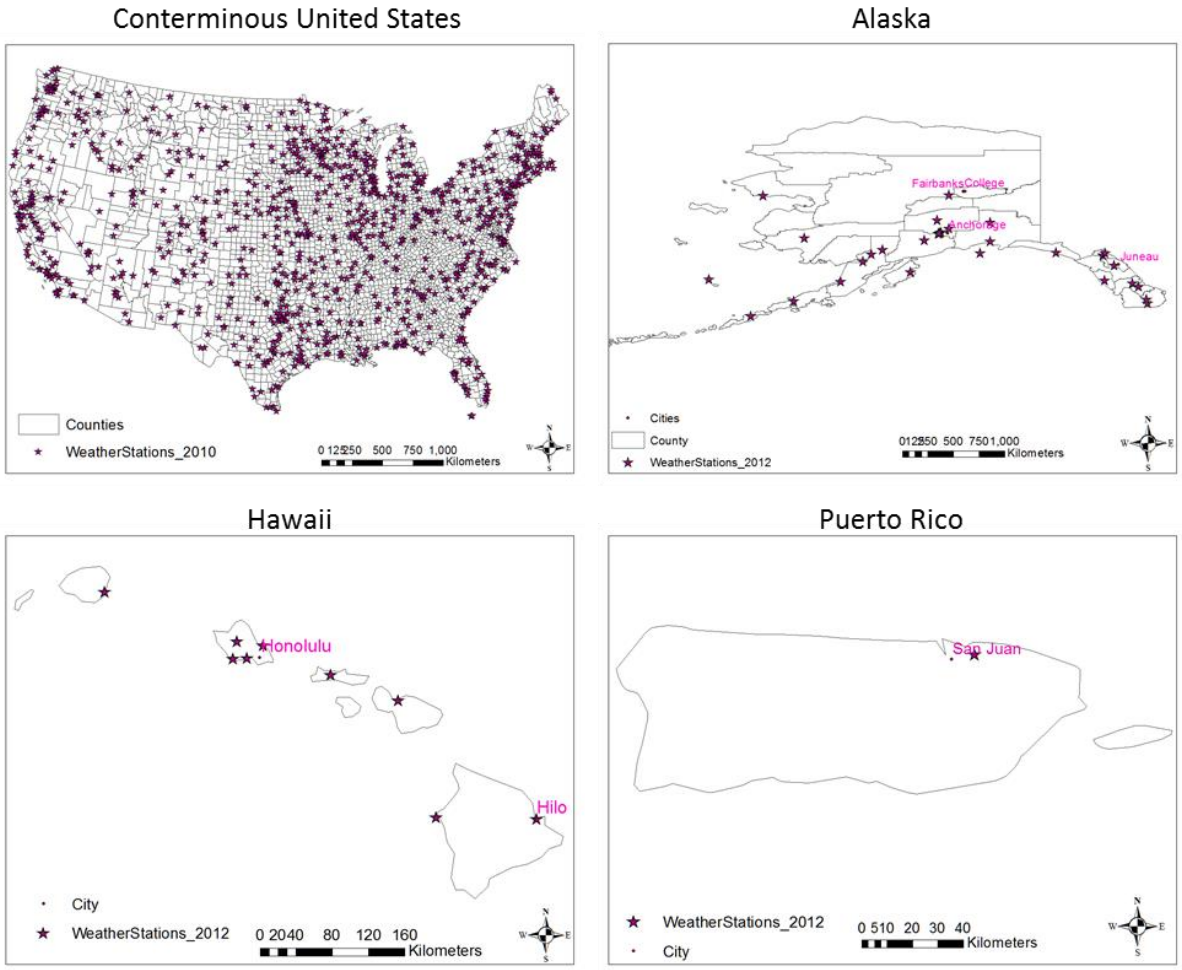

Figure 11 Surface weather station locations in the United States and Puerto Rico

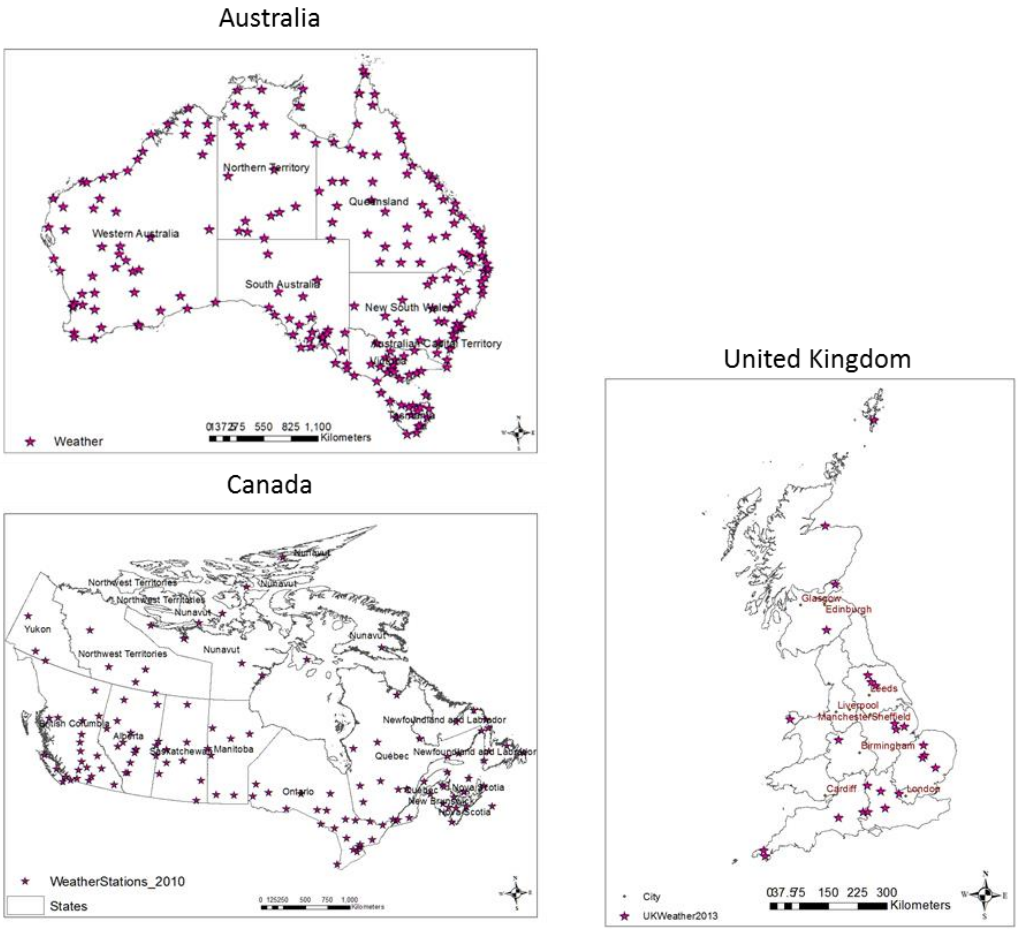

Figure 12 Surface weather station locations in the Australia, Canada, and the UK

4.4 Radiosonde (Upper Air)

Table 17 presents the number of radiosonde stations from 2005 to 2013 in the supported countries/areas as well as other international locations. Figures 13 and 14 present radiosonde station locations. In Hawaii no radiosonde data is available for 2010.

Table 17 Number of radiosonde (upper air) stations

Year	Conterminous US	Alaska	Hawaii	Puerto Rico	Virgin Islands	Australia	Canada	UK	Other International
2005	59	12	2	1	0	34	31	4	283
2006	58	14	2	1	0	32	29	4	283

2007	55	14	2	1	0	34	29	5	301
2008	64	11	2	1	0	34	30	6	316
2009	60	10	2	1	0	0	28	0	95
2010	69	11	0	0	0	32	30	5	325
2011	71	14	2	1	0	0	29	0	252
2012	72	10	2	1	0	30	30	6	311
2013	68	11	2	1	0	28	27	4	300

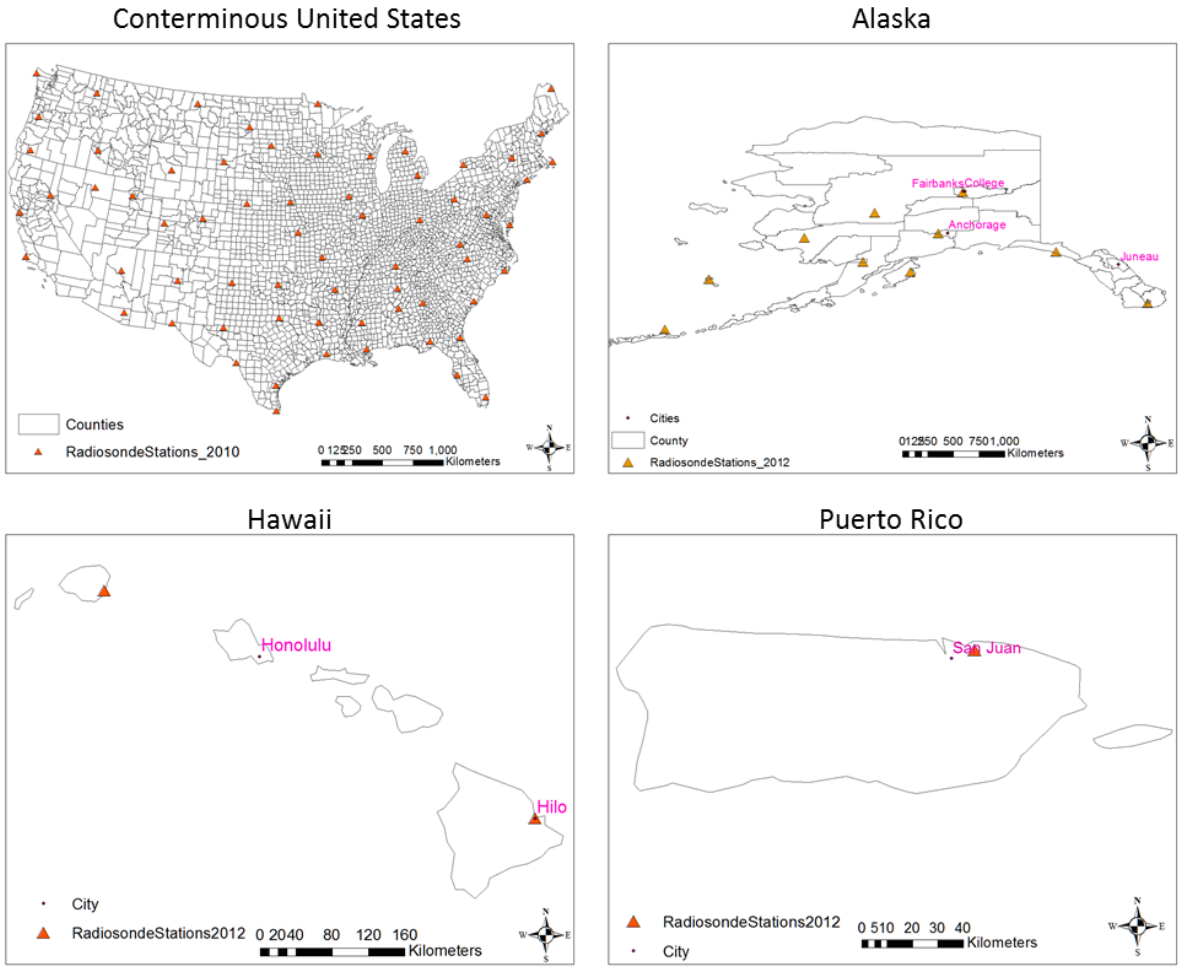

Figure 13 Radiosonde station locations in the United States and Puerto Rico

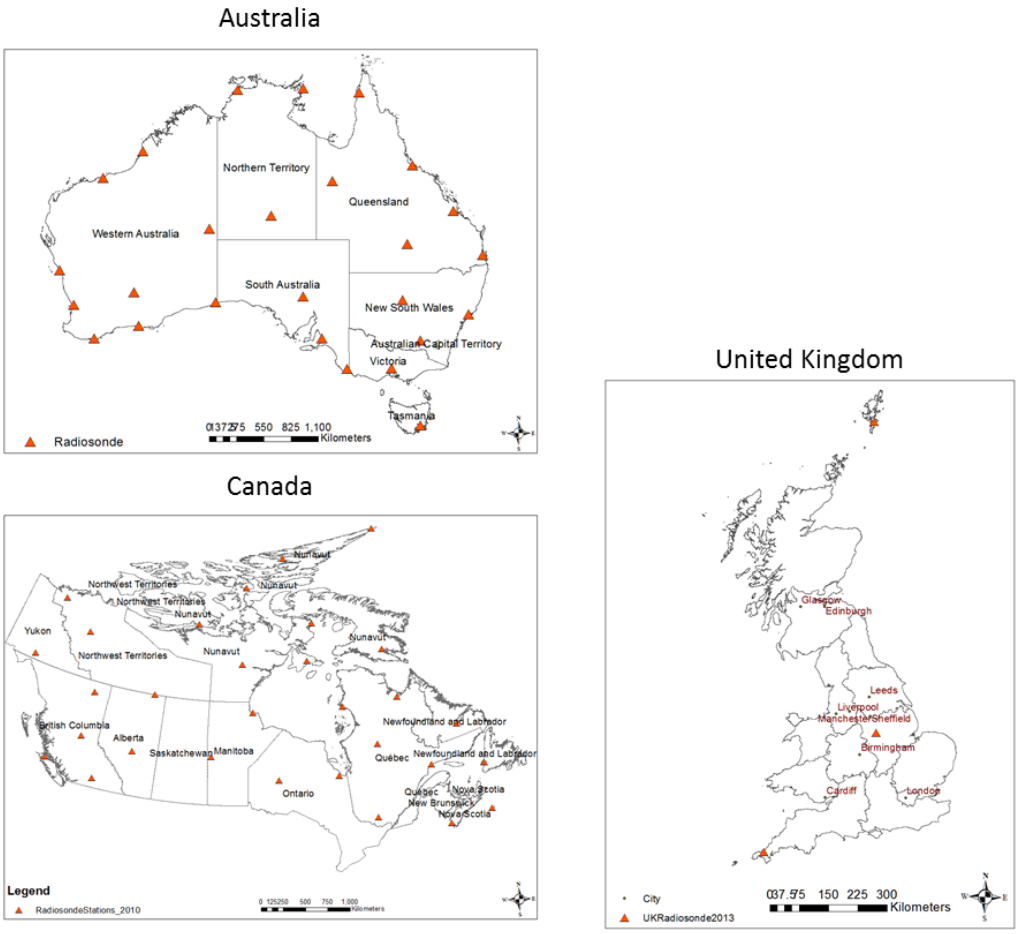

Figure 14 Radiosonde station locations in the Australia, Canada, and the UK

4.5 Tree Cover

4.5.1 Conterminous United States

Tree cover within each county's rural and urban areas in the conterminous United States was derived from 2001 National Land Cover Database (NLCD) 30-m resolution tree cover maps (USGS, 2015c) modified according to the Nowak and Greenfield (2010) photo-interpreted values within individual mapping zones (i.e., tree cover estimates were adjusted to match the photo-interpreted estimates for each land cover class within each mapping zone). Adjusted NLCD tree cover estimates were within 0.1 percent of estimates derived from photointerpretation (PI) of the conterminous United States (PI ¼ 34.2 percent, adjusted NLCD ¼ 34.1 percent), but this difference could be greater at the local scale.

Figure 15 presents tree cover in % and in hectares for rural/urban county areas in the conterminous United States.

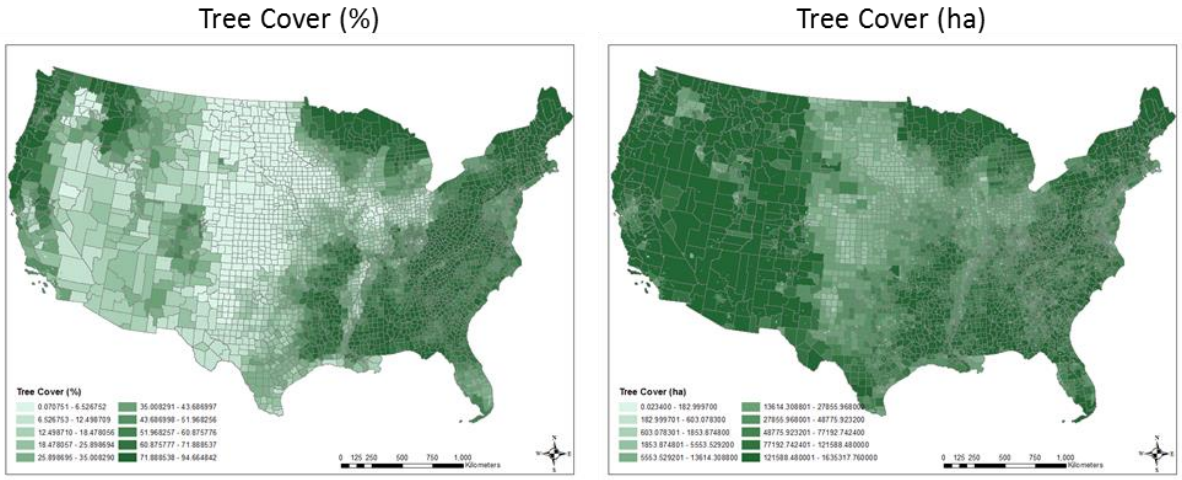

Figure 15 Tree cover (%) and tree cover (ha) for rural and urban county areas in the conterminous United States

4.5.2 Alaska

Tree cover within each county in Alaska was derived from 2005 North American Land Cover data (USGS, 2015b) shown in Figure 16. This map at a spatial resolution of 250 meters provides a harmonized view of the physical cover of Earth's surface across the North American continent in 2005. Nineteen Level II land cover classes were defined using the Land Cover Classification System (LCCS) standard developed by the Food and Agriculture Organization (FAO) of United Nations (FAO, 2015). From these land cover classes, “Temperate or sub-polar needleleaf forest", "Sub-polar taiga needleleaf forest", "Tropical or sub-tropical broadleaf evergreen forest" (none exists in Alaska), "Tropical or sub-tropical broadleaf deciduous forest" (none exists in Alaska), "Temperate or sub-polar broadleaf deciduous forest" and "Mixed forest" were extracted to represent the tree cover (Fig. 17). Figure 18 presents tree cover in % and hectares for each county in Alaska.

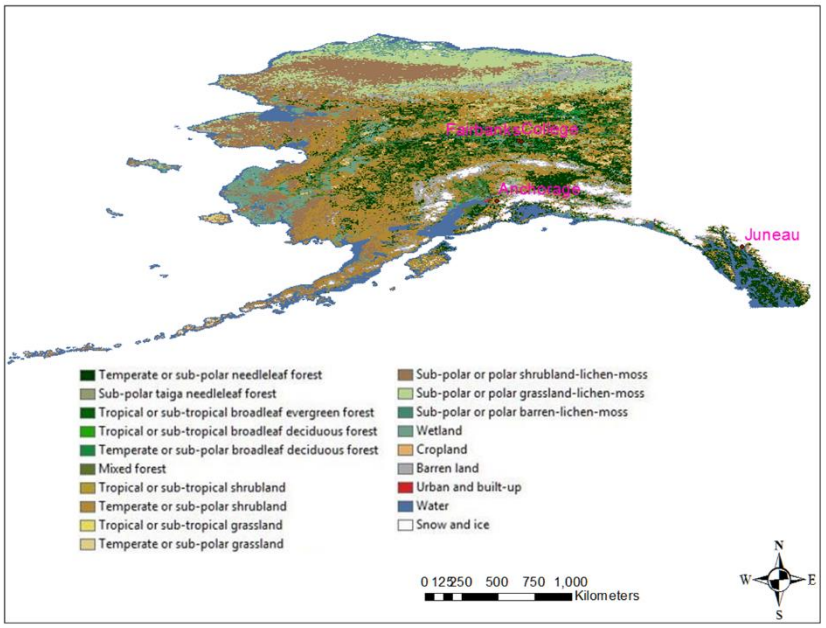

Figure 16 2005 North American Land Cover data for Alaska

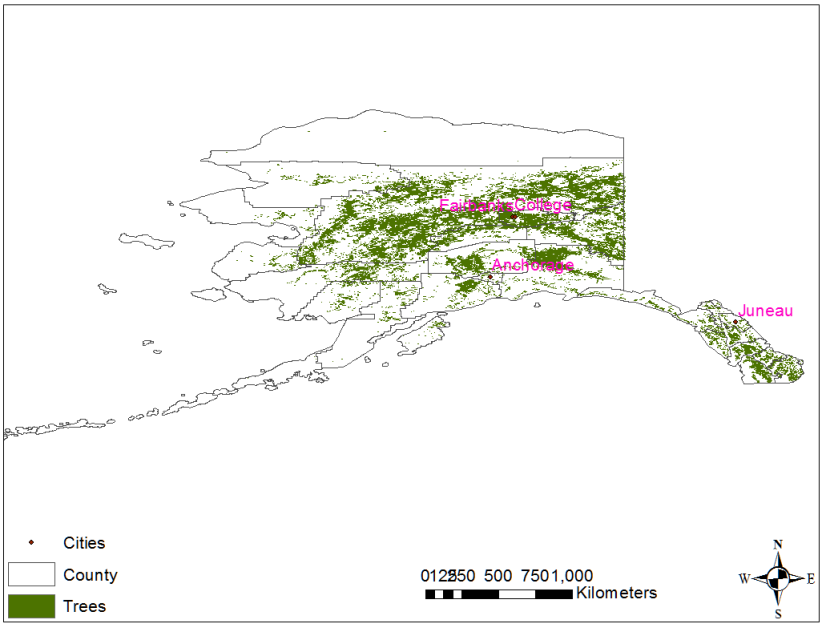

Figure 17 Tree cover for Alaska extracted from 2005 North American Land Cover data

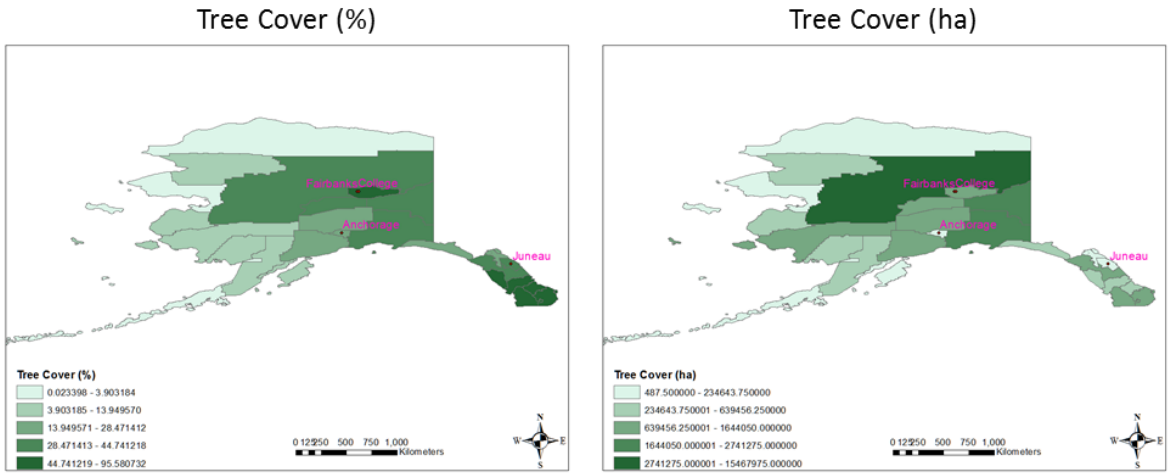

Figure 18 Tree cover (%) and tree cover (ha) for counties in Alaska

4.5.3 Hawaii

Tree cover within each county in Hawaii was derived from 2001 National Land Cover Database (NLCD) 30-m resolution land cover maps (USGS, 2015c) (Fig. 19). "Evergreen Forest" and "Mixed Forest" were extracted to represent the tree cover (Fig. 20). There is no "Deciduous Forest" land covers in Hawaii.

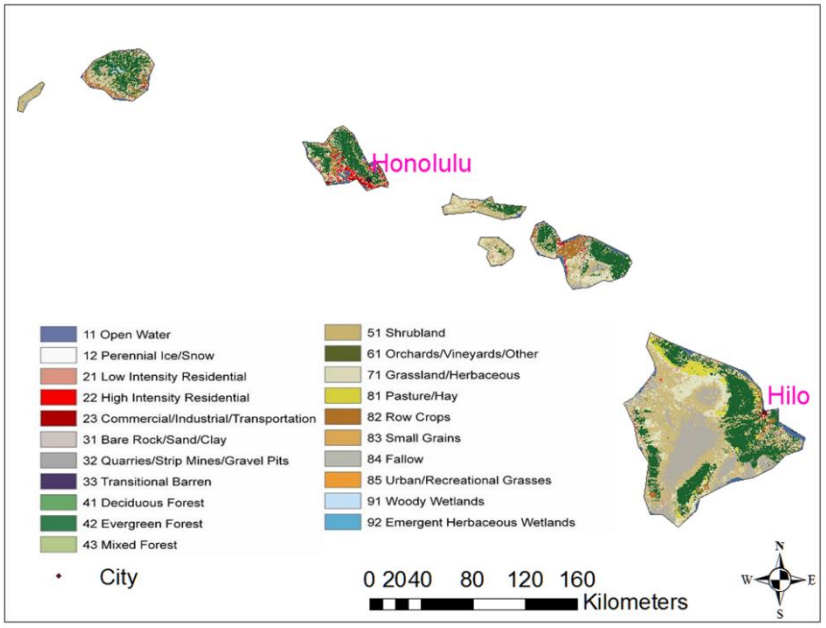

Figure 19 2001 National Land Cover Database (NLCD) data for Hawaii

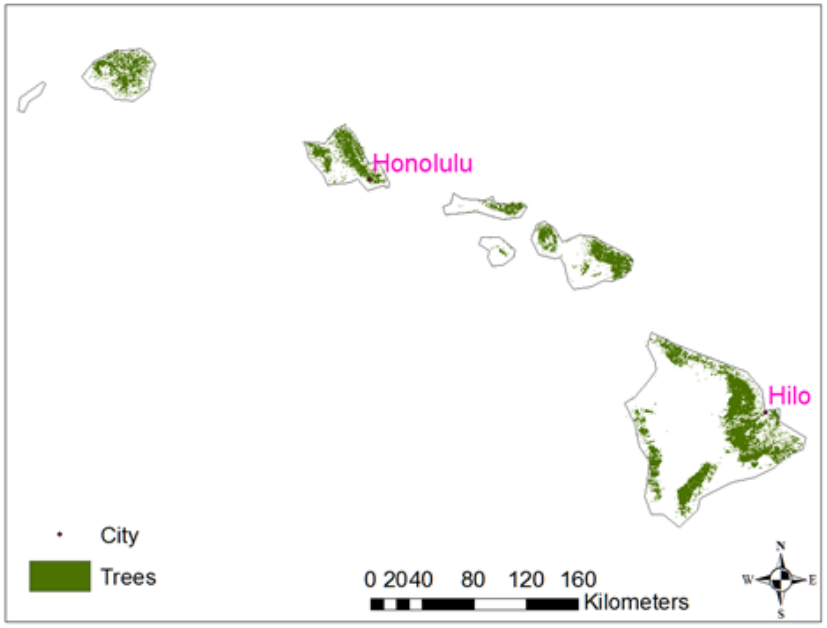

Figure 20 Tree cover for Hawaii extracted from 2005 North American Land Cover data

4.5.4 Puerto Rico

Tree cover for Puerto Rico was derived from 1992 National Land Cover Database (NLCD) 30-m resolution land cover maps (USGS, 2015c) (Fig. 21). “Evergreen Forest” and “Mixed Forest” were extracted to represent the tree cover (Fig. 22). There is no “Deciduous Forest” land covers in Puerto Rico.

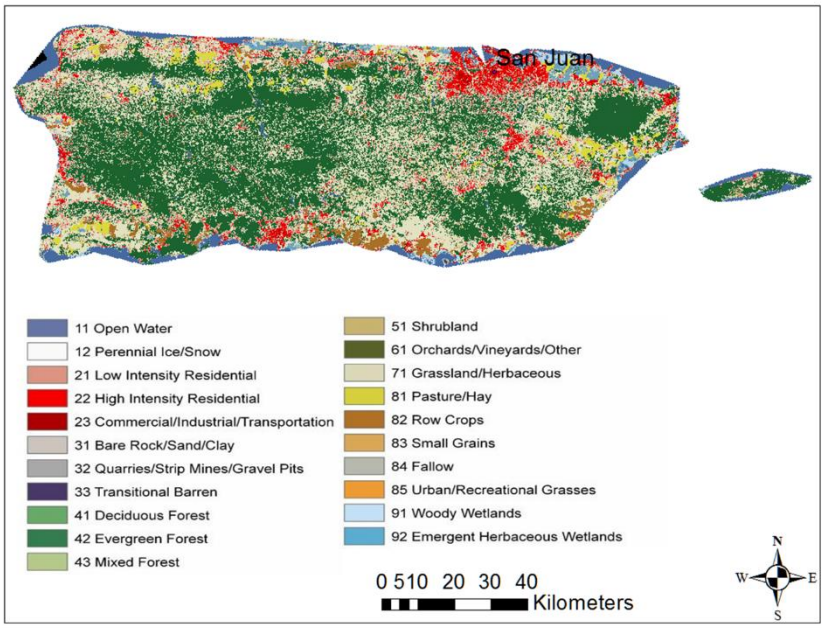

Figure 21 1992 National Land Cover Database (NLCD) data for Puerto Rico

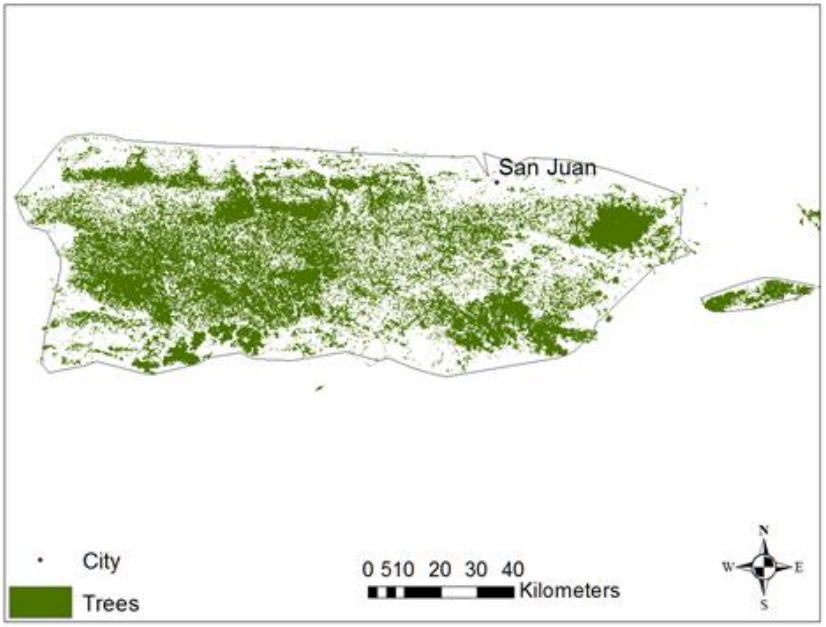

Figure 22 Tree cover for Puerto Rico extracted from 1992 National Land Cover Database (NLCD) data

4.5.5 Australia

Tree cover data for Australia has not been obtained.

4.5.6 Canada

Tree cover within each county in Canada was derived from Canada's National Forest Information System's Earth Observation for Sustainable Development of forests (EOSD) initiative products with a 25m spatial resolution (Canadian Council of Forest Minister, 2015) (Fig. 23). EOSD land cover products were created based on the National Topographic System (NTS) map sheet framework of the National Topographic Database (Wulder et al., 2006). Totally 610 NTS sheets that cover Canada's forested ecozones are downloadable on a 1:250,000 NTS map sheet basis, each of which represents approximately 14,850km^2. The EOSD legend was developed to fit with National Forest Inventory (NFI) (NFI, 2015)'s hierarchical classification (Wulder, 2003). For areas excluded in the EOSD land cover data, 2005 North American Land Cover data was employed (USGS, 2015b). (Fig. 24). "Coniferous – Dense", "Coniferous – Open", "Coniferous – Sparse", "Broadleaf - Dense", "Broadleaf – Open", "Broadleaf – Sparse", "Mixed Wood – Dense", "Mixed Wood – Open", "Mixed Wood – Sparse" land cover classes from the EOSD data and those classes same as Alaska from the 2005 North American Land Cover data were extracted to represent the tree cover (Fig. 25). Figure 26 presents tree cover in % and hectares for each county in Canada.

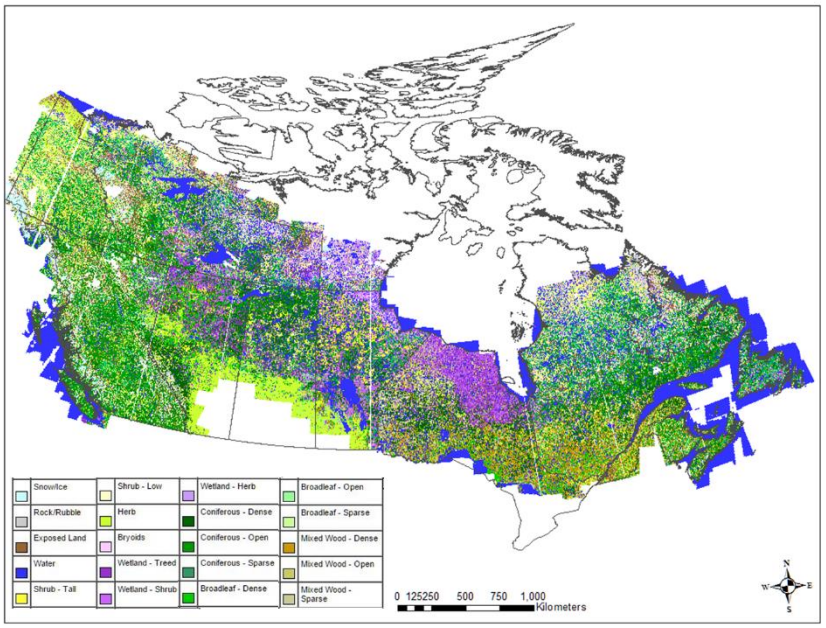

Figure 23 Earth Observation for Sustainable Development of forests land cover data for forested ecozones in Canada

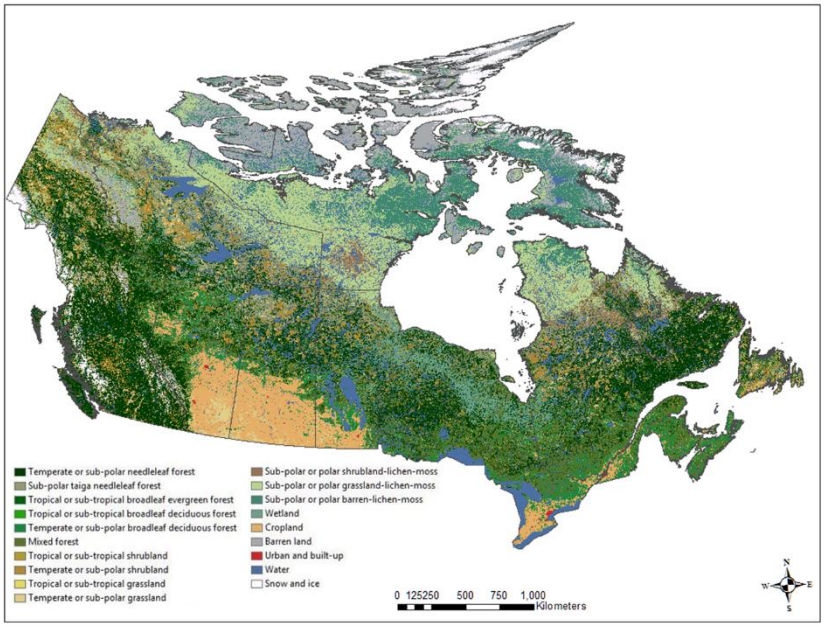

Figure 24 2005 North American Land Cover data for Canada

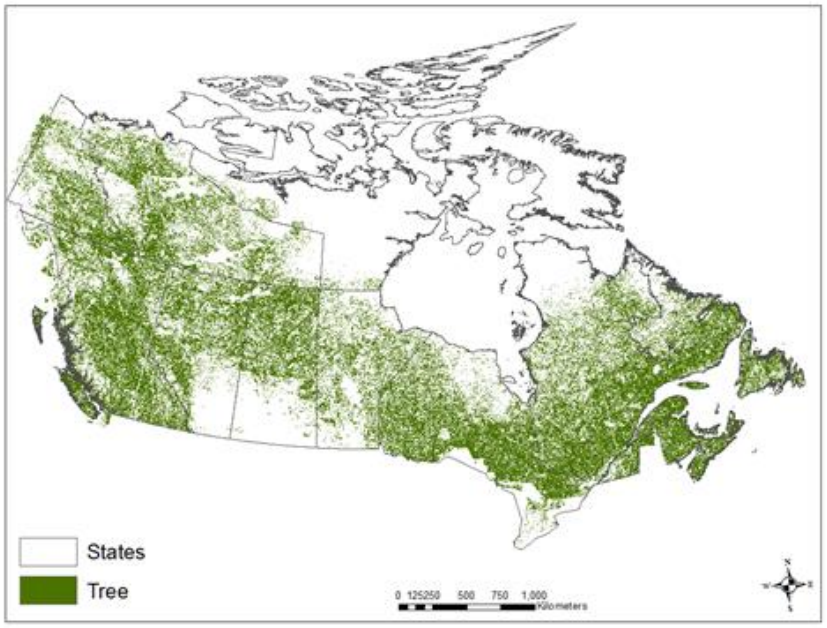

Figure 25 Tree cover for Canada extracted from EOSD land cover data and 2005 North American Land Cover data

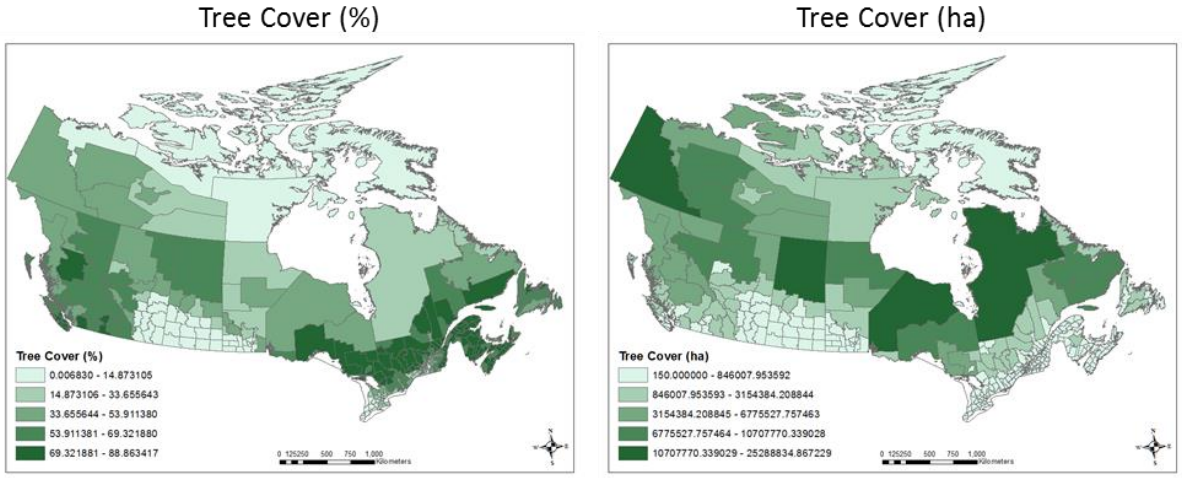

Figure 26 Tree cover (%) and tree cover (ha) for counties in Canada

4.5.7 United Kingdom

Tree cover information for the secondary partitions in the UK was obtained from Forest Research of the UK.

4.6 Evergreen Tree Cover

4.6.1 Conterminous United States

Percent tree cover classified as evergreen was determined for each rural/urban county area based on evergreen, deciduous and mixed forest land covers as classified by the NLCD. The proportion of mixed forest cover that was evergreen was estimated as the proportion of evergreen to evergreen plus deciduous forest cover in each county.

4.6.2 Alaska

"Temperate or sub-polar broadleaf deciduous forest" land cover was extracted to represent the deciduous tree cover, while "Temperate or sub-polar needleleaf forest" and "Sub-polar taiga needleleaf forest" land covers were extracted to represent the evergreen tree cover. Based on these, the percent tree cover classified as evergreen was determined for each county (Fig. 27).

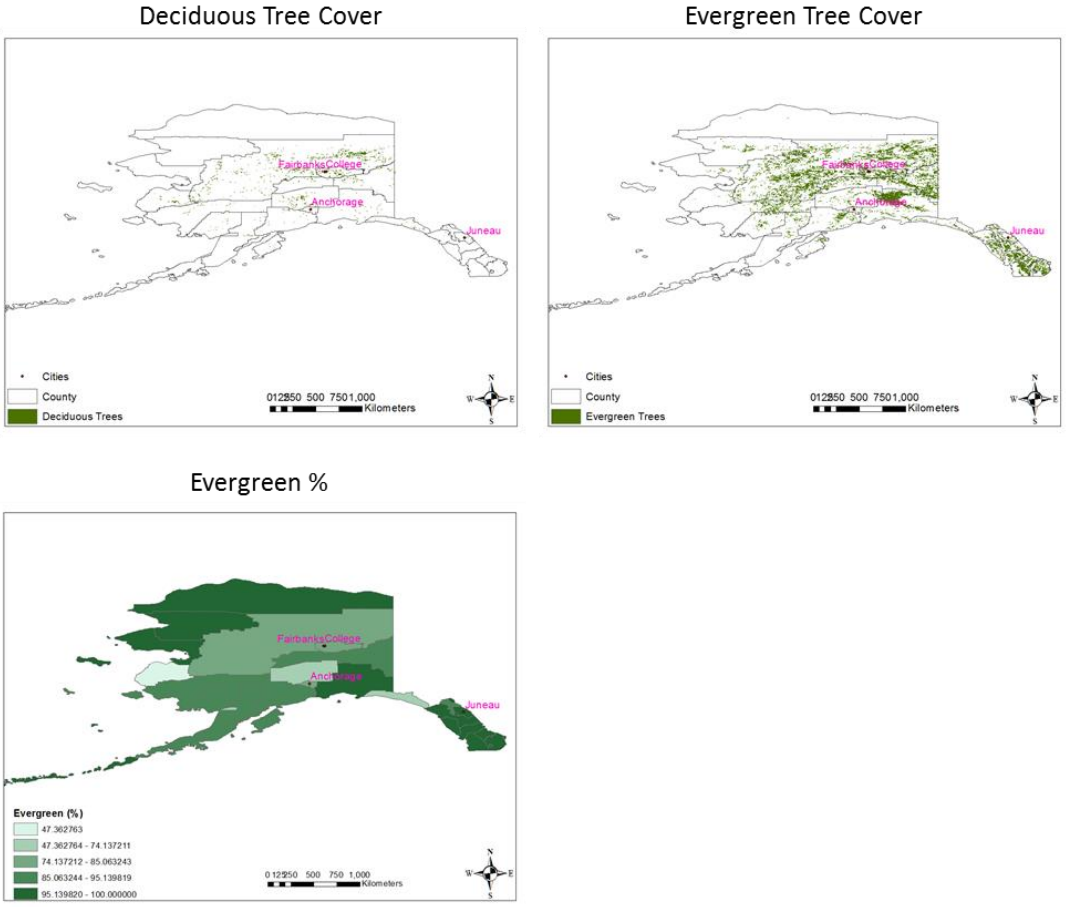

Figure 27 Deciduous and evergreen tree covers in Alaska

4.6.3 Hawaii

As there is no deciduous forest cover in Hawaii, tree cover classified as evergreen is 100%.

4.6.4 Puerto Rico

As there is no deciduous forest cover in Puerto Rico, tree cover classified as evergreen is 100%.

4.6.5 Australia

Tree cover information from Australia has not been obtained.

4.6.6 Canada

“Broadleaf - Dense”, “Broadleaf – Open” and “Broadleaf – Sparse” land cover classes from the EOSD data (Canadian Council of Forest Minister, 2015) and “Temperate or sub-polar broadleaf deciduous forest" land cover class from 2005 North American Land Cover data (USGS, 2015b) were extracted to represent the deciduous tree cover, while “Coniferous – Dense”, “Coniferous – Open”, “Coniferous – Sparse” land cover classes from the EOSD data and “Temperate or sub-polar needleleaf forest" and "Sub-polar taiga needleleaf forest" land covers from 2005 North American Land Cover data were extracted to represent the evergreen tree cover. Based on these, the percent tree cover classified as evergreen was determined for each county in Canada (Fig. 28).

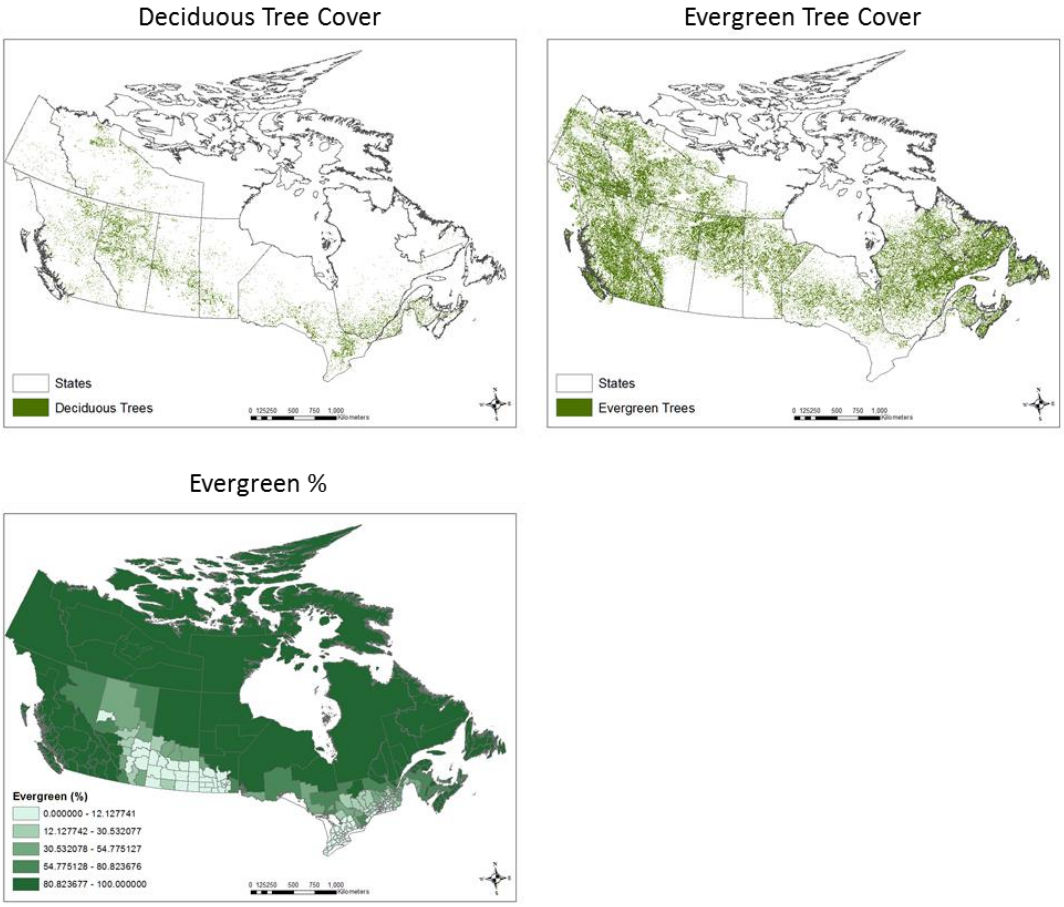

Figure 28 Deciduous and evergreen tree covers in Canada

4.6.7 United Kingdom

Tree cover information for the secondary partitions in the UK was obtained from Forest Research of the UK.

4.7 Leaf Area Index

4.7.1 Conterminous United States

Maximum (mid-summer) leaf area index (LAI: m^2 leaf area per m^2 projected ground area of canopy) values were derived from the level-4 MODIS/Terra global Leaf Area Index product for the growing season. The year 2007 was used for the i-Tree Eco

batch runs for Canopy/Landscape for the conterminous United States. In some areas, LAI values per unit of tree cover were missing or abnormally low and were estimated as 4.9 (Nowak et al., 2008) for urban areas (65 percent of urban areas had missing values) in the conterminous United States and 3.2 (Schlerf et al., 2005) for rural areas in the conterminous United States (14.5 percent of rural areas had missing values) and Alaska and Canada. Many urban areas had missing LAI estimates due to the coarseness of the MODIS data and relatively low amounts of forest cover in urban areas. Figure 29 presents the maximum LAI for each rural/urban area in the conterminous United States.

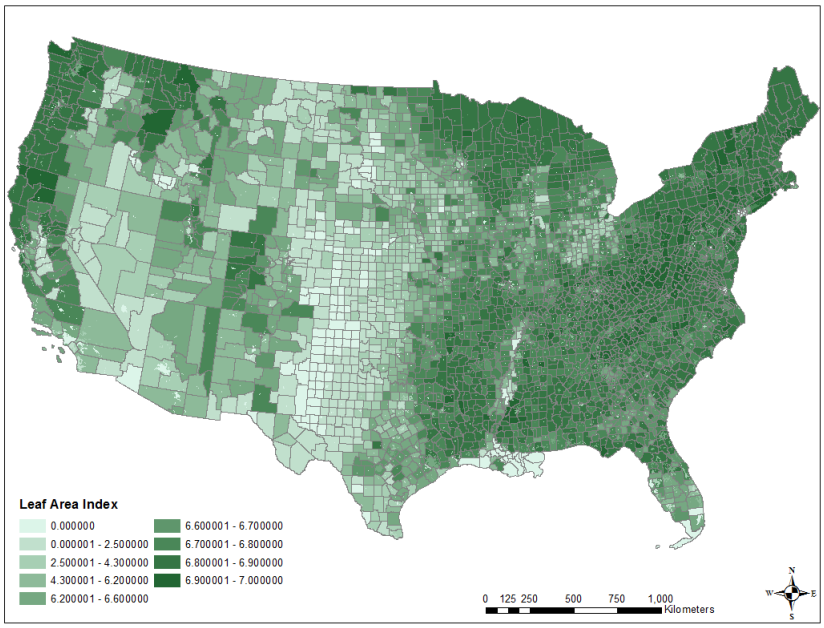

Figure 29 Maximum LAI for rural/urban county areas in the conterminous United States

4.7.2 Alaska

MODIS 2010 LAI data was used for Alaska. Figure 30presents the maximum LAI for each county in Alaska.

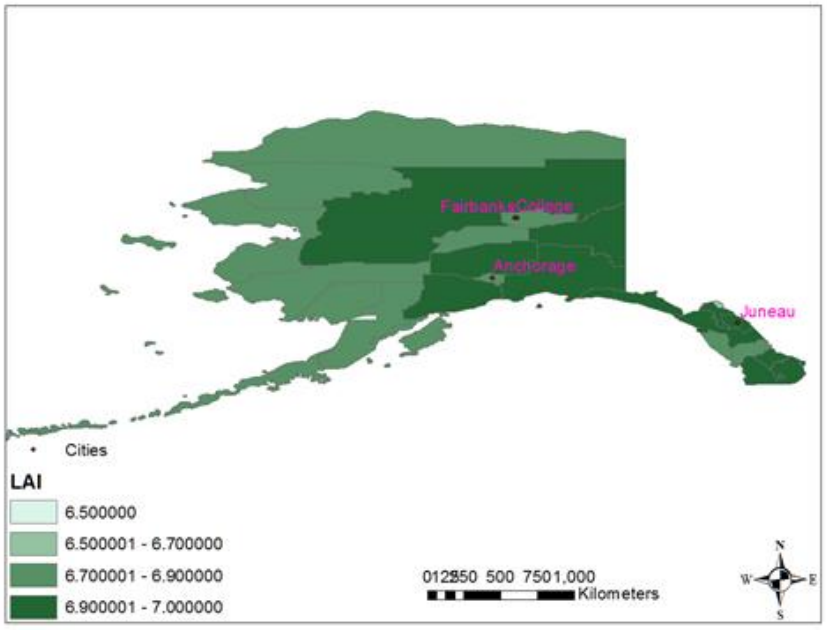

Figure 30 Maximum LAI for each county in Alaska

4.7.3 Hawaii

LAI information for Hawaii has not been processed.

4.7.4 Puerto Rico

LAI information for Puerto Rico has not been processed.

4.7.5 Australia

LAI information for Australia has not been processed.

4.7.6 Canada

MODIS 2010 LAI data was used for Canada. Figure 31 presents the maximum LAI for each county in Canada.

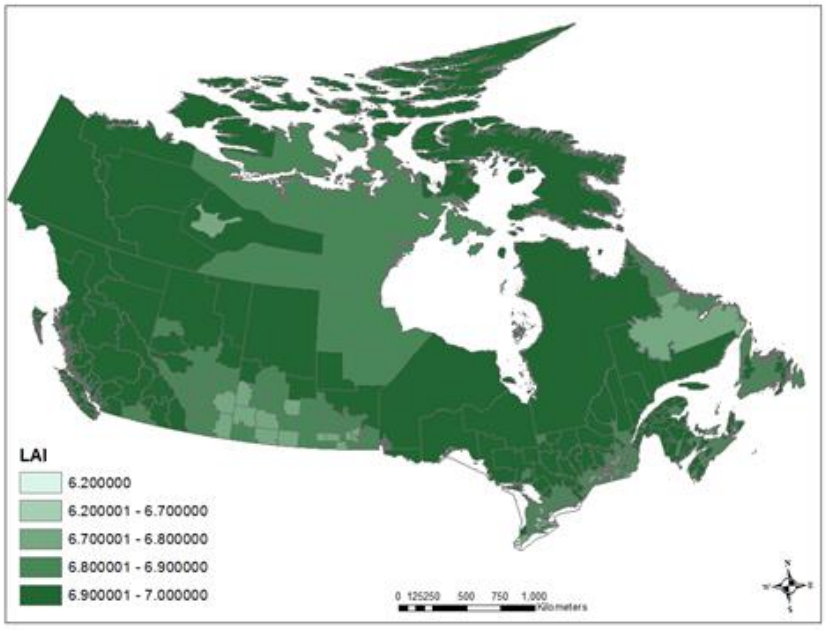

Figure 31 Maximum LAI for each county in Canada

4.7.7 United Kingdom

LAI information for the secondary partitions in the UK was obtained from Forest Research of the UK.

4.8 Impervious Cover

Impervious cover is used in i-Tree Eco to estimate avoided run off due to trees' precipitation interception as well as depression storage in pervious cover.

4.8.1 Conterminous United States

For i-Tree Eco, the national average of impervious cover % (=25.5%) in the urban areas (Nowak and Greenfield, 2010) is used. For i-Tree Eco batch processes for Canopy/Landscape and Design/Forecast, the average impervious cover % for each of rural/urban county area derived from NLCD 2011 (USGS, 2015c) was used. Figure 32 presents impervious cover (%) for each rural/urban county area in the conterminous United States.

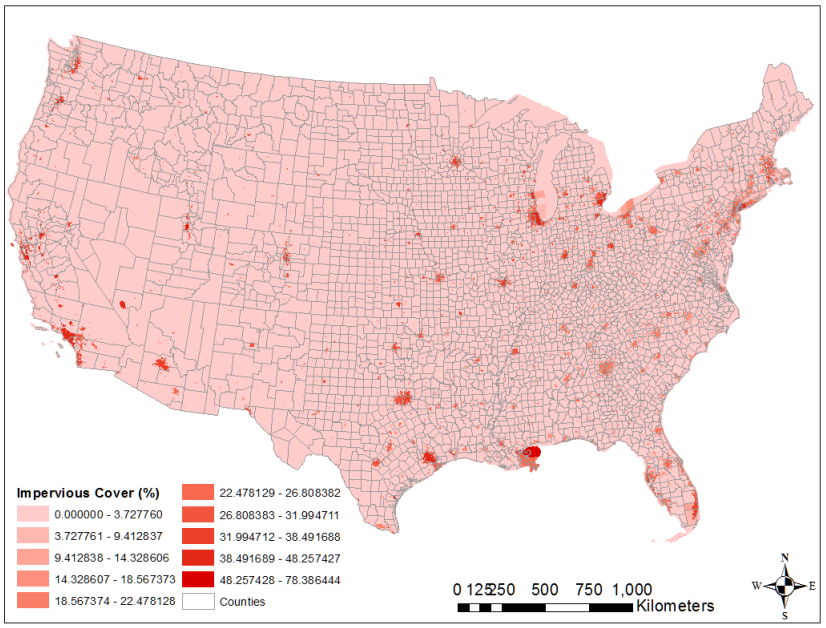

Figure 32 Impervious cover (%) for each rural/urban area in the conterminous United States

4.8.2 Other countries/areas

Impervious cover has not yet processed for the other countries/areas.

5 Results

5.1 Tables in LocationSpecies Database

5.1.1 _LocationBenefits

Based on i-Tree Eco batch runs for the conterminous United States for i-Tree Canopy/Landscape, in which air pollutant removals were calculated for each rural/urban area in the conterminous United States based on actual tree cover, evergreen % and LAI (Table 4), _LocationBenefits table in the LocationSpecies database was created. This table stores BenefitValue (annual monetary values: $/yr associated with air pollutant removal), RemovalRate (annual air pollutant removal: metric tons/yr), minimum and maximum of RemovalRate, and TreeCover (in m^2) for each rural/urban county area and each of six criteria air pollutants for the conterminous United States. Figure 33 shows some records in

the table. BenefitValue and RemovalRate values divided by TreeCover provide per unit tree cover (m^2) result in the multipliers that allow quick estimates of annual air pollutant removal quantity and associated monetary values in i-Tree Canopy and Landscape.

_LocationBenefits

LocationId	PollutantID	Urban	BenefitValue	RemovalRate	MinRemovalRate	MaxRemovalRate	TreeCover
219	1	True	18010427.7792157	12252.5242997296	12220.8047038202	12220.8047038202	96759282291
219	1	False	6734213.25030198	251589.665130447	251523.228841391	251523.228841391	2513821739957
219	2	True	32601264.5332767	67687.782522556	41271.8308094882	85256.5924777494	96759282291
219	2	False	9999772.89322392	1370979.17204938	958162.599416665	1660961.66014674	2513821739957
219	3	True	1497297949.38406	522866.764683427	201340.02334277	690774.288413035	96759282291
219	3	False	721278196.769887	13805621.2128716	7130089.5031529	17828681.6230265	2513821739957
219	5	True	3134605486.17703	26711.2547073185	3530.63936341767	58377.6687554254	96759282291
219	5	False	1451597866.71816	669534.366407698	91231.5191583057	1502842.9087409	2513821739957
219	6	True	4909317.33270587	33274.2262963582	19673.6210291585	52158.0844714424	96759282291
219	6	False	2536473.24868526	873337.473203829	563700.223756991	1338705.31385163	2513821739957
219	8	True	1025413486.08944	148400.46747643	57845.1329457351	231380.53178294	96759282291
219	8	False	585215693.717731	4651109.84136433	1816574.73015642	7266298.92062569	2513821739957

Figure 33 _LocationBenefits table in LocationSpecies database

5.1.2 _LocationCarbon, _LocationPollutant and _LocationPollutantRegression

These three tables were created based on i-Tree Eco batch runs for the conterminous United States, Alaska, Hawaii, Puerto Rico, Canada, and the UK for i-Tree Design/Forecast, in which air pollutant removals were calculated for each rural/urban area in the conterminous United States using actual tree cover area that is covered by 100% deciduous or 100% evergreen trees with LAI = 0 to 18 with 0.5 increments (Tables 4, 5, 6, 7, 9 and 10). These tables can be used to quickly estimate annual air pollutant removal quantity and associated monetary values, depending on forest characteristics, such as deciduous or evergreen tree, LAI, and tree cover area (m^2). The details of calculation can be found in Hirabayashi (2014; 2015a).

_LocationCarbon provides multipliers for CO removal quantity and associated monetary values computed from the median externality value in the United States for a deciduous or evergreen trees of 1 (m^2) of tree cover. Note that the CO removal is not affected by LAI, the LAI for trees to be estimated is not considered. The tree cover area (m^2) of a study area in Design/Forecast multiplied with the multiplier from this table provides annual CO removal and associated value estimates. Figure 34 provides some

records in the _LocationCarbon table.

_LocationCarbon

LocationCarbonId	LocationId	PollutantLeafTypeId	Urban	AmountMultiplier	ValueMultiplier
1	333	1	Yes	0.111383225936726	1.63726224692632E-04
2	333	1	No	0.111383061136895	2.98135174105191E-06
3	333	2	Yes	0.113799581537007	1.6727811301892E-04
4	333	2	No	0.113799416738357	3.04602949282034E-06
5	334	1	Yes	9.51389274886303E-02	1.39848143991343E-04
6	334	1	No	9.51389265626277E-02	2.54655062856184E-06
7	334	2	Yes	9.84157886433162E-02	1.44664920495944E-04
8	334	2	No	9.84157877301763E-02	2.63426123417223E-06

Figure 34 _LocationCarbon table in LocationSpecies database

_LocationPollutantRegression table stores the slope and intercept values for linear regression equations that regress, in a natural log space, per m^2 tree cover multipliers for annual air pollutant removal quantity and associated monetary value with LAIs. Regression equations were created, if possible, for all combinations of four BenMAP air pollutants (NO_2, O_3, $PM_{2.5}$ and SO_2) and leaf types (deciduous or evergreen) for each of rural/urban county area. When calculating the annual air pollutant removals and associated values in Design or Landscape, the natural log of a multiplier firstly needs to be derived by plugging the natural log of LAI into a regression equation, secondly, converted to a real-space multiplier (e.g., real-space multiplier = e^M, M: natural log of the multiplier), lastly, tree cover (m^2) is multiplied with the multiplier. Figure 35 provides some records in the _LocationPollutantRegression table.

_LocationPollutantRegression

LocationPollutantRegressionId	LocationId	PollutantLeafTypeId	Urban	AmountIntercept	AmountSlope	ValueIntercept	ValueSlope
1	333	3	Yes	-1.0447845046777	0.415355325819722	-9.24830053518605	0.355718388208962
2	333	3	No	-1.04477699732269	0.415366397087321	-13.3429447399474	0.42400036759084
3	333	4	Yes	-0.604694389297088	0.422616296450258	-8.80668072170176	0.375777655628717
4	333	4	No	-0.60461911390055	0.422645592487169	-12.8357976940603	0.437462008820369
5	333	5	Yes	0.917924648461012	0.357839125840734	-5.44979107615431	0.343751099620822
6	333	5	No	0.917928485518482	0.357851167121059	-9.25852003394605	0.337084043207026
7	333	6	Yes	1.30651631352498	0.384747815263625	-4.94720340381268	0.373525784113571
8	333	6	No	1.306615569899	0.384785772388794	-8.74767125997406	0.372158669830096
9	333	7	Yes	-3.07660366598969	0.857760266559762	-6.01370722547826	0.870512266960451
10	333	7	No	-3.07662321810486	0.857785532232203	-9.91034448168654	0.879501035124771
11	333	8	Yes	-2.67567272776477	0.88479974245208	-5.39360642971275	0.914859651454374
12	333	8	No	-2.67567505108593	0.884801600069909	-9.28755744413074	0.91738153948746
13	333	9	Yes	-2.30897047018774	0.322256852533484	-11.9333770564592	0.298634938690153
14	333	9	No	-2.30895625851681	0.322263045806635	-15.7059099069845	0.286978408583245
15	333	10	Yes	-1.95740736162001	0.35623553026006	-11.4830654626446	0.339866058480654
16	333	10	No	-1.95731358728217	0.356259944672978	-15.235952441025	0.340121642843291

Figure 35 _LocationPollutantRegression table in LocationSpecies database

_LocationPollutant provides a lookup table for those rural/urban county areas and the combination of the four air pollutants and leaf types where the relationship between multipliers and LAI's were unable to represent by linear equations in a log space. When calculating the annual air pollutant removals and associated values in Design or Landscape, this table is looked up with rural/urban county, air pollutant, and LAI to locate the multiplier, then multiplied with tree cover (m^2) calculates annual estimates. Figure 36 provides some records in the _LocationPollutant table.

_LocationPollutant

LocationPollutantId	LocationId	PollutantLeafTypeId	LAI	Urban	AmountMultiplier	ValueMultiplier
2147	533	7	0	Yes	0	0
2148	533	7	0	No	0	
2149	533	7	0.5	Yes	7.54215347122038E-03	5.31906986825949E-04
2150	533	7	0.5	No	7.54215347122038E-03	
2151	533	7	1	Yes	1.50843069424408E-02	1.06381397365191E-03
2152	533	7	1	No	1.50843069424408E-02	
2153	533	7	1.5	Yes	2.26264604136611E-02	1.59572096047784E-03
2154	533	7	1.5	No	2.26264604136611E-02	
2155	533	7	2	Yes	2.37018652682441E-02	1.79911120297646E-03
2156	533	7	2	No	2.37018652682441E-02	
2157	533	7	2.5	Yes	2.96273315853052E-02	2.24888900372057E-03
2158	533	7	2.5	No	2.96273315853052E-02	
2159	533	7	3	Yes	3.30611104785634E-02	2.5145859782035E-03
2160	533	7	3	No	3.30611104785634E-02	
2161	533	7	3.5	Yes	3.59057697393242E-02	2.88596867072853E-03
2162	533	7	3.5	No	3.59057697393242E-02	

Figure 36 _LocationPollutant table in LocationSpecies database

5.1.3 _LocationHydro

Based on i-Tree Eco batch runs for the conterminous United States for i-Tree Canopy/Landscape, _LocationHydro table in the LocationSpecies database was created. In the batch process six hydrologic variables including potential evaporation, potential evapotranspiration, evaporation, transpiration, precipitation interception and avoided runoff were calculated for each rural/urban area in the conterminous United States based on actual tree cover, evergreen %, LAI and impervious cover % (Table 14). Figure 37 provides some records in this table that stores annual volume (m3/yr) of PotentialEvaporation, PotentialEvapotranspiration, Evaporation, Transpiration, Interception and RunoffAvoided for tree cover area in each of rural/urban county areas in the conterminous United States. These variables divided by TreeCover (m^2) in the _LocationBenefits table result in the multipliers to quickly estimate annual values in i-Tree Canopy (not implemented yet) and

Landscape. The details of methods can be found in Hirabayashi (2013; 2015b). Note that as the national soil characteristics data as well as soil moisture estimates are currently not available in i-Tree Eco, avoided runoffs were calculated based on the overland flow only; it was assumed that the rainfall reached on the pervious cover all infiltrates into the ground and hence subsurface flow (i.e., infiltration excess overland flow and saturation overland flow) were not into accounted. In addition, baseflow was not considered. When the soil parameters across the conterminous United States will be available, the current routines in the i-Tree Eco's internal code to calculate rainfall interception and avoided runoff will be replaced with i-Tree Hydro's executable to fully account for the flows other than overland flows.

_LocationHydro

LocationId	Urban	PotentialEvaporation	PotentialEvapotranspiration	Evaporation	Transpiration	Interception	RunoffAvoided
333	True	9942384.34903073	8521900.99225701	1227605.69691442	2284988.1112545	1231760.33858971	108864.502565633
333	False	706472106.362225	610969153.006326	91868781.0235721	152713001.698901	92172935.8495914	378375.361144776
334	True	105418503.589578	83705980.410969	13054849.788021	27847674.580974	13099546.0824384	2244036.56861416
334	False	443309775.754369	352023524.818803	54909492.5099318	117072516.742564	55097503.3727425	833068.622589666
335	True	3531953.74511867	2946723.60465353	507270.312265546	1093718.43582827	507584.849770509	86224.2330341293
335	False	1196673401.94421	1052158516.43219	215343261.981064	281893479.638367	215695770.10983	532772.909715519
336	True	3879038.48509991	3065232.69330069	380861.225592724	1152541.40862681	381302.093047947	63375.1429568371
336	False	877089986.36553	734034157.89823	107708524.872096	199955051.696913	107853424.635454	937824.626853511

Figure 37 _LocationHydro table in LocationSpecies database

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