

i-Tree Research Suite

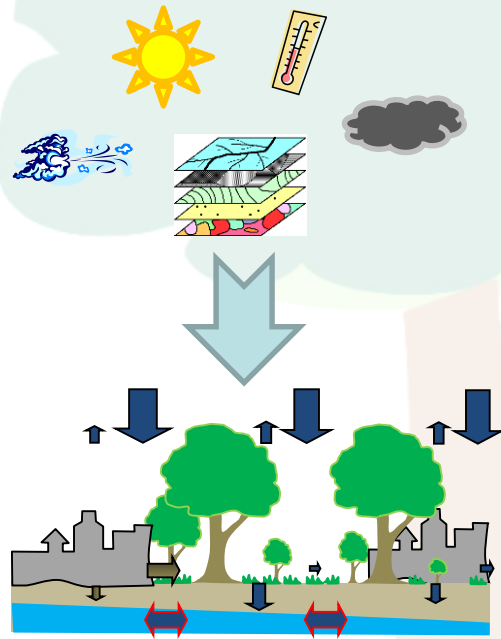


Hydro+ and Green Infrastructure

October 31, 2019

Presented by Robert Coville of the
Davey Institute & USDA Forest Service

Robert.Coville@Davey.com



Outline

1. Intro to the Research Suite
2. Research Suite Tools
 1. Overview of current tools
 2. Availability
 3. How Hydro+ works
 4. Green Infrastructure R&D
3. Additional resources & next steps



i-Tree is a
Cooperative
Initiative among
these partners



DAVEY

 **Arbor Day Foundation**



ESF
State University of New York
College of Environmental Science and Forestry

What is the i-Tree Research Suite?

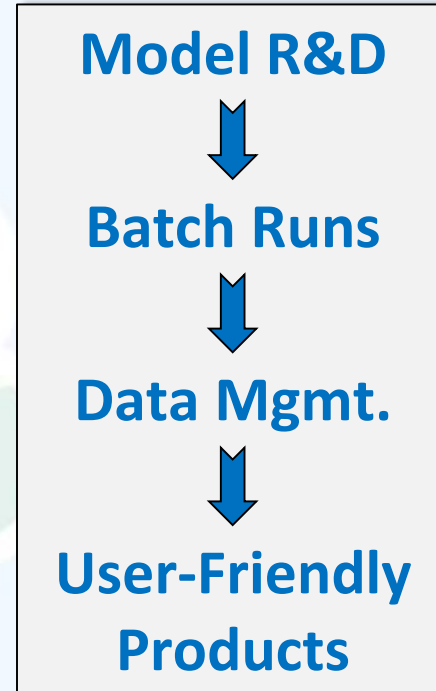


Purpose:

- 🌳 Share cutting-edge environmental models with advanced users and scientific community

Motivated by:

- 🌳 Technical tools from i-Tree R&D
- 🌳 Limited support resources for advanced tools



Differences from Core Tools:

- 🌳 Intermediate environmental science and computer skills required
- 🌳 No installer; materials for each tool provided separately
- 🌳 Minimal or no Graphical User Interface (GUI); Command-Line Interface (CLI)
- 🌳 No free technical support; expert consultation available



What tools are in the Research Suite?



Buffer

- 🌳 Nutrient hotspot model

Cool River

- 🌳 Stream temperature model

Hydro+

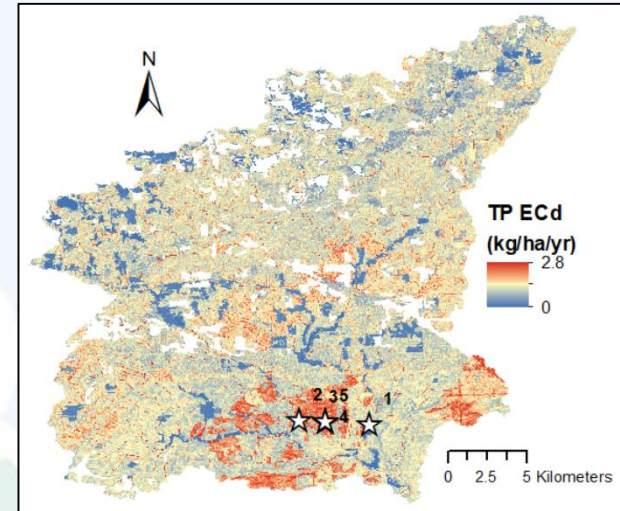
- 🌳 Models sharing code for common functions
- 🌳 **Hydro** is the semi- or fully-distributed hydrology model in i-Tree Hydro
- 🌳 **Cool Air** is an air temperature model coupled with Hydro

Energy

- 🌳 Process-based building heating & cooling model

Tree Compensation Calculator

- 🌳 Data-tables & calculator to estimate replacement cost or planting for lost trees



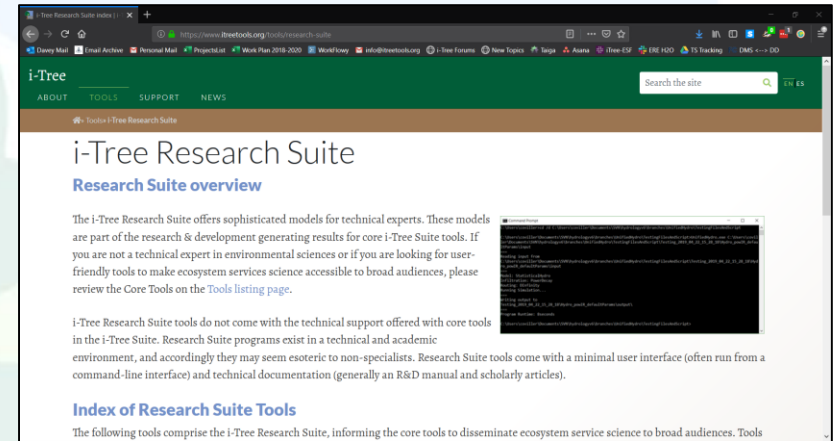
Where to find the Research Suite?



New iTreeTools.org website: www.iTreeTools.org/tools/research-suite

Each tool packaged individually

- 🌳 Tool
- 🌳 Code
- 🌳 Sample I/O
- 🌳 Documentation



Available upon peer-reviewed publication

- 🌳 Not all tools listed are available yet
Buffer, Energy – estimated 2020
- 🌳 Some tools available but with updates & improved documentation coming soon
Cool River – continued improvement through 2019-2020 academic year
- 🌳 Some tools are ready to use
Hydro+, Tree Compensation Calculator – stable versions available now



Hydro+ Highlights

- 🌳 Models sharing code for common functions
- 🌳 **Hydro** is the semi- or fully-distributed hydrology model in i-Tree Hydro
- 🌳 **Cool Air** is an air temperature model coupled with Hydro

Estimates effects of:

- 🌳 Tree cover
- 🌳 Impervious cover
- 🌳 + more

on:

- 🌳 Hourly stream flow
- 🌳 Water quality
- 🌳 Air temperature
- 🌳 + more



i-Tree Hydro+: Key Differences from GUI



Step 1) i-Tree Hydro Project Area Information

Geographic Reference Location

Nation: United States of America
 State: District of Columbia
 County: District of Columbia
 City: Washington

Project Time Period

Start Date / Time (Local): 01/01/2010 00:00:00
 End Date / Time (Local): 12/29/2010 23:00:00

Topographic Data

Select from preloaded topography data
 Select my own topography data

Weather Station Data

Select a weather station from map
 Select raw NCDC weather file
 Select processed weather files

Calibration Data

Select USGS gage from map
 Select raw USGS data file
 Select processed data file
 Not auto calibrating

Stream Gage ID: 01648000

ModelStatus: Running Hydro model with Base Case values...

accept working with pre-loaded data from the available years, simply select the weather station closest to (or most appropriate for) your project area on the

Next: Step 2) i-Tree Hydro Land Cover Inputs

UnifiedHydro

```

    176
    177
    178
    179
    180
    181
    182
    183
    184
    185
    186
    187
    188
    
```

Command Prompt

```

    Microsoft Windows [Version 10.0.16299.1029]
    (c) 2017 Microsoft Corporation. All rights reserved.

    C:\Users\coviller> cd /d C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release
    C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release> UnifiedHydro.exe C:\Users\coviller\Documents\SVN\
    UnifiedHydro_fresh\TestingFiles\AndScript\TestCases\StatHydro\expIR_defaultParams\Input
    
```

File Edit Search View Encoding Language Settings Tools M

UnifiedHydroConfig.xml

```

    1 <UnifiedHydroConfig>
    2   <SimulationStringParams>
    3     <OutputDirectory>C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release
    4     <OutputTimeStep>Hourly</OutputTimeStep>
    5     <CalibrationTimeStep>Hourly</CalibrationTimeStep>
    6     <ExtendedOutputsTimeStep>Hourly</ExtendedOutputsTimeStep>
    7     <Model>StatisticalHydro</Model>
    8     <Infiltration>ExponentialDecay</Infiltration> <!--PowerDecay, ExponentialDecay-->
    9     <Routing>DInfinity</Routing> <!--DInfinity -->
    10    <RefParamFolder>0,0</RefParamFolder><!--0,0 Would use the first drawer, first folder-->
    11  </SimulationStringParams>
    12  <SimulationNumericalParams>
    13    <StartDay>20100101</StartDay> <!--Date format: YYYYMMDD-->
    14    <EndDay>20101229</EndDay>
    15    <CatchmentArea_m2>161440000</CatchmentArea_m2>
    16  </SimulationNumericalParams>
    17  </DataOrganizer>
    
```

eXtensible Markup Language file length: 4,348 lines: 67 Ln: 13 Col: 11 Sel: 0 | 0 Windows (CR LF) UTF-8 INS

Hydro+ (UnifiedHydro.exe)

- 🌳 Development inactive
- 🌳 Interface is relatively user friendly
- 🌳 Some technical support available
- 🌳 Actively improved in i-Tree R&D
- 🌳 Runs from Command-Line Interface
- 🌳 Requires expertise and more involved
- 🌳 No technical support available



i-Tree Hydro+: Who's It For?



Researchers, Advanced Users, Environmental Professionals

- 🌳 Building expertise or extensions for Hydro+ model
- 🌳 Seeking more control or customization of inputs or outputs
- 🌳 Interacting with the latest i-Tree hydrology research & developments

Casual Users and Non-Experts

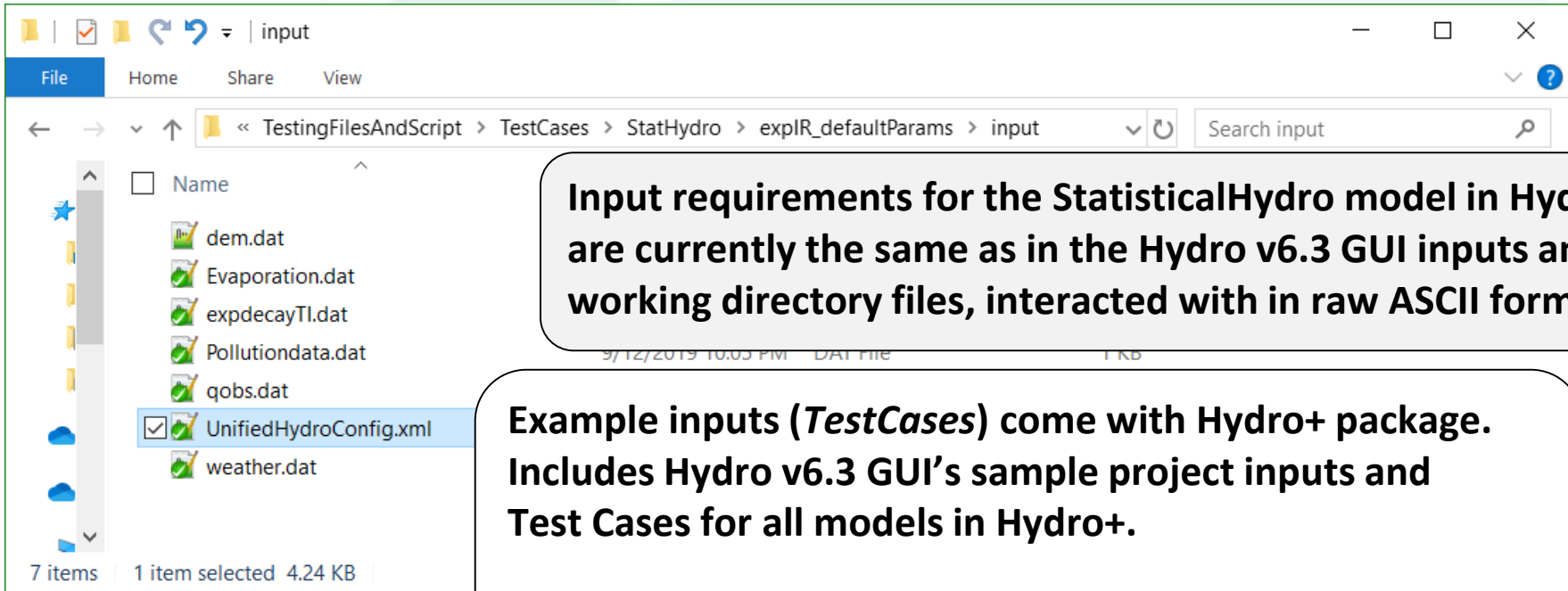
- 🌳 Better served by hydrology features in core i-Tree Tools: Eco, Landscape, etc.
- 🌳 i-Tree Hydro v6 GUI available for land cover scenario assessments, but not receiving latest hydrology R&D that's in Hydro+ or its incorporation into core tools



i-Tree is a
Cooperative
Initiative among
these partners



i-Tree Hydro+: Inputs Overview



Input requirements for the StatisticalHydro model in Hydro+ are currently the same as in the Hydro v6.3 GUI inputs and working directory files, interacted with in raw ASCII format.

Example inputs (*TestCases*) come with Hydro+ package. Includes Hydro v6.3 GUI's sample project inputs and Test Cases for all models in Hydro+.

See *Technical Manual* for input and test case descriptions.

Inputs

- 🌳 Config file parameterization including land cover statistics
- 🌳 Digital Elevation Model (DEM) or Topographic Index (TI) file
- 🌳 Hourly pre-processed weather & potential evaporation files
- 🌳 Optional observed streamflow file to assess validity of predictions
- 🌳 Event Mean Concentration (EMC) water quality coefficients

i-Tree Hydro+: Inputs Gathering



Config file parameterization including land cover statistics

Hydro+ TestCases as template, Hydro v6.3 GUI & User Manual as guide

DEM or TI file

Same DEM preparation as described in Hydro User Manual, or get TI file from GUI

Weather inputs

Need to use GUI, as it includes latest publicly accessible weather preprocessor
Forum FAQs & scientific archives describe requirements and options

Optional observed streamflow

Same sourcing as weather inputs but optional and easier to format. For PEST calibration and validation

Optional water quality coefficients

Nationwide defaults included in TestCases and match Hydro GUI
Localized values upcoming in R&D

**See Hydro+ Technical Manual
for more info**



i-Tree Hydro+: Execution



0) Configure simulation using configuration XML file

```
C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\expIR_defaultParams\input\UnifiedHydroConfig.xml - Notepad++
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
UnifiedHydroConfig.xml
1 <UnifiedHydroConfig>
2 <S
3 <OutputDirectory>C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\expIR_defaultParams\output\</OutputDirectory>
4 <OutputTimeStep>Hourly</OutputTimeStep>
5 <CalibrationTimeStep>Hourly</CalibrationTimeStep> <!-- Possible values: NoCalibration, Hourly, Weekly, Daily, -->
6 <ExtendedOutputsTimeStep>NoExtendedOutputs</ExtendedOutputsTimeStep> <!-- Possible values: NoExtendedOutputs, Hourly -->
7 <Model>StatisticalHydro</Model> <!-- StatisticalHydro, GI, SpatialTemperatureHydro -->
8 <Infiltration>ExponentialDecay</Infiltration> <!-- PowerDecay, ExponentialDecay -->
9 <Routing>DInfinity</Routing> <!-- DInfinity -->
10 <RefParamFolder>0,0</RefParamFolder><!--0,0 Would use the first drawer, first folder for ref params-->
11 </SimulationStringParams>
12 <SimulationNumericalParams>
13 <StartDay>20100101</StartDay> <!--Date format: YYYYMMDD-->
14 <EndDay>20101229</EndDay>
15 <CatchmentArea_m2>161440000</CatchmentArea_m2>
16 </SimulationNumericalParams>
17
18 <DataDrawer>
19 <DataFolder>
20 <Type>BulkArea</Type>
21 <Area>161440000</Area>
22 <PerviousCoverUnderTreeCanopy_frac>0.363</PerviousCoverUnderTreeCanopy_frac>
23 <ImperviousCoverUnderTreeCanopy_frac>0.05</ImperviousCoverUnderTreeCanopy_frac>
24 <ShortVegetationCover_frac>0.297</ShortVegetationCover_frac>
length: 4,348 lines: 67 Ln: 3 Col: 6 Sel: 0 | 0 Windows (CR LF) UTF-8 INS
```

- 🌳 OutputDirectory is a param applicable to all models in UnifiedHydro (Hydro+ code) It's the full path to the directory which output files will be written to, ending with \
- 🌳 To disable tags, they must be wrapped in a <DISABLE></DISABLE> set of tags.
- 🌳 Parameters in each <DataFolder> are used in semi-distributed Hydro simulations.
- 🌳 For more info on parameters see Hydro+ Technical Manual, Hydro v6 User Manual, Hydro science articles at <https://www.itreetools.org/tools/research-suite/hydro-plus>



i-Tree Hydro+: Execution



1) Open command-line interface, navigate to folder containing Hydro+

```
Command Prompt
Microsoft Windows [Version 10.0.16299.1029]
(c) 2017 Microsoft Corporation. All rights reserved.

C:\Users\coviller>cd /d C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release

C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release>
```

- “cd /d” command changes directory using full-path provided
- Latest compilation of code is generated in “Release” directory



i-Tree Hydro+: Execution



2) Enter: <Hydro+ exe name> <Full path to inputs directory>

```
Command Prompt
Microsoft Windows [Version 10.0.16299.1029]
(c) 2017 Microsoft Corporation. All rights reserved.

C:\Users\coviller>cd /d C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release

C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release>UnifiedHydro.exe C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\expIR_defaultParams\input
```

- By default program is referred to as UnifiedHydro.exe
- Input used is “expIR_defaultParams” TestCase which comes with Hydro+ package



i-Tree Cool Air: Execution



3) Hit enter to run the model; confirm run completed with no errors

```
Command Prompt
Microsoft Windows [Version 10.0.16299.1029]
(c) 2017 Microsoft Corporation. All rights reserved.

C:\Users\coviller>cd /d C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release

C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release>UnifiedHydro.exe C:\Users\coviller\Documents\SVN\
UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\expIR_defaultParams\input
===
Reading input from
C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\expIR_defaultParams\input
===
Model: StatisticalHydro
Infiltration: ExponentialDecay
Routing: DInfinity
Running Simulation...
===
Writing output to
C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\expIR_defaultParams\output\
===
Program Runtime: 4seconds

C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\UnifiedHydro\Release>
```

- CLI output is recorded in log.txt in same directory EXE ran from



i-Tree Hydro+: Outputs (Raw)



4) View, analyze, post-process, and report outputs

File Home Share View

TestCases > StatHydro > explR_defaultParams > output

Search output

Name

- CaliQobs.dat
- CaliTotalQQ.dat
- CumOutput.dat
- Output.dat
- Pollution.dat
- VegetationLAIseries.dat
- WaterBalance.dat

7 items

C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\explR_defaultParams\output\Output.dat - Notepad++

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

Output.dat

```

1 Tree LAI: 5 Tree %: 41.3 %
2 Shrub LAI: 2.2 Shrub %: 29.7 %
3
4 Total precipitation : 936.244mm
5 Total rainfall : 883.92mm
6 Total snow water equivalent : 52.324mm
7 Total tree intercepted rain : 74.027mm
8 Total short vegetation intercepted rain : 31.6598mm
9 Total tree intercepted snow water equivalent : 36.517mm
10 Total short vegetation intercepted snow water equivalent : 7.34772mm
11
12 Hourly fitness: VE = 0.195895 CRF1 = -0.685206 CRF2 = -0.00302429 CRF3 = -0.0803219
13 Daily fitness: VE = 0.261419 CRF1 = -0.770702 CRF2 = 0.0178643 CRF3 = -0.0364408
14 Weekly fitness: VE = 0.447104 CRF1 = -0.302436 CRF2 = -0.0060837 CRF3 = -0.144694
15 Monthly fitness: VE = 0.500698 CRF1 = -0.402511 CRF2 = -0.206861 CRF3 = -0.464665
16
17 Total runoff (TotalQ :mm) : 336.706 Total pervious area surface flow (TotalPerviousAreaQ_mm :mm) : 183.779
18 Total Baseflow(BQ:mm) : 82.4679 Total Impervious impervious flow (TotalDCIAQ:mm) : 70.4425
19
20 BQ/TotalQ: 0.244926 TotalDCIAQ_mm/TotalQ: 0.209211
21
22 The unit of the following time series output is : m/DT , DT: simulation time interval, such as 1 hour
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39

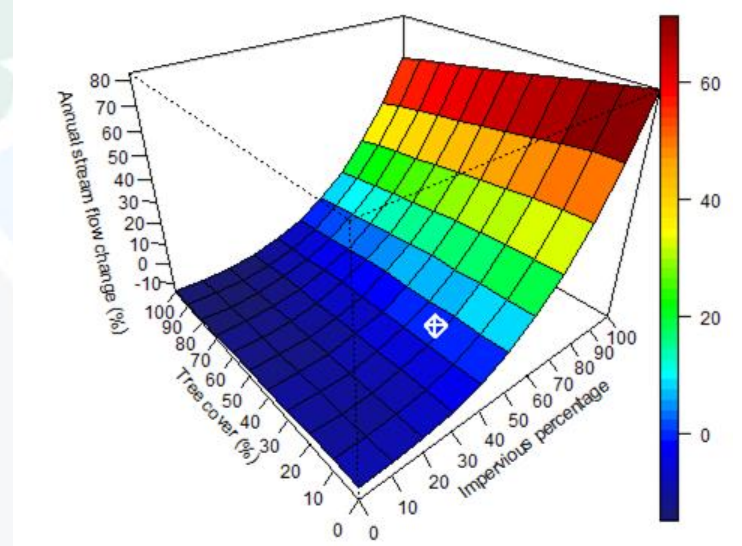
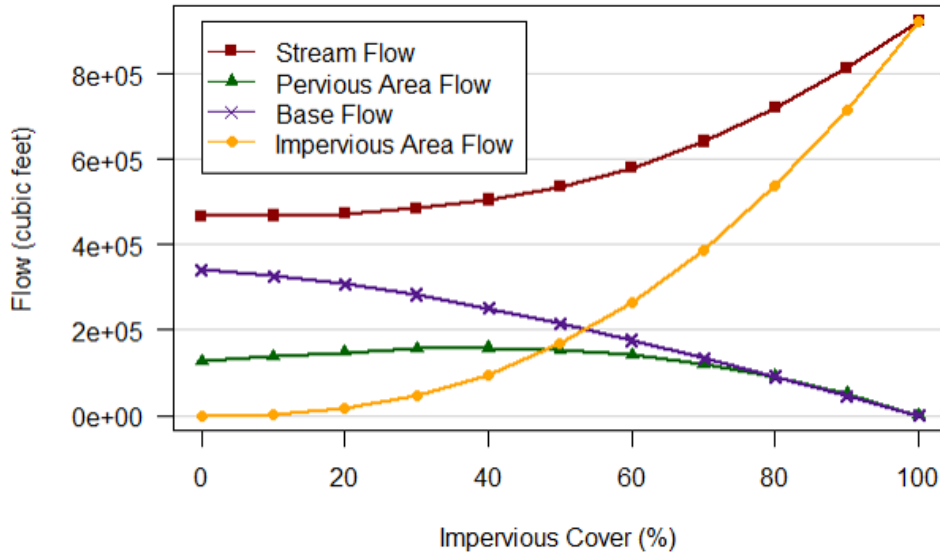
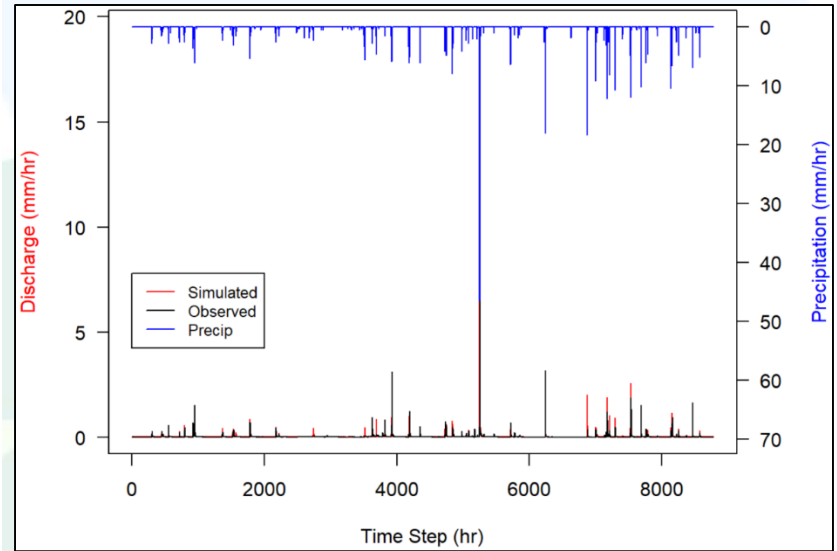
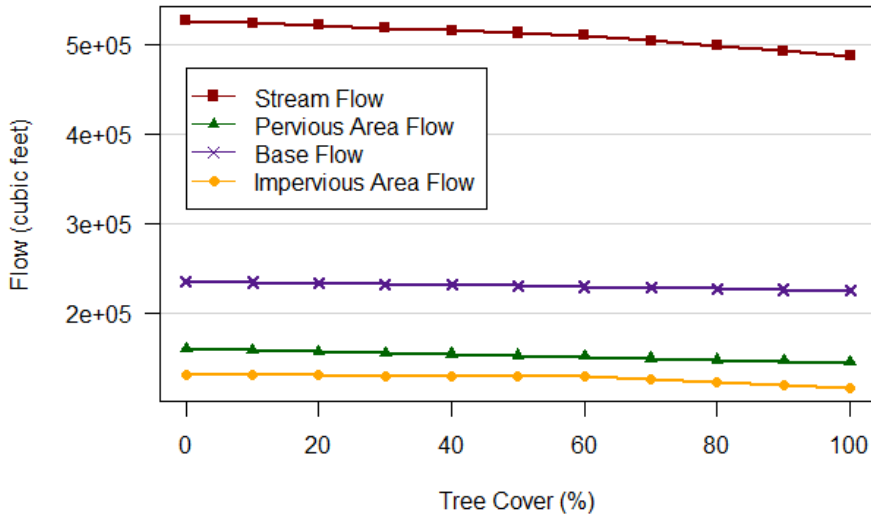
```

yyyyymmdd	hh:mm:ss	Precip	TotalQ	BaseQ	PerviousQ	DCIAQ	Qobs
20100101	00:00:00	0	1.6e-05	2.04248e-31	0	0	0.000116818
20100101	01:00:00	0	2.23538e-16	2.23538e-16	0	0	0.000125658
20100101	02:00:00	0	1.02923e-12	1.02923e-12	0	0	0.000133235
20100101	03:00:00	0	5.08814e-11	5.08814e-11	0	0	0.000138287
20100101	04:00:00	0	4.99398e-10	4.99398e-10	0	0	0.000138287
20100101	05:00:00	0	2.25942e-09	2.25942e-09	0	0	0.000136392
20100101	06:00:00	0	6.62551e-09	6.62551e-09	0	0	0.000131972
20100101	07:00:00	0	1.48592e-08	1.48592e-08	0	0	0.000125658
20100101	08:00:00	0	2.7899e-08	2.7899e-08	0	0	0.000119975
20100101	09:00:00	0	4.62713e-08	4.62713e-08	0	0	0.000114292
20100101	10:00:00	0	7.01293e-08	7.01293e-08	0	0	0.000108609
20100101	11:00:00	0	9.93416e-08	9.93416e-08	0	0	0.000102294
20100101	12:00:00	0	1.33586e-07	1.33586e-07	0	0	9.85056e-05
20100101	13:00:00	0	1.72426e-07	1.72426e-07	0	0	9.3454e-05

Normal text file length: 985,934 lines: 8,738 Ln: 1 Col: 1 Sel: 0 | 0 Windows (CR LF) UTF-8 INS



i-Tree Hydro+: Outputs (Extra Processing)



i-Tree is a Cooperative Initiative among these partners



State University of New York College of Environmental Science and Forestry

Research Suite: Next steps

www.itreetools.org/tools/research-suite

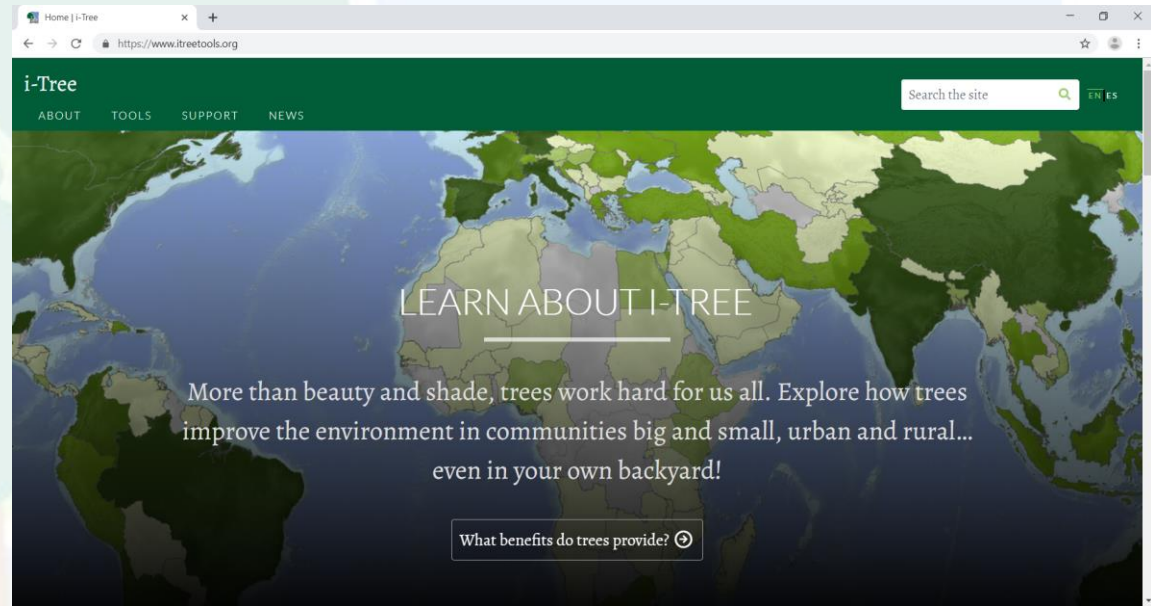
Tools

Documentation

Examples

Code

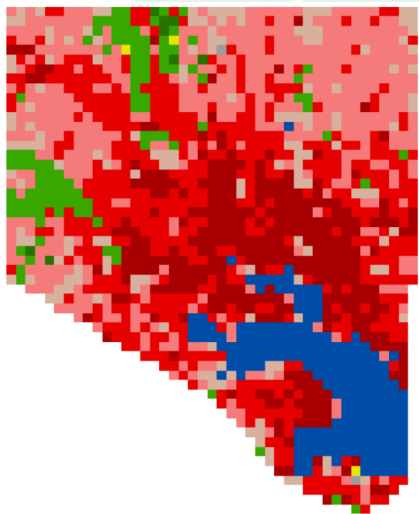
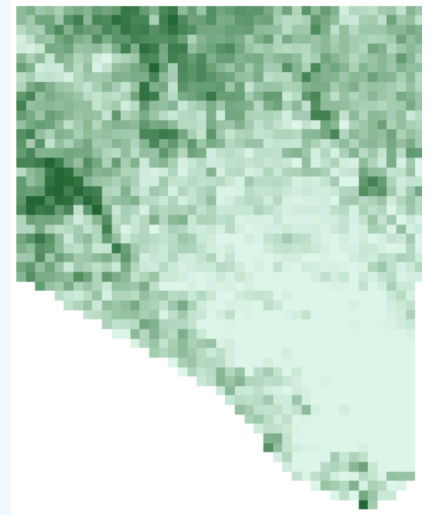
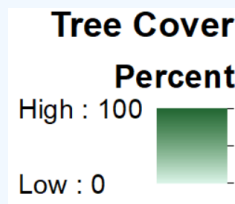
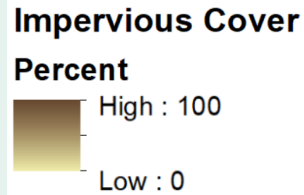
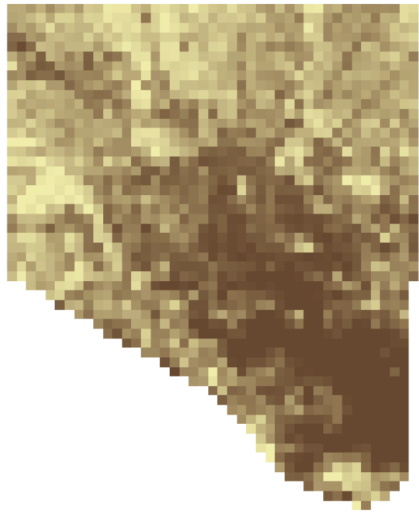
Contacts



For consultation inquiries, reach out to info@itreetools.org



i-Tree Cool Air: Inputs



Inputs

- 🌳 National Land Cover Database (NLCD): Impervious, Tree, and Land Cover raster layers
- 🌳 Digital Elevation Model (DEM)
- 🌳 Hourly weather data
- 🌳 Optional parameterization



i-Tree is a Cooperative Initiative among these partners



i-Tree Cool Air: Execution



0) Configure simulation using configuration XML file

```
C:\Users\coviller\CoolAir\input\UnifiedHydroConfig.xml - Notepad++
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
UnifiedHydroConfig.xml x
1 <UnifiedHydroConfig>
2 <SimulationStringParams>
3   <OutputDirectory>C:\Users\coviller\CoolAir\input\output\</OutputDirectory>
4   <OutputTimeStep>Hourly</OutputTimeStep>
5   <CalibrationTimeStep>NoCalibration</CalibrationTimeStep>
6   <ExtendedOutputsTimeStep>NoExtendedOutputs</ExtendedOutputsTimeStep>
7   <Model>SpatialTemperatureHydro</Model>
8   <Infiltration>PowerDecay</Infiltration>
9   <Routing>DInfinity</Routing>
10  <RefParamFolder>0,0</RefParamFolder><!--0,0 Would use the first drawer, first folder for ref
    params-->
11 </SimulationStringParams>
12 <SimulationNumericalParams>
13   <StartDay>20150621</StartDay>
14   <EndDay>20150623</EndDay>
15   <CatchmentArea_m2>161440000</CatchmentArea_m2>
16 </SimulationNumericalParams>
17 <DataOrganizer>
18 <DataDrawer>
19 <DataFolder>
20   <Type>BulkArea</Type>
21   <Area>70838.08688021062</Area>
22   <PerviousCoverUnderTreeCanopy_frac>0.363</PerviousCoverUnderTreeCanopy_frac>
23   <ImperviousCoverUnderTreeCanopy_frac>0.05</ImperviousCoverUnderTreeCanopy_frac>
24   <ShortVegetationCover_frac>0.297</ShortVegetationCover_frac>
25   <SoilCover_frac>0.007</SoilCover_frac>
26   <ImperviousCover_frac>0.283</ImperviousCover_frac>
27   <DCIA_frac>0.2685</DCIA_frac>
28   <TranspirationDemandUnderTreeCanopy_frac>0.5</TranspirationDemandUnderTreeCanopy_frac>
length: 6,090 lines: 147 Ln: 1 Col: 1 Sel: 0 | 0 Windows (CR LF) UTF-8 INS
```



i-Tree Cool Air: Execution



1) Open command-line interface, navigate to folder containing Hydro+

```
Command Prompt
Microsoft Windows [Version 10.0.16299.1029]
(c) 2017 Microsoft Corporation. All rights reserved.

C:\Users\coviller>cd /d C:\Users\coviller\CoolAir

C:\Users\coviller\CoolAir>
```



i-Tree Cool Air: Execution



2) Enter: <Hydro+ exe name> <Full path to inputs directory>

```
Command Prompt
Microsoft Windows [Version 10.0.16299.1029]
(c) 2017 Microsoft Corporation. All rights reserved.

C:\Users\coviller>cd /d C:\Users\coviller\CoolAir

C:\Users\coviller\CoolAir>UnifiedHydro.exe C:\Users\coviller\CoolAir\input
```



i-Tree is a
Cooperative
Initiative among
these partners



i-Tree Cool Air: Execution



3) Hit enter to run the model; wait for simulation to complete

```
Command Prompt - UnifiedHydro.exe C:\Users\coviller\CoolAir\input
C:\Users\coviller\CoolAir>UnifiedHydro.exe C:\Users\coviller\CoolAir\input
===
Reading input from
C:\Users\coviller\CoolAir\input
===
Model: SpatialTemperatureHydro
Infiltration: PowerDecay
Routing: DInfinity
Running Simulation...
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
```



i-Tree is a
Cooperative
Initiative among
these partners



i-Tree Cool Air: Execution



4) Confirm run completed without error

```
Command Prompt
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
===
Writing output to
C:\Users\coviller\CoolAir\input\output\
===
Program Runtime: 17seconds
C:\Users\coviller\CoolAir>
```



i-Tree Cool Air: Execution



5) View, analyze, post-process, and report outputs

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

Row2Col2Heat.txt

1	ts	Ta	Td	Ea	ImpNR	TreeNR	ShortVegNR	SoilNR	WaterNR	ImpH	ImpLE	TreeH	TreeLE	TreeLEE	TreeLET	Shorti	
2	2015062100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	2015062101	295.605	294.245	0.0184286	0	0	0	79.9	-51.5444	91.1444	0	91.1444	-25.0722	52.4722	0	52.4722	
4	2015062102	295.466	294.852	0.0190868	-12.7395	-13.0077	-13.0077	0	83.5945	0	-3.64762	48.0605	0	48.0605	-0.812215	26.3911	
5	2015062103	295.466	294.783	0.0190114	-12.787	-13.0562	-13.0562	0	77.4933	0	-12.7561	48.4718	0	48.4718	-7.96966	26.5176	
6	2015062104	295.515	294.785	0.0190134	-12.7775	-13.0465	-13.0465	0	77.4677	0	-17.7838	53.4634	0	53.4634	-10.5892	29.1124	
7	2015062105	295.39	294.873	0.01911	-2.7575	-1.6905	-3.0265	0	-51.4886	126.055	-73.5433	105.028	108.219	-3.19171	-60.2925		
8	2015062106	295.897	294.859	0.0190949	89.178	102.515	88.9068	0	-195.483	248.198	-179.363	179.9	184.319	-4.41884	-130.418		
9	2015062107	296.331	294.854	0.0190894	147.72	168.872	147.447	0	-240.382	320.249	-224.448	270.25	275.181	-4.93149	-152.987		
10	2015062108	297.899	294.879	0.0191162	339.83	388.874	339.13	0	-574.308	626.563	-494.638	503.498	506.2	-2.70137	-300.793	4	
11	2015062109	299.188	294.634	0.0188478	541.954	618.18	541.21	0	-810.739	896.59	-684.153	755.572	738.184	17.3874	38.6346	24	
12	2015062110	300.353	294.169	0.0183473	726.011	826.971	725.232	0	-899.124	1028.62	-773.653	921.454	835.062	86.392	72.8485		
13	2015062111	300.696	294.326	0.0185154	745.695	846.789	745.382	0	-886.384	1098.52	-599.357	879.715	617.871	261.844	138.797		
14	2015062112	301.099	294.205	0.0183857	566.266	643.436	565.954	0	-619.551	893.167	-233.278	602.155	602.155	105.37	403.77		
15	2015062113	303.359	294.058	0.0182293	362.797	412.806	362.49	0	246.497	0	-498.745	816.709	0	816.709	-114.432	498.195	0
16	2015062114	304.536	293.378	0.0175218	492.884	562.882	492.081	0	111.106	0	-768.221	876.134	0	876.134	-262.968	555.004	0
17	2015062115	305.028	294.043	0.0182139	531.814	606.893	531.033	0	162.258	0	-701.401	893.582	0	893.582	-204.842	572.31	0
18	2015062116	304.932	293.221	0.0173624	642.452	732.419	641.644	0	148.86	0	-699.969	875.192	0	875.192	-183.093	587.081	0
19	2015062117	305.089	293.238	0.0173739	548.462	625.881	547.657	0	229.223	0	-597.86	896.604	0	896.604	-145.125	595.684	0
20	2015062118	304.607	293.265	0.0174071	385.744	441.434	384.945	0	231.296	0	-542.092	837.701	0	837.701	-164.871	541.898	0
21	2015062119	303.267	292.171	0.0163245	168.414	195.256	167.591	0	216.217	0	-475.463	738.579	0	738.579	-200.964	459.697	0
22	2015062120	301.39	292.374	0.0165205	-14.7225	-14.9735	-15.0435	0	165.008	0	-418.083	594.045	0	594.045	-227.863	343.656	0
23	2015062121	302.095	291.763	0.0159357	-15.846	-16.1796	-16.1796	0	77.4285	0	-616.969	652.523	0	652.523	-358.726	375.737	0
24	2015062122	300.899	291.814	0.0159834	-15.523	-15.8498	-15.8498	0	76.7956	0	-471.735	506.359	0	506.359	-280.872	297.316	0
25	2015062123	299.067	291.869	0.016036	-15.181	-15.5006	-15.5006	0	76.8514	0	-368.417	403.133	0	403.133	-217.023	233.694	0
26	2015062200	299.996	291.784	0.0159554	-15.3045	-15.6267	-15.6267	0	77.0514	0	-378.287	413.284	0	413.284	-229.278	246.119	0
27	2015062201	298.733	291.869	0.0160356	-15.105	-15.423	-15.423	0	76.9343	0	-331.31	366.147	0	366.147	-196.97	213.773	0
28	2015062202	296.938	291.928	0.0160916	-36.822	-37.5972	-37.5972	0	83.328	0	-210.77	253.948	0	253.948	-132.001	145.809	0
29	2015062203	296.532	291.307	0.0155105	-37.5915	-38.3829	-38.3829	0	73.127	0	-225.404	254.016	0	254.016	-143.657	145.381	0
30	2015062204	296.576	291.377	0.0155749	-37.5155	-38.3053	-38.3053	0	72.7356	0	-224.845	252.902	0	252.902	-143.401	144.712	0
31	2015062205	295.097	291.425	0.0156197	-36.94	-35.236	-38.183	0	72.6052	0	-166.126	193.098	0	193.098	-105.944	107.314	0
32	2015062206	296.81	291.816	0.0159851	184.053	215.224	182.81	0	8.79343	0	-276.496	212.856	0	212.856	-116.983	149.358	0
33	2015062207	298.648	292.321	0.0164691	417.5	477.332	416.719	0	47.1704	0	-361.055	368.242	0	368.242	-70.2601	254.718	0
34	2015062208	300.144	291.264	0.0154715	409.838	468.834	409.022	0	161.447	0	-311.653	497.597	0	497.597	-42.9289	352.62	0
35	2015062209	301.085	292.318	0.0164664	403.431	456.707	406.608	0	135.067	0	-323.633	501.37	0	501.37	-60.050	306.000	0

Normal text file length: 13,376 lines: 74 Ln: 1 Col: 1 Sel: 0 | 0 Windows (CR LF) UTF-8 INS



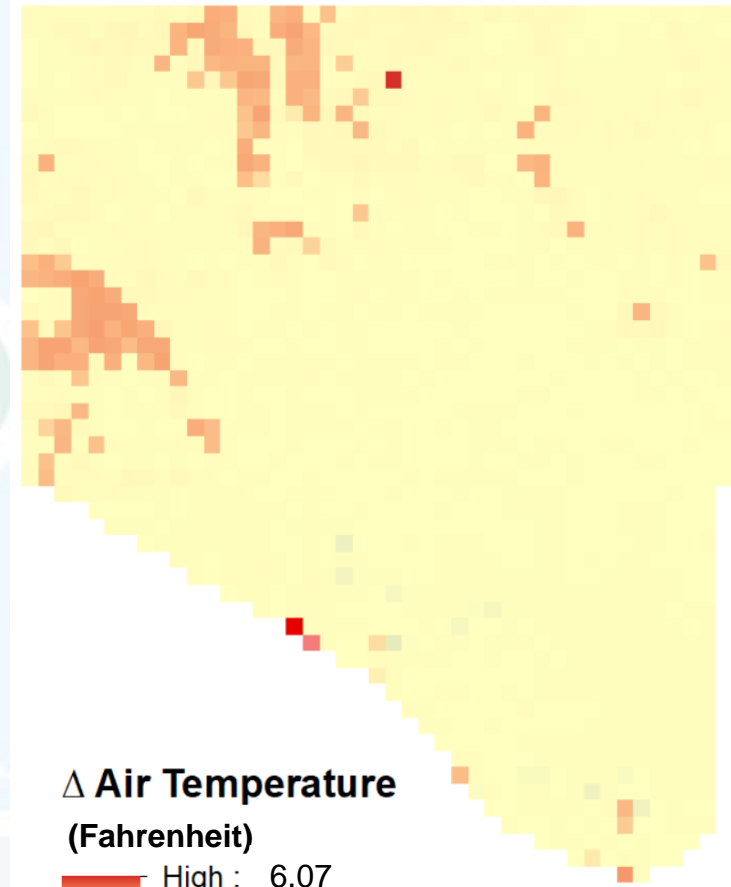
i-Tree Cool Air: Outputs (preliminary)



i-Tree Cool Predictions at Deciduous Forest cell (R3C13); Δ (Alt - Base)
Baltimore, MD; August 1-7, 2015

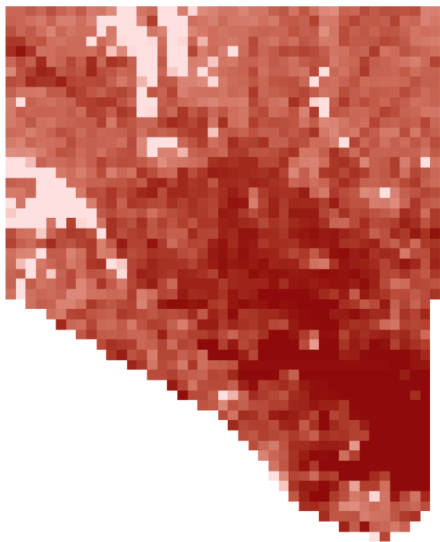


Δ Alternative – Base Case

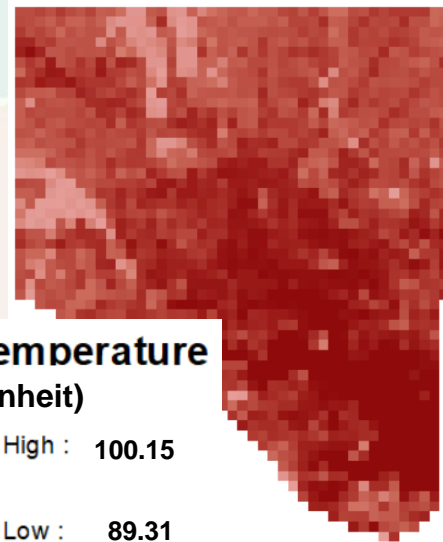


Baltimore, MD – hottest hour of 2015
July 19, 2015, 16:00

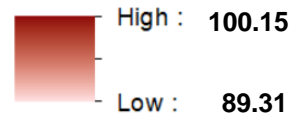
Current Land Cover



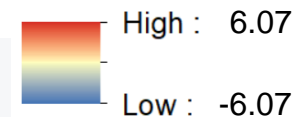
0% Tree Cover Scenario



**Air Temperature
(Fahrenheit)**



**Δ Air Temperature
(Fahrenheit)**



i-Tree is a
Cooperative
Initiative among
these partners



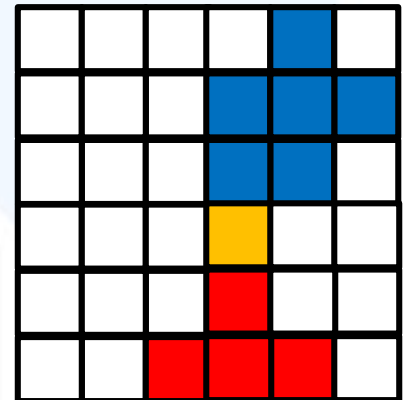


i-Tree Buffer: Introduction



Goal - identify nutrient hotspots in landscape using 3 main factors:

- Nutrient generation on pixel (**orange**)
(i.e. export coefficients)
- Runoff index (**blue**)
- Buffering index (**red**)



i-Tree is a
Cooperative
Initiative among
these partners



DAVEY

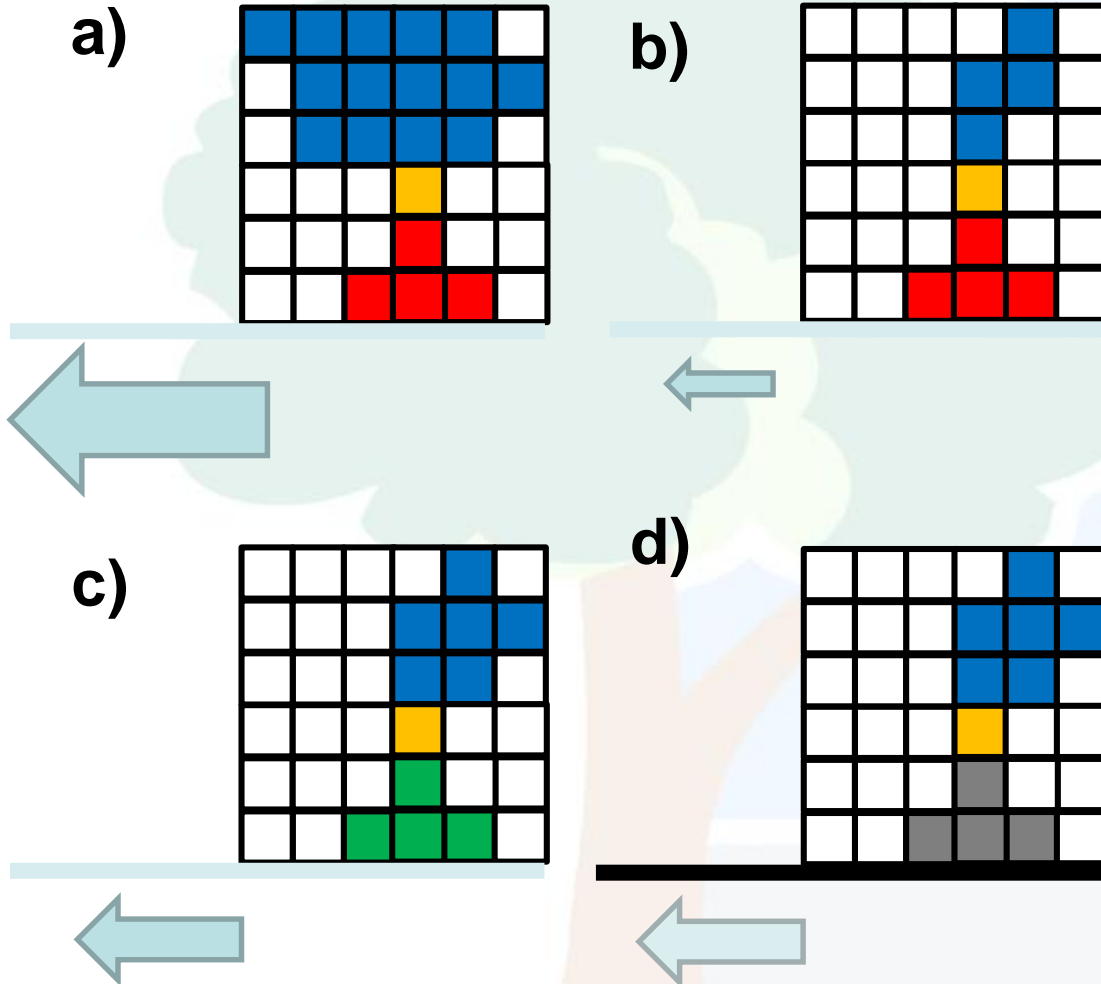


 **Arbor Day Foundation**











ESF
State University of New York
College of Environmental Science and Forestry

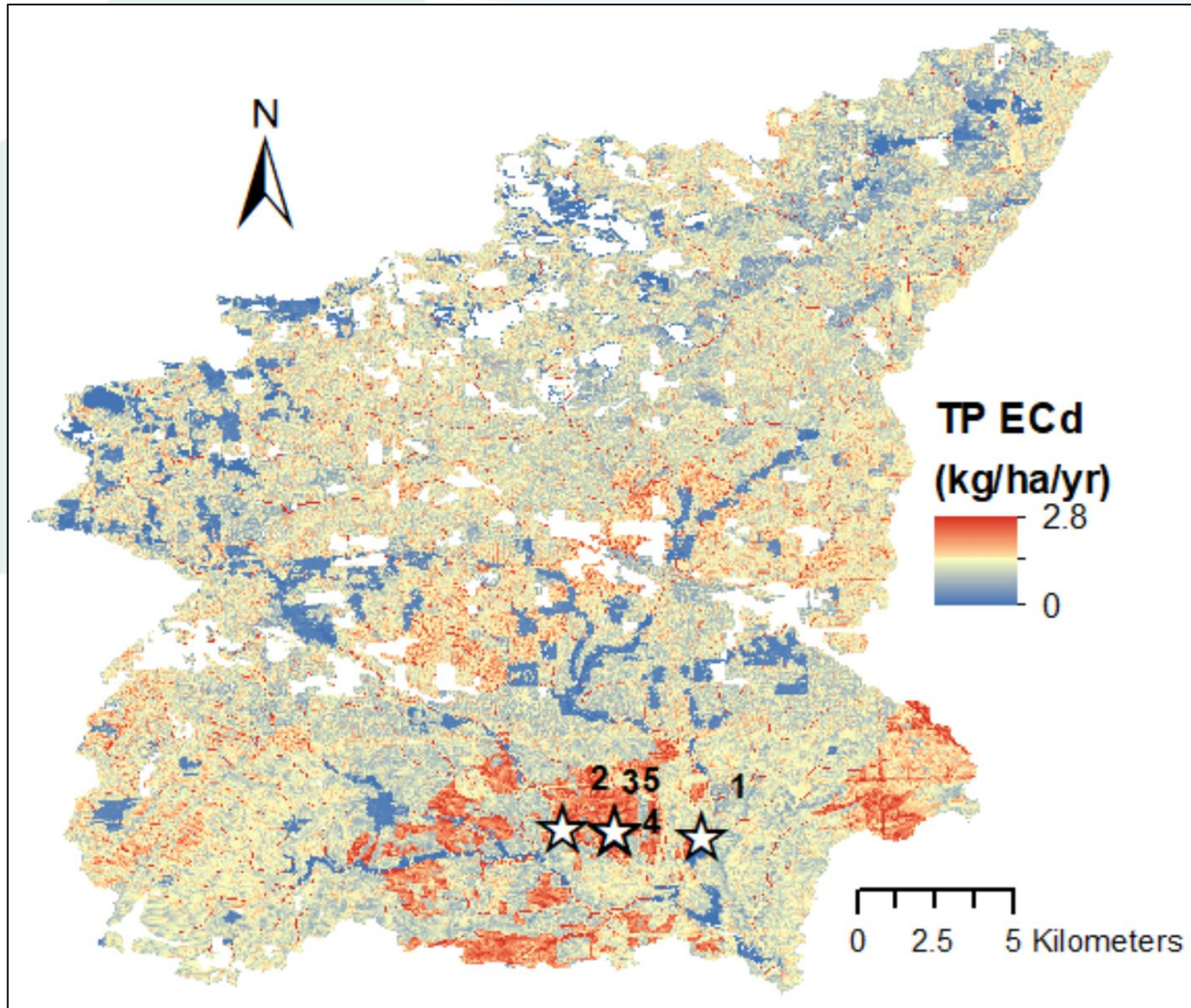
i-Tree Buffer: Theory



Key

-  = pixel of interest (POI)
-  = runoff into POI
-  = buffering from POI
-  = vegetated buffer from POI
-  = developed buffer from POI
-  = magnitude of runoff
-  = clean runoff
-  = polluted runoff

i-Tree Buffer: Results (preliminary)



i-Tree is a
Cooperative
Initiative among
these partners





Green Infrastructure R&D

i-Tree Hydro+ GI: Status



Documentation

- 🌳 Dr. Reza Abdi's dissertation includes detailed information about Hydro+ GI development and validation
- 🌳 Scientific articles are in-review/in-preparation about what Dr. Abdi presented

Availability in Code

- 🌳 Permeable GI features are enabled in code and TestCases
- 🌳 Impermeable GI features coded but not yet available in TestCases
- 🌳 Additional development to be done refining GI configuration file options



i-Tree is a
Cooperative
Initiative among
these partners



i-Tree Hydro+ GI: Where To Start?



🌳 **1) Go to i-Tree Research Suite, Hydro+ page**

<https://www.itreetools.org/tools/research-suite/hydro-plus>

🌳 **2) Download latest available Hydro+ package**

‘Stable’ version doesn’t have GI features yet. Latest includes GI R&D.

🌳 **3) Experiment with running the included GI TestCases**

Begin with powIR_defaultParams_noTI test case as it is comparable with Hydro GUI inputs & outputs. Then see GI test cases, one is available for each GI structure type. Open UnifiedHydroConfig.xml and update output path, explore DataFolder(s), etc.

🌳 **4) Design your own GI scenarios, run and explore results**

Using GI test cases as templates, incorporate desired GI structure types and your own parameters into a project (configuration file, input files) of your own. Refer to publications by Abdi & Endreny for further guidance on parameterization. GI inputs & outputs are designed based on EPA SWMM model LID inputs & outputs and SWMM LID documentation can help with Hydro+ GI parameterization.



i-Tree Hydro+ GI: Inputs



```
C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\Tes...
File Edit Search View Encoding Language Settings Tools Macro Run
Plugins Window ?
UnifiedHydroConfig.xml
1 <UnifiedHydroConfig>
2   <SimulationStringParams>
3     <OutputDirectory>C:\Users\coviller\Documents\SV
4     <OutputTimeStep>Hourly</OutputTimeStep>
5     <CalibrationTimeStep>Weekly</CalibrationTimeSte
6     <ExtendedOutputsTimeStep>Hourly</ExtendedOutput
7     <Model>StatisticalHydro</Model> <!--Statistical
8     <Infiltration>ExponentialDecay</Infiltration> <
9     <Routing>DInfinity</Routing> <!--DInfinity -->
10    <RefParamFolder>0,0</RefParamFolder><!--0,0 Wou
11  </SimulationStringParams>
12  <SimulationNumericalParams>
13    <StartDay>20120508</StartDay> <!--Date format:
14    <EndDay>20120509</EndDay>
15    <CatchmentArea_m2>117359</CatchmentArea_m2>
16    <BulkAreaNumber>1</BulkAreaNumber>
17    <TotalTimeSteps>144</TotalTimeSteps>
18  </SimulationNumericalParams>
19  <DataOrganizer>
20    <DataDrawer>
21    <DataFolder>
22      <Type>BulkArea</Type>
23
24    <PerviousCoverUnderTreeCanopy_frac>0.0</Perv
25    <ImperviousCoverUnderTreeCanopy_frac>0.0</Imp
26    <ShortVegetationCover_frac>0.44</ShortVegetat
```

```
C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\GI\bioRetention...
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
UnifiedHydroConfig.xml
58   <TreeLeafStorage mm>0.0</TreeLeafS
59 </DataFolder>
60 <DataFolder>
61   <Type>BioRetention</Type>
62   <Area>46.45</Area>
63   <giNumber>30.0</giNumber>
64   <upSlopeArea>26206</upSlopeArea>
65   <upSlopeAreaImpFrac>0.499</upSlopeArea
66   <PerviousCoverUnderTreeCanopy_frac>0
67   <ImperviousCoverUnderTreeCanopy_frac>
68   <ShortVegetationCover_frac>0.5</Short
69   <SoilCover_frac>0.5</SoilCover_frac>
70   <ImperviousCover_frac>0.0</Imperviou
71   <ImpAreaTreated_frac>0.8</ImpAreaTre
72   <PerAreaTreated_frac>0.8</PerAreaTre
```

Like Hydro+ StatHydro inputs, GI structures require DataFolder parameterization in UnifiedHydroConfig.xml

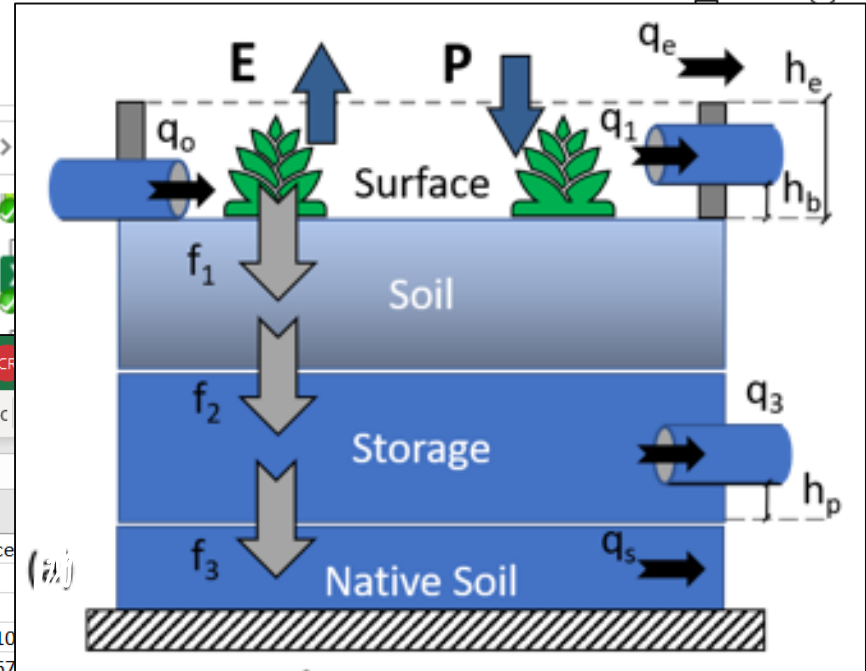
Each DataFolder = individual structure, or aggregate statistics for all structures of same type.



i-Tree Hydro+ GI: Outputs (Raw)



	A	B	C	D	E	F	G	H	I	J
1	yyyyymmdd	Hr:Min:sec	Inflow(q0)	SurfaceInfl	Percolatio	StorageExl	SurfaceOu	StorageDr	paveDepth	surface
2	20120508	12:00:00	0.000614	0.000614	0	0	0	0	0	
3	20120508	12:05:00	0.003491	0.003491	0	0	0	0	0	
4	20120508	12:10:00	0.009067	0.008008	0	0	0	0	0	0.0010
5	20120508	12:15:00	0.014485	0.008807	0	0	0	0	0	0.0067
6	20120508	12:20:00	0.019078	0.009009	0.000285	0.000285	0	0	0	0.016807 0.245157 0
7	20120508	12:25:00	0.035026	0.00907	0.000526	0.000423	0	0	0	0.042763 0.287896 0



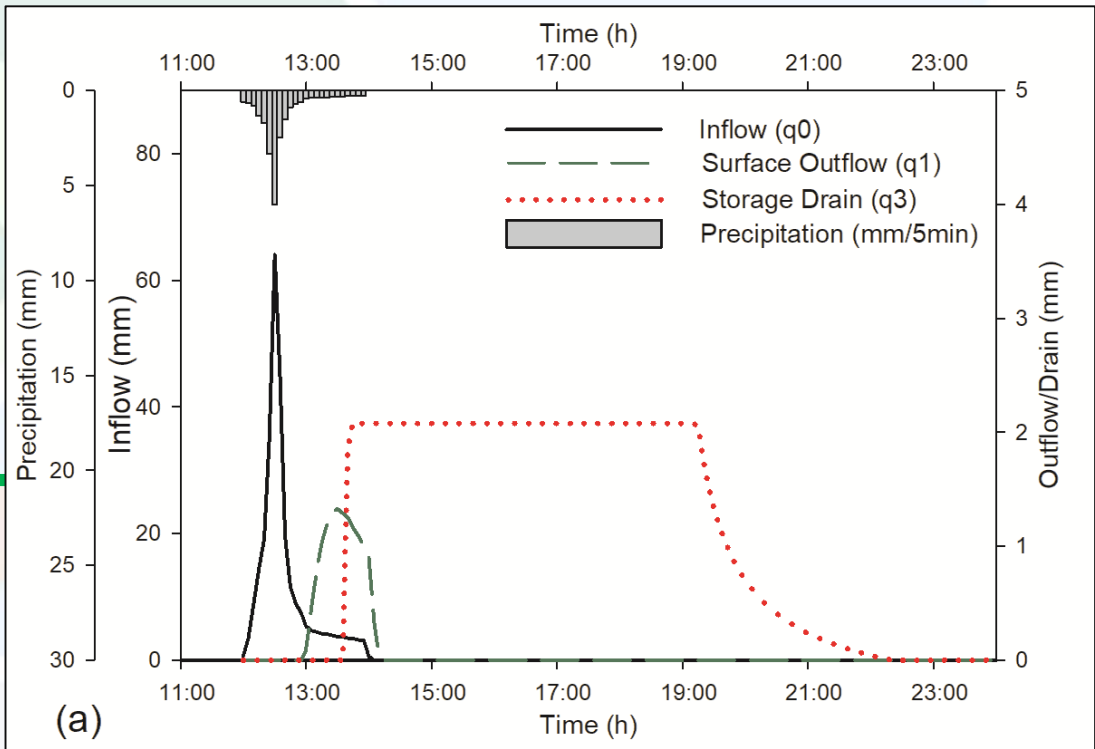
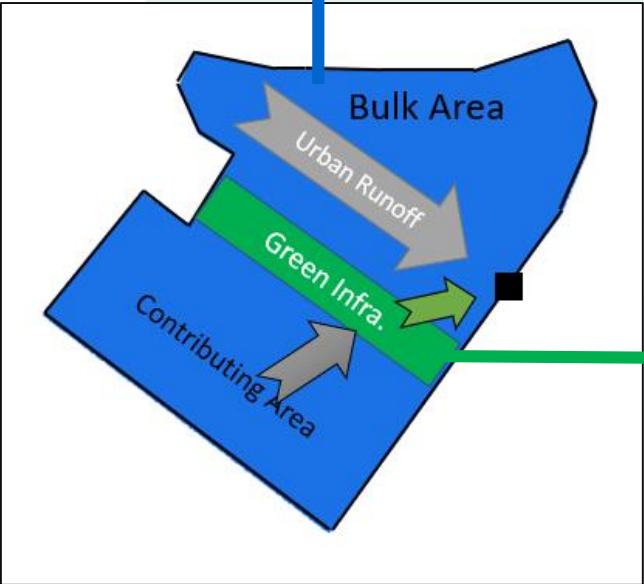
- Adding GI DataFolders to input config file results in WaterBalance_<Structure>.csv
- WaterBalance_<Structure>.csv includes all GI-specific outputs for that structure
- Most Hydro+ GI outputs are aligned with SWMM GI outputs by design
- All other outputs represent 'Bulk Area' non-GI flows



i-Tree Hydro+ GI: Outputs (Extra Processing)



Time period (Year)	No GI Total runoff (m ³)	With Bioretention GI device				Difference (%)
		Untreated (m ³)	Surface outflow (m ³)	Storage drain (m ³)	Total runoff (m ³)	
2018	2083.7	416.7	726.0	257.8	1400.5	32



(a) Bioretention precipitation, inflow, and outflows.



i-Tree is a Cooperative Initiative among these partners



Research Suite: Next steps

www.itreetools.org/tools/research-suite

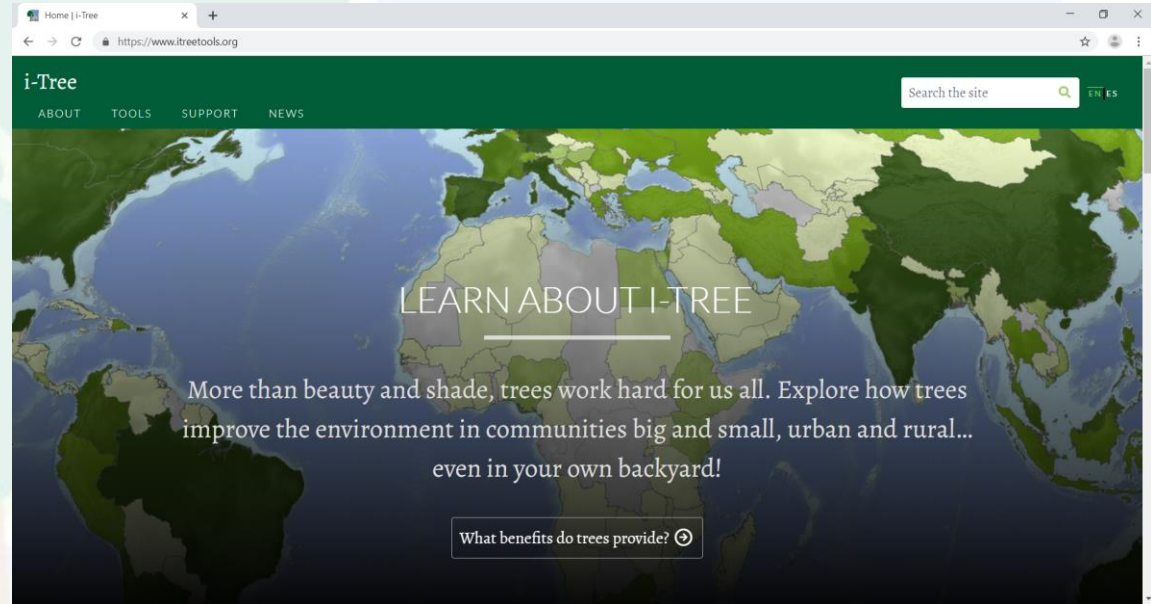
Tools

Documentation

Examples

Code

Contacts



For consultation inquiries, reach out to info@itreetools.org