i-Tree Research Suite

Hydro+ and Green Infrastructure

October 31, 2019

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Davey Institute & USDA Forest Service

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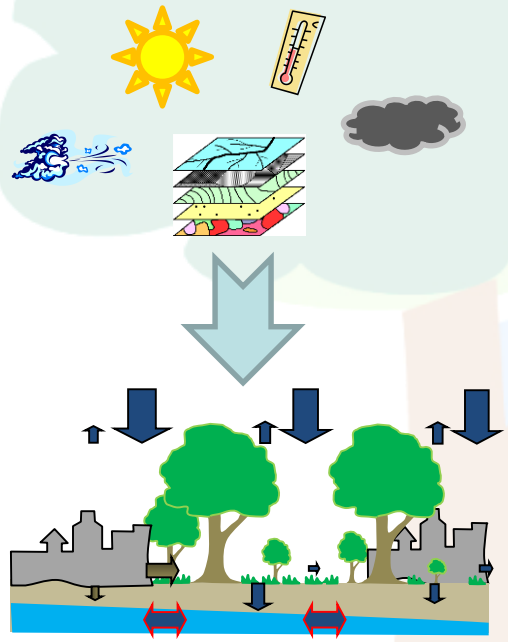


Outline

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

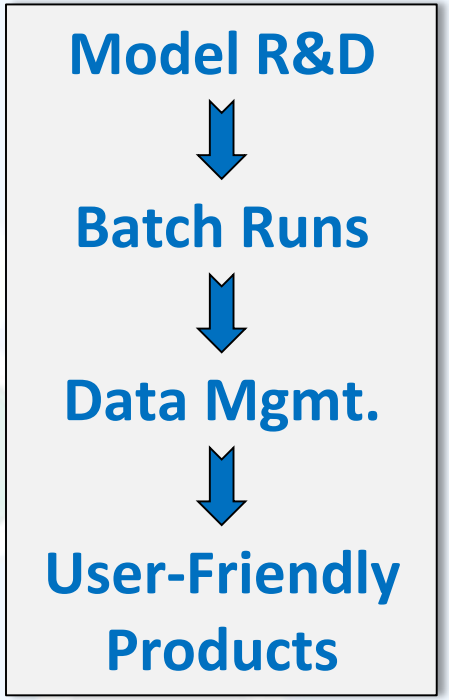
What is the i-Tree Research Suite?

Purpose:

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

Motivated by:

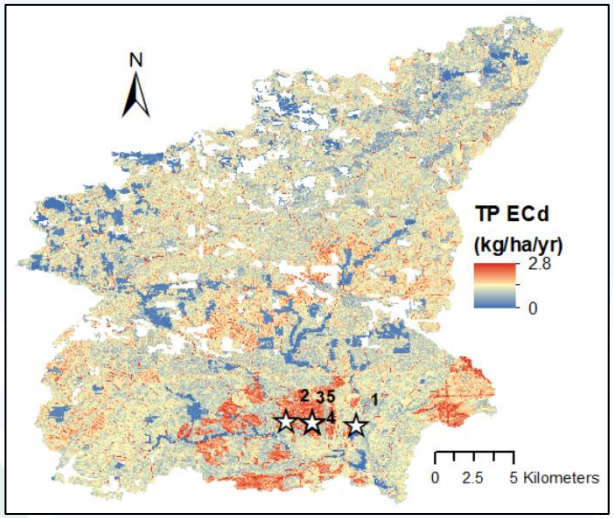
- Technical tools from i-Tree R&D
- Limited support resources for advanced tools



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

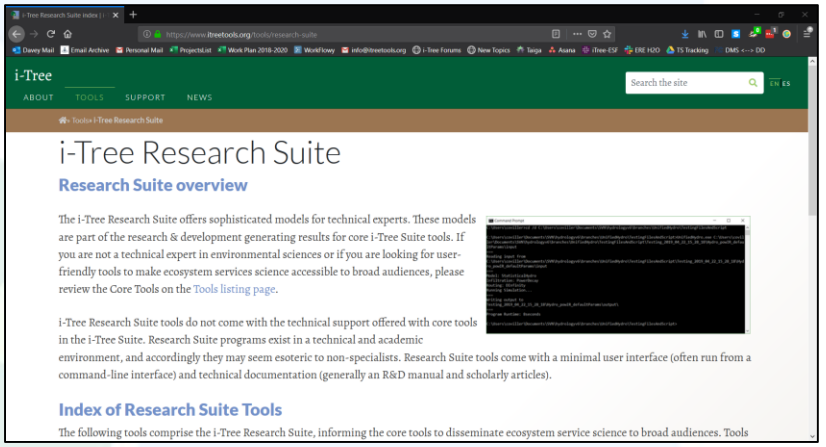
- Data-tables & calculator to estimate replacement cost or planting for lost trees

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

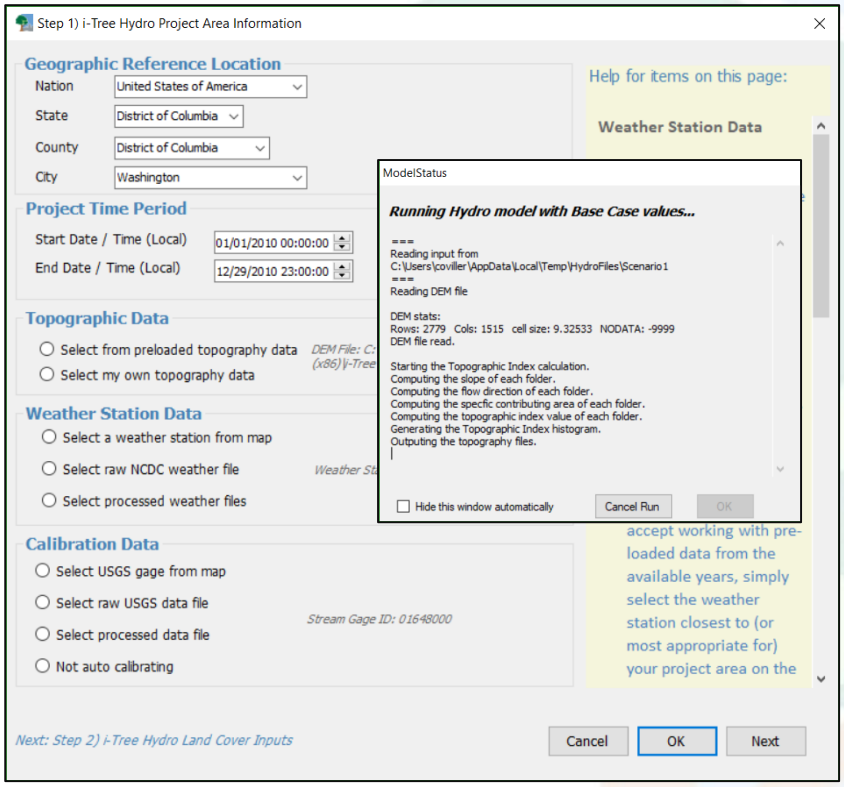
Estimates effects of:

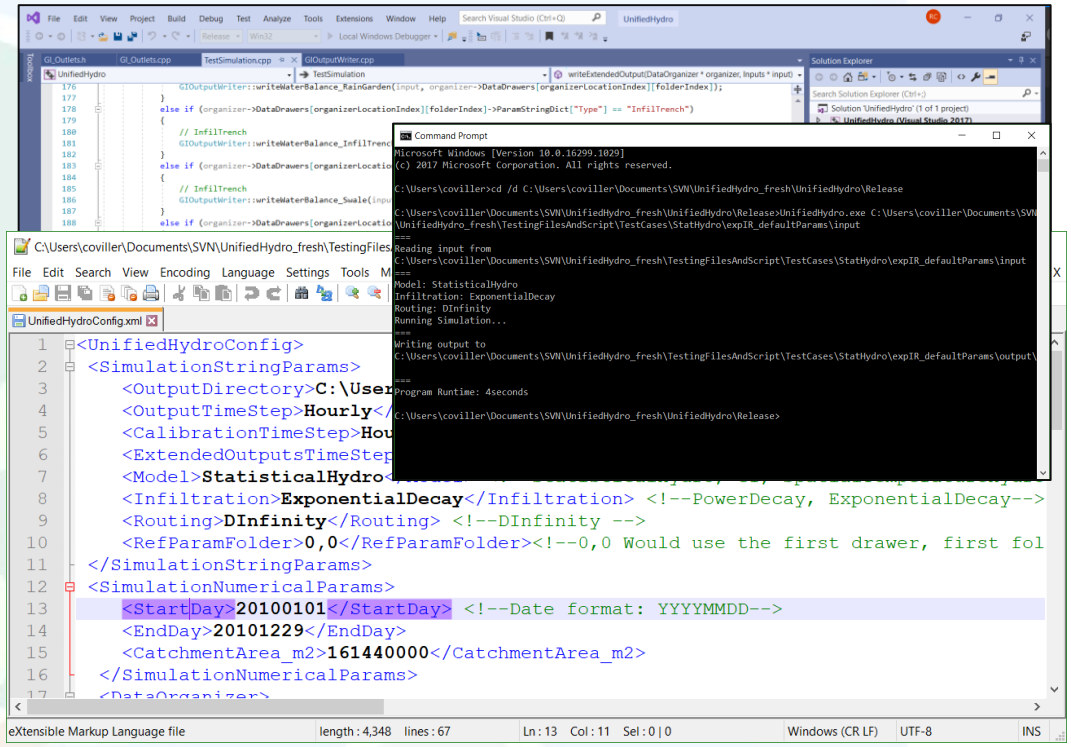
- Tree cover
- Impervious cover
- + more

on:

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

i-Tree Hydro+: Key Differences from GUI





i-Tree Hydro v6.3 GUI

- Development inactive
- Interface is relatively user friendly
- Some technical support available

Hydro+ (UnifiedHydro.exe)

- 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?

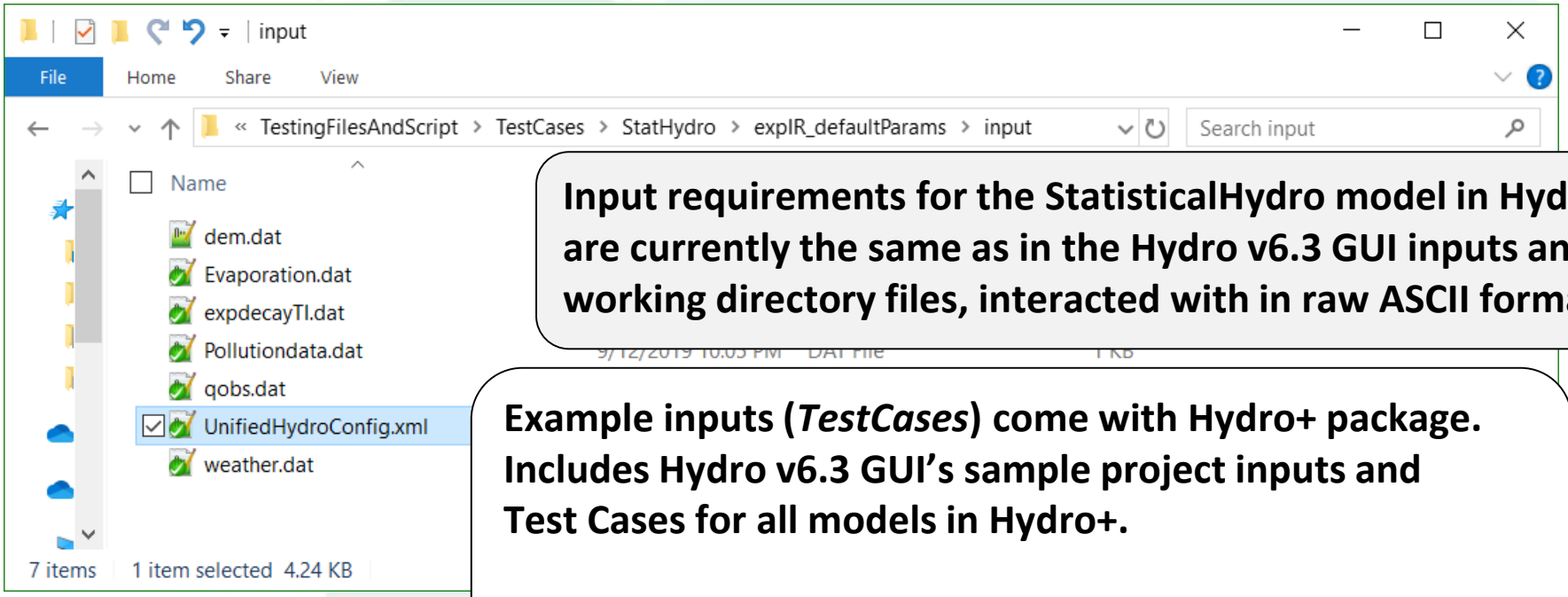
Researchers, Advanced Users, Environmental Professionals

- 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 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

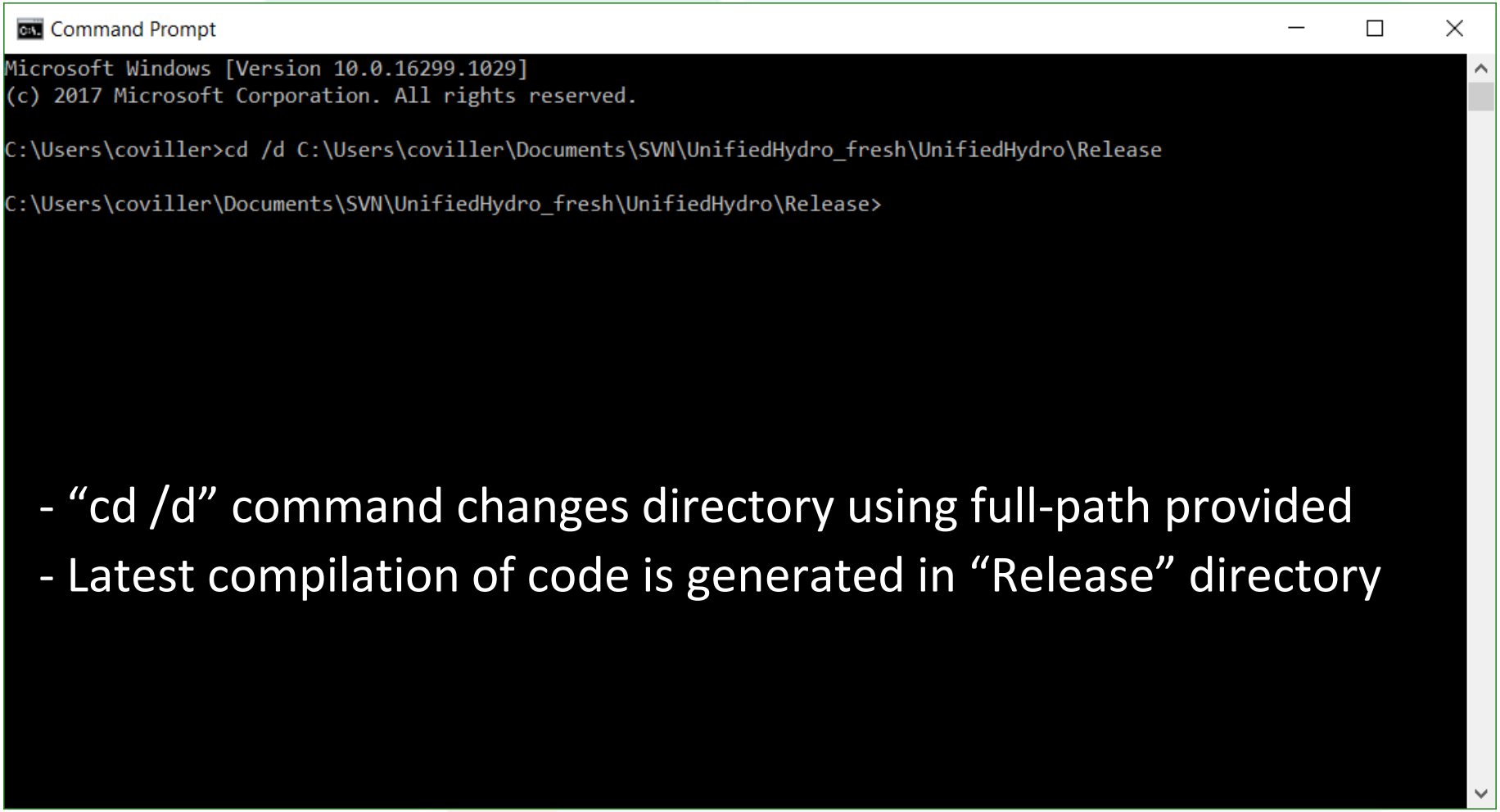
```
<UnifiedHydroConfig>
<Si
    <OutputDirectory>C:\Users\coviller\Documents\SVN\UnifiedHydro_fresh\TestingFilesAndScript\TestCases\StatHydro\expIR_defaultParams\output\</OutputDirectory>
    <OutputTimeStep>Hourly</OutputTimeStep>
    <CalibrationTimeStep>Hourly</CalibrationTimeStep> <!-- Possible values: NoCalibration, Hourly, Weekly, Daily,  -->
    <ExtendedOutputsTimeStep>NoExtendedOutputs</ExtendedOutputsTimeStep> <!-- Possible values: NoExtendedOutputs, Hourly  -->
    <Model>StatisticalHydro</Model> <!--StatisticalHydro, GI, SpatialTemperatureHydro -->
    <Infiltration>ExponentialDecay</Infiltration> <!--PowerDecay, ExponentialDecay-->
    <Routing>DInfinity</Routing> <!--DInfinity -->
    <RefParamFolder>0,0</RefParamFolder><!--0,0 Would use the first drawer, first folder for ref params-->
</SimulationStringParams>
<SimulationNumericalParams>
    <StartDay>20100101</StartDay> <!--Date format: YYYYMMDD-->
    <EndDay>20101229</EndDay>
    <CatchmentArea_m2>161440000</CatchmentArea_m2>
 </SimulationNumericalParams>
<DataDrawer>
<DataFolder>
    <Type>BulkArea</Type>
    <Area>161440000</Area>
    <PerviousCoverUnderTreeCanopy_frac>0.363</PerviousCoverUnderTreeCanopy_frac>
    <ImperviousCoverUnderTreeCanopy_frac>0.05</ImperviousCoverUnderTreeCanopy_frac>
    <ShortVegetationCover_frac>0.297</ShortVegetationCover_frac>
```

eXtensible Markup Language file | 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

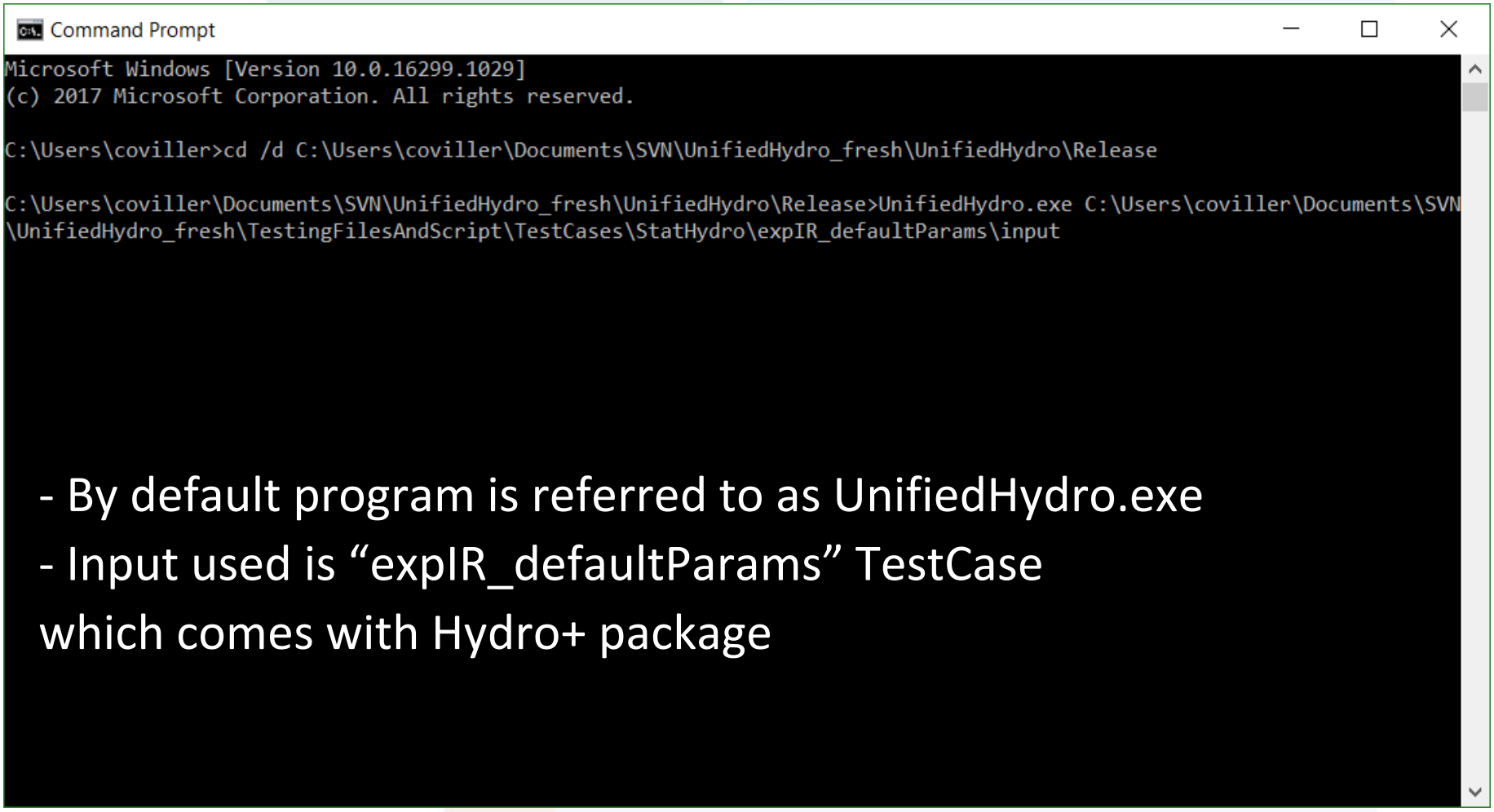
1) Open command-line interface, navigate to folder containing Hydro+



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

i-Tree Hydro+: Execution

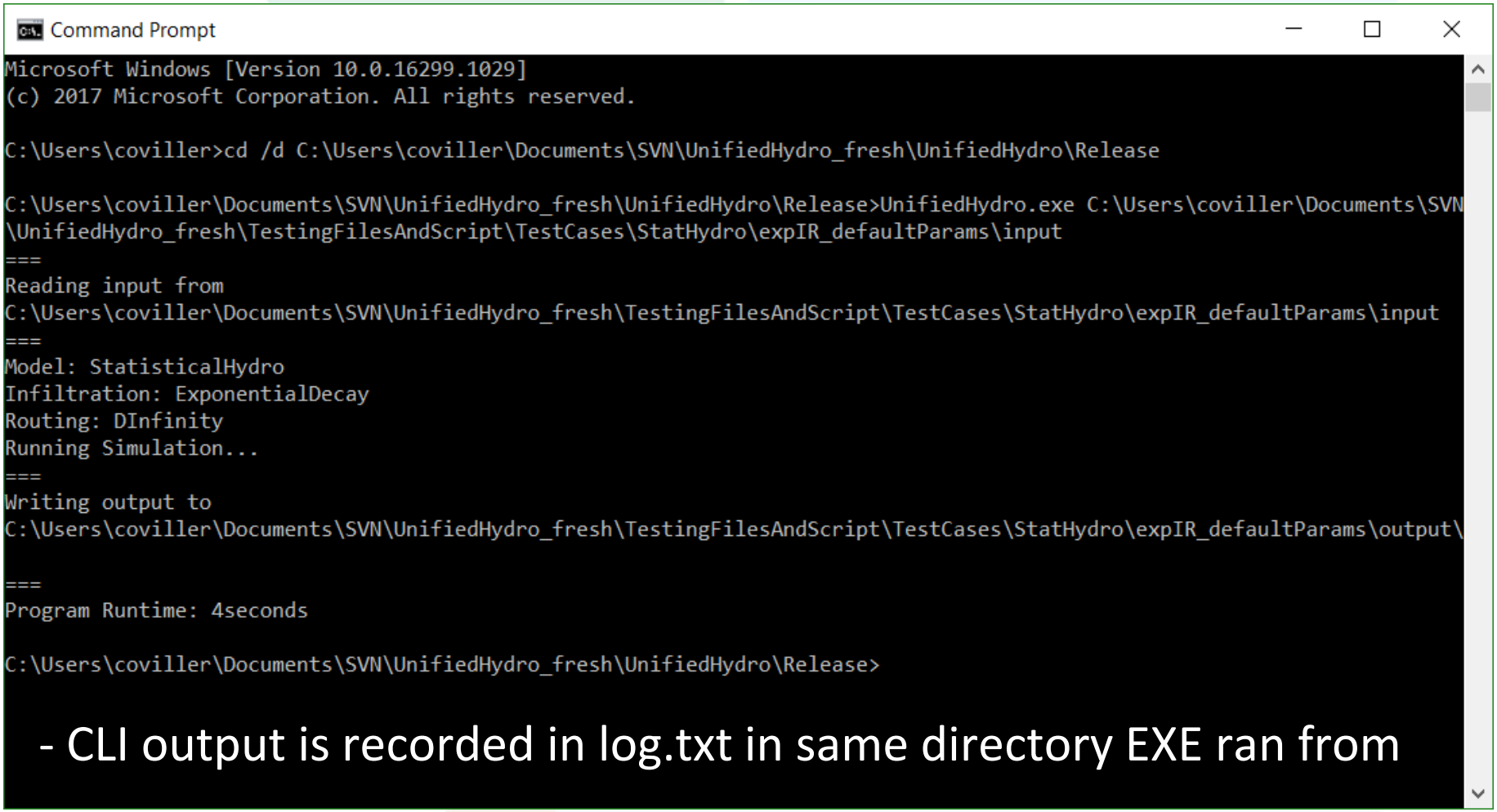
2) Enter: <Hydro+ exe name> <Full path to inputs directory>



- 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

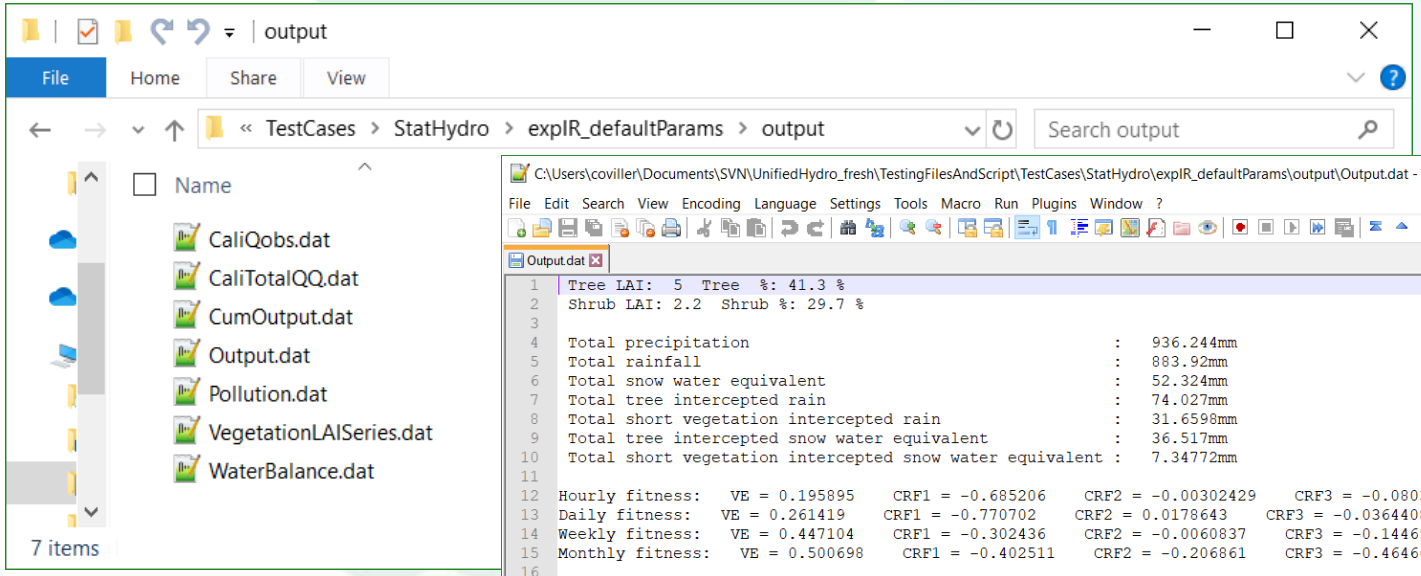
3) Hit enter to run the model; confirm run completed with no errors



- 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



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

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

Output.dat

```
Tree LAI:  5  Tree  %: 41.3 %
Shrub LAI: 2.2  Shrub %: 29.7 %

Total precipitation                                 :   936.244mm
Total rainfall                                      :   883.92mm
Total snow water equivalent                         :   52.324mm
Total tree intercepted rain                         :   74.027mm
Total short vegetation intercepted rain             :   31.6598mm
Total tree intercepted snow water equivalent        :   36.517mm
Total short vegetation intercepted snow water equivalent :   7.34772mm

Hourly fitness:   VE = 0.195895    CRF1 = -0.685206    CRF2 = -0.00302429    CRF3 = -0.0803219
Daily fitness:    VE = 0.261419    CRF1 = -0.770702    CRF2 = 0.0178643      CRF3 = -0.0364408
Weekly fitness:   VE = 0.447104    CRF1 = -0.302436    CRF2 = -0.0060837     CRF3 = -0.144694
Monthly fitness:  VE = 0.500698    CRF1 = -0.402511    CRF2 = -0.206861      CRF3 = -0.464665

Total runoff (TotalQ :mm)       :  336.706     Total pervious area surface flow (TotalPerviousAreaQ_mm :mm) :    183.779
Total Baseflow(BQ:mm)           :   82.4679        Total Impervious impervious flow (TotalDCIAQ:mm)     :    70.4425

 BQ/TotalQ: 0.244926   TotalDCIAQ_mm/TotalQ: 0.209211

The unit of the following time series output is : m/DT , DT: simulation time interval, such as 1 hour

   yyyymmdd    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
```

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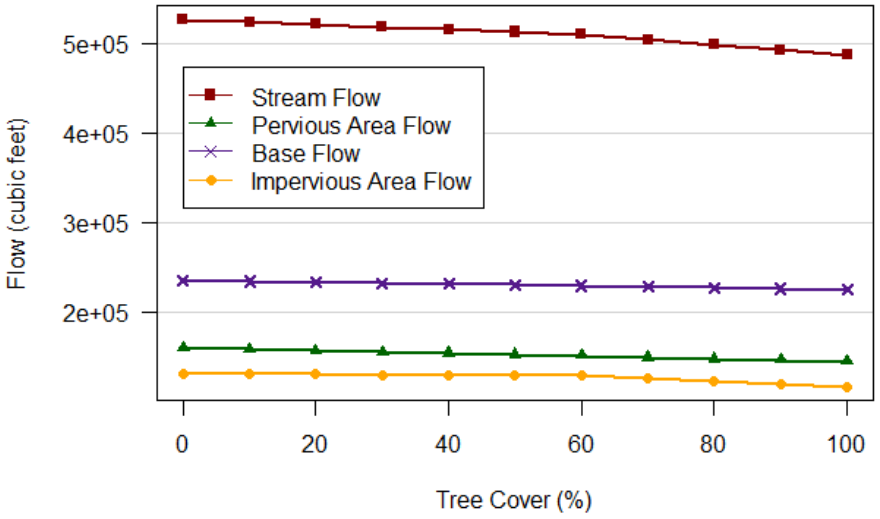
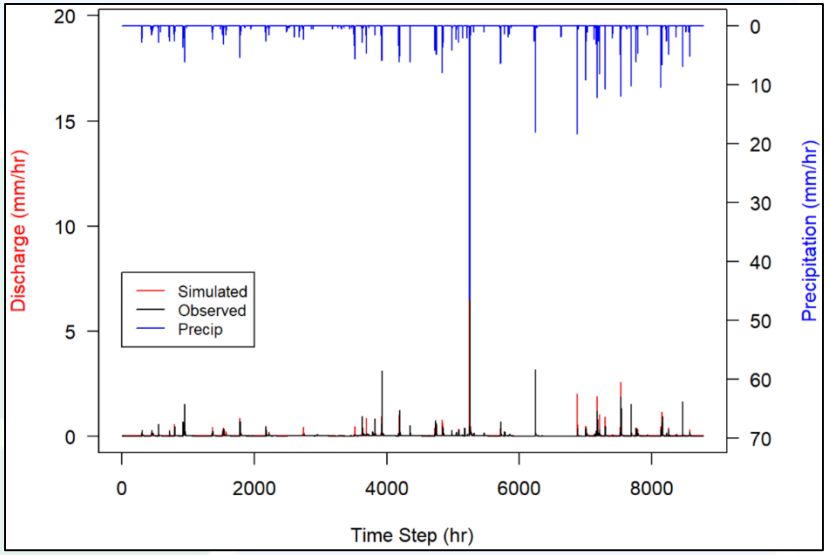
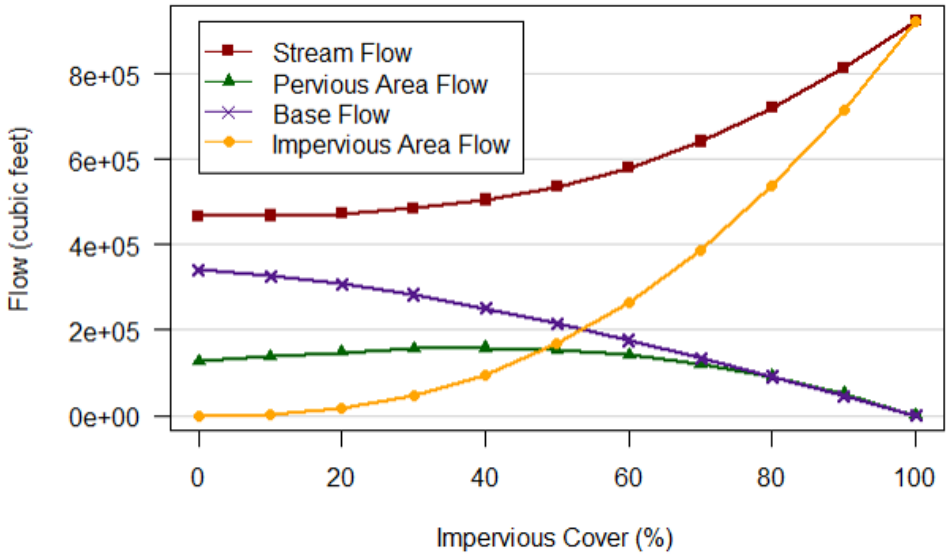
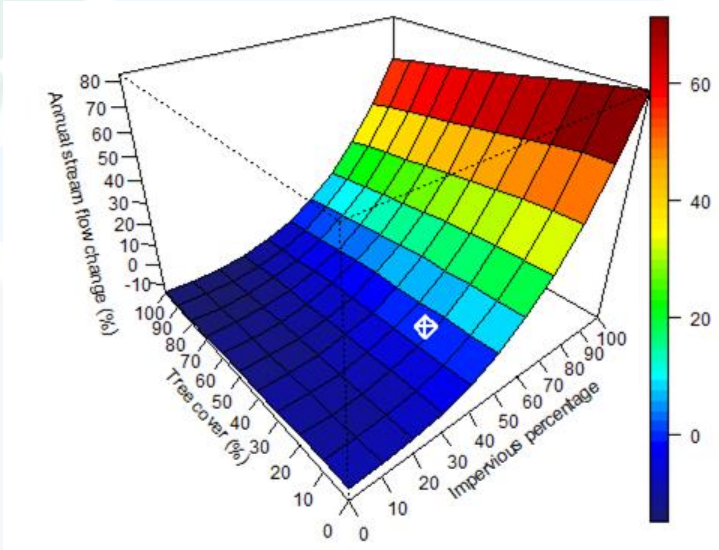
i-Tree Hydro+: Outputs (Extra Processing)









Research Suite: Next steps

www.itreetools.org/tools/research-suite

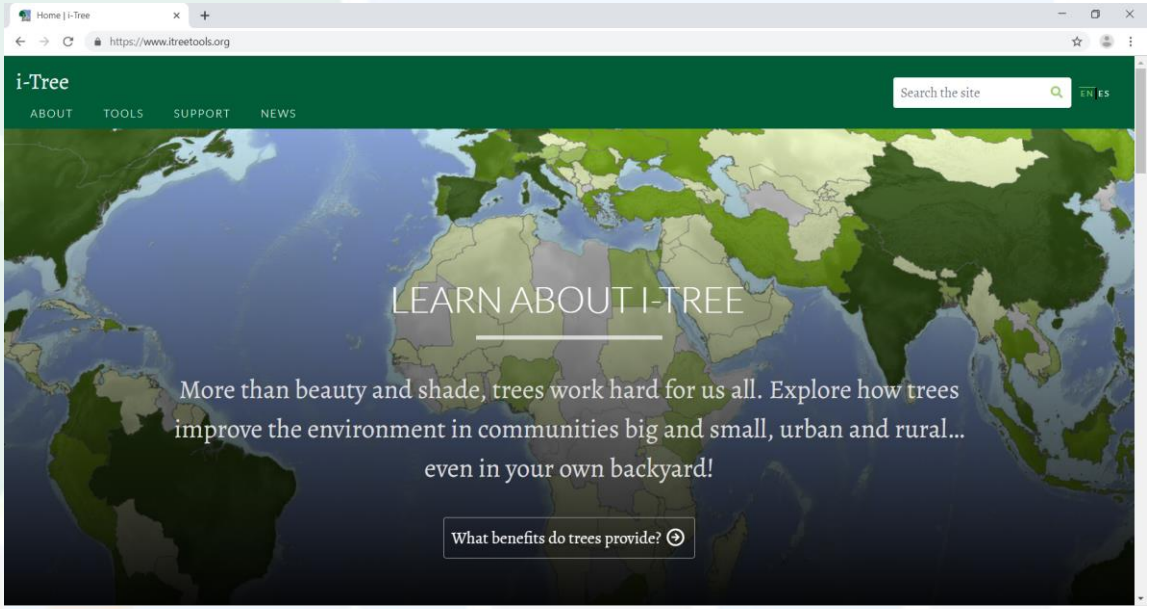
Tools

Documentation

Examples

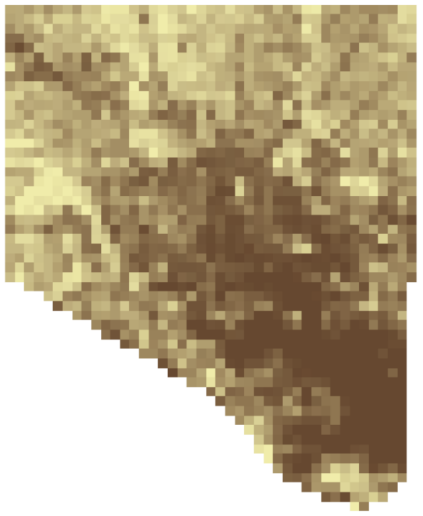
Code

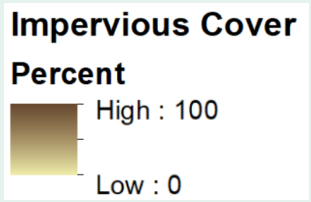
Contacts

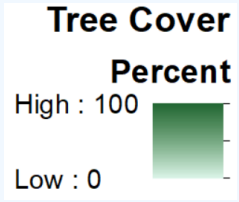


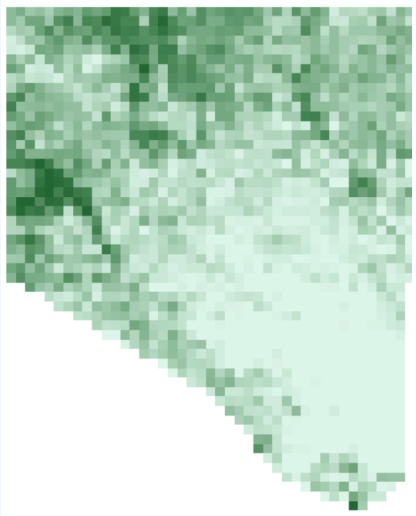
For consultation inquiries, reach out to info@itreetools.org

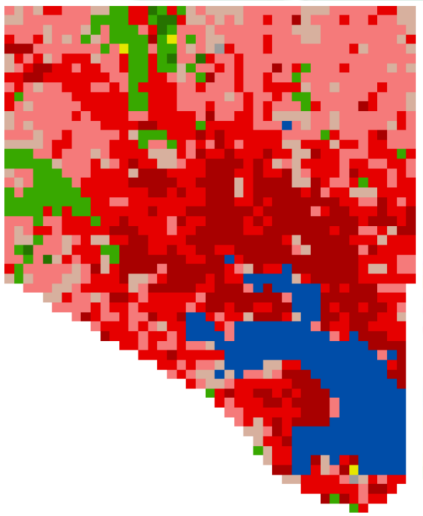
i-Tree Cool Air: Inputs











Inputs

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

i-Tree 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

```
<UnifiedHydroConfig>
 <SimulationStringParams>
    <OutputDirectory>C:\Users\coviller\CoolAir\input\output\</OutputDirectory>
    <OutputTimeStep>Hourly</OutputTimeStep>
    <CalibrationTimeStep>NoCalibration</CalibrationTimeStep>
    <ExtendedOutputsTimeStep>NoExtendedOutputs</ExtendedOutputsTimeStep>
    <Model>SpatialTemperatureHydro</Model>
    <Infiltration>PowerDecay</Infiltration>
    <Routing>DInfinity</Routing>
    <RefParamFolder>0,0</RefParamFolder><!--0,0 Would use the first drawer, first folder for ref
    params-->
 </SimulationStringParams>
 <SimulationNumericalParams>
    <StartDay>20150621</StartDay>
    <EndDay>20150623</EndDay>
    <CatchmentArea_m2>161440000</CatchmentArea_m2>
  </SimulationNumericalParams>
  <DataOrganizer>
  <DataDrawer>
  <DataFolder>
      <Type>BulkArea</Type>
      <Area>70838.08688021062</Area>
      <PerviousCoverUnderTreeCanopy_frac>0.363</PerviousCoverUnderTreeCanopy_frac>
      <ImperviousCoverUnderTreeCanopy_frac>0.05</ImperviousCoverUnderTreeCanopy_frac>
      <ShortVegetationCover_frac>0.297</ShortVegetationCover_frac>
      <SoilCover_frac>0.007</SoilCover_frac>
      <ImperviousCover_frac>0.283</ImperviousCover_frac>
      <DCIA_frac>0.2685</DCIA_frac>
```

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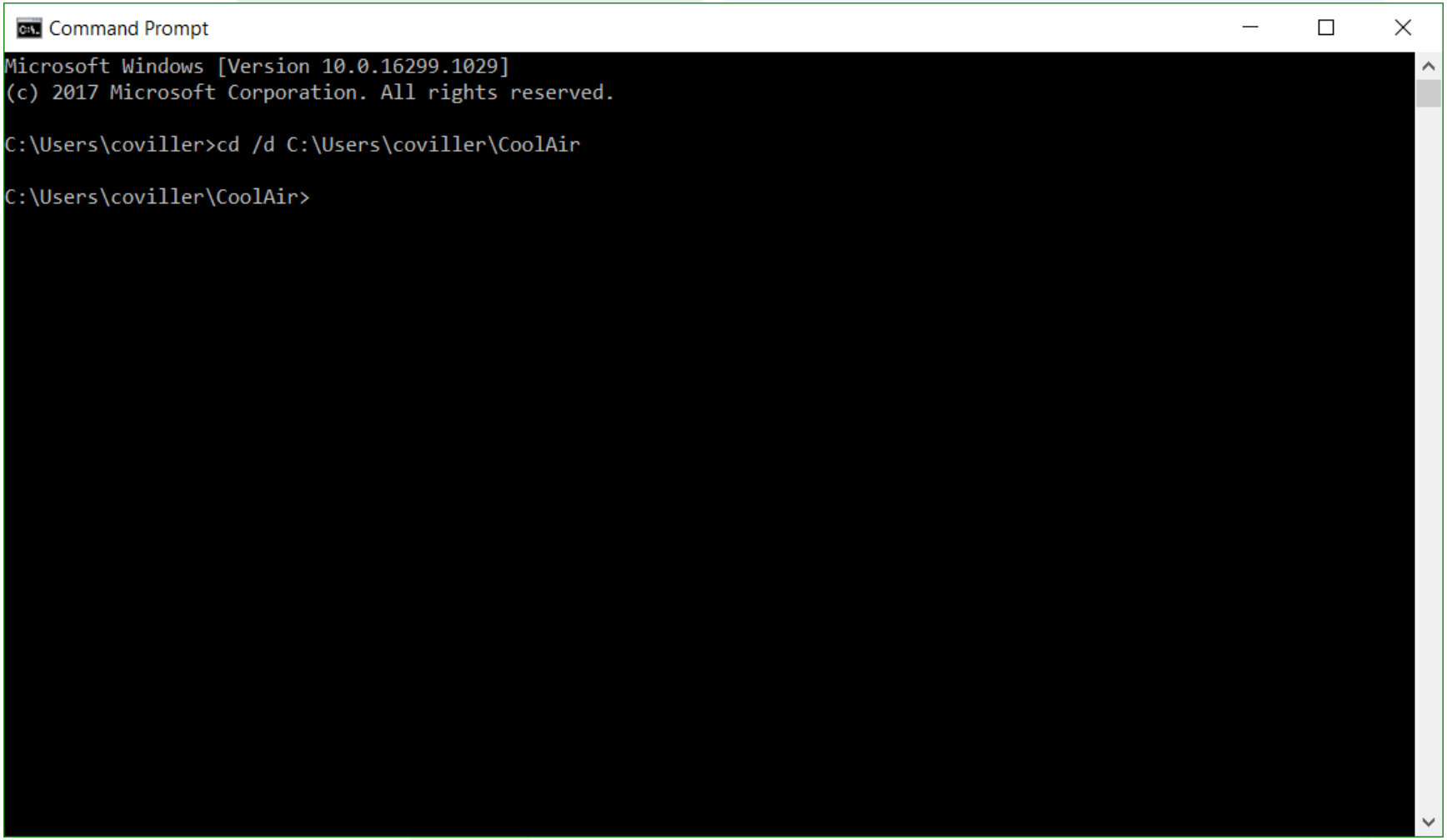
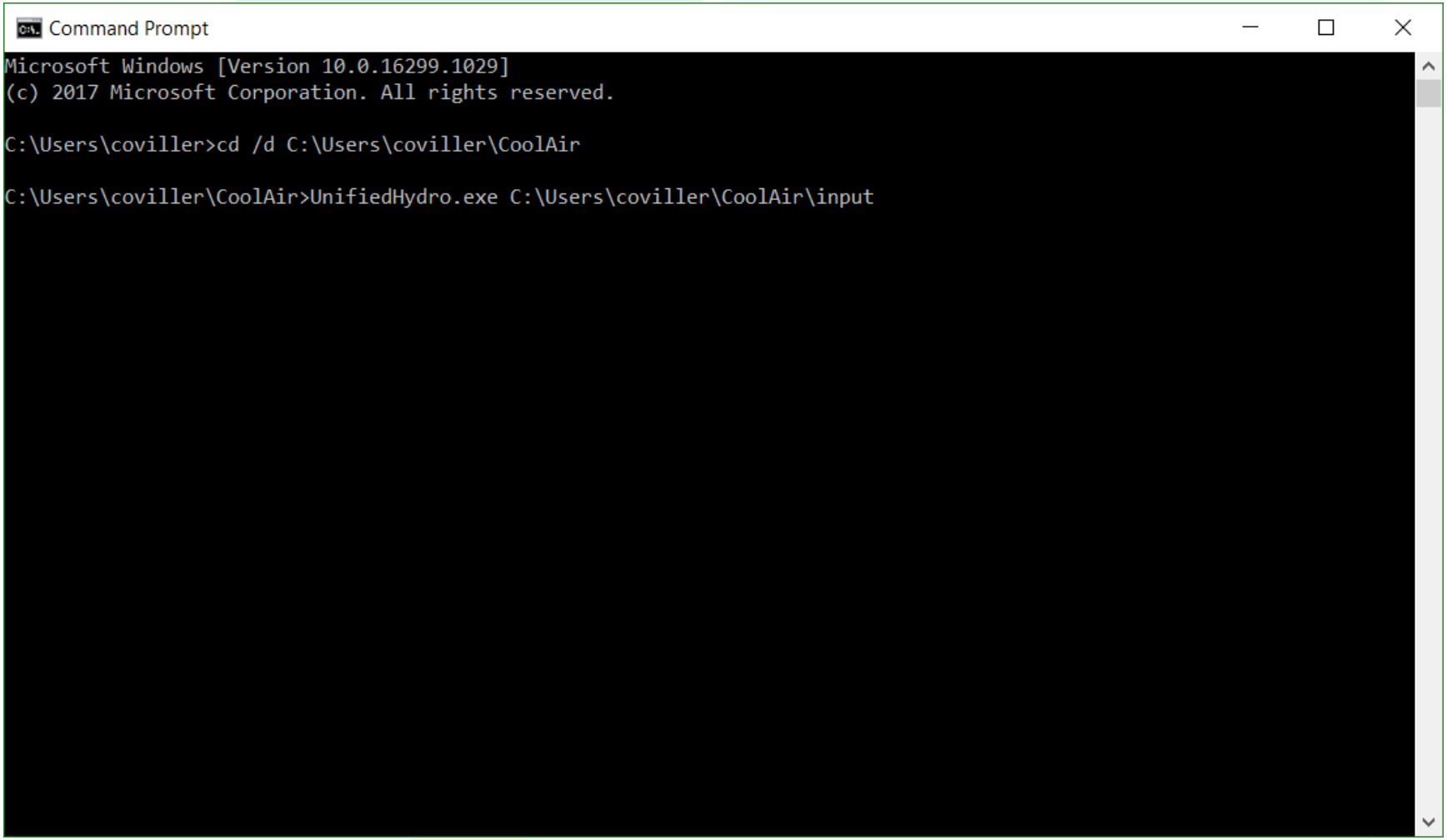
i-Tree Cool Air: Execution

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



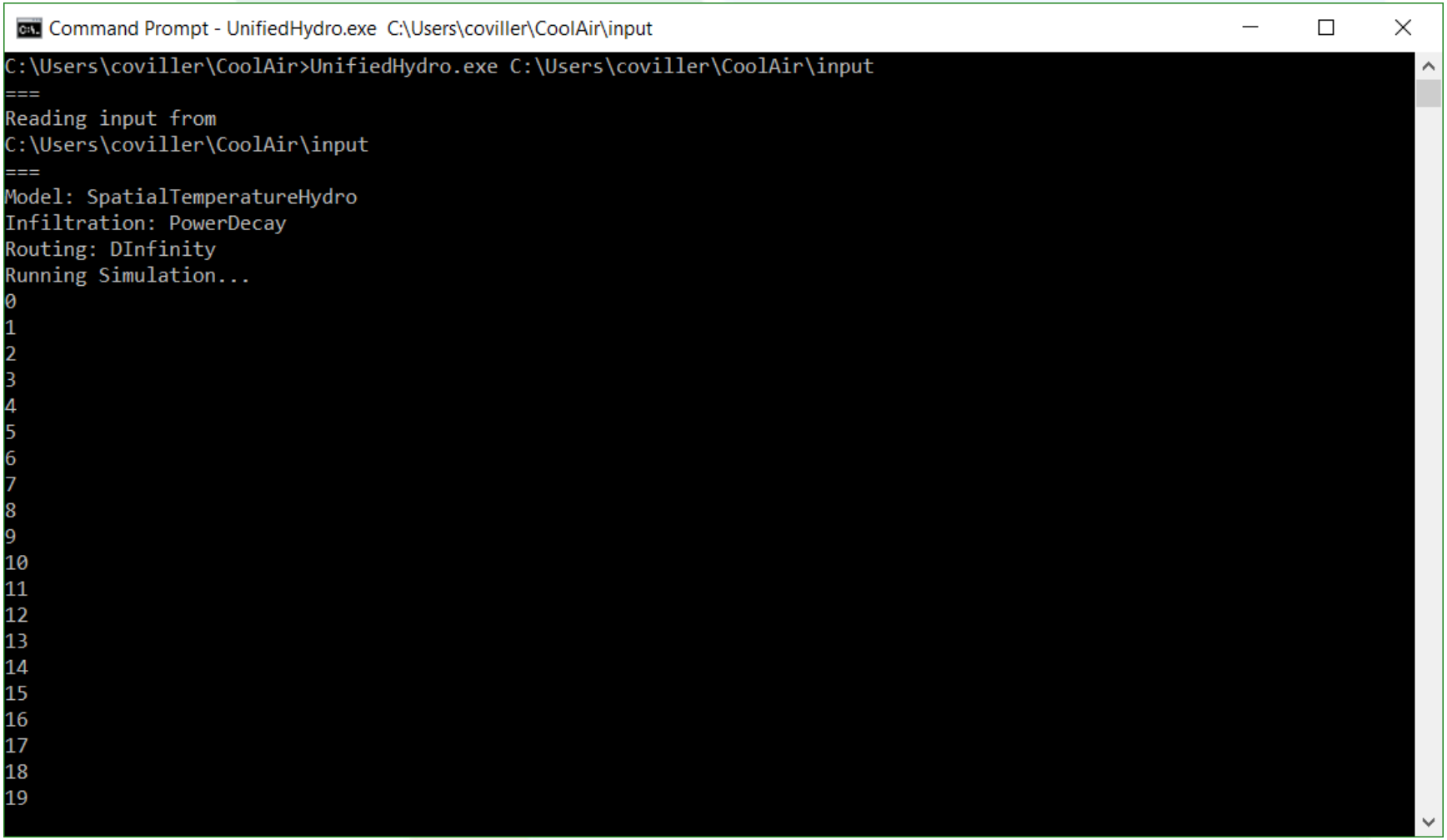
i-Tree Cool Air: Execution

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



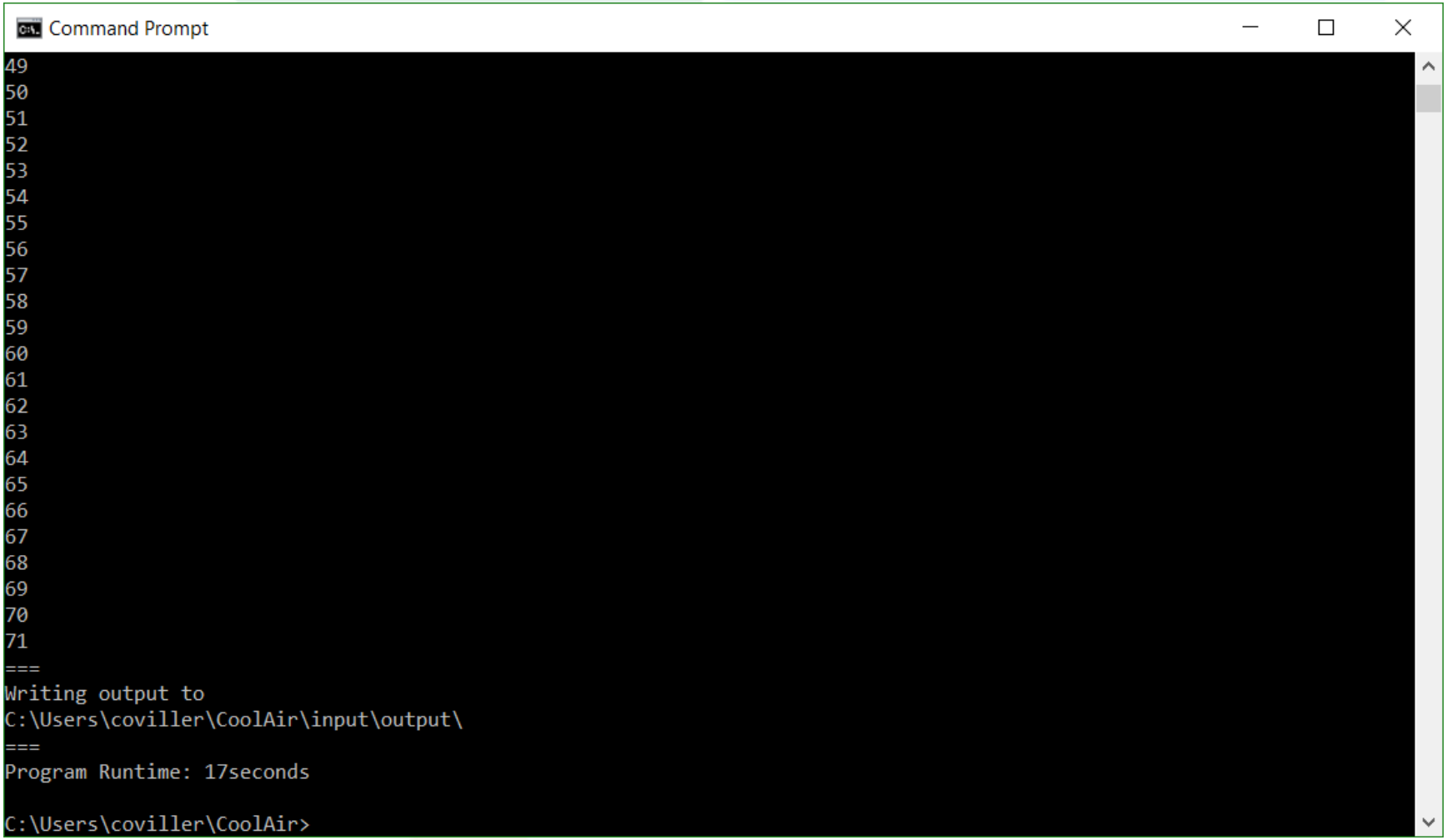
i-Tree Cool Air: Execution

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



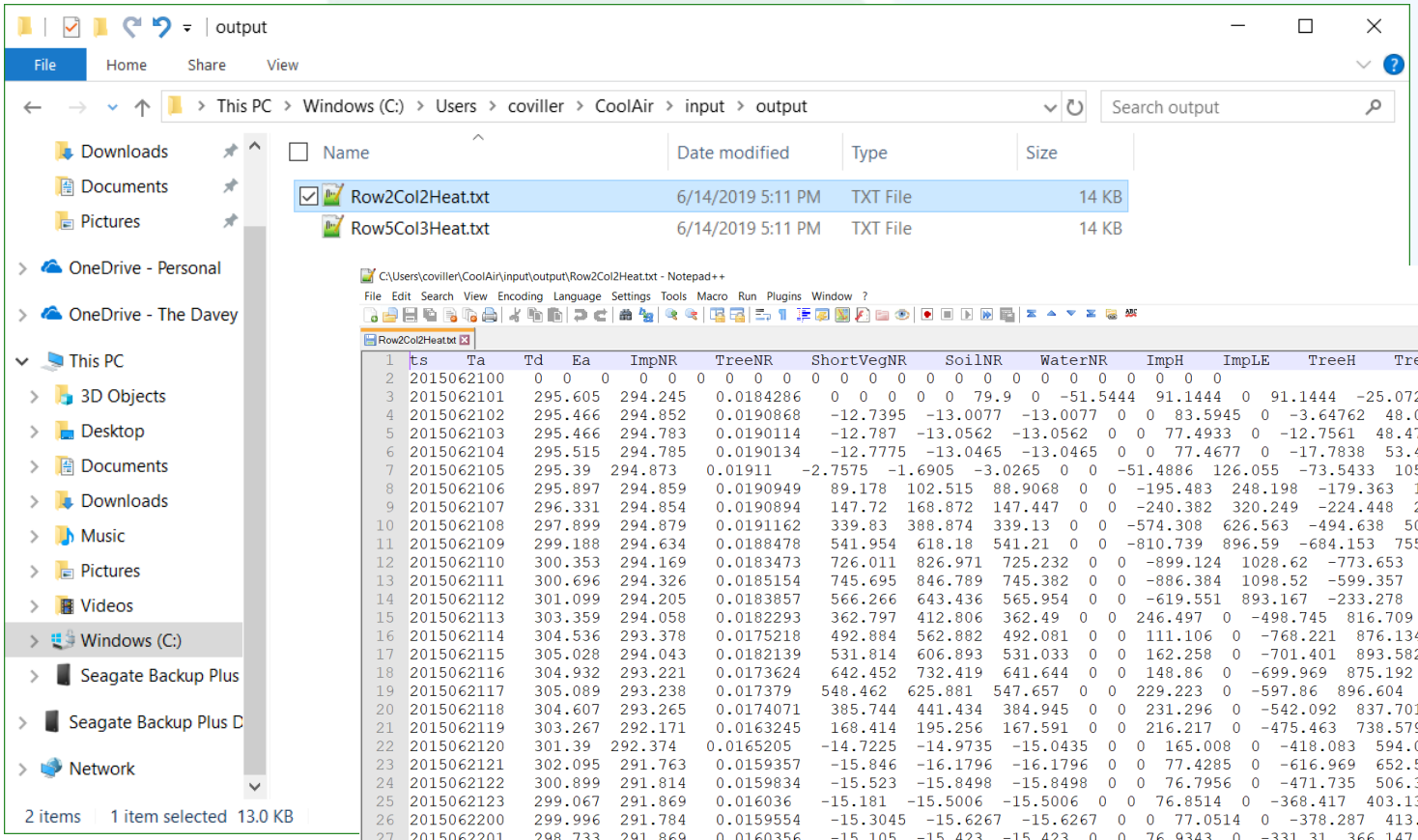
i-Tree Cool Air: Execution

4) Confirm run completed without error

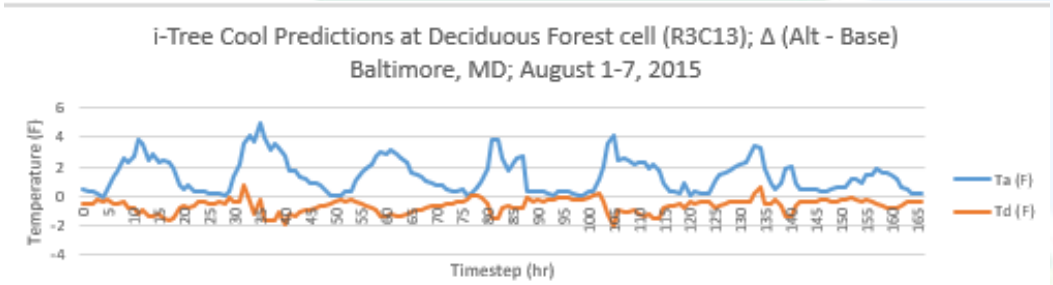


i-Tree Cool Air: Execution

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



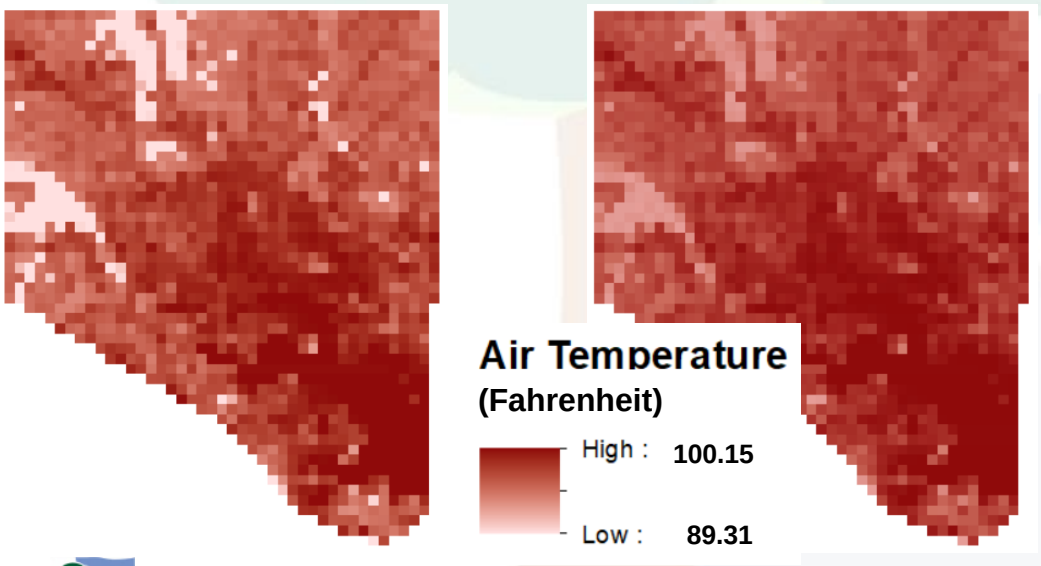
i-Tree Cool Air: Outputs *(preliminary)*



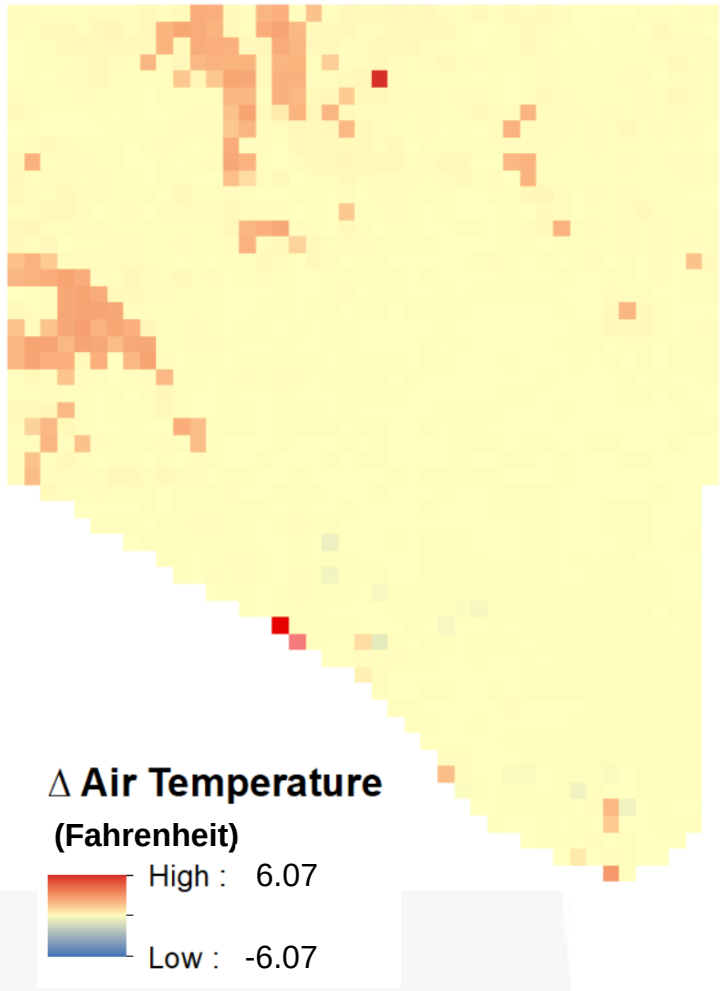
Baltimore, MD – hottest hour of 2015
July 19, 2015, 16:00

Current Land Cover

0% Tree Cover Scenario



Δ Alternative – Base Case



i-Tree is a Cooperative Initiative among these partners

DAVEY

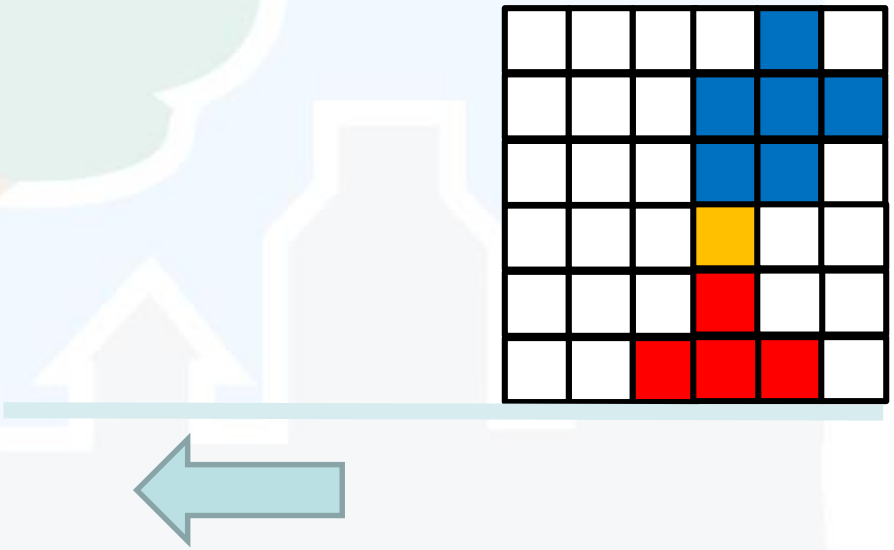
Arbor Day Foundation

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

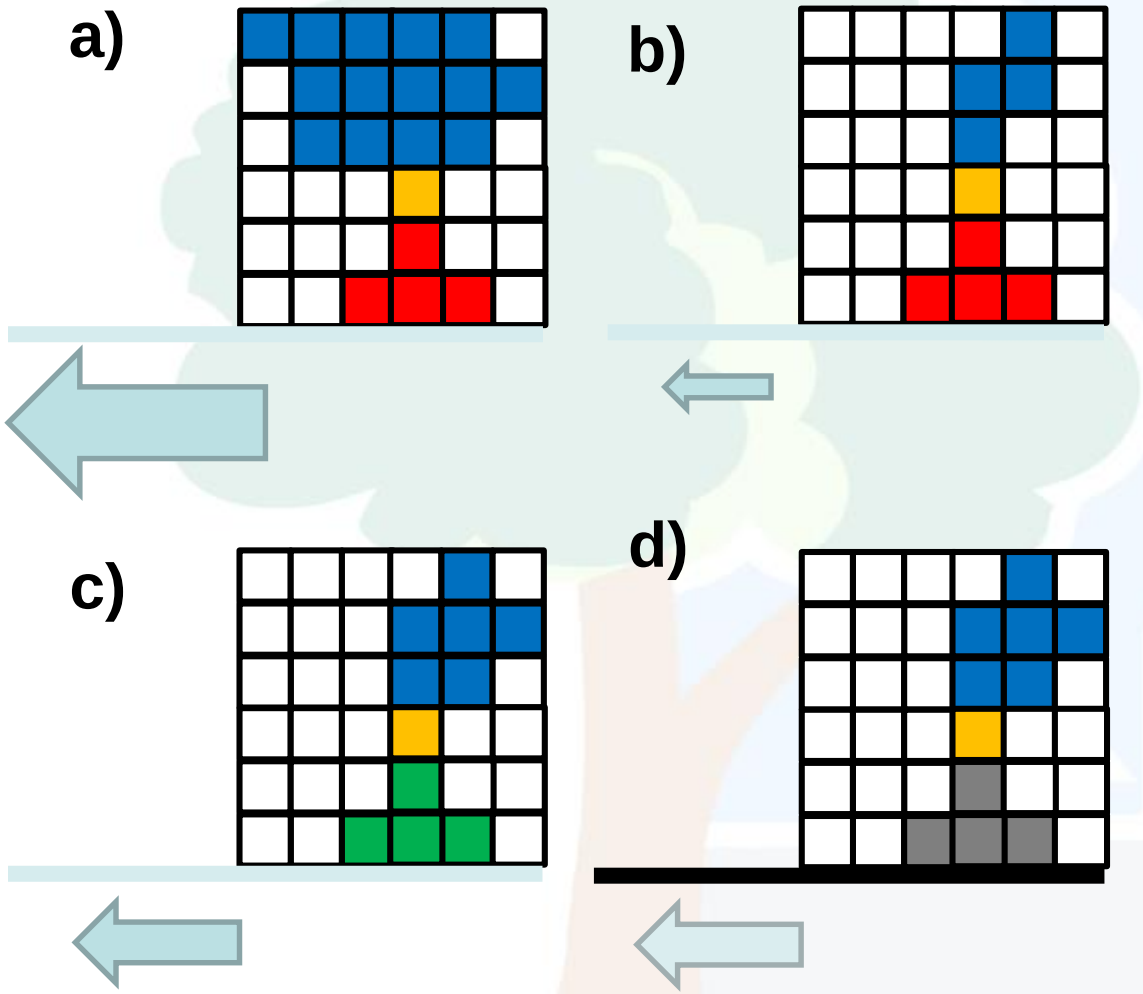
i-Tree Buffer: Introduction

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)**



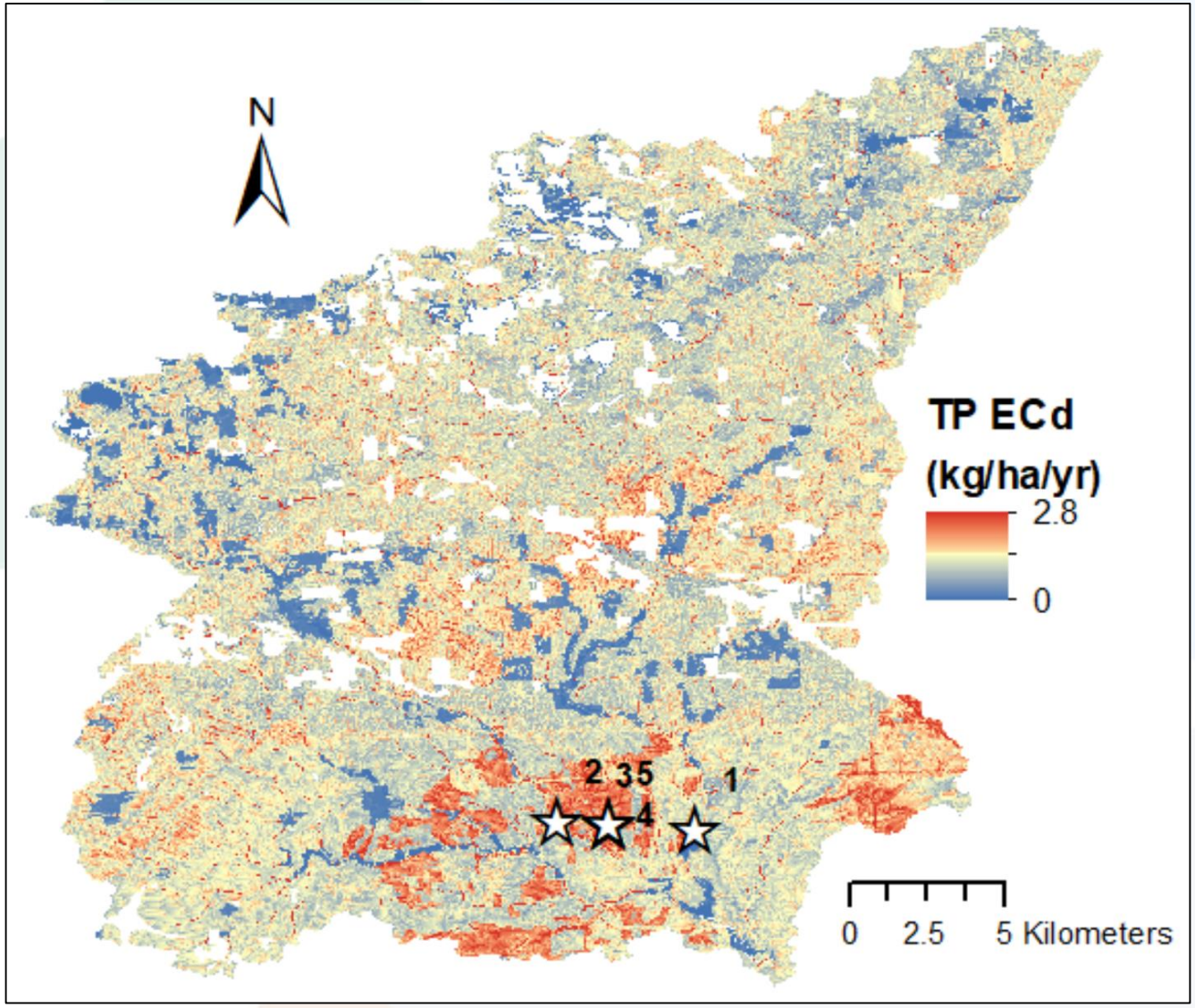
i-Tree Buffer: Theory



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)*



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 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.

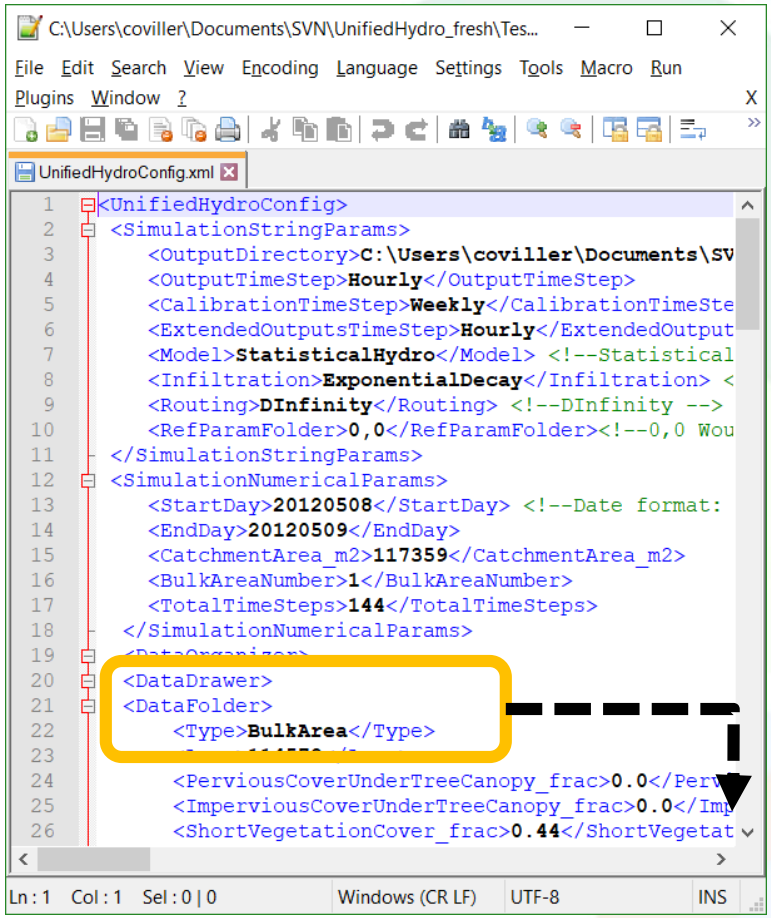
- **4) Design your own GI scenarios, run and explore results**

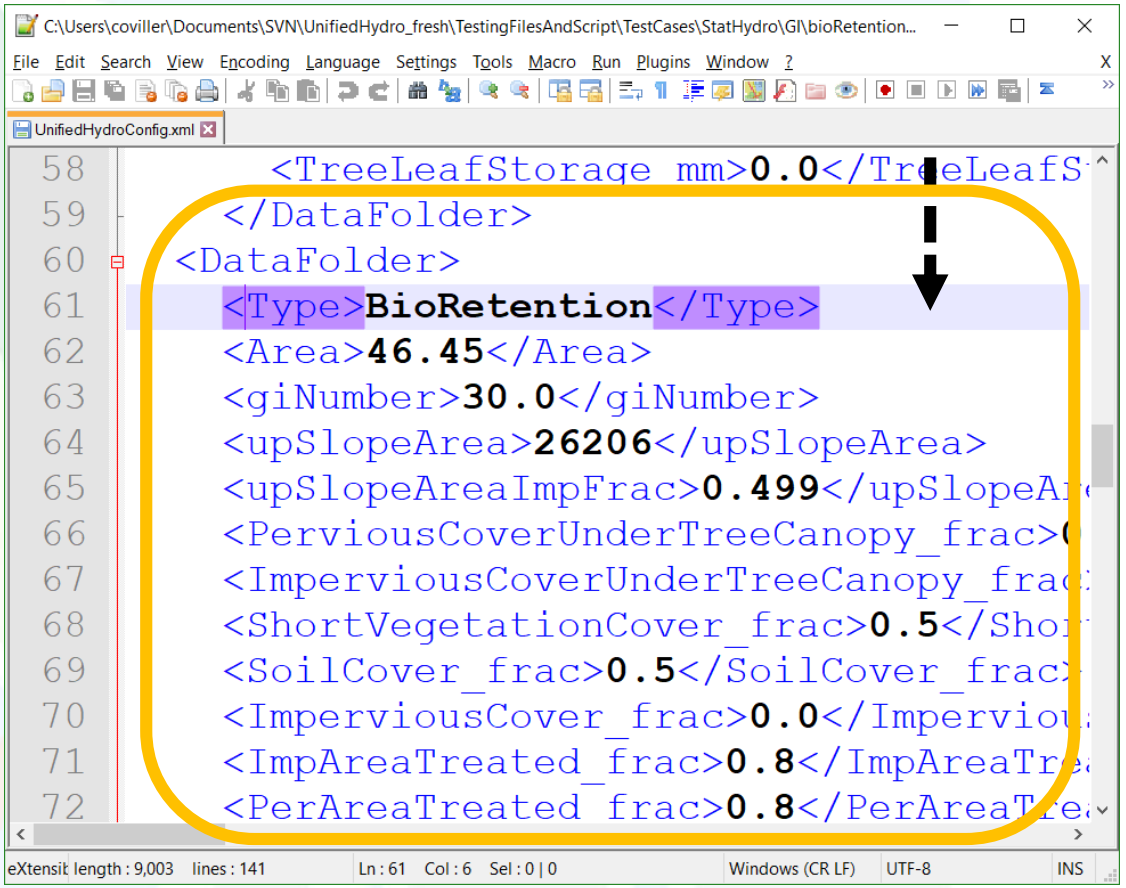
Using GI test cases as templates, incorporate desired GI structure types and your own parameters into a project (configuration file, input files) of your own.

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

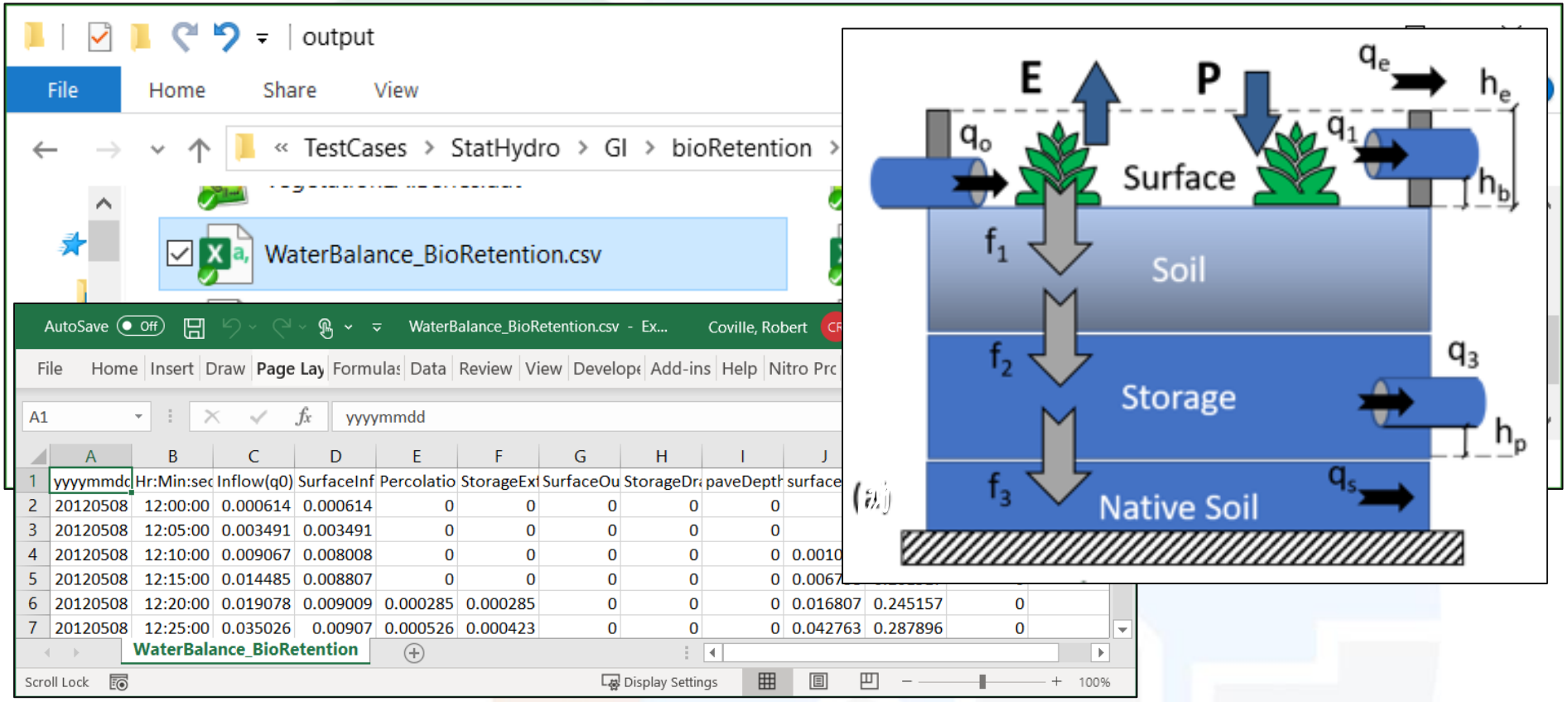




Like Hydro+ StatHydro inputs, GI structures require DataFolder parameterization in UnifiedHydroConfig.xml

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

i-Tree Hydro+ GI: Outputs (Raw)

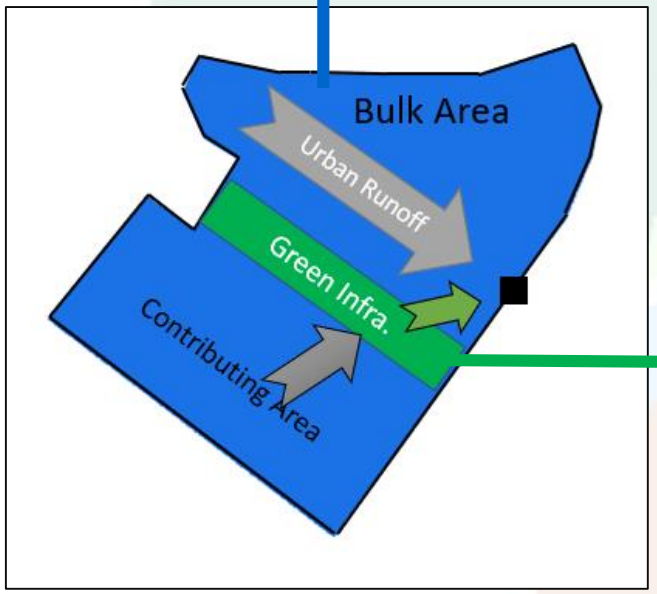


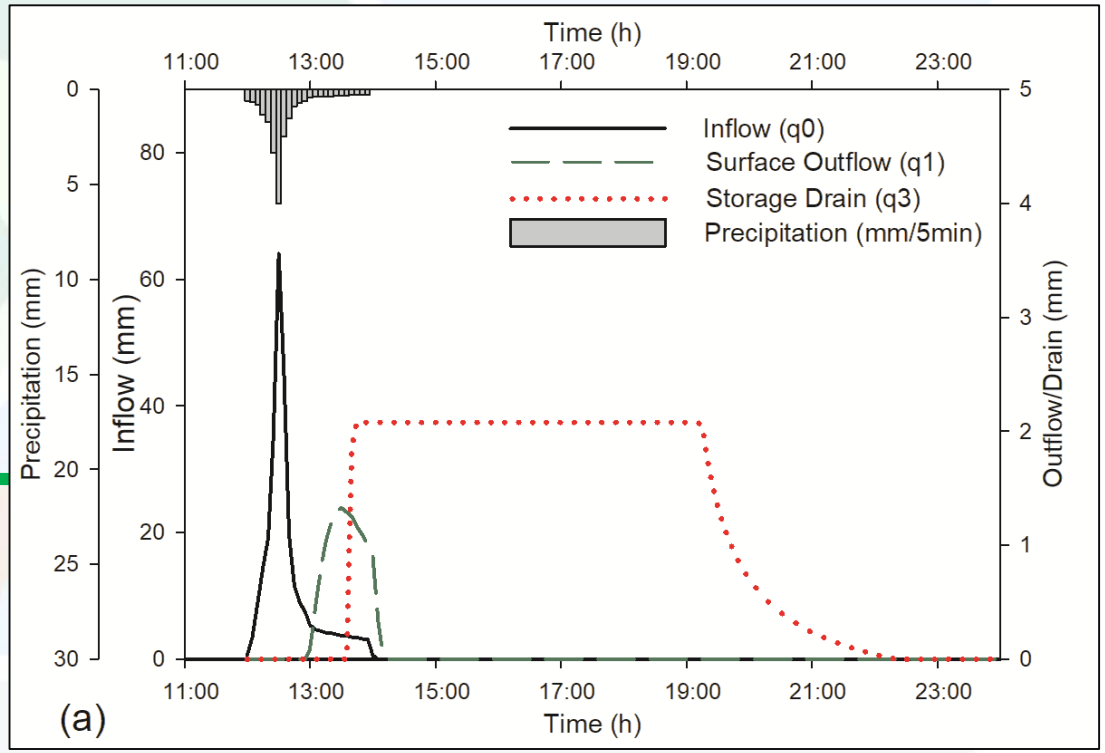
	A	B	C	D	E	F	G	H	I	J		
1	yyyymmdc	Hr:Min:sec	Inflow(q0)	SurfaceInf	Percolatio	StorageEx	SurfaceOu	StorageDr	paveDepth	surface		
2	20120508	12:00:00	0.000614	0.000614	0	0	0	0	0			
3	20120508	12:05:00	0.003491	0.003491	0	0	0	0	0			
4	20120508	12:10:00	0.009067	0.008008	0	0	0	0	0	0.0010		
5	20120508	12:15:00	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.

Research Suite: Next steps

www.itreetools.org/tools/research-suite

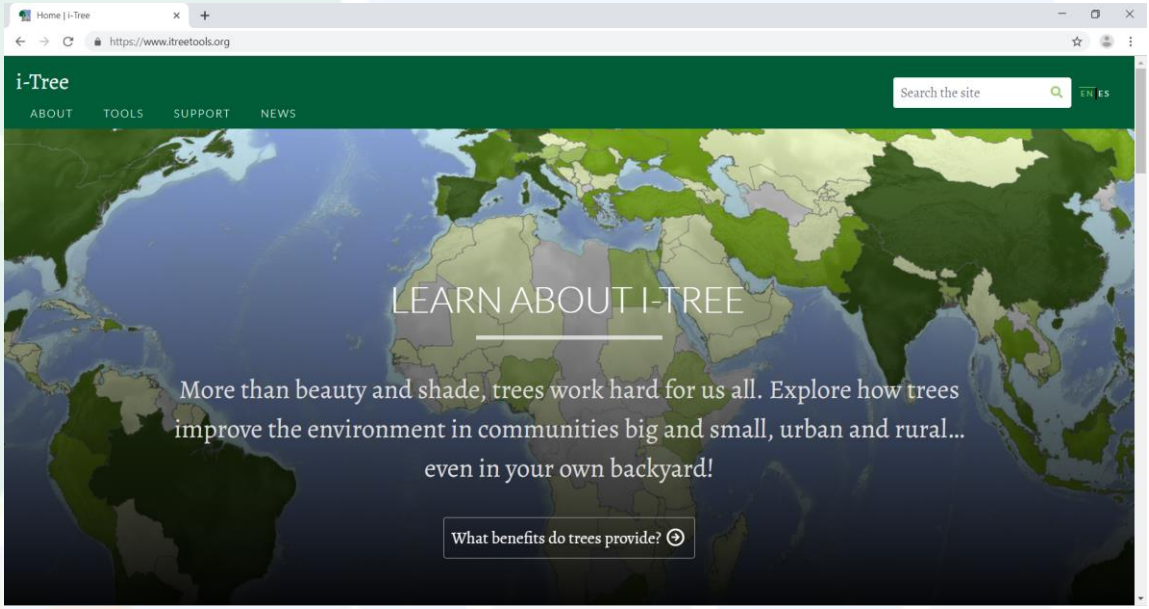
Tools

Documentation

Examples

Code

Contacts



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