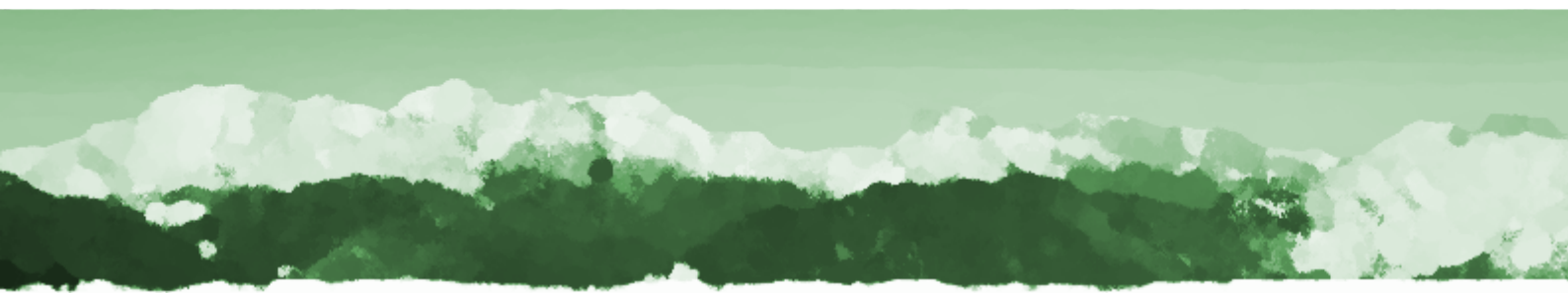


LWRecruitment&Propagation

A tutorial on analysis tools developed within the GSoC2014-GSoC2016



Readme

This manual was written by Silvia Franceschi and Andrea Antonello (HydroloGIS - Free University of Bolzano, Faculty of Science and Technology).

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1. Introduction

This is a short tutorial containing the most important information on the general work-flow of the tools for Large Wood (LW) recruitment from hillslopes and propagation along the network developed within the GSoC2014-GSoC2016 program. The new developed tools will be integrated in the *JGrassTools* library and will be directly available in *gvSIG*.

More information about the modules and the installation instructions are available at www.jgrasstools.org.

The modules developed are named with the name of the activity that will be done by each module with a prefix containing the number of the order of execution considering the entire work-flow. The available modules are:

- LW01_ChannelPolygonMerger
- LW02_NetworkAttributesBuilder
- LW03_NetworkHierarchyToPointsSplitter
- LW04_BankfullWidthAnalyzer
- LW05_BridgesDamsWidthAdder
- LW06_SlopeToNetworkAdder
- LW07_HydraulicParamsToSectionsAdder
- LW08_NetworkBufferWidthCalculator
- LW09_NetworBufferMergerHolesRemover
- LW10_CHM_AreaToNetpointAssociator
- LW10_SingleTree_AreaToNetpointAssociator
- LW11_NetworkPropagator

This tutorial contains a general introduction on the tools with the basic information on licenses and the general work-flow to follow to start form a dataset and obtain the desired results.

1.1. Licenses

All the developed modules for Large Wood will be integrated in the *JGrassTools* library and released under free and open source software. You can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

2. General Work-flow

The general work-flow of the tools is shown in Figure ??.



Figure 2.1: Work-flow of the tools for the evaluation of Large Wood recruitment and propagation.

The inputs of the algorithms of the Large Wood tools are:

- digital models of the terrain and vegetation: DTM, DSM, FSV
- DTM derived geomorphology attributes: contributing areas, slope, connectivity, watershed delineation
- extension of the bankfull area: the area covered by water in standard condition of flow
- position and dimensions of bridges and dams: from a field survey or from local cadasters
- superficial geology: rock or erodible deposits

- hydraulics parameters of the stream network: discharge, roughness coefficient
- vegetation parameters: position and height of the single trees, other parameters of the allometric functions and the hydraulic propagation downstream.

The overview of the input and output of the set of LW tools is shown in Figure ??.

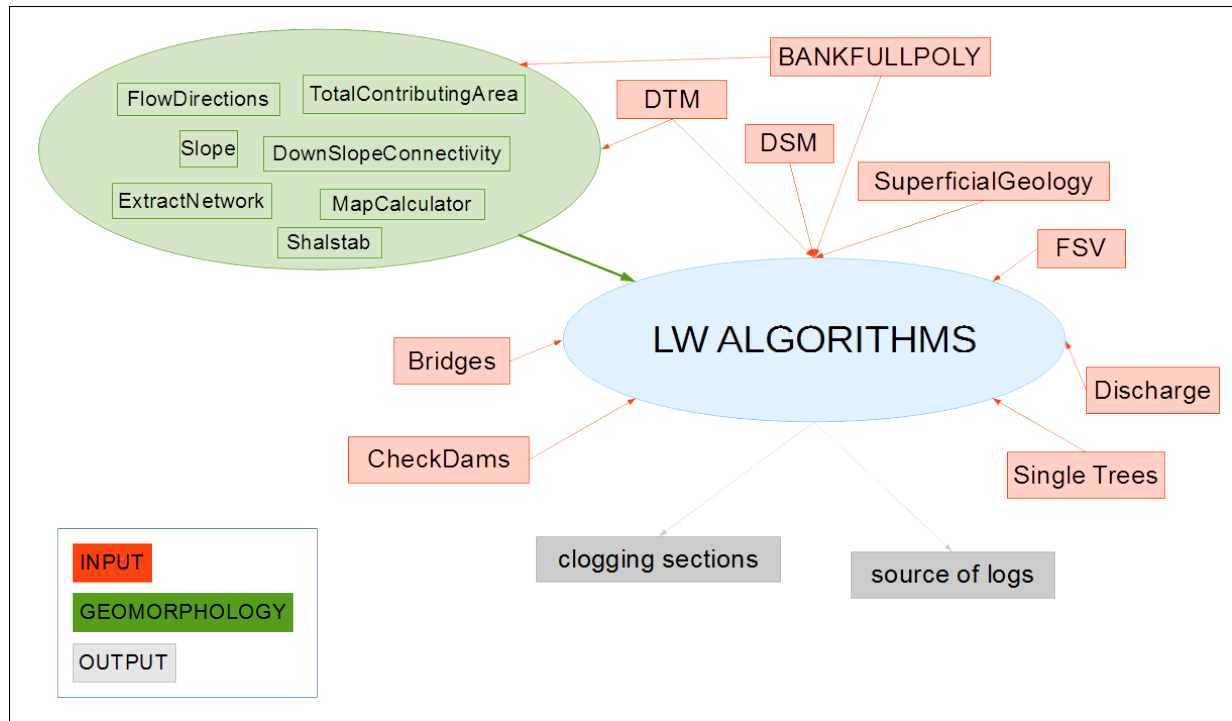


Figure 2.2: Overview of the input and output of the Large Wood recruitment and propagation tools.

A detailed description of the different modules is available in the following chapters.

3. LW01_ChannelPolygonMerger

3.1. Description

Merges the adjacent bankfull polygons in a single geometry for further processing.

Bankfull discharge is defined as a flood with high recurrence frequency (2-years flood or the flood that has a 50% probability of occurring in a given year). The bankfull width represents the river width at the bankfull discharge and usually it is estimated using remote sensing data (orthofoto or satellite images) or on field surveys. Usually this layer is manually drawn and may contain overlapping of polygons and polygons with non uniform boundaries

This first module of the preprocessing tools contains an algorithm that validates and cleans the geometries in the bankfull polygon and merges adjacent bankfull polygons into a single geometry without considering any attributes field.

3.2. Input layers

- inBankfull: the input polygon layer of the bankfull area.

3.3. Output layers

- outBankfull: the output layer with the bankfull polygons validated, cleaned and merged.

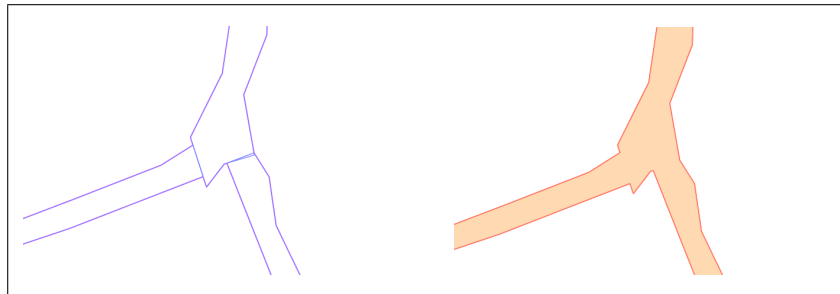


Figure 3.3: Example of the operation of merging bankfull polygons with LW01_ChannelPolygonMerger.

4. LW02_NetworkAttributesBuilder

4.1. Description

This module is a simple call to the already existing module *NetworkAttributesBuilder* of the **JGrassTools** library, to create the vector of the network with hierarchical attributes based on an input raster network.

The resulting network vector layer contains the stream separated in different features at each confluence. The links are orientated from upstream (startpoint) to downstream (endpoint) and the available attributes are:

- **Strahler enumeration**¹: the ordering is based on the hierarchy of tributaries and the main channel is not determined. Strahler's stream ordering starts in initial links which assigns order one. It proceeds downstream. At every node it verifies that there are at least 2 equal tributaries with maximum order. If not it continues with highest order, if yes it increases the node's order by 1 and continues downstream with new order.
- **Hack enumeration**: this main stream of the catchment is set to 1, and consequently all its tributaries receive order 2. Their tributaries receive order 3 etc. The order of every stream remains constant up to its initial link
- **Pfafstetter enumeration** (modified version): this system is hierarchal, and watersheds are delineated from junctions on a river network.

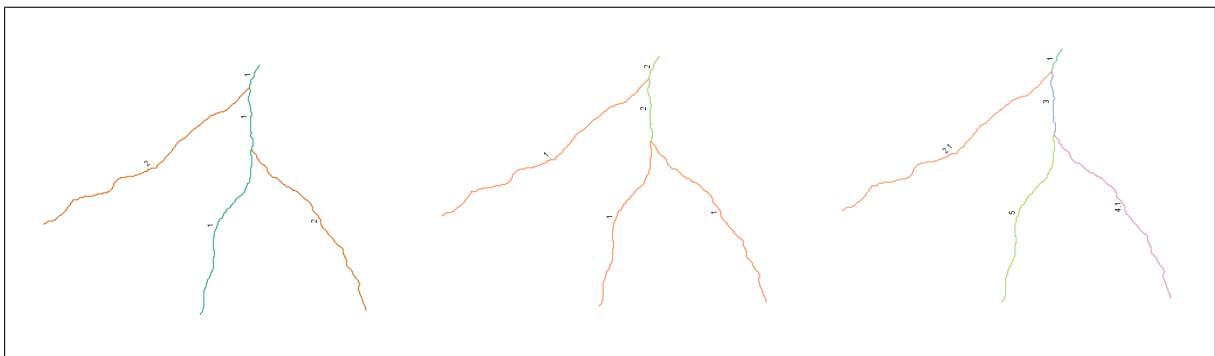


Figure 4.4: Different enumeration of the channel network (starting from left): Hack, Strahler and Pfafstetter.

4.2. Input layers

- inNet: the input network raster layer
- inFlow: the input map of flow directions
- inTca: the input map of total contributing areas.

4.3. Output layers

- outNet: the output vector layer of polylines with the stream network.

¹http://en.wikipedia.org/wiki/Strahler_number

5. LW03_NetworkHierarchyToPointsSplitter

5.1. Description

The evaluation of the possibility to clog of a network depends on the width of the bankfull and/or the width of the inundated areas, therefore we need to evaluate those values in each section of the network. To speed up this procedure we decided to use the points along the stream to identify each section.

This module extracts each point along the network with the Pfafstetter original attributes of the line stream and an additional attribute referring to the position of the point in the link (progressive distance of each point from the starting node).

5.2. Input layers

- inNet: the input hierarchy network vector layer of lines.

5.3. Input parameters

1. pGauklerStrickler: a constant value of the Gaukler and Strickler coefficient of roughness assigned to all the sections, the values can be changed before going on with the other modules simply editing this layer.

5.4. Output layers

- outNet: the output network vector layer of points.

The output point layer is the base for all the other elaboration of Large Wood recruitment and propagation along the network and should contain:

- pfaf: the original Pfafstetter enumeration
- linkid: the identifier of the point inside each link, points are numbered progressively from upstream to downstream in each link
- ks: the average/representative Gaukler and Strickler roughness coefficient for each section.

An example of how it looks the extracted point layer with the attributes table is shown in Figure ??.

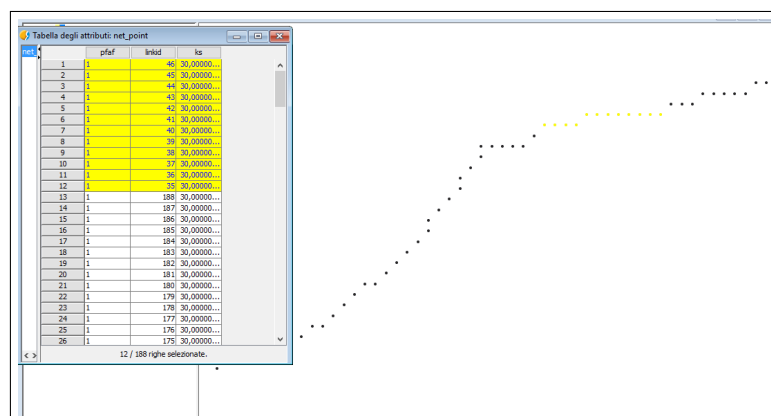


Figure 5.5: Example of the basic points network layer used in LW modules: map and attributes table.

6. LW04_BankfullWidthAnalyzer

6.1. Description

This module extracts the bankfull width for each section of the stream network and adds it as an attribute to the point representing the section. Bankfull width is extracted from the bankfull polygon layer.

The inputs of the model are the network extracted from the DTM and the digitalized bankfull polygons. These two data have usually different origins:

- bankfull layer is derived from orthofoto, satellite data or hydraulics models
- network layer is extracted from DTM using geomorphological functions based on elevation and flow directions.

An example of how different are the two information is the following (Figure ??):

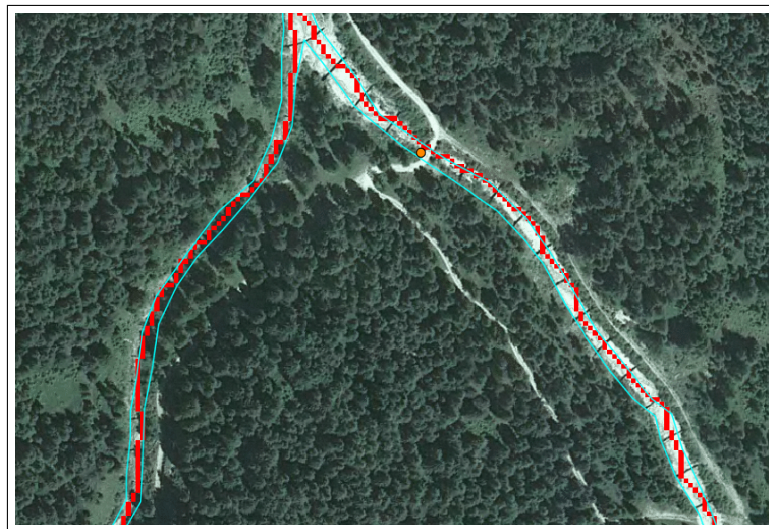


Figure 6.6: *Difference between the extracted network and the digitalized bankfull polygon.*

The different origin of the input data can be a source of problems. In each section there are different situations to consider regarding the position of the extracted network respect to the given polygon:

1. the extracted network is (almost) in the center of the bankfull polygon
2. the extracted network is only tangential to the bankfull polygon
3. the extracted network does not intersect the bankfull polygon.

This module has been developed to handle all these situations in a way that it is possible to assign the bankfull width to a channel section even if there isn't any intersection between the two.

In each point of the network, representing a section, the bankfull width is assigned considering the relative position between the point of the channel and the polygon of the bankfull as the width of the bankfull in the nearest point of channel.

If the channel and the bankfull polygon are too far (maxdist) or if there are others problems in drawing the correspondent section, the point is labelled as problematic and added to the output problem point layer.

6.2. Input layers

- inBankfull: the input polygon layer of the bankfull area
- inNetPoints: the input hierarchy network vector layer of points output of *LW02_NetworkAttributesBuilder*

6.3. Input parameters

1. MAX_DISTANCE_FROM_NETPOINT: the maximum distance that a point can have from the nearest polygon. If the distance is greater, then the netpoint is ignored and labelled as outside the region of interest.
2. MAX_NETWORK_WIDTH
3. MIN_NETWORK_WIDTH

6.4. Output layers

- outNetPoints: the output points layer of the network with the additional attribute of bankfull width
- outBankfullSections: the output layer with the sections lines where the bankfull width has been calculated with the two attributes pfaf and linkid to connect each section to the network point
- outProblemPoints: the output points layer highlighting the position of the problematic sections.

Two additional attribute fields are added to the network point layer:

1. w: bankfull width
2. w_from: origin of the bankfull width, for bankfull polygon 0.

The origin of the bankfull width at the end of this module is fixed to a value of 0. This value will be updated in the next module to consider if in the section there are human structures that force the bankfull width to a defined width (mainly bridges or check dams).

An example of the two outputs are in Figure ?? and Figure ??.

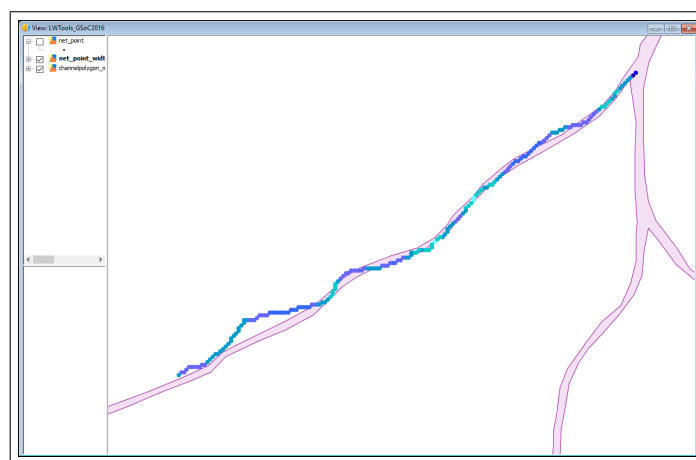


Figure 6.7: *Point layer colored according to the bankfull width.*

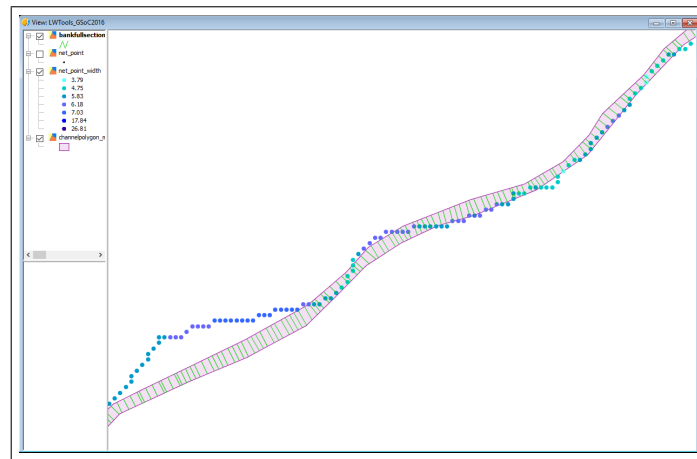


Figure 6.8: *Extracted sections of the bankfull correspondent to each point of the network.*

7.2. Input layers

- inNetPoints: the input hierarchy network layer of points with the attributes fields of the bankfull width and the origin of that value
- inBridges: the input point layer with the bridges to consider to modify channel width
- inDams: the input point layer with the check dams to consider to modify channel width.

7.3. Input parameters

1. fBridgeLenghtField: name of the attribute field of the bridges layer to use as width of the channel under the bridge
2. pDamsOnNetDistance: maximum distance of a dam to be snapped on the network
3. pBridgesOnNetDistance: maximum distance of a bridge to be snapped on the network
4. pFixedDamsWidth: fixed value of the width assigned to the sections where a check dam is located.

7.4. Output layers

- outNetPoints: the output points layer of the network with the bankfull width updated with the information of bridges and dams width
- outProblemBridges: the output layer containing the points of the bridges without information of the width.

The attribute correspondent to the origin of the calculated channel width, w_from , can assume three different values:

- 0: width from bankfull polygon
- 1: width from check dams
- 2: width from bridges.

An example of the modified section width for dams and bridges are shown in Figure ?? and Figure ??.

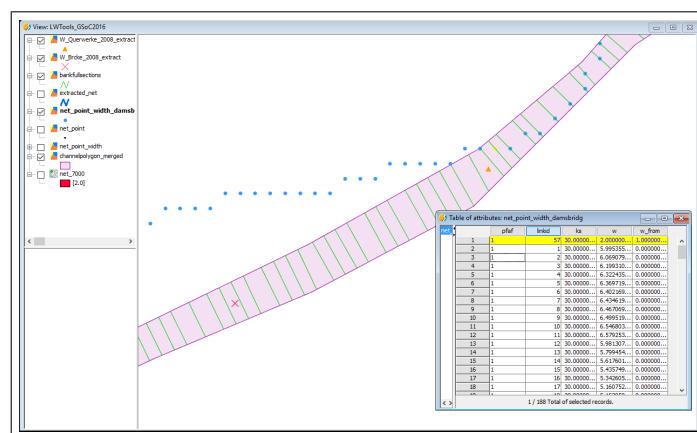
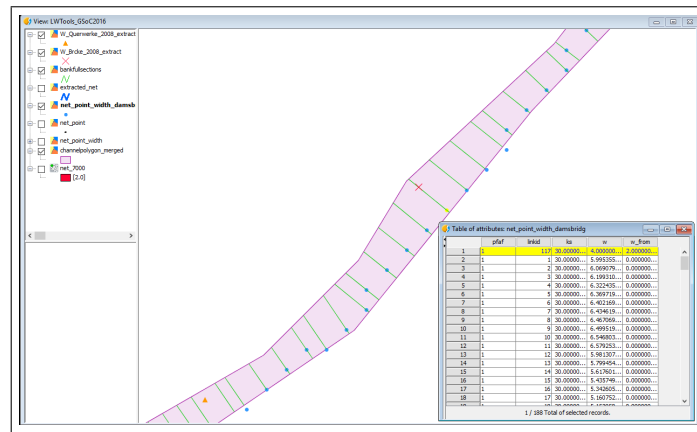


Figure 7.11: Assingment of the fixed value of channel width in the nearest section of a check dams.



8. LW06_SlopeToNetworkAdder

8.1. Description

This module adds the attribute of local slope to the input channel point layer.

This is the starting point for the procedure to evaluate the average channel slope in each section considering also the surrounding cells (upstream and downstream). The average slope will be calculated in the next module together with the maximum widening width which requires almost the same background elaborations on channel points.

8.2. Input layers

- inNetPoints: the input hierarchy network layer of points with the information about the bankfull width, the origin of that value and the roughness coefficient
- inSlope: the input slope raster map of the area covered by the network.

8.3. Output layers

- outNetPoints: the output points layer of the network with the additional attribute of local slope.

The slope is extracted from the raster layer in the pixel where each point of the input network point is placed.

An example of the extracted values of local slope are shown in Figure ??.

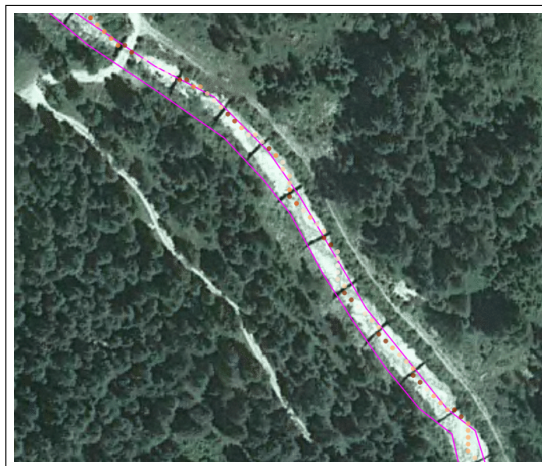


Figure 8.13: *Example of the extracted local slope of the channel sections.*

9. LW07_HydraulicParamsToSectionsAdder

9.1. Description

This module adds to the layer of section points the hydraulic parameters of the transversal section by running a 1D hydraulic model on the given stream network considering the input discharge and the roughness coefficient of each section contained in the input layer of network points.

The model can be used to evaluate the hydraulic conditions of the river (each section) either for the bankfull width and for the maximum width. To choose between the two reference sections a boolean variable has to be set, *doMaxWidening*, which automatically selects the column *w* or *w2* from the attributes table as section width.

NOTE: *This module calls inside the SaintGeo 1D hydraulic model for the evaluation of the hydraulic parameter. The first implementation of the LWTools has been done considering in this phase only one reach of the stream network, this means that there is the need of only one value of discharge to be propagated along the stream. If there are confluences in the river the expected workflow is to calculate these parameters separately for each links and then reconnect all the last tool where the propagation of the logs downstream will be done. The final connection between the links have to keep the right values of the Pfafstetter enumeration in order to proceed with the propagation hierarchically from upstream to downstream.*

The output values of hydraulic parameters are added as attributes in the shapefile of network points and also summarized in two text files, one containing the information more related to water level (sectionID, progressive distance, elevation of water level, elevation of the minimum point of the section, elevation of the right riverbank, elevation of the left riverbank) and one the information more connected to the discharge (sectionID, progressive distance, Froude Number, discharge, water velocity, wetted area).

9.2. Input layers

- inNetPoints: the input hierarchy network layer of lines with the pfafstetter attribute
- inNet: the input hierarchy network layer of points with the information about the bankfull width, the local slope and the roughness coefficient
- inDtm: the input raster layer with the elevation of the terrain.

9.3. Input parameters

1. pDischarge: the input discharge value in the first section upstream, this value is considered constant for all the sections of the stream (link)
2. doMaxWidening: boolean factor to decide to use the bankfull width or the widening width as section width for running the hydraulic 1D model.

9.4. Output layers

- **outNetPoints:** the output points network layer with the additional attribute of the calculated hydraulic parameters:
- **outputLevelFile:** the output text file containing all the hydraulic parameters for each section related to water level
- **outputDischargeFile:** the output text file containing all the hydraulic parameters for each section related to discharge
- **outTransSect:** the output line shapefile with the extracted transversal sections.

The module adds to the input network point layer three fields:

- **b_wlevel:** water level in the current section calculated using and hydraulic 1D model considering as the width of each section the value contained in the column *w*
- **b_wdisch:** discharge in the current section calculated using and hydraulic 1D model considering as the width of each section the value contained in the column *w*
- **b_wvel:** velocity of the water in the current section calculated using and hydraulic 1D model considering as the width of each section the value contained in the column *w*.

An example of the calculated hydraulic parameters for the bankfull sections are shown in Figure ??.

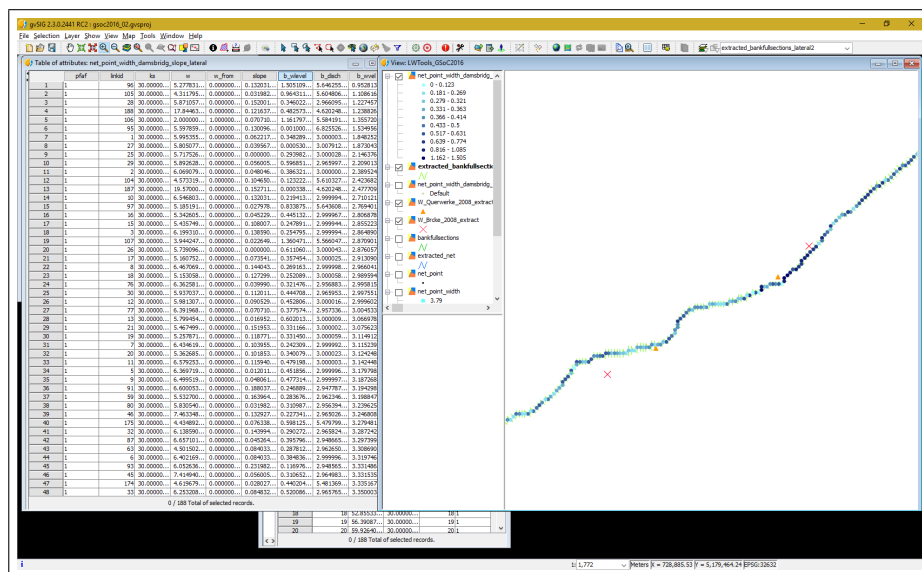


Figure 9.14: Evaluation of hydraulic parameters for the bankfull sections, the colors show the values of the water level.

10. LW08_NetworkBufferWidthCalculator

10.1. Description

This module calculates the possible areas along the channel network where there is the possibility for the water during extreme events to erode and within this process to recruit material from outside the river. The extent of these areas contributing to large wood in the channel are calculated following a power law either considering the bankfull width or the unit stream power. The maximum widening width is calculated as a function of:

- the bankfull width and the channel slope
- the unit stream power: stream power per unit of width, where stream power is a function of local discharge and slope

In both cases the parameters of the power law should be derived from field observations and they are requested as input parameters.

An experimental power law equation is used to evaluate the possible extended inundated width starting from bankfull width or unit stream power. The increased channel width is calculated on the original channel sections: the bankfull sections are equally extended on both sides to reach the new channel width.

The model allows to constrain the widening depending on other criteria. For instance, it gives the possibility to input a polygon layer with the surficial geological formation (quaternary deposits). The widening would be constrained only in these areas and it would be limited by the presence of rocks. Inundation areas will not be extended where the geological superficial formations is rock:

- the sections that intersect the rock in the baricenter of the bankfull will be left as they are: resulting width is the same as bankfull width
- the sections that intersect the rock on the new calculated vertexes will be cut: resulting width will consider only the areas where possible erodible soil is present.

10.2. Input layers

- inNetPoints: the input hierarchy network layer of points with the information about the bankfull width, the local slope and the hydraulic parameters
- inGeo: the polygon layer where the widening is allowed (ex. the superficial geological formations or the areas limited by lateral dikes)
- inTransSect: the input line shapefile with the extracted transversal sections

10.3. Input parameters

1. prePostCount4Slope: the number of cells upstream and downstream to consider to evaluate the average longitudinal slope in each section
2. k, n: parameters of the power law for the evaluation of the new width

$$newWidth = width + k * slope^n \quad W_r = k * omega^n$$

3. MIN_SLOPE: the value to use for the points of the network where the local slope is zero.

10.4. Output layers

- outNetPoints: the output points network layer with the additional attribute of the calculated maximum width and average slope
- outInundationArea: the output polygon layer with the extended contributing areas
- outInundationSections: the output layer with the sections lines corresponding to the extended maximum width.

An example of the calculated maximum width, the delineation of the widening sections and the complete widening polygon, calculated considering the hydraulic parameters (unit stream power) and the superficial geological formations are shown in Figure ??-??-??.

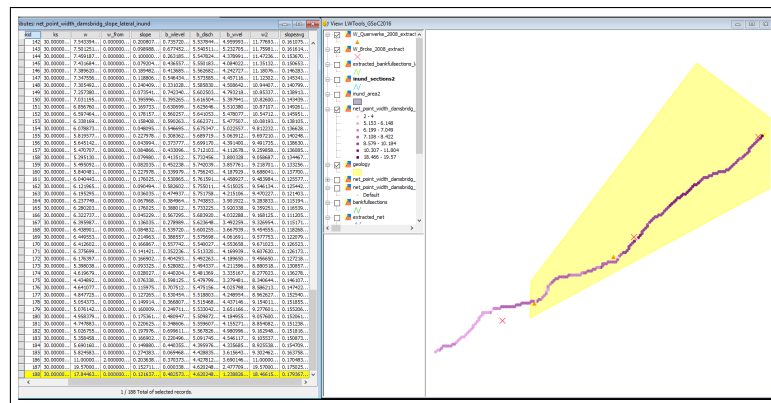


Figure 10.15: Evaluation of extended contributing width considering superficial geological formations.

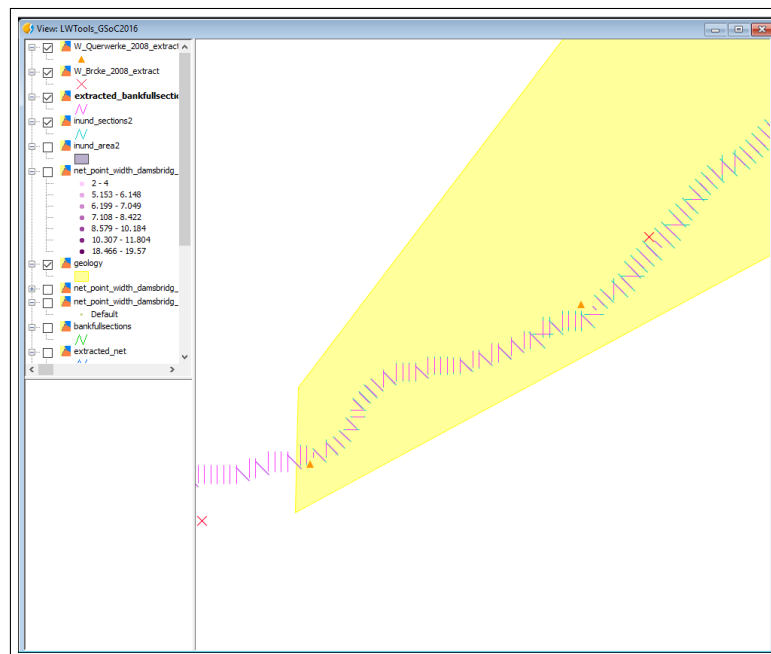


Figure 10.16: Delineation of extended contributing sections drawn considering superficial geological formations.

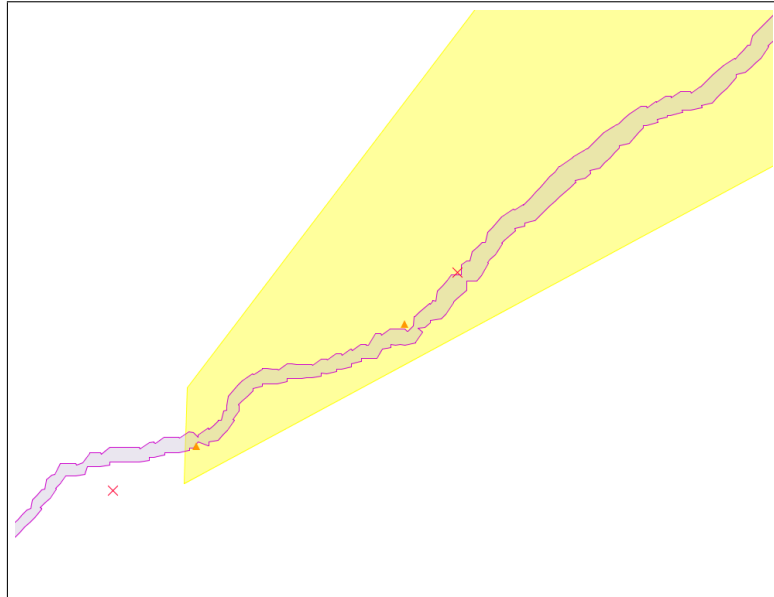


Figure 10.17: *Extracted total inundated area considering superficial geological formations.*

11. LW09_NetworBufferMergerHolesRemover

11.1. Description

The extracted polygons output of the model *LW08_NetworkBufferWidthCalculator* can be disjointed and irregular (see Figure ??) and there is the need to merge the inundated polygons and remove the holes in the new geometries. This simple module merges the inundated polygons and cleans the geometries to avoid strange perimeters.

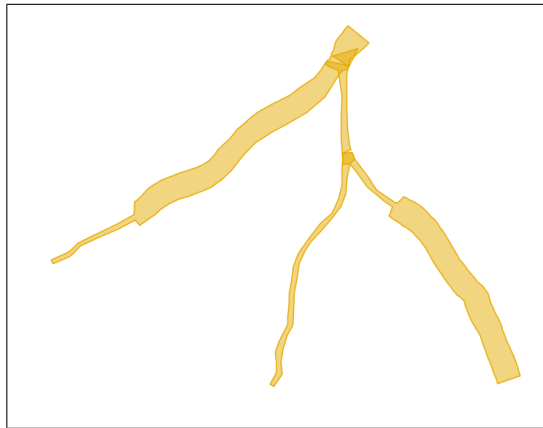


Figure 11.18: *Example of the inundated polygons output of the model LW07_NetworkBufferWidthCalculator.*

11.2. Input layers

- inInundationArea: the input layer with the inundation polygons output from *LW07_NetworkBufferWidthCalculator*

11.3. Output layers

- outInundationArea: the output polygon layer with the merged, and without holes, inundation polygons.

An example of the result of the merging and cleaning of the polygon layer is shown in Figure ??.

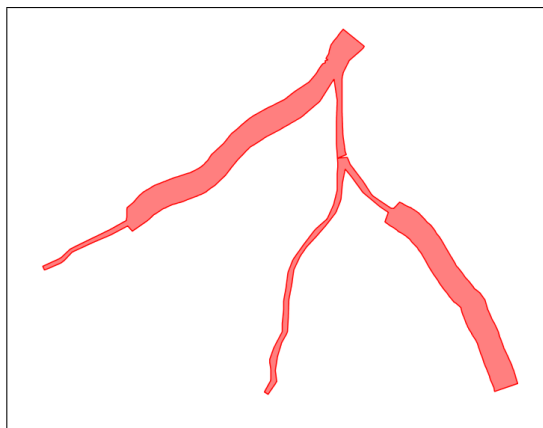


Figure 11.19: *Merged and cleaned inundate polygons.*

12. LW10_AreaToNetpointAssociator

12.1. Description

These modules calculates a user defined representin percentile of vegetation height, total timber volume and, if the approach of single tree is used for the input vegetation, of the diameter of the vegetation coming in the river from unstable and connected areas of the local hillsopes in each section. Considering to have different input data for the vegetation, the modules available are:

1. LW10_CHM_AreaToNetpointAssociator: if the rasters of Canopy Height Model (CHM) and Forest Stand Volume (FSV) are available
2. LW10_SingleTree_AreaToNetpointAssociator: if the vector layer of the position and the height of each single tree are available.

The steps for the evaluation of the amount of Large Wood coming from the local hillslopes in each section are:

1. evaluation of unstable areas: shalstab model (or any other stability model)
2. evaluation of the downslope component of the connectivity index[?] for each pixel using the results of shalstab as weights in the formula

$$D_{dn} = \Sigma \frac{d_i}{W_i S_i}$$

3. extract the subbasin for each point of the channel network
4. extract the unstable and connected areas for each subbasin:
 - pixels inside the inundated polygon are always connected
 - pixels outside the inundated polygon are connected only if the connectivity index is less than a given threshold
5. extract vegetation height and forest volume on unstable and connected areas
6. assign the vegetation attributes to the network points.

In Figure ?? the general simplified workflow of the module is presented.

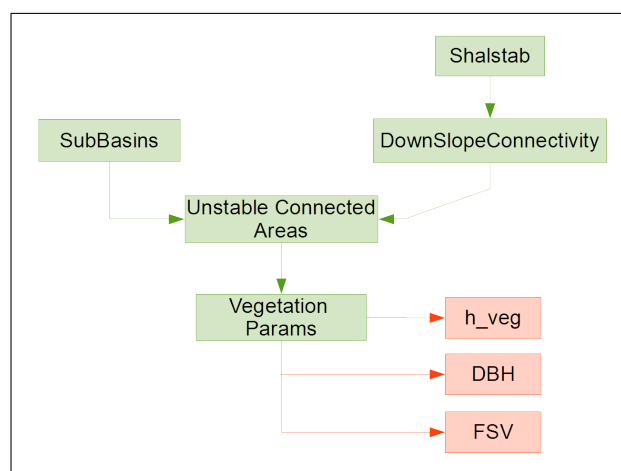


Figure 12.20: *Simplified workflow for the module LW10_AreaToNetpointAssociator.*

12.1.1. Shalstab

Large Wood in rivers comes from the unstable and connected areas of the local hillslopes. We can locate the unstable areas using a stability model with in input an assigned volume of precipitation. Then the connectivity factor will be evaluated using the map of stability coefficients as weights in the connectivity model. One possible stability model already implemented in the JGrassTools library[?] is the **Shalstab** stability model .

One of the outputs of Shalstab is the map of the stability classes for the given input precipitation with 4 different classification classes:

- 1: unconditionally unstable
- 2: unconditionally stable
- 3: stable
- 4: unstable.

This map will be used to derive the map of weights required in the Downslope Connectivity Index. In particular we have to reclassify the map assigning:

- 1 → stable pixels
- 100 → unstable pixels

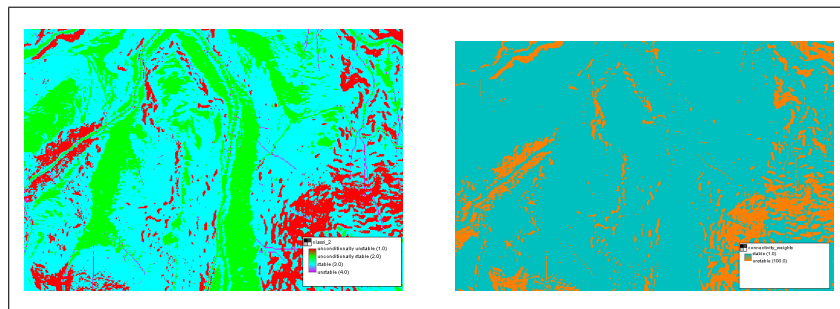


Figure 12.21: Example of the output map of stability classes of the Shalstab model and its classification for the use as weights in the downslope connectivity index.

12.1.2. Downslope Connectivity Index

Not all the unstable areas on hillslopes will reach the stream network because of the distance and the local slope. The Connectivity Index is used to identify which part of the unstable area on the hillslopes can reach the network.

Considering the conditions for the movement of the Large Wood, we can use only the downslope component of the Connectivity Index. The Downslope Connectivity Index module of the JGrassTools library evaluates the downslope component of the connectivity index considering the flow path length that a particle has to travel to arrive to the nearest point of the network[?].

The input maps are:

1. map of flowdirections
2. map of extracted network
3. map of slope
4. map of weights

5. in alternative to the map a constant value of weights.

The output is:

- the map of the Log of the downslope component of the connectivity index.

An example of the resulting map of downslope connectivity index is shown in Figure ??.

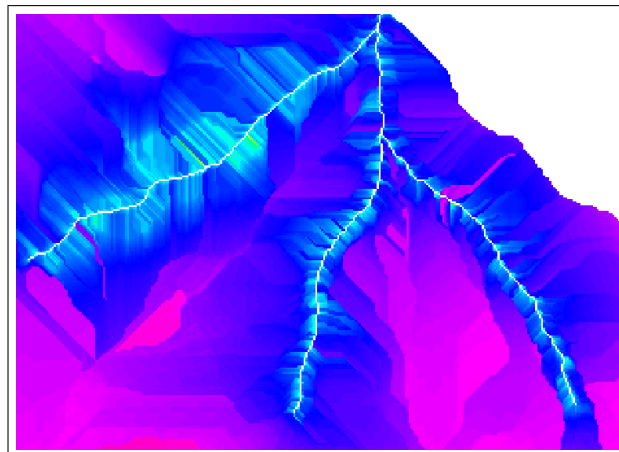


Figure 12.22: *Example of the map of the Downslope Connectivity Index.*

12.1.3. Evaluation of Large Wood recruitment from hillslopes

To evaluate the length of the logs fallen into the network and consequently the possibility for them to stop and to clog the sections we need some vegetation parameters like:

- height of the trees
- distribution and volume of the biomass.

Depending on the available data on the vegetation, there are two modules available to evaluate a representative height and diameter and the volume of the logs contributing in each river section:

- **LW10_CHM_AreaToNetpointAssociator**: extracts the height of the vegetation as the difference between the DSM and the DTM with the possibility to add a threshold on the minimum height to consider; the map of the Forest Stand Volume is also required as input to evaluate the volume of the biomass and can be derived from different sources (LiDAR data, field surveys, literature, ...).
- **LW10_SingleTree_AreaToNetpointAssociator**: uses the characteristics of each single tree extracted from LiDAR data and available as vector layers with the position and height of the extracted trees. The DBH and volume of the trees are calculated using a generic allometric function which parameters are required in input.

The two modules **LW10_AreaToNetpointAssociator** extract the subbasin closing at each network point and evaluates the main vegetation parameters over the unstable and connected areas inside each basin.

To extract the subbasins for each river section the module calls the *NetNumbering* algorithm of the JGrassTools library[?]. NetNumbering assigns a number to each network link between one section and the other and splits the relative subbasins. The call to the module is done using as reference the point layer of the network in input and the extracted subbasin is calculated without considering the draining area of the upstream points of the stream network.

Using the concept of Downslope Connectivity Index it is possible to first extract the unstable and connected areas inside a basin just fixing a threshold on the value of the *Log* of the index. In particular unstable and connected areas are those:

- with a value of connectivity lower than a given threshold
- all those inside the widening area.

The last step of the evaluation of the contribution of hillslopes to the large wood in the network is to calculate the main vegetation parameters, the user defined percentile of vegetation height and DBH (if the single tree approach is used) and the total timber volume, on the unstable and connected areas of each basin. Those parameters will be added to the output points network layer (Figura ??) using one of the two available modules **LW10_CHM_AreaToNetpointAssociator** or **LW10_SingleTree_AreaToNetpointAssociator**.

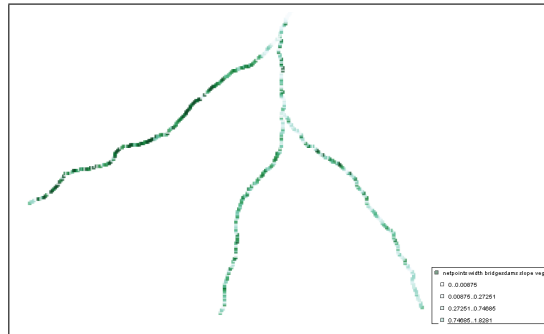


Figure 12.23: *Vegetation parameters added as attributes in the output layer.*

12.2. LW10_CHM_AreaToNetpointAssociator

This module considers in input some general information to extract the vegetation parameters, in particular the height of the trees is calculated as the difference between the CHM and the DTM and the volume of the vegetation is derived from the raster map of FSV.

12.2.1. Input layers

- inNetPoints: the input hierarchy network layer of points with the information about the bankfull width and its origin, the local and average slope and the inundated width
- inInundationArea: the input layer with the maximum widening area
- inFlow: the input raster map of flow directions
- inTca: the input raster map of Total Contributing Areas
- inNet: the input raster map with the extracted network
- inDtm: the input raster map with the terrain elevations
- inDsm: the input raster map with the surface elevations
- inStand: the input raster map with the total stand volume derived from field surveys
- inSlope: the input raster map with the slopes
- inConnectivity: the input raster map of the downslope connectivity index

12.2.2. Input parameters

1. connectivityThreshold: threshold value of connectivity map for extracting unstable connected pixels of each basin.

12.2.3. Output layers

- outNetPoints: the output points layer of the network with two additional attributes: total timber volume from the local hillslopes and median of vegetation height
- outNetnum: the output raster map with the enumeration of the network
- outBasins: the output map with the subbasins closing in each section of the network not taking into account the draining area of the upstream point in the fluvial network.

An example of the attributes table of the resulting layer is shown in Figure ??.

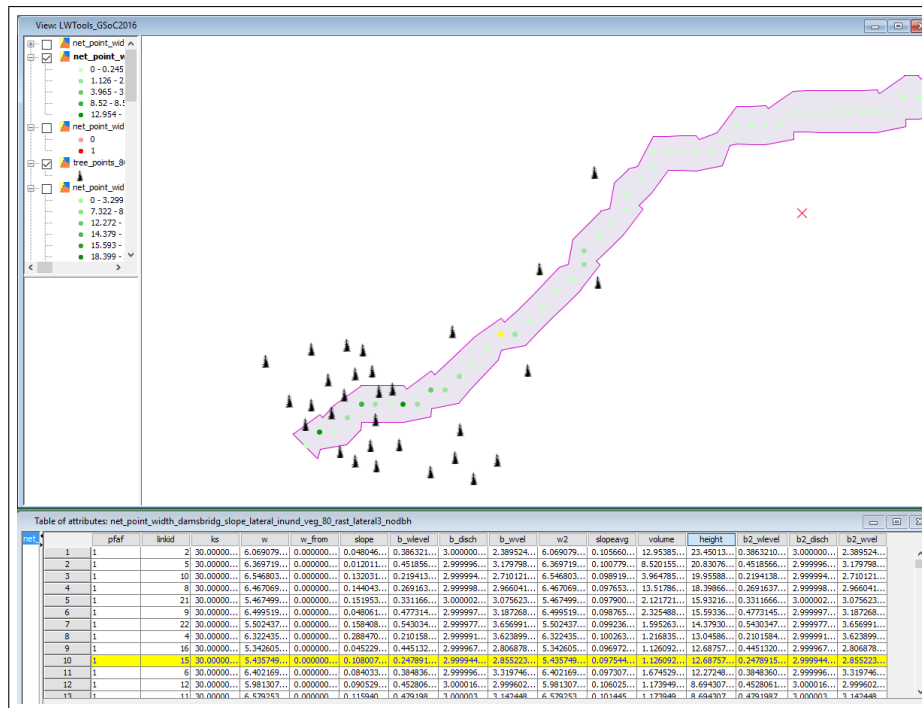


Figure 12.24: Attributes table of the output layer of network points in case of input vegetation data of CHM and FSV.

12.3. LW10_SingleTree_AreaToNetpointAssociator

This module consider the position and height of each single tree near the stream network and it is more completed respect to the one referring to the raster data of CHM and FSV. In particular:

1. since, in general, single trees extracted from LiDAR data do not have any information about the diameter and volume, the evaluation of the volume of the biomass is done using two allometric functions: the first one calculates the DBH starting from the height and the second one considers the DBH and height of the single trees to evaluate the final volume
2. since the value of the height of the trees is very similar to the real one, to consider the effective non flexible lenght of the logs that can clog a section the module uses the diameter of flexibility and the tree taper
3. since during a flooding event all the logs transported by the river downstream are accumulated, also in this case a representative value of the length of the logs is used, this value is an input percentile of the height of the trees.

12.3.1. Input layers

- inNetPoints: the input hierarchy network layer of points with the information about the bankfull width and its origin, the local and average slope, the hydraulic parameters of the bankfull sections and the maximum widening width with the correspondent hydraulic parameters
- inInundationArea: the input layer with the area of maximum widening
- inFlow: the input raster map of flow directions
- inTca: the input raster map of Total Contributing Areas
- inNet: the input raster map with the extracted network
- inConnectivity: the input raster map of the downslope connectivity index

12.3.2. Input parameters

1. pConnectivityThreshold: threshold value of connectivity map for extracting unstable connected pixels of each basin
2. pAllometricCoeff2ndOrder: coefficient of the second order term of tree height of the allometric function relating DBH to H of the trees
3. pAllometricCoeff1stOrder: coefficient of the first order term of tree height of the allometric function relating DBH to H of the trees
4. pAllometricCoeffVolume: coefficient of the first order term of tree height of the allometric function relating tree volume to DBH and H
5. pRepresentingHeightDbhPercentile: percentile of the distribution of tree heights and DBH to be used for the evaluation of the representative height and DBH contributing in each section from the hillslopes
6. pTreeTaper: the tree taper to use to evaluate the effective length of the trees (rastremation index)
7. pFlexibleDiameterLimit: the value of the diameter limit under which the log is flexible, used to evaluate the effective length of the trees.

12.3.3. Output layers

- outNetPoints: the output points layer of the network with two additional attributes: total timber volume from the local hillslopes and median of vegetation height
- outTreePoints: the output tree points layer with additional attribute of the correspondent river section where it will contribute
- outNetnum: the output raster map with the enumeration of the network
- outBasins: the output map with the subbasins closing in each section of the network not taking into account the draining area of the upstream point in the fluvial network.

An example of attributes table of resulting layer in case of input vegetation data of single trees is shown in Figure ??.

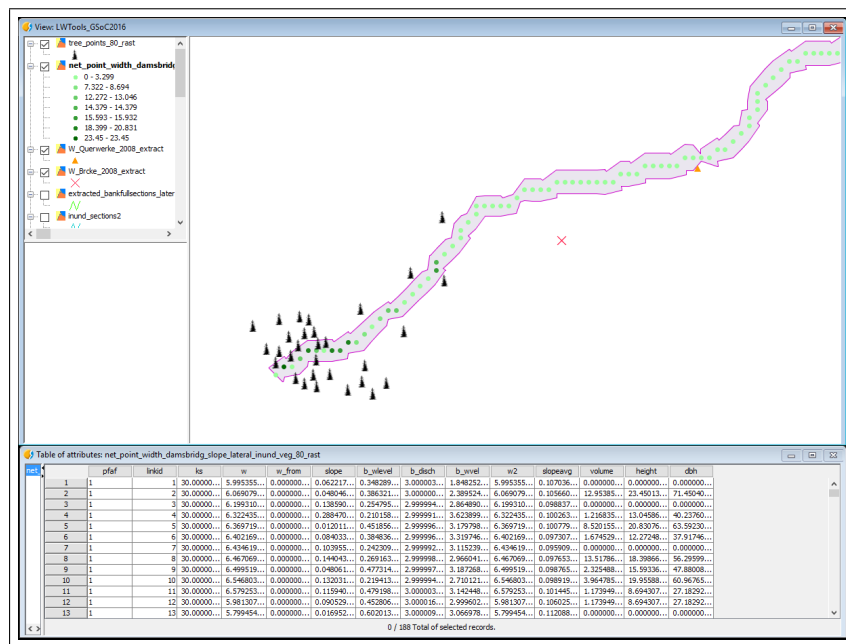


Figure 12.25: Attributes table of the output layer of network points in case of input vegetation data of single trees.

13. LW11_NetworkPropagator

13.1. Description

Identifies the critical section for the transit of Large Wood in the given stream network and identifies the origin of that material.

This final algorithm can handle the Large Wood contributions coming from different links in the stream network. If there are confluences of more links that have been studied separately in the previous tools, here there is the possibility to rejoin the network and consider all the inputs of Large Wood in the river stream coming from the tributaries. The process consists only in:

1. copy all the geometries of the different tributaries in one single layer
2. verify/modify the attribute containing the Pfafstetter enumeration for each channel in order to have coherency between the position of the geometry of the links and the enumeration.

NOTE: *This algorithm takes care only of considering all the contributes in terms of wood and do not consider the discharge. The discharge have to be considered in the steps before while adding the hydraulic parameters to the river points.*

The algorithm works in two different ways depending on the availability of the diameter of the logs in the input layer of channel points. The propagation of the logs downstream consists in a first check based on the comparison between the lenght of the logs and the channel width and, if the diameter characteristics of the logs contributing to each section is available, a second check will be done on the comparison between the water depth and the diameter of the logs. The logs can have two different origins:

1. **local:** logs coming from the unstable areas of the local hillslope
2. **global:** logs coming from the network upstream.

If the representing percentile of the length of the logs is greater than the channel width, the section is labelled as critical for vegetation lenght. In particular, if the vegetation lenght of the unstable areas of the local hillslope is greater than the channel width, the section is critical for local conditions for vegetation lenght, if the vegetation greater is that coming from upstream in the channel network, the section is critical for global conditions for vegetation lenght.

If the representing percentile of the diameter of the logs is greater than the water depth, the section is labelled as critical for diameter. If the diameter of the logs of the unstable areas of the local hillslope is greater than the water depth, the section is critical for local conditions for vegetation diameter, if the diameter greater is that coming from upstream in the channel network, the section is critical for global conditions for vegetation lenght.

In both cases the comparison between the length of the logs with the channel widht and the diameter of the logs with the water depth is done considering a ratio which usually ranges between 0.1 to 1 and it is different for the vegetation coming from the local hillslope and that from upstream in the network and for the check on the length and on the diameter.

13.2. Input layers

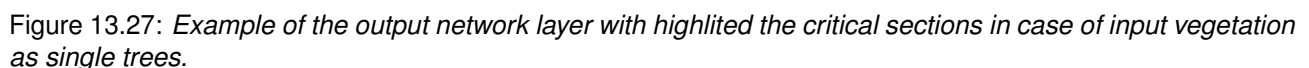
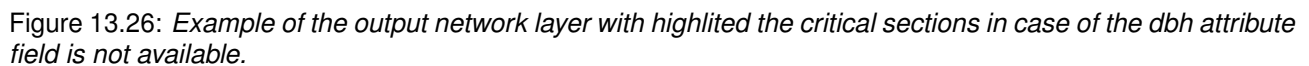
- inNetPoints: the input network points layer with as attributes at least the vegetation height and total timber volume, if the single tree approache is used additional attributes on diameter and water depth are needed.

13.3. Input parameters

1. pRatioLogsDiameterWaterDepth: the ratio between the diameter of the logs and the water depth corresponding to maximum channel width
2. pRatioLogsLengthChannelWidthChannel: the ratio between the length of the logs and the maximum channel width for the vegetation coming from upstream (vegetation characteristics from upstream not blocked)
3. pRatioLogsLengthChannelWidthHillslope: the ratio between the length of the logs and the maximum channel width for the vegetation coming from the hillslopes (vegetation characteristics of the current section)

13.4. Output layers

- outNetPoints: the output network points layer with the labelled critical sections. In the output layer, if in the input layer of network points the attribute field of *dbh* is available, six additional fields will be added, otherwise only the three derived from the check on channel width are added (first three of the following list):
 1. iscritl_h: contains the information about the critical sections for local parameters due to problems on the length of the logs, values are 0 for non critical sections; 1 for critical sections
 2. iscritg_h: contains the information about the critical sections for global parameters due to problems on the length of the logs, values are 0 for non critical sections; 1 for critical sections
 3. critsrc_h: only for critical sections due to problems on the length of the logs, it contains the information about the identification number (Pfaffstetter number - linkID) of the section from where the vegetation blocked in the current section comes from. For sections that are critical for local conditions this field contains the identification of the same section
 4. iscritl_d: contains the information about the critical sections for local parameters due to problems on the diameter of the logs, values are 0 for non critical sections; 1 for critical sections
 5. iscritg_d: contains the information about the critical sections for global parameters due to problems on the diameter of the logs, values are 0 for non critical sections; 1 for critical sections
 6. critsrc_d: only for critical sections due to problems on the diameter of the logs, it contains the information about the identification number (Pfaffstetter number - linkID) of the section from where the vegetation blocked in the current section comes from. For sections that are critical for local conditions this field contains the identification of the same section.



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FSV model