

GIS-Fuzzy logic large wood recruitment toolbox: Quick User Guide (version August. 2022)

Introduction

BEFORE STARTING

This toolbox has been developed within the **WoodFlow** (woodflow.wsl.ch) research **project** and aimed to provide a tool to compute recruitable (delivered or supplied) wood volumes at the catchment scale for three different frequency scenarios using available data in Swiss river catchments. The approach was a variation of the model presented by Ruiz-Villanueva et al., (2014).

The model was built for ESRI **ArcGis 10.7** and it is supplied as a **.tbx** file. The tool requires **Spatial Analyst**, **3D Analyst** extensions (Advanced License).

In addition, to compute **stream sinuosity** index (values between 0 and 1) the following **python** tool is required:

https://www.arcgis.com/home/item.html?id=00e708a448b74810a0e805c4a97f9d46

Please, read the documentation of this tool and install it before starting to use the Wood Recruitment Toolbox. This document does not explain how to use ArcGis and assumes that the user is already familiar with the software.

Because the analysis is based on Fuzzy Logic the following documents are recommended:

http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/fuzzy-membership.htm

http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/fuzzy-overlay.htm

The toolbox is composed of several steps, but each process can be done independently without using the toolbox, and similar approaches could be followed in other GIS software.

The tool was developed considering available input data in Switzerland; therefore, certain analyses were specific for this type of information (i.e., format, resolution, etc.). However, the Toolbox is flexible and could be adapted to a different type of input data.

The Wood Recruitment Toolbox works with raster and feature class files and the required input data is as follows:

- The catchment or study area polygon
- Digital elevation model (DEM)
- Forested area polygon
- Forest density raster in m3/ha
- Stream network lines
- Recruitment processes (i.e., landslides and debris flows) affected areas (raster files or feature class shapefiles to be converted to raster)

WoodFlow

GIS-Fuzzy logic large wood recruitment toolbox: Quick User Guide

GENERAL DESCRIPTION

The general approach is divided into three main steps (see the following Figure):

- terrain analysis to establish the wood sources, such as areas affected by landslides, debris flows and bank erosion, taking into account different scenarios (based on the process frequency and intensity);
- (ii) forest cover and density analysis; and
- (iii) estimation of wood volume for each scenario.



The areas affected by the wood supply (recruitment) processes can be modelled using different approaches (e.g., numerical modelling). This information was available in Switzerland, and the Wood Recruitment Toolbox was developed to use this existing data. For the hillslope processes, the affected areas by shallow landslides and debris flows were defined based on linear trajectories provided by the SilvaProtect-CH dataset from Losey and Wehrli (2013). To transform these lines into areas (and to pixels of raster files), the density of the lines is used to classify the terrain into three scenarios: FREQUENT, MEDIUM, and RARE events (named as E"30", E"100", E"300" respectively as they were assumed equivalent to events of approximately 30, 100 and 300 years return period), for high, medium and low-density line respectively. The reasoning is as follows, high trajectories density is assumed to represent the areas more prone to landslides or debris flows, usually of a higher frequency and therefore, lower magnitude. The same is applied to debris flows. The thresholds to classify the three areas are based on 4 natural breaks.

Once the trajectories are converted to pixels, the connectivity between these pixels and the stream network is analysed. Connectivity is established as a function of both the distance to the channel and the slope (Figure below A). The distance (D) is calculated based on the tree height and a toppling coefficient (k=2): $D=k\cdot Ht$ [1]



Trees located in a landslide-prone pixel or in the toppling influence area (defined as a buffer equal two times the mean tree high), may reach the channel if they are were close enough (Euclidean distance < 50 m) or further away but on a steep slope (>40%). In the case of debris flows, all pixels were assumed to be connected to the stream network.



Figure : (A) Variables describing the connectivity between areas affected by landslides and debris flows and the channel network; (B) width ratio used to define areas affected by bank erosion; (C) definition of channel sinuosity; (D) slope used as a proxy for

For bank erosion the process is slightly different as SilvaProtect does not include this process, and there is not available database for the areas affected by bank erosion in Switzerland. Areas potentially affected by bank erosion areas are computed based on channel sinuosity and slope as a proxy for transport capacity (Figure above C and D), the channel with and the width ratio (Figure B). The width ratio gives the potential final channel width due to bank erosion during floods. This width ratio has been calculated analysing a European database, including several rivers and flood events in Switzerland and other 6 countries, and the three scenarios were defined according to the first and third quartile and the median value for different channel width classes (Figure below).





Figure : (A) Boxplot and density function showing the quartiles used to define the scenarios; (B) boxplots of width ratio values for different channel width classes for rivers with longitudinal slopes lower than 4%; (C) table showing the final values of width

As the Figure above shows, a width ratio value applies to the different channel width categories for the three scenarios. For example, to define the areas affected by high intensity bank erosion (rare event) and for small channels (< 3 m wide) a width ratio equal to 4 is applied (meaning that the area affected by bank erosion covers a width 4 times the initial channel width), while for very large rivers (> 50 m wide) the width ratio for this scenario is equal to 1.5 (only 1.5 times the initial width). To assign the width ratio the stream network has been reclassified according to the channel width provided by the Ecomorphology database (Sohlenbreite). These reclassifications have been done in ArcGis using the following python code (this code defined the width ratio according to initial width for the FREQUENT scenario (E"30") and was adapted for the other two):

def Reclass(GSBREITE):

if GSBREITE <=3: return 1.2

elif GSBREITE >3 and GSBREITE <=5: return 1.1

elif GSBREITE >5 and GSBREITE <=10: return 1.1

elif GSBREITE >10 and GSBREITE <=15: return 1.1

elif GSBREITE >15 and GSBREITE <=20: return 1.1

elif GSBREITE >20 and GSBREITE <=30: return 1

elif GSBREITE >30 and GSBREITE <=40: return 1

Schwemmholz-Management an Fliessgewässern – Ein praxisorientiertes Forschungsprojekt

GIS-Fuzzy logic large wood recruitment toolbox: Quick User Guide



elif GSBREITE >40 and GSBREITE <=50: return 1 elif GSBREITE >50: return 1 width_low= Reclass(!GSBREITE!)

The stream network provided by the ecomorphology database was grouped by the channel width classes as explained above and the width ratio was assigned to estimate the resulted potential erodible width for each stream segment. These buffers were transformed to pixels and the final pixels prone to bank erosion were assigned based on channel sinuosity and gradient. Stream segments characterized with high sinuosity and high gradient were assumed to be more prone to bank erosion.

The described variables (i.e., landslide prone areas, connectivity, debris flow prone areas, bank erosion prone areas, sinuosity and gradient) are transformed to fuzzy sets using the Fuzzy Membership tool in ArcMap 10.1 with a linear membership function. The resulted converted fuzzy variables are combined (e.g., landslides prone pixels and connectivity; sinuosity and gradient) with the Fuzzy Overlay tool. As a result, all pixels are transformed to fuzzy values ranging between 0 and 1, and they are used to compute the volume of wood by multiplying the fuzzy pixel value by the forest density pixel. In case of overlapped pixels, priority was given to areas prone to debris flows, then banks erosion and finally landslides.

To compute the wood volume estimations a forest density map is required. The stand density of living trees in Swiss forests (in $m^3 ha^{-1}$) was derived from a nationwide raster map with an original resolution of 25 x 25 m (rescaled to 1 x 1 m), based on digital stereo aerial photographs from 2007 to 2016 (Ginzler et al., 2019). In addition, previously stored instream wood volumes are also included in the calculations. Detailed information on wood loads across the stream network was not available, so based on a literature review by Rickli and Bucher (2006) and Ruiz-Villanueva et al. (2016), volumes of instream wood are assigned to the different streams grouped by stream order (FGA) classes provided in the stream network dataset. The following python code was used:

def Reclass(FLOZ): if FLOZ <=3: return 0.006 elif FLOZ >3 and FLOZ <=6: return 0.012 elif FLOZ >6: return 0.005 wood_load= Reclass(!FLOZ!)

To complete the final computations and to obtain the estimated recruited wood volume 10 steps must be done (Figure 4), and the user has full control on the entire process, step by step. Step 11 can be used to compute the probable maximum recruitable wood volume, which is the total wood volume potentially recruitable computed without considering the volume reduction by the fuzzy functions.



STEP BY STEP

Before starting, set up the Geoprocessing options as shown in the Figure:

			Geoprocessing Options
File Edit View Bookmarks Insert Selection	Geoprocessing Customize W	findows Help	General Coverwrite the outputs of geoprocessing operations Coverwrite the outputs of geoprocessing operations to a log file Background Processing Coverment Coverm
ରେ ଜୋଲ ଅର୍ଥ ଲେ ଅର୍ଥ ଲେ କାର୍କ୍ କାର୍କ୍ କାର୍କ୍ କାର୍କ୍ କାର୍କ୍ ଲେ ଅର୍ଥ ଲେ ଅନ୍ତ୍ର ସହର ଅନ୍ତ୍ର କାର୍କ୍ କାର୍କ୍ କାର୍କ୍ କାର ଜୋଜ	Clip Intersect Union		Script Tool Editor/Debugger
Arc toolbox Arc Toolbox Bright SD Analyst Tools Bright STools Bright Strools Bright Strools Bright Strools	Merge Dissolve Search For Tools ArcToolbox	rs :\NID_170 Gaert	Debugger:
Conversion Tools Gonversion Tools Gonversion Tools Gonversion Tools Gonversion Tools Gonversion Tools	Image: Second] streamnetwo] streamnetwo] DebrisFlows 1	When connecting elements, display valid parameters when more than one is available. Results Management Keep results younger than: 2 Weeks
 Fuzzy logic large wood recruitment tool_2021 Du 01. (pre-process) Clipping input layers Du 02. Input River Network, Gradient, Sinuosity, 	Python Geoprocessing Options	Landslides_tra	Display / Temporary Data ✓ Add results of geoprocessing operations to the display ☐ Results are temporary by default
			About geoprocessing options OK Cancel

The Toolbox is very intuitive, user friendly and the user needs just to enter the required input data and save the output files, which are used for the following step.

Add the toolbox to the ArcToolbox list:





If you want to add the toolbox "Fuzzy logic large wood recruitment tool_2021" to the default setting mode you have to: right click on ArcToolbox > Save Setting > To Default

	ArcToolbox	
	ArcTostisuu Control Add Toolbox Control Add Tool	To File To Default
 Fuzzy logic large w 01. (pre-procession of the second second	ood recruitment tool s) Clipping input layers Network, Gradient, Sinuosity, c extraction, resampling, unit lides scenarios from SilvaProt ty: Distance and Slope ance and Slope nectivity is flows scenarios from Silval zzy DF to LS raster opes recruitment scenarios m gradient and sinuosity c Erosion scenarios zy BE and cut LS raster W volume ed volume V recruited volume	r, Bank Erosion widths ts conversion and sum tect trajectories

The Fuzzy logic large wood recruitment tool_2022 appears as in the previous Figure.

The correct setting of the workspace it is a very important stage, and it must be checked often to ensure that output files are always saved in the correct geodatabase folder. It is important to double check that the workspace and path for input and output files is the right one. Before starting, it is necessary to check that the workspace is set up in the correct *Geodatabase* folder.



File > Map document Properties > Default 🛃 Geodatabase > > Set the correct folder.

In the following sections, step by step procedures are explained using a case study as an example, the Gaertelbach (NID_170) stream catchment.



For each step, it is important to check that the workspace is set correctly in every single step. The workspace must be the same as the *default geodatabase*.



 02. Input River Networ 03. Line Density 	Open Batch	sion widths	01. (pre-process) Clipping input layers Properties General Parameters Environments Help Iteration Solid the productment at time that are used for	×
¤ 04. VHMV mask extrac	Edit	ion and sun	Geostatistical Analysis	🛠 Environment Settings
98 05. Fuzzy landslides sc	Debug	tories	In Values M Values M Values Horogening Dutput Coordinates Density Processing	* Workspace
PR Ofh Fuzzy Distance an	Copy		Processing Extent	D:\NID_170 Gaertelbach\NID_170.gdb
PB Obc. Fuzzy Connectivit X	Delete		Random Numbers Raster Analysis	Scratch Workspace
9 07a. Fuzzy Debris flow:	Rename	jectories	Raster Storage P Remote Processing Server P Remote Processing Server	* Processing Extent
07b. Extend Fuzzy DF t 08. Fuzzy Hillslopes rec	Set Password			
🔎 09a. Fuzzy stream grad	Export Script		Le Z Values	
🕶 09b. Fuzzy Bank Erosio	Import Script		Values	
¤ 09c. Extend Fuzzy BE a 🍘	Help			OK Cancel Sho
¤ 10. LW recruited volun	Itom Description			
¤ 11. Potential LW recrui 💻	item Description			

1. Pre-process: clipping input layers

This step applies clipping to the initial input larger datasets (e.g., national stream network, forest cover, etc.) to obtain the input data for the catchment or study area polygon. Check that the workspace is set to the correct folder. It must be the same as the default geodatabase.

The clipping includes also the SilvaProtect trajectory lines, so this step is only required when using this dataset. If not the clip tool available in the Spatial Analysis could be used.

O1. (pre-process) Clipping input layers) X
%Workspace%		
D:\WID_170 Gaertelbach\WID_170.gdb		8
Catchment area input		
NID_170	-	
Forested area input		
Silva_V25	-	
Streamnetwork input		
GWN_master	-	
Landslides_trajectories		
HM_170	-	
Debris_flows_trajectories		_
Mur_170	•	
Forest_dip_catchment		_
%Workspace%\Forest		2
Landslides_trajectories_dip_forest_catchment		
%Workspace%\Landslides_trajectories		6
Debrisflows_trajectories_clip_forest_catchment		
%Workspace%\DebrisFlows_trajectories		2
stream_network_dip_catchment		
%Workspace%\streamnetwork		2
stream_network_dip_catchment_forest		
%Workspace%\streamnetwork_forested		
DTM_2m		
DTM_170	-	1
DTM_2m_catchment		
%Workspace%\DTM_2m_mask		6
	OK Cancel Environments Show	Help



Use always full path (avoid %Workspace, as sometimes does not find the right workspace) or select the layers in the browser. Do this in all steps (from 1 to 11).

2. Processing input river network, gradient, sinuosity, bank erosion widths

Before running this step, it is important to check the attribute table of the stream network feature class to verify that some of the fields exist and the names they have:

Table															
:=	- 1 5	2 - I 🖳 🕞	× 16. N												
Gew	aecce	ernetz													
	FID	Shape *	OBJECTID 1	LENGTH	OBJECTID	OBJECTVAL	GWINR	GSBREITE	BREITENVAR	FLOZ	HOFHE	GELAECHE	VORRAT		Shape Leng
b the	0	Polyline	1	483,445919	1614622	Bach	CH0126520000	2	1	2	991.609985	966.891837	94	8,702027	478.93308
	1	Polyline	2	733.992777	1760275	Bach	CH0126520000	2	1	1	1154.109985	1467.985554	94	13.21187	733.992777
	2	Polyline	3	151.90315	1612584	Bach	BE0126520001	2.1	0	2	1061.5	318.996616	94	2.87097	151.90315
	3	Polyline	4	277.965239	1760274	Bach	BE1350960000	1.3	0	1	1125.099976	361.354811	94	3.252193	277.965239
	4	Polyline	5	80.267257	1612583	Bach	BE0126520001	1.3	0	1	1102.800049	104.347434	94	0.939127	80.267257
м	1	1) н <mark> </mark> =	(0 out of 5	Selected)										
Gev	aess	ernetz													

In this step the input stream network is edited to add the variables used for bank erosion (sinuosity and gradient) and the final wood volume calculation (death wood). The river reach gradient is calculated based on the maximum and minimum elevation values provided by the DEM and the longitudinal distance (length) between them by using the Zonal Statistics (Expression: [Max] - [Min]) / [Shape_Length]); the sinuosity is computed using the python tool; the final erodible width is computed based on width ratios as explained above; and the death wood stored in the stream is assigned (field wood_load) according to the stream order which is given by the FLOZ field.

A constant value here in the example equal to 0.7 is used to reduce the final wood volume calculations, assuming that out of the entire erodible area only 70% of it is actually affected by erosion and thus contributes with wood (this is homogeneously reduced from the computed area, and not spatially explicitly distributed). This value can be changed according to the knowledge of the study site.



check and correct if needed the join fields raster elevation (e.g., MAX, MIN) and the raster calculator expression to be sure all fields match and exist



%Workspace%		Instream death wood vol
DEM input		
	2	No description available
Stream network input		
	🖻	
instream death wood vol		
%Workspace%\deathwood	🖻	
Join Fields DEM raster elevation (optional)		
OBJECTID_1	^	
MIN		
SUM SUM		
VARIETY		
MAJORITY	× 1	
Select All Unselect All	Add Field	
Input Join Field stream ID		
OBJECTID_1	~	
Dutput Join Field stream ID		
	~	
zone field zonal stats table	~	
Output zonal statistics to compute gradient		
%Workspace%\ZonalSt_stream_1	P	
nitial channel width raster		
%Workspace%\Initial channel width	A	
%Workspace%/BEArea_MEDfloat07		
Park gradien area DADE float 0.7		
%///or/space%/BEArea DADEfloat07		
Sank erosion area FREQ float 0.7		
%workspace%pearea_rkeQnoatu7		
input constant value bank erosion area		
0.3		
gradient		
%Workspace%\gradient		
sinuosity		
%Workspace%\sinuosity		
	~	
	~	



3. Line Density

This step computes de line density based on the *Landslides* (LS) and *debris flows* (DF) trajectories to define the three scenarios as explained above.

Line density default parameters: pixel size 2m; Radius= 25m. These values can be changed editing the step in the model builder editor.

%Workspace%	F.	\sim	Line density output (2)
Landslides trajectories input			.,
%Workspace%Landslides_trajectories	2		No description available
Line density output	_		
C:\Users\vruizvil\Documents\ArcGIS\Packages\VID_144_64FD1597-203D-4B12-BAB8-4513B3554	6		
Debris flows trajectories input			
%Workspace%\PebrisFlows_trajectories	6		
Line density output (2)			
%Workspace%\linedensity_D	2		

4. VHMV mask extraction, resampling, units conversion and sum

In this step the vegetation density is resampled, and the units are converted and forest and wood volumes are sum.

%Workspace%		\sim	VHMV25m		~
%Workspace%	2				
ADSVHM VORRAT input (25m, m3/ha)			No description av	ailable	
	2				
catchment mask					
	1				
VHMV25m					
%Workspace%\VHMV25m	2				
VHMV Resampled 1m					
%Workspace%\VHMV1m	2				
VHMV 1m m3/m2 output (only trees)					
C:\Users\vruizvil\Documents\ArcGIS\Packages\VID_144_64FD1597-203D-4B12-BAB8-4513B3554	1				
VHMV5perc					
C:\Users\vruizvil\Documents\ArcGIS\Packages\VID_144_64FD1597-203D-4B12-BAB8-4513B3554	2				
VHMV 1m m3/m2 (trees + death wood)					
%Workspace%\VHMVno_instreamwood	1				

WoodFlow

GIS-Fuzzy logic large wood recruitment toolbox: Quick User Guide

5. Fuzzy landslides scenarios from SilvaProtect trajectories

Once the raster files of line density are obtained, the values to define the scenarios are given by the natural breaks of the raster classification as shown in the figures:



Right click on Linedensity_LS > Properties > Symbology > Classify > Classification Method > Natural Breaks (Jenks) and 4 classes. **The same procedure is needed for the debris flows trajectories.**

Droportion				×	Classification	n				Classification Statistics		
Properties				^	Method:	Natural Bre	aks (Jenks)		~	Count:	317	7955
neral Source Exter	nt Display	Symbology			Classes:	4	~			Minimum: Maximum:	13 76541	1042
v:	_				Data Exclusi	ion				Sum:	75.088.85	5634
ue Values	Draw ras	ter grouping values into cla	ises 🖻			Exclusion	Sa	mpling		Mean:	0.236161	1898
sified				_						Standard Deviation:	1.100484	4378
tched	Fields			_	Columns:	100 ≑	Show Std. Dev	. Show Me	an			_
ete Color	Value	<value> Value> No</value>	rmalization <none></none>	\sim		8	8	- <u>-</u>		42	Break Values	
					300	000 T 🖉	9021	3182		5410	0.701766022	2
	Classifica	Natural Breaks (Jenks)		_		10/	2926	0430		376	3.292902101	1
		Natural Di Caks (Jeriks)	Classes 4 V Classify	· .	250	000-0	ei.	œ		Ψ	8.043318247	7
	Color Door			_	200	000					13.76541042	2
	COIOF Ram			~	200							
	Symbol	Range	Label		150	000-						
		0 - 0 701766022	0 - 0 701766022									
		0 701766022 2 202002101	0 701765022 - 2 202002101		100	000-						
		2 202002101 9 042219247	2 202002102 9 042219247		50	000-						
		0.0422102101 - 0.043310247	9.042219249 12.75541042								<	
6 A. I		0.043310247 - 13.70341042	8.045518248 - 15.76541042			0					OK	к
• A. •					1	0	3.441352606	6.882705212	10.324057	32 13.7654104:		-
				and the second se	Snap breat	ke to data vali	100				Cano	col



Using the natural breaks values, the fuzzy scenarios for landslides are defined by applying a linear fuzzy membership as shown in the image:

%Workspace%			
D:WID_170 GaertelbachWID_170.	gdb		
Fuzzy landslides FREQ event output			
%Workspace%\fuzzyLS_FREQ			2
Fuzzy landslides MEDIUM intensity o	utput		
%Workspace%\fuzzyLS_MED			2
Fuzzy landslides RARE event output			
%Workspace%\fuzzyLS_RARE			6
Membership type FREQ event (optio	onal)		
Linear V			
Minimum	8.2		
Maximum	12.9		
	13.0		1
Membership type MEDIUM event (op	otional)	Inedensity_LS	
Linear V		<value></value>	
Minimum	3.5	0 - 0.755686711	
Maniana			
Maximum	8.2	0.755080711 - 5.454507825	
Membership type RARE event (optio	onal)	3.454567824 - 8.150620958	
Linear V		8.150620959 - 13.76429367	
	0.0		J
Minimum	0.0		
Maximum	3.5		
ing density engine			
linedensity IS			-
Interestry_co			
		OK Cancel Environments	Show Help >>
		Concer Environmentant	onon nup //

6a. Connectivity: distance and slope

Here the distance and slope between the landslides and debris flows trajectories and the stream network are calculated:

%Workspace%				_
D:\VID_170 Gaertelbach\VID_170.gdb				2
DEM				
DTM_2m_mask			-	2
Stream Network				
streamnetwork			•	2
Forested catchment area				
Forest			•	6
Masked Euclidean distance to streams				
%Workspace%\EucDistance				6
Masked Slope (percentage)				
%Workspace%\Slope				F3

WoodFlow

GIS-Fuzzy logic large wood recruitment toolbox: Quick User Guide

6b. Fuzzy distance and slope

This step use the Fuzzy Membership tool (or editing the model builder tool), with Fuzzy Membership

%Workspace%				
D:\WID_170 Gaertelbach\WID_170.gdb			6	-
FuzzyDistance			_	
%Workspace%\FuzzyDistance			6	-
FuzzySlope				
%Workspace%\FuzzySlope			F	-3

By default the values are: Lineal: For Distance: min =100, max=50; and for Slope (%): min=90, max=40. They can be changed editing the model builder tool.

6c. Fuzzy connectivity

This step computes the Fuzzy overlay to calculate the fuzzy connectivity:

%Workspace%				_
D:\WID_170 Gaertelbach\WID_170.gdb				2
FuzzyConnectivity				
%Workspace%\FuzzyConnectivity				2
Fuzzy Distance input				
D:\WID_170 Gaertelbach\WID_170.gdb\FuzzyDistance				2
Fuzzy Slope input				
D:\WID_170 Gaertelbach\WID_170.gdb\FuzzySlope			1	2



7a. Fuzzy Debris flows scenarios from SilvaProtect trajectories

As done for landslides, here use the 4 natural breaks of the line density file.

%Workspace%						
D:WID_170 GaertelbachV	NID_170.gdb					2
Fuzzy Debris Flows FREQ e	vent					
%Workspace%\fuzzyDF_	FREQ0					8
Fuzzy Debris Flows MEDIUN	1 event					
%Workspace%\fuzzyDF_	MEDO					B
Fuzzy Debris Flows RARE e	vent					
%Workspace%\fuzzyDF_	RARE0					2
Membership type FREQ eve	ent (optional)					
Linear	~					
Minimum	2.1					
Maximum	3.4					
	5.4					٦
Membership type MEDIUM (event (optional)	E	🛛 🗹 linedensity_DF			
Linear	~		<value></value>			
Minimum	1.1		0 - 0.3504509	17		
Maninam			0.350450917 -	1.07731	2078	
Maximum	2.1		1 077312070	2 0767/	6174	
Membershin type RARE eve	ent (optional)		2.076746175	2.07074	4245	
Linear	V		2.0/6/461/5 -	3.30981	4215	
	0.4	_				
Minimum	0.4					
Maximum	1.1					
line density raster					_	-
inedensity_DF					-	



7b. Extent Fuzzy debris flows (DF) to landslide (LS) raster

fuzzyDF FREO0	
fuzzyDF_FREQ0	2
fuzzyDF_MED0	
fuzzyDF_MED0	
fuzzyDF_RARE0	
fuzzyDF_RARE0	🖆
fuzzyLS_FREQ	
%Workspace%\fuzzyLS_FREQ	
fuzzyLS_MED	
%Workspace%\fuzzyLS_MED	e 1997 -
fuzzyLS_RARE	
%Workspace%\fuzzyLS_RARE	e 1997 -
fuzzyDF_FREQ	
%Workspace%\fuzzyDF_FREQ	e 1997 -
fuzzyDF_MED	
%Workspace%\fuzzyDF_MED	e
fuzzyDF_RARE	
%Workspace%\fuzzyDF_RARE	<u>é</u>
Forest	
Forest	6



Remember: Use always full path (avoid %Workspace, as sometimes does not find the right workspace) or select the layers in the browser. Do this in all steps (from 1 to 11).



8. Fuzzy Hillslopes recruitment scenario (i.e., landslides connected to the stream network)

08. Fuzzy Hillslopes recruitment scenarios				X
%Workspace%				
D:WID_170 GaertelbachWID_170.gdb				2
Input fuzzy landslide FREQ event raster				
%Workspace%\fuzzyLS_FREQ			-	0
Input fuzzy landslide MEDIUM event raster				
%Workspace%\fuzzyLS_MED			-	0
Input fuzzy landslide RARE event raster				
%Workspace%\fuzzyLS_RARE			-	6
Input Fuzzy Connectivity				
%Workspace%\FuzzyConnectivity			•	0
Fuzzy DebrisFlow FREQ				
fuzzyDF_FREQ			•	2
Fuzzy DebrisFlow MED				
fuzzyDF_MED			-	2
Fuzzy DebrisFlow RARE				
fuzzyDF_RARE			•	2
Fuzzy HILLSLOPES noDF FREQ output				
%Workspace%\FuzzyHILLNoDF_FREQ				0
Fuzzy HILLSLOPES noDF MED output				
%Workspace%\FuzzyHILLNoDF_MED				2
Fuzzy HILLSLOPES noDF RARE output				
%Workspace%\FuzzyHILLNoDF_RARE				0
	OK Cancel Envi	ronments	Show He	elp >>



9a. Fuzzy stream gradient and sinuosity

6Workspace%			_
D:WID_170 GaertelbachWID_170.gdb			63
tream sinuosity raster input			
sinuosity		-	6
tream gradient raster input			
gradient		•	2
uzzy gradient output			
%Workspace%\Fuzzy_stream_gradient			6
uzzy sinuosity output			
%Workspace%\Fuzzy_stream_sinuosity			2



9b. Fuzzy Bank Erosion scenarios

Click error and warning icons for more information	×
%Workspace%	
%Workspace%	
Fuzzy bank erosion	
%Workspace%\FuzzyBE	<u> </u>
Bank erosion area FREQ input	
%Workspace%\BEArea_FREQfloat07	6
Bank erosion area MEDIUM input	
%Workspace%\BEArea_MEDfloat07	2
Bank erosion area RARE input	
%Workspace%\BEArea_RAREfloat07	2
Fuzzy stream gradient input	
%Workspace%\Fuzzy_stream_gradient	2
Fuzzy stream sinuosity input	
%Workspace%\Fuzzy_stream_sinuosity	🖻
Fuzzy DebrisFlow FREQ input	
%Workspace%\fuzzyDF_FREQ	🖆 🕹
Fuzzy DebrisFlow MED input	
%Workspace%\fuzzyDF_MED	🖻 🔁
Fuzzy DebrisFlow RARE input	
%Workspace%\fuzzyDF_RARE	6
Fuzzy bank erosion RARE output	
%Workspace%\FuzzyBE_RARE	—
Fuzzy bank erosion FREQ output	
%Workspace%\FuzzyBE_FREQ	2
Fuzzy bank erosion MEDIUM output	
%Workspace%\FuzzyBE_MED	—
FzBENoDF_RARE	
%Workspace%\FzBENoDF_RARE	2
FzBENoDF_FREQ	
%Workspace%\FzBENoDF_FREQ	2
FzBENoDF_MED	
%Workspace%\FzBENoDF_MED	2
Forest	
	<u></u>



When filling this window with the input layers sometimes an error sign appear, ignore and continue filling all layers. If the error persists, then check the path and location of all input



9c. Extent Fuzzy BE and cut LS raster

This step removes overlapped landslides areas

99 09c. Extend Fuzzy BE and cut LS raster)	×
fuzzyLS_RARE								~
%Workspace%\fuzzyLS_RARE						-	1	
fuzzyLS_MED								
%Workspace%\fuzzyLS_MED						•	2	
fuzzyLS_FREQ								
%Workspace%\fuzzyLS_FREQ						•	0	
FzBENoDF_RARE								
%Workspace%\FzBENoDF_RARE						•	0	
FzBENoDF_FREQ								
%Workspace%\FzBENoDF_FREQ						-	3	
FzBENoDF_MED								
%Workspace%\FzBENoDF_MED						•	2	
FuzzyHILLNoDF_FREQ								
%Workspace%\FuzzyHILLNoDF_FREQ						-	2	
FuzzyHILLNoDF_MED								
%Workspace%\FuzzyHILLNoDF_MED						-	2	
FuzzyHILLNoDF_RARE								
%Workspace%\FuzzyHILLNoDF_RARE						•	0	
FzHILLNoDFNoBE_FREQ								
%Workspace%\FzHILLNoDFNoBE_FREQ							2	
FzHILLNoDFNoBE_MED							Second Second	
%Workspace%\FzHILLNoDFNoBE_MED							0	
FzHILLNoDFNoBE_RARE								
%Workspace%\FzHILLNoDFNoBE_RARE							2	\sim
	0	к	Cancel	Environme	ents	Show H	lelp >>	>



10a. Instream LW volume

Click error and warning icons for more information	×
%Workspace%	
%Workspace%	6
Instream wood density (m3/m2)	
	2
Fuzzy hillslopes No DF No BE FREQ event input	
%Workspace%\FzHILLNoDFNoBE_FREQ	6
Fuzzy hillslopes No DF No BE MEDIUM event input	
%Workspace%\FzHILLNoDFNoBE_MED	6
Fuzzy hillslopes No DF No BE RARE event input	
%Workspace%\FzHILLNoDFNoBE_RARE	6
Fuzzy debris flows FREQ event input	
%Workspace%\fuzzyDF_FREQ	6
Fuzzy debris flows MEDIUM event input	
%Workspace%\fuzzyDF_MED	6
Fuzzy debris flows RARE event input	
%Workspace%\fuzzyDF_RARE	6
Fuzzy bank erosion No DF FREQ event input	
%Workspace%\FzBENoDF_FREQ	6
Fuzzy bank erosion No DF MEDIUM event input	
%Workspace%\FzBENoDF_MED	6
Fuzzy bank erosion No DF RARE event input	
%Workspace%\FzBENoDF_RARE	1



	6
Bank erosion FREQ recruited instream wood volume (m3) output	
D:\FGA\p1_\b1gdb\instreamwood_volBE_FREQ	6
Debris flows FREQ recruited instream wood volume (m3) output	
D:\FGA\p1_\p1gdb\instreamwood_IDF_FREQ	2
tillslopes FREQ recruited instream wood volume (m3) output	
D:\FGA\p1_\p1gdb\instreamwood_HIL_FREQ	6
Bank erosion MED recruited instream wood volume (m3) output	
D:\FGA\p1_\p1gdb\instreamwood_BE_MED	2
Debris flows MED recruited instream wood volume (m3) output	
D:\FGA\p1_\p1gdb\instreamwood_DF_MED	1
-illslopes MED recruited instream wood volume (m3) output	
D:\FGA\p1_\p1gdb\instreamwood_HIL_MED	2
Bank erosion RARE recruited instream wood volume (m3) output	
D:\FGA\p1_\p1gdb\instreamwood_BE_RARE	1
Debris flows RARE recruited instream wood volume (m3) output	
D:\FGA\p1_\p1gdb\instreamwood_DF_RARE	1
iilslopes RARE recruited instream wood volume (m3) output	
D:\FGA\p1_\p1gdb\instreamwood_HIL_RARE	1
Table Results instream wood vol Bank Erosion FREO	
%Workspace%\Table_InstreamWood_BankErosion_FREQ	1
Table Results instream wood vol Debris Flows FREO	
%Workspace%\Table_InstreamWood_DebrisFlows_FREQ	1
Table Results instream wood vol HILLS FREO	
%Workspace%\Table_InstreamWood_Hillslopes_FREQ	P
Table Results, instream wood vol Bank Erosion MED	
%Workspace%\Table InstreamWood BankErosion MED	P
Table Results instream wood vol Debris Flows MED	
%Workspace%\Table InstreamWood DebrisFlows MED	
Table Results instream wood vol HTLLS MED	
%Workspace%/Table InstreamWood Hillslopes MED	
Table Results instream wood vol Bank Erosion RARE	
%Workspace%/Table InstreamWood BankErosion RARE	
Table Results instream wood vol Debris Flows RARE	
%Workspace%\Table_InstreamWood_DebrisFlows_RARE	r i i i i i i i i i i i i i i i i i i i
Table Results instream wood vol HILLS RARE	
%Workspace%\Table InstreamWood Hillslopes RARE	
OK Cancel Environments <<	Hide Hel



Remember: Use always full path (avoid %Workspace, as sometimes does not find the right workspace) or select the layers in the browser. Do this in all steps (from 1 to 11).

WoodFlow

GIS-Fuzzy logic large wood recruitment toolbox: Quick User Guide

10b. LW recruited volume

Click error and warning icons for more information	x
%Workspace%	
%Workspace%	2
Vegetation density (no instream wood)	
	😅 -
Fuzzy hillslopes No DF No BE RARE event input	
%Workspace%\FzHILLNoDFNoBE_RARE	2
Fuzzy hillslopes No DF No BE MEDIUM event input	
%Workspace%\FzHILLNoDFNoBE_MED	😅 🔁
Fuzzy hillslopes No DF No BE FREQ event input	
%Workspace%\FzHILLNoDFNoBE_FREQ	😅 -
Fuzzy debris flows RARE event input	
%Workspace%\fuzzyDF_RARE	et 1997 -
Fuzzy debris flows MEDIUM event input	
%Workspace%\fuzzyDF_MED	2
Fuzzy debris flows FREQ event input	
%Workspace%\fuzzyDF_FREQ	2
Fuzzy bank erosion No DF RARE event input	
%Workspace%\FzBENoDF_RARE	😅 -
Fuzzy bank erosion No DF MEDIUM event input	
%Workspace%\FzBENoDF_MED	2
Fuzzy bank erosion No DF FREQ event input	



	 	2	
Bank erosion FREQ recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolBE_FREQ		2	
Debris flows FREQ recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolDF_FREQ		2	
tillslopes FREQ recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolHIL_FREQ		2	1
Bank erosion MED recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolBE_MED		2	
Debris flows MED recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolDF_MED		2	
tillslopes MED recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolHIL_MED		2	
Bank erosion RARE recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolBE_RARE		2	
Debris flows RARE recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolDF_RARE		2	
tillslopes RARE recruited LW volume (m3) output			
D:\FGA\p1_\p1gdb\LWvolHIL_RARE		2	
Fable Results LW vol Bank Erosion FREQ			
%Workspace%\Table_LWvol_BankErosion_FREQ			
Table Results LW vol Debris Flows FREQ			
%Workspace%\Table_LWvol_DebrisFlows_FREQ		2	
Table Results LW vol HILLS FREQ			
%Workspace%\Table_LWvol_Hillslopes_FREQ		2	
Table Results LW vol Bank Erosion MED			
%Workspace%\Table_LWvol_BankErosion_MED		e 🔁 🔁	
Table Results LW vol Debris Flows MED			
%Workspace%\Table_LWvol_DebrisFlows_MED		2	
Table Results LW vol HILLS MED			
%Workspace%\Table_LWvol_Hillslopes_MED		2	
able Results LW vol Bank Erosion RARE			
%Workspace%\Table_LWvol_BankErosion_RARE		2	
Table Results LW vol Debris Flows RARE			
%Workspace%\Table_LWvol_DebrisFlows_RARE		2	
Table Results LW vol HILLS RARE			
%Workspace%\Table_LWvol_Hillslopes_RARE		P	

WoodFlow

GIS-Fuzzy logic large wood recruitment toolbox: Quick User Guide



Results are provided in tables and in raster layers

11. Potential LW recruited volume

%Workspace%	
%Workspace%	🖻
egetation density (NO INSTREAM WOOD)	
	🖆
nstream wood (deathwood)	
%Workspace%\deathwood	🖆
atchment mask input	
	2
one field	
	~
uzzy bank erosion No DF FREQ input	
%Workspace%\FzBENoDF_FREQ	
uzzy debris flows FREQ input	
%Workspace%\fuzzyDF_FREQ	6
uzzy hillslopes No DF No BE FREQ input	
%Workspace%\FzHILLNoDFNoBE_FREQ	6
uzzy bank erosion No DF MED input	
%Workspace%\FzBENoDF_MED	2
uzzy debris flows MED input	
%Workspace%\fuzzyDF_MED	2
uzzy hillslopes No DF No BE MED input	
%Workspace%\FzHILLNoDFNoBE_MED	<u> </u>
uzzy bank erosion No DF RARE input	
%Workspace%\FzBENoDF_RARE	🖻
uzzy debris flows RARE input	
%Workspace%\fuzzyDF_RARE	🔁 🕹
uzzy hillslopes No DF No BE RARE input	
%Workspace%\FzHILLNoDFNoBE_RARE	🔁 🕹
able Results Potential LW vol Mosaic FREQ	
%Workspace%\Table_Pot_LWvol_Mosaic_FREQ	🖻
able Results Potential LW vol Mosaic MED	
%Workspace%\Table_Pot_LWvol_Mosaic_MED	2
able Results Potential LW vol Mosaic RARE	
%Workspace%\Table_Pot_LWvol_Mosaic_RARE	6
HMV_AND_instreamwood	
%Workspace%\VHMV_AND_instreamwood	

Schwemmholz-Management an Fliessgewässern – Ein praxisorientiertes Forschungsprojekt

GIS-Fuzzy logic large wood recruitment toolbox: Quick User Guide

WoodFlow

Results are provided in the following tables:

Table_Pot_LWvol_Mosaic_FREQ
 Table_Pot_LWvol_Mosaic_MED
 Table_Pot_LWvol_Mosaic_RARE



REFERENCES

- Ginzler C, Price B, Bösch R, Fischer C, Hobi ML, Psomas A, Rehush N, Wang Z, Waser LT. 2019. Area-Wide Products. In Swiss National Forest Inventory – Methods and Models of the Fourth Assessment , Fischer C and Traub B (eds). Springer International Publishing: Cham; 125–142.
- Losey S, Wehrli A. 2013. Schutzwald in der Schweiz. Vom Projekt SilvaProtect-CH zum harmonisierten Schutzwald . Bern, Schweiz
- Rickli C, Bucher H. 2006. Einfluss ufernaher Bestockungen auf das Schwemmholzvorkommen in Wildbächen . Eidg. Forschungsanstalt für Wald Schnee und Landschaft WSL: Birmensdorf, 94 pp. (in German)
- Ruiz-Villanueva, V., Díez-Herrero, A., Ballesteros-Canovas, J.A., Bodoque, J.M., 2014. Potential large woody debris recruitment due to landslides, bank erosion and floods in mountain basins: a quantitative estimation approach. River Res. Appl. 30, 81–97. doi:10.1002/rra
- Ruiz-Villanueva V, Piégay H, Gurnell AM, Marston RA, Stoffel M. 2016. Recent advances quantifying the large wood dynamics in river basins: New methods and remaining challenges. Reviews of Geophysics 54 : 611–652. DOI: 10.1002/2015RG000514