USING SPATIAL INFORMATION TO SUPPORT DECISIONS ON SAFEGUARDS AND MULTIPLE BENEFITS FOR REDD+

EXPLORING MULTIPLE BENEFITS USING AN ARCGIS 10.X TOOLBOX

UN-REDD PROGRAMME

Food and Agriculture Organization of the United Nations

UNDP

UN environment programme

The UN-REDD Programme is the United Nations Collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries. The Programme was launched in September 2008 to assist developing countries prepare and implement national REDD+ strategies, and builds on the convening power and expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP).

The UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) is a global Centre of excellence on biodiversity. The Centre operates as a collaboration between the UN Environment Programme and the UK-registered charity WCMC. Together we are confronting the global crisis facing nature.

Prepared by Barbara Pollini and Corinna Ravilious

We welcome comments on any errors or issues. Should readers wish to comment on this document, they are encouraged to get in touch via: ccb@unep-wcmc.org.

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Acknowledgements: These training materials have been produced from materials developed for working sessions held in various countries, to aid the production of maps using GIS software to inform REDD+ planning and safeguards policies.

Contents

1. Introduction

REDD+ is a voluntary climate change mitigation approach that has been developed by Parties to the UNFCCC. It aims to incentivize developing countries to reduce emissions from deforestation and forest degradation, conserve forest carbon stocks, sustainably manage forests and enhance forest carbon stocks. This will involve changing the ways in which forests are used and managed, and may require many different actions, such as protecting forests from fire or illegal logging, or rehabilitating degraded forest areas.

REDD+ has the potential to deliver multiple benefits beyond carbon. For example, it can promote biodiversity conservation and secure ecosystem services from forests such as water regulation, erosion control and non-timber forest products (NTFPs). Some of the potential benefits from REDD+, such as biodiversity conservation, can be enhanced through identifying areas where REDD+ actions might have the greatest impact using spatial analysis and other approaches.

GIS software can be used to undertake spatial analysis of datasets of relevance to multiple benefits and environmental safeguards for REDD+.

This document accompanies a tutorial series and the "UN-REDD Exploring Multiple Benefits ArcGIS 10.x toolbox", developed to support the generation of spatial analyses to identify potential areas where a REDD+ intervention could be undertaken considering the benefits that REDD+ can deliver. The toolbox includes a suite of tools useful to clean and prepare initial data, to explore multiple benefits and finally to develop spatial workflows for the identification of potential areas for undertaking REDD+ interventions.

The purpose of this tutorial series is to help participants in technical working sessions, who are already skilled in GIS, to undertake analyses that are relevant to REDD+. The tutorials have been used to build capacity in a number of countries to produce datasets and maps relevant to their spatial planning for REDD+, and to develop such map products. Maps developed using these approaches appear in a number of publications whose aim is to support planning of strategy options that enhance biodiversity and ecosystem services as well as delivering climate change mitigation (see http://bit.ly/mbs-redd for country materials). There is of course no requirement for countries to use the approaches described in these tutorials.

2. UN-REDD Exploring Multiple Benefit ArcGIS Toolbox

The ExploringMultipleBenefits toolbox is designed to make spatial analysis steps quicker and easier to perform. In the standard ArcGIS toolbox there are multiple ways in which users can overlay datasets. Without the ExploringMultipleBenefits toolbox, users would need to find relevant tools, and understand how and when to use them. With Raster analyses in particular, it is important to use and apply appropriate environment settings to the data which are often hidden and forgotten. The ExploringMultipleBenefits toolbox not only standardises the way that analysis is undertaken in a series of simple steps, but reduces the risk of errors.

The tools are designed to allow users to create their own workflows using combinations of tools in different orders. Each tool clearly outlines what user inputs are required for each of the defined 'parameters'. This information is also stored in the help pages, clearly visible from within the ExploringMultipleBenefits toolbox.

In this current versions of the toolbox (for ArcGIS 10.5 and ArcGIS 10.6), the tools have been restructured into easier to navigate toolsets: **A Minimising errors in a raster analyses** and **B Exploring multiple benefits workflows**. In toolset B, some of the more complex workflows have an accompanying tutorial to help guide the user through the workflows and are available at http://bit.ly/GIStools-redd.

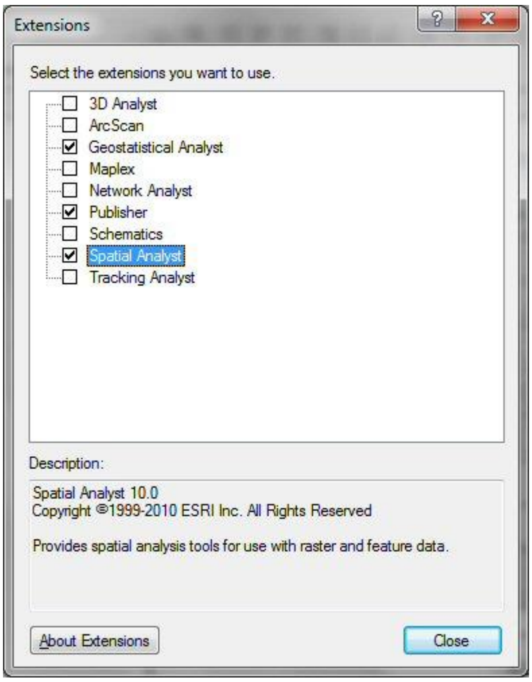
2.1 Instructions for adding the ExploringMultipleBenefits ArcGIS toolbox to ArcMap

The following steps need to be taken in order to make use of the ExploringMultipleBenefits toolbox:

a. **Unzip** the **ExploringMultipleBenefits toolbox** and **save the file** to chosen location.
   Note: the default area to which ArcGIS saves toolboxes is **c:\Documents and Settings\<username>\Application Data\ESRI\ArcToolbox\My Toolboxes.**

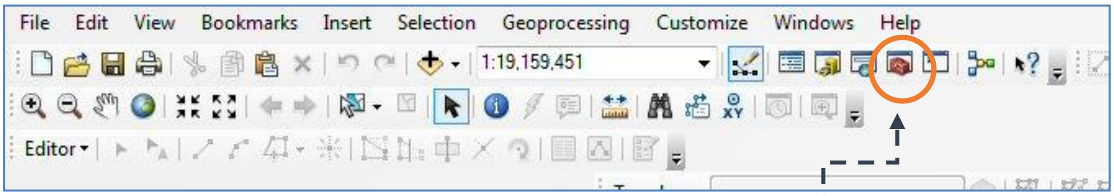
b. Make sure you keep the toolbox in a **sub-folder** called **ExploringMultipleBenefitsTools** otherwise the tools may show broken links.
   It may be preferable to save the toolbox within a current project folder.

c. **Open the ArcMap** software and **activate** the spatial analysis extension by clicking on **Customize>>Extensions** and ensure that the **Spatial Analysis** extension is **ticked**.

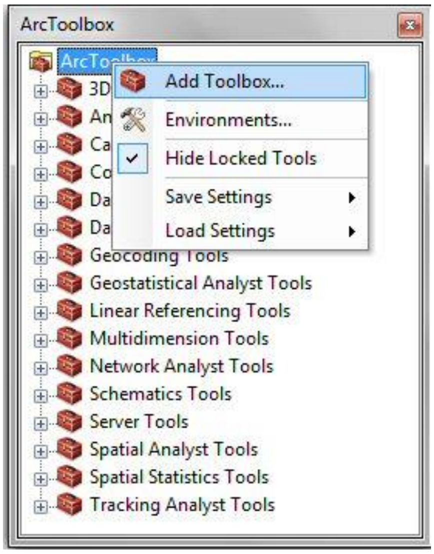


Note: This extension is required to run the ExploringMultipleBenefits tools, therefore if this extension is not available the software vendor will need to be contacted to obtain a licence.

d. Next you need to Add the 'ExploringMultipleBenefits' toolbox to ArcToolbox.

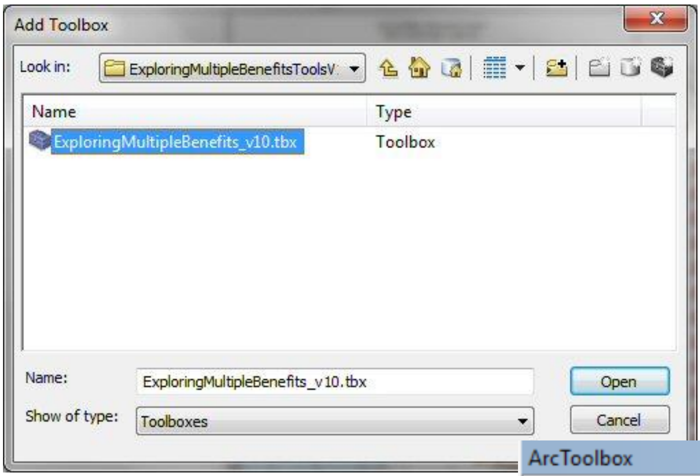


In ArcMap if the ArcToolbox is not already open, **click on the red toolbox button located in the main** horizontal menu bar.

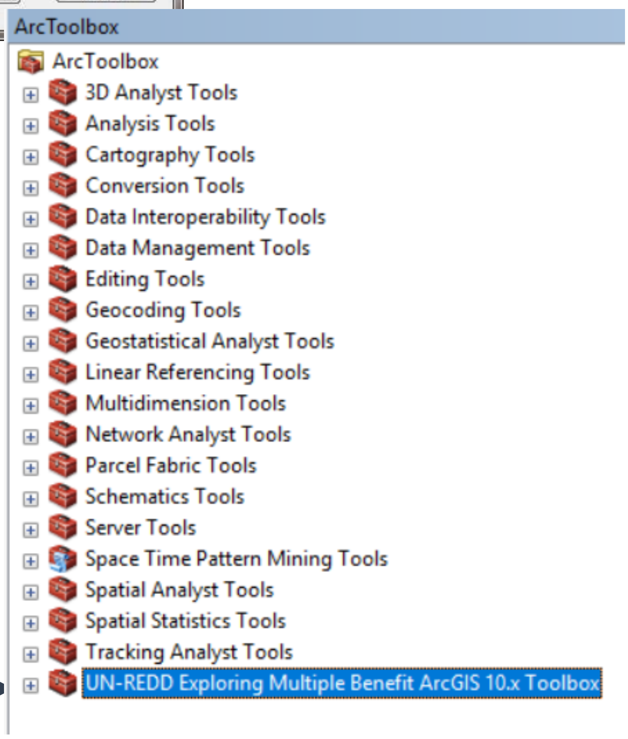


e. Right click on ArcToolbox and click Add Toolbox

f. Navigate to the folder in containing the toolbox (location determined in step a.) and click open

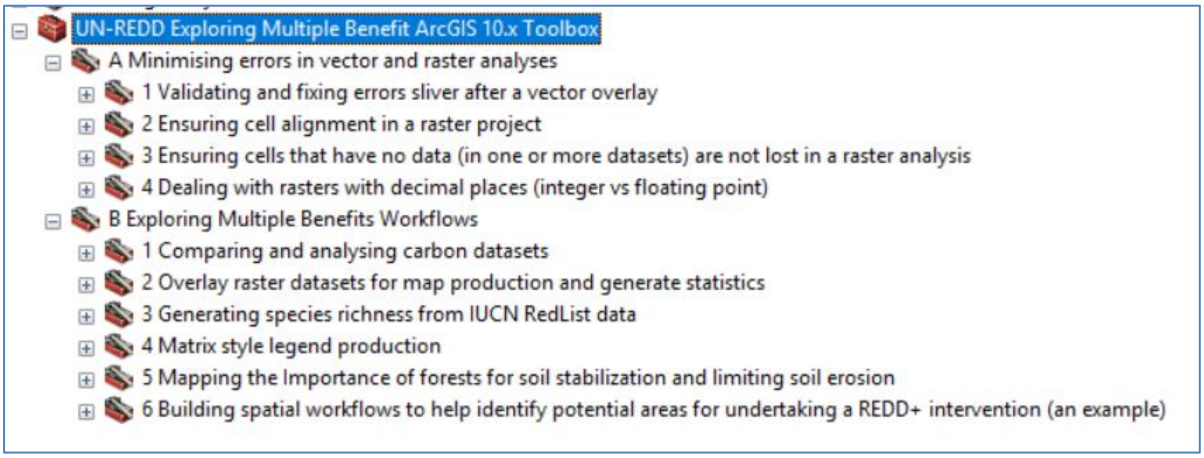


The toolbox will appear in the ArcToolbox



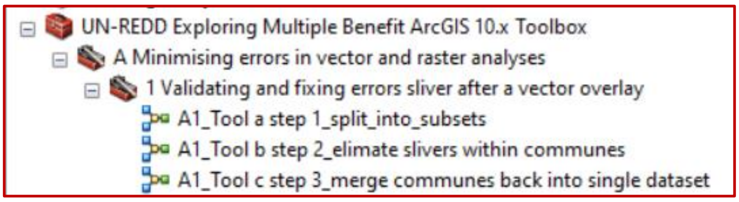
g. **Click** the + button to expand the toolbox to see the tools.

The Exploring Multiple Benefits Toolbox

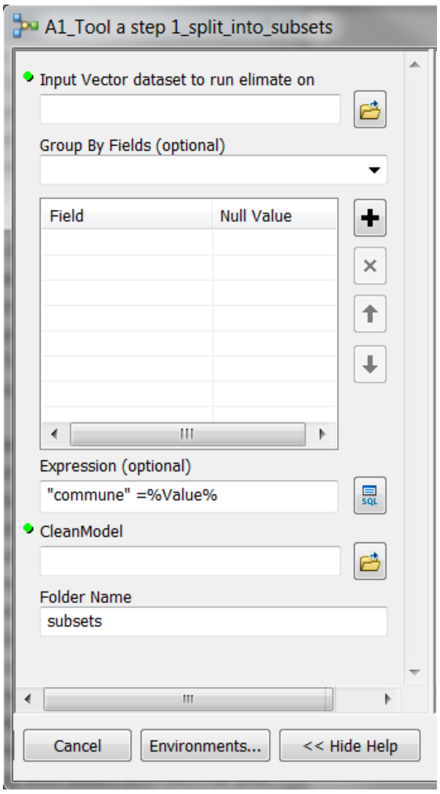


A. Minimising errors in vector and raster analyses

A.1. Validating and fixing errors sliver after a vector overlay



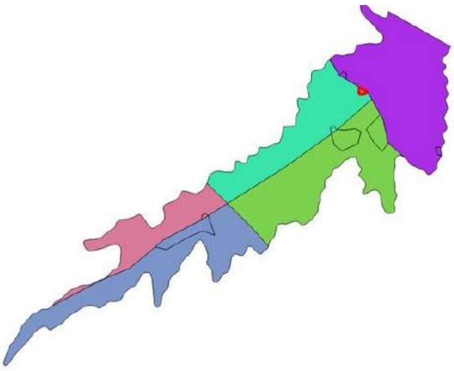
This workflow aims to eliminate small or sliver polygons after an overlay with administrative boundaries.



It includes the following four steps. This workflow eliminates small or sliver polygons whilst keeping official administrative boundary lines intact in the process.

Step 1: Split in subsets

Note: The colours in the illustration represent the different communes. The polygon highlighted in red is the one we want to eliminate.



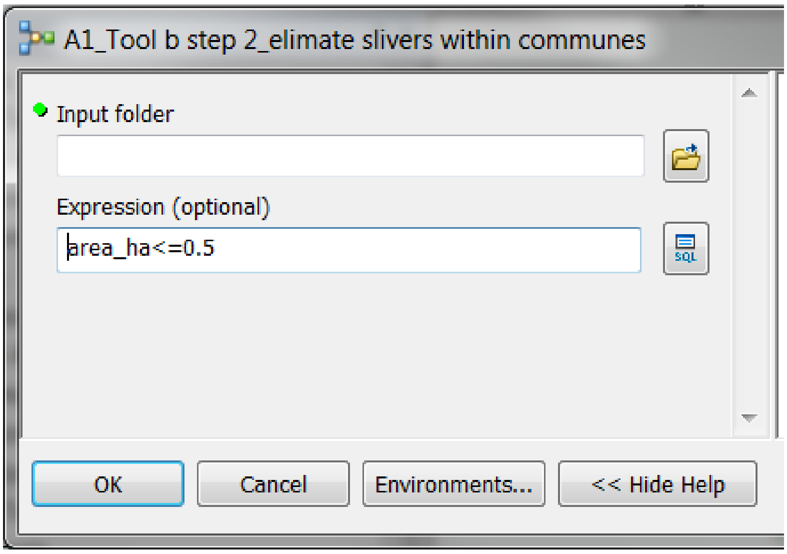
This step will split the input datasets in a subset of data based on a field (e.g. splits into individual commune datasets). It will ensure that the boundary lines are not altered in the process. The subset of datasets will be stored in a separate folder. In the expression you can include the field based on which you want the original dataset to be split (e.g. commune). *Note: the field chosen has to be an integer. You can check the field properties by opening the attribute table, right click on the field and choose "properties".*

Step 2: Eliminate slivers within the subset (e.g. communes)

This step cleans the datasets created in the previous step, for example it eliminates polygons below a defined area. In the SQL expression you can type in the expression based on which the datasets will be cleaned.

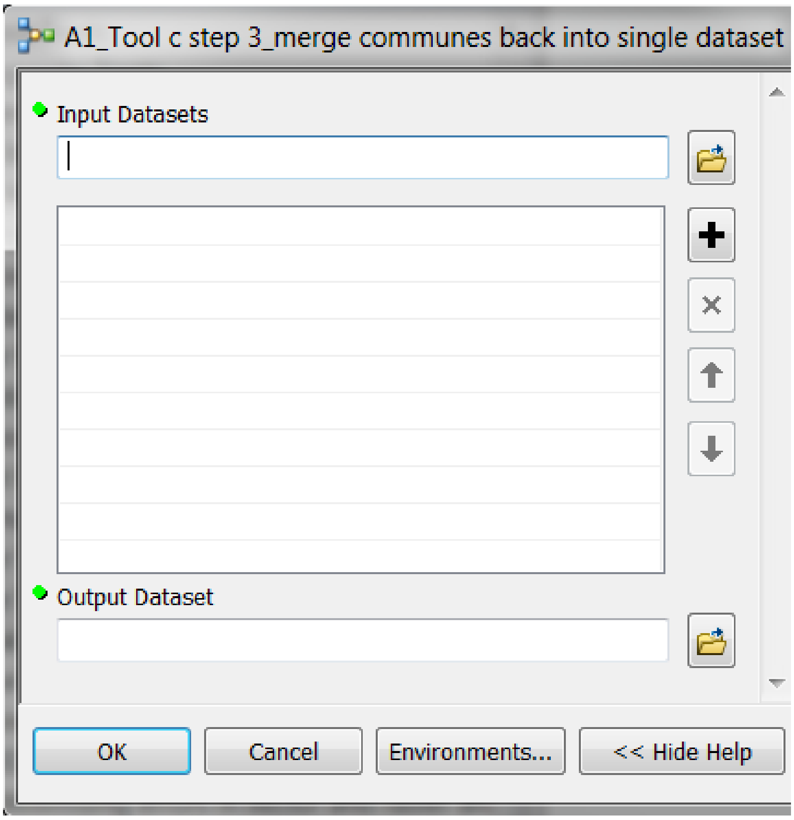
e.g. “area_ha” <=0.5

This cleaning model inputs the folder of subsets created in step 1 and cleans each of these files (eliminating polygons below a certain areas) individually, which are saved in a folder within the subsets folder called "cleaned".

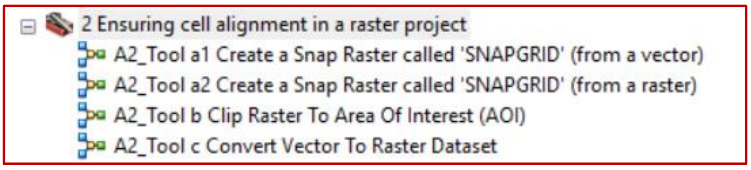


Step 3: Merge subsets (e.g. communes) back into single datasets

This final step will produce one single dataset by merging the cleaned shapefiles produced in the previous step.



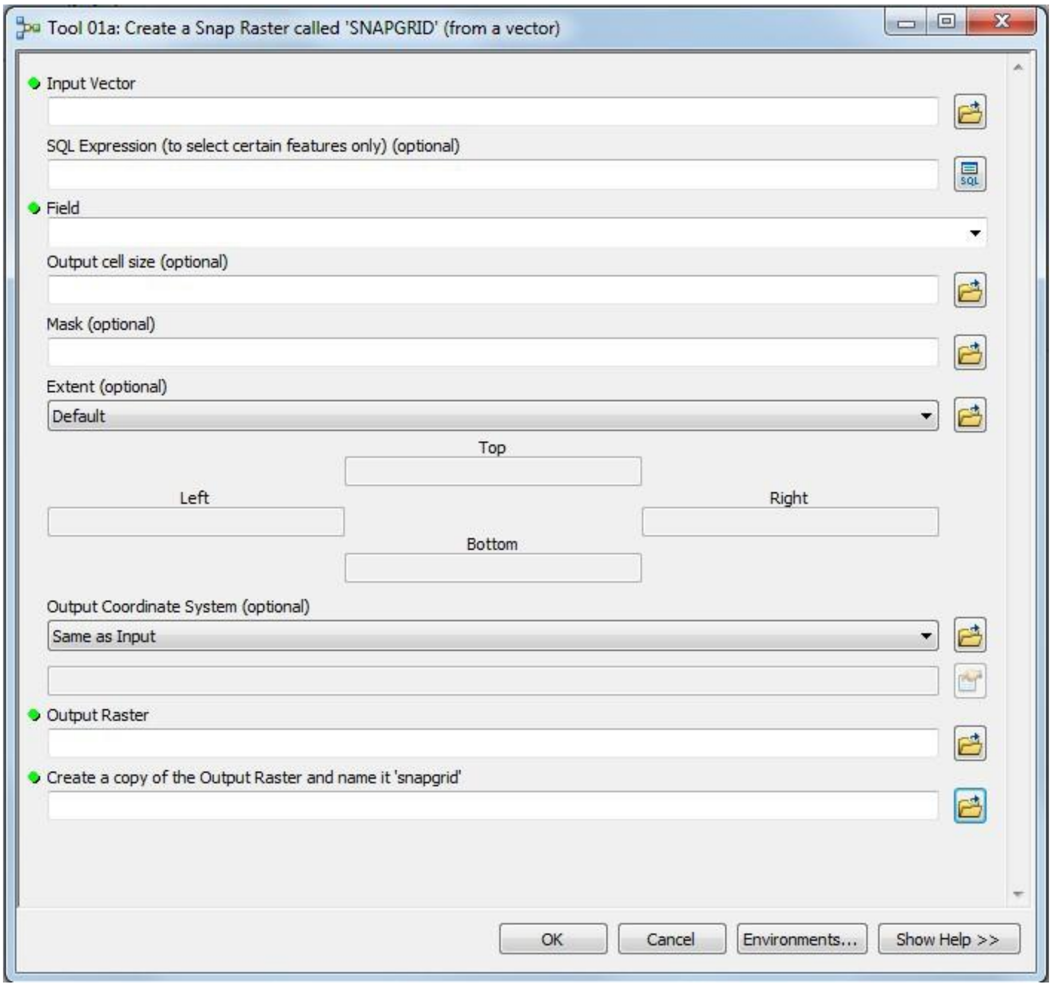
A.2. Ensuring cell alignment in a raster project



When performing spatial analyses is critical to have all the input datasets aligned, otherwise you will get error messages. The set of tools described below will help ensuring that the datasets for your analyses are well aligned for further spatial analyses.

Tool a1: Create a snap raster called "SNAPGRID" (from a vector)

This tool creates a raster dataset from a user specified vector dataset at a user specified cellsize. The 'snap raster' can be used as a template in an analysis to ensure the cell alignment of the output rasters. This is particularly important when running a number of analyses to generate multiple output layers. To ensure the resultant dataset is an integer raster, the field from which the raster will be created must be in the format of long integer or text. If the field is of type 'double', even if the data within that field has no decimal place, it will make the output raster floating point. To check the field types within the vector dataset to be converted in ArcMap, right click on the dataset and click properties: a window will appear. Click on the fields tab. Information about the dataset will appear in this window, including the projection information.

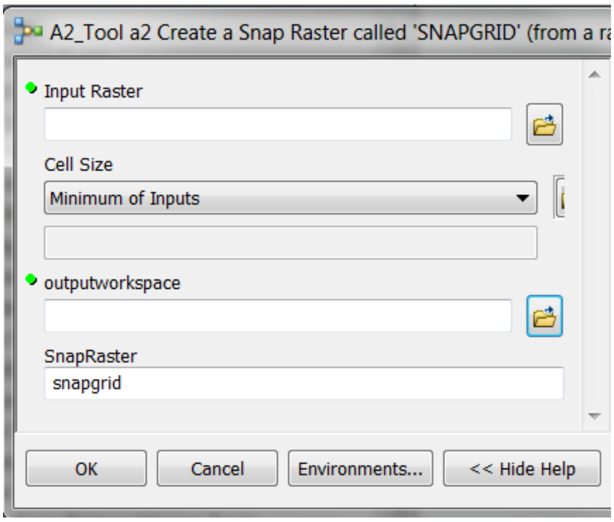


Tool a2: Create a snap raster called "SNAPGRID" (from a raster)

In this case a raster is used to generate a template to ensure cell alignment.

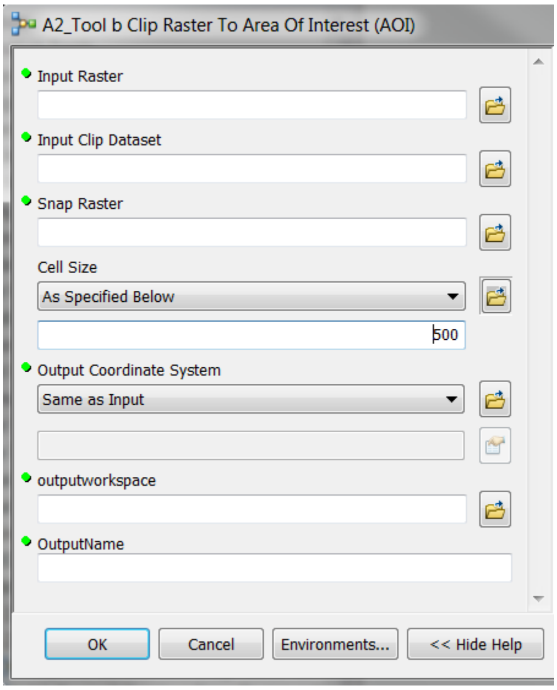
A snap raster is used to ensure that the cell alignment of the output raster in an analysis matches with a chosen input raster. This model creates a raster dataset called 'snapgrid' from a chosen raster dataset and this will be used to set the correct environment setting for the analysis in subsequent tools.

Note: the input raster must be an integer raster.



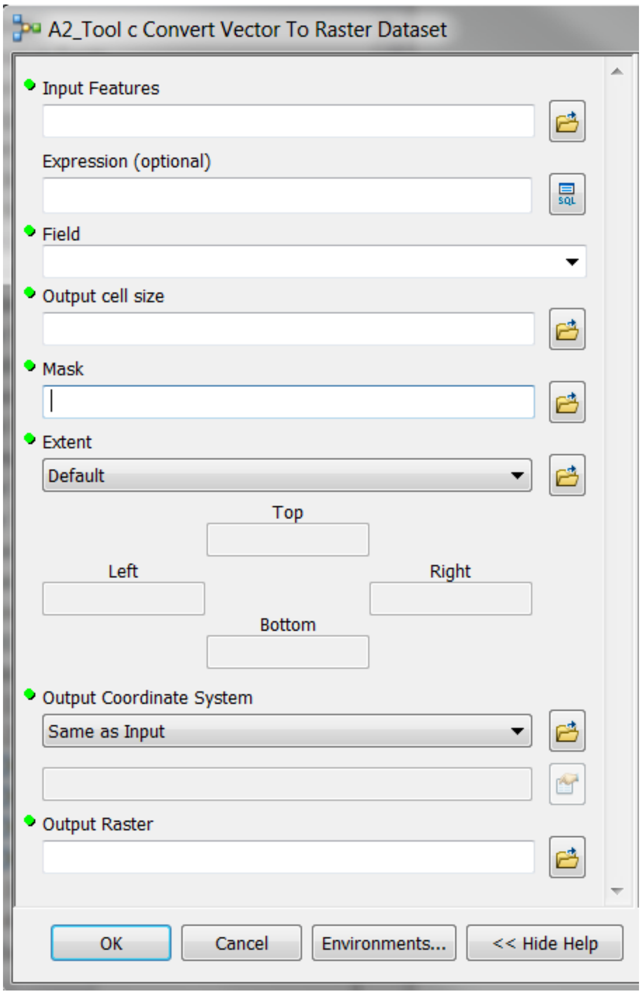
Tool b: Clip raster to Area Of Interest (AOI)

This tool uses a vector or a raster mask to clip a raster dataset to an area of interest.

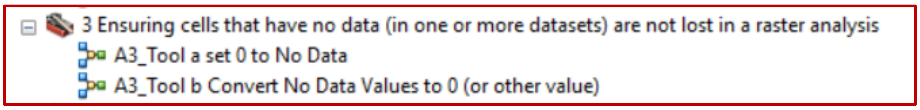


Tool c: Convert vector to raster dataset

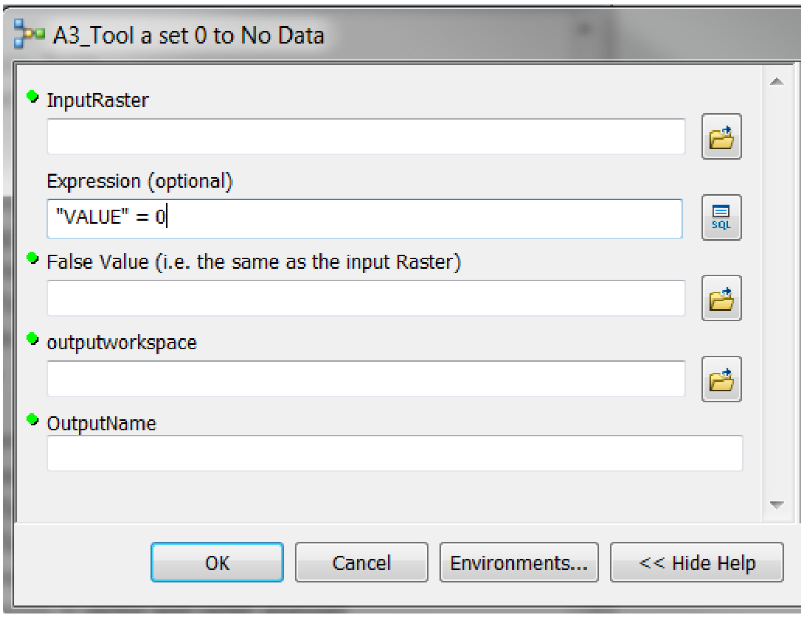
This model will take a vector dataset and convert the features to a raster of a specified cellsize. the model allows the user to either convert all features or selected features. The user can use a mask to clip the dataset to a specified area of interest. To ensure the resultant dataset is an integer raster, the field from which the raster will be created must be in the format of long integer or text. If the field is of type 'double', even if the data within that field has no decimal place, it will make the output raster floating point.



A.3. Ensuring cells that have no data (in or more datasets) are not lost in a raster analysis

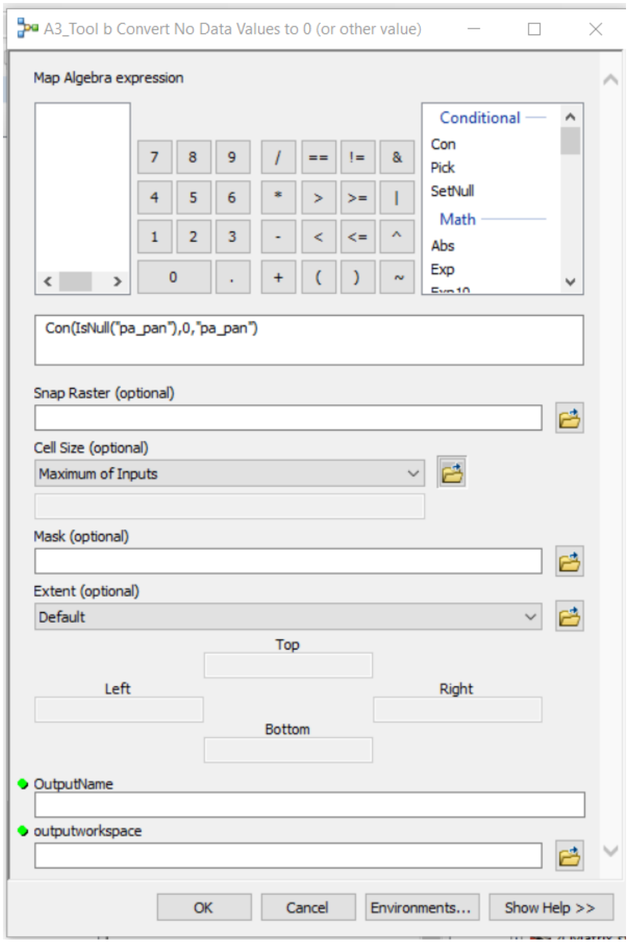


The two tools described below help users to deal with raster dataset characterized by cells with no data or 0 values, which can be lost during further analyses.



Tool a: Set 0 to No Data

This model converts values that are 0 or any other value in a dataset to “no data”. The value to be converted into “no data” can be selected in the SQL expression. E.g. “VALUE” = 0 if the value to be converted is 0.



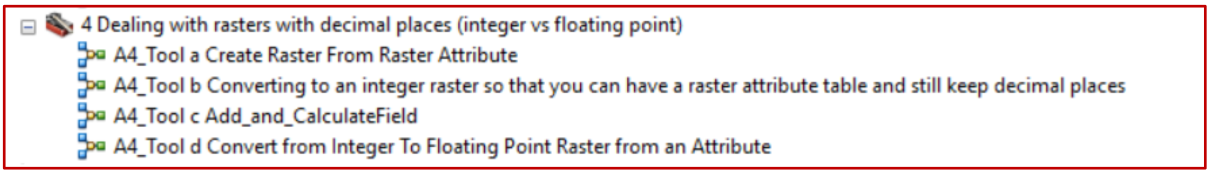
Tool b: Convert No Data values to 0 or other values

This model converts cells with “no data” value in a dataset to a chosen value (e.g. 0 or -999).

The expression takes a dataset e.g pa_pan and converts no data values to 0 and leaves the rest the same as they were in the original dataset.

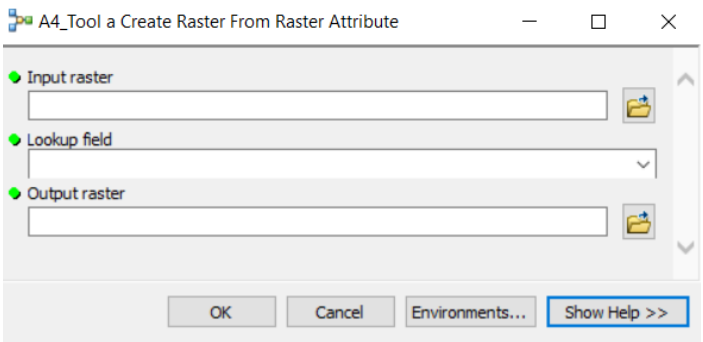
Con(IsNull(”pa_pan”),0,”pa_pan”)

A.4. Dealing with raster with decimal places (integer vs floating point)

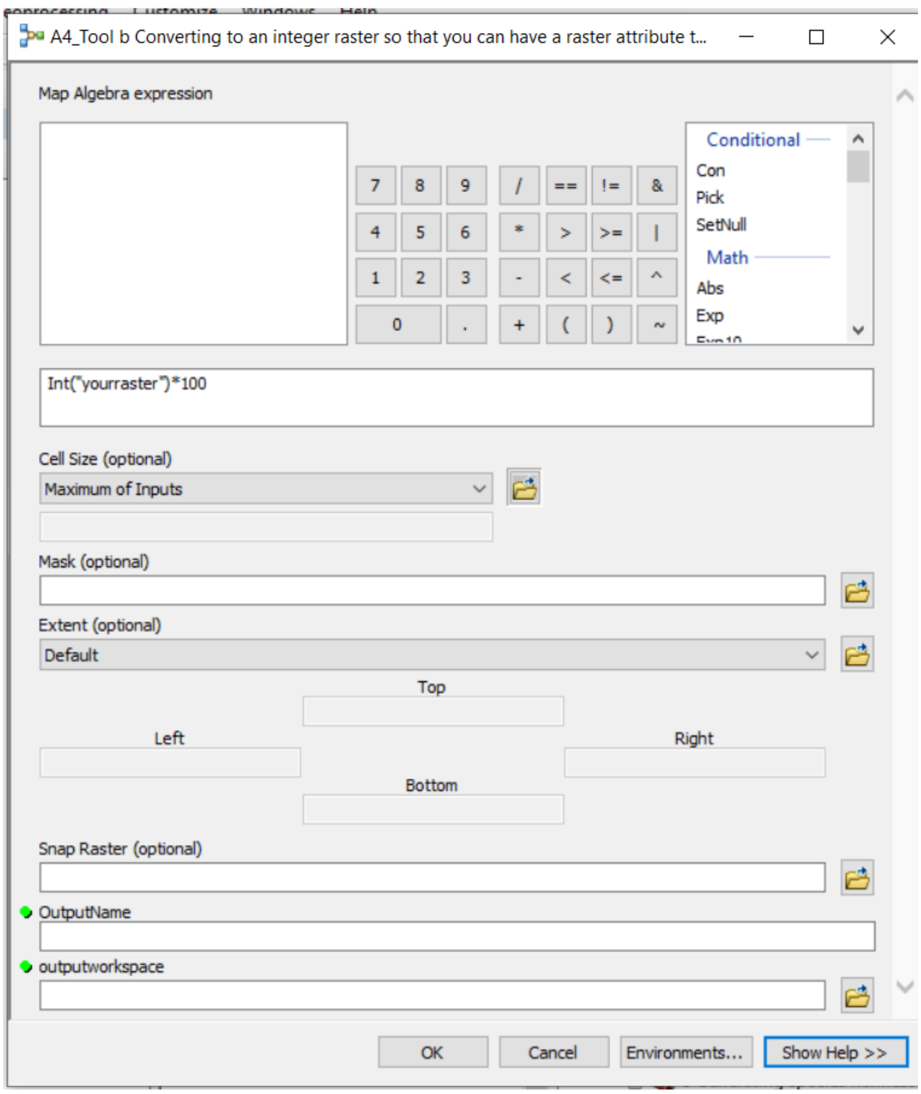


Tool a: Create Raster from Raster Attribute

The model simply generates a new raster dataset using an attribute field from an input raster.



Tool b: Converting to an integer raster so that you can have a raster attribute table and still keep decimal places

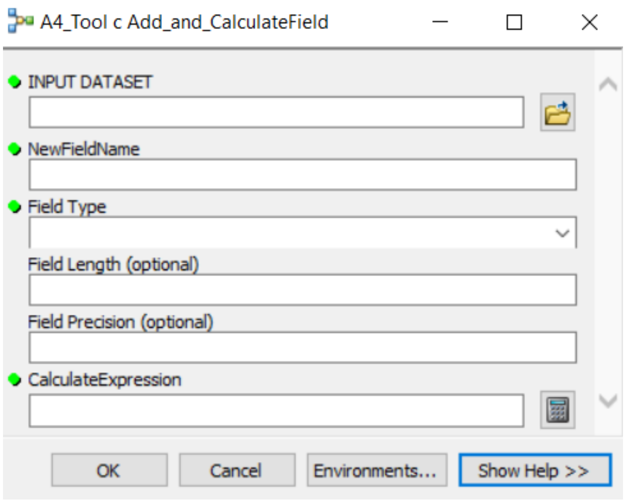


Floating point raster is not suitable for use in this analysis; however, some datasets are floating points (because they need decimal places e.g. a population density raster). This means for use in this analysis they need to be converted from a floating point into an integer raster. This model will multiply the values in the floating point raster by a factor of 10 to keep 1 decimal place, 100 for 2 decimal places, 100 for 3 decimal places etc.

Example syntax:
INT([yourraster] * 100)

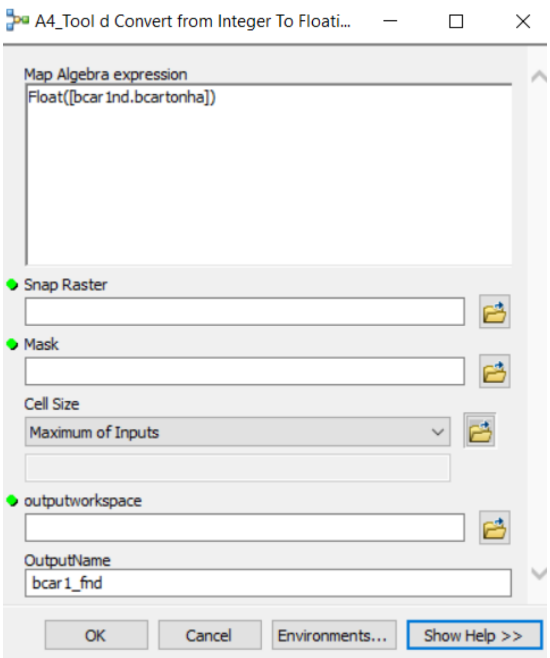
Tool c: Add and calculate field

This model adds a new field and calculates its value according to the SQL expression entered.

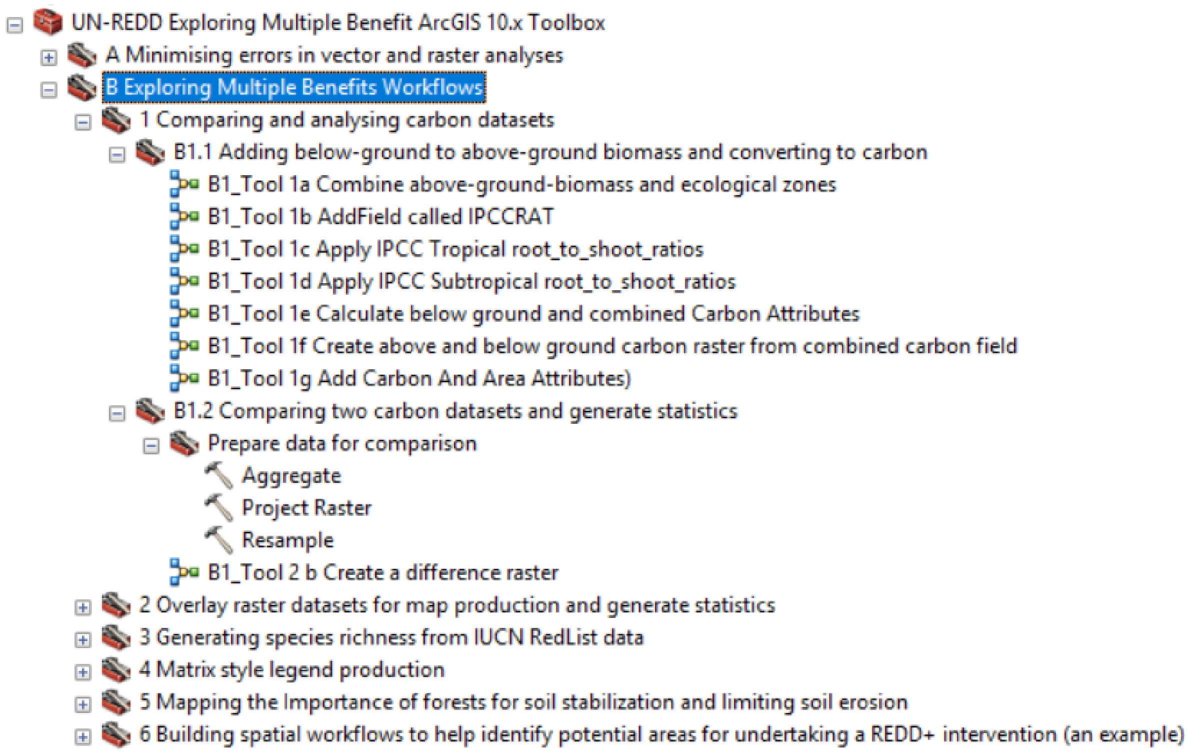


Tool d: Convert from integer to floating point raster from an attribute table

This model creates a floating point raster from a raster attribute. Although floating point raster is not suitable for use in MOST of this analysis. There are some occasions during the analysis that where a floating point raster is necessary to run a particular function.



B. Exploring Multiple Benefits Workflows



B.1. Comparing and analysing carbon datasets

B.1.1. Adding below-ground to above-ground biomass and converting to carbon

This workflow is for adding below-ground to above-ground biomass and converting to carbon.

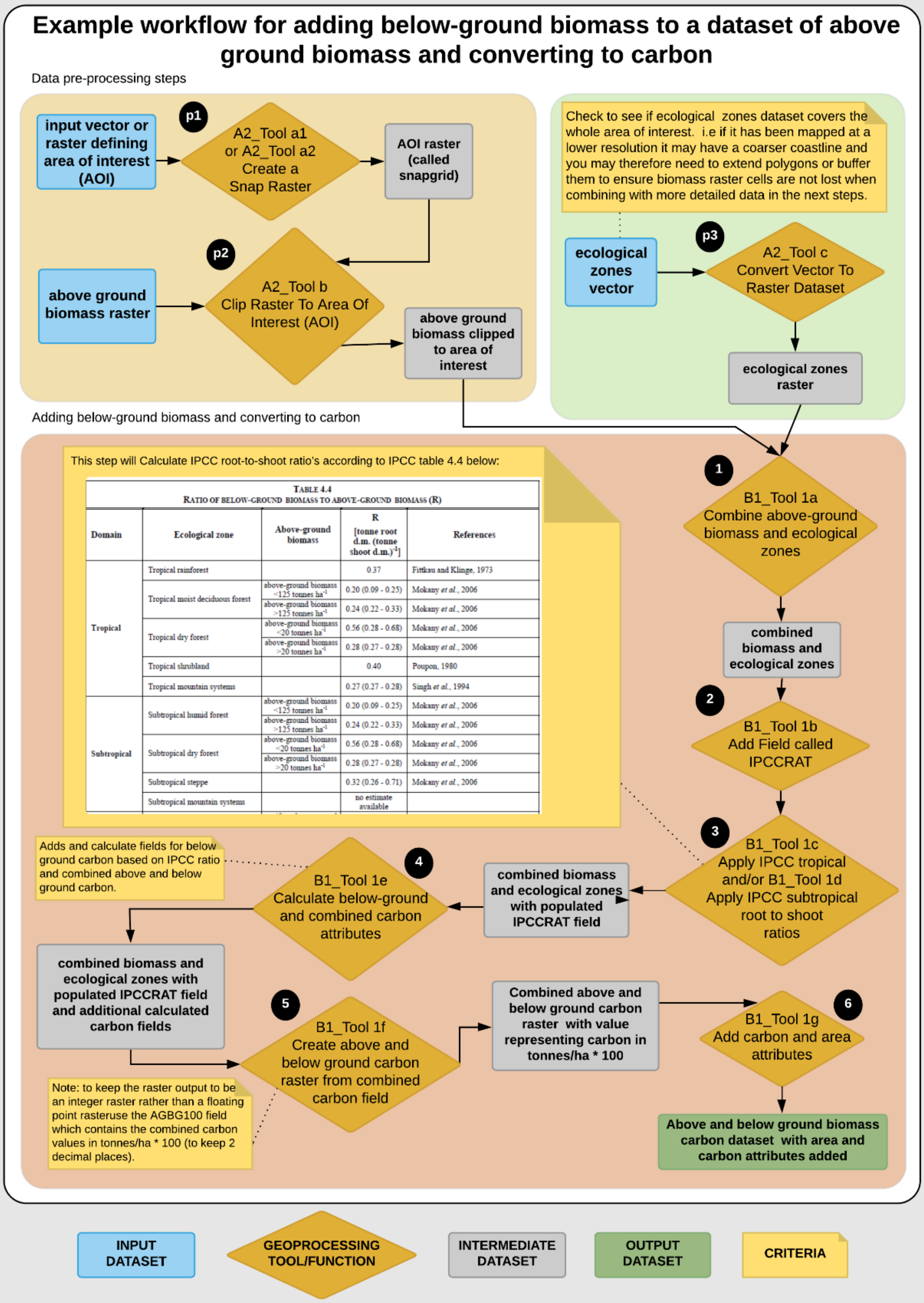


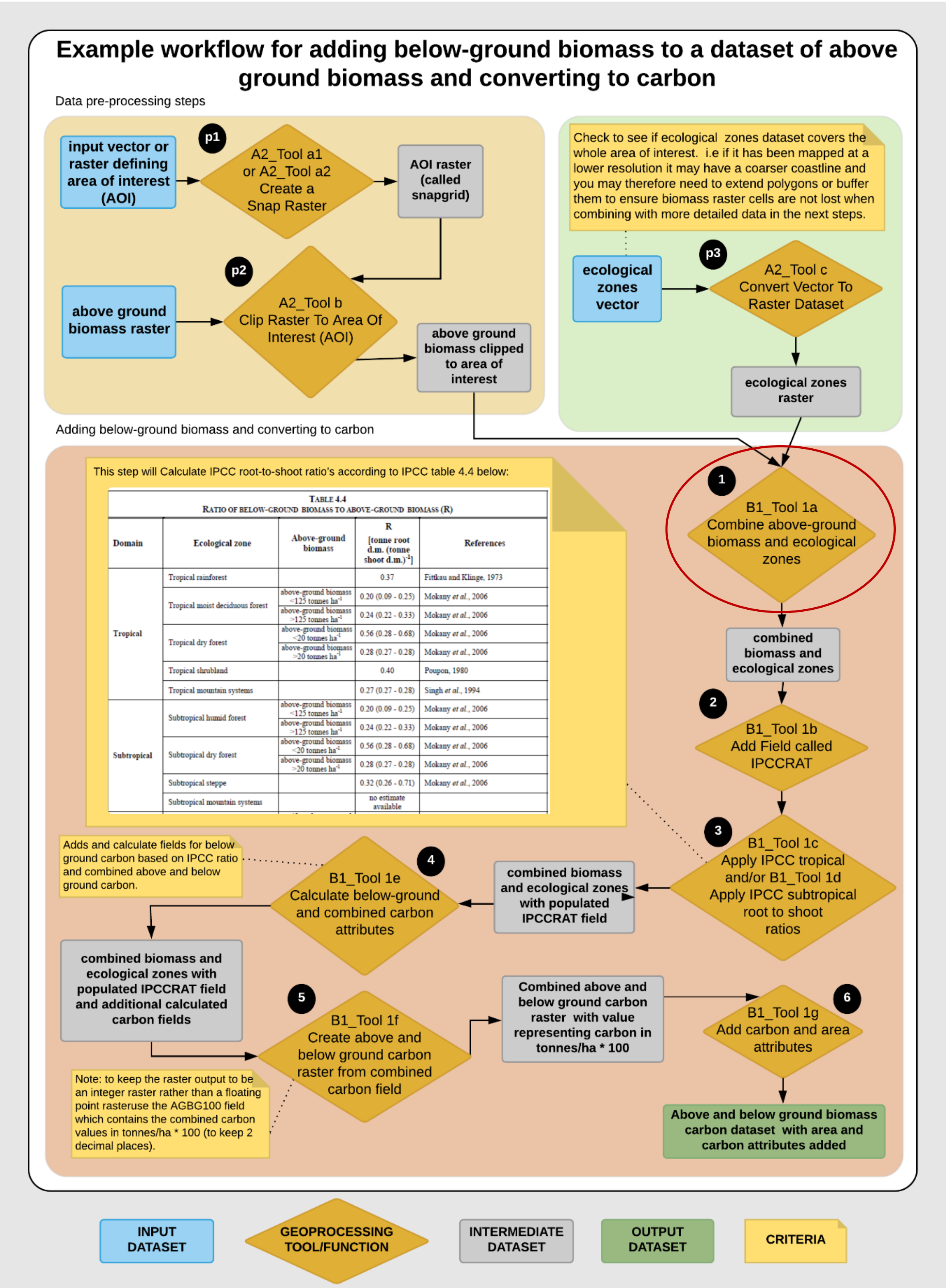
TABLE 4.4
RATIO OF BELOW-GROUND BIOMASS TO ABOVE-GROUND BIOMASS (R)

Domain	Ecological zone	Above-ground biomass	R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]	References
Tropical	Tropical rainforest		0.37	Fittkau and Klinge, 1973
	Tropical moist deciduous forest	above-ground biomass <125 tonnes ha^{-1}	0.20 (0.09 - 0.25)	Mokany *et al.*, 2006
		above-ground biomass >125 tonnes ha^{-1}	0.24 (0.22 - 0.33)	Mokany *et al.*, 2006
	Tropical dry forest	above-ground biomass <20 tonnes ha^{-1}	0.56 (0.28 - 0.68)	Mokany *et al.*, 2006
		above-ground biomass >20 tonnes ha^{-1}	0.28 (0.27 - 0.28)	Mokany *et al.*, 2006
	Tropical shrubland		0.40	Poupon, 1980
	Tropical mountain systems		0.27 (0.27 - 0.28)	Singh *et al.*, 1994
Subtropical	Subtropical humid forest	above-ground biomass <125 tonnes ha^{-1}	0.20 (0.09 - 0.25)	Mokany *et al.*, 2006
		above-ground biomass >125 tonnes ha^{-1}	0.24 (0.22 - 0.33)	Mokany *et al.*, 2006
	Subtropical dry forest	above-ground biomass <20 tonnes ha^{-1}	0.56 (0.28 - 0.68)	Mokany *et al.*, 2006
		above-ground biomass >20 tonnes ha^{-1}	0.28 (0.27 - 0.28)	Mokany *et al.*, 2006
	Subtropical steppe		0.32 (0.26 - 0.71)	Mokany *et al.*, 2006
	Subtropical mountain systems		no estimate available	

Note: if using this workflow for temperate and boreal zones, the root to shoot values can be found in the full IPCC table (Table 4.4) accessed at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

Tool 1a: Combine above-ground biomass and ecological zones

This tool (highlighted in the red circle on the illustration below) is the first step in a workflow for adding below-ground to above-ground biomass and converting to carbon.



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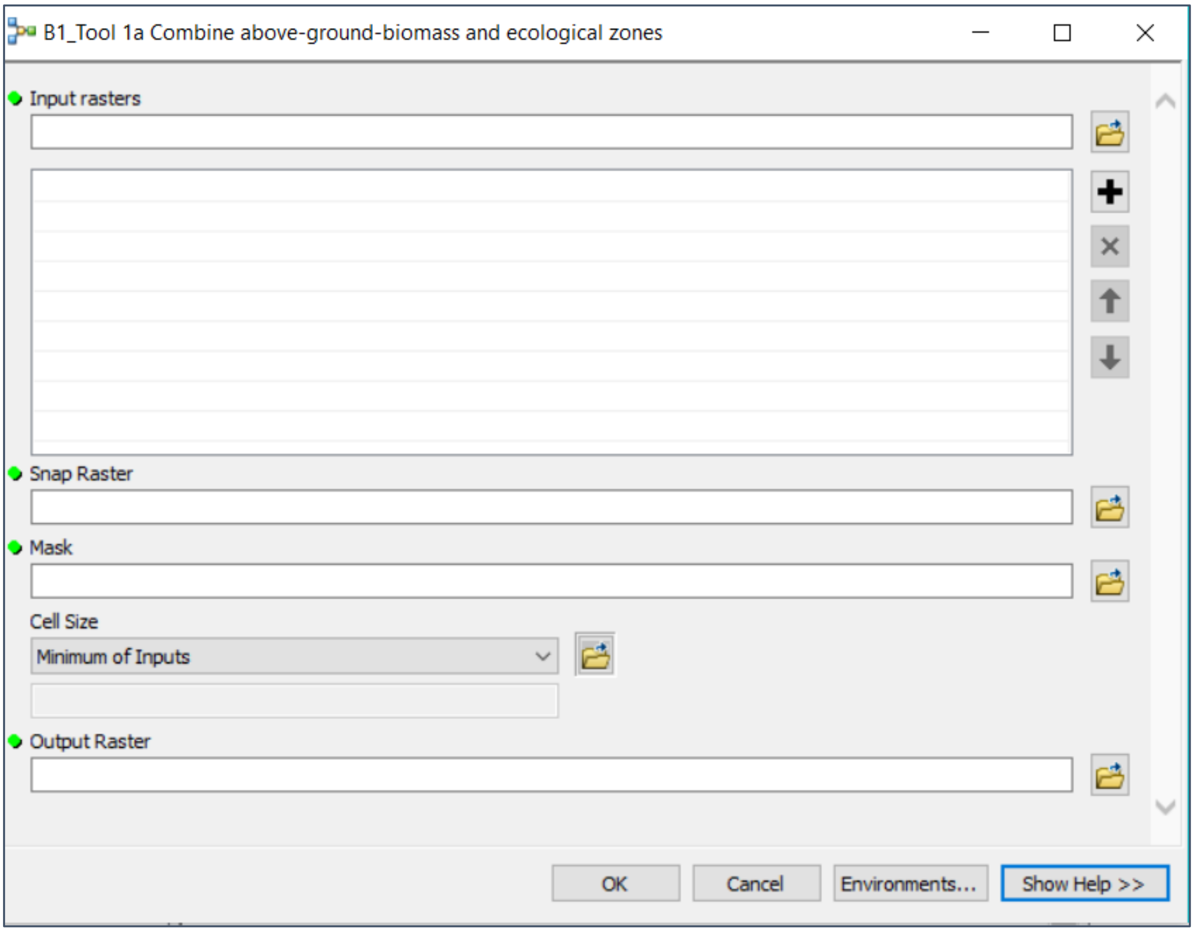
The tool undertakes the following step:

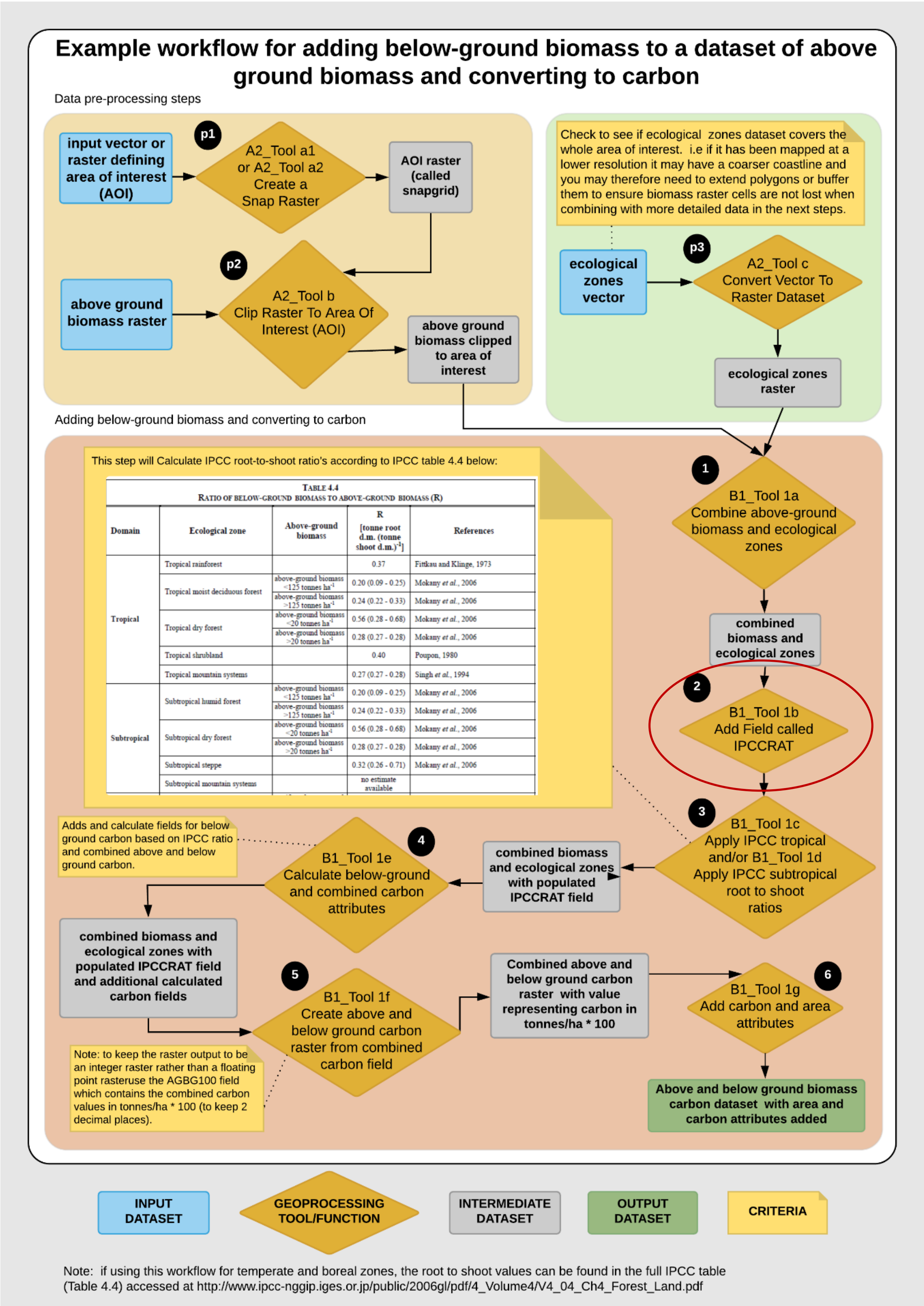
- Combines two input rasters (an above-ground biomass raster with an ecological zone raster) to produce an output dataset containing a unique combination of the inputs. The output raster contains a VALUE and COUNT field and VALUE fields from the input datasets which are given the name of the input datasets

Note: Before running this model, ensure that the pre-processing steps have been run. After running the model check the Output Raster in ArcMap. The combine function used in this step will only keep the Value and Fields from the Raster datasets being combined.



Tool 1b: Add field called IPCCRAT

This tool (highlighted in the red circle on the illustration below) is the second step in a workflow for adding below-ground to above-ground biomass and converting to carbon.



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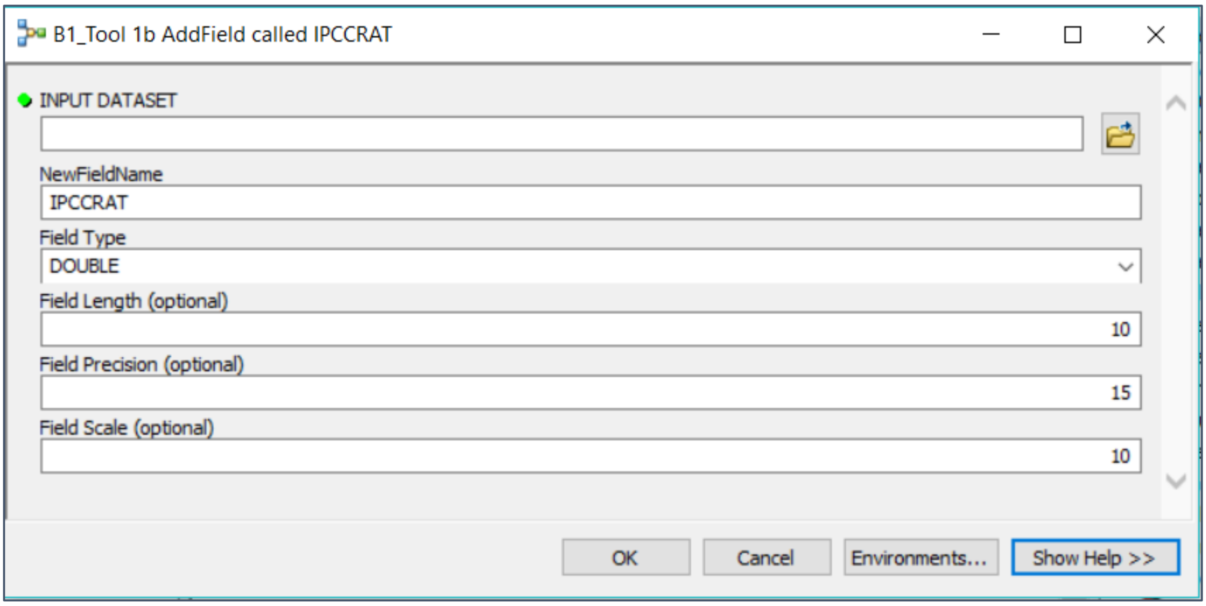
		above-ground biomass >125 tonnes ha^{-1}	0.24 (0.22 - 0.33)	Mokany *et al.*, 2006
	Subtropical dry forest	above-ground biomass <20 tonnes ha^{-1}	0.56 (0.28 - 0.68)	Mokany *et al.*, 2006
		above-ground biomass >20 tonnes ha^{-1}	0.28 (0.27 - 0.28)	Mokany *et al.*, 2006
	Subtropical steppe		0.32 (0.26 - 0.71)	Mokany *et al.*, 2006
	Subtropical mountain systems		no estimate available	

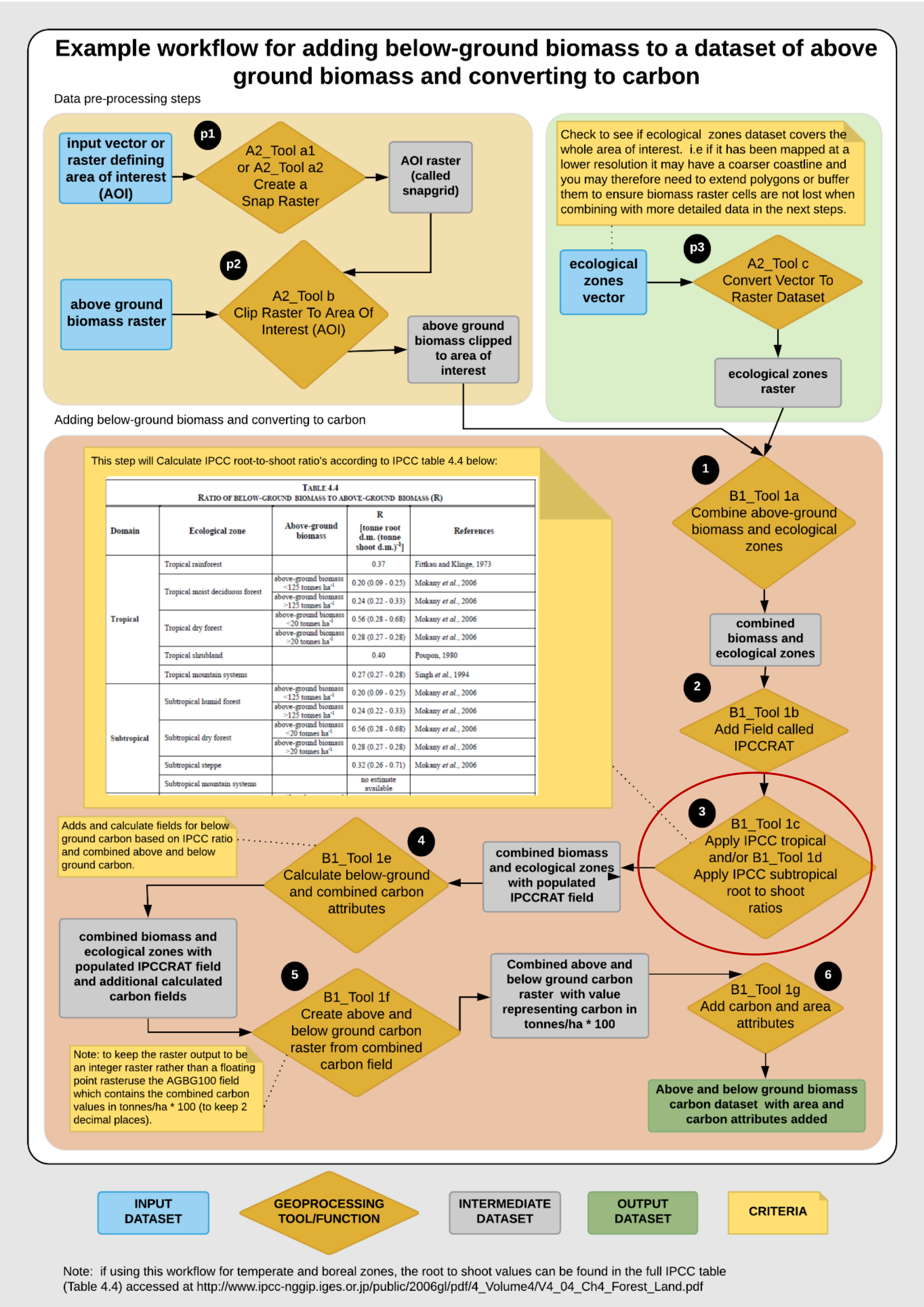
B1_Tool 1b AddField called IPCCRATis highlighted in the red circle on the illustration below and undertakes the following step:

➢ Adds a fieldof type doublecalled IPCCRAT.



Tool 1c and 1d: Apply IPCC (sub-)tropical root to shoot ratios

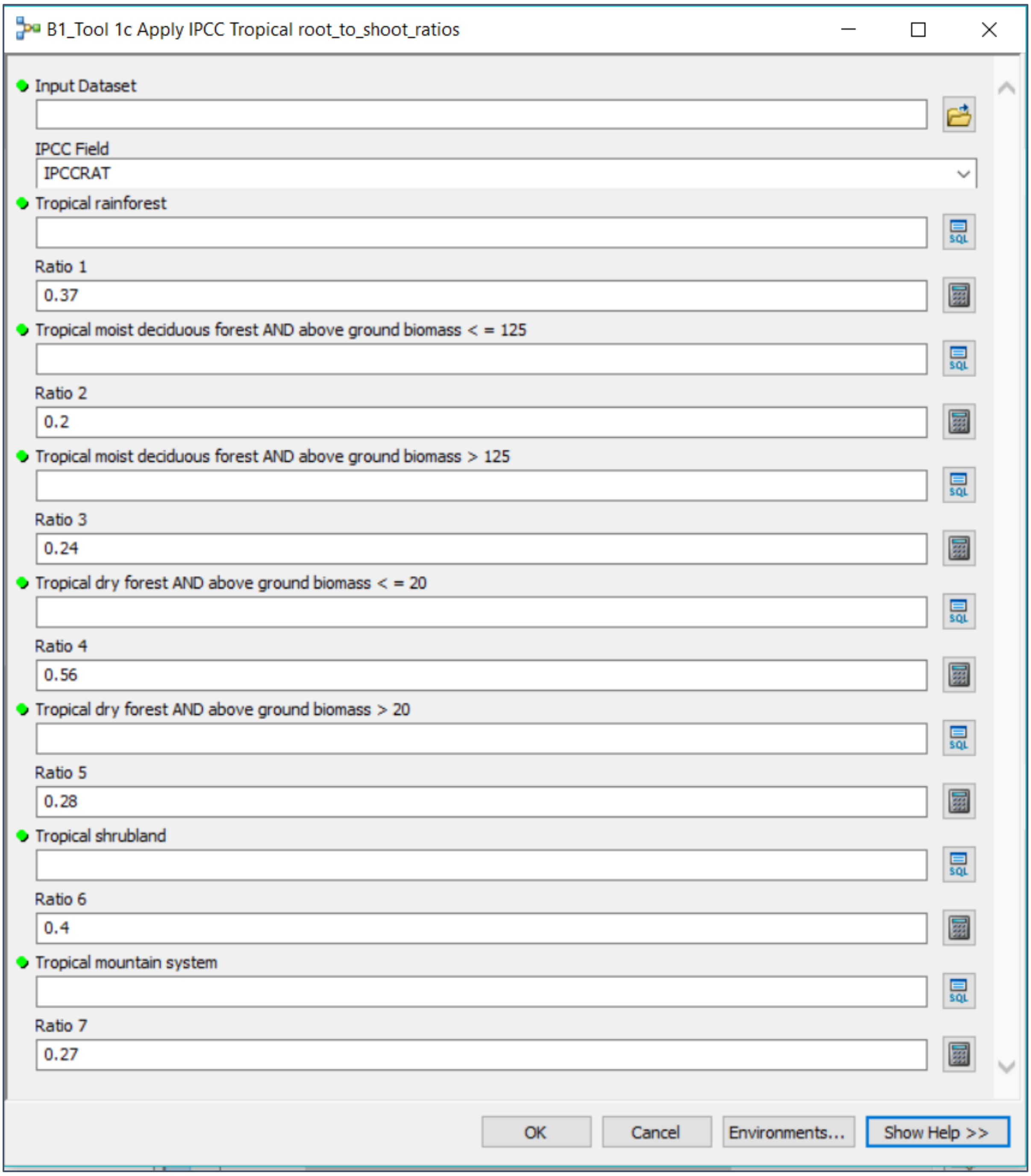
Tools 1c and 1d (highlighted in the red circle on the illustration below) are the third step in a workflow for adding below-ground to above-ground biomass and converting to carbon.

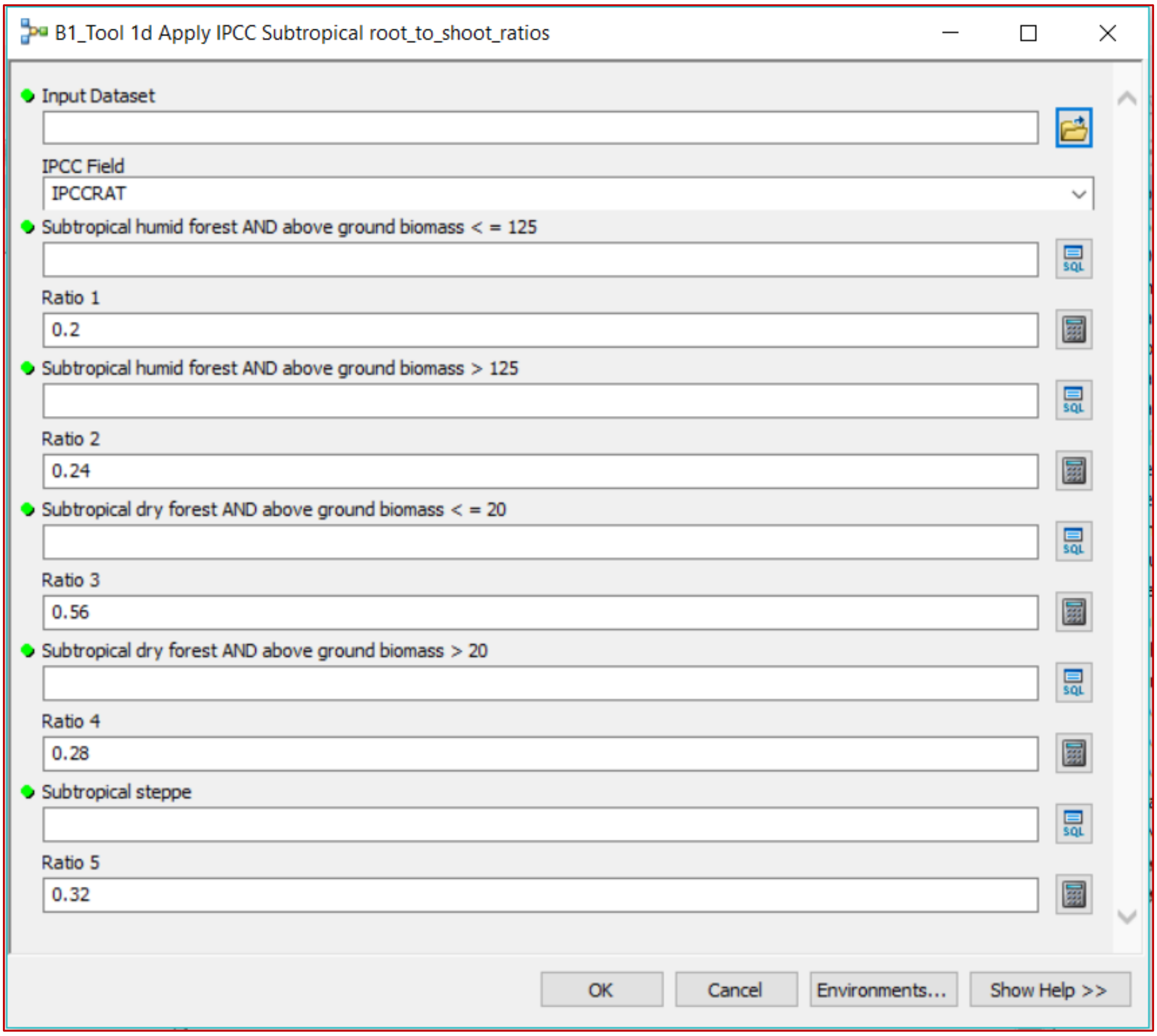


These tool undertakes the following step:

- Populates a field called IPCCRAT according to the root-to-shoot ratios for each tropical and sub-tropical ecological zone as defined by IPCC. This will enable below-ground biomass to be calculated from an above-ground biomass dataset.

Note: Before running this tool check to see which ecological zones are covered by the study area. Run this tool if the study area is within or partially within the tropical zones.




B1_Tool 1d Apply IPCC Subtropical root_to_shoot_ratios
Input Dataset
IPCC Field
IPCCRAT
Subtropical humid forest AND above ground biomass < = 125
Ratio 1
0.2
Subtropical humid forest AND above ground biomass > 125
Ratio 2
0.24
Subtropical dry forest AND above ground biomass < = 20
Ratio 3
0.56
Subtropical dry forest AND above ground biomass > 20
Ratio 4
0.28
Subtropical steppe
Ratio 5
0.32
OK
Cancel
Environments...
Show Help >>

Tool 1e: Calculate below ground and combined carbon attributes

This tool (highlighted in the red circle on the illustration below) is the fourth step in a workflow for adding below-ground to above-ground biomass and converting to carbon.

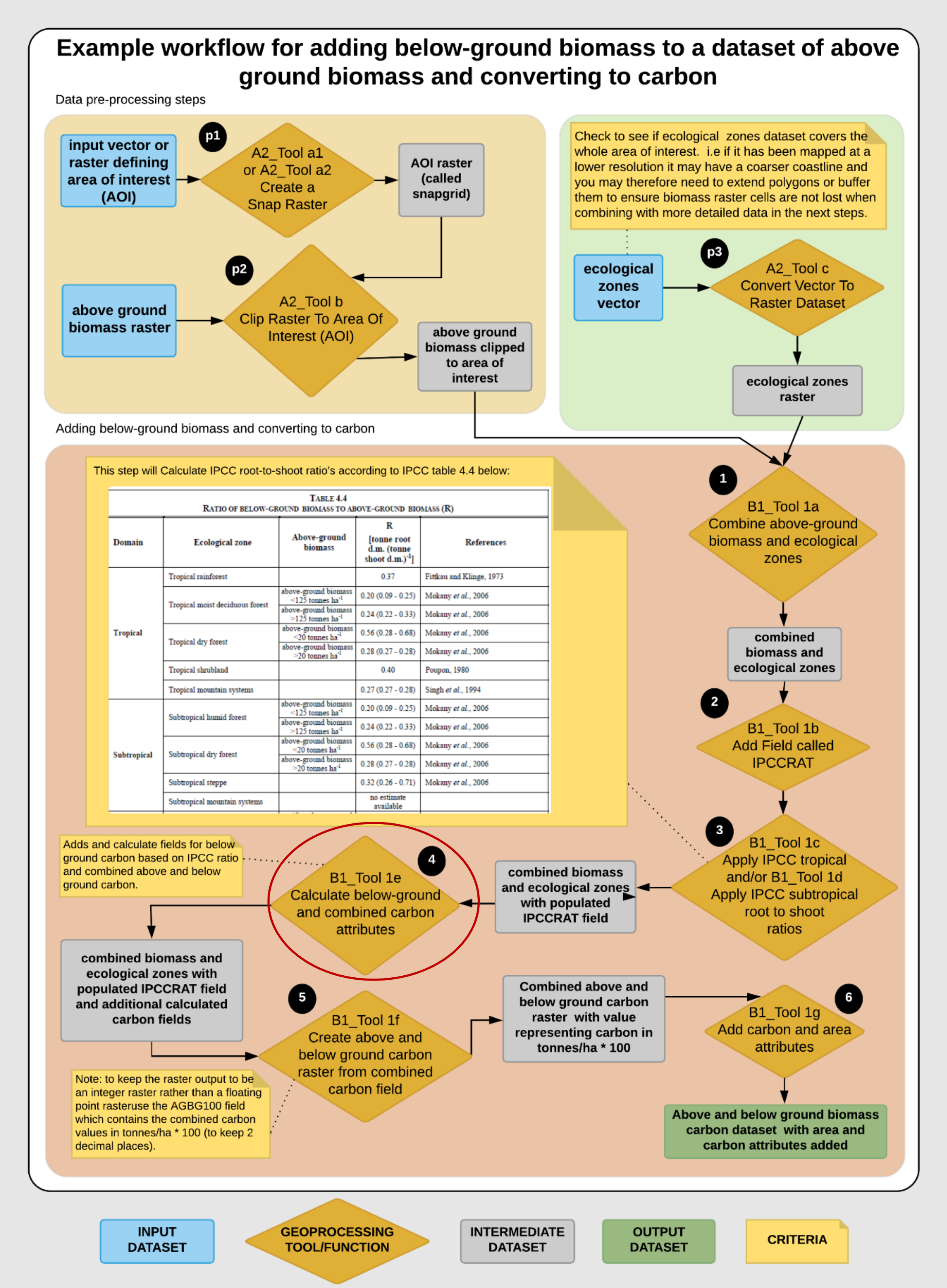
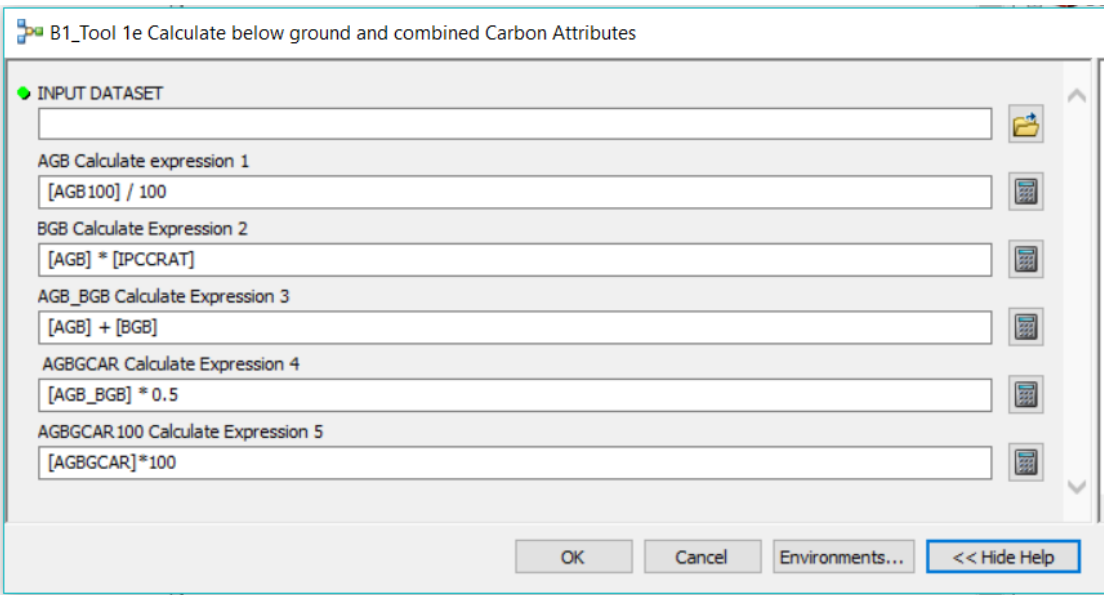


TABLE 4.4
RATIO OF BELOW-GROUND BIOMASS TO ABOVE-GROUND BIOMASS (R)

Domain	Ecological zone	Above-ground biomass	R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]	References
Tropical	Tropical rainforest		0.37	Fittkau and Klinge, 1973
	Tropical moist deciduous forest	above-ground biomass <125 tonnes ha^{-1}	0.20 (0.09 - 0.25)	Mokany *et al.*, 2006
		above-ground biomass >125 tonnes ha^{-1}	0.24 (0.22 - 0.33)	Mokany *et al.*, 2006
	Tropical dry forest	above-ground biomass <20 tonnes ha^{-1}	0.56 (0.28 - 0.68)	Mokany *et al.*, 2006
		above-ground biomass >20 tonnes ha^{-1}	0.28 (0.27 - 0.28)	Mokany *et al.*, 2006
	Tropical shrubland		0.40	Poupon, 1980
	Tropical mountain systems		0.27 (0.27 - 0.28)	Singh *et al.*, 1994
Subtropical	Subtropical humid forest	above-ground biomass <125 tonnes ha^{-1}	0.20 (0.09 - 0.25)	Mokany *et al.*, 2006
		above-ground biomass >125 tonnes ha^{-1}	0.24 (0.22 - 0.33)	Mokany *et al.*, 2006
	Subtropical dry forest	above-ground biomass <20 tonnes ha^{-1}	0.56 (0.28 - 0.68)	Mokany *et al.*, 2006
		above-ground biomass >20 tonnes ha^{-1}	0.28 (0.27 - 0.28)	Mokany *et al.*, 2006
	Subtropical steppe		0.32 (0.26 - 0.71)	Mokany *et al.*, 2006
	Subtropical mountain systems		no estimate available	

Note: if using this workflow for temperate and boreal zones, the root to shoot values can be found in the full IPCC table (Table 4.4) accessed at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

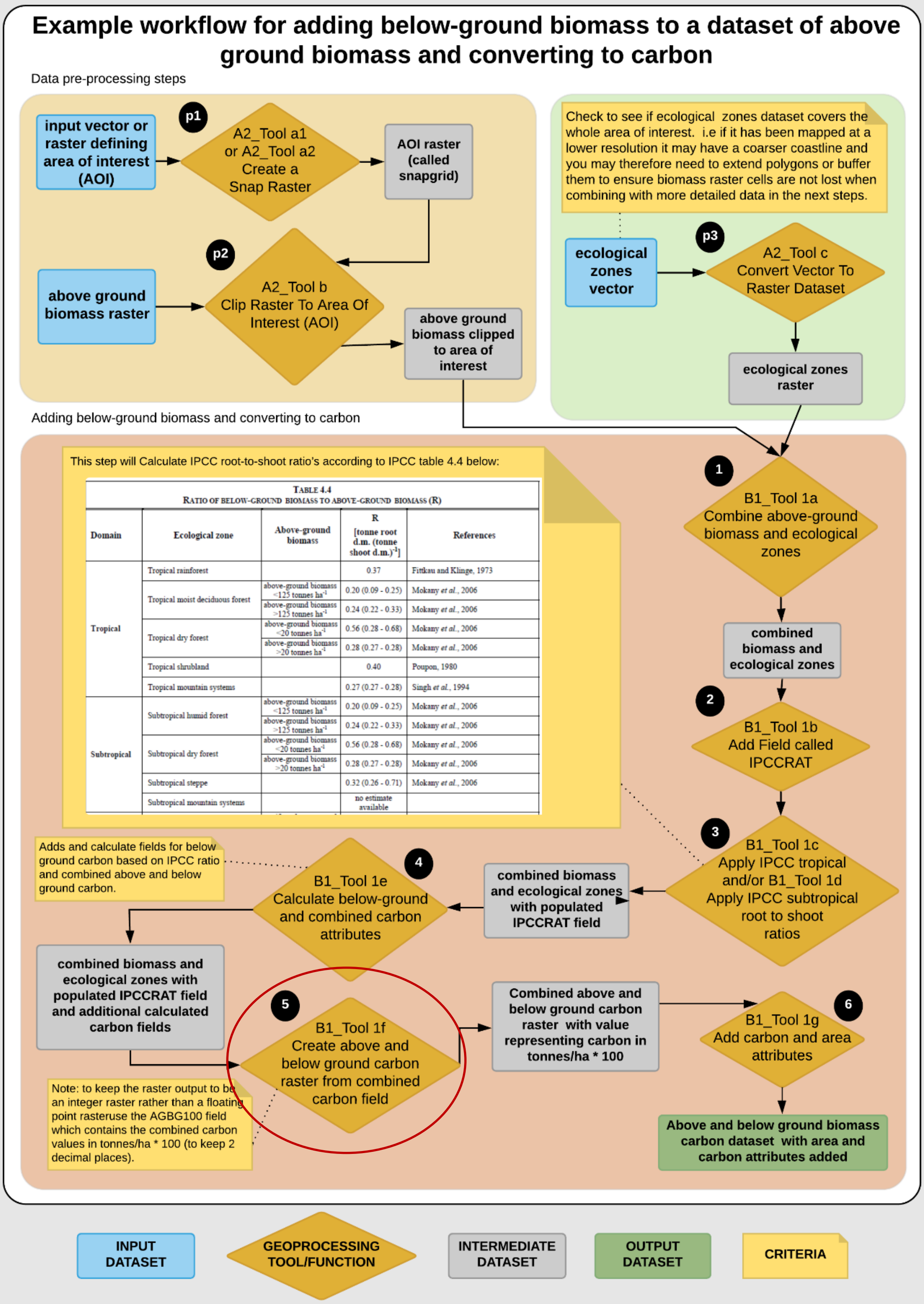
This tool undertakes the following step:

- Adds carbon attribute fields to the combined carbon and ecological zones dataset . The model adds and calculates an above ground biomass field (AGB). a below ground biomass field (BGB), a combined above and below ground biomass field (AGB_BGB), a combined aboveground and below ground carbon field (AGBGCAR) and a combined above ground and below ground carbon field with units in tonnes/ha *100 (AGBGCAR100).
- 

-

Tool 1f: Create above and below ground carbon raster from combined carbon field

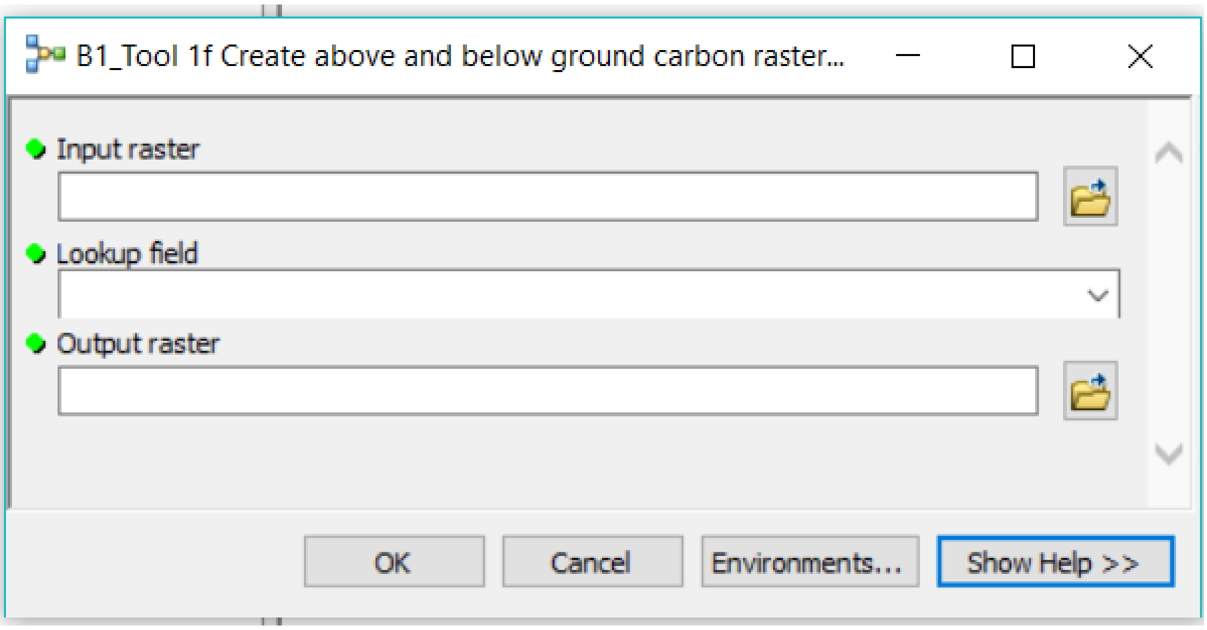
This tool (highlighted in the red circle on the illustration below) is the sixth step in a workflow for adding below-ground to above-ground biomass and converting to carbon.



Note: if using this workflow for temperate and boreal zones, the root to shoot values can be found in the full IPCC table (Table 4.4) accessed at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

This tool undertakes the following step:

- Creates a combined above and below ground biomass carbon dataset from the AGBGCAR100 field added in the previous step.



Tool 1g: Add carbon and area attributes

This tool (highlighted in the red circle on the illustration below) is the last step in a workflow for adding below-ground to above-ground biomass and converting to carbon.

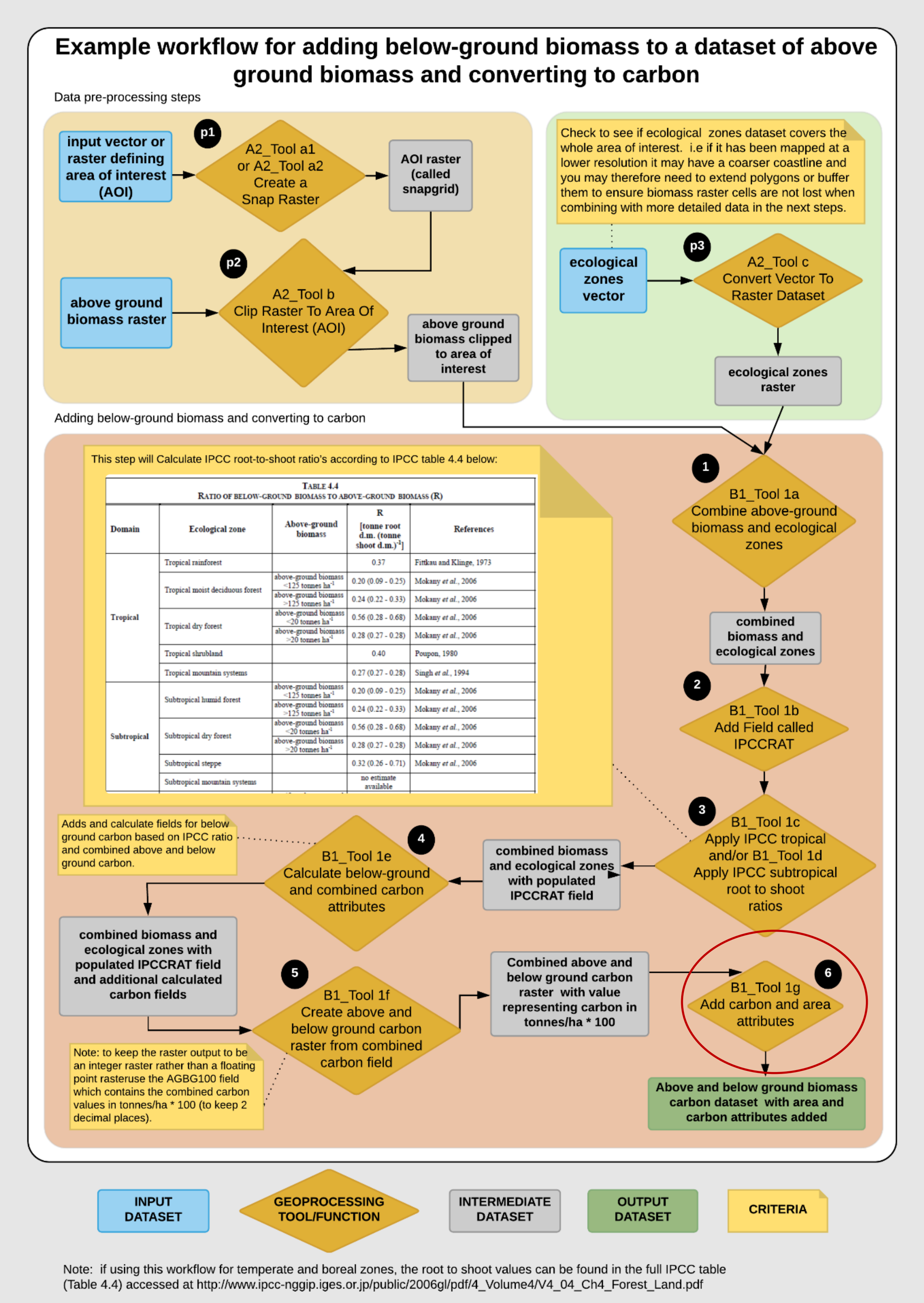


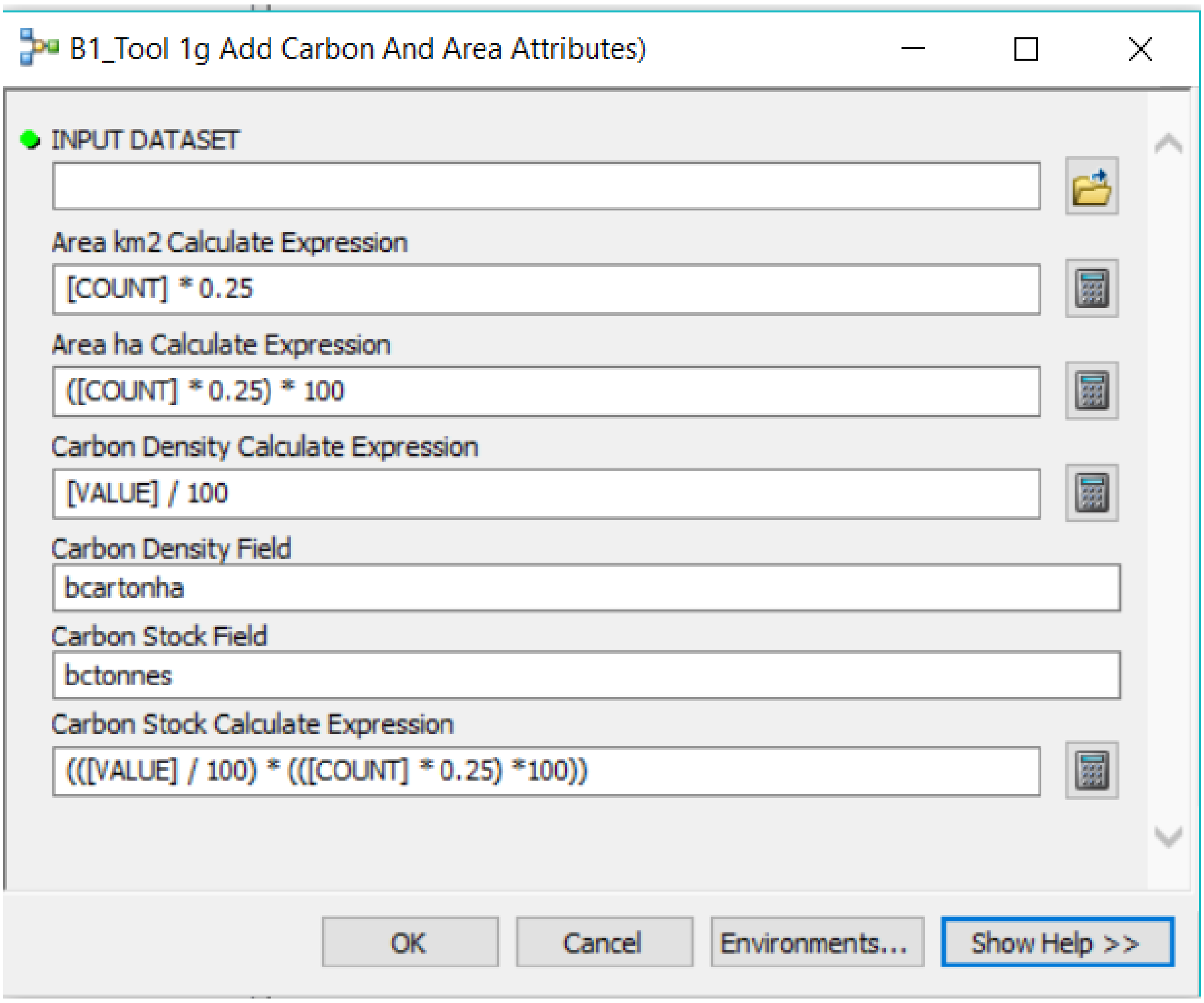
TABLE 4.4
RATIO OF BELOW-GROUND BIOMASS TO ABOVE-GROUND BIOMASS (R)

Domain	Ecological zone	Above-ground biomass	R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]	References
Tropical	Tropical rainforest		0.37	Fittkau and Klinge, 1973
	Tropical moist deciduous forest	above-ground biomass <125 tonnes ha^{-1}	0.20 (0.09 - 0.25)	Mokany *et al.*, 2006
		above-ground biomass >125 tonnes ha^{-1}	0.24 (0.22 - 0.33)	Mokany *et al.*, 2006
	Tropical dry forest	above-ground biomass <20 tonnes ha^{-1}	0.56 (0.28 - 0.68)	Mokany *et al.*, 2006
		above-ground biomass >20 tonnes ha^{-1}	0.28 (0.27 - 0.28)	Mokany *et al.*, 2006
	Tropical shrubland		0.40	Poupon, 1980
	Tropical mountain systems		0.27 (0.27 - 0.28)	Singh *et al.*, 1994
Subtropical	Subtropical humid forest	above-ground biomass <125 tonnes ha^{-1}	0.20 (0.09 - 0.25)	Mokany *et al.*, 2006
		above-ground biomass >125 tonnes ha^{-1}	0.24 (0.22 - 0.33)	Mokany *et al.*, 2006
	Subtropical dry forest	above-ground biomass <20 tonnes ha^{-1}	0.56 (0.28 - 0.68)	Mokany *et al.*, 2006
		above-ground biomass >20 tonnes ha^{-1}	0.28 (0.27 - 0.28)	Mokany *et al.*, 2006
	Subtropical steppe		0.32 (0.26 - 0.71)	Mokany *et al.*, 2006
	Subtropical mountain systems		no estimate available	

This tool undertakes the following step:

- adds new fields to the input carbon dataset for which value is carbon in tonnes/ha * 100.The following fields are added and calculated: area in km2, area in ha, carbon in tonnes/haand carbon stock in tonnes.

Note: Remember to change the value in the Area km2, Area ha, and Carbon Stock Calculate expression fields as they use the Count Field to calculate the area based o the cell size. The illustration is for a 0.5km(cell size 500) resolution dataset so the count is multiplied by 0.25



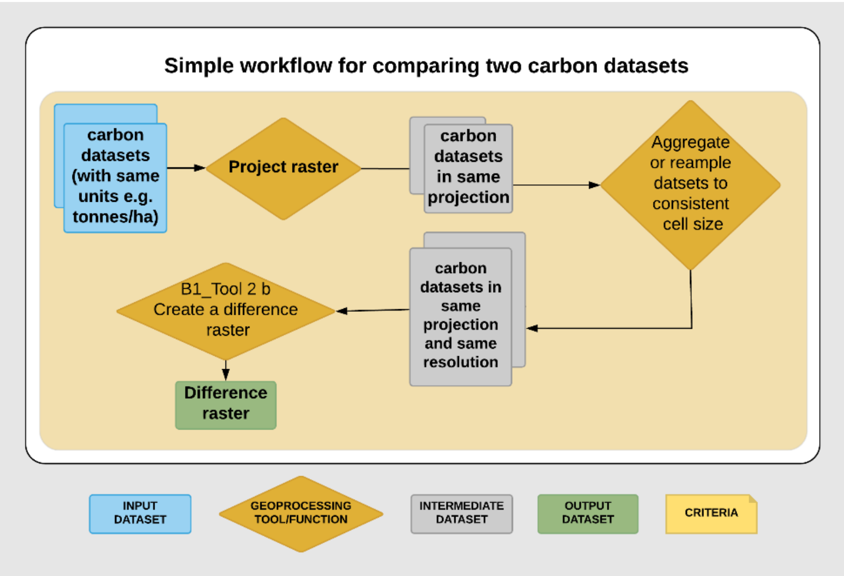
B.1.2. Comparing two carbon datasets and generate statistics.

When more than one carbon dataset is available it is useful to compare them to identify both differences in pattern and values. There is a tool available online for comparing carbon datasets at https://carbonmaps.ourecosystem.com/interface/, however there may be times when you need to make comparisons yourself for datasets not included in this tool.

It is important to also bear in mind when comparing datasets that there may be differences in what is actually mapped in terms of the carbon. One may represent just above-ground biomass for example where as another may represent above and below ground biomass. This means that there may be some preparatory work prior to doing the comparisons. Please also see the QGIS tutorial as the annex provides some guidance on understanding and comparing carbon datasets,

See Tutorial: https://www.unredd.net/documents/global-programme-191/multiple-benefits/gis-tools-3403/15773-step-by-step-tutorial-v10-understanding-and-comparing-carbon-datasets-using-qgis-28/file.html

In the Exploring multiple benefits toolbox the basic workflow is presented below:



The first steps are to prepare the data to ensure that the projection, resolution (size of the cells) and extent (geographic boundaries) are the same in both layers.

➢ Project raster to ensure raster datasets are in the same map projection

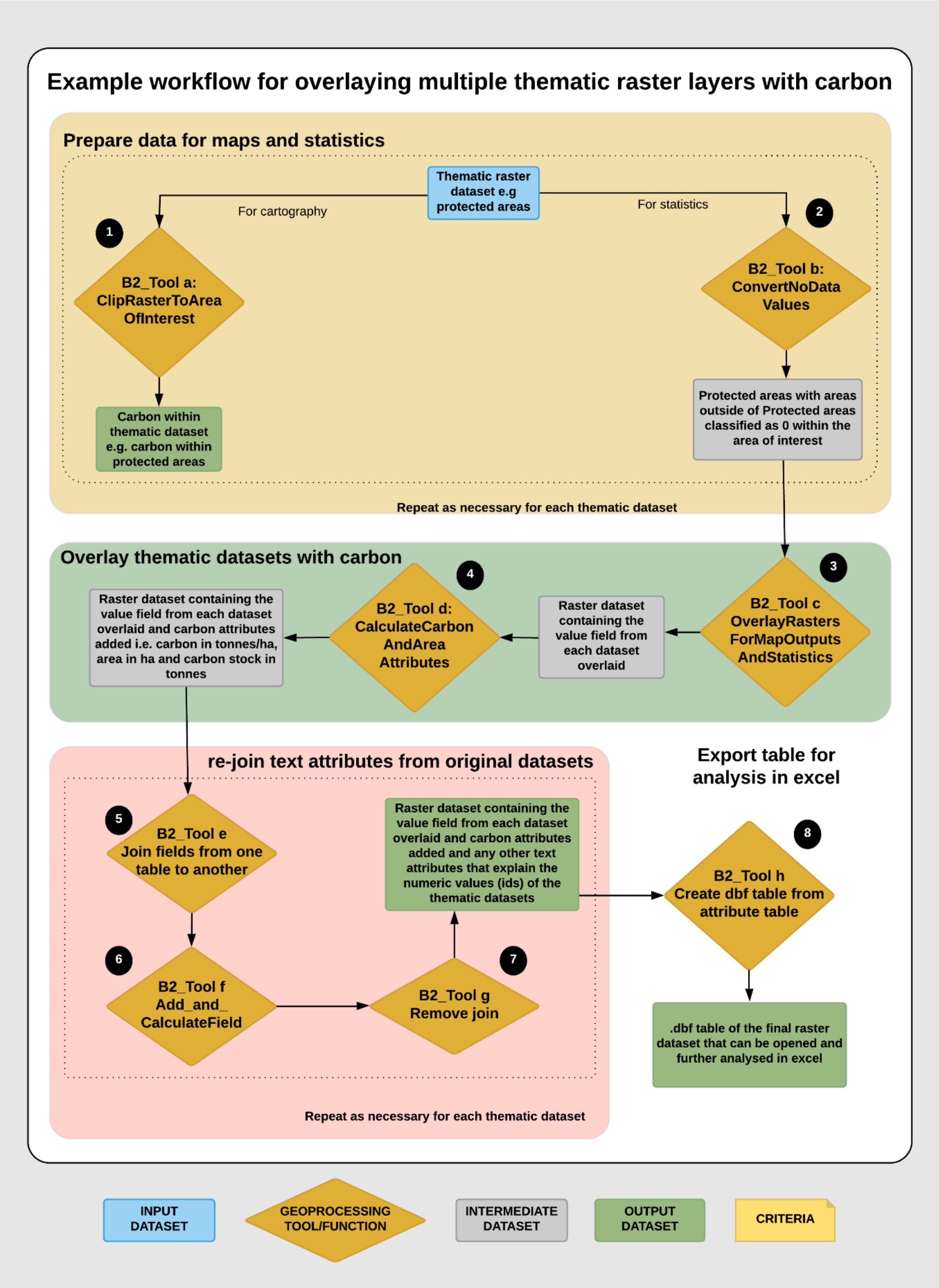
➢ Use Aggregate or Resample to make raster datasets comparable by transforming to the same resolution

To compare the carbon values estimated by the two datasets, a difference map can then be made to graphically see where these estimations agree and disagree. This involves subtract one dataset from another to find the difference using the tool:

- Create a difference raster using Tool 2 b Create a difference raster tool

B.2. Overlay raster datasets for map production and generate statistics

B.2.1. Overlay thematic raster layer with carbon



Tool a Batch Clip Thematic Rasters To Area Of Interest (2)

This model will use a vector or raster mask to clip a dataset to an area of interest.

Tool b Batch Set 0 to No Data In Thematic Rasters (2)

This model converts values that are 0 in a dataset to no data.

Tool c OverlayRastersForMapOutputsAndStatistics (2)

This model combines multiple raster input datasets to produce an output dataset containing a unique combination of the inputs. The output raster contains a VALUE and COUNT field and individual fields for each of the VALUE fields from the input datasets, these fields are given the name of the input datasets

Tool d Calculate Carbon And Area Attributes (2)

This model adds carbon attribute fields to the input carbon dataset for which value is carbon in tonnes/ha * 100. The model adds and calculates an area field in km2, an area field in ha, carbon in ton/ha and carbon stock in tonnes.

Tool e Join fields from one table to another (2)

This model will join on fields from an ‘input’ table (this includes vector and raster attribute tables) to a ‘join’ table based on a common field and create a new dataset containing the permanently add ed fields. The records in the input table are matched to the record in the join table based on the join field and the Input Field when the values are equal.

Tool f Add_and_CalculateField (2)

This model adds a new field and calculates its value according to the SQL expression entered.

Tool g Remove join (2)

This model removed the temporary joins made in the previous steps.

Tool h Create dbf table from attribute table (2)

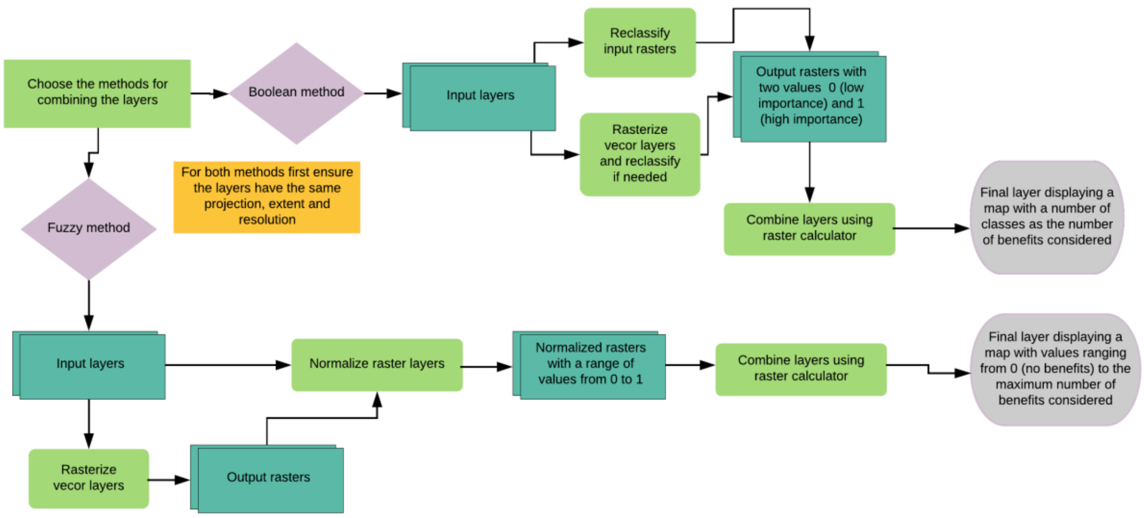
This model will create a new table from an existing table and will only output the selected fields

Tool i Define Class Breaks By Carbon Stock (2)

This model defines class breaks for a carbon dataset based on the carbon stock (in tonnes) rather than by area covered by a particular carbon density class. ArcGIS cannot do this automatically. The model adds and calculates fields called cumstk (cumulative stock) and stkprop (stock proportion) to the carbon dataset. The stkprop field ranges from 0 - 100 so therefore to display the carbon using the carbon density field in tonnes/ha the 5 classes breaks would be at 20, 40, 60, 80 and 100.

B.2.2. Mapping key areas for multiple benefits

Example workflow



Also see QGIS Tutorial available at: https://www.unredd.net/documents/global-programme-191/multiple-benefits/gis-tools-3403/17108-mapping-areas-of-importance-for-multiple-benefits-of-redd-using-qgis-218.html

Tool a Reclassify

This tool is used to reclassify the input rasters before combining them together

Tool b Raster calculator

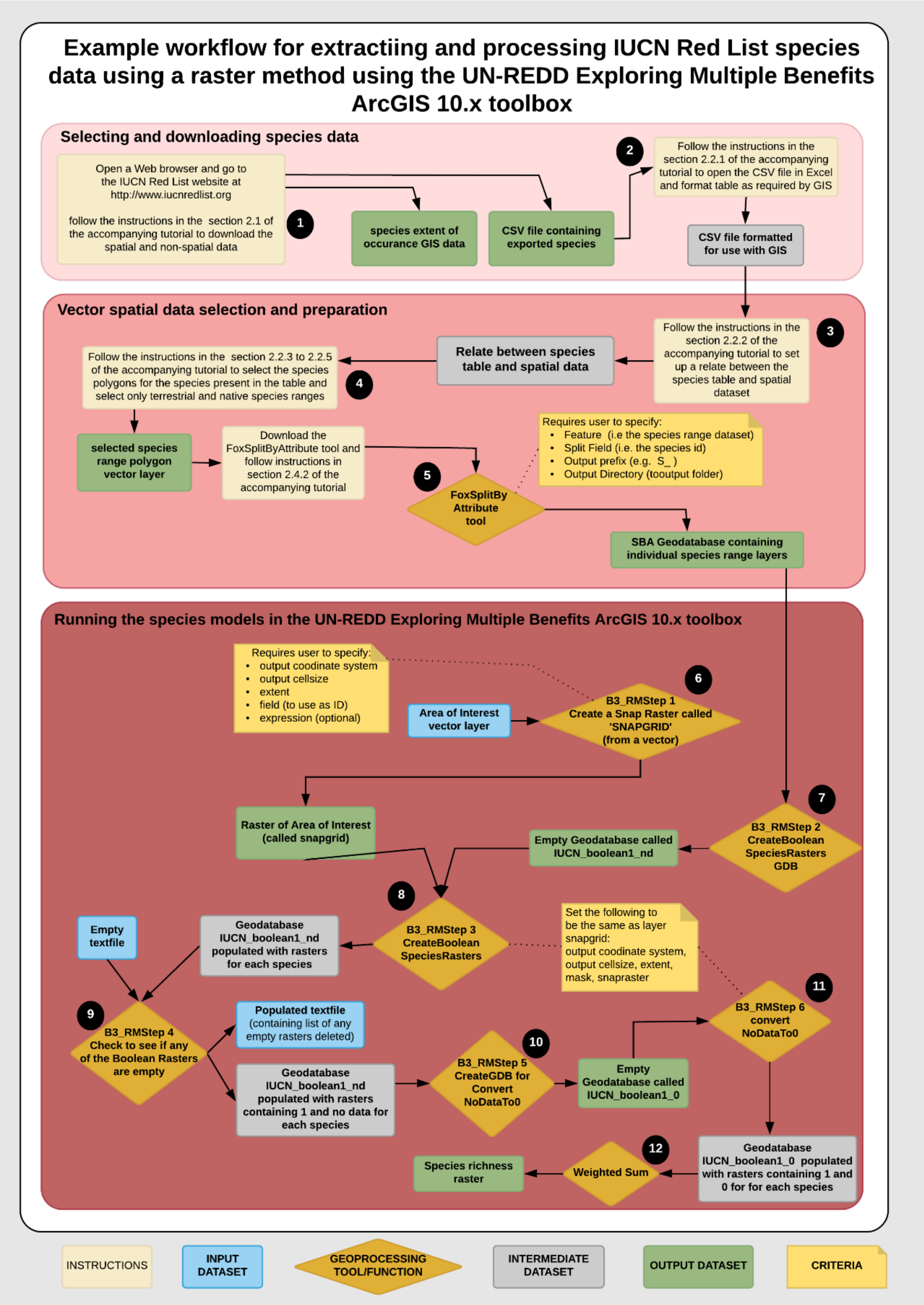
This tool is used to normalise the input rasters and combine rasters together

The QGIS tutorial provides more detailed guidance on the following aspects.

- Mapping areas of importance for multiple benefits
- What data are important for mapping areas of importance for multiple benefits
- Ensure that raster layers have the same extension, projection and resolution
- Combine the benefit layers using a Boolean method
- Symbolize input rasters into discrete class breaks and reclassify
- Rasterise and reclassify input vector benefit layers
- Convert to Raster using a single value
- Convert to Raster using an attribute
- Add Boolean rasters to generate the composite multiple benefits layer
- Combine the benefit layers using a Fuzzy overlay method
- Rasters normalization

B.3. Generating species richness from IUCN RedList data

B.3.1. Raster Method (species richness and rangesize rarity)

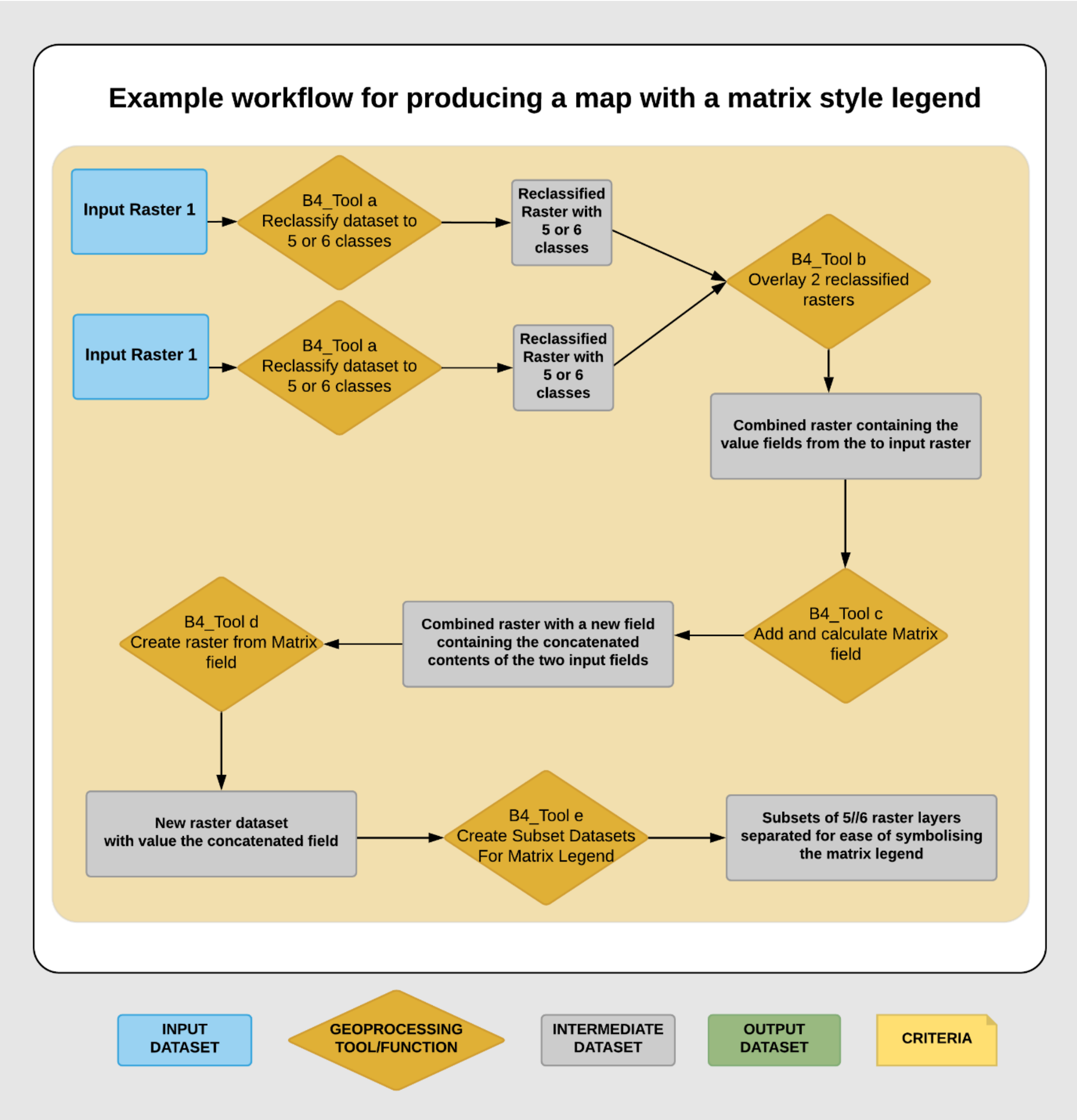


Tutorial available at: https://www.unredd.net/documents/global-programme-191/multiple-benefits/gis-tools-3403/15842-step-by-step-tutorial-v10-extracting-and-processing-iucn-red-list-species-data-using-a-raster-method-using-arcgis-103.html

B.3.2. Vector Method (species richness)

Tutorial available at: https://www.unredd.net/documents/global-programme-191/multiple-benefits/gis-tools-3403/14149-gis-tutorial-6-extracting-and-processing-iucn-red-list-species-data-using-vectors-in-arcgis.html

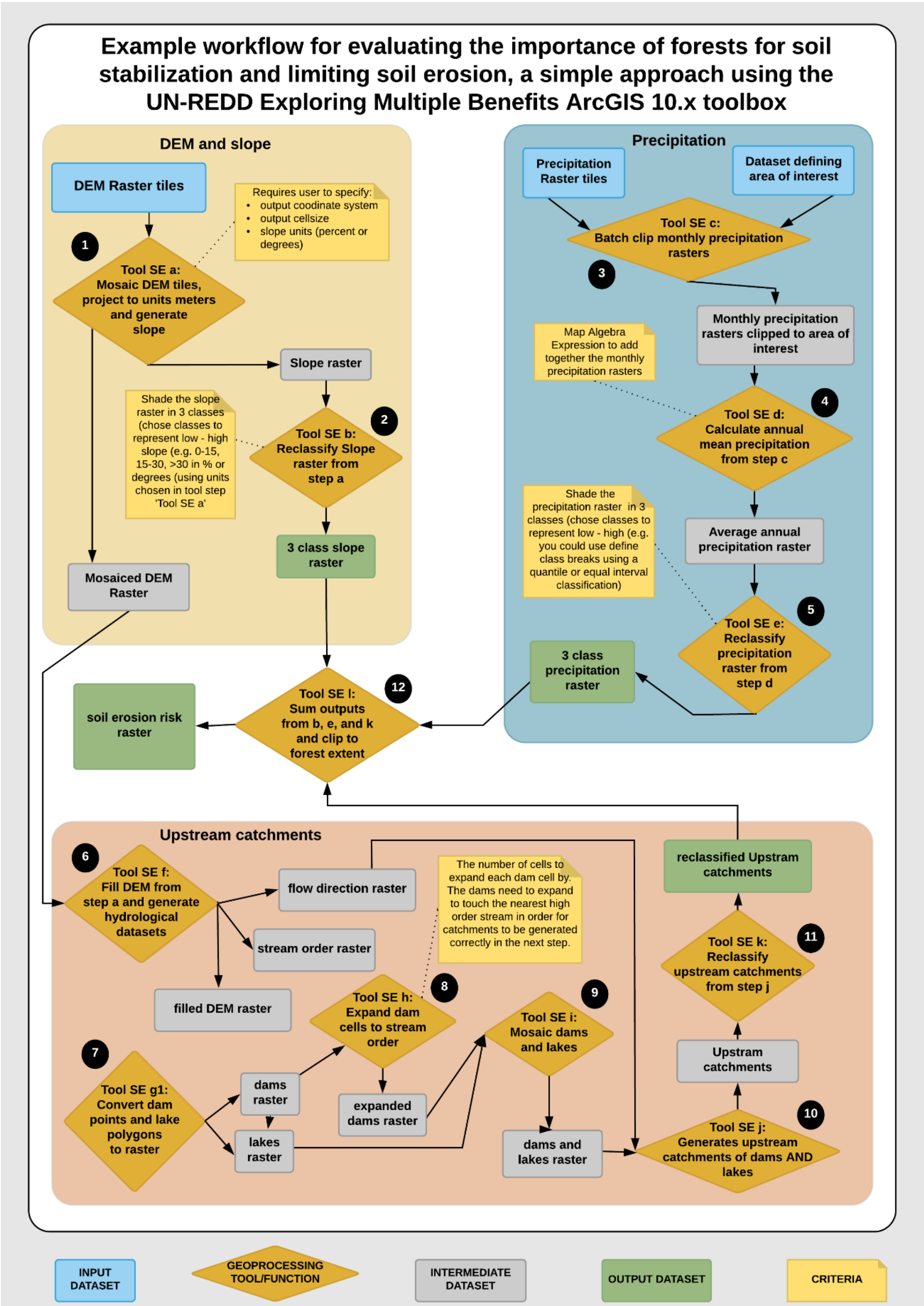
B.4. Matrix style legend production



Tutorial available at: https://www.unredd.net/documents/global-programme-191/multiple-benefits/workshops-and-events-1/1st-joint-working-session-on-spatial-analysis-to-support-the-development-of-prov/15721-gis-tutorial-10-how-to-produce-a-matrix-style-legend-with-raster-data-using-arcgis-10.html

B.5. Mapping the Importance of forests for soil stabilization and limiting soil erosion

Tutorial available at: https://www.unredd.net/documents/global-programme-191/multiple-benefits/workshops-and-events-1/1st-joint-working-session-on-spatial-analysis-to-support-the-development-of-prov/15722-gis-tutorial-8-evaluating-the-importance-of-forests-for-soil-stabilization-using-arcgis-100.html



Tool SEa Mosaic DEM tiles, project to units meters and generate slope

This tool is the first step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water.

This tool undertakes the following steps:

- Stitching DEM tiles for the study area together into a single raster dataset.
- Projecting the raster to a chosen output coordinate system (the dataset cannot be left in geographic EPSG 4326 as the units need to be in meters).
- Calculating slope from the projected raster dataset.

Tool SEb Reclassify Slope Raster from step a

This tool is the second step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Reclassifies the slope raster output from step SEa into 3 classes

Tool SEc Batch clip monthly precipitation rasters

This tool is the third step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Clips monthly precipitation to an area of interest

Tool SEd Calculate annual mean precipitation from step c

This tool is the fourth step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Sums the monthly mean precipitation rasters from step c to create a new raster of mean annual precipitation

Tool SEe Reclassify Precipitation Raster from step d

This tool is the fifth step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Reclassifies the annual mean precipitation raster from step d into 3 classes

Tool SEf Fill DEM from step a and generate hydrological datasets

This tool is the sixth step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following steps:

- Fill the DEM from step a
- Create flow direction raster from filled DEM
- Create flow accumulation raster from flow direction raster
- Create steam order raster from flow accumulation raster

Tool SEg1 Convert dam points and lakes to raster

This tool is the seventh step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following steps:

- Converts dam points to raster
- Converts lake polygons to raster

Tool SEg2: Convert dam points to raster (use if only need to convert dams)

This tool is the eighth step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Converts dam points to raster
- Converts lake polygons to raster

Tool SEh Expand dam cells to stream order

This tool is the nineth step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Expands dams raster (each dam is 1 raster cell) so that dam locations to touch the nearest high order stream. This step is required in order to generate the catchments correctly.

Tool SEi Mosaic expanded dams and lake raster

This tool is the tenth step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Mosaics the expanded dams and Lakes into a single raster

Tool SEj: Generates upstream catchments of dams and/or water bodies from step i

This tool is the eleventh step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Generate catchments to determine the contributing area above a set of cells in a raster (i.e. the upstream catchment of dams and lakes)

Tool SEk: Reclassify upstream catchments from step j

This tool is the twelth step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following step:

- Reclassifies the upstream catchments generate in the previous step and reclassifies them so they all have an id (VALUE) of 1

Tool SEl: Sum outputs from b, e, and k and clip to forest extent

This tool is the last step in a workflow for Mapping the Importance of forests for soil stabilization and limiting soil erosion by water

This tool undertakes the following steps:

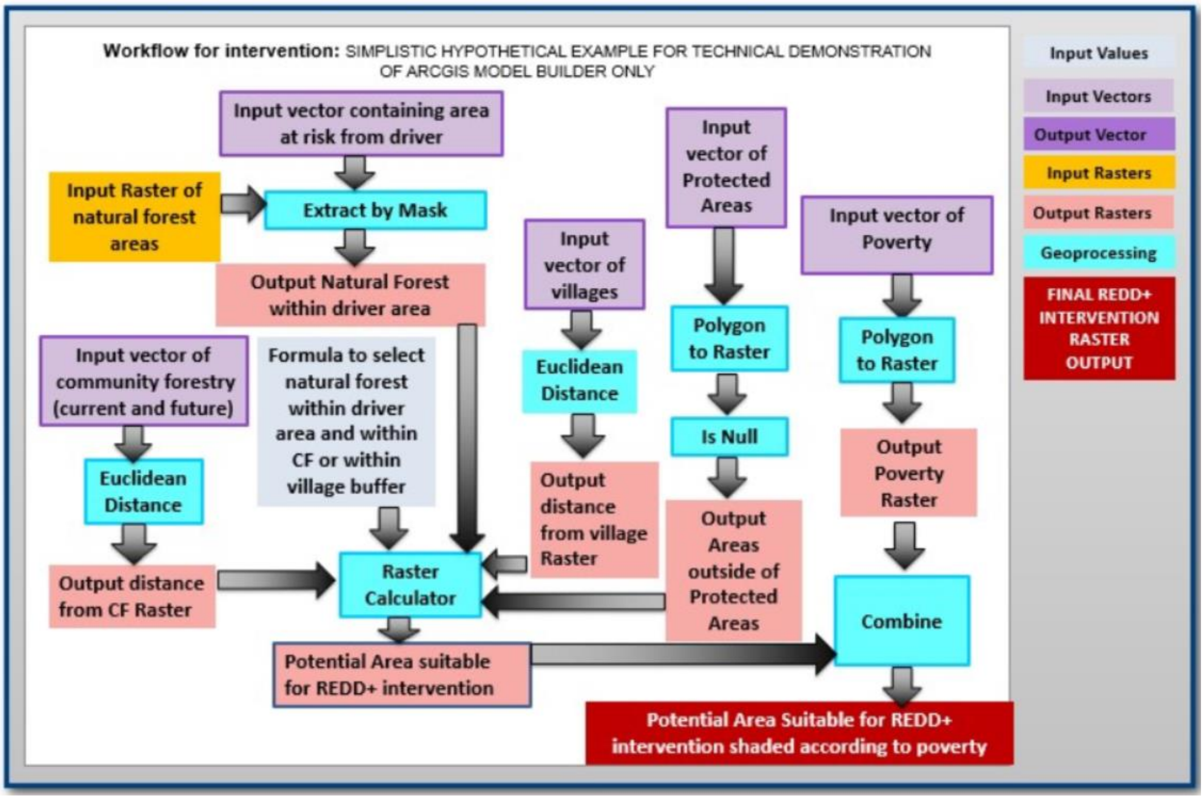
- Sum outputs a, e, and i to create a new raster
- Clip the new raster (result of sum) to forest extent

B.6. Building spatial workflows to help identify potential areas for undertaking a REDD+ intervention (an example)

Tutorial available at: https://www.unredd.net/documents/global-programme-191/multiple-benefits/gis-tools-3403/15772-step-by-step-tutorial-version-10-building-spatial-workflows-to-help-identify-potential-areas-for-undertaking-a-redd-intervention-using-model-builder-in-arcgis-10x.html

This tool is the resultant workflow generated in the tutorial Building spatial workflows to help identify potential areas for undertaking a REDD+ intervention using model builder in ArcGIS 10.x..

This tool and accompanying tutorial uses an imaginary land area to demonstrate how to create and run an analysis using workflows in ArcGIS Model Builder. It covers: mapping the drivers of deforestation and forest degradation, and barriers to the '+'activities; mapping REDD+ interventions; defining spatial logic and creating workflows; sharing the resulting model; and fixing a broken model. The annexes provide more background information on raster data formats and processing for those who are more familiar with vector GIS data, and will guide users in exploring the various raster analysis tools and methods that are available within the ArcGIS Geoprocessing Toolbox.



Annex 1 of the tutorial provides a brief summary of the differences between vector and raster data and an introduction to getting started with raster data analysis. Raster analysis provides users with access to many tools and functions that are not available for vector analysis. Many of these tools are particularly suited to multi-criteria analysis. Raster functions can also be used to generate new data (e.g. hydrology and slope data from digital elevation models). Annex 2 of the tutorial provides links to additional resources and guidance related to ArcGIS Model Builder.