FragScape v1.0

User Manual

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1 OVERVIEW

FragScape is a *QGIS* plugin that computes landscape fragmentation metrics defined in paper "Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation" (Jaeger 2000). Among these metrics, effective mesh size has been widely used to quantify landscape fragmentation. *FragScape* defines a 4 steps process from raw data to computed metrics and allow user to save configuration so that results can be reproduced with same context.

1.1 LANDSCAPE FRAGMENTATION METRICS

Jaeger defined in his paper (Jaeger 2000) three new measures of landscape fragmentation:

- landscape division
- splitting index
- effective mesh size

To compute these measures, landscape elements assessed as fragmenting are removed. Remaining areas are called patches. Landscape is then composed of n patches. A patch area is denoted by A_i with $1 \leq i \leq n$. The total area of the region is denoted by A_t.

1.1.1 Landscape division

The degree of coherence (C), an auxiliary measure, is defined as the probability that two points chosen randomly in a region are connected (e.g. not separated by fragmentation elements such as roads or urban areas):
The degree of landscape division (D) is defined as the probability that two points chosen randomly in a region are not connected:

$$C = \sum_{i=1}^{n} \left(\frac{A_i}{A_t}\right)^2 \qquad D = 1 - C$$

1.1.2 Splitting index

The splitting index (S) is defined as the number of patches one gets when dividing the total region into parts of equal size (meshes) in such a way that this new configuration leads to the same degree of fragmentation of initial configuration:

$$S = \frac{A_t^2}{\sum_{i=1}^{n} A_i^2}$$

It can be interpreted as the effective mesh number of a grid with a constant mesh size dividing the region into S patches which all have the size A_t/S.

1.1.3 Effective mesh size

The effective mesh size (m) denotes the size of the areas when the region is divided into S areas (each of the same size At/S) with the same degree of landscape division as for the initial configuration:

$$m = \frac{A_t}{S} = \frac{1}{A_t} \sum_{i=1}^{n} A_i^2$$

Splitting density (s) is defined as the number of meshes per unit area. Net product (N) is defined as the product of the effective mesh size and the total area of the region:

$$s = \frac{S}{A_t} = \frac{A_t}{\sum_{i=1}^{n} A_i^2} = \frac{1}{m} \qquad N = m.A_t = \sum_{i=1}^{n} A_i^2$$

1.1.4 Cross-Boundary Connection (CBC) method

As other patch-based landscape metrics, above metrics can be biased by the boundaries and the extent of a reporting unit if the boundaries fragment patches. This issue is called the "boundary problem" and has been addressed in paper "Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem" (Moser et al. 2007).
New method called *cross-boundary connections* (CBC) includes area outside boundaries. The complete area of a patch, regardless of boundaries, is denoted by A_i^{cmpl}. The formula of effective mesh size according to CBC method is:

$$m = \frac{1}{A_t} \sum_{i=1}^{n} A_i.A_i^{cmpl}$$

Other metrics are redefined to match CBC method, expressions $\sum_{i=1}^{n} A_i^2$ and A_t^2 are replaced by $\sum_{i=1}^{n} A_i.A_i^{cmpl}$ and $A_t.A_{total}^{cmpl}$, respectively.

1.2 INSTALLATION

FragScape is a *QGIS* plugin.
FragScape is a cross-platform plugin. Tests were performed on Ubuntu bionic, Windows 10 and macOS Sierra.

Encart 1 : Prerequisites

***QGIS* version must be superior to 3.4.0.**

To install *FragScape*, open *QGIS*:

- go to `Extension` menu
- open `Install/Manage extensions` dialog
- go to `Parameters` tab and check that `Show experimental plugins` option is checked
- go back to `All` tab, search for *FragScape*, select it and click on `Install plugin` button

Once installed, *FragScape* icon  shall appear in tools panel.
If not, go to `Extension` menu and a *FragScape* entry shall be present.
If not, installation failed. Please check error message or contact support team.

1.3 GRAPHICAL USER INTERFACE (GUI) OVERVIEW

Figure 1 show an overview of *FragScape* GUI. It contains 4 main components :

- top icons bar : action icons (configuration management, language switch)
- right panel : description of current step
- bottom progress bar : shows progress of current process
- main frame : current step content

In main frame, current step can be composed of :

- parameters that must be set (such as `Workspace`)
- visualisation table that displays current configuration/results
- action buttons (such as `Launch selection`)

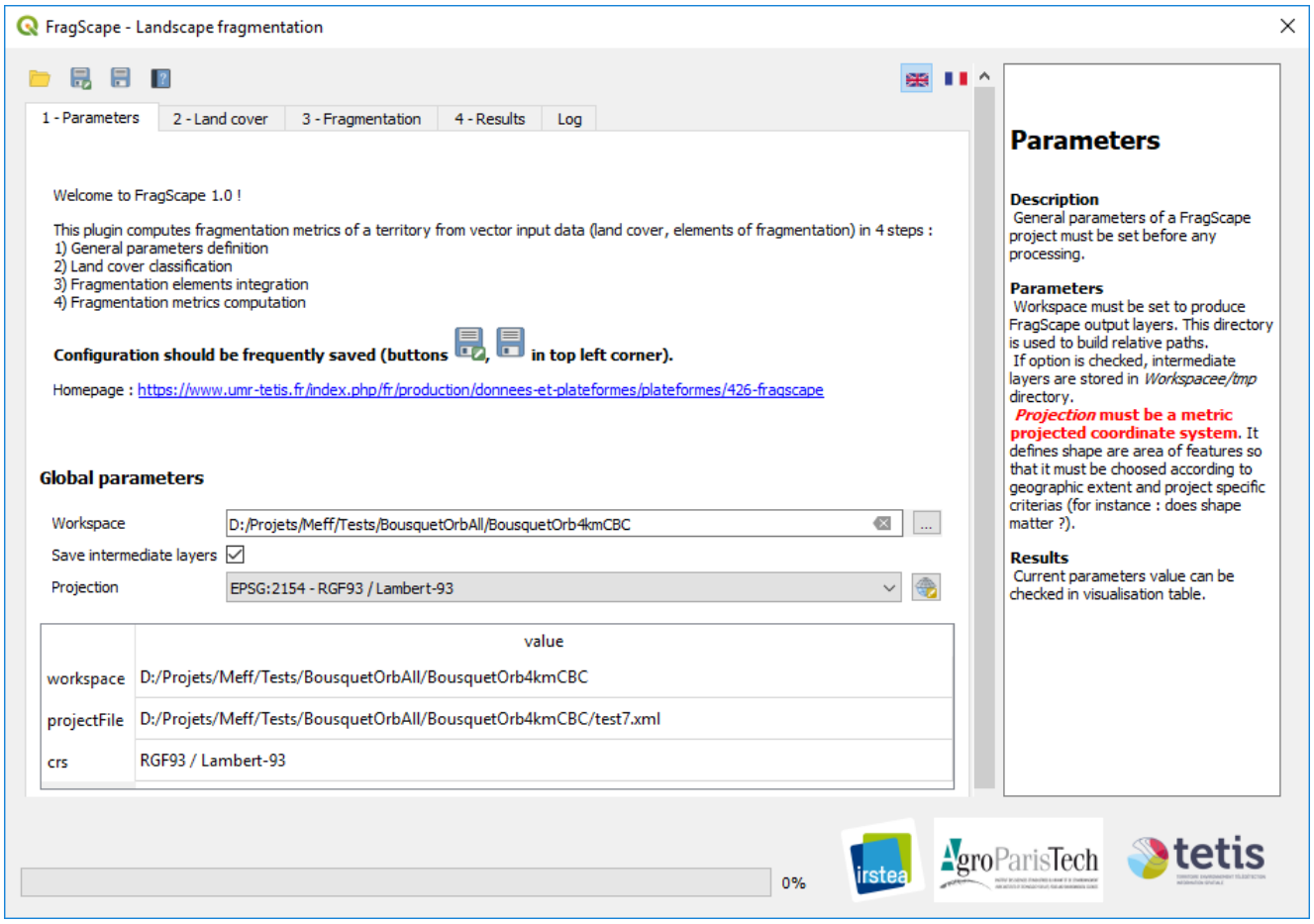


FIGURE 1: *FragScape* v1.0 Graphical User Interface

2 STEPS

FragScape defines a 4 step procedure from raw data to computed metrics.

2.1 PARAMETERS

First step is to define global parameters used for current *FragScape* project.
`Workspace` must be set before any processing as it defines *FragScape* outputs path. Output file of each step is stored in *Workspace/outputs*. Be careful when setting workspace as existing file can be overriden.
If option `Save intermediate layers` is checked, intermediate layers are stored in *Workspace/tmp*. Otherwise, they are stored in *QGIS processing* temporary directory (path is displayed in log when a layer is created).
`Projection` is a projected metric coordinate reference system that must be set according to data geographic extent. It defines entities shape and area.

2.2 LAND COVER

Second step is to select target features from land cover layer.
To do so:

- Select land cover layer (`Input layer` parameter).
- If needed, clip `Input layer` by checking `Clip input data` and selecting `Clip layer`.
- Choose `Selection mode`.
- Choose selection criteria (fields or expression).
- Click on `Launch selection` button.

In `By field values` mode, selection is performed this way:

- Choose `Selection field`, e.g. the field containing land cover classes identifier (such as *CODE_2012* for Corine Land Cover 2012 data).
- User can choose a `Description field` that contains land cover classes description. This step is optional.
- Click on `Show field values` button.
- Select target classes in `toSelect` column of table.

In `By expression` mode, selection is performed by specifying a boolean expression. Every feature verifying this expression is selected. If no expression is specified, all features ares selected.
Figure 2 shows an example of land cover selection interface.

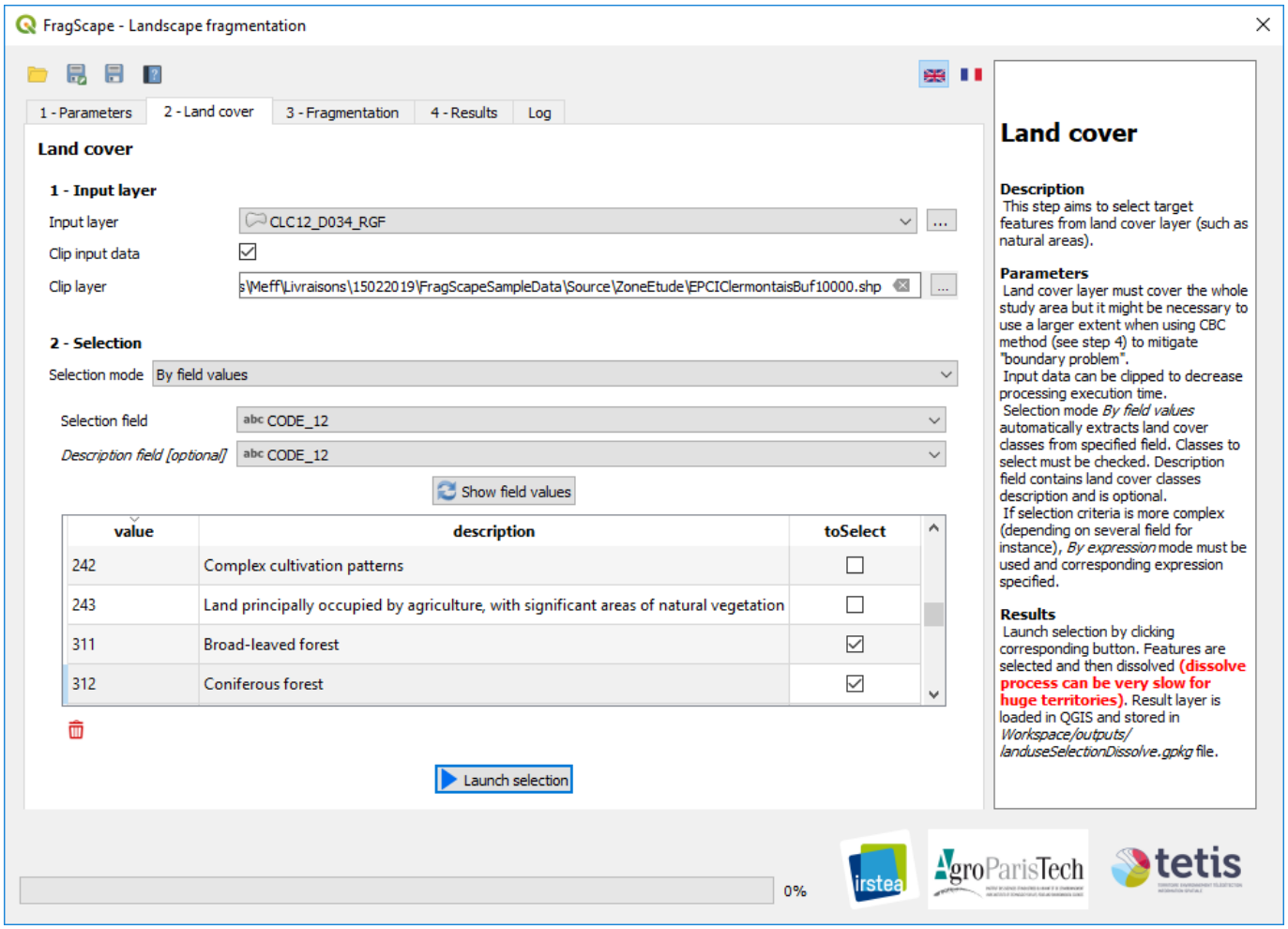


FIGURE 2: *FragScape* v1.0 land cover tab

2.3 FRAGMENTATION

Third step is to select elements of fragmentation.
For each kind of fragmentation, user should:

- Select `Input layer` that contains fragmentation data ($roads.gpkg$ for instance)
- If needed, clip `Input layer` by checking `Clip input data` and selecting `Clip layer`.
- Specify selection `Expression` if needed. Features verifying this expression are selected. All features are selected if expression is empty. Expression must be boolean and built with $\mathcal{E}$ widget.
- Specify `Buffer` expression. Mandatory for line and point data. Expression must be a number. Buffer expression can be variable and built through $\mathcal{E}$ widget.
- Specify `Identifier` string for this kind of fragmentation. Such identifier must be unique in project.
- Click on `Save selection` button. Specified selection of fragmentation data appears as a new line in visualisation table.

Once all kinds of fragmentation selected, click on `Apply fragmentation` button. For each selection, data is selected and specified buffer is applied. Buffered layers are merged to produce a layer with all fragmentation data. This layer is used to process difference with land cover layer (overlaying geometries being removed). Finally, difference layer is cast to single geometry.
Resulting layer is loaded in QGIS and stored in $Workspace/outputs/landuseFragmSingleGeom.gpkg$.

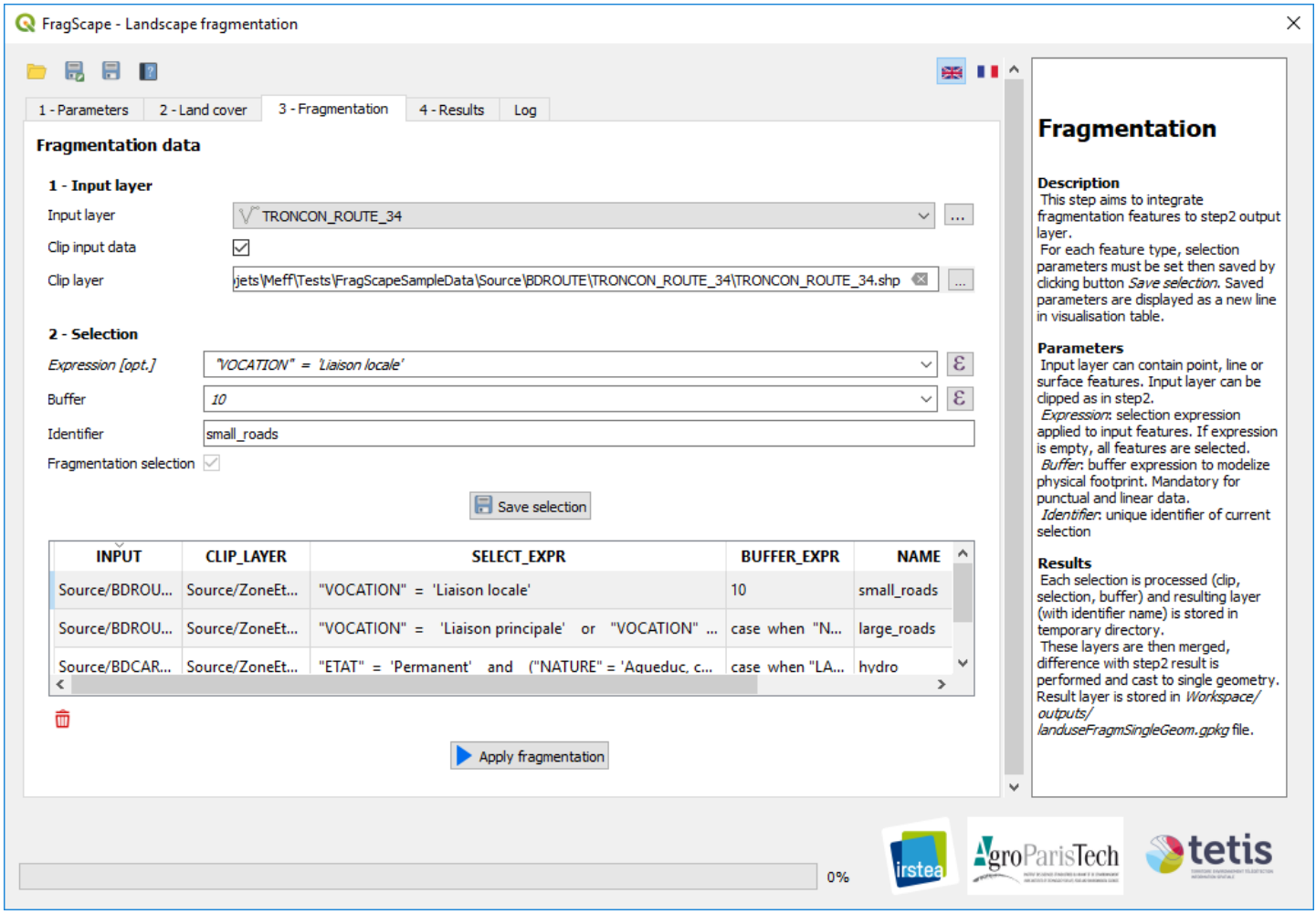


FIGURE 3: *FragScape* v1.0 fragmentation tab

2.4 RESULTS

Fourth step is to compute fragmentation metrics.
To do so:

- If needed, `Filter patches` by specifying a boolean expression (based on area for instance)
- Specify `Reporting layer`. Metrics are computed for each feature of reporting layer. To compute metrics for an entire region, specify a layer with a single feature.
- Select `Cut method` (see section 1.1.4)
- Specify `Output layer`. If not specified, a memory layer is created.
- Specify `Unit of area`: square meters to square kilometers.
- Click on `Compute metrics` button.

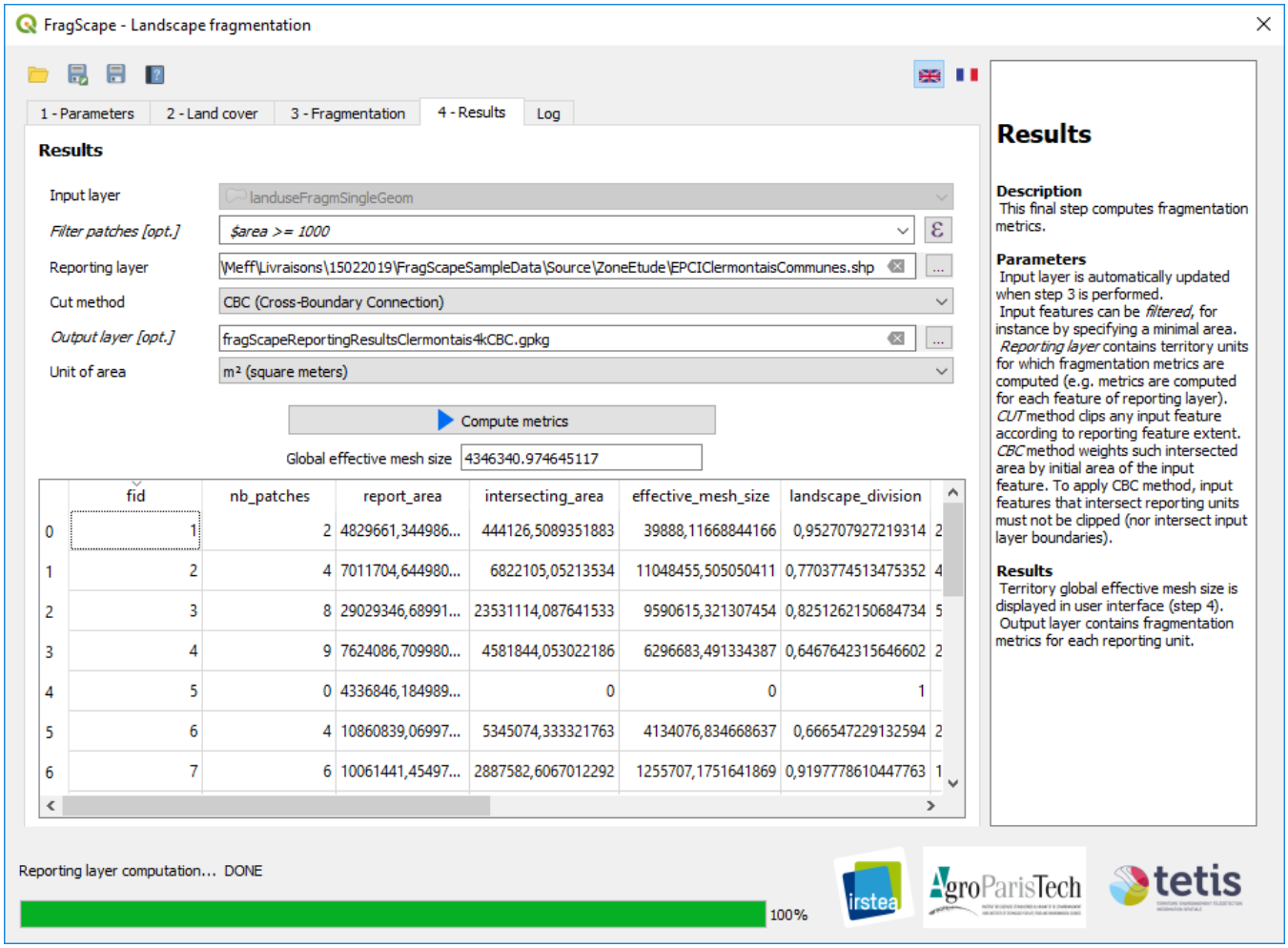


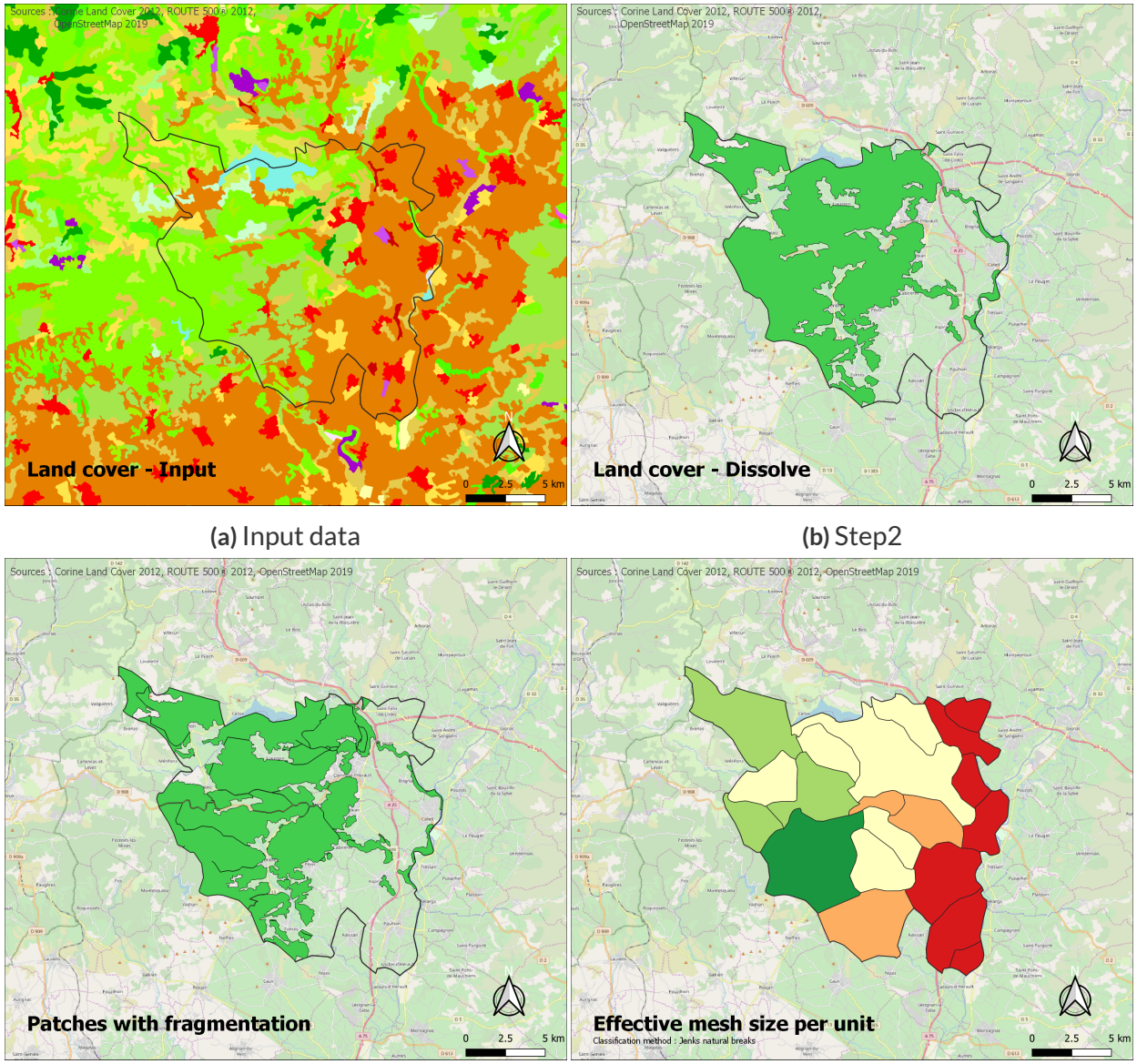
FIGURE 4: *FragScape* v1.0 fragmentation tab

Figure 4 shows results step interface. Once metrics are computed, output layer attributes are loaded in visualisation table and global effective mesh size is displayed. Output layer contains a field for each metrics defined in section 1.1, plus new ones :

- `nb_patches`: number of patches
- `report_area`: area of the reporting unit
- `intersecting_area`: intersection area of patches and reporting unit
- `layer/path`: temporary layer containing initial reporting unit

3 EXAMPLE

This section illustrates *FragScape* use case with provided sample data (subdirectory `sample_data` in *FragScape* plugin directory).



(a) Input data **(b)** Step2

(c) Step 3 **(d)** Step 4

FIGURE 5: *FragScape* use case : from raw data to effective mesh size

Figure 5 shows input data and each step result.
To reproduce results:

- Copy `sample_data` to a local directory
- Open *FragScape*
- Set workspace to `sample_data/CUT`
- Open configuration file `EPCI_Clermontais_2012_CUT.xml` from button
- Check that configuration has been correcty loaded
- Run steps 2 to 4

4 TO GO FURTHER...

4.1 EXECUTION TIME

Execution time depends on region extent and *FragScape* configuration. Longest steps are usually geometries dissolve at step 2 and difference at step 3.
A complete benchmark is currently being performed by applying simple and complex configurations to regions of different scales (french department Hérault, old region Languedoc-Roussillon, new region Occitanie, and finally whole France).
Some examples of execution time (but performed with different configuration and versions of *FragScape*, these are **indicative values**):

Test case	Step 1	Step 2	Step 3
Languedoc-Roussillon	40s	137s	72s
Occitanie	5mn25s	11mn25s	1mn54s
France	122h	19h	5h

4.2 CONFIGURATION FILE

Configuration is saved as an XML file and thus can be opened in a text editor. Figure 6 shows the begining of configuration file `sample_data/ECPI_Clermontais_2012/CBC/ECPI_Clermontais_2012_CBC.xml`

```
<FragScapeModel>
 <Params workspace="D:/Projets/Meff/Tests/EPCI_Clermontais/EPCI_Clermontais_2012/CBC" crs="epsg:2154"/>
 <Landuse in_layer="../Source/CLC/CLC12_D034_RGF.shp" select_mode="0" select_field="CODE_12">
  <LanduseFieldItem   value="111"   description="Continuous urban fabric"   toSelect="False"/>
  <LanduseFieldItem   value="112"   description="Discontinuous urban fabric"   toSelect="False"/>
  <LanduseFieldItem   value="121"   description="Industrial or commercial units"   toSelect="False"/>
  <LanduseFieldItem   value="122"   description="Road and rail networks and associated land"   toSelect="False"/>
  <LanduseFieldItem   value="123"   description="Port areas"   toSelect="False"/>
  <LanduseFieldItem   value="124"   description="Airports"   toSelect="False"/>
```

FIGURE 6: Example of a configuration file

In *Landuse* tag, one can see attributes such as *in_layer* (input layer), *select_mode* (`0` meaning selection mode `By field values`) and *select_field* (selection field of input layer is *CODE_12*). For each loaded field value, a *LanduseFieldItem* tag exists and contains same attributes as in *FragScape* (*value*, *description*, *toSelect*).
Such file can be manually edited if needs be. For instance if relative paths must be changed for a new project (`../Source` becoming `.../../Source`), updating it in *FragScape* tables or creating a new project can be avoided by editing new paths in configuration file and then reloading it.

4.3 ALGORITHMS

FragScape steps are implemented as *QGIS* *processing* algorithms. As shown in figure 7, five algorithms are provided:

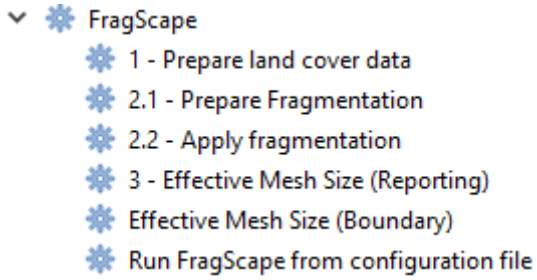


FIGURE 7: *FragScape* algorithms

- `1 - Prepare land cover data`: performs selection and geometries dissolve as in step 2 except that selection expression must be directly provided (in *FragScape*, expression can be built from checked field values)
- `2.1 - Prepare fragmentation data`: performs selection, and applies a buffer to a layer containing fragmentation elements to represent its physical footprint. This algorithm is called for each line/kind of fragmentation in step 3.
- `2.2 - Apply fragmentation`: builds a layer of patches from a land cover layer and fragmentation layers. Fragmentation layers are merged, overlaying geometries with land cover data are removed and remaining ones are cast to single geometry type. This algorithm is called at the end of step 3.
- `3 - Effective mesh size (Reporting)`: computes landscape metrics described in section 1.1 from a layer of patches for each entity of a reporting layer according to specified method (see section 1.1.4). This algorithm is called at step 4 to produce output layer.
- `Effective mesh size (Boundary)`: computes landscape metrics as previous algorithm except that reporting layer must contain only one feature. This algorithm is called at step 4 for each reporting unit and to compute global effective mesh size.
- `Run FragScape from configuration file`: executes *FragScape* processing chain from a *FragScape* configuration file. This algorithm can be useful to reproduce results from an existing configuration, launch processing tasks in background or to executes all steps at once.

5 FAQ

- **Fields are not loaded in field/expression widget, why ?** If they don't appear, it is because associated layer is not loaded even if its path is displayed in combo box. Select another layer and then re-select initial layer.
- **Which method should I use, CUT or CBC ?** CBC method has been designed to address boundary problem and then should be used. CUT method is available to allow comparison with already computed results, or in case boundaries are not a problem.
- **Elements of fragmentation are already included in my land cover layer, should I run step 3 ?** In *FragScape* 1.0, input layer of step 3 and 4 cannot be specified and must be generated by *FragScape*. In case fragmentation elements are already included in land cover data, launch step 3 without any fragmentation element.
- **Can I apply *FragScape* processing to layer not produced by *FragScape* ?** To apply *FragScape* specific processing to specific data, one can use *FragScape* algorithms described in section 4.3.

Encart 2 : Good practices

- Do not use spaces and special characters in file names.
- Do not use special characters in field values.
- Save *FragScape* configuration at each step.
- Check each step result.
- If a problem occurs, save configuration, exit *FragScape* relaunch *FragScape* and re-open saved configuration. If problem still occurs, exit and relaunch QGIS. If problem still occurs, contact support team.

ERROR MESSAGES

- **Layer XXX is already loaded in QGIS, please remove it.** *FragScape* cannot delete file if it is already loaded. Just remove it from QGIS project and relaunch *FragScape* processing.
- **The process cannot access the file because it is being used by another process: XXX.** Check that XXX file is not used by another process. If not, save configuration, save QGIS project, exit QGIS, relaunch QGIS, relaunch *FragScape*, re-open configuration and relaunch *FragScape* processing. This is a known bug when relaunching step 3 after step 4.

References

[1] Jochen Jaeger. "Landscape division, splitting index, and effective mesh size: New measures of landscape fragmentation". In: *Landscape Ecology* 15 (Feb. 2000), pp. 115–130. DOI: 10.1023/A:1008129329289.

[2] Brigitte Moser et al. "Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem". In: *Landscape Ecology* 22 (Mar. 2007), pp. 447–459. DOI: 10.1007/s10980-006-9023-0.