QGIS LightPollutionToolbox Plugin to automate the calcul of light pollution indicators

Instruction for use

Antoine Sensier – INRAE UMR TETIS

Jennifer Amsallem – INRAE UMR TETIS

Sarah Potin – La Telescop

Julie Chaurand – La Telescop

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Foreword

This document presents the QGIS LightPollutionToolbox plugin, which calculates the main pressure indicators for characterizing light pollution from satellite images.

We'd like to thank all those who gave us time to work on this project, in particular Mathieu Chailloux (Géomatricks, and former INRAE colleague) for his experience in developing QGIS extensions, the team at La Telescop who contributed to our reflections, and Hugo Dumonteil (INRAE) who helped us monitor the project's development and assisted us with testing.

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Contacts

Antoine Sensier : antoine.sensier@inrae.fr
Jennifer Amsallem : jennifer.amsallem@inrae.fr
Sarah Potin : sarah.potin@latelescop.fr

Referencing

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Contents

1. Characterizing light pollution

Light pollution contributes to the degradation of the nocturnal environment through the emission of artificial light, with consequent impacts on living organisms and the quality of the night sky.
This constitutes a threat to biodiversity, with repercussions on the day/night cycles of animals (including humans) and flora. This pressure also creates a mechanism of attraction or repulsion that can disrupt the behavior of certain species, particularly their movements, and thus fragment their habitat.
The effects of light pollution are greater if it is located close to or within ecological continuities.
Spatializing and characterizing this type of pollution therefore helps to identify the « trame noire », which aim to identify and preserve nocturnal and crepuscular ecological continuities[1] .

1.1. Data input

The data currently used to identify light pollution can come from satellite images or outdoor public lighting points:

- **Outdoor public lighting points :** This vector data can be very useful, but it requires a detailed, up-to-date database. They still need to be standardized[2] , and are not yet available for most of the country. Finally, the absence of information on private lighting is the main drawback of this type of data.
- **Night-time satellite images :** The advantage of night-time satellite imagery is that it covers the whole of the area under study, making it possible to visualize both public and private lighting. Some available night-time satellite images have too high a spatial resolution (750 meters for VIIRS, and 130 meters for LUOJIA) and are therefore not included here.
  The method currently being developed by La Telescop and INRAE uses images from the JILIN-1 constellation. These have very high spatial resolution, with pixels of around one meter in the three visible channels of red, green and blue, making it possible to characterize sources according to their different spectral emissions.

Other data not directly related to outdoor lighting :

- **Digital Terrain Model (DTM) :** These data, taken from IGN's RGE ALTI database, are used to take relief into account. They are used with a resolution of 1 or 5 meters to calculate the number of visible light sources in the area.
- **Buildings :** This vector data from IGN's BD Topo is used to calculate the number of visible light sources, taking into account the building's height as an obstacle to light.
- **Vegetation :** This data comes from IGN's BD Topo or other local data sources, and can be used as an option to calculate the number of visible light sources. To do this, it is necessary to filter the type of vegetation beforehand, according to its nature, so as to retain only that which can be an obstacle to light. A height must also be indicated, as this is not initially present in the existing data.
- **Digital Surface Model (DSM) :** The DSM is an altimetric description of the ground and its superstructures, i.e. the objects occupying the ground (vegetation, buildings, etc.). However, due to its very limited availability, we use the three data sources mentioned above to create it.

BD TOPO and RGE ALTI data are freely available throughout the country (France), with a relatively high level of accuracy.

- **Study area :** The study area is an optional vector data item, used to filter light pollution indicator calculations for a specific area (municipality, district, etc.).

[1] See methodological report Black line: https://www.trameverteetbleue.fr/documentation/references-bibliographiques/trame-noire
[2] See Ecl-Ext outdoor lighting geostrand: https://cnig.gouv.fr/IMG/pdf/cnig_eclext_v1_1.pdf

- **Grid :** The grid is also optional (because it can be generated): it corresponds to the geographic unit on which each indicator will be calculated.

1.2. Selected pressure indicators

The main pressure indicators modelled were developed by La Telescop in a previous project, using very high spatial resolution images from CG Satellite's JILIN-1 satellite.

Three indicators have been defined to characterize different types of light pollution:

- 1) The light halo contribution aims to classify areas (i.e. by mesh) according to upward light emissions. This indicator is calculated using total radiance from the three spectral bands of satellite images, with quantile classification.
- 2) The share of emissions in the blue part of the spectrum makes it possible to distinguish the areas where the share of blue light is greatest. Current literature shows that these wavelengths have a particularly harmful impact on flora and fauna, including humans. This indicator is calculated on the basis of the ratio of red and blue spectral band values in satellite images.
- 3) The number of visible light sources represents, for an observer at a given height, the number of visible sources per pixel, then the average number per grid cell (or other geographical unit), with quantile classification.
  Each observer height (depending on the type of animal impacted, for example) will generate a different result (see Figure 1).

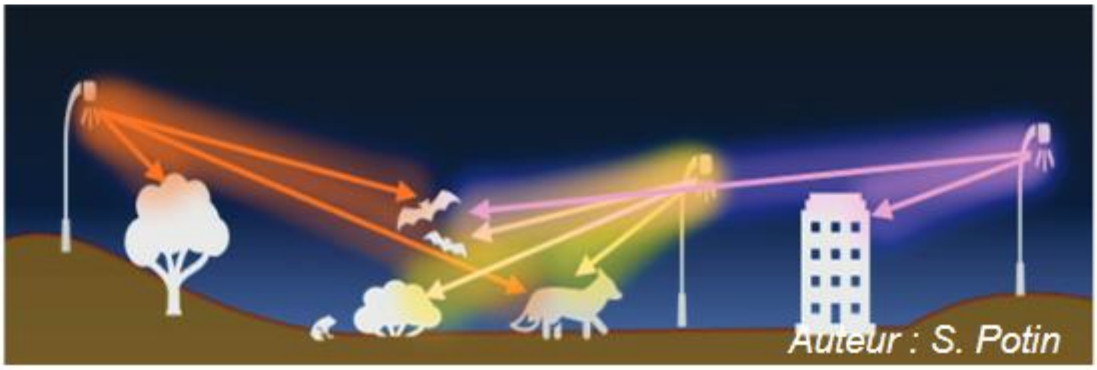

Figure 1:Number of visible sources as a function of viewing height and visual masks

This indicator uses the extraction of light points from JILIN satellite images, as well as relief (with buildings and possibly vegetation in addition) to characterize possible visual masks.

The aim of the QGIS LightPollutionToolbox plugin is to automate the calculation of these three light pollution indicators.

Note that the « Densité Surfacique de Flux lumineux Installé » (DSFLI) indicator has already been implemented in previous work: it is available via the « DSFLI » tab in the plugin toolbox.

The LightPollutionToolbox plugin has its own interface, accessible via a button on the QGIS menu bar. All processing functions are available in the plugin's toolbox.

Each indicator calculation can be configured in a different menu in the interface (see Figure 2). Note that the calculation of the number of visible sources is made up of three sub-menus, each corresponding to a calculation step.

Figure 2: Plugin launch icon and menus for each indicator

The indicator result maps are shown in Figures 15 to 19 in the Appendix.

Hexagonal grid (mesh) representation

For all indicators, the spatial unit is presented by default in the form of a 50 meter diameter hexagonal grid. This size facilitates cross-referencing with biodiversity issues, and absorbs any geometric mismatches that may persist in certain areas. Last but not least, the hexagonal shape makes it possible to have a shape closer to the disk, in order to reduce the geographical offset. The plugin lets the possibility to choose the grid type and size. Moreover, an existing grid can be imported, so users can also choose the geographic unit they want (municipalities, districts, etc.).

2. Data pre-processing

Before processing night-time satellite images, several complex pre-processing operations are carried out, such as radiometric correction, geo-referencing, mosaicing of images, etc.

This pre-processing is carried out upstream on a case-by-case basis as soon as the images are received.

In addition, other pre-processing may be required to facilitate indicator calculation: these have been added to the « Utils Light Pollution Indicators » (Misc) tab of the plugin toolbox (see Figure 3) and are presented below

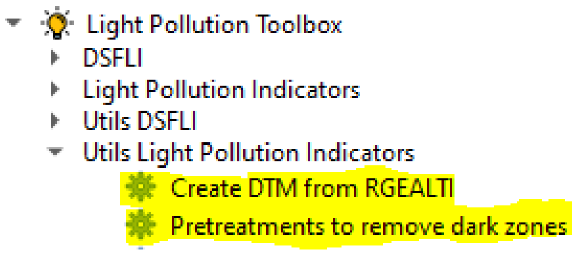

Figure 3 : Pre-processing in the plugin toolbox

2.1. Processing dark areas in satellite images

The dark areas correspond to pixels with the minimum light signal detection levels specific to the sensor in question (which may vary depending on the satellite used), in the three Red / Green / Blue (RGB, for example: 9 / 9 / 11) bands. In this case, the satellite detects no light signal.

These values can bias calculations of radiance or blue light indicators (since they are based on band values).

This pre-processing therefore sets to « 0 » all pixels values whose 3 values in the 3 bands are strictly less than the majority. The majority corresponds to the highest pixel value +1, for each band.

- **Input data and parameters :**

- Study area (optional) : Vector layer of polygon type representing the study area to cut out the satellite image raster.
- Satellite image: the satellite image is in raster format with 3 RGB bands, or with a single band corresponding to total radiance.
- RGB raster band index (advanced parameter), where the index corresponds to the band number of the color in question.

- **Output data :**
  - Raster image, cleaned (and possibly cropped according to the size of the study area), with "dark" pixels set to « 0 ».

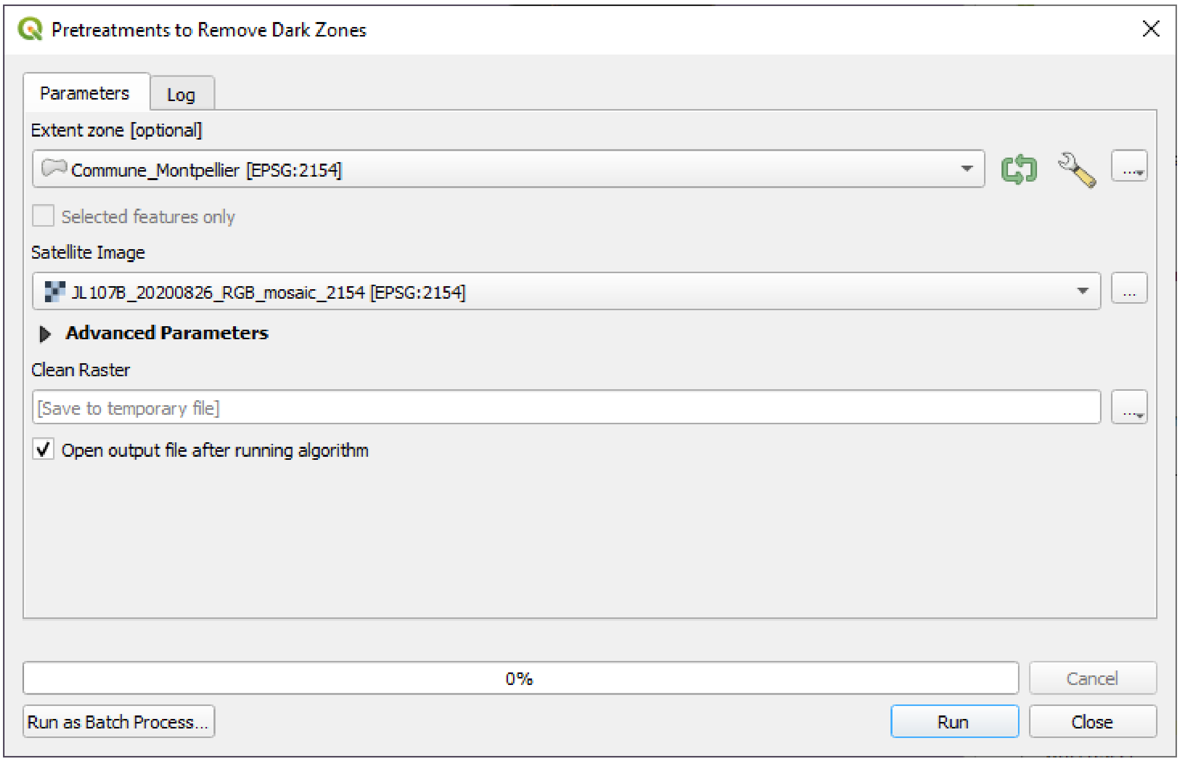

Figure 4 : Treatment interface for removing dark areas

2.2. DTM calculation using RGE ALTI data

The DTM (Digital Terrain Model) raster layer corresponds to the relief, which is then used in processing to calculate the DSM (relief with buildings and vegetation). This data can be downloaded by department with a resolution of 1 or 5 meters via IGN's geo-services:

https://geoservices.ign.fr/rgealti

This data is very voluminous, and is divided into grids of 1000 or 5000 meters. To obtain a DTM for a specific right-of-way, it is necessary to select the right grids on the right-of-way via a vector layer supplied by IGN, then select the corresponding raster files, to then create a mosaic, which can prove tedious.

This process automates the export of the DTM to a predefined area by performing the following steps:

- Application of a buffer to be entered as a parameter, around the study area (optional) ;
- Grids selection from study area ;
- Selection of corresponding ASC files ;
- Create a virtual raster from ;
- Export to raster in tif format.

- **Input data and parameters :**
    - Study area (optional) : Polygon-type vector layer representing the study area, used to select the grids covering this area.
    - Grids: Vector layer corresponding to a 1000 or 5000-meter grid of departmental boundaries. For each grid, a field indicates the name of the corresponding ASC raster. The layer is usually found in the downloaded directory « 3_SUPPLEMENTS_LIVRAISON_... ».
    - DTM ASC file folder: Selectable folder containing all tiles as ASC files. It is usually located in the downloaded directory: « 1_DONNEES_LIVRAISON_.../RGEALTI_MNT_XM_ASC_... ».
- **Output data :**
    - Raster DTM, which corresponds to the mosaic of selected tiles in the study area, built using a virtual raster.

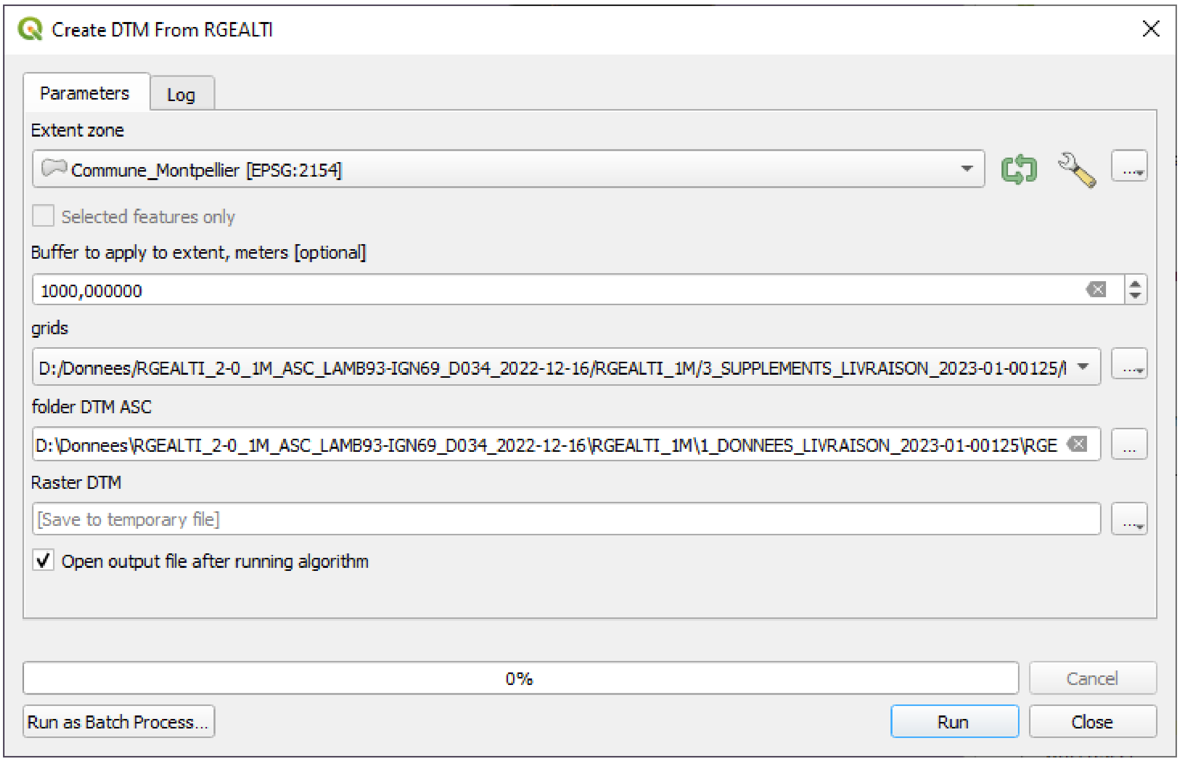

Figure 5 : Interface for creating a DTM from RGE ALTI data

3. Contribution to luminous halo (radiance)

This indicator is used to classify by grid the illuminated areas contributing most to the light halo, based on the level of radiance received by the satellite.

The luminous halo is qualified by the brightness of the sky background (NSB) measured using a Sky Quality Meter (SQM). Although the radiance seen from space and the luminance measured on the ground by the SQM are related, a more accurate prediction of the NSB would require scattering the radiance sources using their intensity. The aim here is not to model the luminous halo directly, but to classify geographical units (by grid, for example) according to the upward light emissions picked up by the satellite and contributing to the formation of the luminous halo.

The indicator can also be calculated for any geographic unit (district, commune, etc.).

3.1. Settings

- **Input data and parameters :**
  - Study area (optional) : Polygon-type vector layer representing the area over which the indicator will be calculated, such as a commune. This data is optional. If left blank, the study area will be the area of the imported grid, or the area of the satellite image.
  - Satellite image: The satellite image is in raster format, and can be composed of the 3 RGB bands, or directly of a single band with total radiance.
  - Grid: It is possible to import a pre-existing grid in vector format, or the user can create the grid in the interface by entering the following two parameters:
    - Resulting grid diameter: Value in meters (minimum 25).
    - Grid type: Shape of grid (hexagon, diamond or square).

    By default, if the user does not import a grid, it will be created with a diameter of 50 meters and a hexagonal shape over the entire right-of-way.
  - RGB raster band index (advanced setting).

NB: Input data projection systems must be identical and in metric units, such as Lambert-93 (EPSG:2154).

- **Output data :**
  - Radiance statistics: Vector layer representing the total radiance value, with an average of the values per grid cell and a quantile classification into 5 classes, from the lowest radiance values to the highest, and, in addition, a class representing grids with no radiance.
  - Total radiance (optional): Raster layer with total radiance per pixel, calculated according to the following formula for the 3 RGB bands of the satellite image: « (0.2989 x B1 red) + (0.5870 x B2 green) + (0.1140 x B3 blue) »[3] .

    The unit of radiance image is W.m-2.sr-1.nm-1.

    Note that if the input satellite image has only one band, then this layer is not generated and is hidden from the interface.

NB: If the paths with the output file names are not filled, they are saved in temporary files.

Figure 6 shows a diagram summarizing the inputs/outputs of the algorithm (see an example diagram in Figure 15 in the Appendix):

[3] Cheng et al. 2020: Automated Extraction of Street Lights From JL1-3B Nighttime Light Data and Assessment of Their Solar Energy Potential. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 13, pp. 675-684. DOI : 10.1109/JSTARS.2020.2971266.

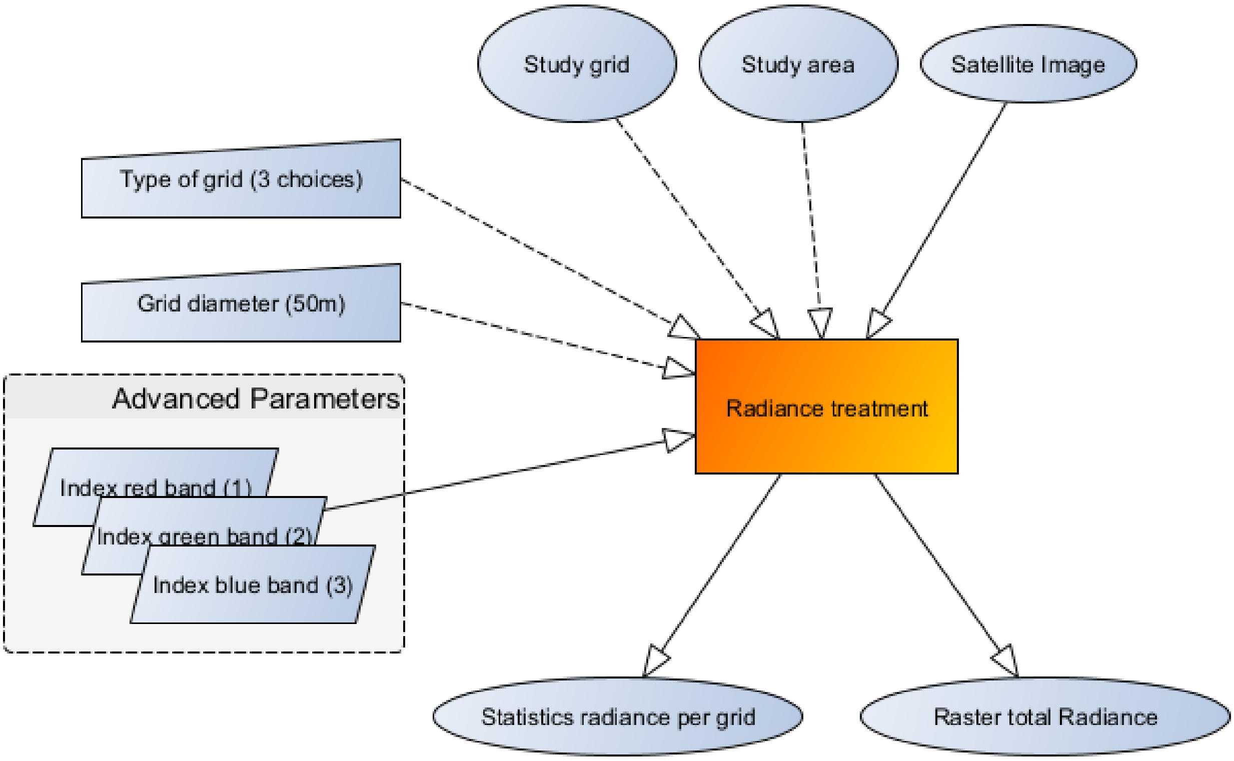

Figure 6 : Total radiance calculation input/output diagram

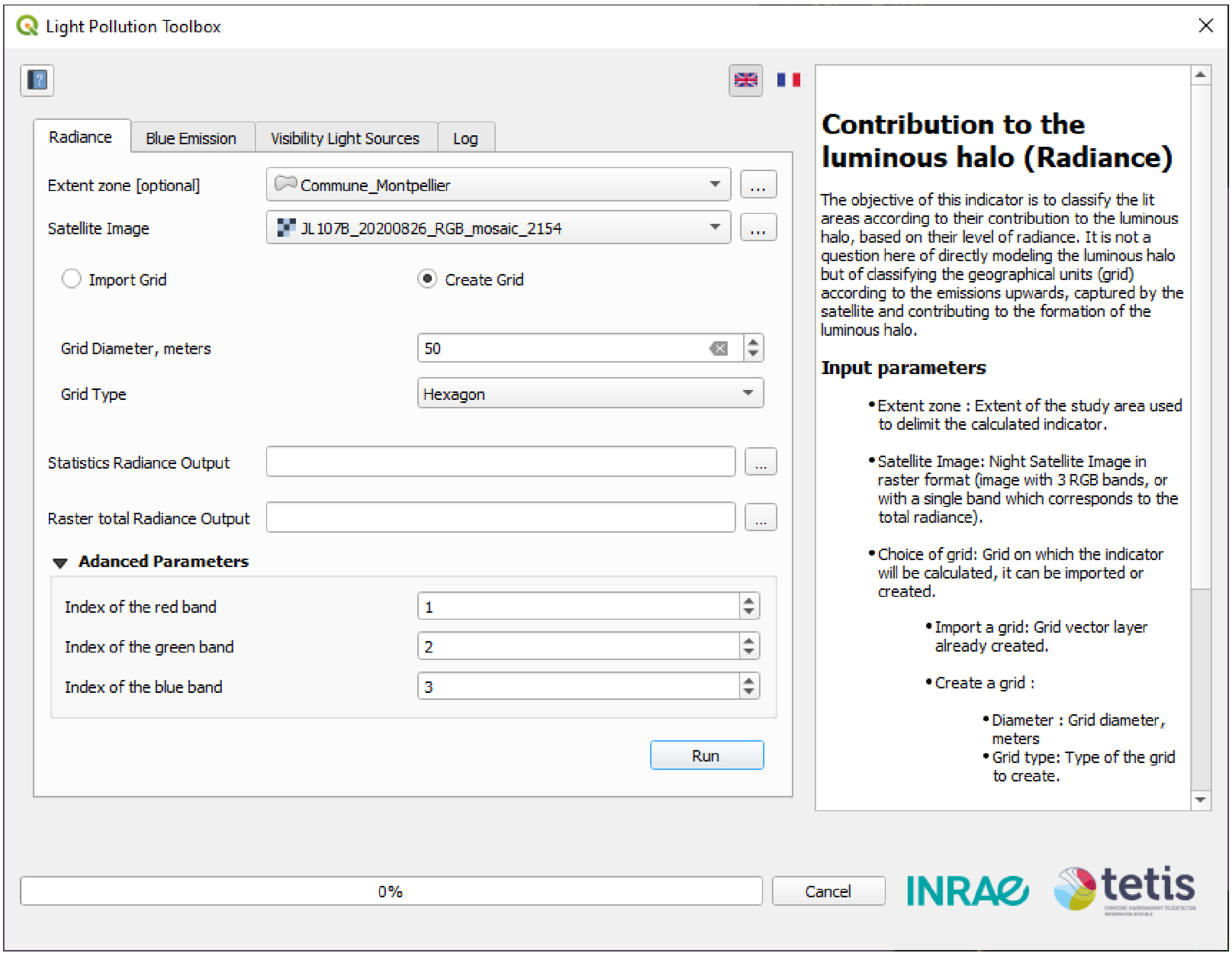

Figure 7 : Total radiance calculation interface

3.2. Treatments

Processing involves calculating total radiance from satellite images.

The average total radiance is calculated for each mesh (or other input polygon instead) from the average pixel value.

Another output shows total radiance in raster format, with a value per pixel (the resolution matches the one in the input raster).

Here are the main steps of the algorithm:

- Retrieve the study area layer. If there is no layer, then the imported grid will be considered as the study area, or the raster layer of the satellite image;
- Satellite image sectioning according to study area ;
- Grid cut (if imported) according to study area ;
- If no grid is available, create a grid based on the size of the study area and the input parameters (grid diameter and type);
- Calculate total radiance using the formula « (0.2989 x B1 red) + (0.5870 x B2 green) + (0.1140 x B3 blue) » ;
- Segmentation to separate illuminated areas for mesh calculations (pixels > majority of pixels +1);
- Raster conversion of illuminated areas to Vector ;
- Geometry repair and indexing ;
- Intersection to extract illuminated meshes thanks to segmentation ;
- Statistics (sum, average) of total radiances on each illuminated mesh ;
- Assigning a zero radiance value to non-illuminated meshes ;
- Classification into 5 categories by quantile, plus a class for meshes without radiance ;
- Application of default symbology (green to red colors).

See Figure 16 in the Appendix for the map showing the results of the indicator calculation for Montpellier in 2020.

3.3. Limits and prospects

Multiples parameters influence the quantity of light perceived by the satellite (atmospheric conditions, coating reflection coefficient, flux orientation, etc.). The coefficients determined from field surveys and JILIN images can therefore vary according to acquisition conditions. The equation gives an estimated value of the illuminance level under specific conditions. The results should be interpreted with caution. They can be used to identify potentially problematic sources, but need to be verified in the field for validation.

4. Share of emissions in the blue part of the spectrum

This indicator classifies the illuminated areas emitting the most in the blue part of the light spectrum according to the « red/blue emissions » ratio, calculated from night-time satellite images.

4.1. Settings

- **Input data and parameters :**
  - Study area (optional) : Polygon-type vector layer representing the area over which the indicator will be calculated. This data is optional. If left blank, the study area will be the area of the imported grid, or the area of the satellite image.
  - Satellite image: The satellite image is in raster format with 3 RGB bands.
  - Grid: It is possible to import a pre-existing mesh in vector format, otherwise the user can create the mesh in the interface by entering the following two parameters:
    - Resulting mesh diameter: Value in meters (minimum 25).
    - Grid type: Shape of mesh (hexagon, diamond or square).

    By default, if the user does not import a grid, it will be created with a diameter of 150 meters and a hexagonal shape over the entire right-of-way.

    The decision to use a 150-meter grid instead of a 50 meters grid is due to the strong dispersion of blue light in the atmosphere.
  - RGB raster band index (advanced setting).

- **Output data :**
  - Blue light statistics: Vector layer representing the average value of the R/B ratio calculated per grid cell, with a decreasing quantile classification into 5 classes to highlight the blue, and, in addition, a class representing meshes with no red or blue value (stronger: 1, weaker: 5, 0 if no value).

Figure 8 shows a diagram summarizing the algorithm's inputs/outputs:

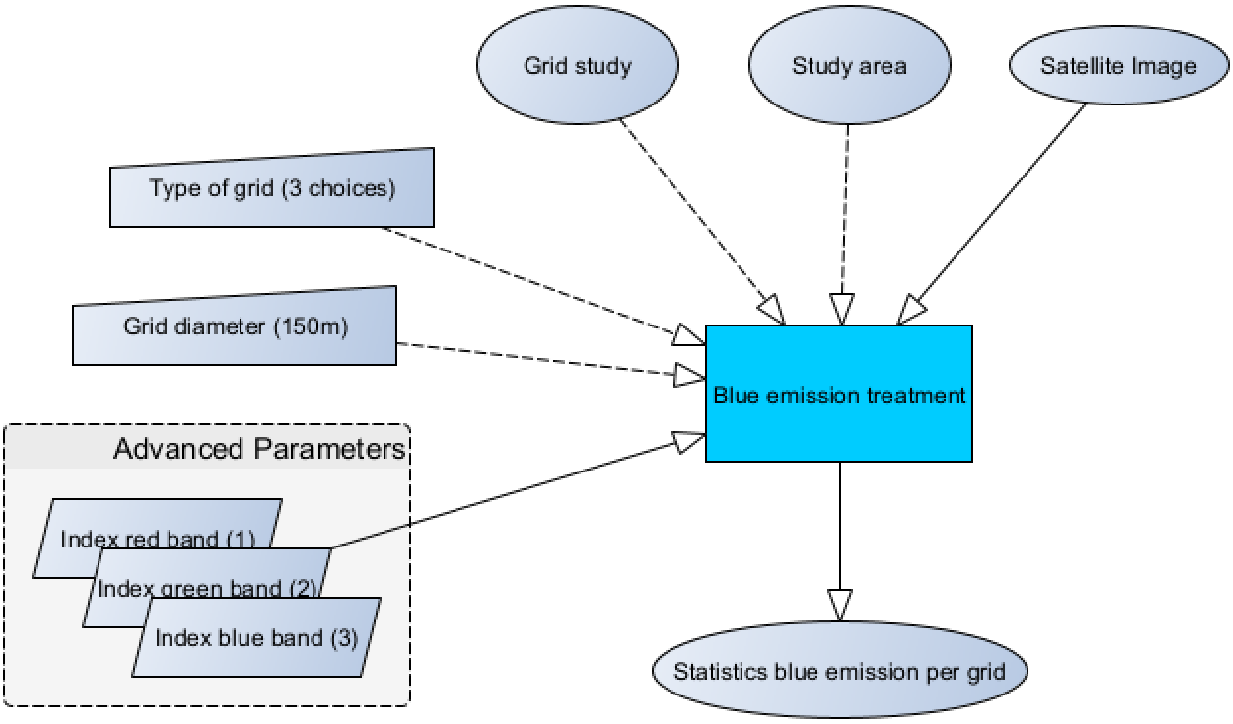

Figure 8 : Input/output diagram for processing the share of blue light emissions

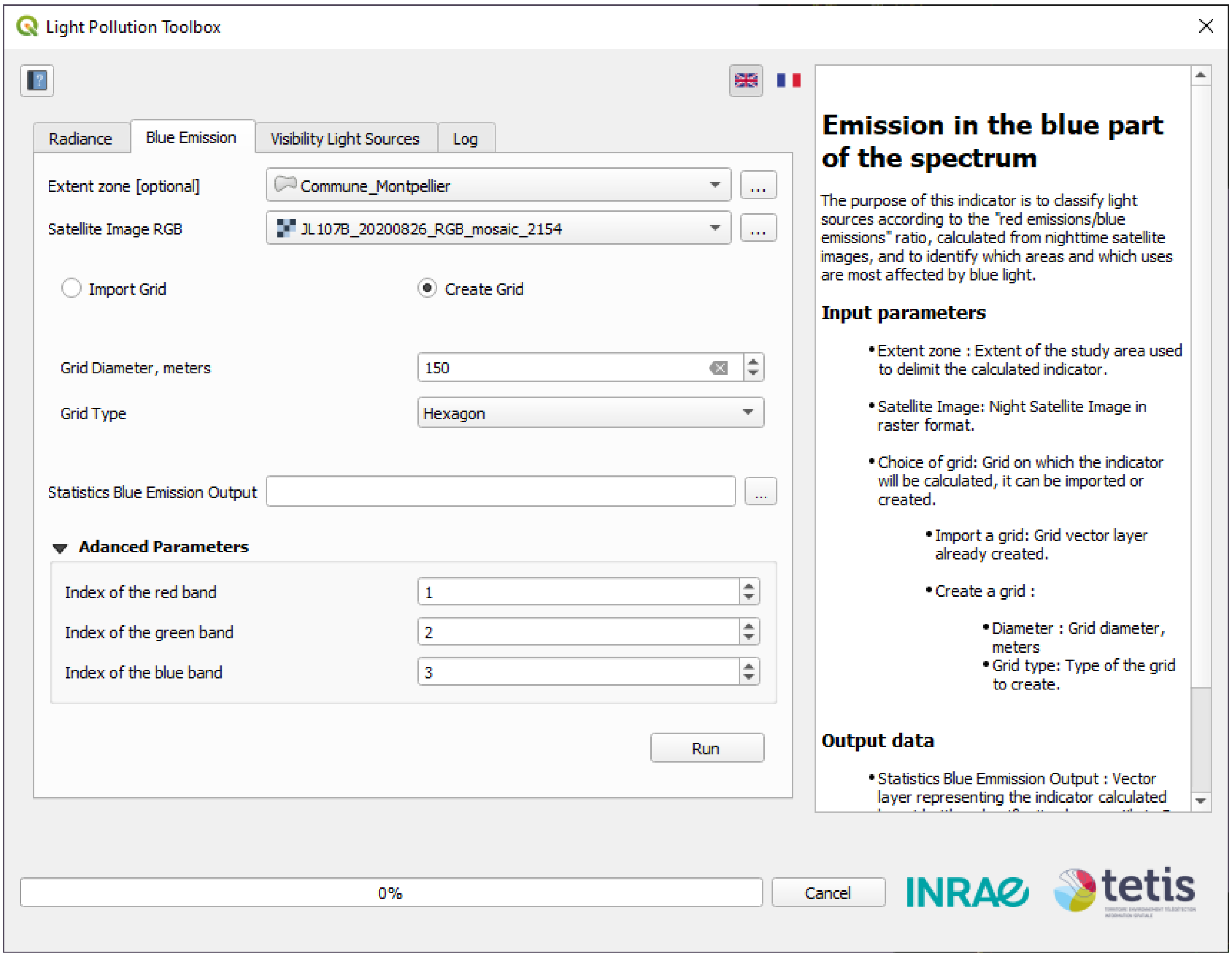

Figure 9 : Interface for calculating the share of emissions in the blue light spectrum

4.2. Treatments

Processing consists of calculating for each grid (or other input polygon instead) the average value of the ratio between the Red/Blue bands calculated from the satellite image.

Here are the main steps of the algorithm:

- Retrieve the study area layer. If there is no layer, then the imported grid will be considered as the study area, or the raster layer of the satellite image;
- Satellite image sectioning according to study area ;
- Grid cut (if imported) according to study area ;
- If no grid is available, create a mesh based on the size of the study area and the input parameters (grid diameter and type);
- Statistics (standard deviation, sum, mean) per mesh in blue and red ;
- R/B field averaging. If one of the bands is zero, the value NULL is assigned;
- Decreasing classification into 5 categories per quantile, plus a class for grids with no value in red or blue (stronger: 1, weaker: 5, 0 if no value);
- Application of default symbology (green to red colors) ;

See Figure 17 in the Appendix for the map showing the results of the indicator calculation for Montpellier in 2020.

4.3. Limits and prospects

Given the low sensitivity of the sensors currently in use, and the high absorption of blue in the atmosphere, it is important to remain cautious when interpreting this indicator. It should be noted that it is still sometimes difficult to identify light sources directed towards the ground (which are poorly perceived by satellites), particularly after renovation work using LEDs, which emit the most blue light.

Pre-processing to remove single-color pixels that correspond to « noise » in the images (in addition to pre-processing the dark areas) helps to improve the result. However, it is still sometimes difficult to distinguish between single-color pixels due to noise and others which correspond to what is actually observed. Work is continuing to improve these preprocessings.

5. Number of visibile light sources

The purpose of this indicator is to evaluate the number of light sources visible to an observer at a given height (defined as a parameter). The height of the light source (also modifiable as a parameter) generally corresponds to the height of street lamps, set at 6 meters by default.

The raw result is produced in Raster format, where each pixel indicates the number of visible sources, depending on the light points identified and the relief with buildings (and possibly vegetation) that can act as visual masks to the light.

The final result is then represented by grid (of configurable size and shape), with the average number of visible sources for an observer at a given height, and with a quantile classification of the number of visible sources.

This final treatment requires three different stages beforehand:

- Extraction of light points;
- Calculating the DSM (Digital Surface Model) ;
- Calculation of the *viewshed* raster, using data from the previous two steps.

To study the number of visible light sources for several types of observer, such as frogs, foxes or low-flying bats, it is necessary to run the *viewshed* processing again (raster of the number of visible sources per pixel), then calculate the number of visible sources per grid cell, but with a different observer height each time (e.g. 0 meters, 1 meter, or 6 meters).

Figure 10 shows a schematic representation of the algorithm's inputs/outputs and the interweaving of all these processes.

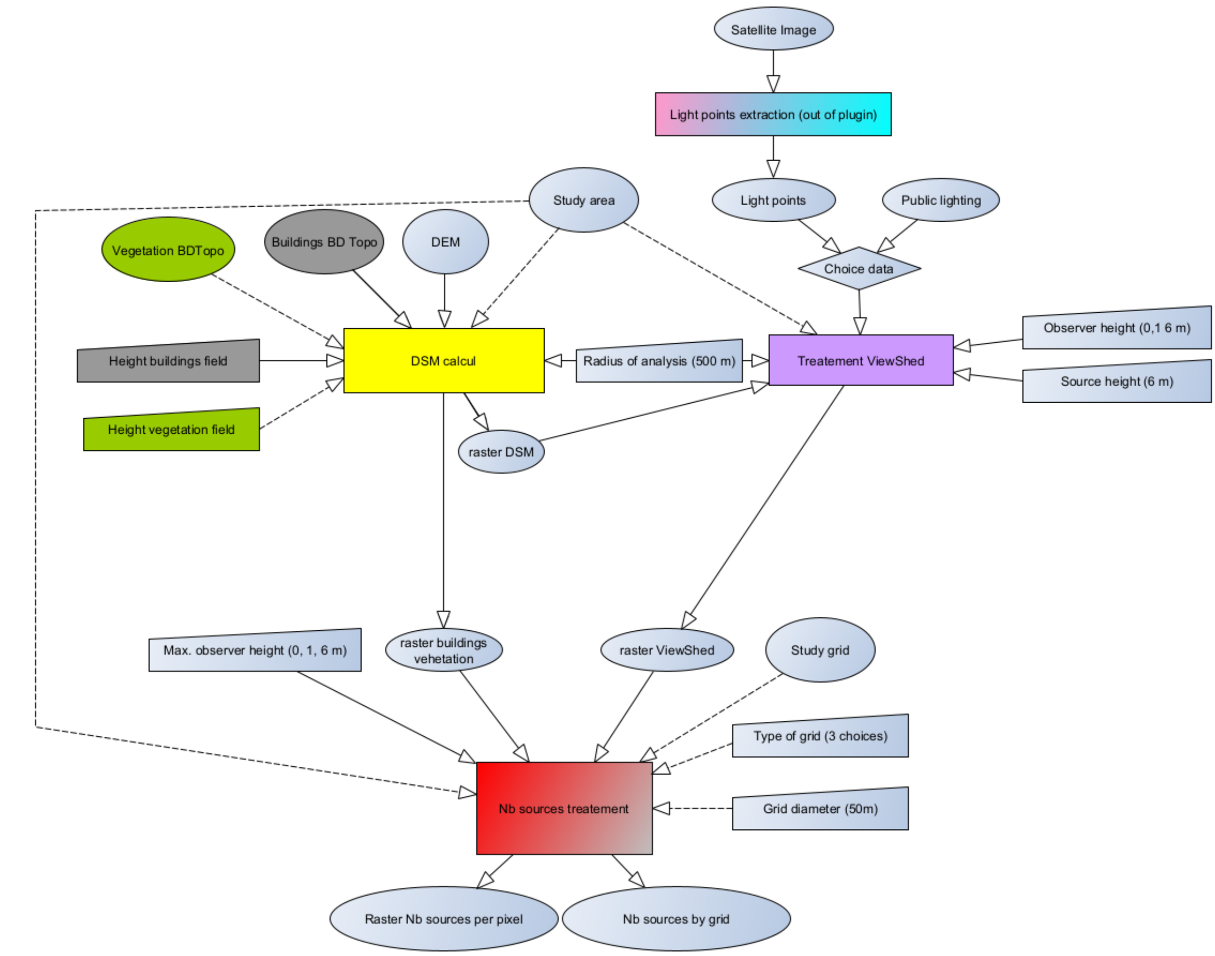

Figure 10 : Diagram summarizing the inputs/outputs and interactions between all the processes involved in calculating the number of light sources

5.1. Extraction of light points

In order to take account of public and private sources, light points are extracted from JILIN night-time satellite images. This extraction process is complex and requires a number of different factors to be taken into account, which vary from image to image. It is assumed that the points layer is supplied with the pre-processed satellite image.

5.2. Calcul du Modèle Numérique de Surface

The DSM is calculated by adding buildings and their heights to the DTM, as well as vegetation (optional).

- **Input data and parameters :**
    - Study area: Extent of the study area used to delimit treatments.
    - DTM: Digital Terrain Model in raster format.
    - Radius of visibility: Buffer distance around the study area (similar to the *viewshed*'s radius of visibility).
    - Buildings: Vector layer of buildings from IGN's BD Topo.
    - Height buildings field: Field representing the building in the buildings layer.
    - Vegetation: Vector layer of vegetation from IGN's BD Topo or another local data source (optional).
    - Vegetation height field: field representing the height of the vegetation layer (optional). Note that vegetation with zero height is not taken into account.

- Default vegetation height: Height value applied to all vegetation if no height field selected (default 6 meters).

- **Output data :**
  - DSM Raster: Raster layer of the Digital Surface Model with the built environment (and vegetation if a layer has been added).
  - Raster building vegetation: Raster layer with pixel values for the height of the building (and vegetation if a layer has been added).

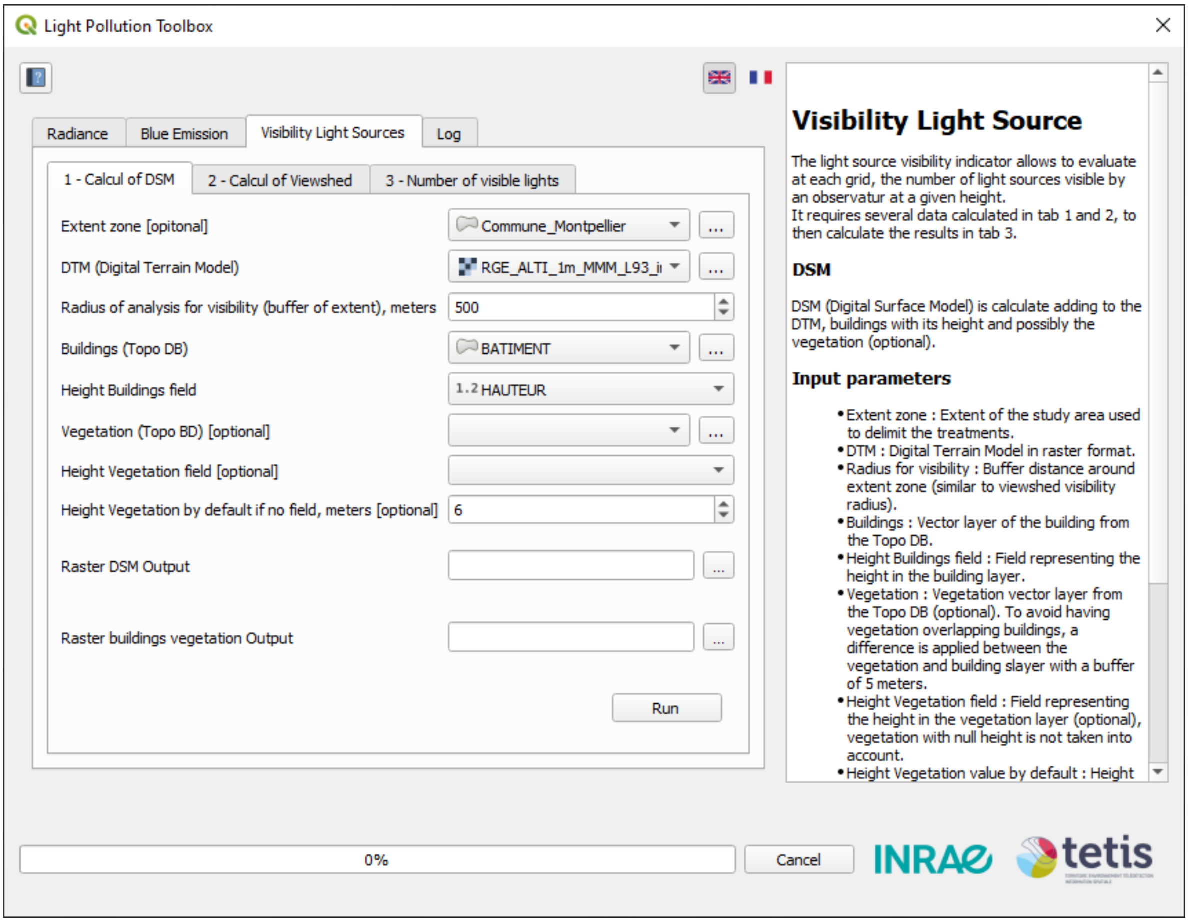

Figure 11 : DSM calculation interface

Treatments :
Here are the main processing steps applied in the algorithm:

- Buffer around study area (value identical to *viewshed* radius) ;
  - If there is no study area, the DTM footprint is used.

  To limit processing time, it is preferable to define a study area and use a DTM with a resolution of 5 metres (this does not degrade the results and is consistent with the precision of JILIN images);

- DTM and building cutting with right-of-way ;
- Add median height if building height is zero.
- If the user has imported a Vegetation layer :
  - If vegetation height field filled in :
    - Removal of vegetation with zero height ;
  - Otherwise, assign the input value for the height ;
  - Cutting out the vegetation with the right-of-way of the study area ;

    - Deletion of vegetation zones when superimposed on the building layer;
    - Combining buildings and vegetation ;
- Rasterization of buildings (and vegetation if present) with height (« building raster » output) ;
- Merging of buildings (with vegetation if present) with DTM (« DSM » output).

5.3. Viewshed calculation

This process calculates a raster that indicates the number of visible light sources for each pixel, based on relief, buildings and any vegetation. It uses part of the Visibility Analysis plugin algorithm:
https://www.zoran-cuckovic.from.hr/QGIS-visibility-analysis
The two main pieces of data required are the light points and the DSM, calculated in the previous step.

- **Input data and parameters :**
    - Study area: Extent of the study area used to delimit treatments.
    - Light point extraction: Vector layer of light points processed from night-time satellite images.
    - Light source height field: field representing the height of the light source in the light point layer (optional).
    - Light source height: Height of light source, if no field selected, 6 meters by default.
    - Observer height: Height of observer in meters.
    - Visibility radius field: field indicating the maximum visibility distance in the light point layer (optional).
    - Visibility radius: maximum visibility distance, if no field selected, default 500 meters.
    - Building-Vegetation Raster: Layer with building (and possibly vegetation) calculated previously with DSM.
    - DSM: Digital Surface Model used to calculate visibility.

- **Output data :**
    - Viewshed Raster: Viewshed raster layer indicating the number of visible sources per pixel.

This visibility calculation step must be run for each observer height: 0, 1 or 6 meters, for example.

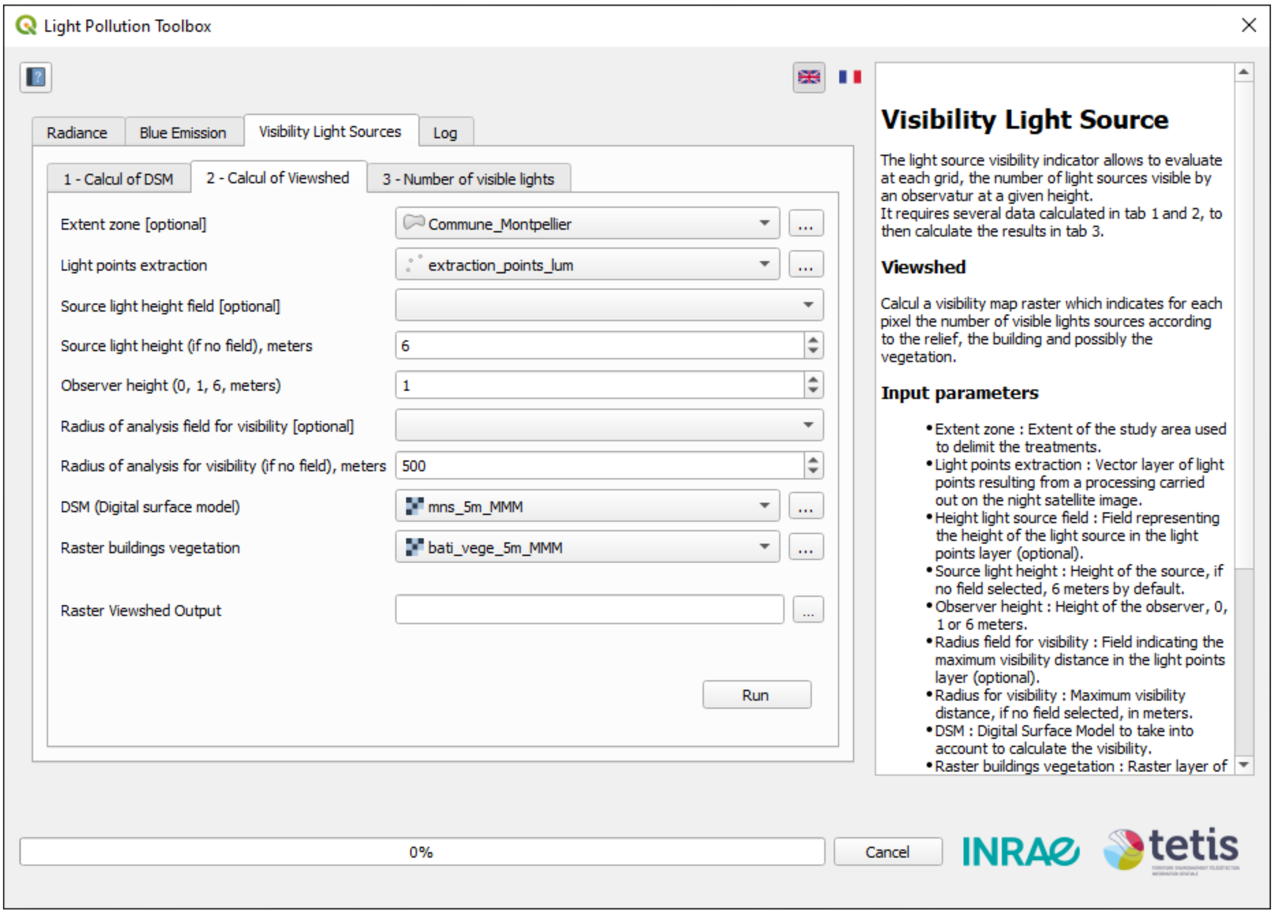

Figure 12 : Viewshed calculation interface

Treatments :

- Buffer around study area (value identical to *viewshed* radius).
  - If there is no study area, the light points are used;
- Extraction of light points in the right-of-way area ;
- Creation of the « ID », « observ_hgt », « source_hgt » and "radius" fields required to calculate *viewshed* ;
- Set the height of the light source ("source_hgt" field) to « 0 » for points intersecting the raster layer of buildings and vegetation, to prevent the height of the source from being added to the buildings (or vegetation);
- *Viewshed* calculation based on DSM and light points modified using the algorithm from the « Visibility Analysis » plugin.

5.4. Calculating the number of light sources per grid

The latter allows the average number of light points observed to be represented per grid cell (imported or created) as a function of the raster data calculated during the viewshed processing.
A mask is also applied to remove the number of sources visible on buildings (and vegetation if present) below an observation height given as a parameter. The processing assumes that the observer is at the top of the buildings, which is not the case, especially for an observer on the ground or at 1 meter. The mask eliminates these outliers.
The raster corresponding to the number of light points observed per pixel after masking outliers (on the building and vegetation where applicable).

- **Input data and parameters :**
  - Study area coverage (optional) : Vector layer representing the area over which the indicator will be calculated.
  - *Viewshed*: Raster layer resulting from *viewshed* processing.
  - Building Vegetation Raster: Raster layer created when calculating the DSM, used to remove the number of sources visible on the building and vegetation (if present).
  - Max. observer height: height in metres of the mask to be applied, so that the number of visible sources is not taken into account if it is less than or equal to this height. It should normally be identical to the observer height indicated in the *viewshed* calculation.
  - Grid: It is possible to import a pre-existing mesh in vector format, otherwise the user can create the grid in the interface with the following two settings:
    - Resulting grid diameter: Value in meters (minimum 25).
    - Grid type: Shape of mesh (hexagon, diamond or square).

    By default, if the user does not import a grid, it will be created with a diameter of 50 meters and a hexagonal shape over the entire right-of-way.
  - Max threshold: Indicates the maximum threshold of the last symbology class represented, default 50 light sources.

- **Output data :**
  - Raster Number of visible light sources: Raster layer representing the number of light sources per pixel of 1 or 5 meters, depending on the *viewshed* resolution. Unlike the *viewshed* result, however, the mask with buildings and any vegetation has been applied to the raster.
  - Number of visible light sources per grid cell: Vector layer representing the average number of light sources per grid cell (or other imported geographic unit), with quantile classification into 5 classes (the maximum threshold for the last class being configurable), and, in addition, a class in the case where there are no visible sources.

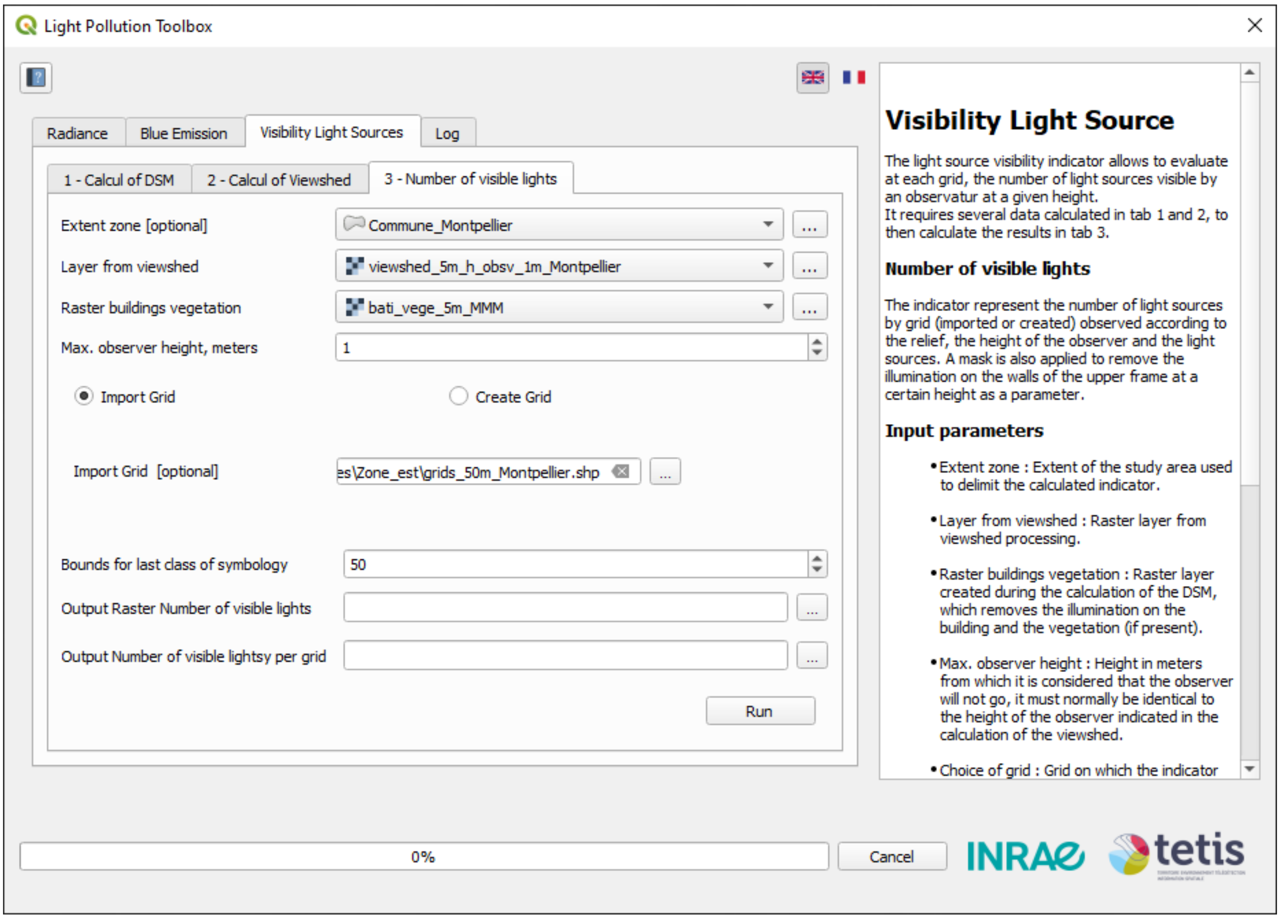

Figure 13 : Interface for calculating the number of visible sources

Treatments :

Here are the main processing steps applied in the algorithm:

- Retrieve the study area layer, if no layer then the area of the imported grid will be considered as the study area, if no imported mesh then the area of the viewshed raster layer;
- The viewshed raster and the « built-up vegetation » raster are cut according to the study area;
- Grid cut (if imported) according to study area ;
- If there is no grid, it is created according to the study area and the parameters entered as input (diameter and mesh type);
- Mask on Raster Building-Vegetation to remove outliers on the frame beyond the maximum height that the observer in question can reach. The number of sources is set to « 0 » if the mask height is greater than the observation height;
    - Create a raster mask with 0 if frame height > max. observer height, 1 otherwise;
    - Application of the mask on the *viewshed* to remove buildings illumination.

    (Similar treatment with vegetation)
- Calculation of the average number of visible sources per grid cell ;
- Classification of the number of sources per quantile into 5 categories, with a parameterizable final threshold and an additional class for meshes with no visible sources;
- Application of default symbology.

See Figure 18, 19 and 20 in the Appendix for the maps showing the results of the indicator calculation for three different observer heights in Montpellier in 2020.

6. QGIS plugin management

6.1. Installation

The plugin is based on QGIS version 3 and requires no additional extensions or libraries beyond those provided by default.
The minimum version required is 3.16.
To install the plugin, go to the menu *Extension* → *Install/Manage extensions* and choose *LightPollutionToolbox.*

Treatments can be called up from the treatment toolbox, or from the plugin interface in the menu bar.

6.2. Architecture

The plugin is based on an existing plugin that calculates the DSFLI indicator.

The algorithms needed to calculate light pollution pressure indicators have been added to the « algs » folder, and an interface (Interface_dialgo_base.ui) and controller algorithms (controller.py for interactions between the interface and the algorithms, tabs.py to manage dynamic display of help panels based on menu tables) have been added to the plugin's root folder, creating an MVC (Model View Controller) architecture.

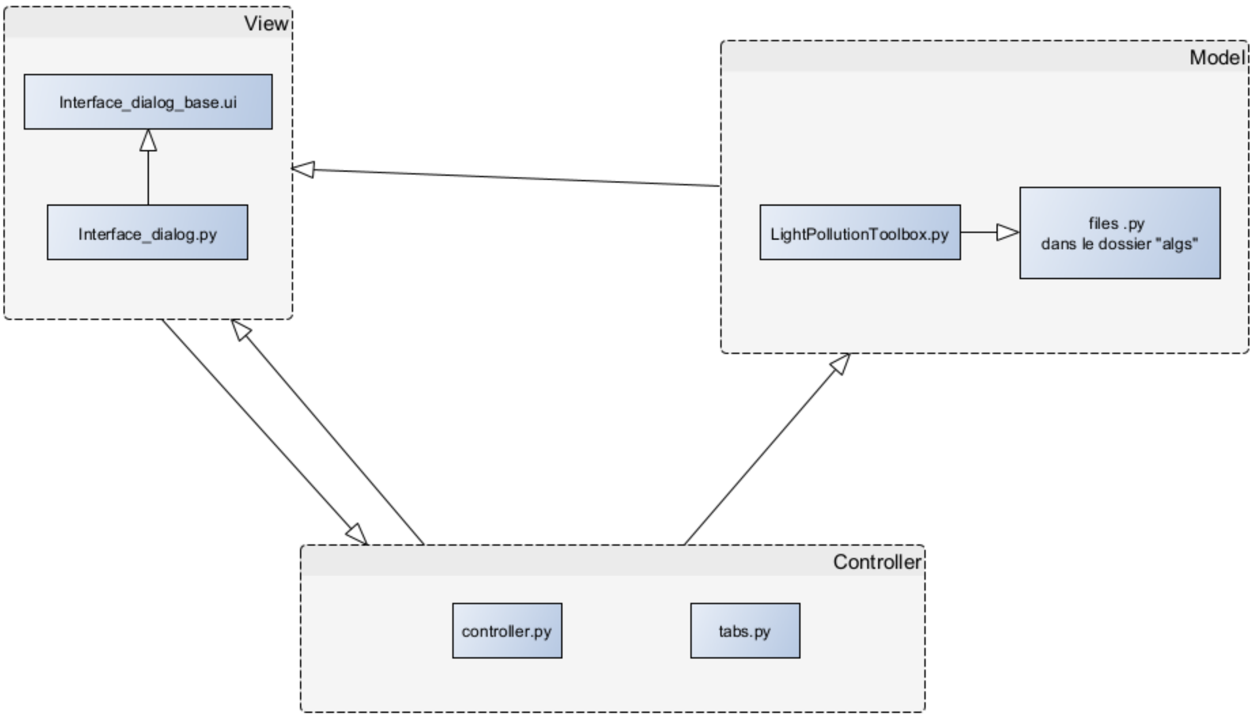

Figure 14 : Plugin MVC architecture

Appendix

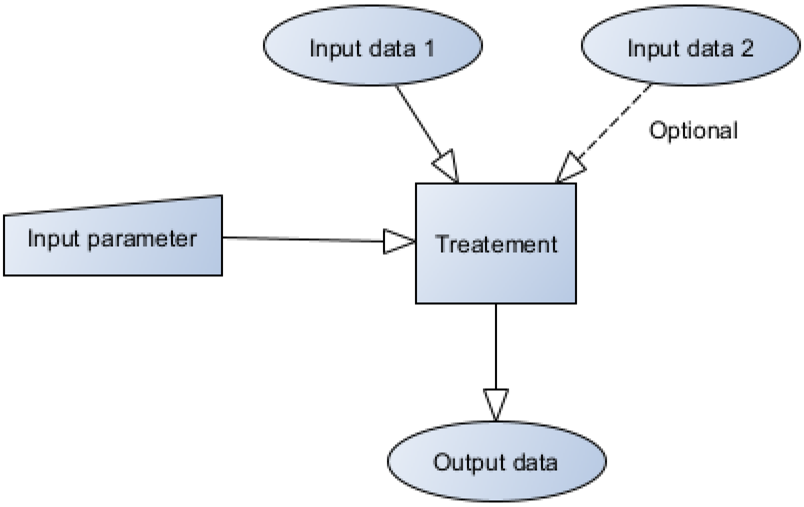

Figure 15 : Exemple of an input/output diagram

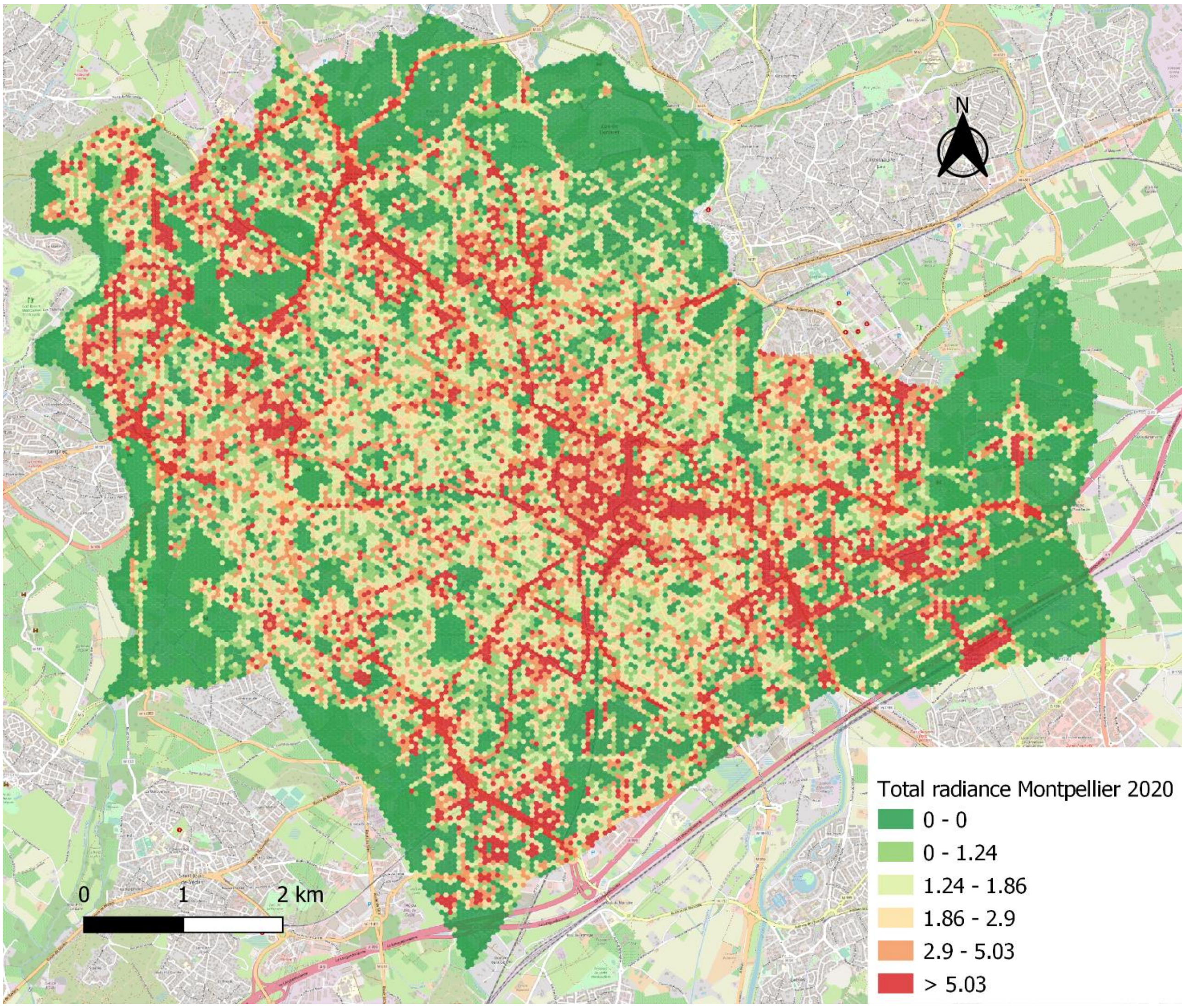

Figure 16 : Contribution to the luminous halo based on total radiance per 50 m grid cell

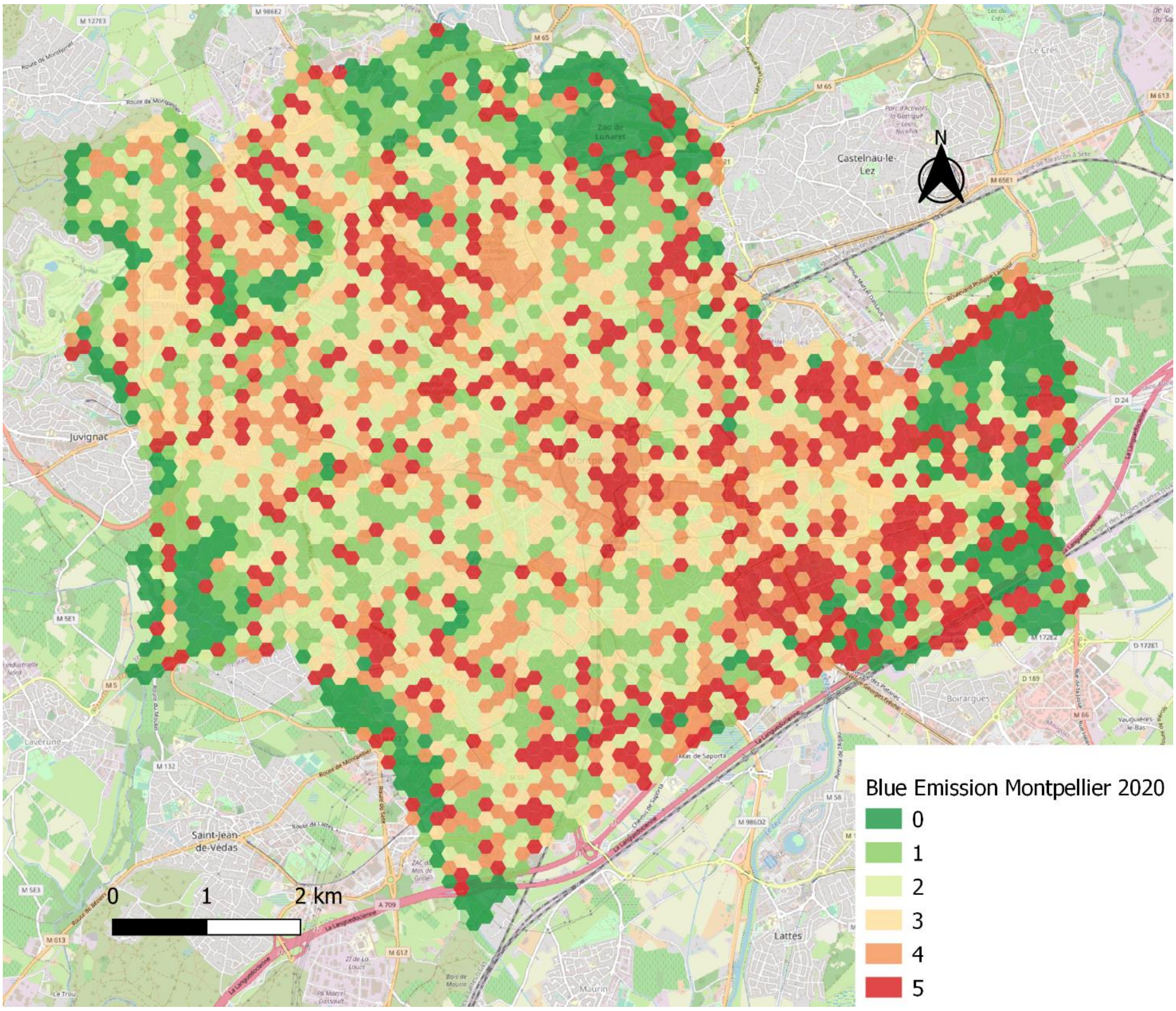

Figure 17 : Blue light emission classification (R/B band ratio) per 150 m grid cell

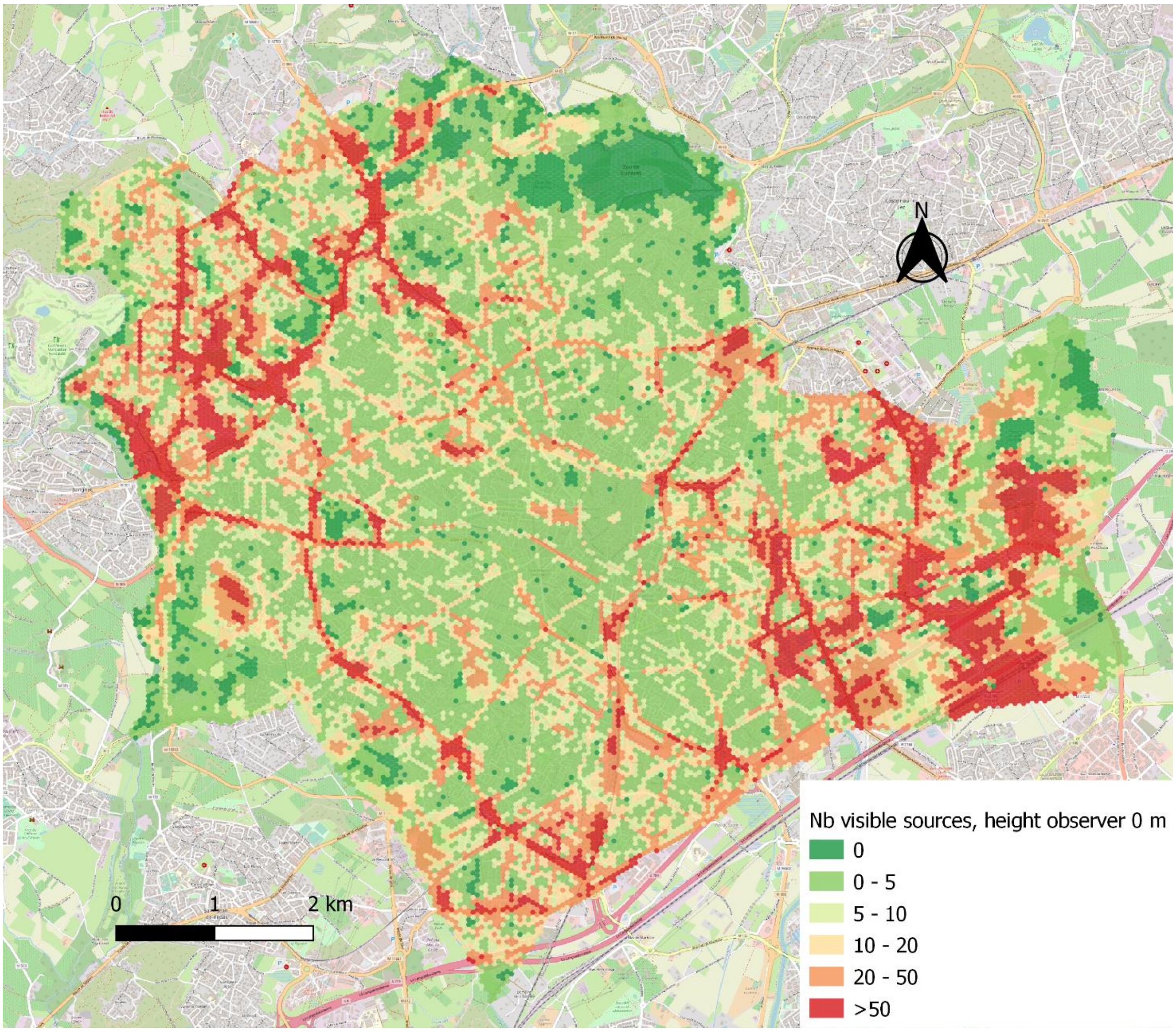

Figure 18 : Average number of visible light sources per 50 m grid, at an observer height of 0 m

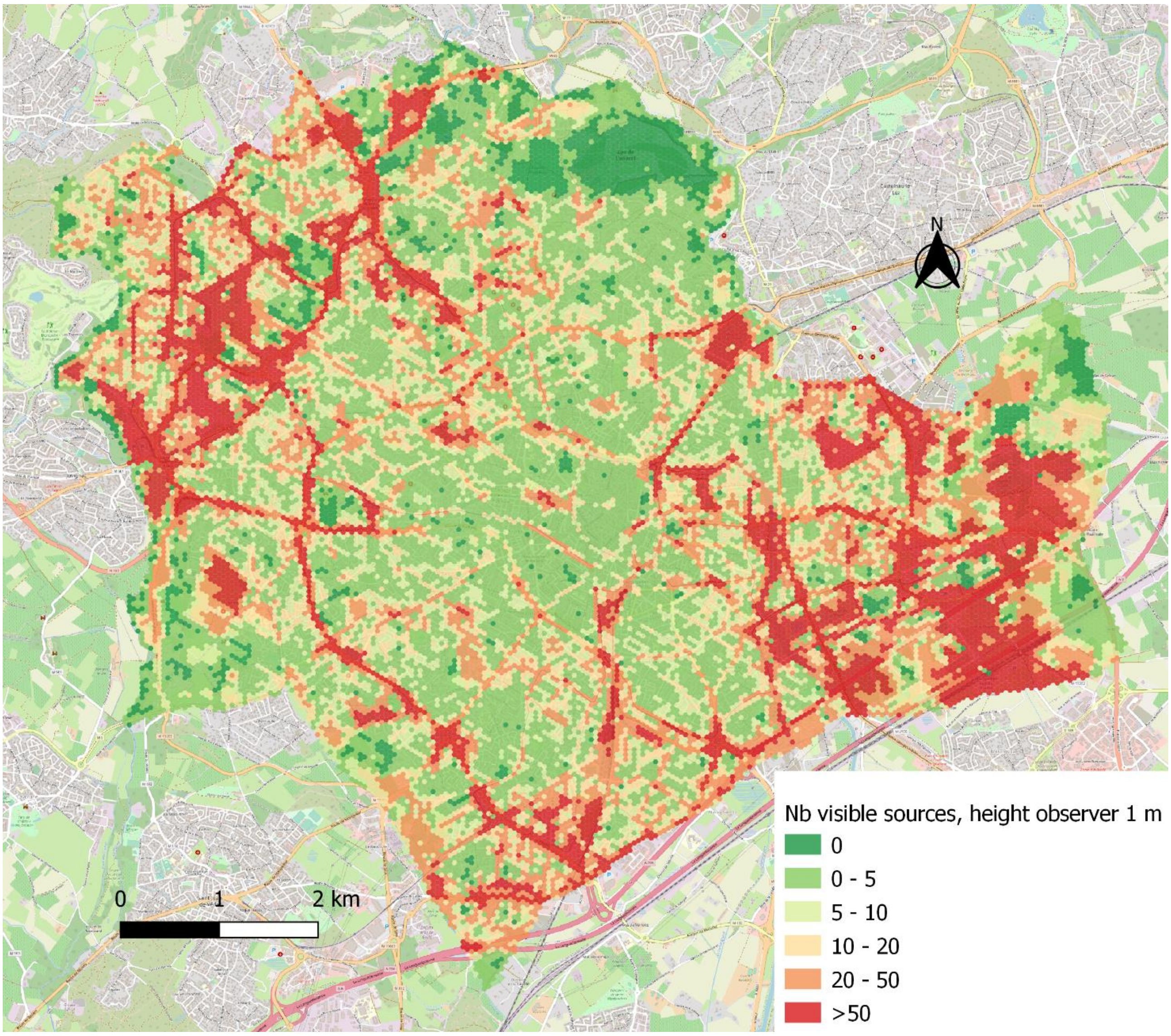

Figure 19 : Average number of visible light sources per 50 m grid, at an observer height of 1 m

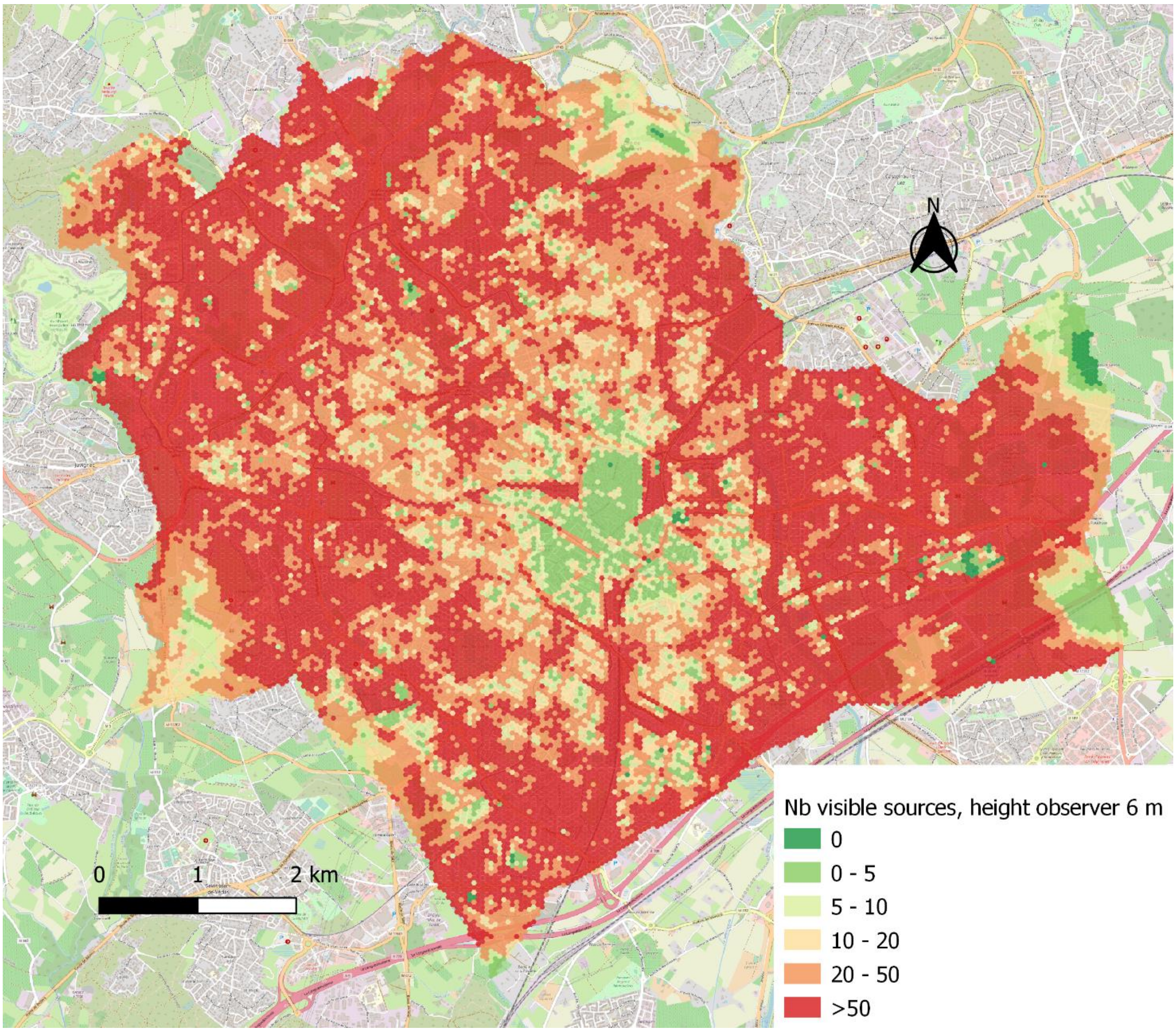

Figure 20 : Average number of visible light sources per 50 m grid, at an observer height of 6 m

Centre INRAE Occitanie - Montpellier
2, place Viala
34000 Montpellier

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