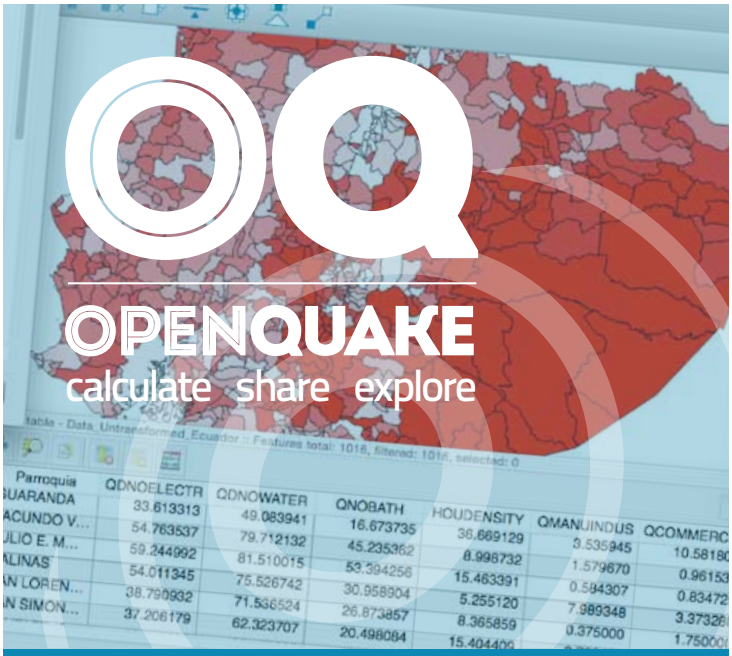

INTEGRATED RISK MODELLING TOOLKIT

USER INSTRUCTION MANUAL

Hands-on-instructions on the different functionalities of the Integrated Risk Modelling Toolkit

GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

Integrated Risk Modelling Toolkit -

User Manual

Release 3.13.0

GEM Foundation

Jan 25, 2022

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CHAPTER

ONE

INSTALLATION AND TROUBLESHOOTING

This plugin runs with QGIS 3.0[1] and above.

On Microsoft Windows, QGIS includes all the software dependencies needed by the plugin.

On macOS and Linux, please make sure that Scipy[2] and Matplotlib[3] with Qt5 backend are installed. On macOS, please also make sure that Pillow[4] is installed.

On macOS:

```
$ python3 -m pip install --upgrade pip
$ python3 -m pip install --upgrade matplotlib scipy Pillow
```

On Ubuntu (Debian and similar):

```
$ sudo apt install python3-scipy python3-matplotlib python3-pyqt5.qtwebkit
```

On Fedora and similar:

```
$ sudo dnf install python3-scipy python3-matplotlib python3-matplotlib-qt5
```

On macOS make sure to run the script located under */Applications/Python 3.6/Install Certificates.command*, after Python has been installed, to update the SSL certificates bundle.

On Fedora, please follow these instructions[5].

The plugin can be installed using the QGIS Plugins Manager, that is accessible through the QGIS menu as *Plugins -> Manage and install plugins*. Please note that the *Settings* of the Plugins Manager contain a checkbox to *Show also experimental plugins*. If that option is checked, the latest version of the plugin that is marked as *experimental* will be available for installation. Otherwise, the latest *stable* version will be installable. Experimental versions contain new functionalities that may have not been properly tested yet, and that could cause the plugin or QGIS to break or to behave unexpectedly.

Some users reported issues about *upgrading* the plugin to its latest version. We recommend to *reinstall* the plugin instead, in order to make sure the new installation is done in a clean folder.

[1] http://qgis.org/it/site/forusers/alldownloads.html
[2] https://www.scipy.org/install.html
[3] https://matplotlib.org/users/installing.html
[4] https://pillow.readthedocs.io/en/stable/installation.html
[5] https://copr.fedorainfracloud.org/coprs/dani/qgis/

1.1 Mirror

A mirror of this repository, hosted in Pavia (Italy), is available at https://mirror.openquake.org/git/GEM/oq-irmt-qgis.git.

1.2 How to run tests and build the documentation

Tests run on a QGIS docker container based on Ubuntu Xenial (16.04LTS), launching one of the following commands from the *svir* directory:

```
$ ../scripts/run_unit_tests.sh
$ ../scripts/run_integration_tests.sh
```

The user manual, both in the html and pdf versions can be built by the same QGIS docker container running the following command from the *svir* directory:

```
$ ../scripts/make_doc.sh
```

CHAPTER

TWO

INTRODUCTION

At the core of the Global Earthquake Model (GEM) is the development of state-of-the-art modeling capabilities and a suite of software tools that can be utilized worldwide for the assessment and communication of earthquake risk. For a more holistic assessment of the scale and consequences of earthquake impacts, a set of methods, metrics, and tools are incorporated into the GEM modelling framework to assess earthquake impact potential beyond direct physical impacts and loss of life. This is because with increased exposure of people, livelihoods, and property to earthquakes, the potential for social and economic impacts of earthquakes cannot be ignored. Not only is it vital to evaluate and benchmark the conditions within social systems that lead to adverse earthquake impacts and loss, it is equally important to measure the capacity of populations to respond to damaging events and to provide a set of metrics for priority setting and decision-making.

The employment of a methodology and workflow necessary for the evaluation of seismic risk that is integrated and holistic begins with the OpenQuake Integrated Risk Modelling Toolkit (OpenQuake IRMT). The OpenQuake IRMT is QGIS plugin that was developed by the Global Earthquake Model (GEM) Foundation[6] and co-designed by GEM and the Center for Disaster Management and Risk Reduction Technology (CEDIM)[7]. The plugin allows users to form an integrated workflow for the construction of metrics used to assess characteristics within societies that affect earthquake risk by providing a GIS-based platform for the construction of indicators and composite indices to foster comparative assessments. Here, an indicator is defined as a piece of information that summarizes the characteristics of a system or highlights what is happening in a system. An indicator is a quantitative or qualitative measure derived from observed facts that simplify and communicate the reality of a complex situation. Indicators reveal the relative position of the phenomena being measured and when evaluated over time, can illustrate the magnitude of change (a little or a lot) as well as direction of change (up or down; increasing or decreasing). The mathematical combination (or aggregation as it is termed) of a set of indicators forms a composite indicator (or composite index or indices).

As part of the workflow, the OpenQuake IRMT facilitates the integration of composite indicators of socio-economic characteristics with measures of physical risk (i.e. estimations of human or economic loss) from the OpenQuake Engine (OQ-engine) ([PMW+14] and [SCP+14]), or other sources, to form what is referred to as an integrated risk assessment. Although the tool may be utilized for any type of indicator development, it is encouraged that composite indicators of social vulnerability are developed within this integrated risk framework. Social vulnerability is defined here as characteristics or qualities within social systems that create the potential for harm or loss from damaging hazard events. Given equal exposure to natural threats, such as an earthquake, two groups may vary in their social vulnerability due to their pre-existing social characteristics, where differences according to wealth, gender, race, class, history, and sociopolitical organization influence the patterns of loss, mortality, and the ability to reconstruct following damaging events.

[6] http://www.globalquakemodel.org/
[7] https://www.cedim.de/english/index.php

The focus on the development of indicators of social vulnerability, and ultimately integrated risk, will allow researchers, decision-makers, and other relevant stakeholders to:

- consider loss and damage as part of a dynamic system in which interactions between natural systems and societal factors redistribute risk before an event and redistribute loss after an event
- mainstream socio-economic vulnerability and resilience in earthquake loss and damage policy discussions
- evaluate loss and damage taking social factors into account at different time and space scales
- use risk assessments in benchmarking exercises to monitor trends in earthquake risk over time
- recognize that both causes and solutions for earthquake loss are found in human, environmental, and built-environmental interactions
- help decision-makers develop a common dialog that pertains to the factors that they should concentrate on to reduce risk and strengthen resilience.

The development of composite indicators is not new to research fields and occupations requiring empirical measurement, and a vast literature on composite indicators exists that outline methodological approaches for index construction and validation. To accompany this manual we suggest the use of two popular resources ([NSST05] and [NSST08]) aimed at providing a guide for the construction and use of composite indicators.

This literature outlines the process of robust composite indicator construction that contains a number of steps. The OpenQuake IRMT leverages the QGIS platform to guide the user through the major steps for index construction. These steps include 1) the selection of variables; 2) data normalization/standardization; 3) weighting and aggregation to produce composite indicators; 4) risk integration using OpenQuake risk estimates; and 5) the presentation of the results.

The OpenQuake IRMT plugin has been extended significantly with respect to its original purposes, in order to make it operate seamlessly with the other main components of the OpenQuake suite, i.e., the OpenQuake Engine[8] and the OpenQuake Platform[9]. This enables a whole end-to-end workflow, where calculations of physical hazard and risk can be run directly from within the QGIS environment (see *Driving the OpenQuake Engine*) and the outputs of such calculations can be loaded as QGIS vector layers. Those of them that can be visualized as maps (e.g. hazard maps) are also automatically styled with respect to fields selected by the user. Others can be plotted as curves (e.g. hazard curves) inside a *Data Viewer* window (see *The OpenQuake IRMT Data Viewer*) that was conceived for this purpose. Users that are willing to share their projects through the OpenQuake Platform, can use the interface of the plugin to upload their work to the Platform. They can also download and edit projects that were shared through the Platform by other users.

Another important addition to the OpenQuake IRMT plugin is a module for post-earthquake recovery modeling (see *Post-Earthquake Recovery Modelling Methodology*), that was supported by the State of California, Alfred E. Alquist Seismic Safety Commission, as part of a collaborative effort between the Global Earthquake Model (GEM) and the University of California at Los Angeles (UCLA), Department of Civil and Environmental Engineering. GEM implemented in the QGIS environment the scientific methodology developed by UCLA [BDL+15].

[8] https://github.com/gem/oq-engine
[9] https://platform.openquake.org/

CHAPTER

THREE

DEFINITIONS AND ACRONYMS

In this manual, the terminology *layer*, *project*, and *project definition* are used ubiquitously, and it is important to explain what the terminology means as well as its use. In QGIS, a *project* or *project file* is a kind of container that acts like a folder storing information on file locations of layers and how these layers are displayed in a map. It is the main QGIS datafile. A *layer* is the mechanism used to display geographic datasets in the QGIS software, and layers provide the data that is manipulated within the OpenQuake IRMT. Each layer references a specific dataset and specifies how that dataset is portrayed within the map. The standard layer format for the OpenQuake IRMT is the ESRI Shapefile [ESRI98] that can be imported within the QGIS software using the default *add data* functionality, or layers may be created on-the-fly within the OpenQuake IRMT using GEM socio-economic databases. A QGIS project can include multiple layers that can be utilized to provide the variables and maps necessary for an integrated risk assessment. For each layer, multiple *project definitions* can be saved. A *project definition* is a set of parameters that are defined within the OpenQuake IRMT to define the integrated risk assessment's workflow. It allows users to create, edit, and manage the workflow needed to systematically develop integrated risk models using layers. The project definition:

- distinguishes which variables within a dataset are to be combined together to obtain a composite indicator;
- defines how variables are grouped together by supporting: 1) deductive models that typically contain fewer than ten indicators that are normalized and aggregated to create the index; and 2) hierarchical models that employ roughly ten to twenty indicators that are separated into groups (sub-indices) that share the same underlying dimension (such as economy and infrastructure) in a manner in which individual indicators are aggregated into sub-indices, and the subindices are aggregated to create the index;
- describes the type of aggregation method including additive modelling, weighted aggregation, and geometric aggregation that can be utilized by users to combine variables;
- establishes the application of weights (if desired) to individual variables or sub-indices; and
- delimits the directionality of variables when the intent is to consider that some variables may add to an index outcome; whereas some variables may need to detract from it. When considering the social vulnerability of populations, a socio-economic status indicator such as the percentage of population with a college education provides an example of a characteristic that may detract from social vulnerability, thereby warranting a negative directionality within an index.

In seismic hazard and risk analysis, a Ground-Motion Measure Type (GMMT) is a physical quantity expressing a particular characteristic of the ground shaking recorded or computed at one site. The most important and frequently used GMMTs are scalar and they indicate the shaking intensity (i.e. the amplitude of the ground shaking). These GMMT are also indicated with the acronym IMT. Other ground-motion measures define, for example, the duration of the shaking. A very common IMT is the

peak ground acceleration, specified with the PGA acronym. The principal IMT used in the OpenQuake-engine are:

- Peak Ground Acceleration – indicated as PGA – measured in fractions of g
- Peak Ground Velocity – indicated as PGV – measured in cm/s
- Peak Ground Displacement – indicated as PGV – measured in cm
- Spectral Acceleration for a given period T – indicated as Sa(T) - measured in fractions of g

An Intensity Measure Level (IML) is a value of a specific IMT.

CHAPTER

FOUR

THE PLUGIN MENU

When the OpenQuake IRMT plugin is installed, it adds its own menu to those available on the QGIS graphical user interface. The plugin menu contains the options listed below. For each option, this manual provides a separate chapter with the description of its functionality and of the typical workflows in which it is used. Please follow the links next to the option icons, to reach the corresponding documentation.

Note: The menu options are disabled when the corresponding functionalities can not be performed. For instance, the *Transform attributes* option will be available only as long as one of the loaded layers is activated.

- OpenQuake Platform
  - *Loading socioeconomic indicators from the OpenQuake Platform*
  - *Downloading a project from the OpenQuake Platform*
  - *Uploading a project to the OpenQuake Platform*
- OpenQuake Engine
  - OpenQuake Risk Input Preparation Toolkit[10]: Online tools used to create exposure, fragility and vulnerability risk input models.
  - OpenQuake TaxtWEB[11]: Online graphical tool for editing GEM Taxonomy strings.
  - *Driving the OpenQuake Engine*
- Integrated risk
  - *Project definitions manager*

[10] https://github.com/gem/oq-platform-ipt
[11] https://github.com/gem/oq-platform-taxtweb

  - *Weighting data and calculating indices*

- Recovery modeling
  - *Post-Earthquake Recovery Modelling Methodology*
  - *Setting up the configuration variables to run the recovery modelling algorithm*
- Utilities
  - *Aggregating points by zone*
  - *Transforming attributes*
- *OpenQuake IRMT settings*
- *The OpenQuake IRMT Data Viewer*
- OpenQuake IRMT manual: a web browser will be opened, showing the html version of this manual

CHAPTER

FIVE

OPENQUAKE IRMT SETTINGS

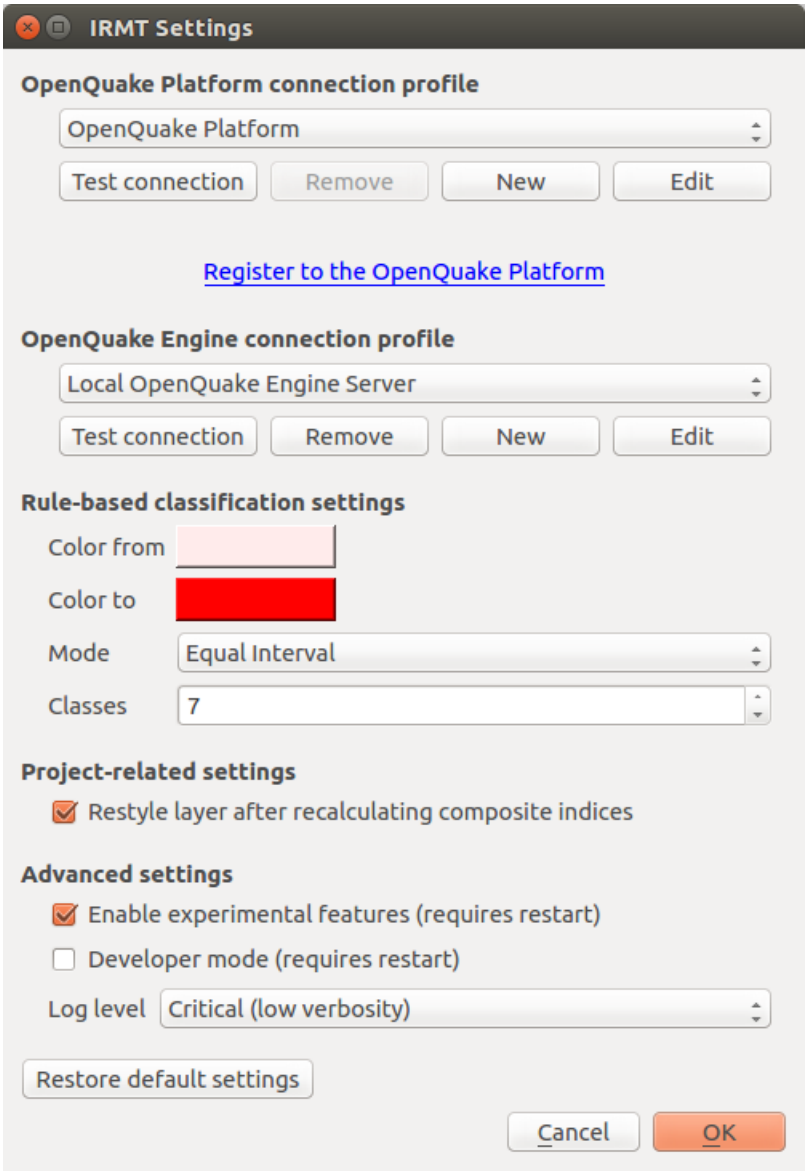


Fig. 5.1: OpenQuake IRMT settings

Some of the functionalities provided by the plugin, such as the ability to work with GEM data, require the interaction between the plugin itself and the OpenQuake Platform (OQ-Platform) or the OpenQuake Engine (OQ-Engine).

The OQ-Platform is a web-based portal to visualize, explore and share GEM's datasets, tools and models. In the *OpenQuake IRMT Settings* dialog displayed in Fig. 5.1, credentials must be inserted to authenticate the user and to allow the user to log into the OQ-Platform. In the *Host* field insert the URL of GEM production installation of the OQ-Platform[12] or a different installation if you have URL access. If you still haven't registered to use the OQ-Platform, you can do so by clicking *Register to the OQ-Platform*. This will open a new web browser and a sign up page[13].

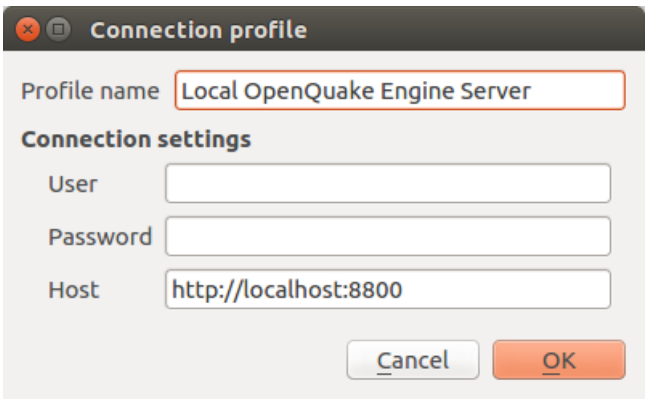


Fig. 5.2: Connection profile

The OQ-Engine[14] is an open source application that allows users to compute seismic hazard and seismic risk of earthquakes on a global scale. It can run locally on the user's machine, or on a remote workstation or cluster. The OQ Engine Server[15] provides an HTTP RESTful API. The OpenQuake IRMT plugin leverages this API to enable the user to drive the OQ-Engine directly from within QGIS. In order to interface the plugin with a running OQ Engine Server (WebUI), it is necessary to insert in this dialog the user credentials (if they are required by the server) and the web URL where the service is hosted (see Fig. 5.2). By default, the host is set to *http://localhost:8800*, meaning that the plugin will attempt to connect to a OQ Engine Server (WebUI) running locally, on port *8800*.

It is possible to create multiple connection profiles, and to edit or remove existing ones. For instance, you might want to use alternatively an OpenQuake Engine Server running on your local machine and a remote one running on a cluster. For this purpose, you can create the two connection profiles, and then select one or the other from the *OpenQuake Engine connection profile* dropdown menu. The buttons *Test connection* can be used to check if the plugin is able to connect to the corresponding server using the specified host name and credentials.

When the plugin loads an OQ-Engine hazard/risk map as a layer or when integrated risk indices are calculated, the corresponding map is automatically styled applying a rule-based classification with the parameters specified in the *Rule-based classification settings*. By default, whenever composite indices are calculated, the rule-based classification is applied and the layer is styled accordingly. On a project level, it is possible to avoid restyling the layer at each recalculation of the composite indices, by unchecking the corresponding option.

5.1 Advanced settings

The checkbox labeled *Enable experimental features (requires restart)* enables some functionalities of the plugin that are still experimental and not completely tested. It is not recommended for standard

[12] https://platform.openquake.org
[13] https://platform.openquake.org/account/signup/
[14] https://github.com/gem/oq-engine
[15] https://github.com/gem/oq-engine/blob/master/doc/running/server.md

users.

It is possible to change the verbosity of the plugin log, by selecting a *Log level* in the corresponding dropdown menu. Levels are:

- Info (high verbosity): whatever is notified to the user through the message box in the graphical user interface, will be also printed in the log.
- Warning (medium verbosity): only critical messages (errors) and warnings will be printed in the log.
- Critical (low verbosity): only critical messages (errors) will be printed in the log.

The checkbox labeled *Developer mode (requires restart)* can be used to log additional information for debugging purposes. It is useful for developers or advanced users for troubleshooting, but it is not recommended for standard users.

The button *Restore default settings* can be used to discard the settings customized by the user and to replace them with the factory defaults. Please be aware that such operation, once confirmed, can not be undone.

CHAPTER

SIX

LOADING SOCIOECONOMIC INDICATORS FROM THE OPENQUAKE PLATFORM

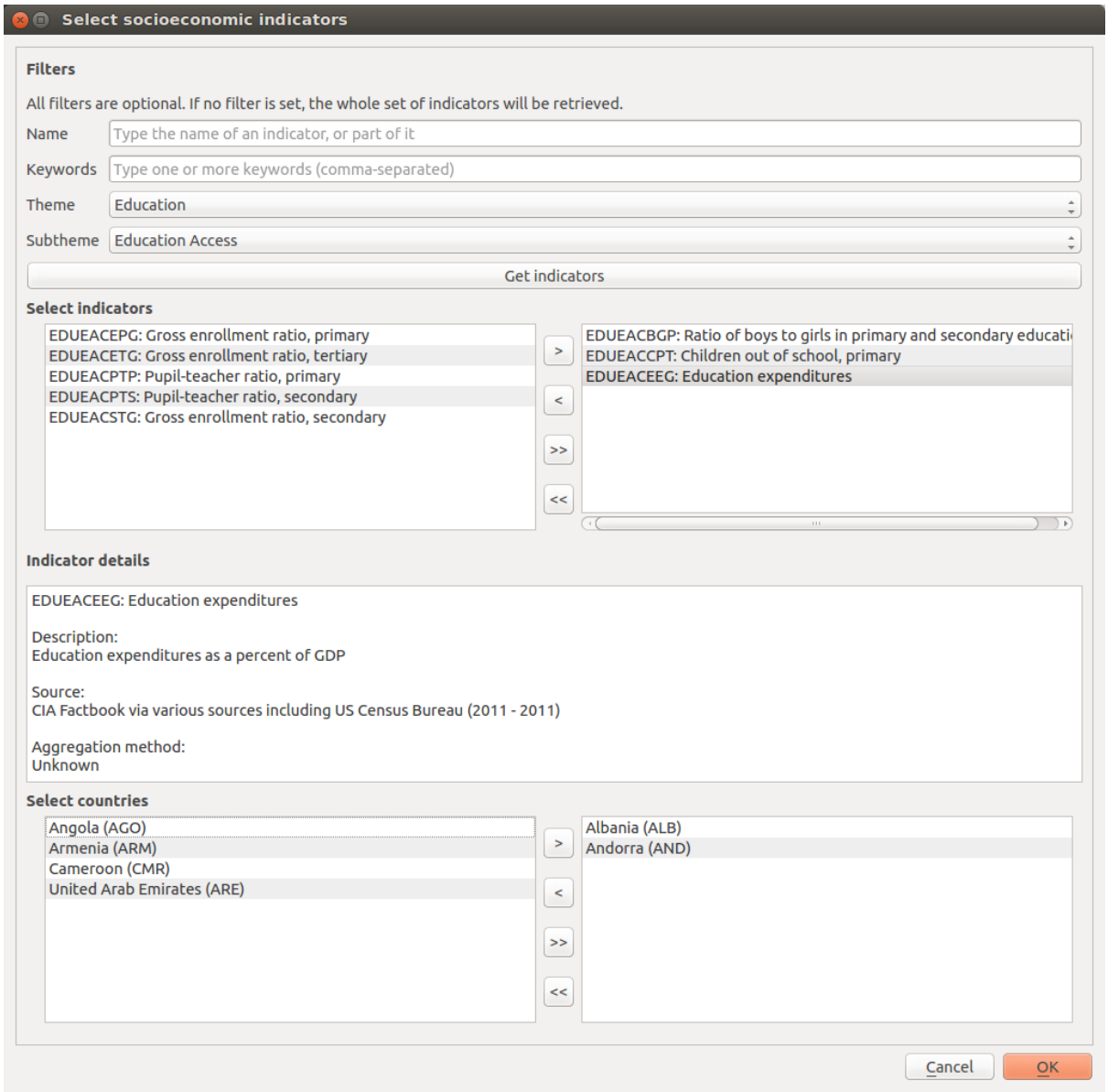


Fig. 6.1: Socio-economic indicators selection portal

The selection of data comprises an essential step for an assessment of risk from an integrated and holistic

perspective using indicators. The strengths and weaknesses of composite indicators are derived to a great extent by the quality of the underlying variables. Ideally, variables should be selected based on their relevance to the phenomenon being measured, analytical soundness, accessibility, and completeness [NSST08]. Proxy measures for social and economic vulnerability have been provided by the Global Earthquake Model that have been stringently tested for representativeness, robustness, coverage and analytical soundness [KBT+14]. These are currently accessible in the OpenQuake IRMT at the national level of geography (gadm L1). Future software releases will add access to data at gadm level 2 (L2) for a selection of countries and regions. This will include the eight Andean countries of South America and countries within Sub-Saharan Africa.

Fig. 6.1. displays the *Select Socioeconomic Indicators* dialog that was developed to allow users to select indicators based on a number of factors and filtering mechanisms. A *Filters* section was developed to enable users to filter indicators by name, keywords, theme (e.g. Economy) and subtheme (e.g Resource Distribution and Poverty). The *subtheme* dropdown menu is automatically populated depending on the selection of a respective theme. When *Get indicators* is pressed, a list of filtered indicators is populated on the left side of the dialog within the *Select indicators* window. If no filters are set, then the whole list of indicators available within the database is retrieved and displayed within the *Select indicators* window.

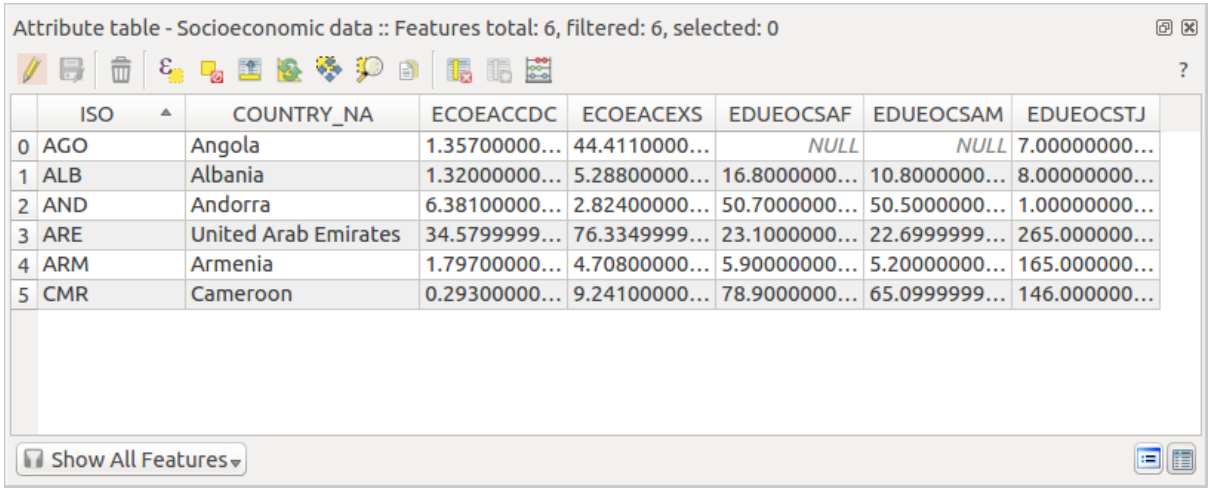
From the *Select indicators* window, it is possible to select one or more indicators by single-clicking them in the *Unselected* list on the left. Double-clicking the selected indicator(s) moves them to the *Selected* list on the right, and the corresponding data will be downloaded from the OQ-Platform. Another way to move items to the right, or back to the left, is to use the four central buttons (*add the selected items*, *remove the selected items*, *add all*, *remove all*). The *Indicator details* section displays information about the last selected indicator: code, short name, longer description, source and aggregation method.

The *Select countries* dialog contains the list of enumeration types (in this case countries) that socioeconomic data is available for within the database. Countries can be selected from the list in the same manner that indicators are selected using *Select indicators*. Once at least one indicator and one country has been selected, the *OK* button will be enabled. By pressing the *OK* button, data will be downloaded from the OQ-Platform and compiled into a vector shapefile for display and manipulation within QGIS (another dialog will ask you where to save the shapefile that will be obtained). The layer will contain features equal to the number of selected countries and will contain all attributes selected as indicators for the given countries. Additional attributes will include fields containing country ISO codes and country names.

Note: When a socioeconomic indicator is downloaded from the OpenQuake Platform, the layer field that is created to store the indicator values will be named after the indicator code. This is because the code is shorter than 10 character, which is the maximum length for a field name according with the shapefiles specifications. The code is not so easily readable though, therefore the plugin assigns to the field also an alias, containing the full name of the socioeconomic indicator. In this way, when the layer attribute table is opened, its header will display the full name of the indicator. The code will still be visible as a tooltip, by pointing the mouse over the column header. Please note that aliases are not stored in the shapefile, but they are linked to it through the project properties. Therefore, if only the shapefile is saved and opened in a different project, those aliases will not be available anymore. In order to keep track of aliases, it is therefore necessary to save the project, including the shapefile in it.

To reduce processing time, detailed country geometries were simplified using ESRI Bend Simplify algorithm[16]. Bend Simplify removes extraneous bends and small intrusions and extrusions within an area topology without destroying its essential shape.

[16] http://resources.arcgis.com/en/help/main/10.1/index.html#//007000000010000000



	ISO	COUNTRY_NA	ECOEACCDC	ECOEACEXS	EDUEOCSAF	EDUEOCSAM	EDUEOCSTJ
0	AGO	Angola	1.35700000...	44.4110000...	*NULL*	*NULL*	7.00000000...
1	ALB	Albania	1.32000000...	5.28800000...	16.8000000...	10.8000000...	8.00000000...
2	AND	Andorra	6.38100000...	2.82400000...	50.7000000...	50.5000000...	1.00000000...
3	ARE	United Arab Emirates	34.5799999...	76.3349999...	23.1000000...	22.6999999...	265.000000...
4	ARM	Armenia	1.79700000...	4.70800000...	5.90000000...	5.20000000...	165.000000...
5	CMR	Cameroon	0.29300000...	9.24100000...	78.9000000...	65.0999999...	146.000000...

Fig. 6.2: Layer attribute table

Fig. 6.2 shows the attribute table of a sample vector layer compiled and downloaded within the OpenQuake IRMT.

Note: For some countries the values of indicators might be unavailable (displayed in the attribute table as `NULL`).

When the tool downloads the socioeconomic data, a project definition is automatically built taking into account how the data was organized in the socioeconomic database. At the country level data was grouped together by theme meaning that indicators belonging to the same theme will be grouped together in a hierarchical structure. This structure considers: 1) vulnerable populations; 2) economies; 3) education; 4) infrastructure; 5) health; 6) governance and institutional capacities; and 7) the environment.

CHAPTER

SEVEN

DOWNLOADING A PROJECT FROM THE OPENQUAKE PLATFORM

An additional option to access data is by downloading projects shared by others on the OQ-Platform. By clicking the *Download project from the OpenQuake Platform*, the above dialog is opened (Fig. 7.1). Here, a list of available projects is displayed. The list will contain the titles of projects for which the user has been granted editing privileges (their own projects or those shared with them by other users). When a project is selected from the list, its title, abstract, bounding box and keywords are displayed in the lower textbox that is utilized to delineate important attributes of the project definition. The label directly above the textbox displays an ID that uniquely identifies the layer used in the OpenQuake-platform.

By pressing *OK*, the layer will be downloaded into the QGIS. Prior to downloading, the layer will first have to be saved as a new shapefile locally by navigating to a folder in which the shapefile is to be saved. If the associated project only contains one *project definition*, it will be automatically be selected and downloaded. Otherwise, the project definition manager will open (see *Project definitions manager*) allowing the user to choose one of the available project definitions. Once a project definition is selected, the composite indicators delineated within the project definition are re-calculated, and the layer is styled and rendered accordingly. This process may take some time, depending on the complexity of the project.

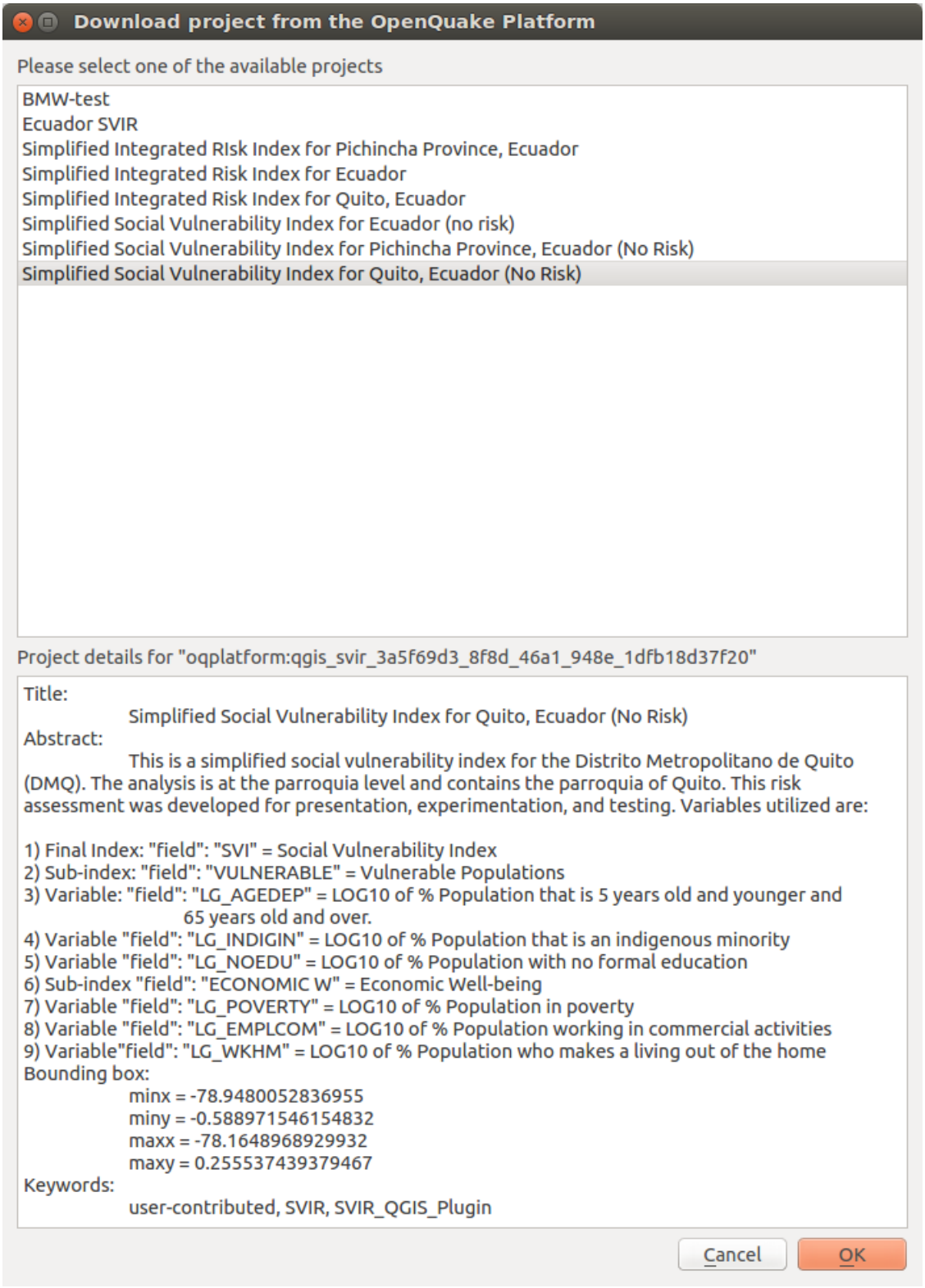


Fig. 7.1: Downloading a project from the OpenQuake Platform

CHAPTER

EIGHT

TRANSFORMING ATTRIBUTES

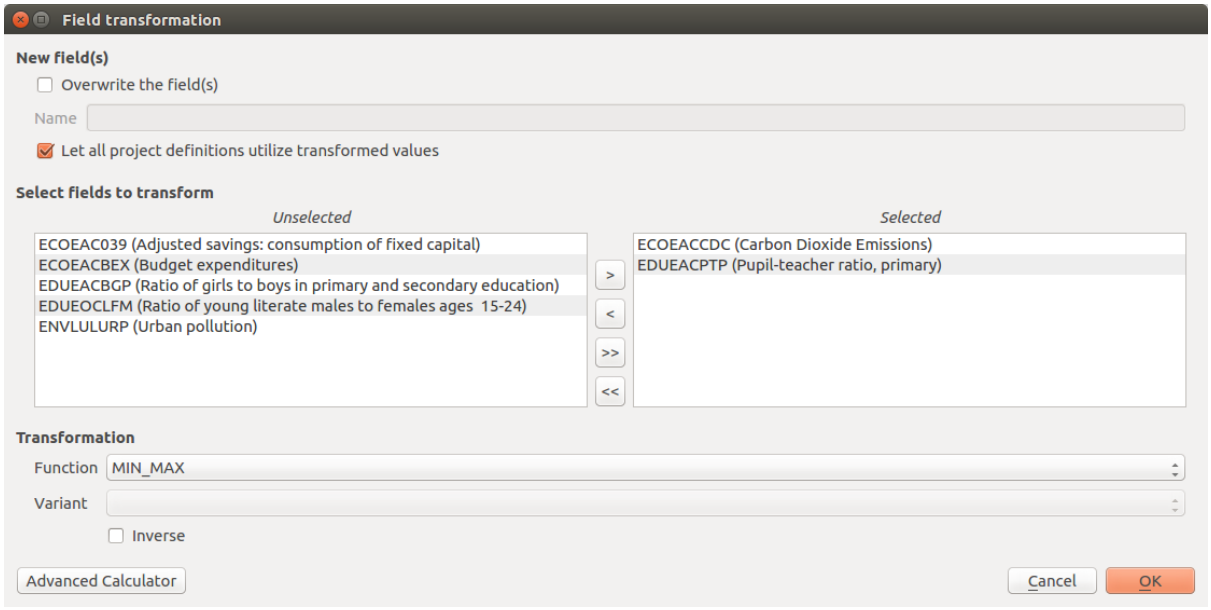


Fig. 8.1: Variable transformation and batch transformation functionality

When variables are defined in incommensurate ranges or scales, they can be standardized to avoid problems inherent when mixing measurement units, and normalization is employed to avoid having extreme values dominate an indicator, and to partially correct for data quality problems. The QGIS platform natively provides a *Field calculator* that can be used to update existing fields, or to create new ones, in order to perform a wide variety of mathematical operations for the standardization/transformation of data. In addition, the OpenQuake IRMT provides a number of transformation functions found in popular statistical and mathematical modelling packages (Table 8.1).

Table 8.1: Selection of transformation functions with equations found in the OpenQuake IRMT.

Standardization (or Z-scores)	$Z(x_i) = \frac{x_i - \mu_x}{\sigma_x}$ $(\mu_x = mean\ \sigma_x = stddev)$
Min-Max	$M(x_i) = \frac{x_i - \min_{i \in \{1,\ldots,n\}}(x_i)}{\max_{i \in \{1,\ldots,n\}}(x_i) - \min_{i \in \{1,\ldots,n\}}(x_i)}$
Logistig Sigmoid	$S(x_i) = \frac{1}{1+e^{-x_i}}$
Simple Quadratic	$Q(x_i) = \frac{x^2}{\max_{i \in \{1,\ldots,n\}}(x_i)}$

Warning: Not all layer types can be edited. For instance, it is impossible to add or modify fields of a csv-based layer. Prior to apply transformations to non-editable layers, it is necessary to save them as shapefiles or as another editable kind.

These include:

1. **Ranking** is the simplest standardization technique. It is not affected by outliers and allows the performance of enumeration units to be benchmarked over time in terms of their relative positions (rankings). The ranking algorithm deals with ties using a chosen strategy between those listed below (see https://en.wikipedia.org/wiki/Ranking#Strategies_for_assigning_rankings):
   - Average - Fractional (1 2.5 2.5 4)
   - Standard competition - Minimum (1 2 2 4)
   - Modified competition - Maximum (1 3 3 4)
   - Dense (1 2 2 3)
   - Ordinal (1 2 3 4)
2. **Z-scores normalization** is the most common standardization technique. A Z-score converts indicators to a common scale with a mean of zero and standard deviation of one. Indicators with outliers that are extreme values may have a greater effect on the composite indicator. The latter may not be desirable if the intention is to support compensability where a deficit in one variable can be offset (or compensated) by a surplus in another. Summarizing: Z-score handles outliers, but does not produce normalized data with the exact same scale.
3. **Min-Max normalization** is a type of transformation that rescales variables into an identical range between 0 and 1. Extreme values/or outliers could distort the transformed risk indicator. However, the Min-Max transformation can widen a range of indicators lying within a small interval, increasing the effect of the variable on the composite indicator more than the Z-scores. In brief: Min-Max guarantees all normalized fields will have the exact same scale but does not handle outliers well.
4. **Log10** is one of a class of logarithmic transformations that include natural log, log2, log3, log4, etc. Within the current plugin, we offer functionality for log10 only, yet these transformations are possible within the advanced *field calculator*. A logarithm of any negative number or zero is undefined. This algorithm copes with the case in which any zeros are present in the input data, offering two strategies:
   - Ignore zeros: each zero in input is transformed into nan
   - Increment all values by one: each input value is incremented by 1 before running the transformation.

   The algorithm uses the numpy.log10 function to transform the (possibly modified) list of values.
5. **Sigmoid function** is a transformation function having an *S* shape (sigmoid curve). A Sigmoid function is used to transform values on $(-\infty, \infty)$ into numbers on $(0, 1)$. The Sigmoid function is often utilized because the transformation is relative to a convergence upon an upper limit as defined by the S-curve. The OpenQuake IRMT utilizes a *simple sigmoid function* as well as its inverse. The Inverse of the Sigmoid function is a logit function which transfers variables on $(0, 1)$ into a new variable on $(-\infty, \infty)$.
6. **Quadratic or U-shaped functions** are the product of a polynomial equation of degree 2. In a quadratic function, the variable is always squared resulting in a parabola or U-shaped curve.

The OpenQuake IRMT offers an increasing or decreasing variant of the quadratic equation for horizontal translations and the respective inverses of the two for vertical translations.

Note: It may be desirable to visualize the results of the application of transformation functions to data. Although not feasible within the plugin at this point, we intend to build data plotting and curve manipulating functionalities into future versions of the toolkit.

The *Transform attribute* dialog (Fig. 8.1) was designed to be quite straightforward. The user is required to select one or more numeric fields (variables) available in the active layer. For the selection to be completed, the user must move the variables (either one at a time, or in a batch) to the *Selected variables* window on the right side of the interface. The user must then select the function necessary to transform the selected variables. For some functions, more than one variant is available. For functions that have an implementation of an inverse transformation, the *Inverse* checkbox will be enabled to allow users to invert the outcome of the transformation.

The *New field(s)* section contains two checkboxes and a text field. If the first checkbox *Overwrite the field(s)* is selected, the original values of the transformed fields will be overwritten by the results of the calculations; otherwise, a new field for each transformed variable will be created to store the results. In situations in which a user may desire to transform variables one at a time rather than using a batch transformation process, it is possible for the user to name each respective new field (editing the default one proposed by the tool). Otherwise, the names of the new fields will be automatically assigned using the following convention: if the original attribute is named *ORIGINALNA*, the name of the transformed attribute becomes *_ORIGINALN* (prepending "_" and truncating to 10 characters which is the maximum length permitted for field names in shapefiles). If the layer does not have the limitations of a shapefile, the name of the transformed field will *not* be truncated to 10 characters.

Note: In the lists of fields, both the field name and the field alias are displayed, with the format *name (alias)*. If no alias is specified for the field, the parenthesis will be empty. The plugin automatically assigns to the transformed field the same alias of the original one (if available). Please make sure that the names of the fields to be transformed do not contain parentheses, otherwise the plugin would erroneously interpret them as containers for the alias; therefore the selected name would be incomplete (being taken excluding the parentheses) and it would not be found in the layer.

If the checkbox *Let all project definitions utilize transformed values* is checked, all the project definitions associated with the active layer will reference the transformed fields instead of the original ones. Otherwise, they will keep the links to the original selected attributes. In most cases it is recommended to keep this checkbox checked. This automatic update of field references simplifies the workflow because it avoids the need to manually remove the original nodes from the weighting and aggregation tree (discussed in detail in *Weighting data and calculating indices*) in order to add the transformed nodes and to set again the nodes' weights. In other words, if a project was developed by weighting and aggregating untransformed indicators, this functionality allows for variables used in the project definition to be replaced on-the-fly (and automatically) by transformed variables. This saves the user from having to augment the model manually.

By clicking the *Advanced Calculator* button, the native QGIS field calculator is opened. Please refer to the code documentation for the detailed description of all the agorithms and variants provided by the OpenQuake IRMT.

The plugin is also an algorithm provider (the *OpenQuake IRMT* provider) for the Processing Toolbox. The transformation functions described above are available under the *Field transformation* group.

CHAPTER

NINE

PROJECT DEFINITIONS MANAGER

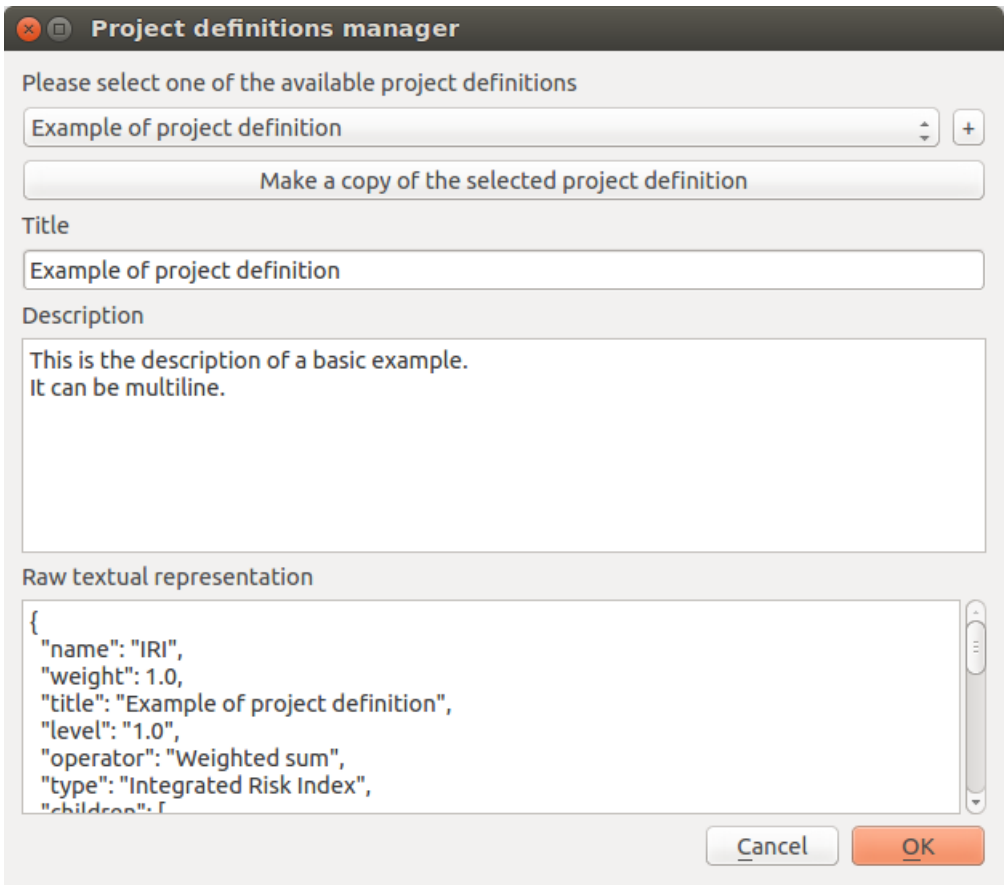


Fig. 9.1: Project definitions manager

The *Project Definitions Manager* is a module that was developed to allow users to create multiple models that can be accessed with a click of a button using a single layer. Each *project definition* (see *Definitions and acronyms*) can define a different model structure, weighting and aggregation scheme, and variable selections among data available in the underlying layer. It allows users to seamlessly toggle through various integrated risk assessment projects without having to refer to different *QGIS projects* or different *layers* containing data for a given area or areas, and without having to re-symbolize data to compare results of assessments using different methodological parameters. The *Project definitions manager* was developed around a dialog window that enables users to edit the current project definition, to switch from the current project definition to a different one, to add a new project definition, or to clone an existing project definition.

While contributing to the *Title* and *Description* textbox of the project definitions manager, the *Raw textual representation* is updated accordingly.

Warning: It is not recommended for users to edit the parameters directly inside the *raw textual representation* portion of the project definition manager, although it is not forbidden. This especially applies to variable names (field names) and sub-indicators (also field names) defined by nodes within the weighting and aggregation tree (see *Weighting data and calculating indices*). Manual adjustments can be useful in some corner cases, by experienced users, but manual adjustments can cause the toolkit to behave unexpectedly and can cause shapefiles to behave unexpectedly. Users performing these adjustments are at risk of compromise their data.

The + button at the right of the dropdown menu can be used to associate the current layer with a new project definition. By clicking it, a new basic project definition is created and the user is invited to provide the new project definition with a title and, possibly, a description. The button *Make a copy of the selected project definition*, assigns to the active layer within the QGIS a new project definition that is an exact clone of the selected one. Having two similar project definitions can be useful to easily visualize how the output of a project is changed based on updated variable selections, weighting, and aggregation schemes. This visualization is possible because a simple click is sufficient to switch between *before* and *after* project definitions. When *OK* is pressed, the composite indices are re-calculated accordingly with the project definition and the layer is styled as a consequence via a default classification and symbolization that is adjustable within the QGIS. This computation can take some time, depending on the complexity of the layer.

CHAPTER

TEN

WEIGHTING DATA AND CALCULATING INDICES

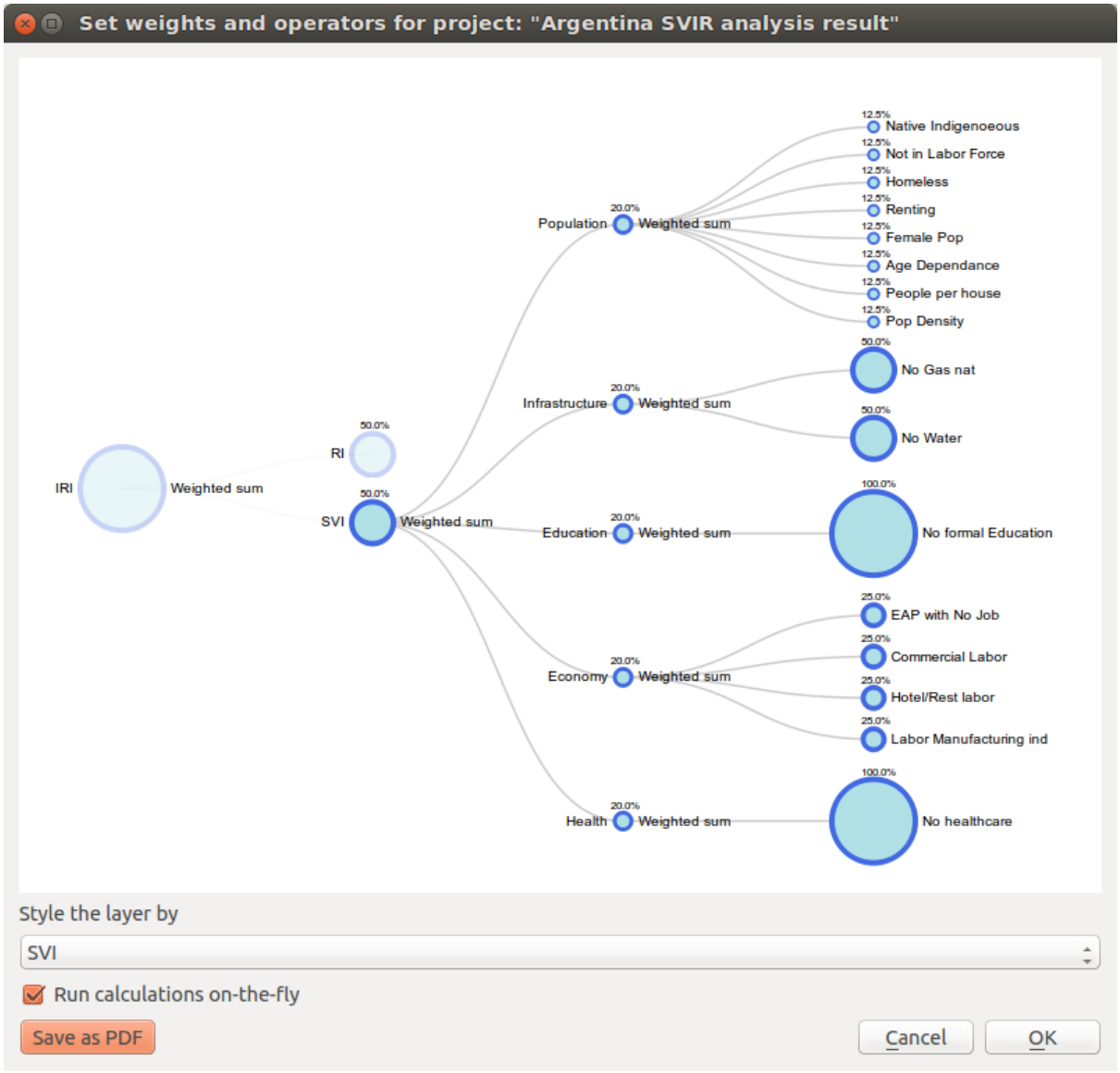


Fig. 10.1: Tree chart structure for the development of composite indicators

Central to the construction of composite indicators is the need to meaningfully combine different data dimensions, and consideration must be given to weighting and aggregation procedures. Most composite indicators rely on equal weighting largely for simplicity. Equal weighting, however, implies that all

variables within the composite indicator are of equal importance when this may not actually be the case. The issue of aggregation is similar to the weighting process. Different aggregation rules may be applied depending on the underlying theoretical framework chosen by the user for the modelling process. Sub-indicators may be summed up (linear aggregation) for instance, multiplied, or geometrically aggregated to correct for compensability (i.e., the possibility of offsetting a deficit in some dimension with an outstanding performance in another). Each technique has specific consequences, implies different assumptions, and could ignore or incorporate weights.

The *Weight data and calculate indices* widget (Fig. 10.1) is the key module of the IMRT. It contains the model building functionality of the OpenQuake IRMT, and it is used to create, edit, and manage composite indicator(s) and integrated risk model development. It provides users with an intuitive way to develop composite models by building and editing the selected project definition through the use of a dynamic graphical interface that was developed explicitly to guide the construction of composite indicators in a manner that is simple, visual, and straight-forward. The latter is accomplished through a window that embeds a dynamic model builder that takes the form of a tree chart (see Fig. 10.1). This structure (or weighting and aggregation tree) defines a workflow that strings together sequences of steps to describe how variables are combined together to obtain the composite indices.

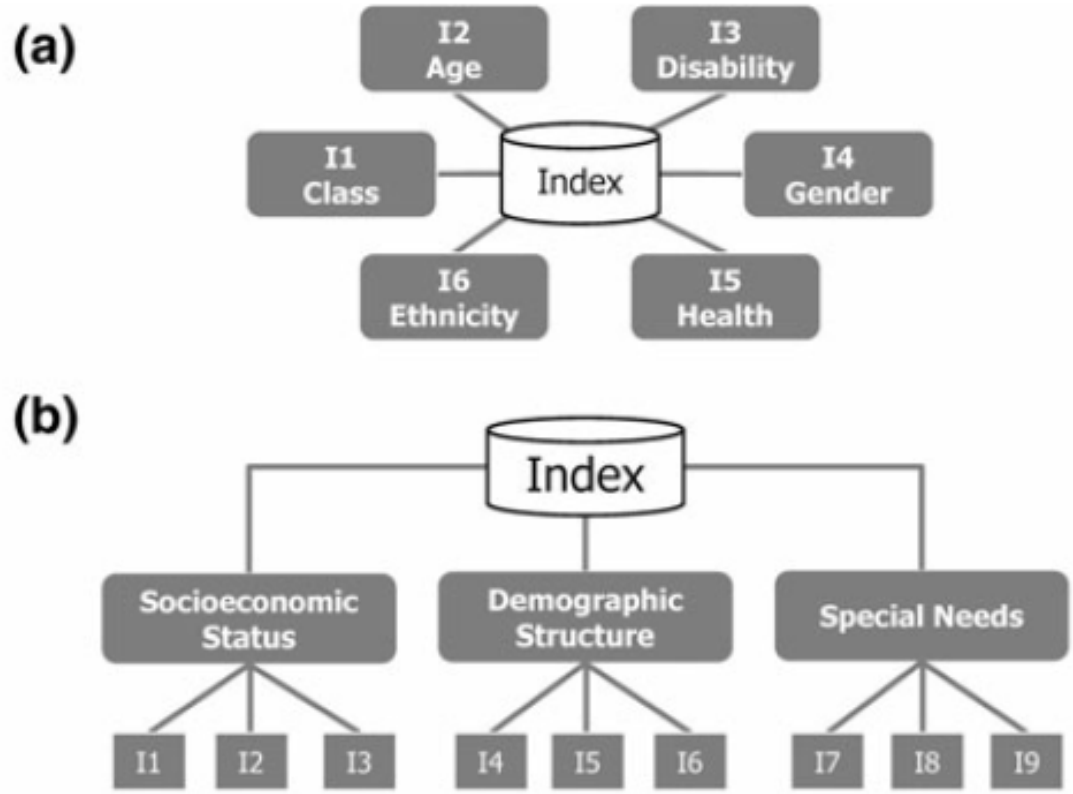


Fig. 10.2: Composite indicator types

Currently, the OpenQuake IRMT supports the development of two composite model types: a) deductive and, b) hierarchical (Fig. 10.2[17]). Deductive models typically contain fewer than ten indicators that are normalized and aggregated to create an index. Hierarchical models typically employ ten to twenty indicators that are separated into groups (sub-indices) that share the same underlying dimension of a concept (in this case socio-economic parameters of earthquake risk such as population, economy, infrastructure, education, and governance). Individual indicators are aggregated into sub-indices (e.g., population, economy, etc.), and the sub-indices are aggregated to form a final composite index (e.g.,

[17] Adapted from [TAT12]

social vulnerability or integrated risk index). The tree structure of the *Weight data and calculate indices* widget encourages the development of hierarchical models of integrated risk. The starting point is a *root node* that corresponds to the development of a hierarchical model that can be: 1) an *Integrated Risk Index* (IRI) which is a function of the aggregation of a *Social Vulnerability Index* (SVI) and a *Risk Index* (RI); or 2) a *Social Vulnerability Index* (SVI) that is the result of the aggregation of various sub-indicators defined by the user (e.g., Economy, Education, and Environment as shown within Fig. 10.1). The tree can be modified dynamically by adding or removing nodes, *inverting* variables, setting a weight to each variable or node and choosing the operators to be used to combine variables together.

Note: The dialog can be resized, and it is possible to pan and zoom within the tree area using your mouse. By pressing *Save as PDF*, and specifying the destination file, the project representation can be printed as PDF.

Whenever *Update* or *Update and close* are clicked, the project definition is updated and the composite indices are re-calculated. As a consequence, the map is rendered and styled accordingly. This allows the user to have an immediate feedback on how the map changes depending on how the project definition is set. Such automatic re-calculations and rendering can take some time, depending on the complexity of the project and number of enumeration units analysed. Sometimes it is more convenient to disable the on-the-fly calculations while changing the project structure, and enable it again once the project has been built. In order to do so, it is sufficient to toggle the *Run calculations on-the-fly* checkbox.

The main functional elements of the weighting and aggregation tree are discussed in the subsections below.

10.1 Adding a node

Individual nodes correspond to aggregated composite indicators within the weighting and aggregation tree. To add a node (i.e., a composite sub-indicator) within the tree, it is possible to begin by left-clicking on the default node (i.e., SVI). Clicking on the default SVI node allows the addition of multiple new sub-indicators, each with its own user-provided name.

Note: It is not possible to add nodes stemming from the IRI.

When a newly created node is clicked, a new dialog is initiated to give users the option to select the variables available in the layer (and not already used in the node) to populate the sub-indicator being under construction. The dropdown menu to select the field name displays, for each field, the corresponding alias (where available). When a field is selected, the proposed name to be displayed in the tree is set by default equal to the field alias (if available) or equal to the field name.

Note: The SVI can be calculated if each socioeconomic sub-indicator has at least one variable.

In order to add an indicator to one of the socioeconomic sub-indicators, you can click on the corresponding node. When adding an indicator to the RI, or to one of the socioeconomic sub-indicators, the description of the node will be automatically set to be equal to the name of the corresponding layer's variable. Users can edit this description, however, by clicking on the text displayed next to the node in the tree and then by clicking within the corresponding textbox to change the text.

10.2 Removing a node

In order to remove one of the nodes from the tree, users can perform a right-click on that node. A popup dialog window will ask you to confirm if you really intend to delete the node and all of its *children* (the lower level nodes connected to it).

Note: Removing a node from the tree will *not* delete the corresponding field from the layer.

10.3 Setting the operators to be used to aggregate variables

On the right of each node, the tree indicates the name of the operator to be used to combine (or aggregate) the variables making up the node. By clicking on the operator name, a dialog to set weights and operators is opened. The same happens when clicking on the name of one of the children nodes. The operator can be chosen from a dropdown menu. Some operators (e.g., *Weighted sum*) take into account the weights applied to the child nodes. Other operators (e.g., *Average (ignore weights)*) do not take into account weights. When the chosen operator is one of the latter, the child nodes will be rendered on the graphical display all with the same radius and their weights will not be rendered (see Fig. 10.1 for a demonstration of how the radius of nodes corresponds with the respective weights of variables). Otherwise, the radius of a node is proportional to its weight, and the weight is rendered next to the node.

The following table lists the basic operators available in the plugin. Each formula assumes that we are combining a set x of n variables (tree nodes), and that each variable x_i has been assigned a weight w_i. Each weight is defined in the interval $[0, 1]$ and the sum of all weights is 1 ($\sum_{i=1}^{n} w_i = 1$).

Operator	Formula
Simple sum (ignore weights)	$\sum_{i=1}^{n} x_i$
Weighted sum	$\sum_{i=1}^{n} w_i x_i$
Average (ignore weights)	$\frac{1}{n} \sum_{i=1}^{n} x_i$
Simple multiplication (ignore weights)	$\prod_{i=1}^{n} x_i$
Weighted multiplication	$\prod_{i=1}^{n} w_i x_i$
Geometric mean (ignore weights)	$\sqrt[n]{\prod_{i=1}^{n} x_i}$

In case the user wants to combine indices using a customized formula that is not included in the set of the available operators, it is possible to select from the dropdown menu the item *Use a custom field*, and to specify which one of the layer fields has to be used to store the data. If nothing else is specified, the tool will not modify the contents of the selected field anymore, assuming that the user will take full responsibility in performing the customized calculation and storing the results in that field. In order to keep track of the workflow, it is possible to add a *Field description* of how the node is calculated. Optionally, the user can also specify the *Custom formula* used to calculate the field. The formula must be in the same format used by the QGIS Field Calculator, i.e., a valid *QgsExpression*. If the tool accepts the formula as valid, the node will be recalculated usin that formula, whenever the project definition

is modified. Otherwise (if either the formula is not specified or it is invalid), the node will not be recalculated, therefore its values will remain unchanged.

Note: When using a custom operator, we suggest first to create the corresponding field using the QGIS Field Calculator, and to set the project definition afterwards. The expression that is used within the field calculator can be copied and pasted into the *Custom formula* text field. This ensures the plugin will recalculate the node afterwards using the same valid expression.

10.4 Setting weights

Central to the construction of composite indicators in the need to combine data which implies decisions on weighting. The dialog to set weights is opened in the same way as described in *Setting the operators to be used to aggregate variables*. Several weighting techniques are available, and some make use of statistical models. For the OpenQuake IRMT we implemented a simple solution to weighting that is often based on the results of participatory approaches. A weight can be edited manually by clicking on its value and overwriting it with a new value. A weight can also be edited by clicking on the spinner arrows to increase or decrease the weight. By clicking *Update*, the weights will be re-calculated in order to make them sum to 1. In other words, if you have 3 variables and you set their weights to 1, 2 and 5 and you press *Update*, the weights will be re-calculated to be respectively 0.125, 0.250 and 0.625, keeping the same proportion between each other, and summing to 1.

10.5 Inverting a variable

The dialog to invert variables is opened in the same way as described in *Setting the operators to be used to aggregate variables*. If a variable contributes in a *negative* way to the composite indicator (e.g., a higher education corresponding to a lower social vulnerability), it is possible to indicate such an inverse relationship by pressing the *Invert* button next to the variable name. The effect on a composite indicator in response to this decision process and setting is that each value of an *inverted* variable will be to multiplied by -1 each time the variable is used in a calculation.

Note: Please note that the layer field will keep holding the original value of the variable, and that the inversion will be performed on-the-fly for the purpose of the calculation.

Please also be aware of the fact that multiplying a variable by -1 is not always what is actually needed to invert the meaning of an indicator. For instance, let us suppose we want to meaningfully "invert" a percentage of 80%. The correct way to do so would be to calculate 100% - 80% = 20%. Such kind of transformation can be easily performed using the QGIS Field Calculator, in order to obtain a new field to be used in the project.

10.6 Assigning a new name to a variable

The dialog to assign a new name to a variable is also opened in the same way as described in *Setting the operators to be used to aggregate variables*. By clicking on the variable's name, a popup dialog asks users to insert the new name. The project definition will be updated accordingly, linking the layer's fieldname with the modified description.

10.7 Styling the layer by a chosen field

The dropdown menu entitled *Style layer by* on the bottom of the *Set weights and operators* module can be used to choose fields within a layer, i.e., fields other than those delineated within the project definition to be symbolized, allowing all fields in a layer to be to be symbolized on-the-fly. This can be useful, for instance, to map the values calculated for different sub-indicators, or even individual variables if they are of interest. By default, the selection is blank. In the default case, the tool will adopt the following convention: 1) if the IRI can be computed, then the layer will be symbolized according to it; 2) otherwise, if the SVI can be computed, then it will be used as the default case for symbolization in the absence of IRI; 3) otherwise, the convention will apply with respect to the RI; and 4) if none of main sub-indicators can be calculated, then the layer will not be re-styled unless the user uses the dropdown menu to specify a specific symbolization field.

CHAPTER

ELEVEN

AGGREGATING POINTS BY ZONE

The development of an integrated risk model (IRI) arises from the convolution of two main components: 1) estimations of physical risk (RI), and 2) a social vulnerability index (SVI). The convolution of earthquake physical risk and social vulnerability parameters can be accomplished by selecting layers that contain estimations of physical risk, (*points layer*) or some other type of risk model, and a layer containing zonal geometries of the study area (e.g., country borders, district borders) and socioeconomic indicators.

As a subsequent step, earthquake risk data imported into the tool should be standardized to render the data commensurate to the socioeconomic indicators created within the tool.

In previous versions of this plugin, there was a specific tool to perform the geospatial aggregation. Recently, it was dismissed because its functionalities overlap with those of a powerful algorithm available in the Processing Toolbox. Therefore, the button that pointed to our customized implementation now points to the corresponding Processing tool, called "Join attributes by location (summary)". Such button, *Aggregate points by zone*, is under the *Utilities* submenu of the *OpenQuake IRMT* menu.

In order to obtain a similar workflow with respect to what was done previously with our tool, we suggest to select the *zonal layer* as "Input layer" and the *points layer* as "Join layer", then keep checked "intersects" as "Geometric predicate", and choose the fields to summarize and the summaries to calculate (that in our case were "sum" and "mean"). When the plugin opens the user interface of the algorithm, it presets the above configuration by default.

Afterwards, it is possible to style the layer using the standard QGIS layer symbology menu, for instance setting a "Graduated" renderer by a chosen column and applying the classification by a chosen number of classes. In our standard workflow, the column to be chosen is the "_sum" field that was created by the aggregation tool.

CHAPTER

TWELVE

UPLOADING A PROJECT TO THE OPENQUAKE PLATFORM

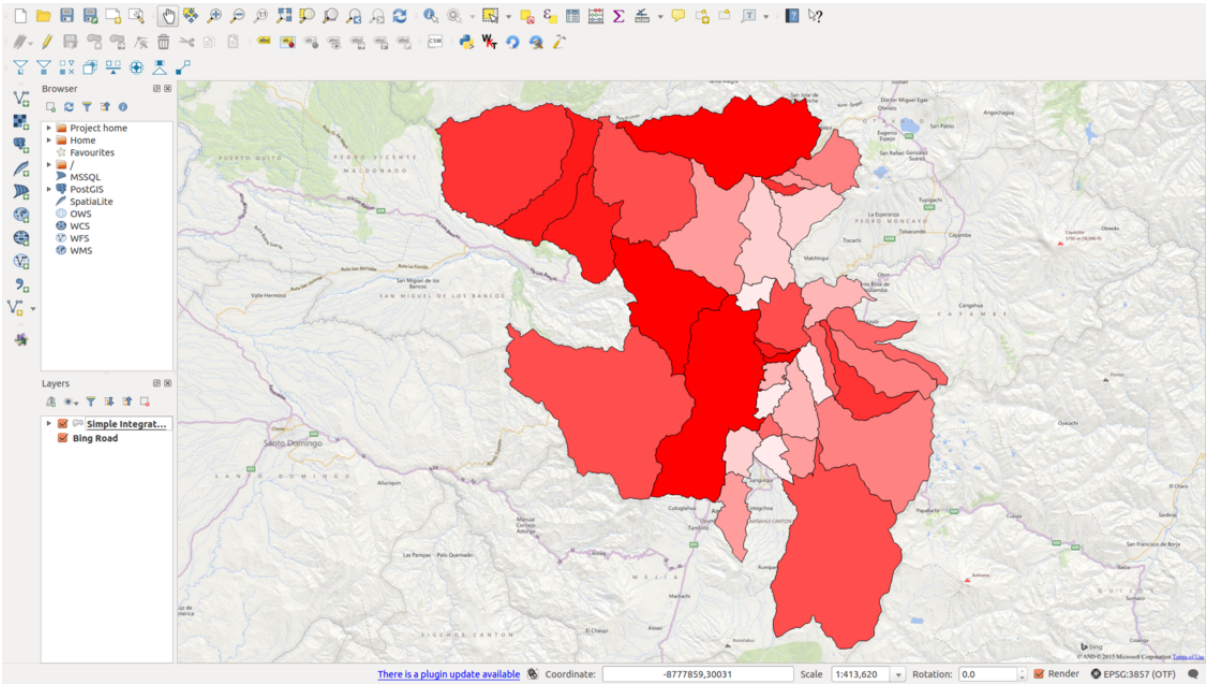


Fig. 12.1: Simplified Integrated Risk analysis as it is seen inside QGIS right before the project is uploaded to the OpenQuake Platform

Once an integrated risk model is complete, and the user is satisfied with results such as those obtained for the example displayed in Fig. 12.1, it is possible to upload projects through the OQ-Platform. Projects are uploaded in order to share them with the wider earthquake risk assessment, earthquake risk reduction, GIS communities, etc. Uploading to the OQ-Platform also supports the ability to visualize models using advanced visualization tools and the mapping of the data over the web. In addition, sharing the models on the OQ-Platform allows users that are not QGIS savvy to dynamically interact with the data. The mapping and visualization over the web is accomplished using the OQ-Platform (Fig. 12.2) and the Social Vulnerability and Integrated Risk Viewer (see the web application[18] and the corresponding documentation[19]).

To upload a project to the OQ-Platform, click *Upload project to the OpenQuake Platform*. This will result in the opening of a dialog window in which, depending on the context, the window will look like those delineated in Fig. 12.3 or Fig. 12.4. The former will be displayed if the current project has never been uploaded to the OQ-Platform. In such cases, the user is invited to provide a project title that will

[18] https://platform.openquake.org/irv_viewer/

[19] http://storage.globalquakemodel.org/openquake/support/documentation/platform/irv/

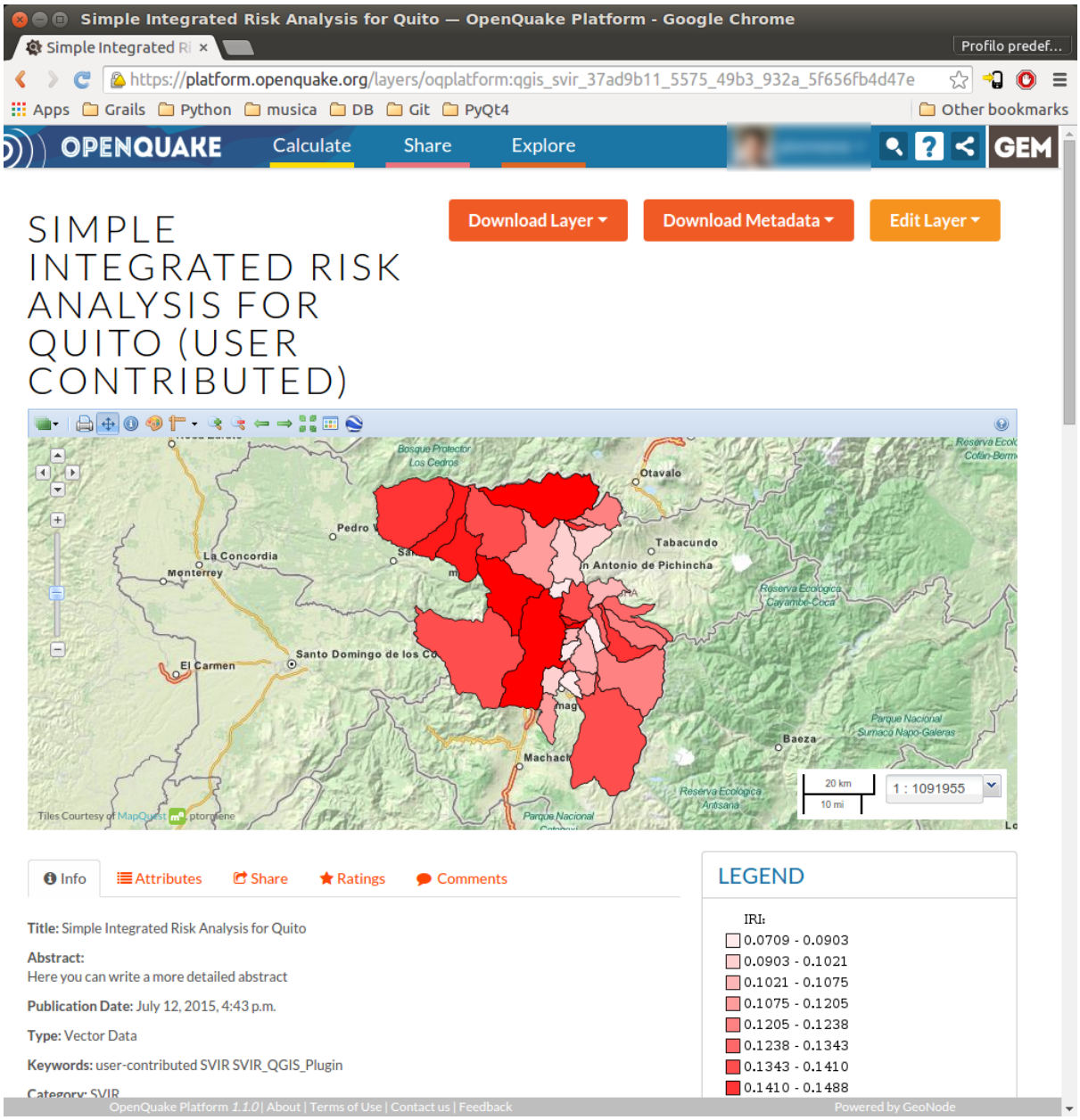


Fig. 12.2: The same simple example shown in Fig. 12.1, visualized through a web browser after it has been uploaded to the OpenQuake Platform

become the title of the layer that will be created on the Platform. A second field will contain the abstract, where the user can provide a general description of the project.

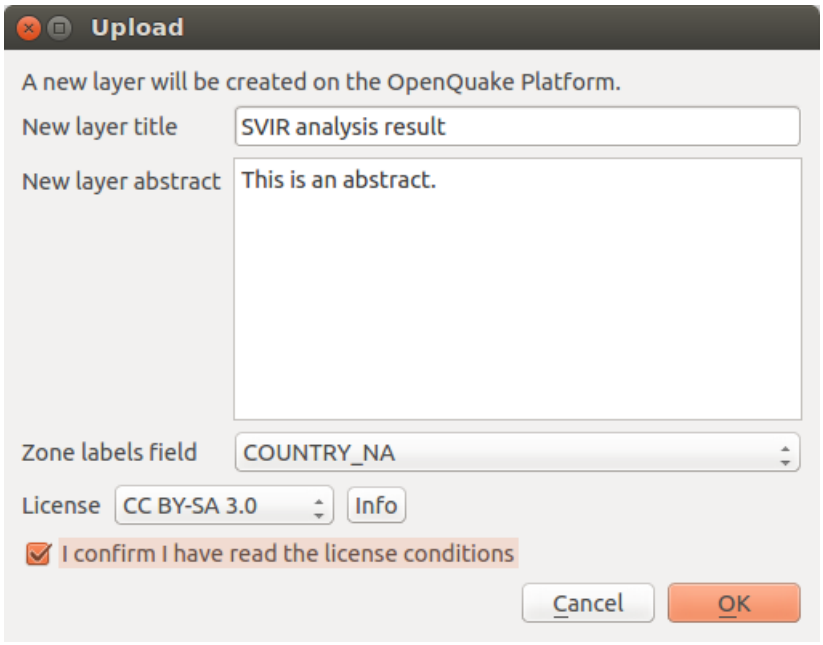


Fig. 12.3: Uploading a project to the OpenQuake Platform

Note: In order to be able to correctly utilize the advanced visualization tools found on the OQ-Platform, the selection of a *Zone labels field* is required (see Fig. 12.3).

The user must designate the *Zone labels field* within their dataset. The latter is a field containing unique labels (or identifiers) whether these are individual country names, district names, or census block numbers, etc. Delineating a zone field when uploading to the OQ-Platform is imperative to allow the graphing components of the Social Vulnerability and Integrated Risk Viewer to render the visualization using the zone labels. Without the latter, comparisons among places within the graphing tools are not possible. It is also mandatory to choose a license and to click on the checkbox to confirm to be informed about the license conditions. By clicking the *Info* button, a web browser will be opened, pointing to a page that describes the license selected in the *License* dropdown menu. When *OK* is pressed, the active layer is uploaded to the OQ-Platform and it is applied in the same style visible in QGIS. Furthermore, the current project definition is saved into the layer metadata, inside the *Supplemental information* field.

This second version of the *Upload* dialog window is displayed when the active layer appears to have been already shared through the OQ-Platform (the ID of a OQ-Platform layer was previously associated with this layer). In such cases, it is possible to create a brand new layer, ignoring the previously uploaded (or downloaded) project, or to update the current layer. The updating process consists of adding the current project definition to the set of project definitions associated to that layer on the OQ-Platform. This is a much faster procedure because no geometries need to be uploaded, and only the metadata of the layer will be changed.

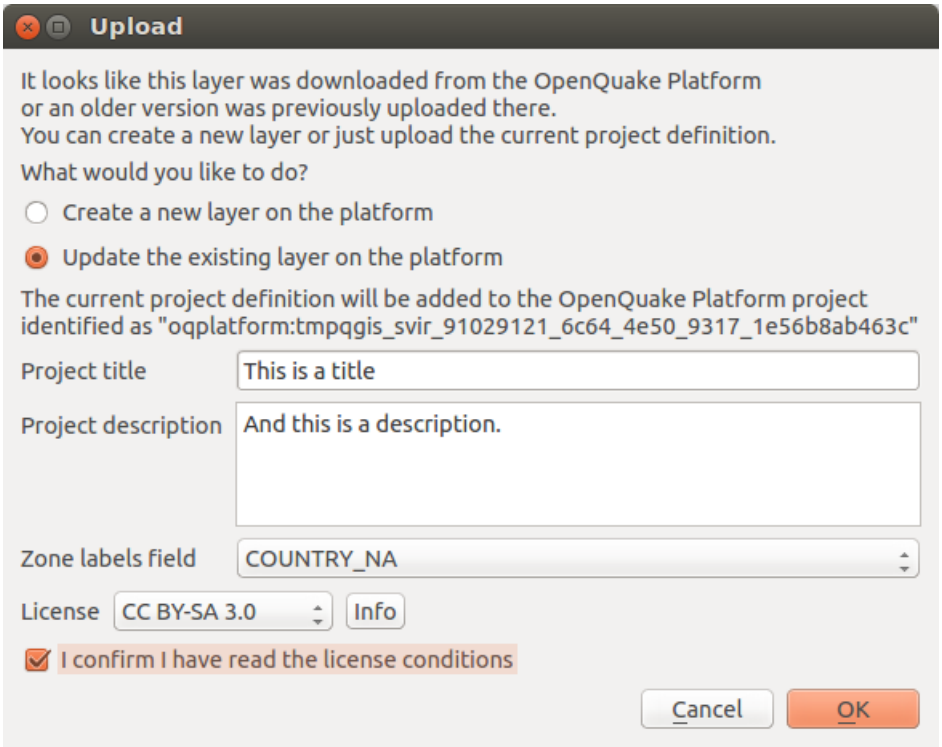


Fig. 12.4: Updating a project that has already been uploaded to the OpenQuake Platform

CHAPTER

THIRTEEN

LEVERAGING R TO PERFORM STATISTICAL ANALYSIS IN QGIS

Socioeconomic analysis often involve statistical investigation, for instance for dimensionality reduction in problems involving a considerable number of variables. QGIS is well integrated with tools that can be leveraged for this kind of purpose. R[20] is a well-known free software environment for statistical computing and graphics. It is widely used and easily installable on all the most used operating systems. QGIS enables users to drive R scripts from within the QGIS Processing Toolbox[21]. This documentation[22] explains how to make R scripts available in the Processing Toolbox. You can create your own scripts or download examples from a public repository[23]. Scripts can be managed and edited directly within QGIS, through an embedded graphical widget. This feature is especially convenient to users who need to quickly customize existing scripts. However, it does not provide the same flexibility and interactivity that the R console offers, therefore the coding process becomes a little more challenging. By default, on unix-based systems, scripts are locally collected in the directory *~/.qgis2/processing/rscripts* and they are identified by a file like *scriptname.rsx*, that contains the script itself, and an optional file like *scriptname.rsx.help*, that provides the corresponding documentation. An example taken from the above public repository is the following:

File *Summary_statistics.rsx*:

```
##Basic statistics=group
##Layer=vector
##Field=Field Layer
Summary_statistics<-data.frame(rbind(sum(Layer[[Field]]),
length(Layer[[Field]]),
length(unique(Layer[[Field]])),
min(Layer[[Field]]),
max(Layer[[Field]]),
max(Layer[[Field]])-min(Layer[[Field]]),
mean(Layer[[Field]]),
median(Layer[[Field]]),
sd(Layer[[Field]])),row.names=c("Sum:","Count:","Unique values:","Minimum␣
↪value:","Maximum value:","Range:","Mean value:","Median value:",
↪"Standard deviation:"))
colnames(Summary_statistics)<-c(Field)
>Summary_statistics
```

File *Summary_statistics.rsx.help*:

```
{"ALG_DESC": "This tool calculates the following summary statistics for a
              numeric field: (1) Sum, (2) Count, (3) Unique values,
```

(continues on next page)

[20] https://www.r-project.org/
[21] http://docs.qgis.org/2.0/en/docs/user_manual/processing/toolbox.html
[22] https://docs.qgis.org/testing/en/docs/training_manual/processing/r_intro.html
[23] https://github.com/qgis/QGIS-Processing/tree/master/rscripts

(continued from previous page)

```
                (4) Minimum value, (5) Maximum value, (6) Range, (7) Mean,
                (8) Median and (9) Standard deviation.\n\n",
"R_CONSOLE_OUTPUT": "Summary statistics table",
"ALG_CREATOR": "Filipe S. Dias, filipesdias(at)gmail.com",
"Layer": "Input vector with at least one numeric field",
"Field": "Numeric field",
"ALG_HELP_CREATOR": "Filipe S. Dias, filipesdias(at)gmail.com"}
```

Note that the header of the script contains some lines beginning with ##. These lines are used by the QGIS Processing Toolkit to build a graphical user interface that will be displayed every time the script is launched, and that enables users to graphically set up some parameters that will be used by the script. In the example, for instance, a dropdown menu will list all the available vector layers; once a layer is selected, another dropdown menu will list all its fields. Please refer to the QGIS documentation[24] for a more detailed description of the script syntax.

A brief list of statistical techniques that are often needed in socioeconomic analysis, that are all available in R, are as follows:

- Summary statistics (mean, median, high value, low value, standard deviation)
- Boxplots as well as measures of skewness and curtosis
- Histograms
- Scatter plotting
- Correlation (Pearson's R, Spearman Rank, Kendall's Tau)
- Cronbach's Alpha (which is based on correlation)
- Principal Components Analysis/Factor Analysis

Some of these require the statistical platform to take into account one single field (e.g., summary statistics) or a couple of fields (e.g. scatterplot). In such cases, it is sufficient to add parametric references to those fields into the header of the script. Things become more complicated where the number of parameters required is not known in advance, as in the case of Principal Components Analysis. In older versions of QGIS, the widgets that can be used through the script header syntax[25] did not include a multiselection functionality. Therefore, it was impossible for the user to graphically select an indefinite number of fields from the complete list. However, even without a multiselect widget, it was possible to let a script perform the analysis on the whole set of numeric fields available in the selected layer. In order to exclude some numeric fields from the analysis, we can add to the script header the reference to a textual field to be added to the GUI, in which the user can insert a list of comma-separated names of fields to be ignored. The script becomes something like:

```
##Basic statistics=group
##Layer=vector
##Exclude=String
layerData <- data.frame(Layer)
numericFields <- sapply(layerData, is.numeric)
numericData <- layerData[, numericFields]
excludedFields <- trimws(strsplit(Exclude, ",")[[1]])
analyzedData <- numericData[, !(names(numericData) %in% excludedFields)]
comps <- prcomp(analyzedData, scale=TRUE)
>comps
```

[24] http://docs.qgis.org/2.8/en/docs/user_manual/processing/3rdParty.html#r-creating-r-scripts
[25] http://docs.qgis.org/2.0/en/docs/user_manual/processing/modeler.html#definition-of-inputs

Since a multiple selector for layer fields has been made available, it is possible to run R algorithms such as in the following example, using the *multiple field* widget type:

```
##Basic statistics=group
##Layer=vector
##ChosenFields=multiple field Layer
layerData <- data.frame(Layer)
numericFields <- sapply(layerData, is.numeric)
numericData <- layerData[, numericFields]
chosen <- trimws(strsplit(ChosenFields, ";")[[1]])
analyzedData <- numericData[, names(numericData) %in% chosen]
comps <- prcomp(analyzedData, scale=TRUE)
>comps
```

This script creates automatically a graphical user interface that lets the user select one of the available layers. Once the layer is selected, the corresponding fields are listed in a multi-select widget, where a set of them can be chosen. As soon as the *Run* button is pressed, the algorithm collects the chosen fields and it performs the Principal Components Analysis on them, excluding the non-numeric ones that might have been erroneously selected.

What if we want to build a vector layer using the results of a calculation performed by R? Examples of this are available in the documentation linked above. The following example shows how to load a vector layer from those available in QGIS, make a copy of it, perform a calculation, save the result in a new field of the new layer, and make the final layer available in QGIS. In this basic example, the calculation is extremely simple, just summing the values of two fields. However, it can be easily extended to obtain complex results.

```
##Vector processing=group
##Layer=vector
##First=Field Layer
##Second=Field Layer
##output=output vector
modified <- data.frame(Layer)
modified['SUM'] <- NA
modified$SUM <- Layer[[First]] + Layer[[Second]]
output=SpatialPolygonsDataFrame(Layer, as.data.frame(modified))
```

We have just seen in the latter example that the output of a script can be a vector layer (*##output=output vector*). In the previous example, *>comps* indicated to the Processing Toolkit that the object *comps* had to be shown to the user as text in a dedicated output window. A third possibility is to display the output as a plot, using the *##showplots* directive as follows:

```
##Vector processing=group
##showplots
##Layer=vector
##Field=Field Layer
##Unit=String
boxplot(Layer[[Field]], main="BOXPLOT", xlab=paste(Field),␣
↪ylab=paste(Unit))
```

When the script is executed, the dialog shown in Fig. 13.1 allows the user select one of the available layers, then one of its fields. In the *Unit* text field, the user can write the measurement unit to be displayed in the y label in the plot. By pressing *Run*, R is started, running the *boxplot* function on the selected data and setting the plot labels accordingly (see Fig. 13.2).

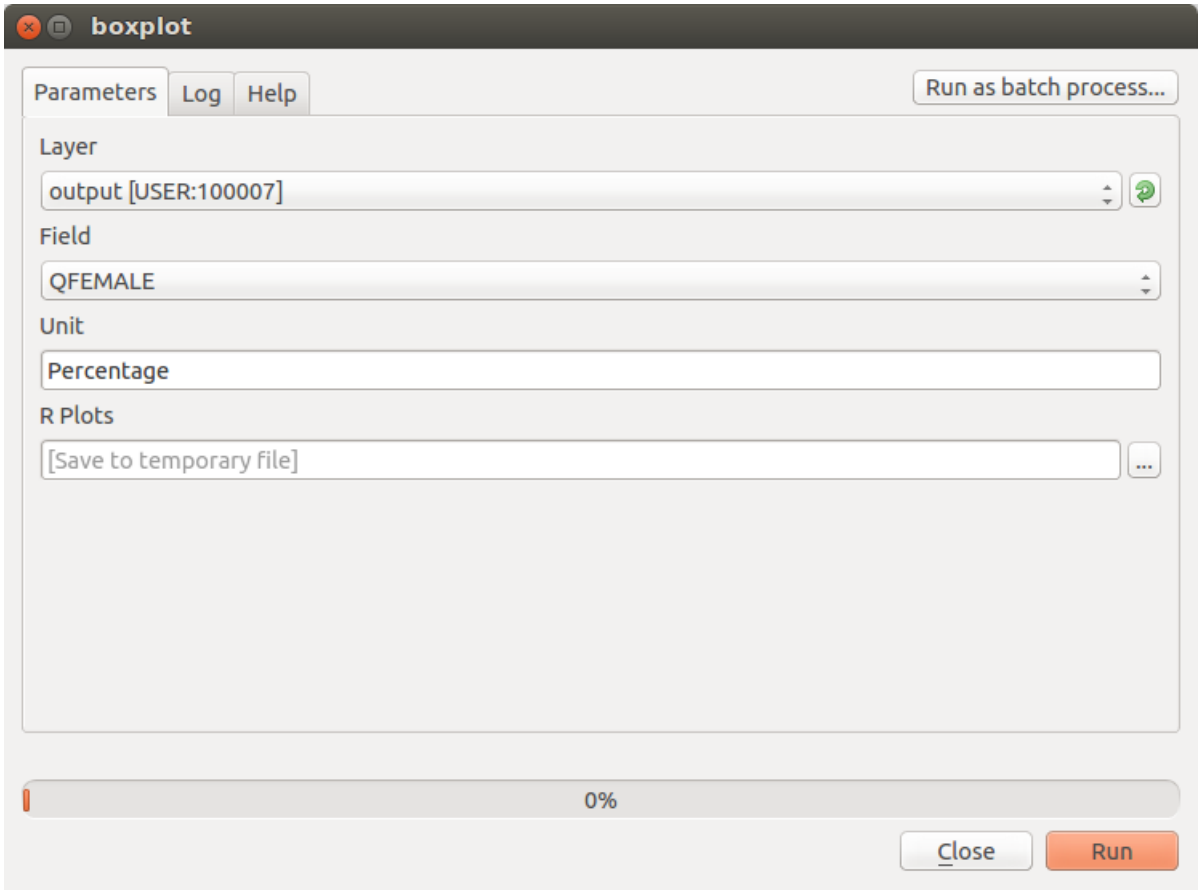


Fig. 13.1: Boxplot Dialog Window

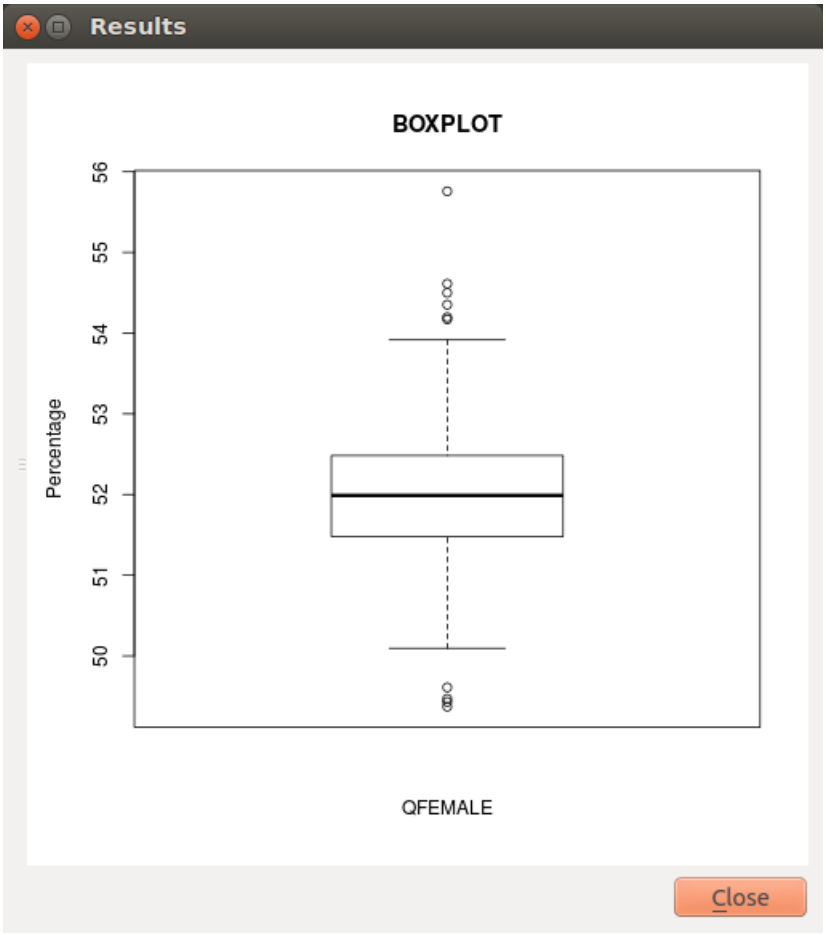


Fig. 13.2: Boxplot Output Window

CHAPTER

FOURTEEN

POST-EARTHQUAKE RECOVERY MODELLING METHODOLOGY

This work was supported by the State of California, Alfred E. Alquist Seismic Safety Commission and is part of a collaborative effort between the Global Earthquake Model (GEM) and the University of California at Los Angeles (UCLA), Department of Civil and Environmental Engineering. GEM implemented the scientific methodology developed by UCLA [BDL+15] and integrated it into the QGIS framework as part of the OpenQuake IRMT plugin.

This computational tool was developed to quantify the effectiveness of specific resilience-building actions (preparedness and response) that would enhance the process of recovery following an earthquake. Building performance is assessed using metrics that are explicitly linked to community seismic resilience such as functionality, occupiability and repairability. A probabilistic approach to mapping the fragility function parameters for the loss-based damage states used in OpenQuake and HAZUS (e.g. slight, moderate, extensive, complete) to the recovery-based damage states (e.g. functional loss, uninhabitable, irreparable) that are needed to assess seismic resilience is applied. A discrete state-based stochastic simulation model is used to quantify recovery trajectories for damaged buildings. Deterministic recovery paths conditioned on the post-earthquake damage state are described by discrete recovery states and the time spent in each state. The uncertainty in the recovery trajectory is captured by generating multiple realizations of the recovery path (Monte Carlo Simulation) accounting for the uncertainty in the time spent in each state. The function that describes community-level (or neighborhood-level) recovery is obtained by aggregating the recovery curves for the individual buildings after accounting for the variation in shaking and damage at each site and various exogenous and endogenous factors that affect the pace of recovery.

This tool provides an effective way to engage key stakeholders from government, industry and other groups, who are concerned with enhancing post-disaster recovery of communities. For example, focus groups with practitioners and emergency managers can be held to demonstrate its capabilities and explore their questions and concerns with regards to post-earthquake recovery. By allowing them to explore various trajectories for specific earthquake scenarios, the simulator will assist policy-makers, municipal governments and planners in understanding the possible interventions and tradeoffs associated with post-earthquake recovery. The simulation model can also be used to investigate hypotheses derived from findings and conclusions from previous earthquakes. Hypothesis examples include the following:

1. increased utility restoration rates increase recovery rates,
2. higher insurance penetration rates reduce household displacement,
3. designing for higher building performance levels prevents outmigration from the city, and
4. 'residential red zones' or temporary building moratoriums are preferable to patchwork reconstruction.

The recovery framework previously described was incorporated into this plugin, resulting in a dynamic and user-friendly software tool for generating both building-by-building and community level

post-earthquake recovery predictions. The OpenQuake IRMT allows users to:

1. incorporate their local knowledge and data;
2. develop composite indicators (or indices) to measure social vulnerability and/or disaster resilience;
3. integrate these indices with physical risk estimates from OpenQuake or other software platforms; and
4. visualize the results.

In the following steps, a brief description of the basic workflow to develop an end-to-end recovery prediction is presented, where the main features and capabilities of the tool are highlighted.

14.1 Preparation of the input files for the OpenQuake Engine analysis

The recovery modelling algorithm requires users to provide a CSV file containing the probability of exceedance of each limit state for each individual building in the exposure model. The latter can be computed by running a Scenario Damage Assessment, which is a type of analysis supported by the risk component of the OpenQuake Engine. The input files necessary for running a scenario damage calculation and the resulting output files are depicted in Fig. 14.1 For technical details, definitions and examples of each component, readers are referred to [PMW+14] and [SCP+14].

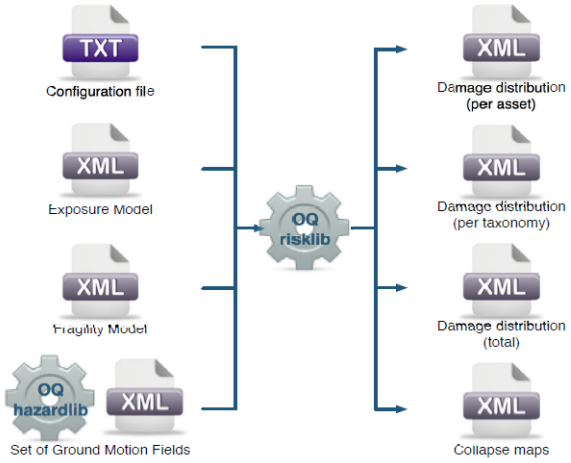


Fig. 14.1: Scenario Damage Calculator input/output structure

The window that requests users to upload the input files and run the scenario damage calculation is shown in Fig. 15.1.

It should be noted that in order to use the OpenQuake Engine from QGIS, the user needs to set up the connection with a working OpenQuake Engine Server using the *OpenQuake IRMT settings* dialog; the server can be installed in the same machine where the plugin is used. Alternatively, it is possible to use a remote server or cluster.

14.2 Setting up the configuration variables to run the recovery modelling algorithm

The configuration variables that are necessary to perform the recovery modeling analysis can be edited using the dialog shown in Fig. 14.2.

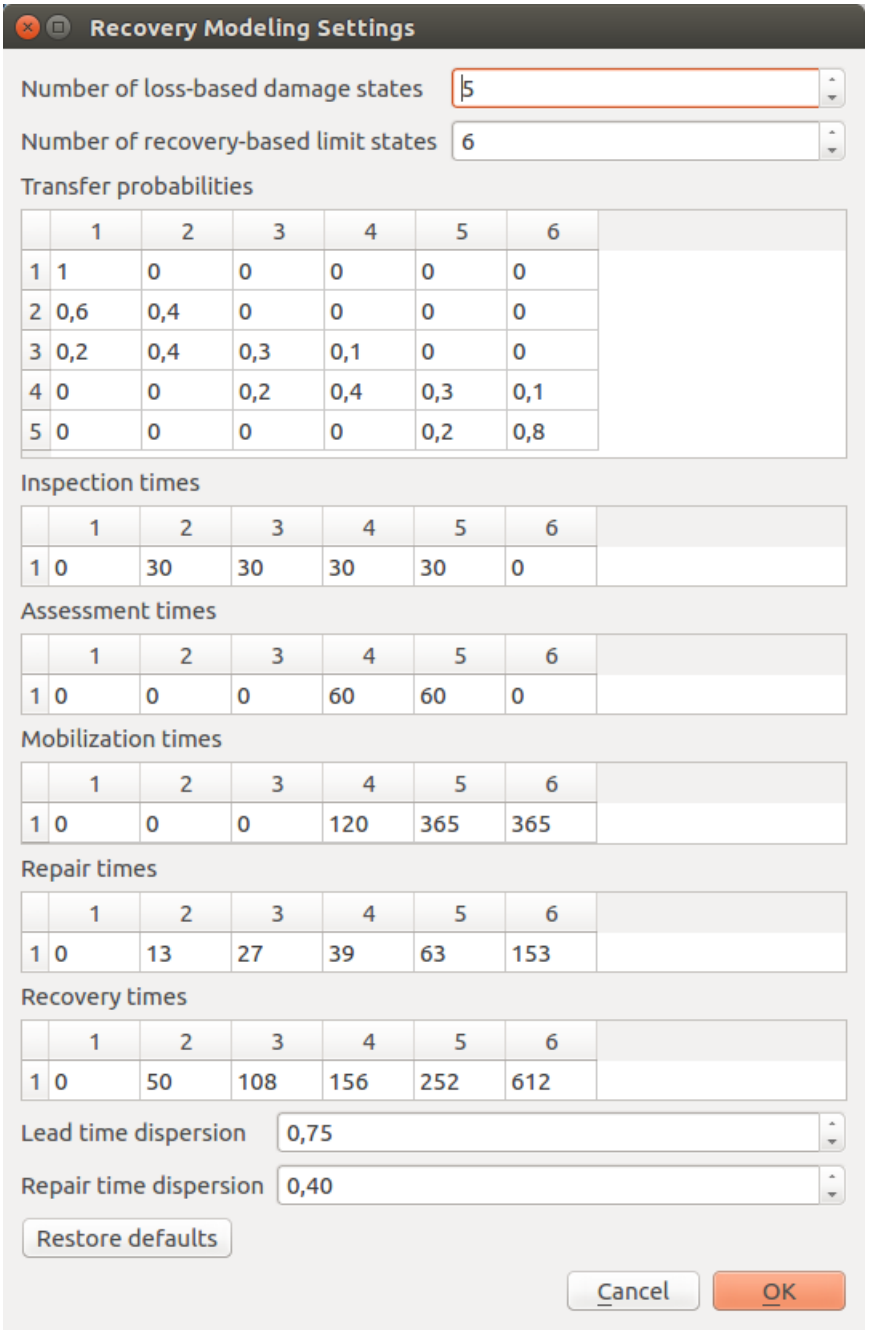


Fig. 14.2: Recovery modeling settings dialog

The following variables should be adjusted to the available data and needs of the user:

Configuration variable	Explanation
Number of loss-based damage states	Default is 5 (no damage, slight, moderate, extensive, complete)
Number of functional-based limit states	Default is 6 (no damage, trigger inspection, loss function, not occupiable, irreparable, collapse)
Transfer Probabilities	The element (i, j) of the matrix is the probability that the recovery-based limit state j occurs, given the loss-based damage state i
Assessment times	Time to conduct engineering assessment
Inspection times	Time to complete inspections
Mobilization times	Time to mobilize for construction
Recovery times	Period between the occurrence of the earthquake and the restoration of full functionality
Repair times	Time to replace elements in buildings or to reconstruct buildings
Repair times dispersion	Level of uncertainty associated with the repair times
Lead times dispersion	Level of uncertainty associated with the lead times

The list of the outputs from the Scenario Damage calculation can be visualized in Fig. 15.1. The tool offers the possibility to load the 'Damage by asset' CSV file (damages-rlzs) as a QGIS vector layer, stored in the user's computer as a shapefile. In addition, it is possible to automatically style the layer with respect to a chosen damage state. Alternatively, the user can upload on QGIS the 'Damage by asset' CSV file, structured in the same format as produced by the OpenQuake Engine. If the user does not need to edit the layer by adding or removing fields to/from it, it is possible to perform the recovery modelling calculation using the CSV-based layer. Otherwise, the layer should be converted and saved as a shapefile. Please note that shapefile limitations will reduce the field names to a maximum length of 10 characters each. At this point, the user may choose between two workflows on how to proceed to the generation of single buildings and/or community level recovery curves.

14.3 Interactive workflow

The user can select individual buildings (or a group of buildings) and the respective recovery curve (single or aggregated) is automatically developed. The curve can be edited, digitized and exported as a CSV, as well as saved as an image. The user requests the development of recovery curves by selecting the relevant layer, opening the *OpenQuake IRMT Data Viewer* (making sure that the *Toggle viewer dock* option is checked in the OpenQuake IRMT menu), and setting the *Output Type* tab to *Recovery Curves*. One of two available algorithmic approaches, regarding the estimation of the recovery, has to be chosen. The *Aggregate* approach produces the recovery model as a single process, whereas the *Disaggregate* approach takes into account four processes: inspection, assessment, mobilization and repair. In addition, the user can manually select the fields of the layer that contain the probabilities of being in each damage state (Fig. 16.3). If the file with the damage state probabilities is in the same format as produced by OpenQuake, the software pre-selects the appropriate fields for the recovery modelling algorithm. The number of simulations per building is the number of damage realizations used in Monte Carlo Simulation.

Warning: Increasing the number of simulations, the model becomes more accurate, but the calculation becomes slower and more expensive in terms of memory consumption

It should be emphasized that the integration of the recovery modelling algorithm in the QGIS software enables the users to adapt the workflow to their needs, leveraging all the features provided by the QGIS framework. The QGIS Processing Toolbox gives access to a wide variety of geoalgorithms, seamlessly integrating several different open-source resources, such as R, SAGA or GDAL. For instance, they can be used to aggregate by zone a set of selected assets, resulting in relating each asset to the identifier of the geographical area (zone) where it belongs. Following, the selection of the set of assets to be considered in the analysis can be performed in several different ways. The user can directly select points by clicking them on the map, or select points by using a formula. If points have been labeled with the identifier of the zone, the selection can be done with respect to the zone identification (or ID).

14.4 Batch workflow

Initially, the user must select the layer containing the information regarding the damage state probabilities per asset (see *Preparation of the input files for the OpenQuake Engine analysis*), after which the specific fields that contain these probabilities shall be opted. Next, the user must select a specific recovery time approach (Aggregate/Disaggregate) and set the number of simulations per building (number of damage realizations used in Monte Carlo Simulation). Here, it is possible to select the layer of the study area with zonal geometries and generate aggregated recovery curves by zones.

By unchecking the *Aggregate assets by zone* box (Fig. 14.3) the algorithm generates a single community recovery curve by aggregating the recovery curves of all the buildings within the region. The graphs, like the one shown in Fig. 14.4, are saved in the output directory designated by the user. In addition, building-by-building recovery curves are digitized and can be saved as text files (.txt) in the same output directory. The user can decide whether or not to generate the building-by-building recovery curves by (un)checking the *Save individual building curves* tab. The data can be further used (e.g. with a spreadsheet editor like LibreOffice Calc or Microsoft Excel) to generate and visualize individual building recovery curves that may be of interest to the user.

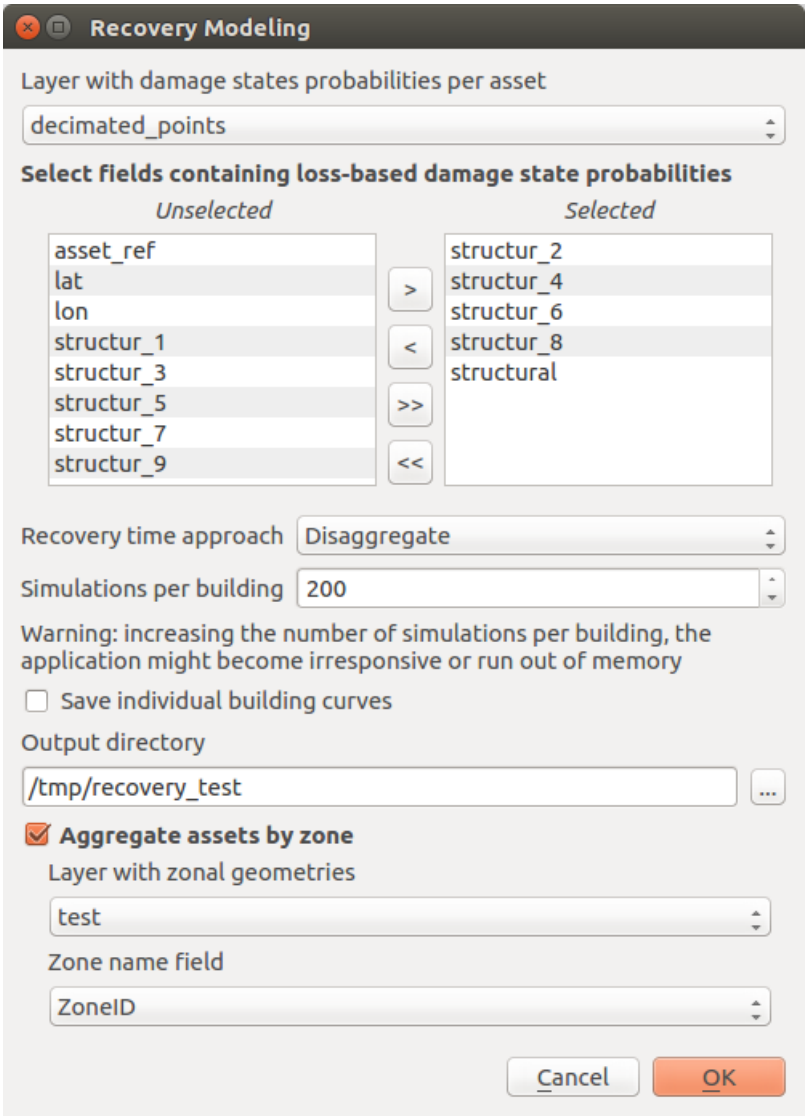


Fig. 14.3: Dialog to perform recovery modeling on the whole data set (also enabling zonal aggregation)

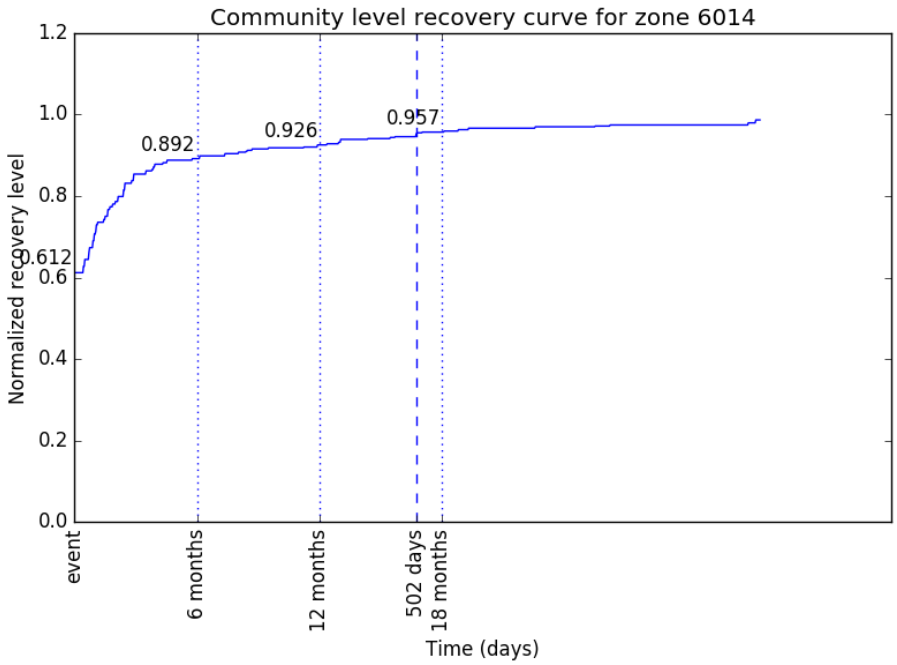


Fig. 14.4: The community-level recovery function for one of the zones under analysis, showing how the normalized recovery level evolves with time after the earthquake

CHAPTER

FIFTEEN

DRIVING THE OPENQUAKE ENGINE

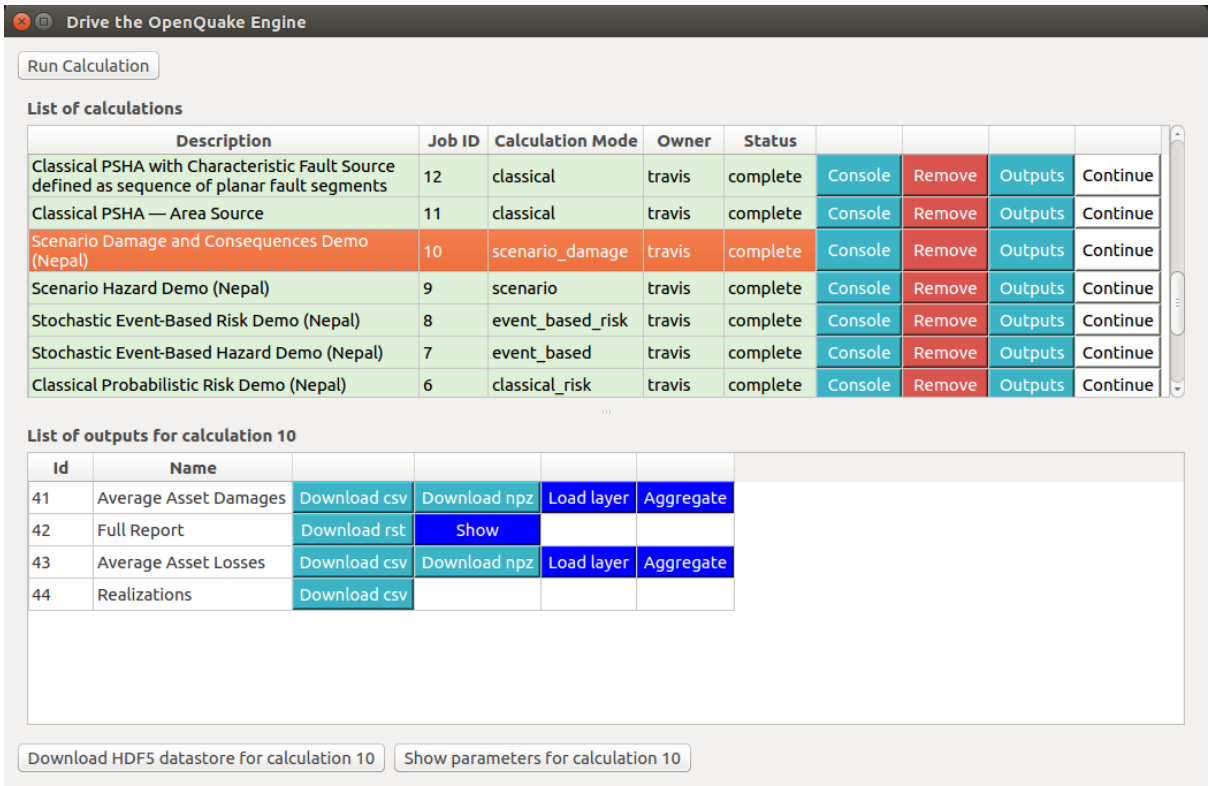


Fig. 15.1: Dialog to run the OpenQuake Engine server

The plugin enables to drive the OpenQuake Engine[26], submitting new jobs, watching calculation progress, retrieving and visualizing results, seamlessly within the QGIS interface. This is made possible by leveraging the OpenQuake Engine Server HTTP RESTful API[27]. The connection with a running OQ-Engine Server (WebUI)[28] has to be properly set up as described in *OpenQuake IRMT settings*. The server can run locally in the same computer where QGIS is running, or remotely. For instance, it is possible to connect to a remote cluster, to perform jobs that are highly demanding in terms of computational resources.

[26] https://github.com/gem/oq-engine
[27] https://github.com/gem/oq-engine/blob/master/doc/web-api.md
[28] https://github.com/gem/oq-engine/blob/master/doc/running/server.md

15.1 Run a calculation

When the *Run Calculation* button is pressed, a file explorer is opened, enabling to select the input files needed to run the job (or a zip archive containing them), including the *job.ini* file. By pressing *Open* to confirm, the job is submitted. The interface keeps querying the server asynchronously, and displaying the status of the calculation.

15.2 The list of calculations

For each calculation available on the connected OQ-Engine server (only those that the current user is authorized to visualize), the *List of calculations* (see *Dialog to run the OpenQuake Engine server*) shows its *Description*, its unique *Job ID*, its *Calculation Mode*, its *Owner* and its *Status* (indicating if the calculation is still running, if it failed or if it was successfully completed). The list is refreshed at regular intervals of few seconds and it displays the most recent 100 calculations.

Note: Before OpenQuake Engine 2.6, the *Job Type* was displayed instead of the *Calculation Mode*, specifying only if a calculation was classified as *hazard* or *risk*. If the plugin attempts to connect to an outdated OpenQuake Engine Server that is older than version 2.6, the column *Calculation Mode* will display the value *unknown* for all calculations. In case it happens, we recommend to update the OQ Engine Server or to downgrade the plugin to an earlier version, in order to ensure maximum compatibility between the two software versions.

It is possible to scroll the list up and down and to resize it with respect to the *List of outputs*. When any row of the list of calculations is selected, the row is highlighted and the list of outputs for the corresponding calculation is populated (it will be an empty list if the calculation has not been successfully completed). While a row is selected, it is automatically centered in the visible area of the list, at each refresh. By clicking again on the currently selected row, it will be unhighlighted, resetting the default scrolling behavior of the table.

15.3 Watch the console log

It is possible to watch the log of a calculation, by pressing the *Console* button in the corresponding row. The log will be displayed in a separate window as shown in *Example of console output for a OQ-Engine calculation*.

15.4 Download outputs

If a calculation was completed successfully, an *Outputs* button is provided. When it is clicked, the list of available outputs is shown, which depends on the type of artifacts generated by the calculation. Outputs can be downloaded in one of the available formats, by clicking the corresponding button. In some cases, they can also be loaded as QGIS layers (whenever a corresponding *Load layer* button is available), and a default styling is applied, based on parameters chosen by the user. In some cases (e.g., damage by asset), while loading the layer, it is also possible to aggregate points by zone. In order to do so, it is necessary to specify another available layer, with polygons geospatially containing the points to be collected. The aggregation is performed leveraging an algorithm provided by the QGIS processing toolbox, called "Join attributes by location (summary)".

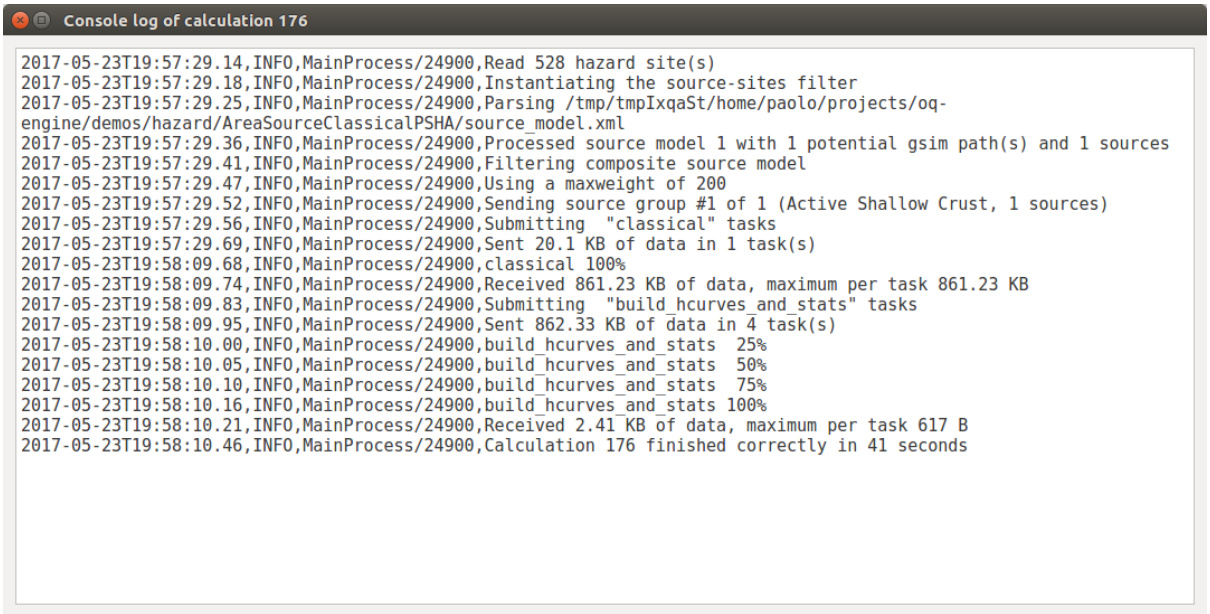


Fig. 15.2: Example of console output for a OQ-Engine calculation

Warning: The layers that are automatically imported from OQ-Engine outputs are stored *in memory*, unless they are explicitly saved by the user into a persistent format, such as a shapefile. Please be aware that the contents of *in memory* layers will not be saved when the QGIS project that contains them is saved. Furthermore, saving an *in memory* layer into a persistent file, only the contents of the layer will be saved, and not its style. If you want to save also the style, you have to right-click on the original layer and select *Styles -> Copy Style*, and then do the same on the target persistent layer and select *Styles -> Paste Style*.

It is also possible to download the HDF5 datastore corresponding to a chosen calculation. When the *Outputs* button is pressed, the *Download HDF5 datastore for calculation N* button is enabled (where *N* is the calculation ID). By pressing it and selecting a destination folder, the file is downloaded and its full path is displayed both in the QGIS message bar and in the *Log Messages Panel*.

Another button that becomes available when a calculation identified as *N* is selected is *Show parameters of calculation N*. It opens a dialog window with a text area displaying the parameters of the calculation (see *Example showing parameters of a OQ-Engine calculation*).

A hazard map defines the geographic distribution of the values of a scalar IMT (see also *Definitions and acronyms*) characterized by a fixed probability of being exceeded at least once in a time span T. For computing a hazard map with the OpenQuake-engine the user defines an IMT, a region over which the map will be computed and, the corresponding probability of exceedance. An alternative representation of a hazard map fixes the value of IMT and computes over an area the corresponding probability of at least on exceedance in T; this typology of result is currently not supported by the OpenQuake-engine.

A loss map provides the estimated losses for a collection of assets, for a certain return period (or probability of exceedance within a given interval of time). It is important to understand that these maps are not providing the distribution of losses for a seismic event or level of ground motion with the chosen return period, nor can the losses shown on the map be summed to obtain the corresponding aggregate loss with the same return period. This type of maps is simply providing the expected loss for a specified frequency of occurrence (or return period), for each asset.

Fig. 15.3: Example showing parameters of a OQ-Engine calculation

---

Note: All layers created loading data from OQ-Engine outputs contain metadata that can be visualized within the "Layer Properties" panel. The "Title" of the calculation can be found in the "Identification" tab. Dozens of other parameters that are specific for each calculation type are stored in the "Keywords" tab.

Other kinds of outputs (e.g. hazard curves and uniform hazard spectra) can be visualized in the OpenQuake IRMT Data Viewer (see *The OpenQuake IRMT Data Viewer*).

15.5 Run a postprocessing (or risk) calculation on top of a previously computed hazard

To run a postprocessing or risk calculation on top of a previous hazard one you have to click the *Continue* button on the corresponding hazard calculation and select the files including the postprocessing or risk *job.ini* and the related inputs (or a zip archive containing them).

15.6 Remove a calculation

To remove a calculation, press the *Remove* button. It will remove the calculation from the list, from the database and from the datastore.

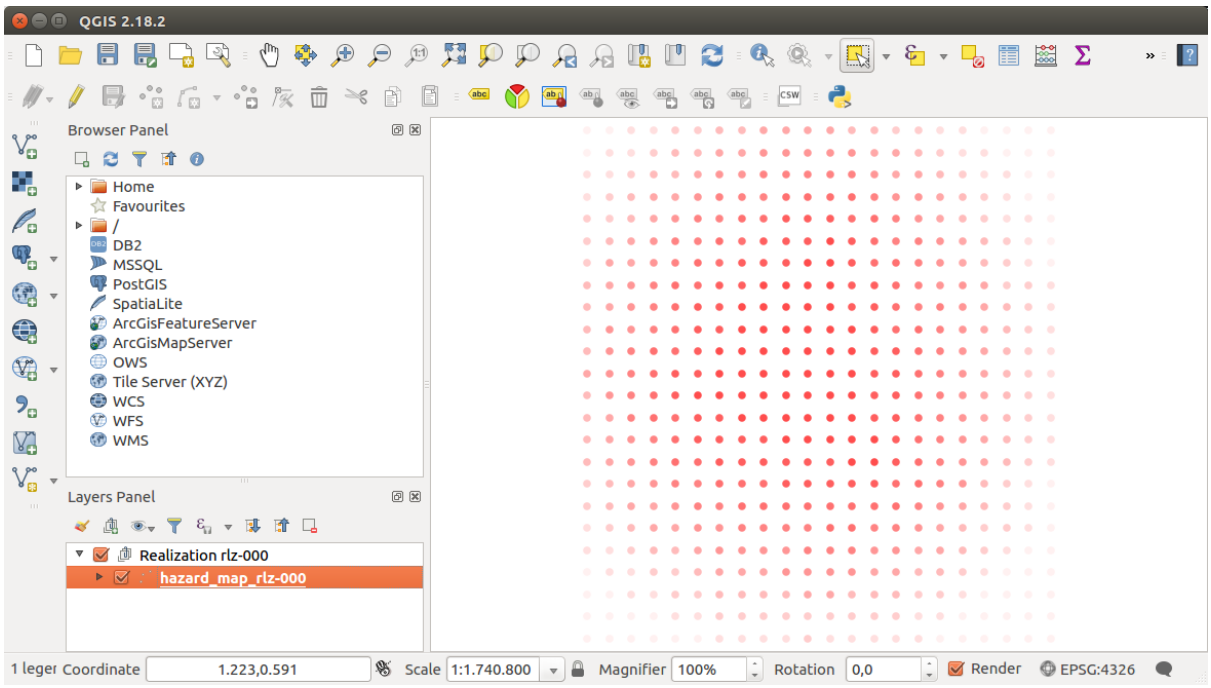


Fig. 15.4: Example of a hazard map produced by the OpenQuake Engine

15.7 Abort a calculation

To abort a calculation while it is still running, press the *Abort* button. The aborted calculation will still be visible in the list, and it will be possible to visualize the corresponding console log. Afterwards, it will be possible to completely remove the calculation from the list, from the database and from the datastore, by pressing the button *Remove*.

15.8 Calculation status

The *Status* column of the *List of calculations* indicates the current status of a calculation, which can be one of the following: *created*, *executing*, *complete*, *failed*.

The reason behind a *failed* calculation can be inspected by watching the console log, by means of the *Console* button.

CHAPTER

SIXTEEN

THE OPENQUAKE IRMT DATA VIEWER

The OpenQuake IRMT Data Viewer is a dock window added to QGIS by the OpenQuake IRMT plugin, used for data visualization. It is shown/hidden by pressing the button *Toggle OpenQuake IRMT Data Viewer*.

In its initial state, the window displays a *Output Type* selector, that enables to trigger the visualization of different types of data, and an initially empty plotting area.

The viewer can plot some of the outputs produced by the OpenQuake Engine, such as hazard curves and uniform hazard spectra, and recovery curves (see also *Definitions and acronyms*).

When a layer containing compatible data is activated in the QGIS and the corresponding output type is selected, the viewer is ready to visualize the outputs corresponding to the features that will be selected in the map.

Plots are obtained using the *Matplotlib* library. Below the plotting area, Matplotlib provides a toolbox with standard functionalities that enable modifying markers, labels, axes, zooming level and other parameters, saving the plot to file and exporting the selected curves into a csv format.

16.1 Visulalizing outputs of hazard calculations

This section describes how to drive the user interface of the plugin to visualize some of the hazard outputs produced by OpenQuake Engine calculations. For an extensive explanation of those outputs, please refer to the user manual of the OpenQuake Engine[29].

16.1.1 Visualizing hazard curves

A hazard curve defines the relation between a scalar IML and the probability of at least one exceedance of that IML within a time span T. The OpenQuake-engine computes discrete hazard curves described by a two-dimensional array containing a first column of n values of an IMT and a second column including values of the probability of exceedance of the resultant IML in the time span T (which is indicated in the OpenQuake-engine configuration file). A hazard curve is the primary result of a PSHA analysis for a particular site. From hazard curves it is possible to compute other result-typologies such as hazard maps and uniform hazard spectra.

As described in *Driving the OpenQuake Engine*, the plugin enables to run hazard calculations and to download the corresponding outputs. For outputs of type *hcurves*, it is possible to load the data into a QGIS layer by pressing the button *Load npz as layer*. The layer will contain, for each point, the set of intensity measure levels and the corresponding values of probability of exceedance, for each of

[29] https://docs.openquake.org/oq-engine/stable/

the available intensity measure types. While the layer is active, it is possible to select the *Output Type Hazard Curves*, to activate the visualization. When one or more points are selected in the map, the hazard curves for the chosen *Intensity Measure Type* are plotted together (Fig. 16.1). The legend also specifies the longitude and latitude of the points corresponding to each of the curves in the plot. By hovering on the legend items or on the curves, the corresponding points in the map are highlighted.

Warning: The highlighting effect produced by hovering with the mouse on legend items or curves, stops working correctly when a layer is loaded using the OpenLayers Plugin. Please note that, starting from QGIS 2.18, base maps can be added as layers without installing any external plugin (such as OpenLayers), but using the new core functionality *XYZ driver* instead. In order to do so, you have to open the *Browser Panel*, right-click on the *Tile Server (XYZ)* and select *New connection...*. Then, for instance, to add a connection to OpenStreetMap, you can insert into the text box the following string: *http://tile.openstreetmap.org/{z}/{x}/{y}.png*. Then press *Ok* and insert a name for the tile layer (e.g., *OpenStreetMap*). Afterwards, it is sufficient to double-click on the new item you have just created, to add OpenStreetMap to the *Layers Panel* and to visualize it in the map canvas.

16.1.2 Visualizing uniform hazard spectra

A Uniform Hazard Spectrum (UHS) is a typology of result that is site-specific – as in the case of hazard curves. A UHS defines a relationship between the period (or frequency) of a period-dependent (or frequency-dependent) IMT such as spectral acceleration and the resulting IMT value with a fixed probability of exceedance in a time span T.

The workflow to visualize uniform hazard spectra is almost the same as the one described above for visualizing hazard curves. In this case, the *Output Type* to be loaded as layer is *Uniform Hazard Spectra* (Fig. 16.2).

16.2 Visualizing outputs of risk calculations

This section describes how to drive the user interface of the plugin to visualize some of the risk outputs produced by OpenQuake Engine calculations. For an extensive explanation of those outputs, please refer to the user manual of the OpenQuake Engine[30].

16.2.1 Visualizing aggregate loss curves

Aggregate loss curves describe the exceedance probabilities for a set of loss values for the entire portfolio of assets defined in the exposure model.

When the button *Show* is pressed, the Data Viewer is automatically opened, providing a dropdown menu to select one of the available loss types, and a tool to select multiple realizations or statistics. By default, the first available loss type is pre-selected and all the realization or statistics are displayed in the plot. Any change in these selections produces an automatic update of the plot. The plot shows in abscissa the return period (in years) and in ordinate the aggregate loss (the measurement unit depends on the parameters of the OQ-Engine calculation).

[30] https://docs.openquake.org/oq-engine/stable/

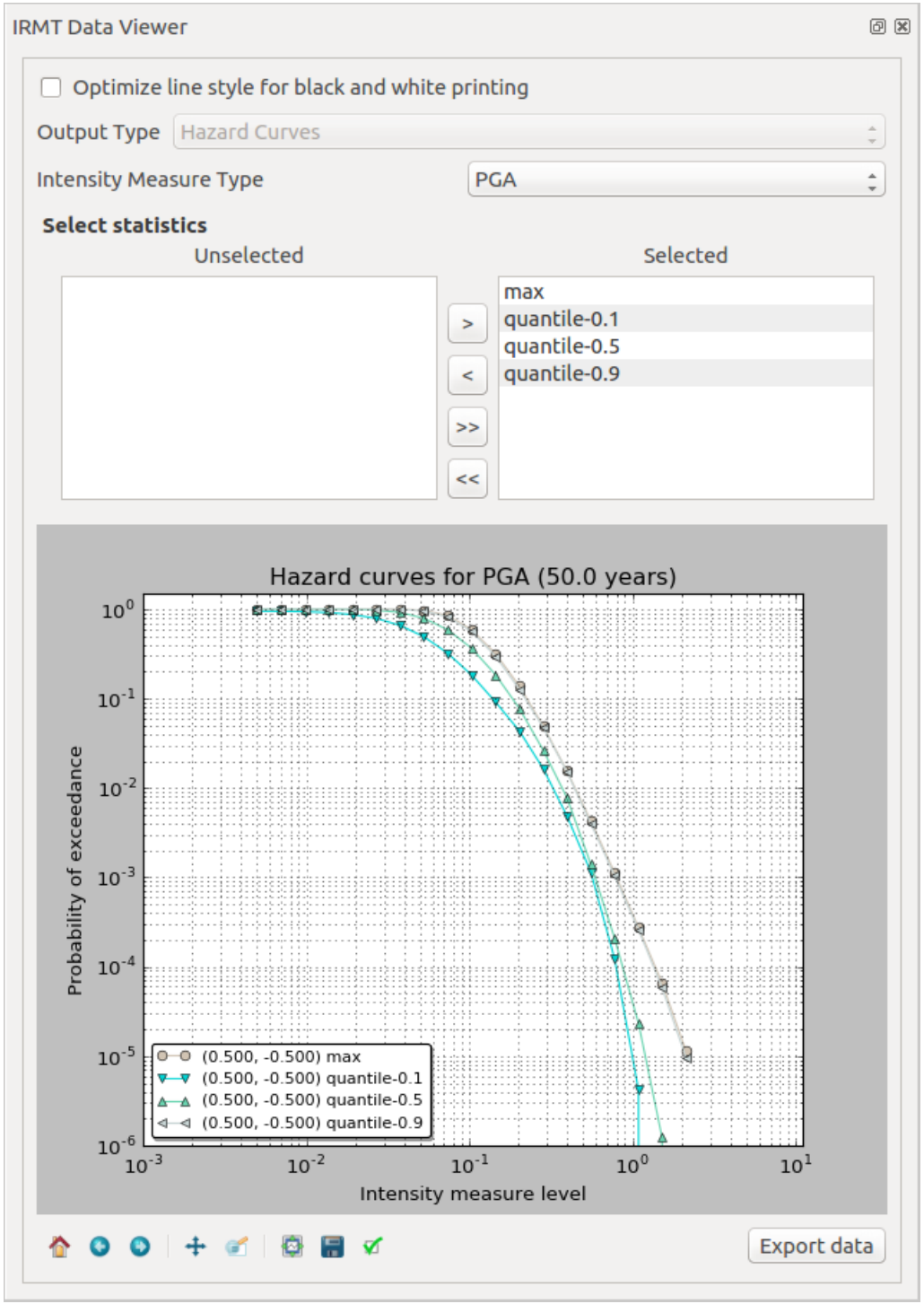


Fig. 16.1: OpenQuake IRMT Data Viewer used for displaying hazard curves

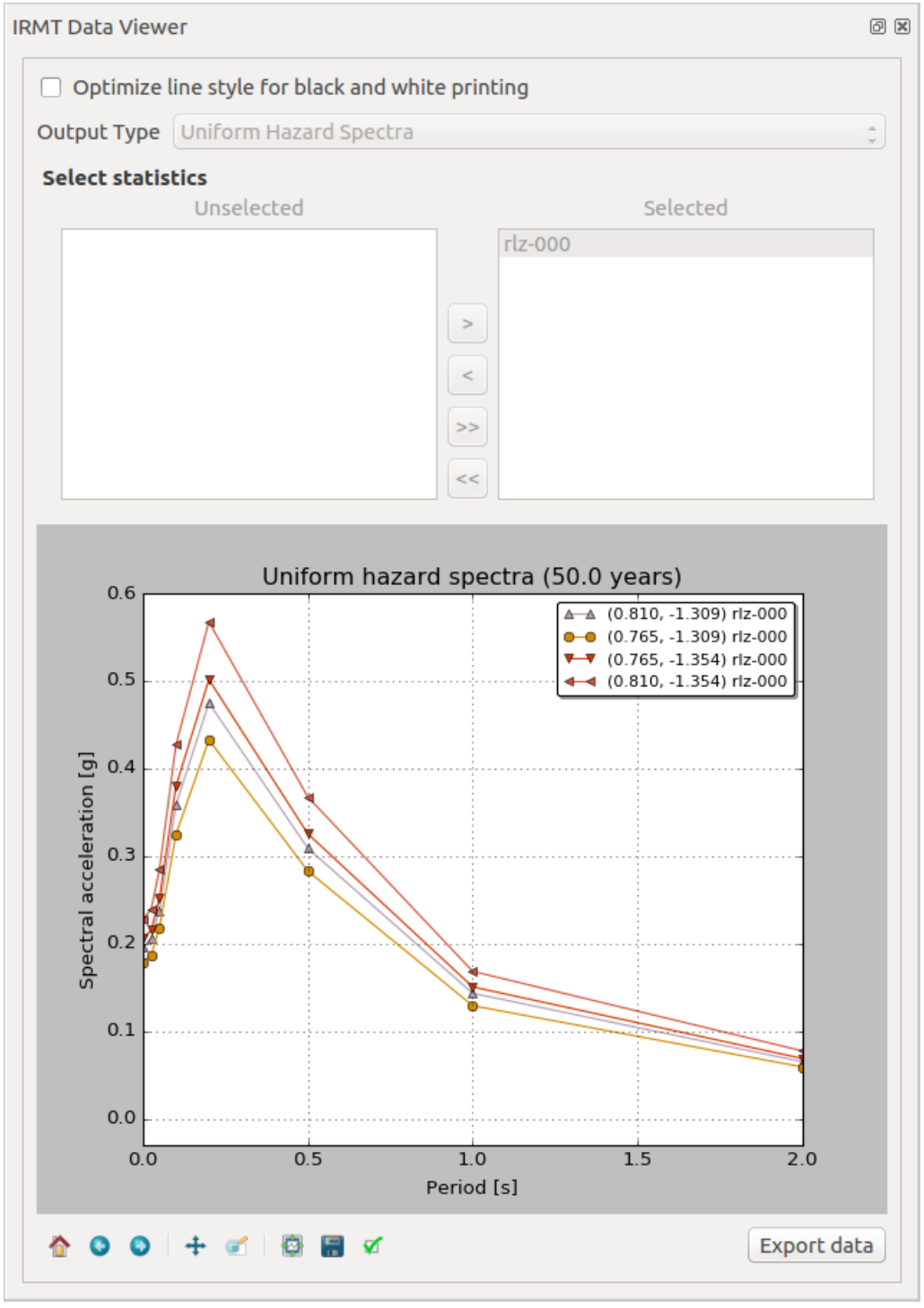


Fig. 16.2: OpenQuake IRMT Data Viewer used for displaying Uniform Hazard Spectra

16.2.2 Visualizing aggregate damage by asset

When the button *Aggregate* is pressed, the Data Viewer is automatically opened, providing a dropdown menu to select one of the available realizations, and another one to select one of the available loss types. Two widgets enable the selection of multiple tag names and, for each tag, one or more of its values. The additional checkbox *Exclude "no damage"* is checked by default, excluding from the plot the damage "no damage" state, which in most cases is predominant with respect to the others and therefore the corresponding bar would look too high in proportion with the others. The bar plot shows the damage distribution, where each bar corresponds to one of the damage states, and the height of the bar corresponds to the number of asset in that damage state. If no filter is selected, the whole damage distribution is displayed. If something is selected, a text field lists the selected tags, each with the chosen value. If a tag is selected, but no corresponding value is chosen, the filter will not be applied.

16.2.3 Visualizing aggregate losses by asset

When the button *Aggregate* is pressed, the Data Viewer is automatically opened, providing a dropdown menu to select one of the available loss types. Two widgets enable the selection of multiple tag names and, for each tag, one or more of its values. If the value * is chosen, aggregate losses for each value are reported. The results are presented as a table containing, for each tag and for each realization, the corresponding aggregate loss. If no filter is selected, the total losses for each realization are displayed. If something is selected, a text field lists the selected tags, each with the chosen value. If a tag is selected, but no corresponding value is chosen, the filter will not be applied.

16.3 Visualizing recovery curves

Please refer to *Post-Earthquake Recovery Modelling Methodology* for a general overview of the recovery modeling workflow, its scientific background and the description of the parameters and of the configuration files.

When one point is selected in the map, the corresponding building-level recovery curve is plotted. By selecting two or more points, the corresponding community-level recovery curve is displayed.

The selection can be made by clicking points directly in the map, or by leveraging other selection tools available in QGIS. For instance, it might be useful to select buildings that share a specific taxonomy. In order to do so, it is sufficient to click the *Select features using an expression* button in the QGIS toolbar, and to use the expression editor to perform the desired query. A useful example could be an expression such as: *"taxonomy" LIKE 'LC-%'*, that would select all those features for which the *taxonomy* field begins with the string *"LC-"*, i.e., all "low building code" assets.

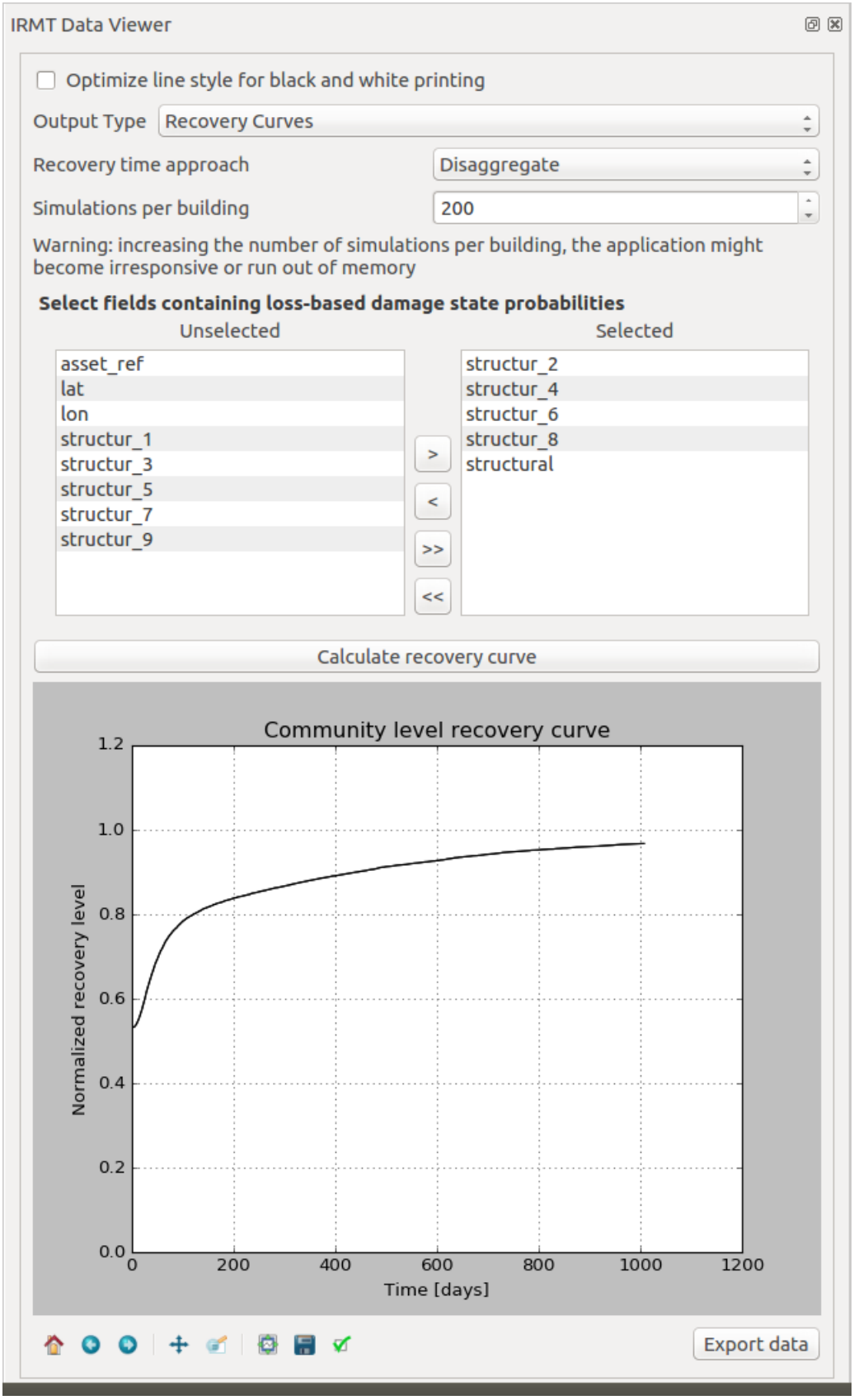


Fig. 16.3: OpenQuake IRMT Data Viewer used for recovery modeling analysis

CHAPTER

SEVENTEEN

VISUALIZING OPENQUAKE VOLCANO SCENARIO CALCULATOR OUTPUTS

The volcano scenario calculator serves as a pilot case for using OpenQuake-engine to assess risk due to hazards different than earthquakes. Detailed information for earthquake analyses is available in the user manual of the OpenQuake Engine[31]. A video tutorial explaining how to use the OpenQuake engine and the plugin for volcano scenario calculations is available on YouTube[32].

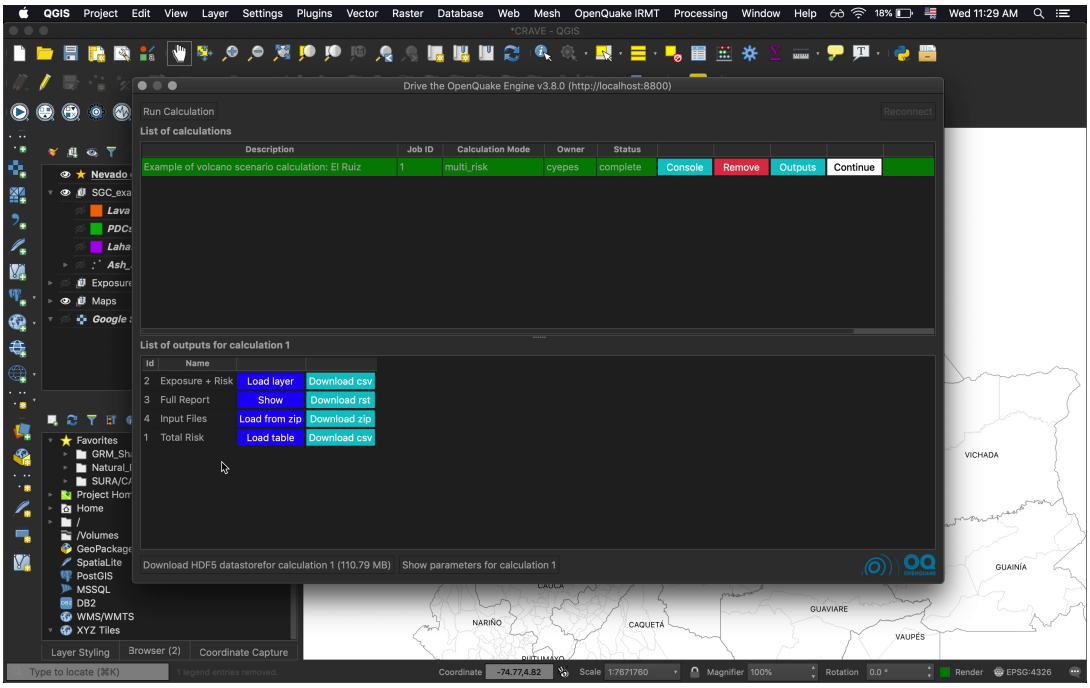


Fig. 17.1: List of outputs for a multi_risk calculation.

17.1 Visualizing Exposure + Risk

By pressing the *Load layer* button corresponding to the *Exposure + Risk* row in the list of outputs for the *multi_risk* calculation, the dialog in figures *Dialog to select parameters for the visualization of exposure.* and *Dialog to select parameters for the visualization of risk.* will be displayed:

Selecting the corresponding radio button, it is possible to visualize either the exposure or the risk. In this example, the exposure can be considered in terms of number of buildings or occupants, or in terms of

[31] https://docs.openquake.org/oq-engine/stable/
[32] https://www.youtube.com/watch?v=I2KEHUAZ-j8

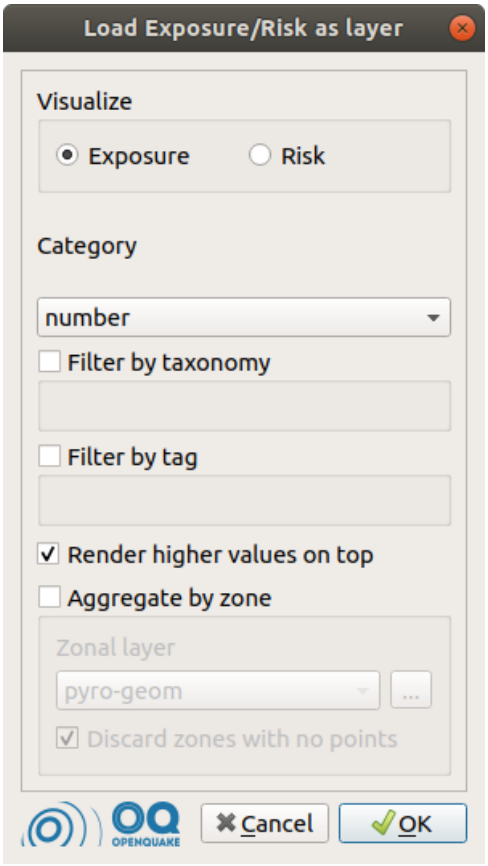


Fig. 17.2: Dialog to select parameters for the visualization of exposure.

structural value. For what concerns the risk, it is possible to select the kind of peril to take into account (in this case: dry or wet ash, lava, lahars or pyroclastic flow) and the category of interest (e.g.: structural collapse, loss or no-damage).

Both for exposure and risk, it is possible to filter the available data by taxonomy and/or by tag. One or multiple items of interest can be chosen (multiple taxonomies and/or multiple values per one of the available tags).

The checkbox *Render higher values on top* is checked by default, as it is recommended. It prevents features with smaller values from overlapping more interesting, higher-valued features that might be located at the same coordinates or very close to them.

Once all the parameters above are set, it is possible to load the corresponding data as a QGIS layer, by pressing the *OK* button. If the *Aggregate by zone* checkbox is not selected, the resulting layer will contain points at the coordinates for which the output data has been calculated. It is also possible to press the *OK* button after checking *Aggregate by zone* and selecting a layer containing polygonal geometries (e.g., each polygon may represent the boundaries of a different municipality). In this case, a geospatial aggregation is performed, summing the values of points contained in each polygon.

In both cases, with or without zonal aggregation, the layer that is produced will be styled automatically.

17.2 Visualizing Input Files

By pressing *Load from zip*, the following dialog is displayed.

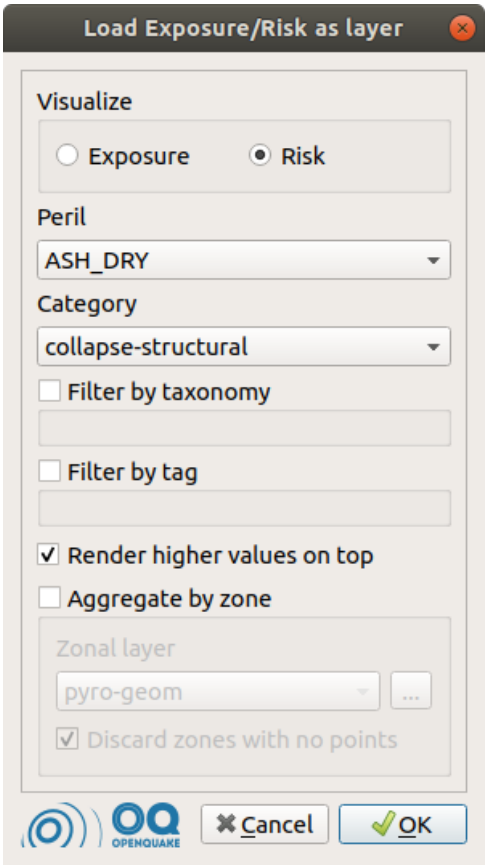


Fig. 17.3: Dialog to select parameters for the visualization of risk.

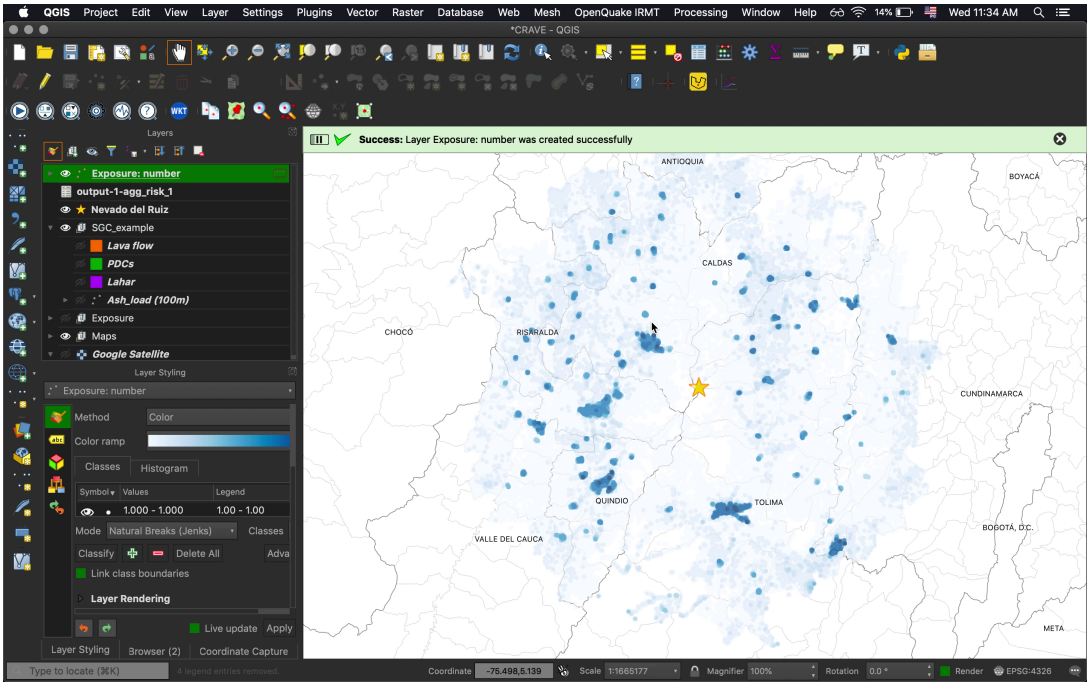


Fig. 17.4: An example of exposure map in terms of number of buildings.

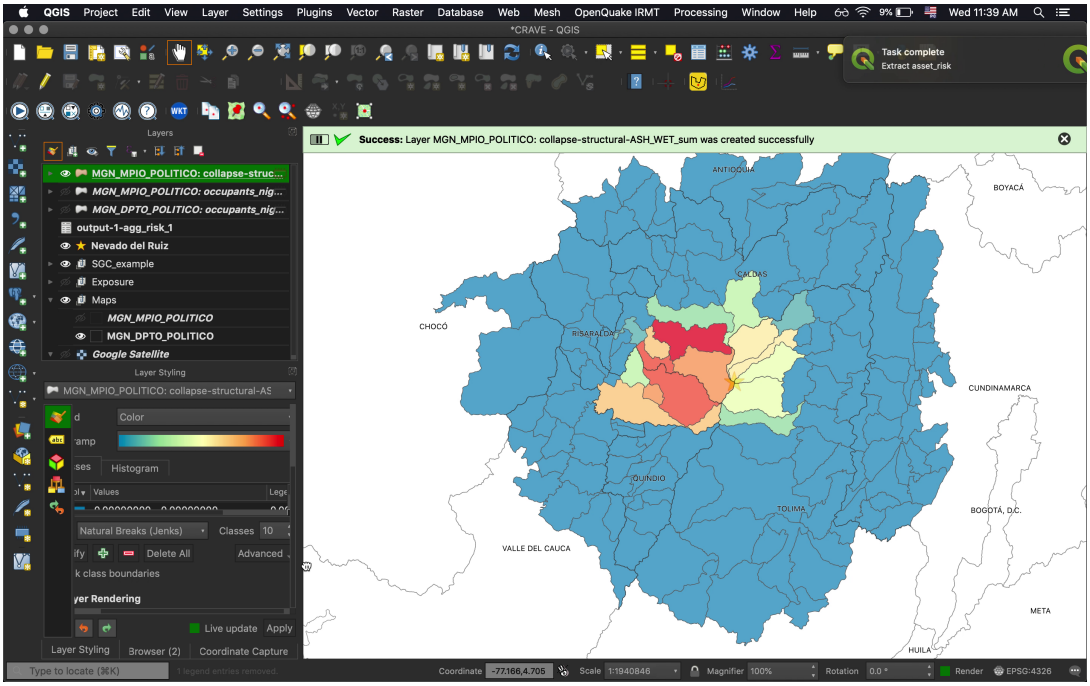


Fig. 17.5: An example displaying the estimated number of buildings per region that would collapse due to wet ash fall.

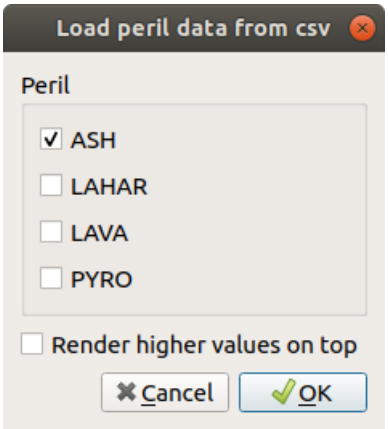


Fig. 17.6: Dialog to select the input files corresponding to the footprints of the perils to be visualized.

It allows to visualize the input data corresponding to the selected perils. Also in this case, it is possible to check *Render higher values on top*, in order to avoid hiding interesting high-valued points below other rendered points.

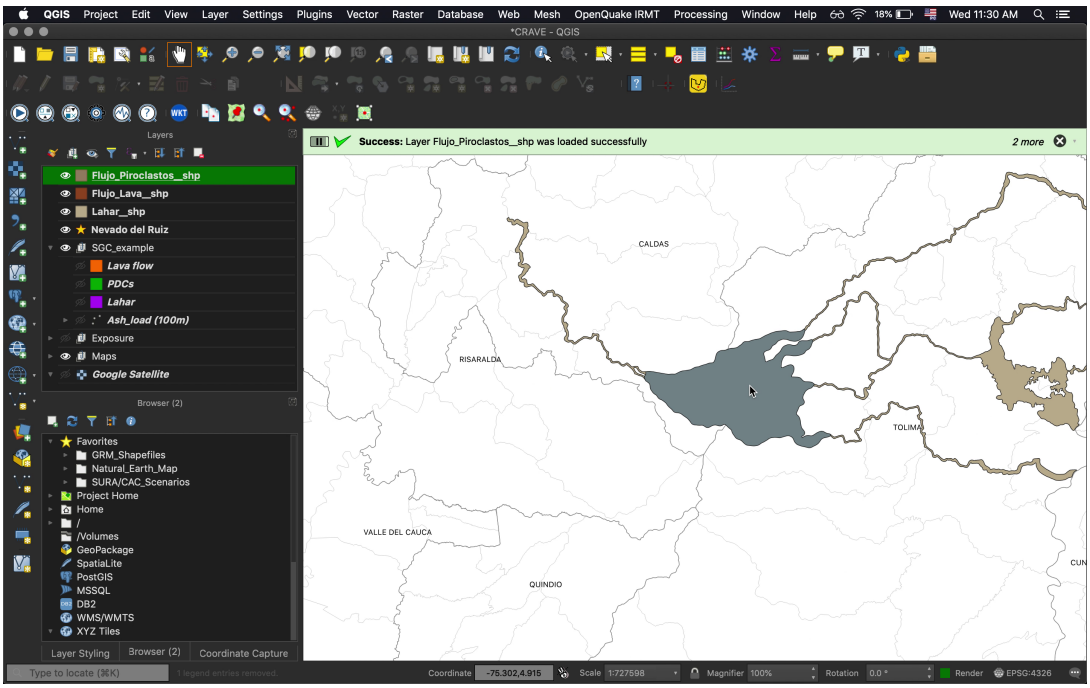
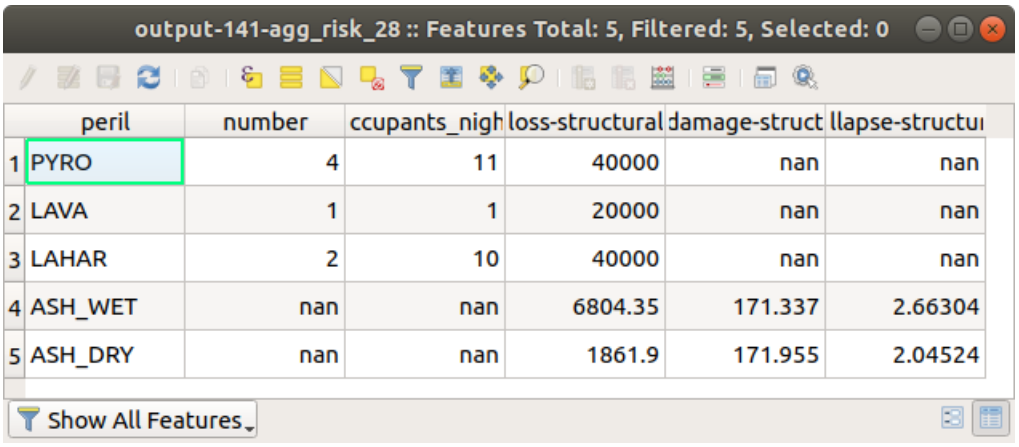


Fig. 17.7: An example of volcano footprint input.

17.3 Visualizing Total Risk

By pressing *Load table*, the plugin will display a summary of the total risk for each of the analyzed perils, with respect to each category of risk and exposure.



	peril	number	ccupants_nigh	loss-structural	damage-struct	llapse-structu
1	PYRO	4	11	40000	nan	nan
2	LAVA	1	1	20000	nan	nan
3	LAHAR	2	10	40000	nan	nan
4	ASH_WET	nan	nan	6804.35	171.337	2.66304
5	ASH_DRY	nan	nan	1861.9	171.955	2.04524

Fig. 17.8: Table summarizing the total risk.

Note: The style that is assigned automatically to the layers might need to be slightly modified on a case-by-case basis, for instance modifying the classification criteria, e.g. changing the number of classes and/or the classification mode (using equal intervals, quantiles, pretty breaks, etc.). A convenient way to do so is to use the "Layer styling" panel and select one of the available layers to visualize and modify

its styling settings. The same can be obtained by double clicking one of the listed layer names, thus opening the layer properties dialog, and using the functionalities offered by the "Symbology" tab.

Links:

Code repository[33]

Bug tracker[34]

Note: This documentation is distributed within the plugin package and it is also available online at http://docs.openquake.org/oq-irmt-qgis/

[33] https://github.com/gem/oq-irmt-qgis
[34] https://github.com/gem/oq-irmt-qgis/issues

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