



FuseGI - "Cooperation for fusing skills on Cloud-based Open Geoinformatics: Innovative Environmental Management"

IO4

Training toolkit

Final Version 30/07/2022

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INTELLECTUAL OUTPUT 4 FINAL REPORT CREATION

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SUMMARY

AVIGNON UNIVERSITE, in cooperation with DEMOCRITUS UNIVERSITY OF THRACE, EE4S, INSTITUTE OF INFORMATION AND COMMUNICATION TECHNOLOGIES, MAISON REGIONALE DE L'EAU, INTERNATIONAL HELLENIC UNIVERSITY and HELLENIC FORESTS (OLYMPUS PC), has undertaken the implementation of the project entitled ***"FuseGI – Cooperation for fusing skills on Cloud-based Open Geoinformatics: Innovative Environmental management"*** under the Agreement n° 2019-1-FR01-KA203-062767 with Agence Erasmus + France, within the **"2019 Round 1 KA2 - Cooperation for innovation and the exchange of good practices KA203 - Strategic Partnerships for higher education"** Call.

More precisely, this intellectual output aims to address all call priorities described in the Application Form, meaning: Open education and innovative practices in a digital era (Horizontal) by creating a set of free novel courses in a public platform including hands on training and self-evaluation techniques, Tackling skills gaps and mismatches (HE) since it follows the assessment of market needs (IO1) and educational gaps (IO2) covering an important part of the draft curricula, and Supporting individuals in acquiring and developing basic skills and key competences (Horizontal) since it actually provides an environment for this through 9 courses and 4 specialized practical case studies that were created responding in actual market tasks.

This report presents the design and implementation of Intellectual Output 4 "Training toolkit" highlighting the innovative means adopted in methodological approach to create tangible and transferable results in the Geographic Information (GI) field.

This IO aims to deliver a pilot training program, covering basic theory required for geospatial data in order to introduce students to the practical part, freeware (software) training, providing extra (free) training material, tests, self-evaluation, course and project evaluation forms, including also hands on practice, podcasts and practical case studies among others. The training toolkit was formed trying to reach a variety of people, of different academic levels and fields.

The IO4 builds upon the findings of IO1 using field review to locate the gap between the actual and desired market skills, IO2 assessing the gap in GIS education in the participating countries and setting a draft curricula, and IO3 researching the available cloud-based platforms, VLE applicability and opportunities for building interactive novel courses, with complementarity and not overlapping.

The findings from the course creation, the course and platform testing and evaluation, of IO4 on diverse subfields of the environmental sciences were used as input data in the core of IO5 with the ability to upgrade and expand them.

ABBREVIATIONS

GI	Geoinformatics
GIS	Geographic Information Systems
IO	Intellectual Output
VLE	Virtual Learning Environment
ICT	Information communication Technology

1 Introduction

1.1 Overall objectives, implemented activities and results of the FuseGI Project

The FuseGI consortium had identified a gap between what the academic world provides towards its teachings and what the environmental labor market requires in terms of Geographic Information Systems (GIS) skills. Skills that are nevertheless essential for environmental and health risks management.

The goal of this consortium was to conduct an in-depth study (qualitative and quantitative) on the subject and then to design, develop and make available an adapted online tool to fill this GIS skills shortage to students and young professionals for the needs of the labor market.

The FuseGI consortium is composed of experts in the fields of water management, forestry and health (from both the academic world and the private sector) as well as computer scientists capable of setting up and sustaining online training tools. It was therefore relevant from the perspective of the project. ERASMUS+ through the projects "Cooperation in innovation and exchange of best practices" was the ideal and most relevant framework to achieve a project in this direction.

The overall objectives of the FuseGI project were:

1. Establishment of a transnational, interdisciplinary and open collaboration between academia and industry within the EU to address the training needs in GIS for better functionality and better environmental and health risks management.
2. Knowledge transfer and bridging of gaps in academic and professional experience of the partners in the use of GIS applications in different key environmental and health sectors.
3. Improved professional skills in the use of open GIS platforms for interdisciplinary collaborative data processing.
4. Development, implementation and validation of a virtual learning environment (VLE).
5. Design of the architecture of an adapted curriculum, corresponding to the needs of the market world, for master's degree courses.

Five transferable, innovative and tangible outputs:

IO1: Research and field review

IO2: Draft Curricula

IO3: Learning platform

IO4: Training toolkit

IO5: Final Curricula

1.2 Interrelations of project Intellectual Outputs

The concept and the methodological approach of the FuseGI project allowed strong interactions between all intellectual outputs. Each intellectual output represent an innovative, transferable and tangible result also as a necessary step for the project finalisation.

The following scheme (Fig. 1) represent the interrelations and connectivity of the FuseGI intellectual outputs.

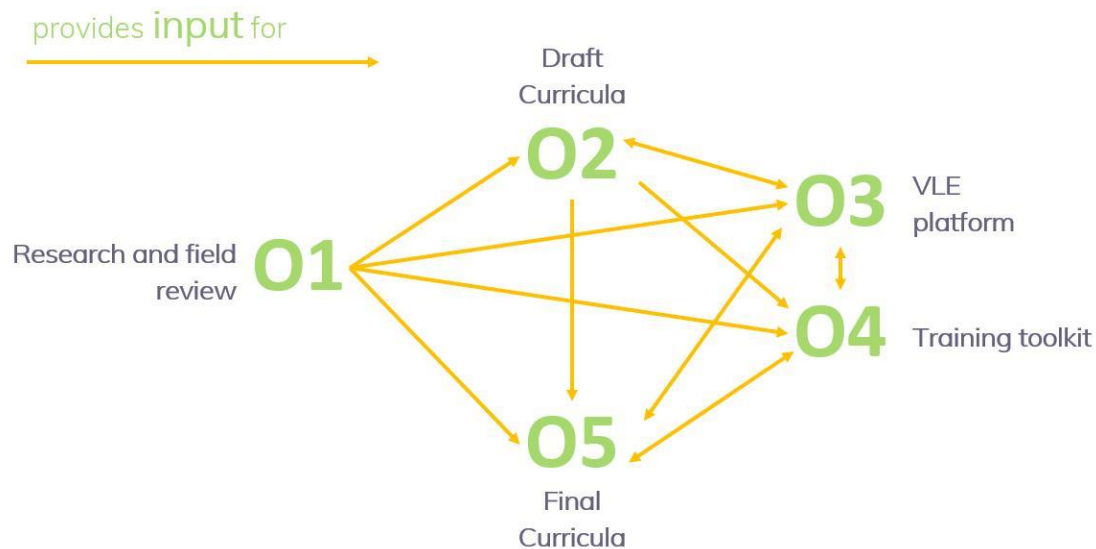


Figure 1 : Scheme of interrelations of FuseGI intellectual outputs

The IO4 builds upon the findings of IO1 using field review to locate the gap between the actual and desired market skills through GIS systems and curricula revision, questionnaires. It also incorporates IO2 assessing the gap in GIS education in the participating countries and setting draft curricula, lectures and courses. IO4 and IO3 co-development and creation provided the basis through researching the available cloud-based platforms, VLE applicability and opportunities for building interactive novel courses. All IOs are really important standalone procedures, necessary to map gaps, needs, tools and methods, in a market with advancing needs as they owed in a study-based project, and all are fused with complementarity and not overlapping points

1.3 Scope and Objectives of Intellectual Output 4

The scope of this Output is a multiple one since it actually creates a solid tool to be adopted by institutions, enterprises and individuals willing to learn or deepen their knowledge on GIS. FuseGI within this project will develop a program toolkit in order to present the program features, methodology, contents and delivery mechanisms.

The toolkit was designed to assist the user to articulate a clear understanding of the context of FuseGI and actively engage themselves to learning process and accomplish courses as well

as enhance the operational capacity of FuseGI project to deliver successful GI and Environmental Management knowledge.

All training material/ references are uploaded at the project’s platform and will be updated. Training coordinators, curriculum developers, and trainers can all use the Toolkit in preparing and presenting GI and Environmental Management training as was stated in the AF.

Though, through the solid findings of the previous IOs and the partnership’s will to create something timeless as a basis for further development this toolkit was even developed to a complete set of courses, able to be included even in graduate and master programmes with an equivalence of 7 ECTS. What’s more, the entire tool is based on freeware (QGIS) supporting openness in its entity using explicitly creative commons rights, open data, open courses and free books and manuals in the PowerPoints and in the supplementary material and operating through an open VLE platform.

The consortium’s effort surpassed the foreseen working man-days but created more than a platform, but a self-tutoring tool for scholars and businesses, free from rights, easy and accessible.

1.4 Structure of Intellectual Output 4

The content of this report is organized as shown below.

1st section describes introductory elements for the IO4

2nd section delineates the methodological approach adopted for the IO4 production

3rd section details on each course separately

4th section details on each case study

5th section highlights the importance of the findings delineating innovation, tangibility and transferability

1.5 Intellectual Output 4 Sub tasks

Sub task
Strategic design to apply the FuseGI vision using open software
Consulting professionals on teaching methods and desired outcomes for building a curriculum
Revise existing available training and teaching material
Definition of access criteria, the participants profile, entry requirements and selection process
Setting courses’ and case studies’ criteria (format, duration, rights, training, testing, evaluation)
Testing VLE platforms compatibility and extensions
Determination of Desired Cognitive skills and course thematic structuring
Creation of the courses (ppts, podcasts, accompanying documents, training material, tests and evaluation forms)
Selection and formatting of real-life practical case studies

Testing of toolkit within the platform
Launching the training toolkit
Review period (internal and external)
Launching the revised final version of the toolkit

2 Methodological approach

In order to effectively train the users of the platform, 9 online courses are available on the platform as well as 4 case studies to put into practice the theoretical explanations.

The FuseGI VLE platform currently offers 9 courses to bridge the gap between the knowledge of graduating students and the expectations of professionals for the job. Classes may sometimes contain small exercises to help understand the lesson. In addition, a case study is available to implement all the functionalities of GIS and more particularly QGIS.

The structure of each course is very similar: we first find an introduction, then a plan defining the different parts of the development, the development in question and then a conclusion and the associated sources. In addition, the language used for the courses is English, as it is universal, it facilitates access to all European users.

2.1 Preparatory phase

After having conceived the Strategic design how to apply the FuseGI vision and how to conform with the AF stating “The tool kit will be organized in several major units. Each unit will be made up of modules which themselves will contain smaller units covering an important component and learning objectives of GI and Environmental Management” we selected using open GIS software and the optimal selection was QGIS based on the availability of a range of add-ons and the compatibility with other software.

Given the recent covid period and the “activation” of distance learning techniques, we consulted professionals on teaching methods and desired outcomes for building a curriculum based on the IO2.

Then we revised the existing available training and teaching material from institution open courses, data providers, QGIS tutorials and tips, and existing exercises in order not to overlap with already accessible material (but to use it as supportive providing links and databases)

In close collaboration with the VLE platform, we defined the access criteria, the inclusivity (e.g. for people with impaired vision), the broad range of participants profile, entry requirements and selection process adopting the idea that the theory that is taught and the information given must be understood by both a graduate of an engineering school and philosophy.

The next step was setting courses’ and case studies’ criteria (format, duration, rights, training, testing, evaluation). So, for each course, we selected to provide a course summary, the cognitive skills, a podcast for the course presentation, the basic PowerPoint presentation, keywords, sources and literature used, a folder with additional data supplementary material

(links, books, databases, exercises), create a short quiz (mostly for self-assessment reasons, not for grading) with multiple takes ability and both a course and project evaluation form.

Then we tested the selected open VLE platform Moodle for compatibility with embedded video and document players safeguarding also inclusion policy.

2.2 Creation of courses, case studies and testing

Based on the Outcomes of IO2 and IO3 and the recognized range of gaps both in market skills and GeoInformatics education we deemed that a set of 9 courses, 3 of them introductory and 6 practical (including also QGIS addons like GRASS) as described in the pictures below (Fig. 2, 3).

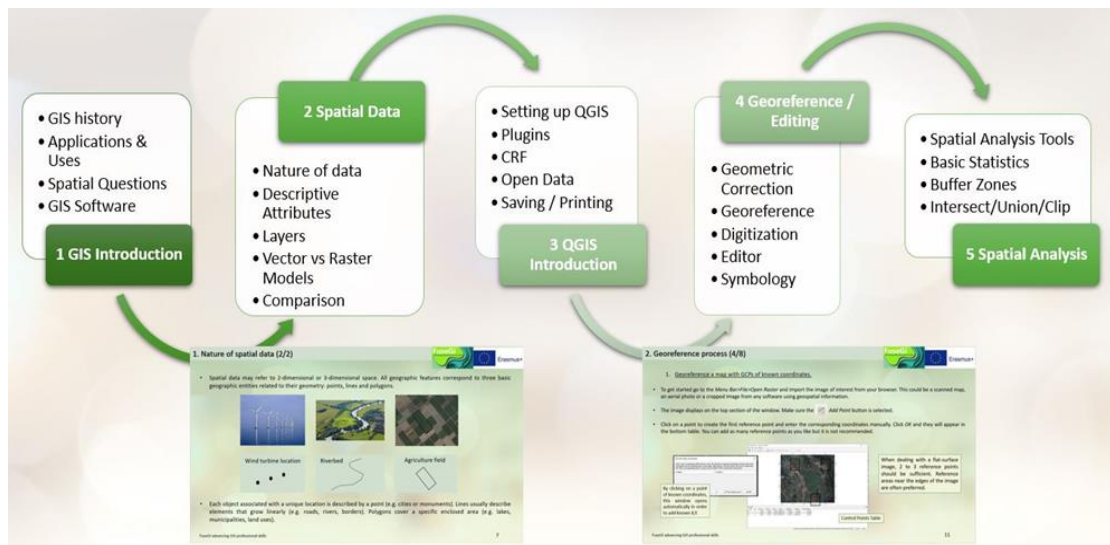


Figure 2. Lessons 1 to 5 flow chart with basic context presentation.

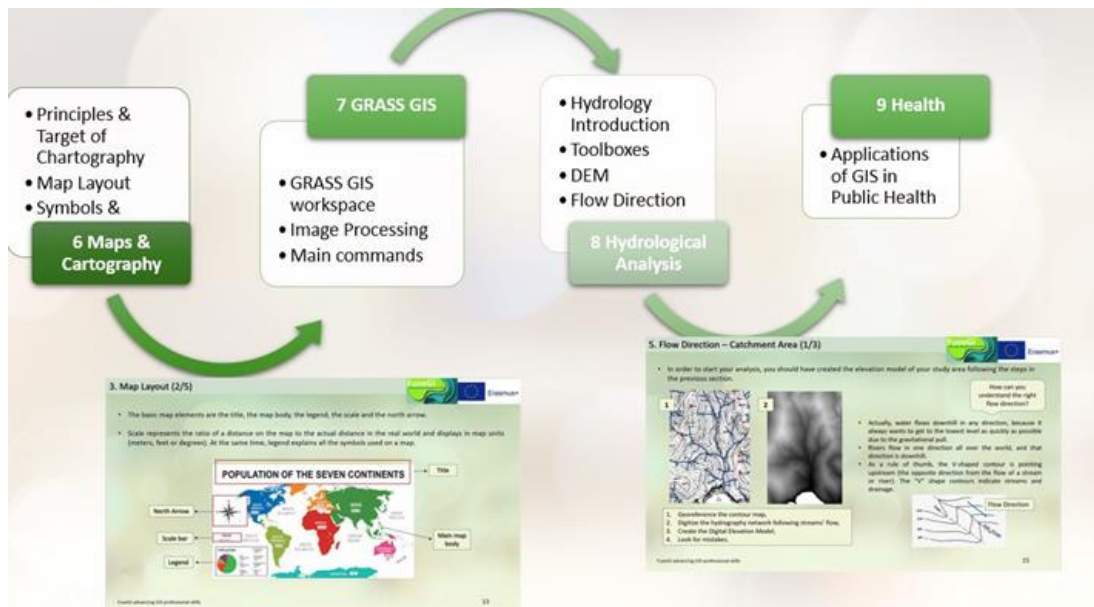


Figure 3. Lessons 6 to 9 flow chart with basic context presentation.

As the case study selection, we came in contact with experts and professionals in the fields of water, forests and health to meet their most usual tasks and needs through these case studies. Then we had to find the primary-raw data and select the proper articulation for describing the problem at hand and the solution we seek. Then we chose to “assist” the students by providing them optionally with a series of sub-tasks, as steps for the case study completion and where they could find each QGIS command to perform each action.

Then, before the official launch of the toolkit, we tested it with experts and then with students from participating universities (master and graduate) both individually and during C2 and C3 joint training event. Corrections were made according to indications.

2.3 Revising the toolkit

The first version was completed in time according to the Application Form. The final teaching material included in IO4 was produced by co-shaping the IO5 final Fuse GI curricula. This approach was selected in order to endorse the results from the validation phases that were held during the program, meaning the first edition of the platform tested by the consortium, focus groups, students and dissemination events as described in the Application Form. These gave important feedback that allowed us to evolve and adapt the material. These findings could be concluded in:

Augmented need for extra hands-on practice.

So, the second version of the toolkit had a clear aim: to ensure the competency-based approach promoted by IO5 finalized so as to fully master the newly acquired knowledge on QGIS tools and techniques.

The actual revised version of the toolkit had some adjustments for every level of the Finalcurricula design according to the competency-based approach.

Discovery level: The introductory courses were increased from 2 to 3 courses to distribute (equalize) the teaching duration and break it into more easily assimilable lectures.

Getting started level: There was the need for even more supplementary material related to the training for further self-engagement. The courses already included databases and practice exercises but in the final version, these were doubled in number.

Advanced use level: The revised version of the toolkit, trying to cope with the range of skills of the involved “students” of the program decided to raise the difficulty in two real-life case studies, naming Forestry and Hydrology ones along with the addition of Hydrology 2 case study related with biodiversity.

This series of adjustments in the first version advanced the training material (structure and content) and increased the overall quality of the toolkit ensuring competency-based approach which is the goal of IO5.

3 The courses

In order to effectively train the users of the platform, **9 online courses** are available on the platform as well as **4 case studies** to put into practice the theoretical explanations.

The FuseGI VLE platform currently offers 9 courses to bridge the gap between the knowledge of graduating students and the expectations of professionals for the job. Classes may

sometimes contain small exercises to help understand the lesson. In addition, a case study is available to implement all the functionalities of GIS and more particularly QGIS.

The structure of each course is very similar: we first find an introduction, then a plan defining the different parts of the development, the development in question and then a conclusion and the associated sources. In addition, the language used for the courses is English, as it is universal, it facilitates access to all European users.

3.1 Course 1: Introduction

The first course introduces the **basic concepts of GIS**, but also the definitions. We also find key figures and the history of GIS. We also learn more about the **possible applications of GIS** and its uses in certain areas. These courses allows to anyone know the **types of questions that can be solved thanks to GIS** and it also highlights the different software that can be used to make GIS. This course also illustrates the advantages and disadvantages of using GIS (**Figure 4**).

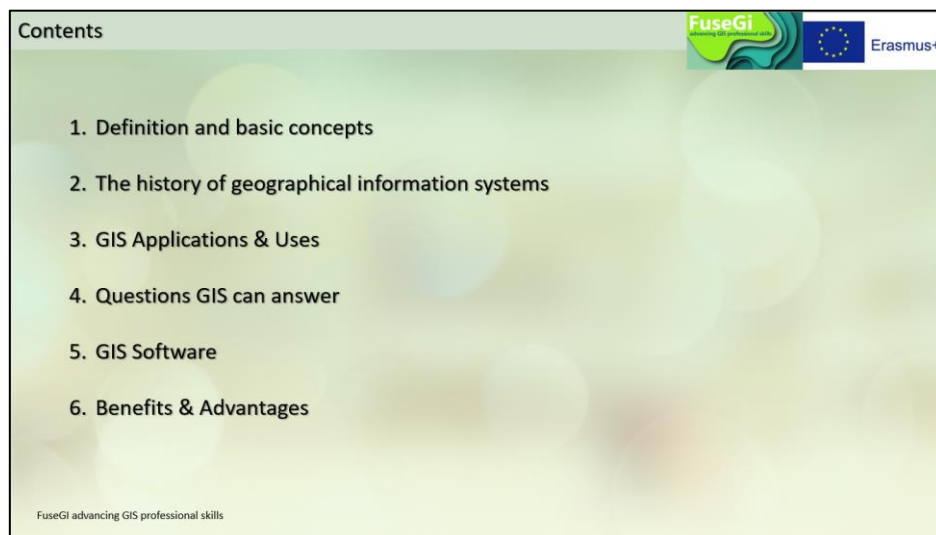


Figure 4 : Slideshow map of course 1, available via the FuseGI VLE platform.

The first part of this course defines the basic concepts of GIS, as well as the different reasons for using them to improve communication between different scientists (**Figure 5**).

1. Definition and basic concepts

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- For several reasons, it is difficult to give a proper definition of Geographical Information Systems.
- GIS include both manual and computer-based information systems. The most common and acceptable definition could be the following:

A geographical information system is a system that can capture, store or create, manage, analyze and map all types of data.

- Different kind of data is connected to a map providing useful information in order to improve communication through scientists as well as better management and decision making.
- GIS uses data that is attached to a unique location and perform a number of management and analysis functions.

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Figure 5 : Slide 6 of course 1, available through the FuseGI VLE platform.

The courses are quite simple to understand, a maximum of figures are added to the text to facilitate the understanding of it (Figure 6). For example, in order to explain the history of GIS, it is possible to use a timeline.

2. The history of Geographical Information Systems (1/2)

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Between 1854-1960 there was limited development in GIS while mapping was paper based. In 1960s computers started developing. Michael Goodchild's research on spatial analysis and visualization brought revolution in the world of geographic science.

Howard Fisher created one of the first computer mapping software programs known as SYMAP.

1960

1963

1965

1969

Roger Tomlinson created the first GIS in the world for the Canadian government. Tomlinson designed an automated system in order to store large amounts of data concerning Canadian natural resources.


Two members of the Harvard team founded Environmental Systems Researchers Institute (ESRI).The ESRI' s team developed many of the GIS mapping and spatial analysis methods that are used even today.

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Figure 6 : Slide 7 of course 1, available via the FuseGI VLE platform.

The second part of this module traces the history and improvements of GIS over time, from its inception in 1960 to the present day (Figure 7).


3. GIS Applications & Uses (2/4)




Climate Change



Sea Level Rise



Desertification



Land Surface Temperature Change

Collecting data on sea level rise from different regions of the planet. All of this data can be processed and presented through GIS applications. The purpose of this research is to find the most vulnerable coastal areas and construct the appropriate protection projects.

Understanding the causes of desertification such as inappropriate agriculture practices and drought. Areas affected by drought or high rainfall are recorded in order to help decision makers in proper management of water resources and construction of hydraulic projects.

Studying how land surface temperature changes year by year. Through GIS, researchers can extract fluctuating maps with a combination of data and study temperature changes in order to implement the most appropriate policy.

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3. GIS Applications & Uses (3/4)



Ecology



Honeybees



Migratory Birds



Fragstats



Species Biodiversity

Analyzing relationships between environmental characteristics and honey bee health. In the regions where bees are healthy and people take care of them, flowering and better ecological condition of the plants are observed.


Using GPS tools for migratory bird locations in order to reduce aircraft strikes and also protect rare species from harmful human actions.

Computing landscape metrics and fragmentation over time in areas burdened by human factor. GIS tools can give important data about the changes that urban fabric has brought to natural landscape.


GIS maps can study either the decrease in biodiversity or the abundance of species and help make the right decision in order to protect species biodiversity.

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3. GIS Applications & Uses (4/4)




Hydrology




Flow Accumulation




HEC-HMS / HEC-RAS Flow Model / MIKE21




Flow Direction & Estimation




Forestry




Forest Heights



Wildfire Simulation



Forest Fires



Forest Carbon Reserves

Spread of wildfire in time can be presented using the 3D virtual workspace of Capaware.

By introducing the right contour lines in GIS, researchers can create 3D elevation models and estimate flow direction.

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Figure 9 : Slides 10, 12 and 13 of course 1, available via the FuseGI VLE platform.

The fourth part provides a better understanding of the use of GIS. Indeed, this part explains what types of problems can be solved using GIS, such as defining a forest area sensitive to climate change (Figure 10).

4. Questions GIS can answer (1/3)

- GIS enables to visualize information in ways that can reveal important relationships and trends.
- It can give answers to a variety of questions and spatial problems through the processing of both spatial and attribute data.
- Users of GIS can answer geographic queries and analysis and make better decisions by creating better solutions.
- GIS can identify spatial relationships between different map features.
- **What is at..?** This is the first and main question that GIS can answer by giving a variety of information concerning a specific geographical area. A GIS map can combine different kind of data for a particular area e.g. place name, streets, buildings or even trend of population. Users have access to both quantitative and qualitative characteristics of the geographical area under study.
- **Where is what..?** This could be the second most important function of GIS combining spatial information. Instead of identifying locations, it can also find places where special conditions are satisfied. Users can find places that meet specific requirements. This GIS feature might be the most important in decision making.

4. Questions GIS can answer (2/3)

- A GIS map can combine different layers of data. Landscape-hydrography-natural characteristics-buildings-roads and land uses. That is why GIS can be applied to almost any profession and science.
- **Researchers** can be interested in finding water bodies close to industrial areas. **Hydrologists** can capture water flow and suggest new hydraulic projects. **Ecologists** can search and study natura areas close to residential areas or study the increasing or decreasing trends of flora and fauna in each area. **Foresters** can find, study or create buffer zones around vulnerable areas to fires. **Engineers** can study population growth and design new projects.
- The integrated management of water resources, coastal areas, natura areas and the organization and planning of cities requires the use of GIS.
- **What has changed..?** GIS can show land use changes over time providing useful information and results for landscape fragmentation.



4. Questions GIS can answer (3/3)

- Understanding the need to manage environmental issues, European Union has developed the Copernicus program in cooperation with the European Space Agency (ESA). The idea firstly developed under the name Global Monitoring for Environmental Security (GMES), which was later renamed **Copernicus**.
- The aim of the program is to achieve a global, continuous and high quality observation of the Earth in order to provide accurate and in-time information to improve environmental management, understand the effects of climate change and ensure security policy.
- The program was established by the regulation 377/2014 [2] in April 2014. The platform was designed in a way that it can gather all the information about the environment and monitor land uses. Decision makers can export any time the picture of earth's "health".



<https://land.copernicus.eu/global/products/lc>

Figure 10 : Slides 13, 14, 15 of course 1, available via the FuseGi VLE platform.

In the fifth part, users of the platform become aware of all types of software using GIS, whether paid software, such as ArcGIS, or the QGIS suite of free and open-source software (Figure 11).

5. GIS Software (1/2)

- Researchers and companies of any size in industries like healthcare, marketing, construction, management and more can use GIS and its capabilities to take their business one step further.
- GIS software can be stored into different categories: open source software & commercial or proprietary GIS software.
- Open source GIS are based on three main groups in terms of programming languages: 'C' languages, Java and .NET.
- A project started in 1982 by the United States Army but is now open source, known as Quantum GIS (QGIS) is the most popular 'C' based open source GIS software.
- Java offers geospatial functions like union or buffer and allows comparison between objects. Open Map and Geotools are among the most known open source GIS using Java tools.
- In the GIS software market, companies with the highest share are the following:
 - ESRI-ArcMap, ArcGIS
 - Autodesk-AutoCAD including Map 3D
 - ERDAS IMAGINE-Erdas Apollo, Leica Photogrammetry Suite
 - Intergraph-GeoMedia

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5. GIS Software (2/2)

- The first open source system appeared in 1978. GRASS GIS is the earliest open source GIS supported both raster and vector data and was originally developed by the United States Army Corps of Engineers.
- Open source GIS software available are the following:
 - QGIS
 - GRASS GIS
 - Integrated Land and Water Information System (ILWIS)
 - uDig
 - SAGA GIS
- Other GIS open services: Google Earth Pro, Google Maps.
- Other GIS open tools: Capaware - 3D simulation of the progress of a forest fire. Kalyppo software – offers rainfall/rainoff simulation and flood mapping tools.
- With a quick web research, prospective users can search reviews for every available software considering the following criteria: editing, imagery, analysis and cartography tools.

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Figure 11 : Slides 16 and 17 of course 1, available via the FuseGI VLE platform.

The sixth and final part of this first GIS course is a list of advantages and benefits of using GIS in the different areas listed above (**Figure 12**).

6. Benefits & Advantages

- The advantages of using GIS can be described in five main categories:
 - 1. Improving the management and decision-making process.**
GIS can manage not only spatial data and maps but also data from several sources in order to create digital maps and give answers to geospatial questions. It is a helpful and necessary tool in policy making.
 - 2. Cost reducing due to greater efficiency.**
Costs in human resources and labor are reduced due to the increasing efficiency of new technological tools. Complex analyzes are performed in less time.
 - 3. Better storage and manage of geographic information.**
GIS has considerable tools in data collection and analysis. Processing different layers of data at the same time.
 - 4. Improving communication and cooperation between organizations.**
Companies and individuals can share any kind of data and results. Researchers around the world can share their work and exchange data and information.
 - 5. Improving the quality of research and professional opportunities.**
GIS technologies increase employment opportunities.

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Figure 12 : Slide 18 of course 1, available via the FuseGI VLE platform.

This first course teaches the basics of GIS as well as when to use GIS to process information and communicate with other scientists and professionals

3.2 Course 2: Spatial Data

The second course **defines raster and vector models**. These concepts are very important for using GIS. It also includes criteria for selecting raster and vector models and a comparison between the two models. This course also introduces the **concepts of layers and objects, descriptive attributes, the nature of spatial data, and spatial data models (Figure 13)**.



Figure 13 : Course outline 2, available via the FuseGI VLE platform.

First, the course defines the concepts of data collection as well as the characteristics of spatial or geographical data (Figure 14).

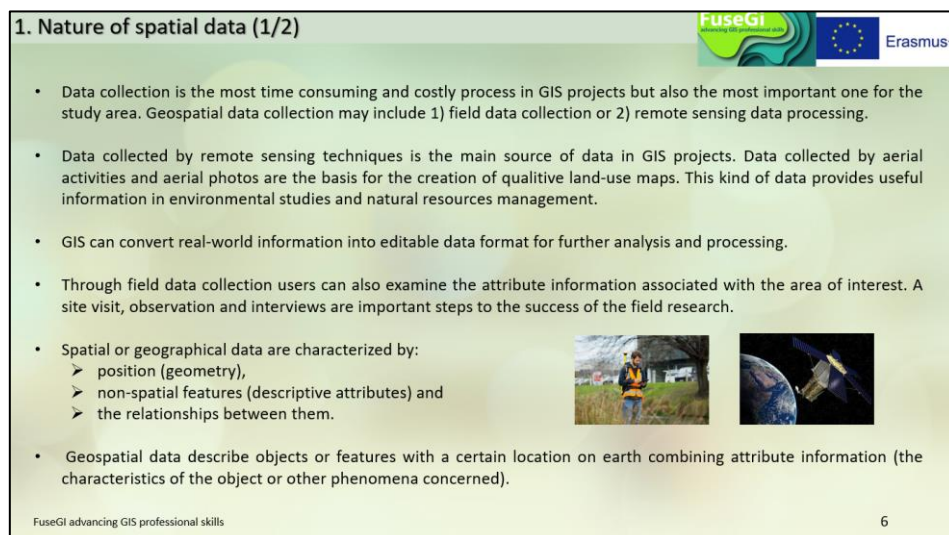



Figure 14 : Slide 6 of course 2, available via the FuseGI VLE platform.

Next, the course develops the three geographical features that can be connected with geometric elements: points corresponding to an object with a precise location, lines that can represent linear elements such as a river, and polygons representing specific areas (Figure 15).

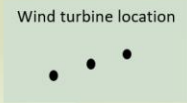
1. Nature of spatial data (2/2)


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- Spatial data may refer to 2-dimensional or 3-dimensional space. All geographic features correspond to three basic geographic entities related to their geometry: points, lines and polygons.





Wind turbine location



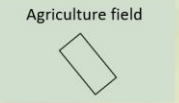


Riverbed





Agriculture field



- Each object associated with a unique location is described by a point (e.g. cities or monuments). Lines usually describe elements that grow linearly (e.g. roads, rivers, borders). Polygons cover a specific enclosed area (e.g. lakes, municipalities, land uses).

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Figure 15 : Slide 7 of course 2, available via the FuseGI VLE platform.

Slide 8 allows platform users to better understand attributes and their usefulness in a GIS project (**Figure 16**).

2. Descriptive attributes

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- Spatial data contain more information than only a location on the surface of the Earth. Any additional information that describes a feature is referred as an attribute.
- Each geographical entity may have more than one descriptive attribute.
- For example, contouring maps include points where every point can give a non-spatial information, that of the altitude. A map displaying buildings of a region not only give the coordinates of their location but may also have additional attributes such as the type of use or the number of floors it has.
- Users enter manually the descriptive attributes of the objects they digitize. The information given can be displayed on the desktop in the form of tables, known as *attribute table*.
- Attributes can be numbers (e.g. the students of a school. School can be rendered as a digitized polygon on a map.) or text (e.g. school's name).
- Entering the proper entities' attributes is one of the basic processes of data collection, data organization and data transfer to the environment of GIS coming from the field.

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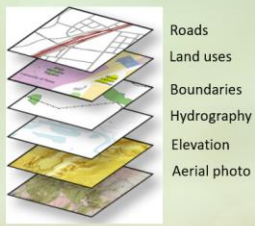
Figure 16 : Slide 8 of course 2, available via the FuseGI VLE platform.

This course is widely used to define the basics for beginners or to make reminders to more experienced users, with for example the slide "Layers and objects (1/2)" which defines what a layer is (**Figure 17**).


3. Layers and objects (1/2)

A. Layers

- The traditional method of mapping the geographical space occupied by spatial data is a series of layers. The first space modeling method developed is known as *layer based approach* and is still used today.
- Layers are defined based on:
 - Geographical phenomenon,
 - Geometry (contains data of geographic entities: points, lines or polygons) and
 - Descriptive attributes.
- Examples of thematic layers: hydrological network, buildings, road network or ground cover. Depending on map's purpose layers alternate and vary.
- Layers analysis determines the degree of the model's completeness (how many?) and depends on the purpose (which?).




From reality



GIS →

To a map



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Figure 17 : Slide 9 of course 2, available via the FuseGI VLE platform.

Like the previous slide, this one is intended to define another concept that is very important for the use of GIS, the notion of object. It therefore defines objects and helps to understand their uses (**Figure 18**).

3. Layers and objects (2/2)

B. Objects

- The space consists of distinct objects (object oriented approach). Each of them competes as a distinct object and there is always a gap between them. For example, a model of reality of the electricity supply network consists of the objects below: cables, columns and power stations.
- Object oriented approach aims to improve the quality of system analysis and make it more usable. It refers to a programming language or software methodology that is built based on logical objects.
- An object exists within problem domain and can be identified by data (attribute) or behavior. Between them there are relationships under processing and examination.
- The following processes are performed on the objects analysis:
 - Construction/De-construction, creating new parameters of a class or deleting existing ones.
 - Update, changing values to an object's attribute.
 - Query, finding answers without changing any attributes.
- Each group of similar types of objects belongs to a certain layer. Combining layers displays the reality through mapping.

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Figure 18 : Slide 10 of course 2, available via the FuseGI VLE platform.

Then, the course again defines very important concepts to understand such as the difference between a raster model and a raster model. In addition, it defines and informs on the particularities of each of these types of models (**Figure 19**).

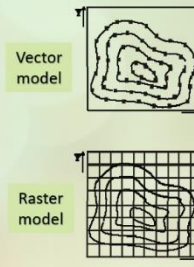
5. Vector and raster models (1/6)

- Geographic information systems and spatial databases use spatial models for the digitalization of geographic data. The main spatial models at the conceptual level are:
 - The **vector** models and
 - The **raster/grid** or tesseral models.

- The conceptual spatial model must then be adequately described so that it is practically possible to register its elements in a computer environment.

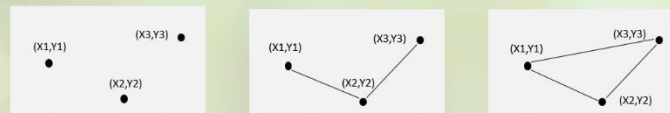
➤ A. Vector models

- There are three main types of vector data: points, lines and polygons. Vector data could be assumed as the graphical representation of the world's surface. Connecting points create lines and connecting lines create polygons.
- Vector data are usually stored in a file format known as shapefiles (.shp).
- Vector points are a latitude and longitude or simply XY coordinates. Every point has a unique location.

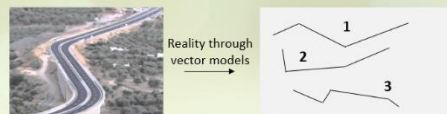


5. Vector and raster models (2/6)

- Line is the basic logical unit expressed by a series of vertices with x,y coordinates. Points can be expressed as lines of zero length. Polygons are expressed by the set of lines enclosing them.
- Vector models are suitable for digitizing discrete entities or phenomena.



- Descriptive attributes of the entities of the vector models are given through the *attribute table*.

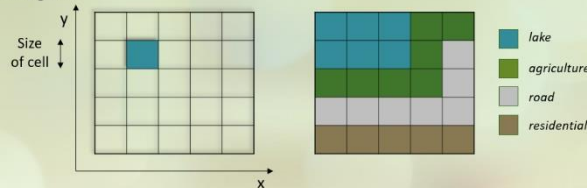


Attribute Table			
Id	Type	Status	Length
1	National road	Open	56.7 km
2	Provincial road	Open	9.6 km
3	Dirt Trail	Closed	2.1 km

5. Vector and raster models (3/6)

➤ A. Raster/Grid models


- On the other hand, raster data are presented through grid of pixels that each one has a value. This kind of data comes from photos taken from satellites or other aerial activities.
- In raster models geographical space is divided into cells of regular shape. Each cell constitutes the basic logical unit. All cells together form a grid.

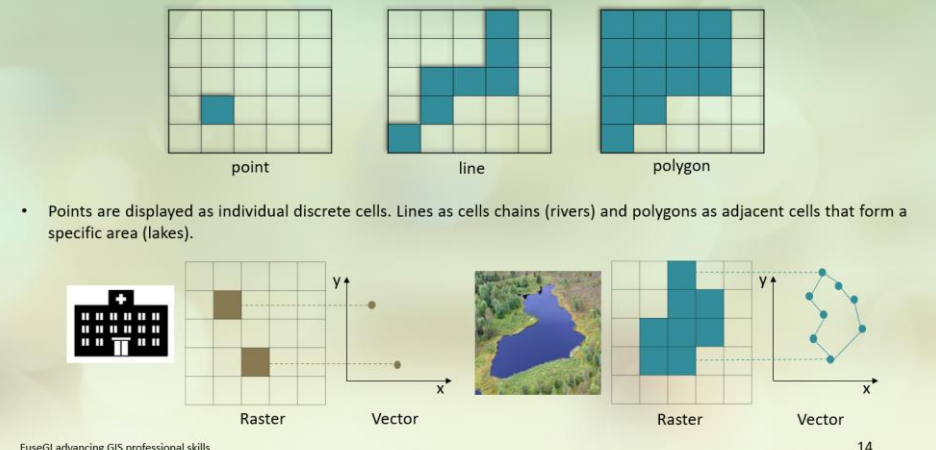


- The content of each cell corresponds to the value of a continuous variable. Raster models are suitable to describe continuous phenomena. They are used for satellite images, scanned maps, Digital Terrestrial Model (DTM), temperature maps etc.

Figure 19 : Slides 11, 12, 13 of course 2, available via the FuseGI VLE platform.

The course also helps to understand the geometric difference between vector and raster type representations of points, lines and polygons (Figure 20).

5. Vector and raster models (4/6) FuseGI 




- Points are displayed as individual discrete cells. Lines as cells chains (rivers) and polygons as adjacent cells that form a specific area (lakes).

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Figure 20 : Slide 14 of course 2, available via the FuseGI VLE platform.

Thanks to this course, it will be possible for users of the platform to choose the appropriate type of model based on the data they want to analyze (**Figure 21**).

5. Vector and raster models / Selection criteria (5/6) FuseGI 

- Choosing the appropriate spatial model is a crucial decision. The representation of spatial data affects the format and the quality of the analysis.
- Modern GIS serve both categories of models and effectively contributes to the co-processing and co-utilization of data (both vector and raster) relating to the same area.
- Spatial data selection criteria:
 - Completeness, the degree of reality's representation by each model.
 - Durability, refers to the possibility by which a spatial model can handle special cases, such as when one polygon encloses another polygon (topology).
 - Ease of transformation of spatial data in the desired format.
 - Ability of saving memory in the computer system.
- The ability of saving memory can be measured, so a quantitative comparison can be made between spatial models. On the other hand, completeness and durability are qualitative criteria.
- The main difference between vector and raster models: Vector models are used to describe discrete entities while raster models describe continuous variables.

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Figure 21 : Slide 15 of course 2, available via the FuseGI VLE platform.

Then, the course makes the connection between the type of data and the format used in GIS software like QGIS. For example, Shapefile files are used in vector format while GeoTiff files are used in raster format (**Figure 22**).

5. Vector and raster models / Data formats (6/6)

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- Most popular data format of vector and raster models used in GIS:
 - Vector
 - **DXF**, Drawing eXchange Format, developed by Autodesk,
 - **Shapefile**, developed by Esri,
 - **GML**, Geography Markup Language, XML template for recording OGC geospatial data,
 - **WKT**, Well known text, text markup language,
 - **GeoJSON**, template used by open source GIS software,
 - **KML**, Keyhole Markup Language, XML OGC template for recording cartographic symbolism.
 - Raster
 - **GeoTiff**, TIFF file containing georeferencing data,
 - **IMG**, georeferenced images developed for ERDAS IMAGINE.
 - **Esri grid**, georeferenced raster data developed by Esri.
 - **Binary File**.

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Figure 22 : Slide 16 of course 2, available via the FuseGI VLE platform.

Finally, this course concludes with a comparison of the two types of model by listing the advantages and disadvantages of each (**Figure 23**).

6. Comparison

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- Both models have advantages and disadvantages regarding:
 - The need for storage space,
 - The fidelity of displaying the location and attributes of real world's spatial data,
 - The ability of changing the efficiency scale and
 - The possibilities of analytical processing.

<ul style="list-style-type: none"> • Vector models <ul style="list-style-type: none"> ➢ Advantages • Ability to fully describe topological relationships, • Direct definition of surfaces, • High level cartographic performance, • Ability to enter descriptive attributes and • Ease of updating the database. ➢ Disadvantages • Complex data structures and • High processing requirements in multi-layer combination case. 	<ul style="list-style-type: none"> • Raster models <ul style="list-style-type: none"> ➢ Advantages • Simple data structures, • Ease of combining layers, ➢ Disadvantages • Requirement for large memory space, that is no longer problem. • Problems arise when the performance scale requires better analysis than the raster model already has.
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Figure 23 : Slide 17 of course 2, available via the FuseGI VLE platform.

3.3 Course 3: Introduction to QGIS Software

The third course **introduces QGIS software**. This software is free and open access. The course consists of an introduction to QGIS software. Part of this course explains how to **download** the latest version of this software to users' personal computers, as well as the **steps to install the software**. The rest of the course **presents the different menu bars of the software**, but also how to install the **extensions** in it. In addition, this course provides an understanding of **the use of different coordinate systems**, open data, but also how to **add data and create layers**. It also helps us to properly save files and export the different projects (**Figure 24**).

Contents	
1. About QGIS	
2. Setting up QGIS	
3. Running QGIS	
4. Plugins	
5. Coordinate Reference System	
6. Open Data	
7. Layer Properties	
8. Saving / Printing	


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Figure 24 : Course outline 3, available via the FuseGI VLE platform.

First, the course begins with an introduction defining the QGIS software suite (**Figure 25**).

1. About QGIS

- Quantum GIS known as **QGIS** is an open source Geographic Information System developed under the GNU General Public License. This license allows the source code to be modified and gives users the assurance that they will always have access to a free GIS software.





- It started in May 2002 and was officially established by the Source Forge community June of the same year. The project's purpose was the development of a free GIS software for anyone who has access to a personal computer. It is also supported by the Open Source Geospatial Foundation (OSGeo).
- QGIS can be installed on many operating systems (Windows, Android, Mac OSX, Linux, Unix), supporting a variety of formats and functionalities for managing and processing spatial data.
- In addition to the basic functions, its users have created a plugin repository with aiming the constantly expanding its capabilities for everyone.
- QGIS has a friendly work environment and integrates tools and functions in order to manage, storage and analyze spatial vector or raster data. It allows Coordinate System transformations, spatial analysis, geoprocessing of data and publication on the internet. Editing capabilities are expanded with GRASS and other tool libraries.

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Figure 25 : Slide 6 of course 3, available through the FuseGI VLE platform.

In this course is explained the path to follow in order to successfully install QGIS (**Figure 26**). It is important to know that this software is downloaded with other GIS software, such as GRASS GIS and SAGA.

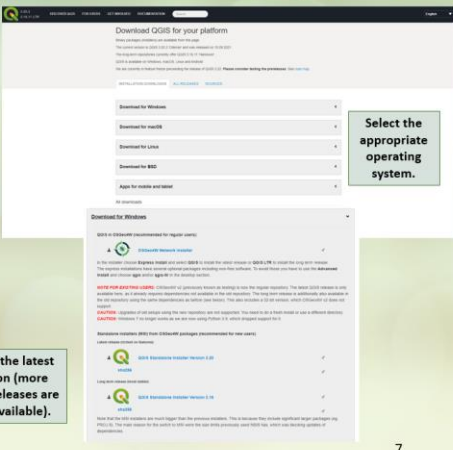
2. Setting up QGIS (1/2)

Installation

- Users can download and install the appropriate version of QGIS from <http://www.qgis.org/>.
- New versions of QGIS are usually released every few months but it's not necessary to upgrade the version you are already using. Users are constantly adding new features as everyone can modify the open source code. It is possible to have installed and run more than one versions at the same time.
- Installing QGIS is very simple. The latest version of QGIS can be downloaded from <http://download.qgis.org/>.

Select the latest version (more older releases are also available).





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Figure 26 : Slide 7 of course 3, available through the FuseGi VLE platform.


The third course is useful for learning the features of QGIS software for beginners and also serves as a reminder for more experienced users. Indeed, the menu bar is detailed to help the use of the software (Figure 27).

3. Running QGIS (1/3)

- The initial environment may be different for each user depending the language and toolbars displayed. There are five areas that can be distinguished: Menu, Toolbox, Layers, Map Area and Status Bar.

1. Main menu bar



Project	Is used to open, save, defining properties and printing of a project	Vector	Contains tools in order to manage vector data
Edit	Is used to edit data of a layer, add, correct, delete, etc.	Raster	Contains tools in order to manage raster data
View	Contains tools for navigating within a map, defining the design area, etc.	Database	Contains tools in order to manage databases
Layer	Is used to manage layers, creating or deleting ones	Processing	Contains additional tools for managing vector and raster data
Settings	Manages the characteristics of each project (options), symbolism, etc.	Help	Leads to various helpful links
Plugins	Manages additional tools		

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Figure 27 : Slide 9 of course 3, available through the FuseGi VLE platform.

This third course also describes the working environment of the QGIS software, such as the toolbar, the location of the list of layers created or added, the visualization area of the map as well as the status bar where we find the scale or the type of coordinates used for the project (Figure 28).

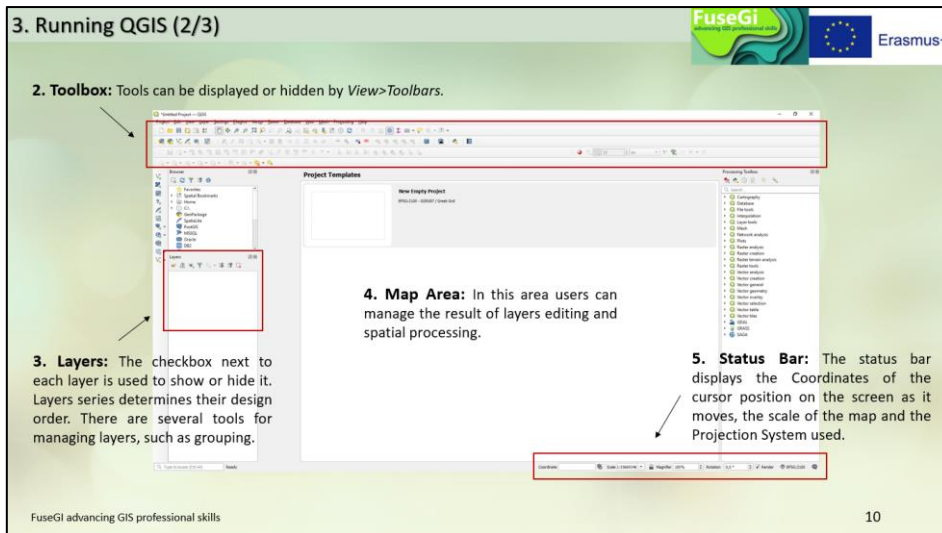


Figure 28 : Slide 10 of course 3, available through the FuseGI VLE platform.

As QGIS software is open-source software, it is possible to add extensions (plugins) in order to extend the functionality of the software. This course shows users how to install extensions in QGIS (Figure 29).

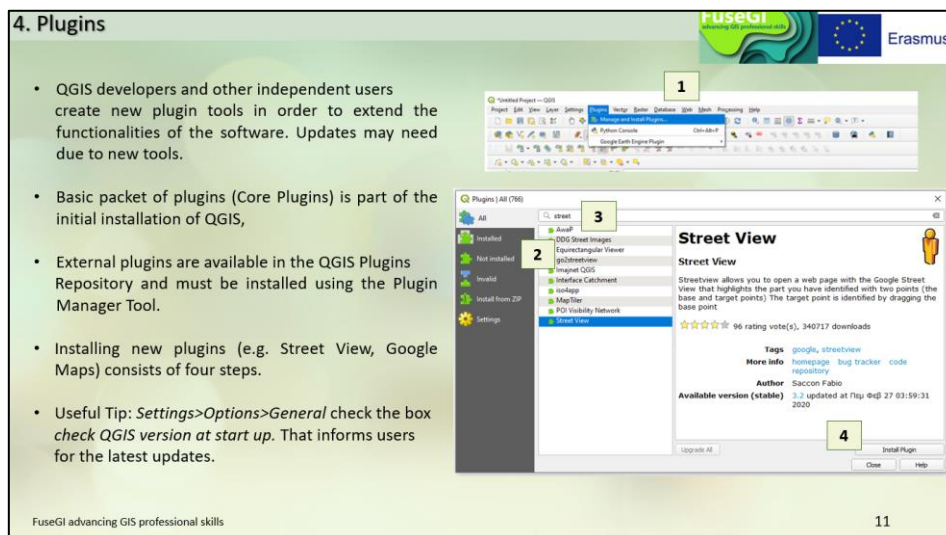


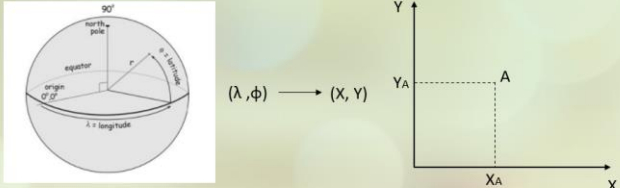
Figure 29 : Slide 11 of course 3, available via the FuseGI VLE platform.

Another essential point for the proper use of QGIS software is the reference coordinate system used for the project. Indeed, it must be adapted to the area studied and is specific to it. First, the course defines what a reference coordinate system is (Figure 30).

5. Coordinate Reference System (1/2)

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- To accurately determine the position of an object must be known:
 - The geographical coordinates (λ, ϕ) and
 - The cartesian coordinates (x, y).
- Cartographic projection is a way to represent parts of the surface of the Earth on a flat map. Each point of the Earth's surface is ambiguously connected to its counterpart on the map.



- Due to deformations every time the reference surface is transformed (sphere or ellipse) into a plane, it is not possible to faithfully represent all the geometric relations that exist in it.

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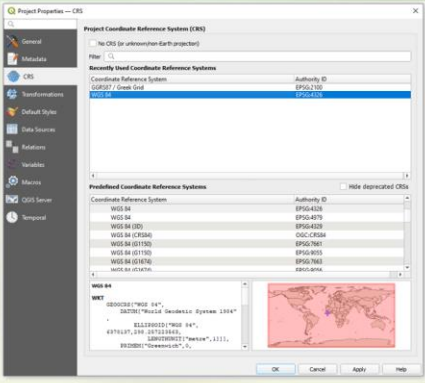
Figure 30 : Slide 12 of course 3, available via the FuseGI VLE platform.

Then, it shows the path to follow in order to define the coordinate system for each of the layers of the project (Figure 31).

5. Coordinate Reference System (2/2)

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- Choosing the right Coordinate System is one of the first steps a user must take and depends on the data source to be processed and the area in which it is located.
- Through the path below *Menu>Project>Properties>CRS* users define the right Coordinate System.
- Geographic Information Systems have developed mainly to analyze spatial data. Georeferencing satellite images or digitizing objects are among the main functions require proper Coordinate Systems to be defined.
- Sometimes layers and data coming from different regions and source may be referenced to different systems and that is why the right transformations must be done.
- Another way: click on the Coordinate System given in the *Status Bar*.



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Figure 31 : Slide 13 of course 3, available via the FuseGI VLE platform.

Open data is data that is freely accessible, reusable and redistributable by everyone. These data may be provided by public or private sources. In the sixth part of the third course, open data is defined and some sites where it is possible to download data for free are cited (Figure 32).

6. Open Data (1/4)

- Organizations that publish standards for geographic information play a specific role in promoting interoperability. For example:
 - International Organization for Standardization (ISO): creates international standards, e.g. ISO/TC 211.

ISO 19115:2003 has been revised by ISO 19115-1:2014 concerning Geographic Information – Metadata. ISO 19115 defines the scheme required for describing geographic information and services. It provides information about the identification, the extent, the quality, the spatial and temporal scheme, spatial reference and distribution of digital geographic data (<https://www.iso.org/standard/26020.html>).
 Though ISO 19115 is applicable to digital data, its principles can be extended to many other forms of geographic data such as maps, charts and textual documents as well as non-geographic data.

 - European Committee for Standardization (CEN): covers European interoperability issues, e.g. TC 287 Geographic Information.
 - Open Geospatial Consortium (OGC): develops standards for geographic data, e.g. Simple feature, GML, KML.
- The European directive INSPIRE (2007/2/EC) is responsible for geospatial environmental infrastructure and other activities that have an impact on the environment.

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6. Open Data (2/4)

- Geospatial data may be available from other sources:
 - In different model types (raster or vector models),
 - As files in a wide range of managed formats (shapefiles),
 - From online sources,
 - As a result of a voluntary geographic information collection initiative (VGI-Volunteered Geographic Information).
- Users and researchers can also find data through open sources. "Open data" can be used free of charge or with restrictive terms of ownership.
- Web sites offered geospatial data are the following:
 - Global Self-consistent Hierarchical High-Resolution Shoreline (GSHHS),
 - Natural Earth: public domain cartography data <http://www.naturalearthdata.com> (scales used: 1:10.000.000, 1:50.000.000, 1:110.000.000),
 - European Environment Agency <http://www.eea.europa.eu/>,
 - Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER),
 - Esri Open Data Hub <https://hub.arcgis.com/search>,
 - USGS Earth Explorer <https://earthexplorer.usgs.gov/>,
 - Open Street Map <https://www.openstreetmap.org/#map=7/38.359/23.810>,
 - Geotopo30 <https://ita.cr.usgs.gov/GTOPO30>.

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Figure 32 : Slides 14 and 15 of course 3, available via the FuseGI VLE platform.

Next, the course shows how to integrate the downloaded data into the QGIS software (Figure 33).

6. Open Data / input (3/4)

- Geospatial data may be available in different model types (raster or vector models).
- Data in QGIS are added as separate layers. Images (can be scanned maps or results of aerial activities) are entered as raster data, shapefiles as vector data.
- In QGIS: **Main Tool Bar > Layer > Add Layer.**

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Figure 33 : Slide 16 of course 3, available via the FuseGI VLE platform.

This course also allows you to understand and use the browser and layer panels available in QGIS (Figure 34).

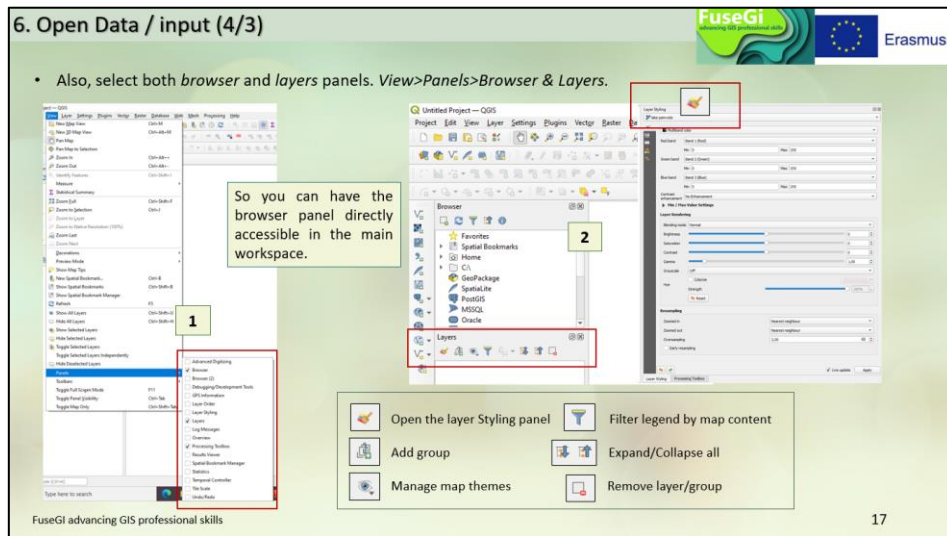


Figure 34 : Slide 17 of course 3, available via the FuseGI VLE platform.

This third course is also useful for learning the basics of using QGIS, such as creating layers, whether for drawing lines, points, or polygons (Figure 35).

7. Create layers (1/2)

- In a GIS project geospatial data are represented through different kind of layers. Layers may be found and studies as open data in various web sources or can be created by users.
- In order to create layers: *Main tool bar>Layer>Create Layer*. Most common layer forms used are shapefiles. Clicking on *New Shapefile Layer* will take them to the following window.

- Layers created by the following steps do not contain any information. Users should digitize the reported elements. The digitization process will be represented in the next lesson.

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7. Create layers (2/2)

Layer names always given in Latin characters. The storage path is also selected. Choose the appropriate coordinate system referring the study area.

Shapefiles may be points (hospitals, museums etc.), lines (roads, rivers, etc.) or polygons (lakes, areas of interest). The appropriate geometry is selected depending to the elements to be digitized.

Below, the information of the elements that the shapefile will contain is given. This information is entered by the user and displayed through the attribute tables.

e.g.

Road name	text
Road length	number

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Figure 35 : Slides 18 and 19 of course 3, available via the FuseGI VLE platform.

Finally, the last slide of this third course shows how to save and save the project (Figure 36).

8. Saving / Printing

- Save your progress: *Main menu>Project>Save as*. QGIS projects are saved as .qgz files and contains all the images, layers and elements of your present work for future processing. The extension for QGIS projects is .qgs but when saving from QGIS, the default is to save using a compressed format with the .qgz extension. The .qgs file is embedded in the .qgz file. Use Latin characters for the file names and avoid spaces.

- Through QGIS you can export your maps to images or .pdf or .dxf file formats.

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Figure 36 : Slide 20 of course 3, available via the FuseGI VLE platform.

3.4 Course 4: Georeferencing, Scanning and Editing Tools

This fourth course allows to continue **deepen the mastery of QGIS software**. Indeed, we can find in it the different steps to follow to carry out the **georeferencing process, the creation of layers** or those of correcting **the geometry of a layer (Figure 37)**.

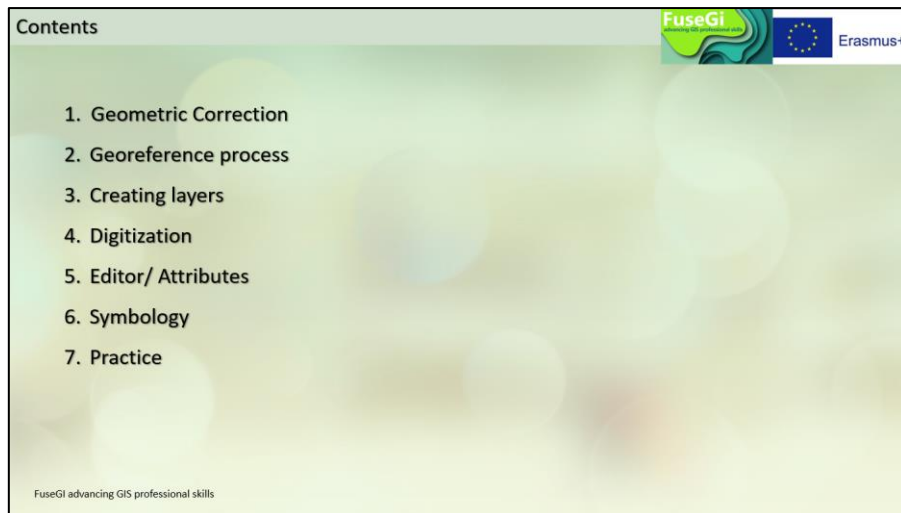





Figure 37 : Course outline 4, available via the FuseGI VLE platform.

After learning in the previous course how to create layers, it is important to know the editing tools, georeferencing as well as scanning. This is why the course begins by defining the usefulness and purpose of the geometric correction of photographic data made in QGIS **(Figure 38)**.

1. Geometric Correction (1/2)



- GIS projects use satellite images and aerial photos for a wide range of applications. These photos are used as base maps for urban planning purposes and for agricultural monitoring. This kind of analysis requires that the location of features in the image are accurately determined planimetrically (X,Y) and elevationally (Z).

The above image is a historical aerial photo taken by a military aircraft. In order to be used as a base in a GIS project needs to be corrected.


- The position of each feature should represent its true and exact location on the earth's surface.
- Geometric correction is the process of correcting satellite images or aerial photos from their displacements and ensures that pixels/features in the images are in their proper and exact position.
- Through geometric correction spatial distortions in the original image are eliminated or minimized and the output dimensions correspond to a chosen geographic reference system.

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1. Geometric Correction (2/2)

- Satellite images and aerial photos contain a number of geometric distortions due to the data recording procedure and the shape and rotation of the Earth.
- Erdas Imagine is of the most well-known software, providing tools for remote sensing and photogrammetry. Erdas Imagine simplifies image classification and segmentation, orthorectification and image interpretation and it is widely used in geometric correction. QGIS can also be used to geometrically correct images.
- One way to geometrically correct the original image is to collect a set of Ground Control Points (GCPs). These points are locations that can precisely identified both on remotely sensed imagery and in the target geographic reference system. Coordinates of GCPs can be obtained either by a GPS survey on the ground or by identifying GCP locations on a second image or on a digital map layer that has already been georeferenced.



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Figure 38 : Slides 6 and 7 of course 4, available via the FuseGI VLE platform.

The georeferencing process is an indispensable process for adding photographs to GIS projects (**Figure 39**).

2. Georeference process (1/8)

- Main sources of geometric distortion:
 - Sensor characteristics, optical distortion and non-linear mirror velocity.
 - Motions of the drone/aircraft or satellite, earth rotation and altitude changes.
 - Viewing geometry, panoramic effect and earth curvature.
- Correcting the distortions is often costly and time consuming. On the other hand georeferencing is the process of recording the absolute location of data while georectification refers to the removal of geometric distortions.
- The process of Georeference is completed by selecting pixels in the digital image and assigning them geographic coordinates. It is a fundamental process to geospatial technologies in general.
- By definition, geographic information systems need location accuracy. Georeference may be applied to any kind of object that can be related to a geographical location, such as points of interest, roads or buildings.
- Historical images may contain essential information. Through Georeference historical images can be compared with that currently available. It can be used to analyze the changes in a study area over time.
- To Georeference an image, you should firstly establish control points with known geographic coordinates and then choose the right coordinate systems and projection parameters.

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Figure 39 : Slide 8 of course 4, available through the FuseGI VLE platform.

This process uses files in GeoPDF or GeoTiff formats, the tool used to perform georeferencing is already included in QGIS (**Figure 40**).

2. Georeference process (2/8)

- **GeoPDF** and **GeoTiff** are examples of georeferenced file formats.
- Georeferencing images in their right position allows basic map analysis to be done, to calculate distances and areas and determine any other spatial information.

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2. Georeference process (3/8)

- Georeferencing is already part of QGIS installation. *Main menu>Raster>Georeferencer*. Then a separate window opens, which is divided into two sections.

- The process of Georeference actually involves four basic steps. The images (or scanned maps) are firstly imported by *File>Open Raster*. Next, the user must click on GCPs and enter their coordinates manually and choose the transformation settings by *Settings>Transformation Settings*. Finally, *File>Start Georeferencing*. The georeferenced image is automatically displayed in the main QGIS workspace.


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Figure 40 : Slides 9 and 10 of course 4, available via the FuseGI VLE platform.

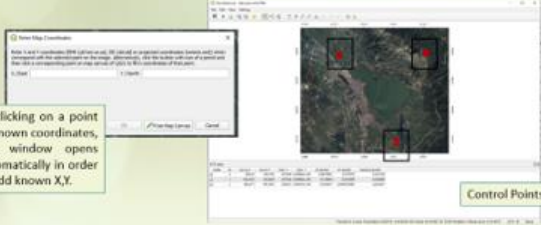
Then, instructions on how to use the "georeferencing" tool are given in the slides "Georeference process 4/8" and "Georeference process 5/8". The first case of georeferencing a photograph is when a map and known coordinates are used. It is important to choose the type of transformation algorithm to georeference the image (**Figure 41**).

2. Georeference process (4/8)

1. Georeference a map with GCPs of known coordinates.

- To get started go to the *Menu Bar>File>Open Raster* and import the image of interest from your browser. This could be a scanned map, an aerial photo or a cropped image from any software using geospatial information.
- The image displays on the top section of the window. Make sure the  *Add Point* button is selected.
- Click on a point to create the first reference point and enter the corresponding coordinates manually. Click *OK* and they will appear in the bottom table. You can add as many reference points as you like but it is not recommended.

By clicking on a point of known coordinates, this window opens automatically in order to add known X,Y.




Control Points Table

When dealing with a flat-surface image, 2 to 3 reference points should be sufficient. Reference areas near the edges of the image are often preferred.

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2. Georeference process (5/8)

- After you have added the Ground Control Points to the raster image, you should define the transformation settings for the georeferencing process.



- The choice of transformation algorithm is dependent on the type and quality of input data and the number of geometric distortion that you are willing to introduce to the final result.
- The *Linear* algorithm does not actually transform the raster pixels and it is used to create a world file. At least 2 GCPs are needed. The *Helmert* transformation allows rotation and it is useful if your raster is good quality local map or an orthorectified aerial image. At least 2 GCPs are needed. The *Polynomial 1* algorithm is used to georeference data cartograms and at least 3 GCPs are required. The *Polynomial 2-3* algorithms need at least 6 GCPs. The *Projective* algorithm requires a minimum of 4 GCPs and it is used for georeferencing angled *photographs*. The *Thin Plate Spline* is most useful for georeferencing damaged, deformed or otherwise slightly inaccurate maps or poorly orthorectified aerial photos.
- QGIS allows five different resampling methods. Choosing the *Nearest Neighbor* does not change statistics of the raster.
- As default a new output raster will be created in the same folder of the original image with the extension *_modified*.
- If you wish to continue working with this image click the last option so to load the georeferenced image in the main QGIS workspace.

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Figure 41 : Slides 11 and 12 of course 4, available via the FuseGI VLE platform.

In case the coordinates of the photo to be georeferenced are known from Google Earth, the process is a little different (Figure 42).

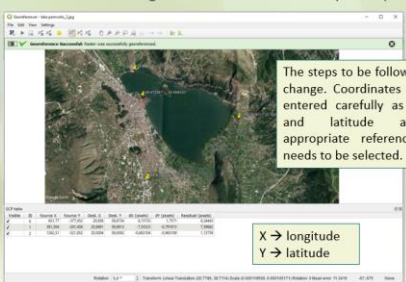
2. Georeference process (7/8)

2. Georeference an aerial photo using known coordinates from open software Google Earth.

- Another way to georeference an image in QGIS uses Google Earth software. Google Earth is a geospatial analysis platform that enables analysis to satellite images of the planet and is available for free.
- Google Earth tools allow you to save points with known coordinates according to the World Geodetic System (WGS84).

Image taken from Google Earth using the *Add Placemark* tool.

Latitude	Longitude
39.624275°	20.863215°
39.673387°	20.856032°
39.691272°	20.848147°
39.659195°	20.930364°



The steps to be followed do not change. Coordinates should be entered carefully as longitude and latitude and the appropriate reference system needs to be selected.


X → longitude
Y → latitude

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Figure 42 : Slide 14 of course 4, available via the FuseGI VLE platform.

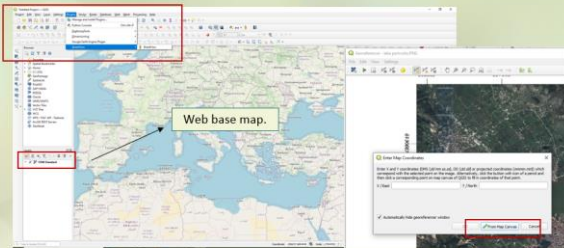
In the latter case, the photo to be georeferenced is based on the use of an additional map such as Google Street View. The purpose of these steps is to place points on the image to be georeferenced as well as on the map at the same points chosen at the same points. The more points there are, the more accurate the georeferencing is (**Figure 43**).

2. Georeference process (8/8)


FuseGI 

3. Georeference an aerial photo using a web based map.

- Previous methods involved reading and entering the coordinates manually. In that case you can use another georeferenced data source as your input. Using existing open data sources in the georeferencing process.
- This method uses the OpenStreetMap layer as the reference layer. Firstly go to *Main tool bar>Plugins>Manage & Install Plugins* and install the plugin of *Street View*.



Web base map.



Click on a point and choose to enter the coordinates with the tool *From Map Canvas*. Automatically leads you to select the same point on the web based map which is already georeferenced. Repeat for 2 more GCPs and start the process.

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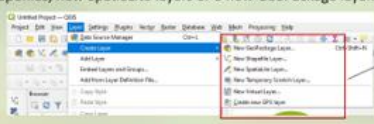
Figure 43 : Slide 15 of course 4, available via the FuseGI VLE platform.

Next, the course provides a reminder of how to use the layer creation tool (**Figure 44**).


3. Creating layers (1/2)

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- The main work in QGIS include creating and editing different kind of layers. QGIS provides tools to import and export layers in different kind of formats.
- Layers can be created in many ways, including empty layers from scratch or existing layers. QGIS allows you to create new Shapefiles, new SpatialLite layers or a new GeoPackage layer. Choose *Main Tool Bar>Layer>Create Layer*.



Type of layers that QGIS allows you to create.



Layer info.

- To create a new Shapefile, choose the right type of geometry (between point, line, polygon) and the proper Coordinate Reference System. Add the attributes of each spatial element by giving a name and type, click on the *Add to field list* button.
- After entering all the information required, provide a name for the Shapefile. QGIS will automatically add the *.shp* extension. The new layer will be added to the map in order to digitize its the spatial elements.


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3. Creating layers (2/2)

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- When creating a *GeoPackage* layer, QGIS automatically adds the *.gpkg* extension. GeoPackage is a standard OGC data package that can store different types of spatial data. Several layers can be saved in just one GeoPackage.
- QGIS also supports the use of a file format called *Spatialite* that is lightweight. Choose *Create Layer>New Spatialite Layer*. Firstly, you should select an existing Spatialite database or to create a new one. Add a name, define the layer type and specify the CRS. Click OK when you complete importing attributes and QGIS will automatically add the new layer to the legend.
- Temporary Scratch* layers are in-memory layers, meaning that they are not saved on disk and will be discarded when QGIS is closed. They are used temporarily to store features during geoprocessing operations.
- GPX* layer format needs to load the GPS plugin first and activate the GPS Tools checkbox.

In order to avoid losing any data when closing a project with temporary scratch layers, you can save these layers to any vector format that QGIS can support.



line point polygons

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Figure 44 : Slides 16 and 17 of course 4, available via the FuseGI VLE platform.

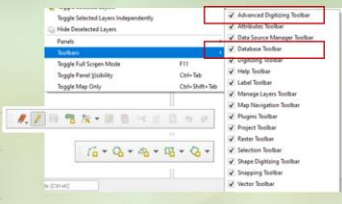
These processes are essential for a good use of the software and a mastery of GIS. This course also teaches how to scan, symbology, edit and use attributes. In addition, an exercise to apply the concepts learned is available at the end of this course. This course gives us many examples and explanations of the tools that can be used with the QGIS software (Figure 45).

4. Digitization (1/3)

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- Shapefiles are created in order to digitize spatial elements. Through QGIS you can edit any layer using the right tools. Go to *View>Toolbars* and click ok the digitization toolbar.
- Using the basic digitizing tools, you can perform the following functions.

Current edits	Toggle Editing
Add Feature: Capture Point	Add Feature: Capture Line
Add Feature: Capture Polygon	Move Feature
Add Circular String	Add Circular String by Radius
Nade Tool	Delete Selected
Cut Features	Copy Features
Paste Features	Save layer Edits



- Editing starts by choosing the *Toggle Editing* option. Additional tool buttons will become available once the editing process starts.
- You can still zoom or pan in the map canvas while using any of the digitizing tools.

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Figure 45 : Slide 18 of course 4, available via the FuseGI VLE platform.

Then, the course defines and allows the use of tools allowing the digitization of data and new characteristics useful to the GIS project (**Figure 46**).

4. Digitization (2/3)

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- Depending on the type of feature to be digitized you can choose between:

Add point feature
 All line feature
 Add polygon feature

- You will notice that clicking on different layers (points, lines or polygons) activates different digitization tools.
- Left-click on the map area to create the first point and then enter its attributes (name, type, etc). Keep on left-clicking for each additional point you wish to capture for linear geometries. When you have finished adding points, right-click anywhere on the map area to confirm that you have finished entering the desirable features.
- The attribute window will automatically appear in order to enter the information for the new feature.
- Example given: for the digitization of a road network it is necessary to digitize the different highways with tools related to line features and enter attributes such as allowed speed in each road.
- Right-click on a layer>Open Attribute Table. In this window there are useful editing tools between attributes and their values.

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Figure 46 : Slide 19 of course 4, available via the FuseGi VLE platform.

Then, two videos are available in the slideshow to illustrate the digitization of the data and facilitate the understanding of the manipulations to be carried out (**Figure 47**).

4. Digitization (3/3)

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Layers: Water Bodies, Buildings, lake 3, Roads

Layer Properties — Buildings — Information

Information from provider

Name	Buildings
Path	241004303
Storage	ESRI Shapefile
Coordinate	
Encoding	System
Geometry	Point (Multipart)
CRS	EPSG:4326 - WGS 84 - Geographic
Extent	23.72102573703090468, 32.04115433333333, 23.728848712
Units	decimal
Feature count	5

Buildings — Features Total: 5, Filtered: 5, Selected: 0

ID	Floors	Year	Use
1, no1	2	2004	Parking
2, no2	1	2001	Museum
3, no3	3	1997	Town Hall
4, no4	2	1995	School
5, no5	2	2005	Church

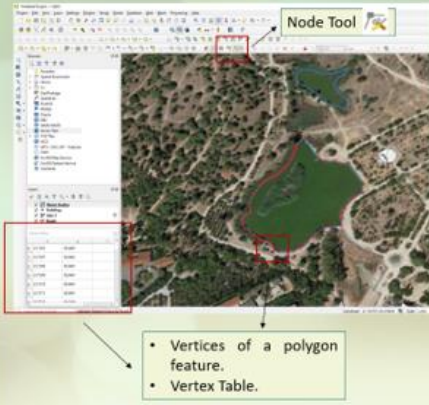
Video 1 Video 2

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Figure 47 : Slide 20 of course 4, available via the FuseGi VLE platform.

Each of the data that is added to the project or created for it has visible data in the layer parameters or in the attribute table. In addition, it is possible to modify, add or remove this data (**Figure 48**).

5. Editor / Attributes (1/2)



• Vertices of a polygon feature.

• Vertex Table.

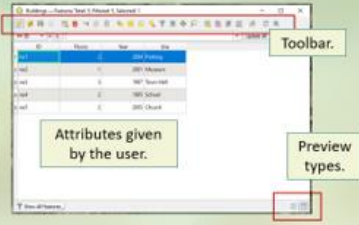
- Every click you made to digitize a feature (either the perimeter of a lake or a building) it automatically creates a vertex point.
- Activating the *Node Tool* the Vertex Table displays in the main workspace of the project. X, Y columns refer to each vertex coordinates' according to the selecting reference system.
- QGIS provides *selecting, adding, deleting or moving vertices*.
- To add a vertex, double click near an edge and a new vertex will appear near to the cursor. To delete a vertex, select the vertices and click the delete button from your clipboard.
- Also, select a row in the table does select the corresponding vertex in the map area.

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5. Editor / Attributes (2/2)

- Right-click on a layer and choose *Open Attribute Table*. A new window will open that displays the feature attributes of the selected layer.
- Note that depending on your QGIS version, some tools may not be available.
- Through the tools given you can hide/organize columns, filter features, edit attribute values or perform calculations on the existing attribute values.
- Editing attribute values can be done by typing the new value directly in the cell.
- If you want to calculate the length in km of the roads layer from the QGIS click on Toggle editing mode and open the Field Calculator dialog.
- Select *Create a new field* checkbox to save the calculations into a new field. Add *length* as output field name and *real* as output field type. Double click on function *length* in the *Geometry* group to add it into the field calculator expression box.



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Figure 48 : Slides 21 and 22 of course 4, available via the FuseGI VLE platform.

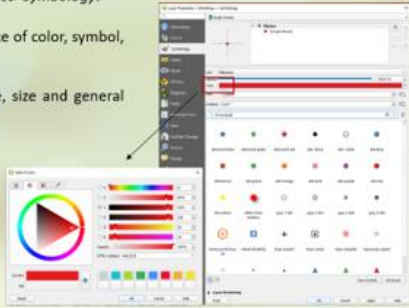
It is also possible to customize the layers and the style of these, whether they are points, lines or polygons (**Figure 49**).

6. Symbology (1/2)

- QGIS offers a dynamic representation of the spatial data. Right symbology is essential to produce functional and easy to use maps.
- QGIS software provides a large library of colors and symbols to create any symbology for any vector. To change a layer's symbology right click on the layer to be edit *Layer Properties>Symbology*.
- Layer's display (points, lines, polygons) based on the choice of color, symbol, width or line style.
- In cartography there are specific instructions for the use, size and general creation of symbols.

➤ **Point Symbols**

When dealing with points, users have the option of choosing between symbols and colors of the adjacent image. QGIS also provides special symbols of various toponyms. *Apply* and then click *OK* to save your edits.



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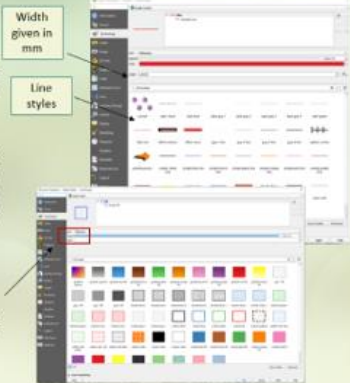
6. Symbology (2/2)

➤ **Line Symbols**

- There are three basic steps. Style, Color, Width.
- The choice of color and line style depends on the respective spatial data to be represented. Displaying data with symbols must follow a logical continuity.
- For example in the representation of the hydrographic network streams should be displayed with lower width lines than the main river. Also, in the representation of road network, each category of roads must appear with a different color or line thickness in order to be visible.

➤ **Polygon Symbols**

- Polygons represent specific land surfaces (water bodies, land uses, etc). A useful tool for representing polygons in addition to outline style and fill color is the transparency rate to be selected.




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Figure 49 : Slides 23 and 24 of course 4, available via the FuseGI VLE platform.

In order to better understand all the tools described in the course, an exercise is available (Figure 50).


7. Practice

1. Find your area of interest through Google Earth where longitude and latitude are given. Use the Add Placemark tool to create Ground Control Points or use a map with known coordinate. Follow the steps given.
2. Create your own layers. Points, lines or polygons depending on the spatial data you need to digitize. Enter the right attributes.
3. Start digitization of spatial data using the right tools. Check the attribute tables when finishing. Go to Layer Properties and change symbols.



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Practice 1: Georeference the *image_1*. Create the follow shapefiles: Polygons (sports fields), Lines (road network). Attributes needed: Name and type of each field, year of construction. Start digitization and choose the right symbols.



Practice 2: Search for open data from Copernicus or your governments websites. Extract images and maps with contour lines (<https://ngmdb.usgs.gov/topoview/viewer/>, <https://cloud.maptiler.com/maps/>). Digitize hydrography networks.

Good luck!

Figure 50 : Slide 25 of course 4, available via the FuseGI VLE platform.

3.5 Course 5: Spatial Analysis

This fifth course aims to **explain spatial analysis tools** as well as **spatial queries with location selection** and **basic statistics (Figure 51)**. It allows you to learn more about buffer zones as well as to master other layer processing tools such as union, clip, intersection tools for example.

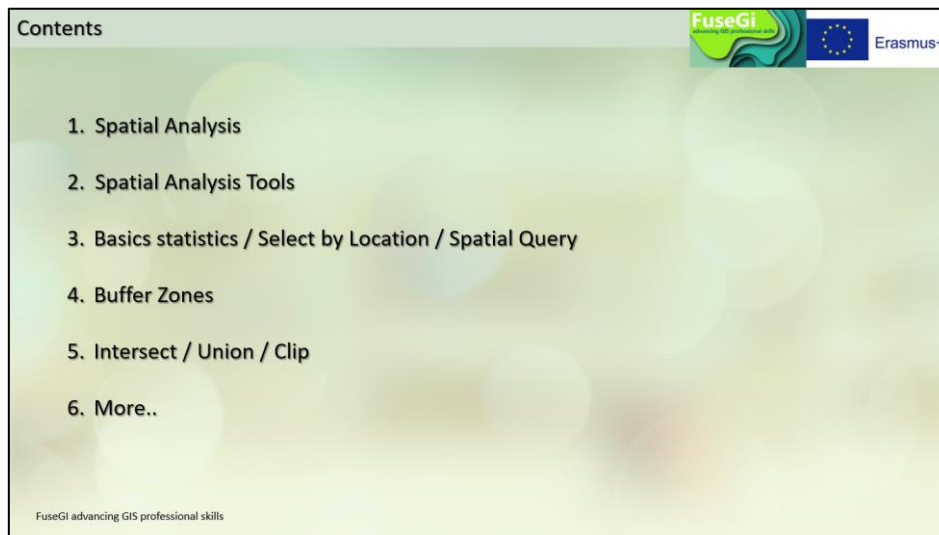


Figure 51 : Course outline 5, available via the FuseGI VLE platform.

First, we find in the course a definition of spatial analyses as well as an overview of the type of domain that can use these analyses (**Figure 52**).

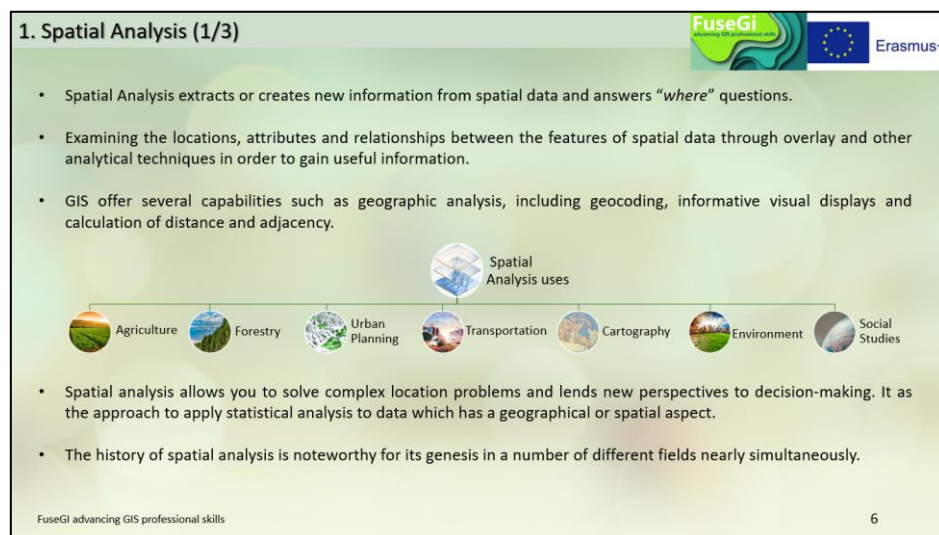


Figure 52 : Slide 6 of course 5, available via the FuseGI VLE platform.

The course provides an understanding of the conditions under which spatial analyses are carried out (**Figure 53**).

1. Spatial Analysis (2/3)



- Types of spatial analysis are queries and reasoning, measurements, transformations, descriptive summaries, optimization and hypothesis testing.
- Spatial analysis include measuring distances and shapes, setting routes and tracking transportations, establishing correlations between objects, events and places via referring their locations to geographical positions.
- It includes all of the transformations and methods that can be applied to geographic data to turn them into useful information.
- Methods of spatial analysis can be either very simple or very sophisticated.
- Through spatial analysis, you can combine information from many independent sources and derive new sets of information by applying a set of spatial operators.
- Organizations that use spatial analysis in their work are wide ranging: local and state governments, businesses of all kinds, universities, etc.
- Spatial analysis studies the characteristics of places and the relationships between them and requires an underlying spatial framework in which to locate the spatial phenomena under study.

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1. Spatial Analysis (3/3)





Spatial Analysis / GIS


- QGIS is the most commonly used free open source software for analysis and visualization of spatial data.
- GIS applications are computer-based tools that allow the user to create interactive queries, store and edit spatial and non-spatial data, analyze spatial information output and presenting them as maps.
- Spatial analysis is playing an increasingly central role in measurement, hypothesis development and validation of theoretical constructs.
- GIS and spatial analysis have revolutionized the manipulations of geospatial data in broader sections of the private and public sector, such as in urban planning, decision making policies, marketing etc.

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Figure 53 : Slides 7 and 8 of course 5, available via the FuseGI VLE platform.

The next slide defines spatial analysis tools and explains what these tools can do, such as analyzing patterns or modeling spatial relationships (**Figure 54**).

2. Spatial Analysis Tools (1/2)



- The last decades there was an increasing demand for systems that “do something” other than display maps and organize data. Researchers and GIS developers aimed to introduce a mean of integrating spatial analysis with GIS technology.
- Due to the growing demand for spatial analysis tools, new software packages were developed and new tools were integrated into the existing ones.
- Spatial analysis deals with two distinct types of information. One concerns the attributes of spatial objects, which includes measures such as area, population etc. The other one concerns location information about the spatial objects.
- The spatial objects concerned in most analyses are polygons which correspond to measurement zones and statistical reporting areas.
- There are four core analytical toolsets: measuring geographic distributions, analyzing patterns, mapping clusters and modeling spatial relationships.
- Tools to perform spatial analysis have been extended over the years to include geostatistical techniques, raster analysis, analytical methods for business, 3D analysis and network analytics.

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



Figure 54 : Slide 9 of course 5, available via the FuseGI VLE platform.

In the course, 6 spatial analysis tools are mentioned such as QGIS, GRASS GIS or Google Earth (Figure 55).

2. Spatial Analysis Tools (2/2)

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- There are several software that can perform spatial analysis processes. Free of charge are the following.

Package	Website	Main Features
QGIS	 https://qgis.org/en/site/	Easy to use, ability to expand functionality with Python plugins.
GRASS	 https://grass.osgeo.org/	Extensive set of GIS tools for both raster and vector data.
Google Earth	 https://earth.google.com/web/@0,0,0a,22251752.77375655d,35y,0h,0t,0r	Easy to use, dynamic graphics, historical maps.
Fragstats	 http://www.umass.edu/landeco/research/fragstats/fragstats.html	Area, edge metrics. Shape metrics and fragmentation.
SAGA	 http://www.saga-gis.org/en/index.html	Grid analysis, Terrain analysis, hydrology simulation.
GeoDaSpace	 https://geodacenter.github.io/	Advanced spatial models for cross section.

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Figure 55 : Slide 10 of course 5, available via the FuseGI VLE platform.


Basic statistics are a method defined in the course since it is very often used to carry out research concerning scale, geostatistics or classifications (Figure 56).

3. Basics statistics / Select by Location / Spatial Query (1/4)

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➤ Basic statistics

- Spatial statistics allows you to analyze and understand what is going on in given vector dataset.
- From GIS dictionary spatial statistics are defined as “the field of study statistical methods that use space and spatial relationships (such as distance, area, volume, length, height and/or other spatial characteristics of data).
- The spatial statistical methods in current use and upon which research is continuing include: spatial association, pattern analysis, scale and zoning, geostatistics, classification, spatial sampling and spatial econometrics.
- The effect of the new technology on spatial statistical analysis has led to a broadening of the process of hypothesis testing.



Traditional and GIS approach of spatial statistics analysis Fig. 1 of Cvetis, A. (1999). Spatial statistics. *Geographical information systems*, 1, 239-251.

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Figure 56 : Slide 11 of course 5, available through the FuseGI VLE platform.

The course allows to know the path to the basic statistical analysis tool, available in the QGIS software (Figure 57).

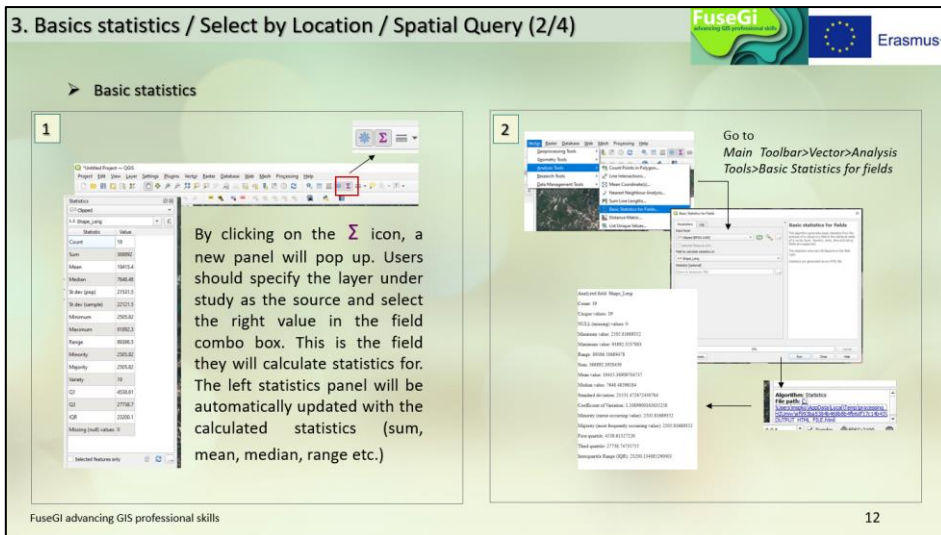


Figure 57 : Slide 12 of course 5, available via the FuseGI VLE platform.

The course defines and shows the path of the "select by location" tool. In addition, an example of use illustrates the slide which facilitates understanding (Figure 58).

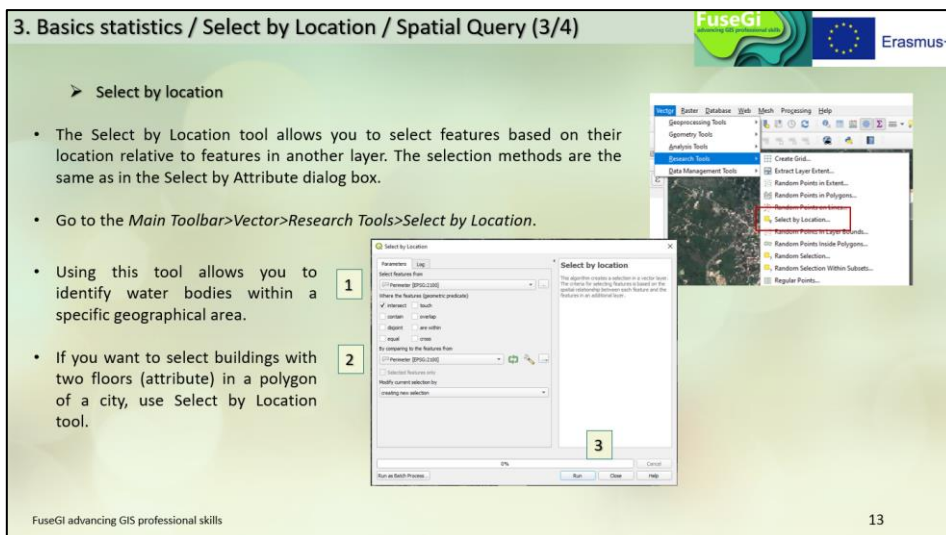


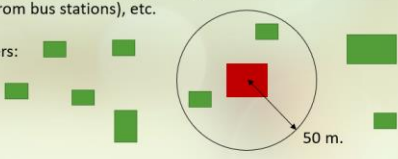
Figure 58 : Slide 13 of course 5, available via the FuseGI VLE platform.

Finally, a final spatial analysis tool is presented, the "spatial query" tool (Figure 59).

3. Basics statistics / Select by Location / Spatial Query (4/4)

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➤ Spatial Query

- Spatial queries are come to many types of GIS analysis. Spatial queries allows you to select features in a layer by their spatial relationships with features from another layer.
- The Spatial Query plugin allows you to make a spatial query in a target layer with reference to another layer. The functionality is based on the GEOS library and depends on the selected source feature layer.
- Possible operators are: Contains, Equal, Overlap, Crosses, Intersects, Touches, Within.
- Examples of spatial queries: features that intersect with other features, features within other features (e.g. hotspot within a forest area), features with a distance from another area (buildings 20 meters from main roads, industrial areas 10 km from natura areas, schools 10 meters from bus stations), etc.
- Select the buildings in a perimeter of 50 meters: 

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Figure 59 : Slide 14 of course 5, available via the FuseGI VLE platform.


The following slides are devoted to the definition and use of the "buffer" tool (Figure 60).


4. Buffer Zones (1/3)

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- In Geographical Information Systems, a buffer is a zone that is drawn around any point, line or polygon that encompasses all of the area within a specified distance of the feature (e.g. 200 meters). This zone is a new polygon around the selected objects.
- Common types of buffer zones may be greenbelts between residential and commercial areas or zones around natura areas where any industrial activities are prohibited. Buffer zones can also be border zones between countries, noise protection zones around airports or pollution protection zones along rivers.
- Buffering is a spatial analysis toll that can be carried out with vector data. It can be done on all three types of vector data (point, line or polygon) and the result given is a polygon file.

 Buffer zones around point feature.



 Buffer zone around polygon feature.

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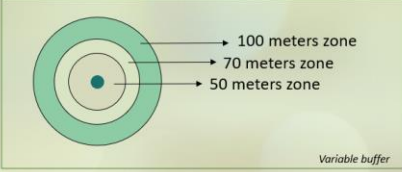
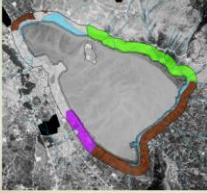
Figure 60 : Slide 15 of course 5, available through the FuseGI VLE platform.

It is possible to create buffer zones of different diameters (Figure 61).

4. Buffer Zones (2/3)

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- Buffers around polylines, such as road network, do not have to be on both sides of the lines. Users can choose either the left side or the right side of the line feature.
- Most often buffers are measured in uniform distance. A buffer based on different distances is called variable buffer. A feature can also have more than one buffer zone. For example, studying land uses changes (natural vegetation, agriculture areas, artificial surfaces or wetlands) around a water body at 50, 100 or 500 meters gives greater analysis and better results.

Variable buffer

100 meters zone
70 meters zone
50 meters zone

Buffer zone of 500 meters around the perimeter of a lake.

- Buffering is an important tool to determine the area covered within a specific location.

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Figure 61 : Slide 16 of course 5, available through the FuseGi VLE platform.

The path to the "buffer" tool is described in the fifth course. An example of the use of the tool is also available and provides a better understanding of the use of this tool (Figure 62).

4. Buffer Zones (3/3)

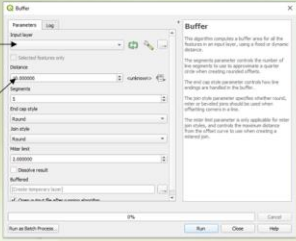
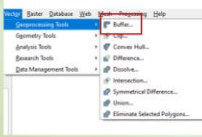

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- Buffer zones around polygon features are usually extended outward from a polygon boundary but it is also possible to create a buffer zone inward from a polygon boundary.
- In order to create a buffer zone around a feature go to the *Main Toolbar>Vector>Geoprocessing Tools>Buffer*.

Geoprocessing tools is a set of tools for processing geographic and related data and performing spatial operations.

Choose the vector layer under study.

Choose the distance of the buffer zone to be created.

Before buffering

After buffering

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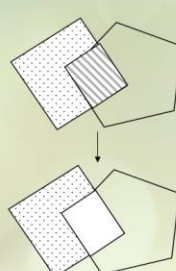
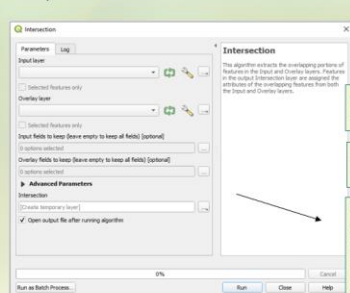
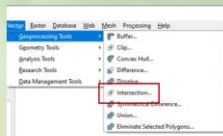
Figure 62 : Slide 17 of course 5, available through the FuseGi VLE platform.

Other tools described in this course include the "intersection", "union" and "cut" tools. The "intersection" tool is used to extract the features superimposed by two layers (Figure 63).

5. Intersection / Union / Clip (1/4)

➤ Intersection

- Intersect tools allow you to exclude the area that is not overlapping. The algorithm combines features from the input layer and the intersect layer resulting in features that cover both layers' features.

One layer containing features to be combined.

Second layer containing the features to be combined.

Where to save the intersection layer. Can be saved to file, a temporary file or a memory layer.

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Figure 63 : Slide 18 of course 5, available via the FuseGI VLE platform.

The "union" tool verifies overlaps between two-layer entities and creates separate entities for overlapping and non-overlapping parts (Figure 64).

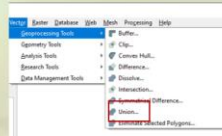
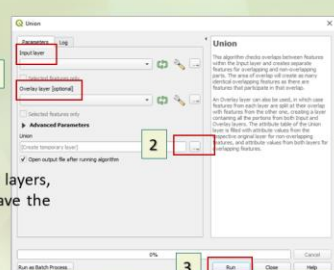
5. Intersection / Union / Clip (2/4)

➤ Union

- Union tool allows to merge two layers into one new layer. Attributes from both input layers are copied. It maintains all input features boundaries and attributes in the output feature class.



- Go to **Main Toolbar>Vector>Geoprocessing Tools>Union**.

- Choose the two input layers,
- Choose the path to save the output layer,
- Run the process.

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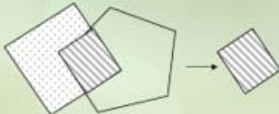
Figure 64 : Slide 19 of course 5, available via the FuseGI VLE platform.

The "cut" tool extracts the common parts between two layers by creating a new vector layer (Figure 65).

5. Intersection / Union / Clip (3/4)

➤ Clip


- Clip tool creates spatial cut-out of the data of a particular area. The input layer is the layer which you want to retrieve your data from. Clipping allows to clip the feature with the defined boundary line.
- Users usually download a dataset that is larger than the area they need. This will slow processing time and data loading.
- Like a cookie-cutter the output is a new clipped output. The input layer can be points, lines or polygons and the clipping layer must be a polygon.
- The main difference between clip tool and intersect toll is the resulting attributes. When you run the clip tool, only the input features attributes will be in the output. When using the intersect tool, the attributes from all features will be in the output.
- Clipping tool is one of the most important geoprocessing tools. It creates a new feature class concerning a study area or a specific area of interest. When analysts and researchers deals with large volumes of data, they can discard the unnecessary spatial information.




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5. Intersection / Union / Clip (4/4)

- Go to **Main Toolbar>Vector>Geoprocessing Tools>Clip**.



Input vector layer to be clipped.



To the example given the Corine Land Cover of 2012 was used as the input vector layer clipped by the buffer zone of 500 meters giving the result on the right image. Through this process, researchers are able to investigate the historical land use changes in the perimeter of any water body.

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Figure 65 : Slides 20 and 21 of course 5, available via the FuseGI VLE platform.

3.6 Course 6: Cartography

The sixth course teaches us the **principle of cartography**, but also how to **create our own maps using the QGIS software (Figure 66)**. The mapping tool allows you to export the layers present in the project into data that can feed a map. This course teaches us how to change the symbols and colors of the map, create the legends and how to export the document.

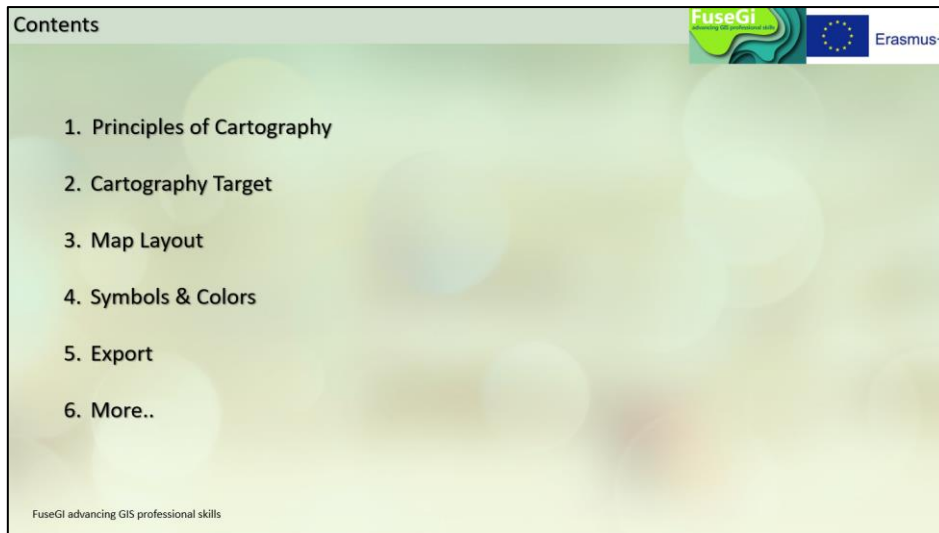


Figure 66 : Course outline 6, available via the FuseGI VLE platform.

This course begins with the basics and principles of cartography (Figure 67).

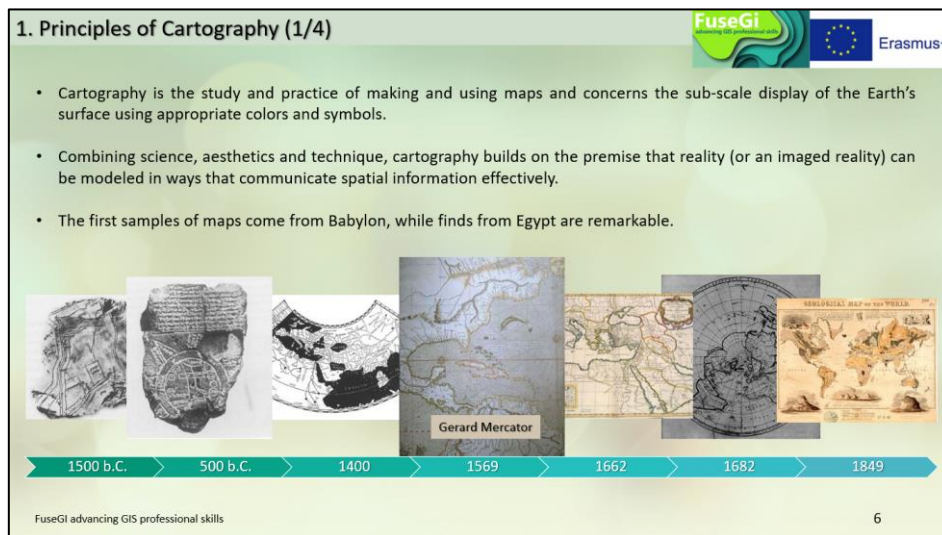


Figure 67 : Slide 6 of course 6, available via the FuseGI VLE platform.

The following slides are slow reminders and define the principles of mapping (Figure 68).

1. Principles of Cartography (2/4)

- Cartography is closely related to Geography, since maps are one of the main means of presentation and study of geographical data.
- GIS applications and GIS software aim to represent geospatial data and results through maps, so Cartography can be closely related to GIS too.
- Maps are models that represent various elements from the real world on a piece of paper.
- Cartographic principles are laid out to guide GIS users through the process of transforming GIS data into attractive, useful maps for print and display.
- In cartography there is difference between principles and rules contribute to the design process. Rules can't guarantee a good outcome like the principles that must be followed.
- Statements of cartographic design:
 - The purpose of design is to focus the attention of the user.
 - The principles of cartographic design are timeless, the results are not.
 - The rules of cartographic design can be taught and be learnt, principles and concepts have to be acquired.

1. Principles of Cartography (3/4)

- The five (5) principles of map design (as written from the British Cartographic Society Design Group):
1. **Concept before compilation**
 - Without a grasp of concept, the whole of the design process is negated. Once concept is understood, no design or content feature will be included which does not fit it.
 - Design the whole before the part. Design comes in two stages, concept and parameters and detail in execution. Design once, devise and design again.
 - User first, user last. What does the user want from this map? What can the user get from this map?
 2. **Hierarchy with harmony**
 - Important things must look important and the most important thing should look the most important.
 - Harmony is subliminal. Successful harmony leads to repose. Perfect harmony of elements leads to a neutral bloom.
 3. **Simplicity from sacrifice**
 - Great design tends towards simplicity. It's not what you put in that makes a great map but what you take out.
 - The map design stage is complete when you take nothing else out.
 - Content may determine scale or scale may determine content and each determines the level of generalization.

1. Principles of Cartography (4/4)

4. **Maximum information at minimum cost**
 - How much information can be gained from this map, at a glance. Functionality not utility. Design makes utility functional.
 - The spark which makes a map special often only comes when the map is complete.
 5. **Engage the emotion to engage the understanding**
 - Design with emotion to engage the emotion. Only by feeling what the user feels can we see what the user sees.
 - Designers use cartographic fictions, cartographic impressions, cartographic illusions to make a map.
 - Good design is a result of the tension between the environment and the designer. Design uses aesthetics but the principles of aesthetics are not those of design.
- Cartographers are not just prettying maps up.
 - The philosophy is simple:
 - Beauty (aesthetics) focuses the attention,
 - Focusing the attention is the purpose of map design and
 - User first, user last.



Figure 68 : Slides 7, 8 and 9 of course 6, available via the FuseGi VLE platform.

Next, the course shows us the basic functions of a map and what types of information can be found in a map (Figure 69).

2. Cartography Target (1/2)

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- The main purpose of Cartography is to convey to the user information related to geospatial data.
- The purpose of the cartographer is to enhance the ability of the user to retrieve the geographical information contained in map and relate it to the real world.
- Maps are used in two basic functions:
 - They are a mean of storage of geospatial information,
 - They provide a picture of the world around us so we can easily understand spatial patterns, spatial relationships and environmental complexity.
- Maps can tell us:
 - Where something is,
 - (Sometimes) When it is,
 - What is close to something, how close or away, in what direction or how we can go there,
 - What other things are there and
 - If there is any relationship between them.
- Each map has a predefined purpose and is a mean of communication between people for the transmission of information.

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Figure 69 : Slide 10 of course 6, available through the FuseGI VLE platform.

In addition, the course indicates what types of maps can be represented using GIS (**Figure 70**).

2. Cartography Target (2/2)

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- Depending on their scale
- Depending on their function (use)



- Political Map (national boundaries)
- Physical Map (water bodies, mountains)
- Topographic Map
- Climatic Map (temperature, humidity)
- Road Map
- Economic Map

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Figure 70 : Slide 11 of course 6, available via the FuseGI VLE platform.

After processing the data and the different layers, it is possible thanks to the QGIS software to create cartographic representations. These map representations follow 5 design principles presented in the next slide (**Figure 71**).

3. Map Layout (1/5)

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- Cartographers apply the five following design principles:
 - **Visual contrast**
It relates to how map features and page elements contrast with each other and their background. The higher the contrast between features, the more something will stand out, usually the feature that is darker or brighter.
 - **Legibility**
It is the ability to be seen and understood and it depends in good decision-making for selecting symbols that are familiar and choosing appropriate sizes so that the results are effortlessly seen and easily understood.
 - **Figure-Ground Operation**
It is the spontaneous separation of the figure in the foreground from an “amorphous” background.
 - **Hierarchical Organization and**
Separating meaningful characteristics so that some types of features will be seen as more important than other kinds of features, and some features will seem more important than other features of the same type.
 - **Balance**
It refers in the organization of the map and other elements on the page (scale, north arrow, legend).

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Figure 71 : Slide 12 of course 6, available via the FuseGI VLE platform.

It is possible to add all the basic elements of a map such as the title, the arrow indicating north, the scale bar, the legend and the map itself (**Figure 72**).

3. Map Layout (2/5)

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- The basic map elements are the title, the map body, the legend, the scale and the north arrow.
- Scale represents the ratio of a distance on the map to the actual distance in the real world and displays in map units (meters, feet or degrees). At the same time, legend explains all the symbols used on a map.




The figure shows a world map titled "POPULATION OF THE SEVEN CONTINENTS". The map is color-coded by continent: North America (blue), South America (green), Africa (red), Asia (orange), Europe (yellow), Australia (pink), and Antarctica (white). A legend in the bottom left corner shows a pie chart representing population distribution. A scale bar is located above the legend, and a north arrow is in the top left. Callout boxes with arrows point to the Title, North Arrow, Scale bar, Legend, and Main map body.

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


Figure 72 : Slide 13 of course 6, available via the FuseGI VLE platform.


All of these items listed above are available in the QGIS mapping workspace (**Figure 73**).

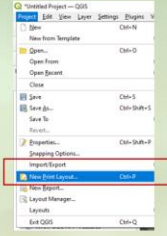
3. Map Layout (3/5)

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- QGIS is an open source GIS software enabling the user to visualize, manage, edit, analyze data and compose printable maps.
- QGIS has a tool called *Print Layout* (Main menu>Project>New Print Layout) that allows you to take GIS layers and package them to create maps. It allows the creation of maps and addition of essential map elements that can be printed or published.

-  Add Map
-  Add Picture
-  Add Title
-  Add Legend
-  Add Scale Bar
-  Add North Arrow






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Figure 73 : Slide 14 of course 6, available via the FuseGI VLE platform.

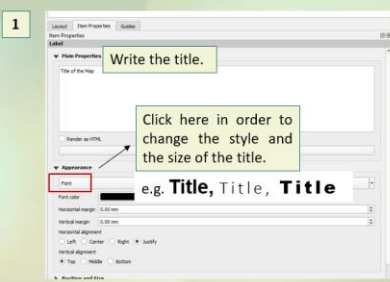
It is possible to change the titles of the legend and the color and appearance of the symbols (Figure 74).

3. Map Layout (4/5)

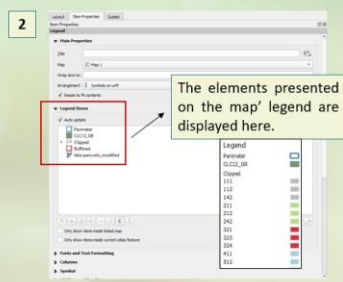
FuseGI 

- On the right side of the window you can edit the elements of the map.

1



2



- QGIS allows you to perform a variety of edits. You can add color or an image as a background of your map's title.
- By clicking on the legend button we can edit the elements and symbols displayed on the map. Colors, size and style.

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Figure 74 : Slide 15 of course 6, available via the FuseGI VLE platform.

In addition, elements such as the arrow indicating north or the scale bar are customizable (Figure 75).

3. Map Layout (5/5)

3 Choose the right symbol to represent the north arrow.

4 Click here to change units (kilometers, meters etc.)
Click here to change scale bar's format.

- The most used north arrow symbol:
- The most used scale bar symbols:

Single Box	
Double Box	
Line Ticks Middle	

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Figure 75 : Slide 16 of course 6, available via the FuseGI VLE platform.

In order to have a better visibility of the information on the map, it is possible to customize the symbols used. To do this, go to the "settings" of the layer to modify and open the "symbology" tab (Figure 76).

4. Symbols & Colors (1/4)

- Layers in QGIS represent geospatial data that describe objects or features. Symbols used to describe objects can have shape and color.

Airport

Swimming pool

Hotel

Airport

- Continuous attributes can't be represented by single symbols either the variables with multiple values.
- In order to represent temperature we need to use graduated colors depending on its values.
- On the other hand, there are variables (e.g. land uses) that cannot be described by single symbols. To represent land uses on a map it is necessary to use categorized colors. Each value takes a certain color in order to be recognized.



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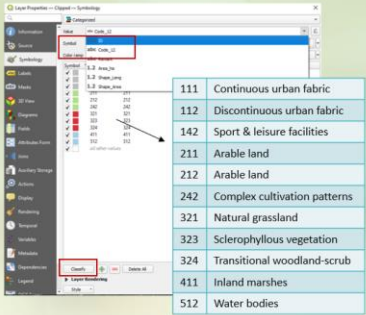
Figure 76 : Slide 17 of course 6, available through the FuseGI VLE platform.

In addition, it is possible to categorize information, add information, or remove information (Figure 77).

4. Symbols & Colors (2/4)

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- Colors convey: meaning, emphasis, aesthetics, abstraction and reality.
- Colors are used to indicate different values of a variable. QGIS allows you to use colors for each class so that visualization becomes easier. The land uses visualization is a representative example of using categorized colors.
- Right click on the layer *Properties>Symbology*.
- Choose the method you wish to represent the information given by the geospatial data. For the example given, we choose the categorized method.
- In the next step, you need to select the value from which the categorization will be made. (Remember that these values are given by the user during the digitization phase.) And then click *Classify*.
- You can either add  or remove  any values.
- Every code represent a unique land use as given in Corine land cover maps. The user is responsible for the color rendering of each code.



111	Continuous urban fabric
112	Discontinuous urban fabric
142	Sport & leisure facilities
211	Arable land
212	Arable land
242	Complex cultivation patterns
321	Natural grassland
323	Sclerophyllous vegetation
324	Transitional woodland-scrub
411	Inland marshes
512	Water bodies

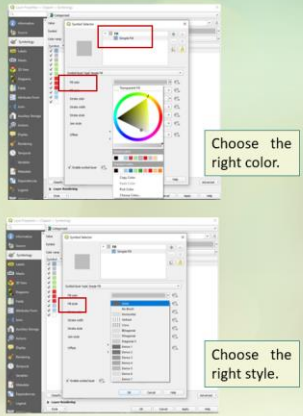
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Figure 77 : Slide 18 of course 6, available via the FuseGI VLE platform.

In the course, there are examples of card personalization. Each of the colours represents a different environment such as agricultural land or artificial surfaces (Figure 78).

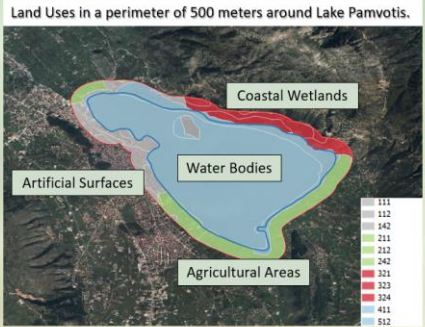
4. Symbols & Colors (3/4)

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Choose the right color.

Choose the right style.



Land Uses in a perimeter of 500 meters around Lake Pamvotis.

111	Continuous urban fabric
112	Discontinuous urban fabric
142	Sport & leisure facilities
211	Arable land
212	Arable land
242	Complex cultivation patterns
321	Natural grassland
323	Sclerophyllous vegetation
324	Transitional woodland-scrub
411	Inland marshes
512	Water bodies

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Figure 78 : Slide 19 of course 6, available via the FuseGI VLE platform.

Another example of map customization is available. This time, it is the customization of layers thanks to the "graduated" option in the "symbology" section of the layer parameters that is presented (Figure 79).

4. Symbols & Colors (4/4)

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- Graduated colors:

QGIS gives a variety of color ramps.

Surface air temperature anomaly for November 2021

(Data: ERA5. Reference period: 1991-2020. Credit: Copernicus)

<https://climate.copernicus.eu/surface-air-temperature-november-2021>

Depending on the map to be created the right color ramp should be selected.

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Figure 79 : Slide 20 of course 6, available through the FuseGI VLE platform.

Finally, all cartographic representations can be exported and saved in PDF for example (Figure 80).

5. Export

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- When it comes to export your Map. Main menu (of New Print Layout)>Layout>Export.
- QGIS allows you to export the map you have created as an image, or as scalable vector graphics (.svg) file or as .pdf.
- Export as an image is the most common form to export your map so you can use it for your writing or presentations.

Final Result:

Land Uses in a perimeter of 500 meters around Lake Pamvotis

Lake Pamvotis

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Figure 80 : Slide 21 of course 6, available through the FuseGI VLE platform.

3.7 Course 7: Grass GIS

The seventh course **introduces the basics for using another software, the Grass GIS software.** This is downloaded and installed along with the QGIS software (Figure 81). This course presents us the possible uses of this software, its workspace. Like QGIS software, this software uses raster and vector data; In particular, it allows the processing of images and the processing of public data.



Figure 81 : Course outline 7, available via the FuseGI VLE platform.

The seventh course introduces the GRASS GIS software, the follow-up of this course will then allow the user to master the basics of the software to be able to use it in addition to QGIS (Figure 82).

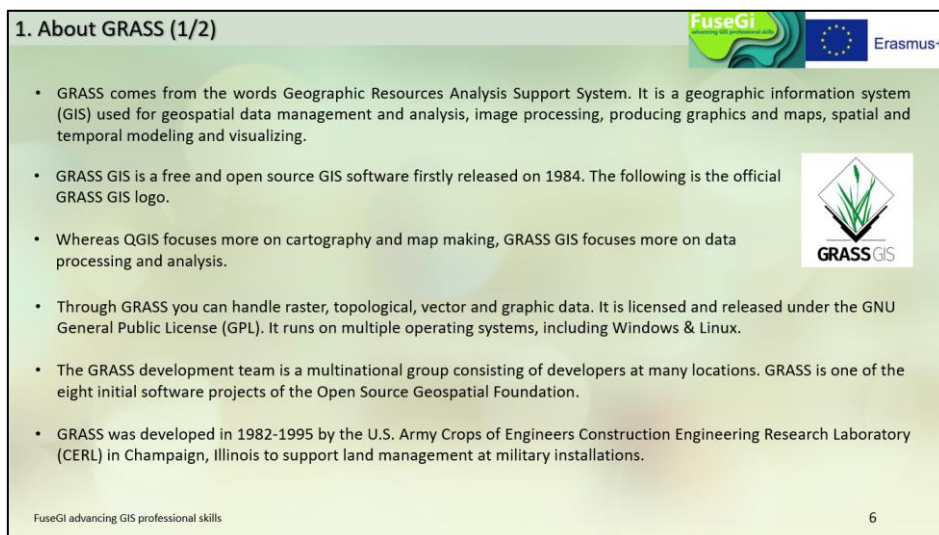



Figure 82 : Slide 6 of course 7, available through the FuseGI VLE platform.

The first slides introduce and define the principles for using the GRASS GIS software (Figure 83).

1. About GRASS (2/2)

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- The idea of Open Source software has been around as long as software has been developed. Over the past few years a growing number of Open Source GIS, Web mapping and GPS projects has been established with different goals.
- In February 2006, the Open Source Geospatial Foundation has been created to support and promote worldwide use and collaborative development of Open Source geospatial technologies and data.
- GRASS is a raster/vector GIS combined with integrated image processing and data visualization subsystems.
- For the GRASS users, the license offers various advantages. Full access to the source code, low cost and access to the new features and capabilities developed between the releases.
- GRASS can be loaded as a plugin by clicking on *Plugins>Manage and Install Plugins* through QGIS. It may be already downloaded as a shortcut when you download QGIS software.
- You can either freely download GRASS software from the main GRASS web site: <https://grass.osgeo.org/download/>.



FuseGI advancing GIS professional skills 7

Figure 83 : Slide 7 of course 7, available via the FuseGI VLE platform.


It is possible to use the GRASS GIS software in addition to the QGIS software. In addition, GRASS GIS can be used for scientific research or engineering applications (Figure 84).

2. GRASS workspace (1/4)

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- GRASS is designed as an environment in which tools that perform specific GIS computations are executed.
- There is cooperation between the GRASS and QGIS projects. Recent versions of QGIS can be executed within the GRASS environment.
- Since then, GRASS has evolved into a powerful software suite with a wide range of applications in many different scientific research and engineering.
- GRASS is also used in academic and commercial settings around the world and in many government agencies including NASA, NOAA, USGS and many environmental consulting companies.

- Selecting the GIS Database directory
- Selecting the Location (a project)
- Selecting the MAPSET (a subproject)
- Location Wizard
- Download a sample Location
- Start GRASS: Once you have selected an existing location/mapset or defined a new one, you can enter GRASS.



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Figure 84 : Slide 8 of course 7, available through the FuseGI VLE platform.

The next slide describes the GRASS GIS application workspace (Figure 85).

2. GRASS workspace (2/4)

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- **Database:** GRASS data is organized on a database which is essentially a dedicated file folder structure.
 - To create the GRASS database:
 1. Find a place on your disk where you have write access and that has enough disk space to hold your spatial data.
 2. Create a subdirectory that will hold the general GRASS database.
- **Location:** It is defined by its coordinate system, map projection and geographical boundaries. The subdirectories and files defining a Location are created automatically when GRASS is started the first time with a new location. It is important to understand that each projection stays in its own location.
- **Mapsets:** Each location can have many mapsets. Each mapset is a location's subdirectory. New mapset can be added as GRASS startup.
 - Permanent: They usually contain read-only data that is visible by all users.
 - Owner: They are created by users and represent specific study areas in a location.
- **Region:** It is a subset of location and sets the boundaries for a master map.

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Figure 85 : Slide 9 of course 7, available through the FuseGI VLE platform.

The GRASS GIS database can be accessed directly from QGIS by installing an extension of QGIS (Figure 86).

2. GRASS workspace (3/4)

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- Once you load the Plugin go to the *Main menu>Plugins>GRASS*. The GRASS plugin provides access to GRASS GIS databases and functionalities. The following main features are provided with the toolbar menu when you start the GRASS plugin:

	Open Mapset		Create new GRASS vector
	New Mapset		Edit GRASS vector layer
	Close Mapset		Open GRASS tools
	Add GRASS vector layer		Display current GRASS region
	Add GRASS raster layer		Edit current GRASS region
- You can load vector or raster layers using the appropriate button on the toolbar menu from an existing GRASS location or you can create a new GRASS location with QGIS and import some raster and vector data for further analysis with the GRASS Toolbox.
- GRASS data are stored in a directory referred to as GISDBASE. This directory must be created before you start working with the GRASS plugin in QGIS. The GRASS GIS data are organized by projects stored in subdirectories called locations.

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Figure 86 : Slide 10 of course 7, available via the FuseGI VLE platform.

Once the extension is installed, it is very simple to use the data from GRASS GIS through QGIS (Figure 87).

3. Working with raster & vector data (2/4)   Erasmus+

➤ **Raster Commands**



r.basins.fill	Generates watershed subbasins raster map	r.colors	Creates/modifies the color table associates with a raster map
r.blend	Blends color components of two raster maps by a given ratio	r.colors.out	Exports the color table associated with a raster map
r.buffer	Creates a raster map showing buffer zones surrounding cells that contain non-NULL category values	r.distance	Locates the closest points between objects in two raster points.
r.carve	Generates stream channels	r.in.bin	Import a binary raster file into a GRASS raster map layer.
r.circle	Creates a raster map containing concentric rings around a given point	r.in.png	Imports non-georeferenced PNG format image.
r.clump	Recategorizes data in a raster map by grouping cells that form physically discrete areas into unique categories	r.out.png	Export a GRASS raster map as a non-georeferenced PNG image.

More at: <https://grass.osgeo.org/grass76/manuals/raster.html>

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Figure 89 : Slide 13 of course 7, available via the FuseGI VLE platform.

In a second step, the course specifies how to process the information of a vector through the GRASS GIS application (**Figure 90**).

3. Working with raster & vector data (3/4)   Erasmus+

➤ **Vector data processing in GRASS GIS**


- A vector map is a data layer consisting of a number of sparse features in geographic space. These might be data points, lines, polygons, volumes or some combination of all these.
- Typically each feature in the map will be tied to a set of attribute layers stored in a database (road names, geologic type etc.).
- The **v.in.ogr** module offers a common interface for many different vector formats. Additionally, it offers options such as on-the-fly creation of new locations or extension of the default region to match the extent of the imported vector map.
- With **v.external** external maps can be virtually linked into a mapset, only pseudo-topology is generated but the vector geometry is not imported. GRASS vector map processing is always performed on the full map. If this is not desired, the input map has to be clipped to the current region beforehand (**v.in.region**, **v.overlay**, **v.select**).
- GRASS is a topological GIS. This means that adjacent geographic components in a single vector map are related. Topological representation of vector data helps to produce and maintain vector maps with clean geometry as well as enables certain analyses that can not be conducted with non-topological data.

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Figure 90 : Slide 14 of course 7, available through the FuseGI VLE platform.

Many commands are available to create and analyze vector data using GRASS (**Figure 91**).

3. Working with raster & vector data (4/4)

FuseGI 

➤ Vector Commands

v.buffer	Creates a buffer around vector features of given type	v.db.droprw	Removes a vector feature from a vector map through attribute selection
v.build	Creates topology for vector map	v.db.droptable	Removes existing attribute table of a vector map
v.class	Classifies attribute data, e.g. for thematic mapping	v.db.select	Prints vector map attributes
v.clip	Extracts features of input map which overlay features of clip map	v.drape	Converts 2D vector features to 3D by sampling of elevation raster map
v.cluster	Performs cluster identification	v.edit	Edits a vector map, allows adding, deleting and modifying selected vector features
v.colors	Creates/modifies the color table associated with a vector map	v.generalize	Performs vector based generalization
v.in region	Creates a vector polygon from the current region extent	v.patch	Creates a new vector map by combining other vector maps


More at: <https://grass.osgeo.org/grass78/manuals/vector.html>

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Figure 91 : Slide 15 of course 7, available via the FuseGI VLE platform.

The GRASS GIS software also allows raster data to be processed as images (Figure 92).


4. Image Processing (1/2)

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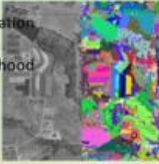
- Satellite imagery is commonly stored in Digital Numbers (DN) for minimizing the storage volume, i.e. the originally sampled analog physical value (color, temperature, etc) is stored a discrete representation in 8-16 bits.
- To obtain physical values from DNs, satellite image providers use a liner transform equation ($y=a*x+b$) to encode the radiance-at-sensor in 8 to 16 bits. DNs can be turned back into physical values by applying the reverse formula $(x-(y+b)/a)$.
- In GRASS GIS, there are two ways to apply atmospheric correction for satellite imagery. A simple, less accurate way for Landsat is with `i.landsat.toar`, using the DOS correction method.
- Image data are identical to raster data However, a couple of commands are explicitly dedicated to image processing.
- As a general rule in GRASS:
 1. Raster/imagery output maps have their bounds and resolution equal to those of the current region.
 2. Raster/imagery input maps are automatically cropped/padded and rescaled (using nearest-neighbor resampling) to match the current region.
- GRASS raster/imagery map processing is always performed in the current region settings, i.e. The current region extent and current raster resolution is used. If the resolution differs from that of the input raster map(s), on-the-fly resampling is performed (nearest neighbor resampling).

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4. Image Processing (2/2)

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- An image processing system has at least five elements: image input, image storage, image analysis, accuracy assessment and information reporting.
- Single and multispectral data can be classified to user defined land use/land cover classes. In case of a single channel, segmentation will be used. GRASS supports the following methods:
 - Radiometric classification:
 - Unsupervised classification (`i.cluster`, `i.maxlik`) using the Maximum Likelihood classification method.
 - Supervised classification (`i.gensig` or `g.gui.iclass`, `i.maxlik`) using the Maximum Likelihood classification method
 - Combined radiometric/geometric (segmentation base) classification:
 - Supervised classification (`i.gensigset`, `i.smap`)
 - Object-oriented classification:
 - Unsupervised classification (segmentation based: `i.segment`)
- In case of using multispectral data, improvements of the resolution can be gained by merging the panchromatic channel with color channels. GRASS provides the HIS (`i.rgb.his`, `i.his.rgb`) and the Brovey and the PVA transform (`i.pansharpen`) methods.
- Atmospheric effects can be removed with `i.atcorr`. Correction for topographic/terrain effects is offered in `i.topo.corr`.



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Figure 92 : Slides 16 and 17 of course 7, available via the FuseGI VLE platform.

Finally, it is possible to find public data repositories in the course, via links, to access useful data to obtain information on the biosphere or the environment for example (Figure 93).

5. Public Data Repositories (1/2)

- **Atlas of the Biosphere**
In this website you will find maps of environmental variables, human impacts and land use. The Center for Sustainability and the Global Environment brings together researchers from the natural, health and social sciences, engineering and other fields to study problems stemming from interactions between environmental systems, natural resources and human activity, and to inform technology and policy solutions. <https://sage.nelson.wisc.edu/>
- **National Wetlands Inventory (NWI)**
The National Wetlands Inventory (NWI) has been producing wetlands maps geospatial wetland data for the United States since the mid 1970s. Maps and geospatial data developed by the NWI is available online and can be downloaded. By HUC 8 Watershed Boundary or by State. <https://www.fws.gov/wetlands/Data/Data-Download.html>
- **NOAA National Center for Environmental Information**
The National Center for Environmental Information is the world's largest provider of weather and climate data. NOAA manages one of the largest archives of atmospheric, coastal, geophysical and ocean research in the world. <https://www.ncei.noaa.gov/>

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5. Public Data Repositories (2/2)

- **Soil Climate Analysis Network (SCAN)**
SCAN is a continuous climate monitoring program that is an outgrowth of the SM/ST Pilot Project. The SM/ST Pilot Project was designed to examine network communications, sensors, data collection electronics, data management and climate information system. <https://www.wcc.nrcs.usda.gov/scan/>
- **National Renewable Energy Laboratory**
NREL advances the science and engineering of energy efficiency, sustainable transportation and renewable power technologies and provides the knowledge to integrate and optimize energy systems. <https://www.nrel.gov/index.html>
- **USGS National Water-Quality Assessment (NAWQA)**
The NAWQA project is a leading source of scientific data and knowledge for development of science-based policies and management strategies to improve and protect water resources. <https://www.usgs.gov/>
- **Multistate Aquatic Resources Information System (MARIS)**
MARIS is a cooperative effort between state and federal agencies to share fisheries information collected as part of ongoing sampling programs.

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Figure 93 : Slides 18 and 19 of course 7, available via the FuseGI VLE platform.

3.8 Course 8: Hydrological Analysis and QGIS Tools

The eighth course is **entirely focused on one discipline, hydrology**. This course is therefore more specific since it is directly related to this field. Nevertheless, it is **not inaccessible to people who do not know this field**. It consists of an introduction to hydrology and a presentation of software used for hydrology. We can also find a description of the useful tools and the procedure to follow for a hydrological analysis (Figure 94).



Figure 94 : Course outline 8, available via the FuseGI VLE platform.

This course learns, for example, how to use GIS to define a catchment area or flow direction, as well as the basics of hydrology (**Figure 95**).

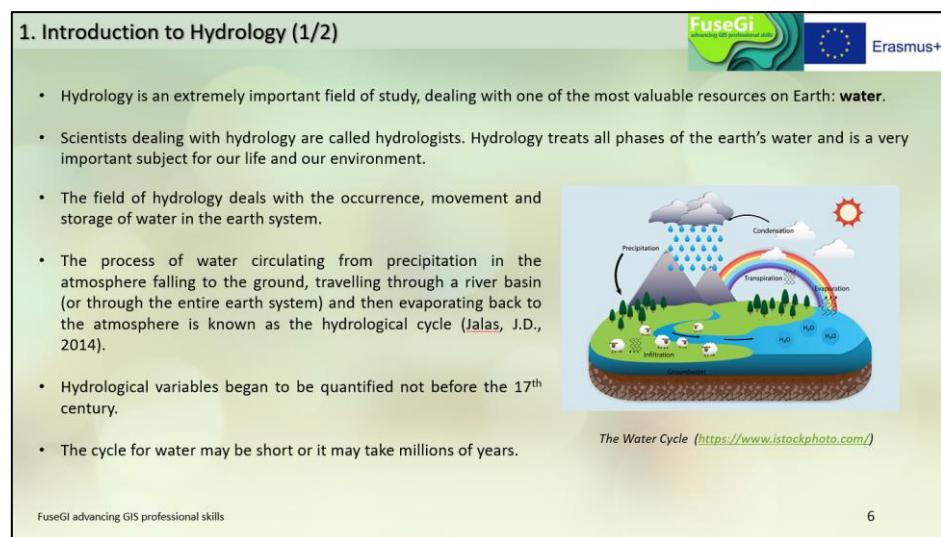


Figure 95 : Slide 6 of course 8, available through the FuseGI VLE platform.

The first slides introduce hydrology to participants who are not in this field or to make some reminders for those working or studying in the field of hydrology (**Figure 96**).

1. Introduction to Hydrology (2/2)

- There are many pathways the water may take in its continuous cycle of falling as rainfall or snowfall and returning to the atmosphere.
- The engineering hydrologist, or water resource engineer is involved in the planning, analysis, design, construction and operation of projects for the control, utilization and management of water resources.
- Hydrologists apply scientific knowledge and mathematical principles to solve water-related problems in society: problems of quantity, quality and availability.
- Practical applications of hydrology: design and operation of hydraulic structures, water supply, irrigation, drainage, hydropower generation, flood control or wastewater treatment and disposal.



Figure 96 : Slide 7 of course 8, available via the FuseGI VLE platform.

Hydrological analysis tools are a very important resource in this area. GIS software is used, but river modeling software or hydraulic modeling software is also used (**Figure 97**).

2. Hydrological Software (1/2)



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- Hydrological analysis tools are important resources and are used in a variety of programs to define how the geographic range of an area interacts with water.
- Hydrological analysis through Geographic Information Systems can help researchers identify the source and pathway of groundwater. A variety of programs can be used to perform hydrological analysis including ARCGIS, QGIS, ILWIS and SAGA GIS.
 - Geographical Information Systems
- **QGIS**, a free and open source software, offers hydrology tools for performing hydrological analysis and creating digital elevation models. It is the most popular GIS tool in Water Resources.


- **SAGA GIS** is a powerful software containing tools for spatial analysis and characterization of basins. The interpolation options in SAGA GIS are better implemented than in other free and commercial software.



Web: <http://www.saga-gis.org/en/index.html>

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2. Hydrological Software (2/2)



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- River Modeling
- **HEC-RAS** is developed by the U.S. Army Corps of Engineers. It helps evaluating the flow depth, velocities and flooded zones. The Hydrologic Engineering Center (HEC) developed the River Analysis System (RAS) to aid hydraulic engineers in channel flow analysis and floodplain determination.



Web: <https://www.hec.usace.army.mil/software/hecras/>
- **iRIC** is a software developed to provide a complete river simulation environment and its results can be exported and used for analysis, mitigation and disaster prevention, through the visualization of river simulation results. Web: <https://i-ric.org/en/>


- Hydrologic Modeling
- **HEC-HMS** is designed to simulate the hydrologic processes in basins. It includes many hydrologic analysis procedures such as event infiltration, unit hydrographs and hydrologic routing.

Web: <https://www.hec.usace.army.mil/software/hechms/>
- **PRMS** is a deterministic, distributed-parameter, physical process based modeling system developed to evaluate the response of various combinations of climate and land use in streamflow and general watershed hydrology.

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Figure 97 : Slides 8 and 9 of course 8, available via the FuseGI VLE platform.

There is a toolbox available with QGIS that allows hydrological analyses to be carried out. This toolkit is known as SAGA (**Figure 98**).

3. Hydrological Analysis - Toolboxes (1/3)

- Hydrological analysis tools are important resources and are used in a variety of programs to define how the geographic range of an area interacts with water.
- It is performed to quantify the volumetric flow rate of water draining from a watershed (e.g. drainage area) over time.
- Hydrological analysis can aid researchers and emergency personnel in identifying the source and pathway of groundwater, delineating watersheds and identifying communities prone to flooding conditions.
- GIS software includes methods for describing hydrologic characteristics and tools to calculate flow across an elevation surface, calculate flow path length and assign stream orders.
- These kinds of derived data are often used to aggregate landscape information for input to hydrologic models.
- Hydrological data can help us prepare and plan for extreme events by identifying where the risks are highest and better manage water resources in ways that suit the economical state and the environmental needs.
- Hydrological analysis is mainly based on a digital elevation model (DEM) raster data to establish a water system model, which is used to study the hydrological characteristics and simulation of surface during the hydrological process.

3. Hydrological Analysis - Toolboxes (2/3)

- QGIS has an extensive set of tools available for hydrological analyses located in the hydrology toolbox.
- There are many tools for spatial data processing of hydrological model inputs. These tools are not native QGIS commands, most of them come from SAGA GIS and GRASS GIS under the processing tool.
- These tools allow you to:
 - Perform depressionless elevation layers,
 - Extract stream networks,
 - Delimitate basins and channel networks.

• *Processing Tab > Toolbox > SAGA.*
 SAGA (System for Automated Geoscientific Analysis) is a free, hybrid, cross-platform GIS software which provide many geoscientific methods bundled in so-called module libraries.

• The plugin does not include SAGA itself. To use the plugin you need to install SAGA. Visit the SAGA homepage for installations and packages.

• Tools given in SAGA library can be used as any other processing algorithm: as a standalone tool, in batch processes, in models and scripts.



3. Hydrological Analysis - Toolboxes (3/3)

- *Processing Tab > Toolbox > SAGA.*
 - *Simulation – Hydrology*
 - *Terrain Analysis – Channels*
 - *Terrain Analysis – Hydrology*

• These three libraries of tools can mainly used in a hydrological exercise.

• You will also need tools such as *clip* and *extract* so to isolate the data of your study area.

• Add land-cover data or other spatial data depending on every case.

• Create 2D maps using the right tools and symbols.

• A complete hydrological analysis uses a variety of QGIS toolboxes, not only for data extraction but also their presentation.

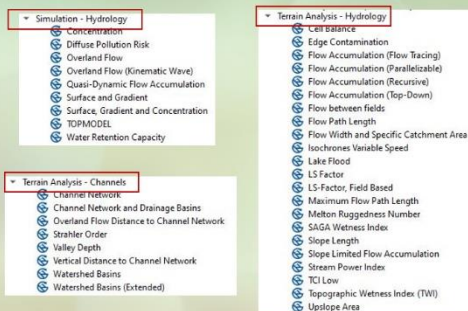


Figure 98 : Slides 10, 11, and 12 of course 8, available through the FuseGI VLE platform.

The digital elevation model is widely used in environmental science, whether in hydrology or vegetation cover management. This course allows you to define and create this type of model (Figure 99).

4. Digital Elevation Model (DEM) (1/2)

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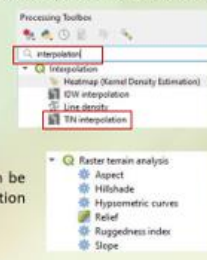
- DEMs can be generated using point data sets from elevation data or from aerial imagery using remotely sensed data.
- Often, DEM datasets that are already interpolated can be quite large, so if you are looking to analyze a large area, it might be best to find elevation point data and interpolate them yourself.
- It is very important to create a working directory where you will keep all your data and progress files. After opening QGIS, create a new project and save it to your working directory.
- Users can either download Digital Elevation Models from websites online or create them from the contour layers.
- Elevation data is abundant, it is just a matter of finding the right one to suit your needs. Check the follow free global DEM data sources:
 1. Space Shuttle Radar Topography Mission (SRTM)
 2. ASTER Global Digital Elevation Model
 3. JAXA's Global ALOS 3d World
 4. Light Detection and Ranging (LiDAR)
 5. Mars Orbiter Laser Altimeter (MOLA)

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4. Digital Elevation Model (DEM) (2/2)

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- To create a Digital Elevation Model in QGIS you need a file of height point data or a file of contours of known elevation. You can either find this data online or digitize it on your own. Create a new shapefile of points, in point attribute select the elevation field. When digitizing the points add the elevation variables.
- QGIS offers two methods of generating TIN, Linear and Clough-Topcher, the second produces smoother surface.
- So, it is possible to generate surfaces of a variable by interpolation, generally using coordinate points with elevation information.
- Load or create the vector file. To access the interpolation tools go to *Processing Toolbox > Interpolation > TIN Interpolation*.
- On the extension tab click on the corner button > *Use Canvas Layer Extension*. Set the pixel size and define the output files.
- For further analysis of your DEMs use the Raster Terrain Analysis Plugin. This plugin can be used to calculate the slope, aspect, hillshade, ruggedness index and relief of digital elevation models. *Processing Toolbox > Raster Terrain Analysis*.



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Figure 99 : Slides 13 and 14 of course 8, available via the FuseGi VLE platform.

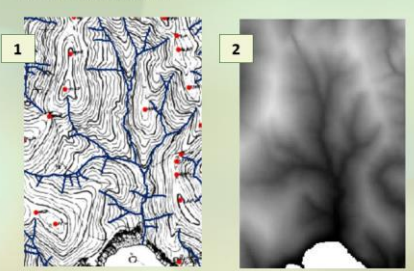
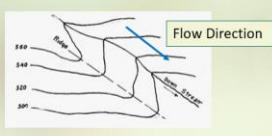
In addition, the digital elevation model allows the creation of rainwater and surface water flow direction (Figure 100).

5. Flow Direction – Catchment Area (1/3)

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How can you understand the right flow direction?

- In order to start your analysis, you should have created the elevation model of your study area following the steps in the previous section.
- Actually, water flows downhill in any direction, because it always wants to get to the lowest level as quickly as possible due to the gravitational pull.
- Rivers flow in one direction all over the world, and that direction is downhill.
- As a rule of thumb, the V-shaped contour is pointing upstream (the opposite direction from the flow of a stream or river). The “V” shape contours indicate streams and drainage.

1. Georeference the contour map,
2. Digitize the hydrography network following streams' flow,
3. Create the Digital Elevation Model,
4. Look for mistakes.

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Figure 100 : Slide 15 of course 8, available through the FuseGi VLE platform.


Then, it is possible to determine the watershed in different areas (**Figure 101**).

5. Flow Direction – Catchment Area (2/3)

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- A catchment area is otherwise considered a drainage basin. The basin is where water flows over topographic terrain and consists of water runoff into surrounding rivers, streams and lakes.
- Flow direction is the main direction of water run-off over the geographic area of interest. Flow is determined with the algorithm differentiating where a given pixel would go depending on elevation and cell height values.
- Elevation > Insert DEM data layer
- Method > Choose one model to apply to the DEM data layer
There are five methods to choose from when delineating a catchment area from a DEM.

[0] Deterministic 8 (D8)
[1] Rho 8
[2] Braunschweiger Reliefmodell
[3] Deterministic Infinity
[4] Multiple Flow Direction
[5] Multiple Triangular Direction



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Figure 101 : Slide 16 of course 8, available through the FuseGI VLE platform.

And finally, it is possible to perform additional analyses, such as determining the importance of the different watercourses in the watershed using the SAGA tool (**Figure 102**).

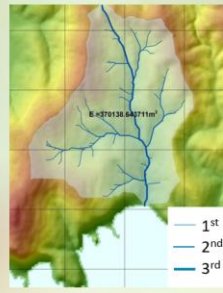
5. Flow Direction – Catchment Area (3/3)

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- The following steps must be completed in order to calculate the flow direction:

Download DEM tiles → Mosaic DEM tiles → Reproject DEM → Subset DEM → Fill sinks/ remove spikes

- Calculate Strahler order and determine threshold for streams. SAGA > Terrain Analysis – Channels > Strahler order. The higher the order, the bigger the stream. Make a nice legend, where the highest Strahler orders are more blue so you can clearer see what the rivers are.
- Calculate flow direction, channel network and catchments. SAGA > Terrain Analysis – Channels > Channel Network and drainage basins.
- Define outflow point, where the water join another water body, such as a river, lake, sea or ocean.
- Delineate catchment. SAGA > Terrain Analysis – Hydrology > Upslope Area. Remove all unnecessary layers and clip all the data outside the study area. Create a .pdf map.



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Figure 102 : Slide 17 of course 8, available through the FuseGI VLE platform.

3.9 Course 9: Web Scraping Applications in QGIS

The ninth and final course of the platform is specific to learning "web scraping", i.e. searching for information online and **processing this information with online tools or with software such as QGIS**. This course consists of the introduction of the notion of "web scraping" then the method of searching for online data, the presentation of a realistic case study in the field of health, and finally the method of using "web scraping" and QGIS (**Figure 103**).

Contents

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1. Web Scraping Definition
2. Export Data from the Web
3. A Realistic Application of Web Scraping - Health
4. Combining Web Scraping & QGIS

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Figure 103 : Course outline 9, available via the FuseGi VLE platform.

First, web scraping involves importing online data into spreadsheets such as Excel (Figure 104).

1. Web Scraping Definition - Clean Data sources (1/2)

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Webscrapping of various data sources...

Provinces de Limbourg | modifier | modifier le code

- Nempert et Overpelt (département Paal)
- Mouvaens-Durbion et Olgelotte (département Oudbergien)

WIKIPÉDIA
L'encyclopédie libre

Liste des communes | modifier | modifier le code

#	Commune	1846	1900	1947	2000	2020	Surf. km²	Pop. (2020)	Densité (2020)			
1	Avenas	119 892	363 357	538 398	446 925	627 763	100	323 444	376 445	254,51	2 572	87,7
2	Gueld	128 828	222 895	254 216	224 180	283 614	100	173 187	174 205	156,18	1 688	102,6
3	Charleroi	54 694	198 837	232 737	200 827	232 376	100	264 427	267 272	102,08	1 992	73,3
4	Loup	88 947	138 361	231 522	182 679	199 423	100	239 287	238 219	92,39	2 554	81,5
5	Ville de Bruxelles	126 600	218 023	154 638	133 859	180 287	100	169 143	163 141	32,61	5 021	69,8
6	Schaumburg	6 271	63 536	123 671	102 892	121 546	100	1 023 189	1 702 219	6,74	18 160	80,2
7	Ardenne	9 900	47 029	90 412	87 812	120 029	100	803 448	1 472 232	17,74	6 785	64,1
8	Bruges	60 865	70 277	93 362	118 246	118 636	100	110 153	131 105	138,40	608	111,2
9	Namur	42 929	62 427	77 584	118 418	111 227	100	147 182	248 281	175,69	631	85,1
10	Couvaix	38 234	58 023	67 322	88 614	100 126	100	186 191	249 289	58,63	1 803	173,0
11	Méroménil-Saint-Jean	12 360	58 440	63 822	71 219	97 262	100	484 320	580 867	6,89	18 031	106,4
12	Méro	82 106	77 263	84 972	90 930	95 908	100	148 101	179 105	148,93	103	68,2

What does Webscrapping mean?
Import data from a website to a spreadsheet table.

Excel & Chrome browser offer tools to import tables from wikipedia/website into an « Excel » spreadsheet. The easiest is the Excel « Data » dongle.

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Figure 104 : Slide 6 of course 9, available through the FuseGi VLE platform.

The process is simple to execute, just follow the instructions available in the course (Figure 104).

1. Web Scraping Definition - Clean Data sources (2/2)

1. Webscraping of **heterogenous data sources** in Excel, from a .url web address
 2. Webscraping from Chrome web browser (Add-in, not used in this case study)

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Figure 105 : Slide 7 of course 9, available via the FuseGI VLE platform.

The export of this data is a rather simple process but can cause some problems, some solutions of which are given in the course (Figure 106).

2. Export Data from the Web (1/2)

Web Scraping and improving the quality of the data:

Typical Web Scraping problems and cleaning solutions

Names mismatching	Wrong Numbers/ Characters	
communes	colonne1.2.1	colonne1
Anderlecht	121	394
Brusssel / Bruxelles	187	686
Elsene / Ixelles	86	917
Etterbeek	48	223
Evere	43	481
Ganshoren	25	202
Jette	52	604
Koekelberg	21	997
Oudergem / Auderghem	34	937
Schaerbeek / Schaerbeek	130	270
Sint-Agatha-Berchem / Berchem-Sainte-Agathe	25	288
Sint-Gillis / Saint-Gilles	48	458
Sint-Jans-Molenbeek / Molenbeek-Saint-Jean	97	102
Sint-Joost-ten-Node / Saint-Josse-ten-Noode	26	809
Sint-Lambrechts-Woluwe / Woluwe-Saint-Lambert	58	448
Sint-Pieters-Woluwe / Woluwe-Saint-Pierre	42	106
Ukkel / Uccle	84	647
Vorst / Forest	56	271
Watermaal-Bosvoorde / Watermaal-Boitsfort	25	190

PowerQuery

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Figure 106 : Slide 8 of course 9, available via the FuseGI VLE platform.

When extracting data, the use of a table such as Excel is essential (Figure 107).

2. Export Data from the Web (2/2)

Web Scraping: Cleaning the data with Excel PowerQuery
Reference : Online PowerQuery course (Microsoft)
Tools : Splitting/Merging/Removing Characters in data

The slide displays the Excel interface with the 'Données' (Data) tab selected. A dropdown menu for 'Obtenir des données' (Get Data) is open, showing options like 'À partir d'un fichier texte/CSV', 'À partir du web', and 'À partir d'un tableau ou d'une plage'. A table of municipalities is shown with columns for name, population, and area.

communes	Population	Superficie
1 Anderlecht	1221	394
2 Brussel / Bruxelles	187	686
4 Elsenne / Ixelles	86	917
5 Etterbeek	48	223
6 Evere	43	481
7 Ganshoren	25	202
8 Jette	52	604

Figure 107 : Slide 9 of course 9, available via the FuseGI VLE platform.

A case study on web scraping is available to practice its use. This course introduces this case study (Figure 108).

3. A Realistic Application of Web Scraping – Health (1/ 7)

What happened in Brussels during pandemic...

1. Brussels region context : the epidemic keeps spreading in Brussels region, due to lack of vaccination in some part of the city. The Minister has to solve this by creating a targeted local vaccination campaign in some area (street vaccination). →scope.
2. How to understand and geolocalize areas with a too small proportion of vaccinated people ?
3. Webscrapping of heterogenous data sources. Matching them with the Minister confidential data
4. Graphic correlations with ages, revenues, neighborhood...

Figure 108 : Slide 10 of course 9, available through the FuseGI VLE platform.

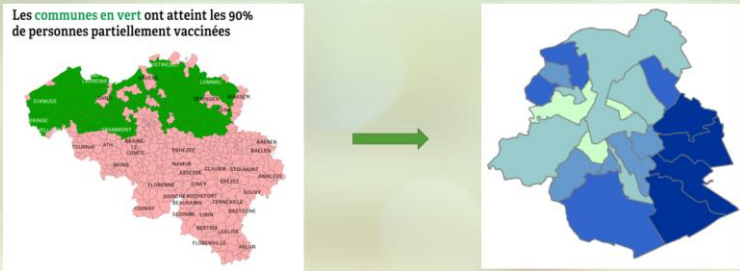
It is important to use a . Json to delimit the contours of municipalities (Figure 109).

3. A Realistic Application of Web Scraping – Health (2/7)

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From country → to localities.
You need a *.Json file with the borders of Municipalities. Restrict it to Brussels region municipalities

Les communes en vert ont atteint les 90% de personnes partiellement vaccinées



Json subfiles for the targeted municipalities

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Figure 109 : Slide 11 of course 9, available through the FuseGI VLE platform.

The general steps of the case study as well as the purpose of the case study are detailed in this course. The case study includes more specific and simple steps to follow (**Figure 110**).

3. A Realistic Application of Web Scraping – Health (3/7)

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1. Sources : Json / Minister / website national institute of statistics
2. Goals : simple GIS tasks with tools simpler than Qgis/ArcGis
3. Easy GIS visualization tool : Datawrapper/(Floorish)
4. Webscrapping of heterogenous data sources
5. GIS mapping From country to neighborhood level
6. Correlations with ages, revenues, neighborhood

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Figure 110 : Slide 12 of course 9, available via the FuseGI VLE platform.

In the example of the course, the cartographic representation is created using the online tool "Data wrapper", not with the QGIS software (**Figure 111**).

3. A Realistic Application of Web Scraping – Health (4/ 7)

1) Select the map. → 2) Copy-paste the cleaned data. → 3) Choose the column to visualize

A	nom (fr.)	B	values
1	Municipality	% new	Vaccinationnel March
3	Auderghem		9.797636
4	Berchem-Sainte-Agathe		21.357956
5	Bruxelles		23.381073
6	Etterbeek		14.83317
7	Evere		17.175218
8	Forest		28.324857
9	Ganshoren		21.799857
10	Ixelles		16.81144
11	Jette		22.864862
12	Knake-Thorn		17.888888

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Figure 111 : Slide 13 of course 9, available via the FuseGI VLE platform.

The data is also sorted through the use of a table such as Excel or LibreOffice (Figure 112).

3. A Realistic Application of Web Scraping – Health (5/7)

➤ Cleaning of dirty data sources with Excel/LibreOffice

Commune	Consommation d'antibiotiques - conditionnements (1)
Auderghem	2,28
Auderghem	2,38
Auderghem	2,39
Auderghem	2,57
Auderghem	2,45
Auderghem	2,68
Auderghem	2,37
Auderghem	2,97
Auderghem	3,27
Auderghem	1,44
Auderghem	2,12
Auderghem	3,08

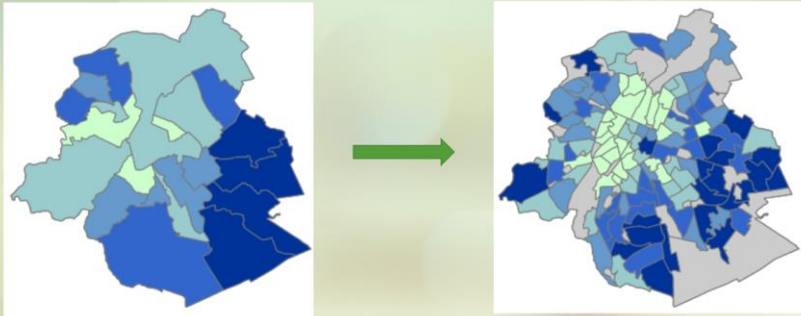
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Figure 112 : Slide 14 of course 9, available via the FuseGI VLE platform.

These data are actual data of the vaccinated or unvaccinated population in the region and municipality of Brussels (Figure 113).

4. Combing Web Scraping and QGIS (1/4)

Add the vector file of the region..



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17

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Figure 114 : Slide 17 of course 9, available via the FuseGI VLE platform.

It is also possible to correlate average incomes with the percentage of vaccination or to correlate the average ages of populations with vaccination rates in the region and municipality of Brussels (**Figure 115**).

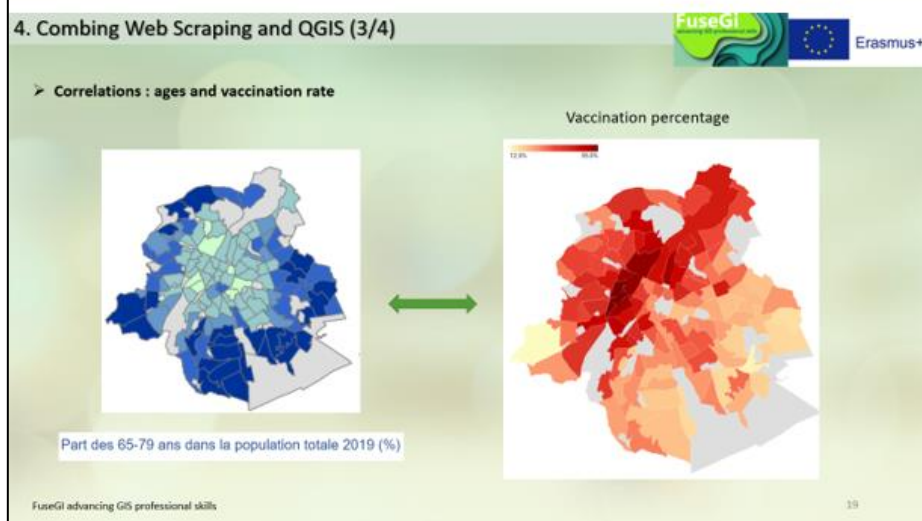
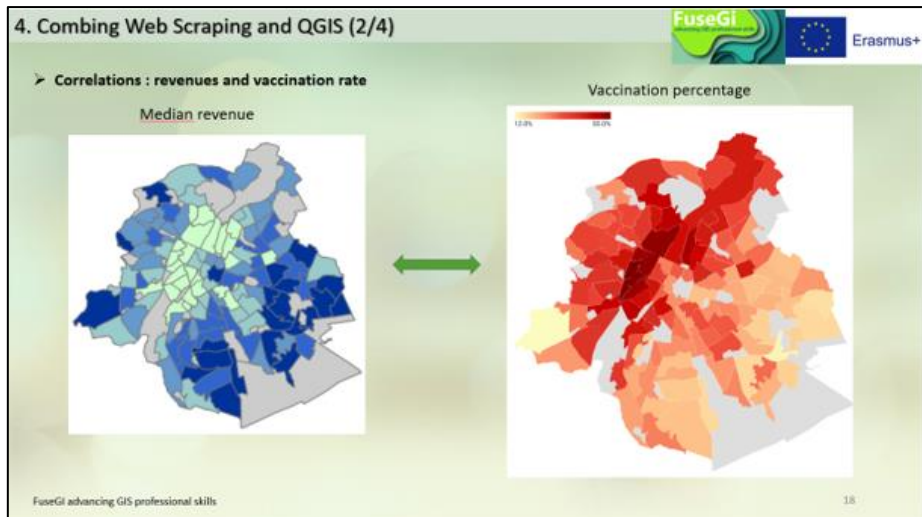


Figure 115 : Slides 18 and 19 of course 9, available via the FuseGI VLE platform.

Then, it is possible to make assumptions about the observed correlations (Figure 116).

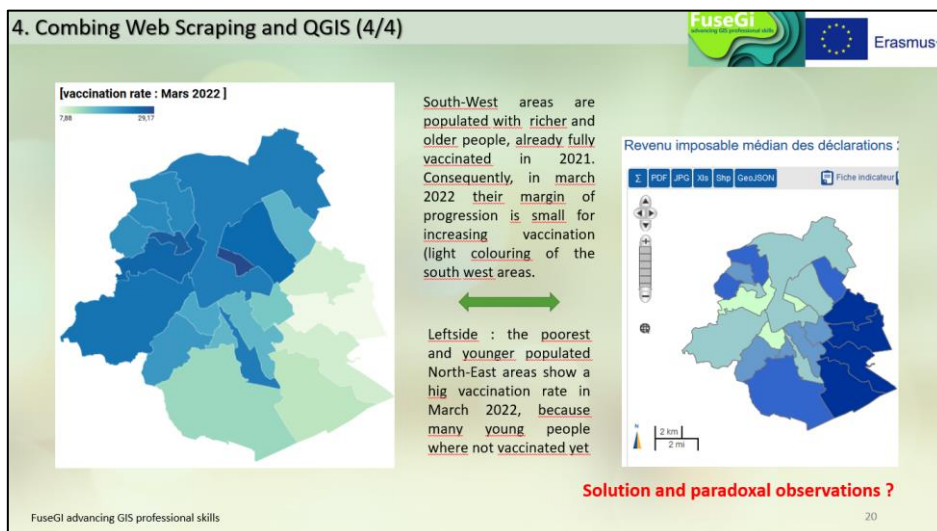
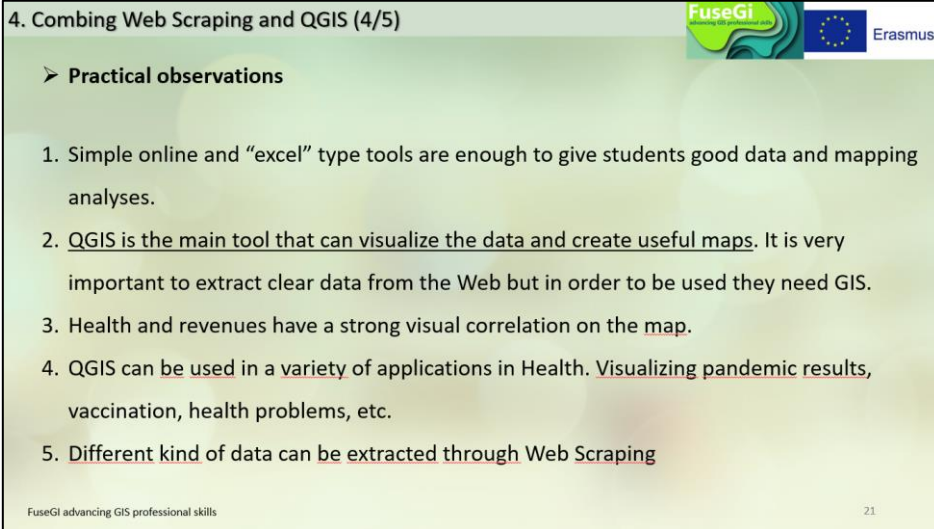


Figure 116 : Slide 20 of course 9, available via the FuseGI VLE platform.

Finally, this course concludes with practical observations concerning the use of web scraping and QGIS (**Figure 117**).



4. Combing Web Scraping and QGIS (4/5)

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➤ **Practical observations**

1. Simple online and “excel” type tools are enough to give students good data and mapping analyses.
2. QGIS is the main tool that can visualize the data and create useful maps. It is very important to extract clear data from the Web but in order to be used they need GIS.
3. Health and revenues have a strong visual correlation on the map.
4. QGIS can be used in a variety of applications in Health. Visualizing pandemic results, vaccination, health problems, etc.
5. Different kind of data can be extracted through Web Scraping

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Figure 117 : Slide 21 of course 9, available via the FuseGI VLE platform.

4 The case studies

The case studies aim to **put into practice the theoretical knowledge acquired** through the courses. The **four available case studies** are linked to the three areas applied throughout the project, i.e. **forestry, health and hydrology**. Of these four case studies, one focuses on forest, one on health and the last two are oriented towards the field of hydrology. Despite the different areas of the case studies, **each brings essential knowledge to fully use GIS**.

4.1 LULC/FOREST case study

This first **case study is intended to take ownership of LULC**, i.e. **land use and land cover** for a defined area. The area studied is the island of Chios located in Greece. LULC is a dynamic feature that is useful to track relevant changes in land cover. This case study is created to test the skills acquired during the courses, aiming to map forest changes in Chios in three areas of different altitudes. The main questions are: **How has forest changed the last 10 years in Chios. Is there gain or loss of forest and is this gain/loss dependent to elevation?** The instruction for this exercise is given in the form of a succession of steps to follow (**Figure 118**). This sequence of steps is intended to answer a specific question (**Figure 119**).

1. Download 2012 LULC data from Copernicus site, following the directions provided online.
2. Clip the polygons that correspond to Chios, using the provided polygon boundary
 - ✓ Course 5 (hint – spatial analysis)
3. Dissolve LULC polygons, into classes of the first MAES level
 - ✓ Course 5 (hint – spatial analysis)
4. Use Google earth basemap to identify and digitise LULC changes. Cut polygons where the change has occurred and enter the new class code, in a new column in the attribute table.
 - ✓ Course 4 (hint – digitization)
5. Reclassify DEM into 3 elevation zones (0 - 500 - 800 - top)
 - ✓ Course 5 (hint – spatial analysis)
6. Convert raster elevation zones to vector elevation zones
 - ✓ Course 5 (hint – spatial analysis)
7. Intersect LULC polygons with the 3 polygon elevation zones
 - ✓ Course 5 (hint – spatial analysis)
8. Find the area of changes in each zone
 - ✓ Course 4 (hint – attribute table)
9. Create a map that shows the areas where there is gain of forest (use green colour) or loss of forest (use orange colour), while you also show the forest that remains unchanged, the elevation zones, as well as a table with the respective areas (in hectares) for each of the 3 elevation zones
 - ✓ Course 6 (hint – map layout)

Figure 118 : sequence of steps to complete the LULC exercise, available on the FuseGI VLE platform.

Basic question

How has forest changed the last 10 years in Chios? Is there gain or loss of forest and is this gain/loss dependent to elevation?

Figure 119 : Final question of the exercise, available on the FuseGI platform.

This exercise can be done in about 8 hours for people who are new to the field of GIS and are not familiar with using QGIS software.

As a first step, it is important to upload all the data available on the platform in the "provided material" space. Then simply launch the QGIS software and start the exercise. First, add the polygon downloaded from the island of Chios, then add the LULC (**Figure 120**).

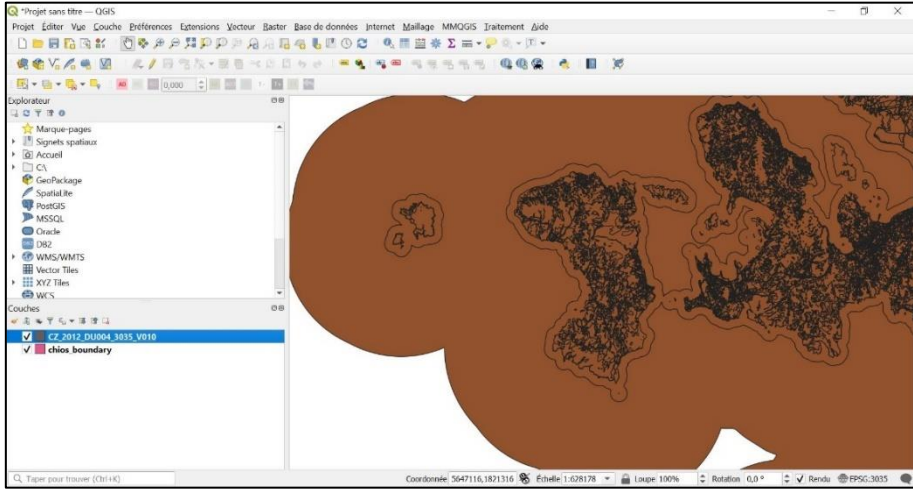


Figure 120 : Overview of the "Chios polygon" layers and LULC in the QGIS software.

It is possible to cut the LULC directly to the shape of the polygon or to do it in the next step. In this example, we have chosen to categorize LULC into different classes. All you have to do is change the symbology of the LULC layer using the "categorized" symbol type and selecting

the value with which we want to categorize the polygon. Next, change the style and select a style downloaded with the data for the exercise (**Figure 121**).

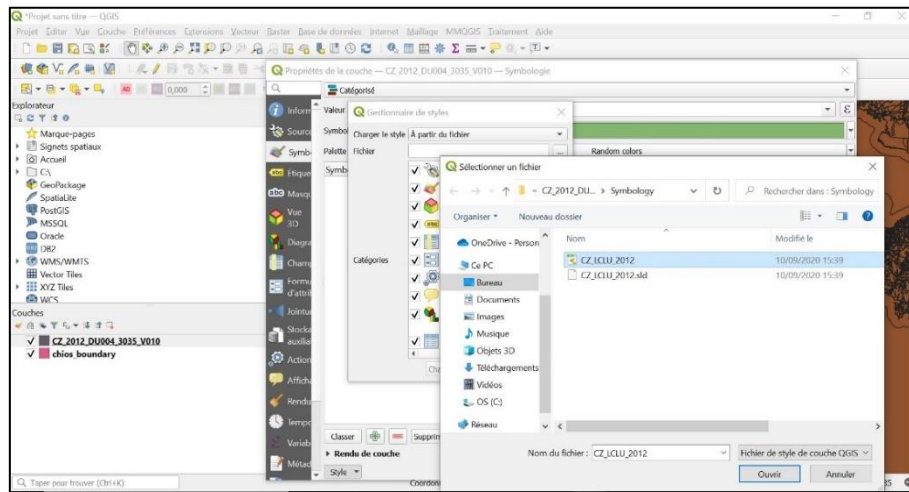


Figure 121 : Overview of the path to change the style of LULC.

We then obtain the map of Europe of several colors corresponding to different types of land cover (**Figure 122**).

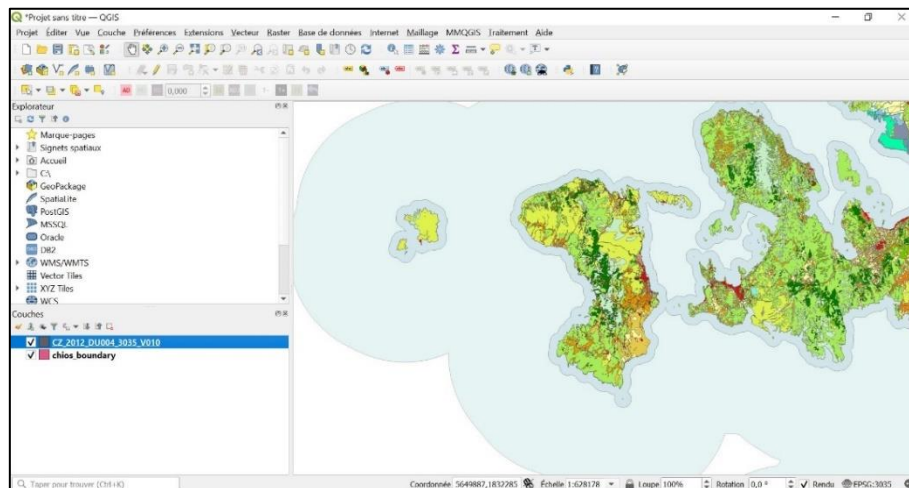


Figure 122 - The result of changing the style of the LULC layer.

To make loading in QGIS faster, it is important to cut the studied area with the "Cut" tool (**Figure 123**).

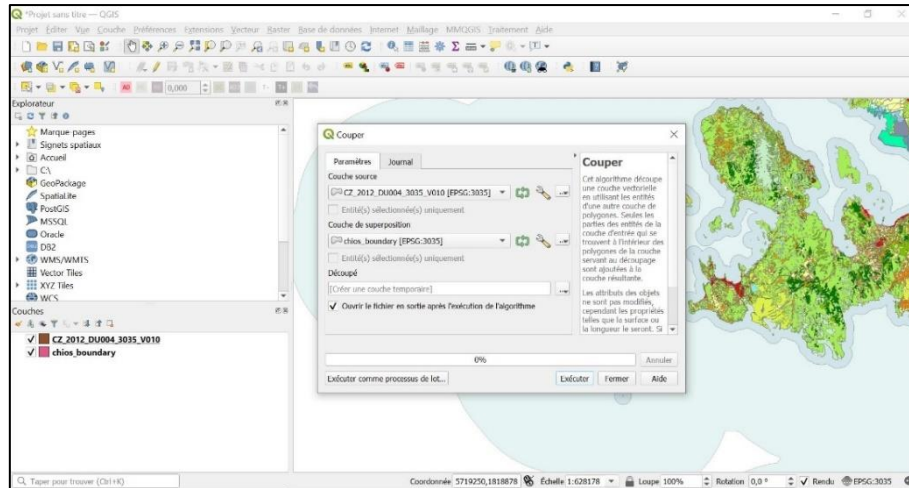


Figure 123 : Using the "cut" tool.

We then obtain the following result (**Figure 124**):

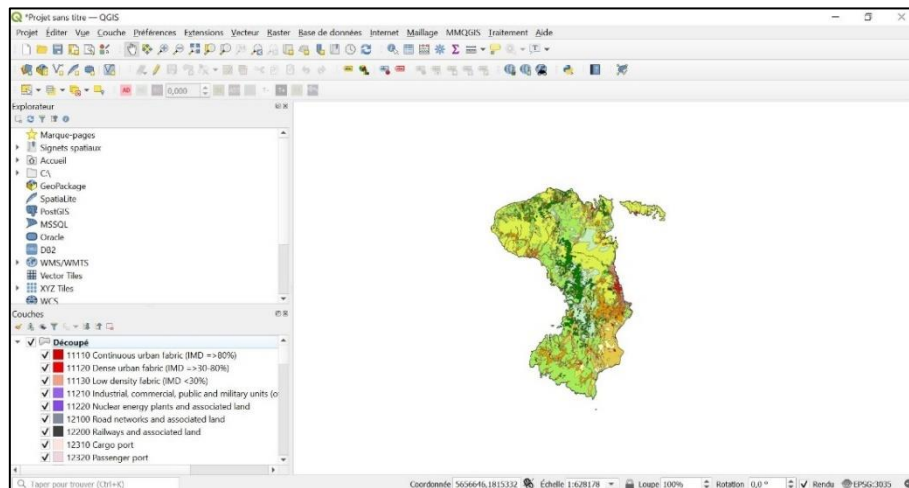


Figure 124 : Result of cutting the LULC layer.

Next, it is requested to add Google Earth in order to visualize the vegetation differences between the LULC and the aerial view (**Figure 125**).

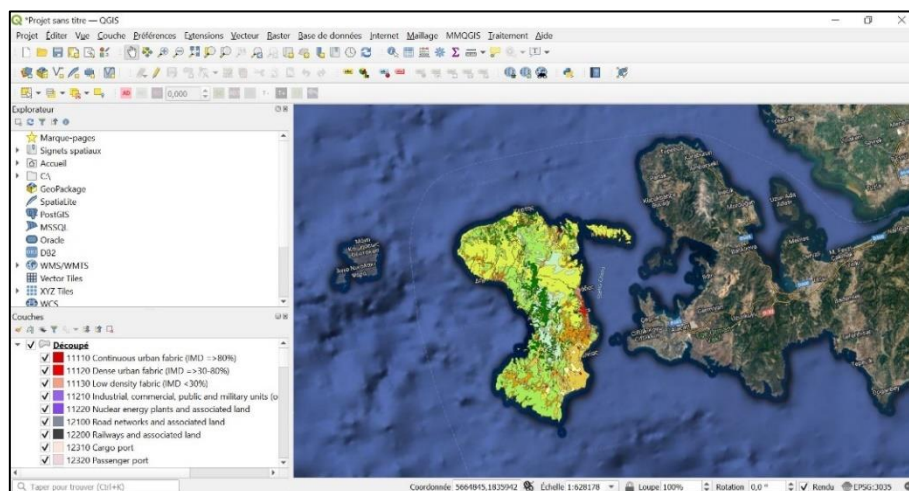


Figure 125 : LULC layer superimposed with the aerial view of Google Earth.

The next step is to add a DEM layer. DEM layers are raster-like layers presented with the ".tif" extension (**Figure 126**).

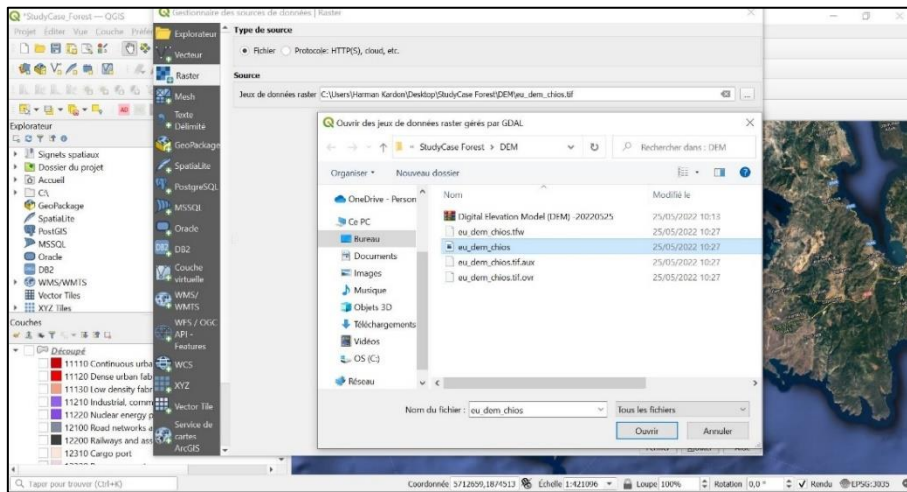


Figure 126 : The path to add the DEM raster layer.

We then obtain a raster type layer of the different altitudes on the island of Chios. It is possible to modify the style by categorizing it with the different altitude levels, but this step is not mandatory (**Figure 127**).

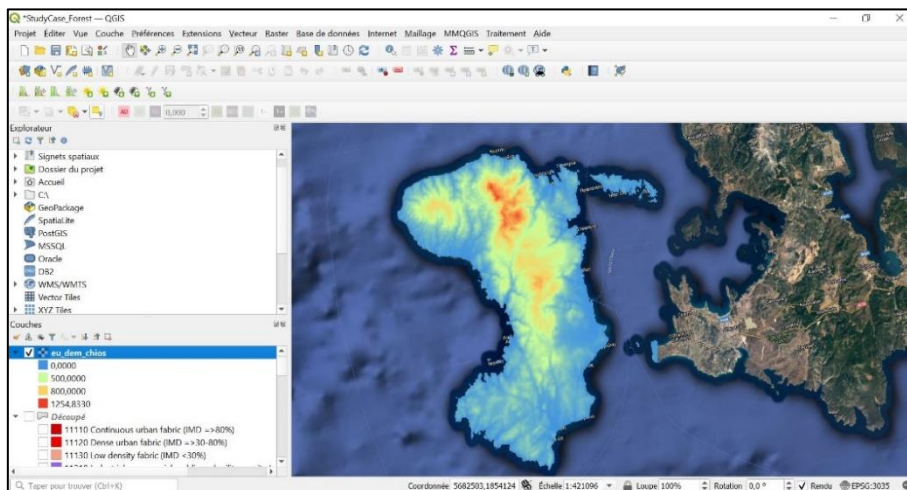


Figure 127 : Categorization of the different altitude levels.

Next, the raster must be reclassified using the "reclassify by table" tool. This step will assign a new value based on the ranges specified in a fixed table (**Figure 128**).

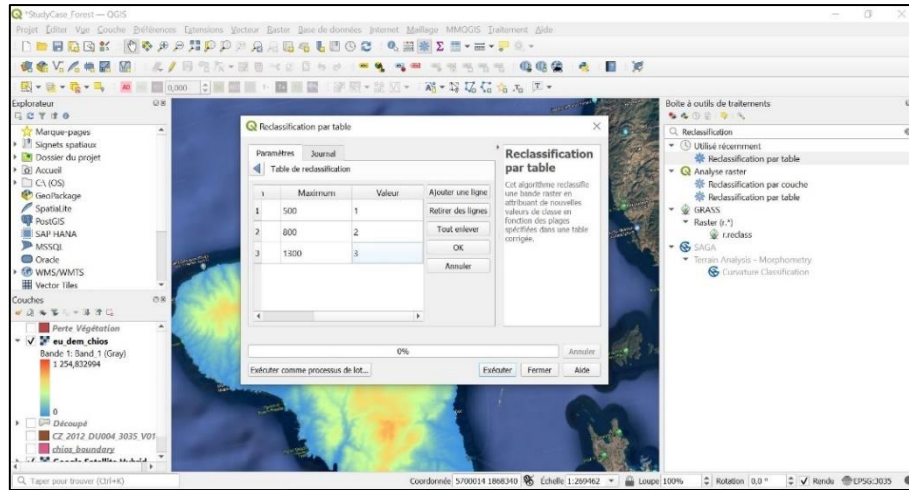


Figure 128 : Preview of the table to modify using the "reclassification by table" tool.

We then get a map with only three different elevation zones (Figure 129).

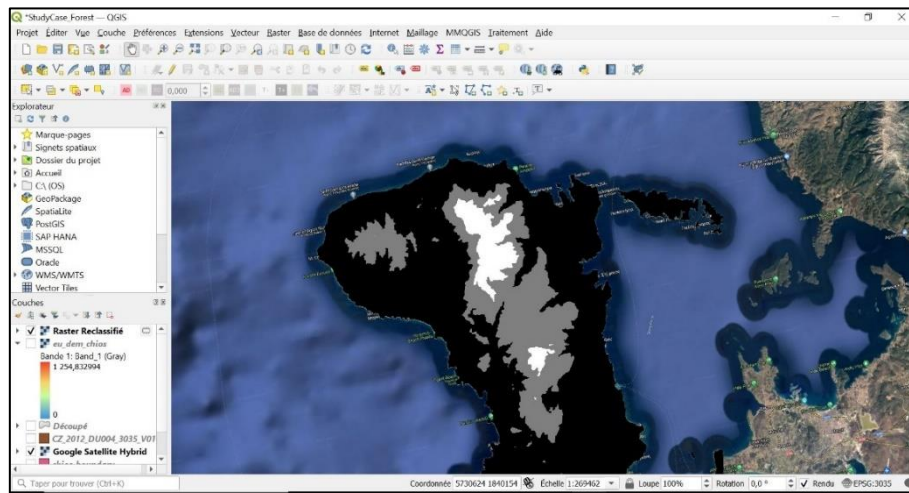


Figure 129 : Result obtained by reclassifying the raster layer to DEM.

Then, it is asked to polygonize the DEM raster into a vector using the "polygonize" tool. This tool creates a polygon with an attribute indicating the pixel value of the polygon (Figure 130).

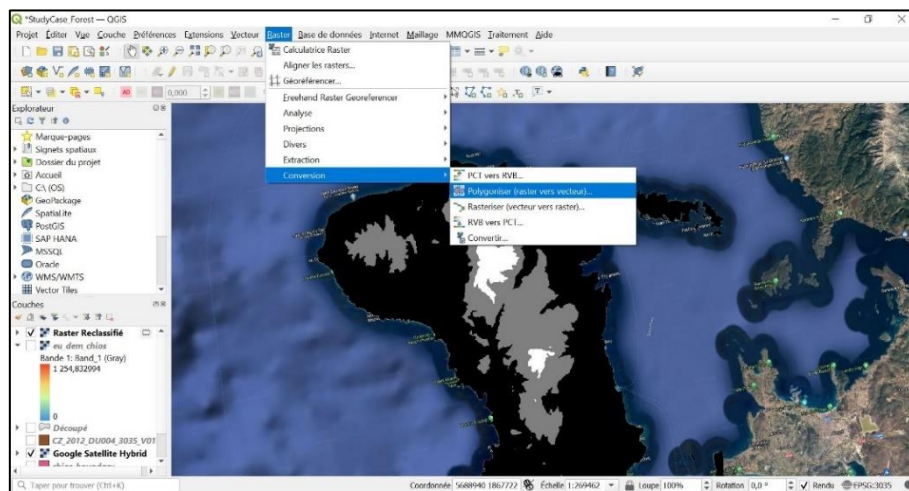


Figure 130 : The path to follow in order to polygonize the raster layer into a raster layer.

It is therefore possible to merge the layers of the vectorized DEM and those of the LULC using the "intersection" tool (**Figure 131**).

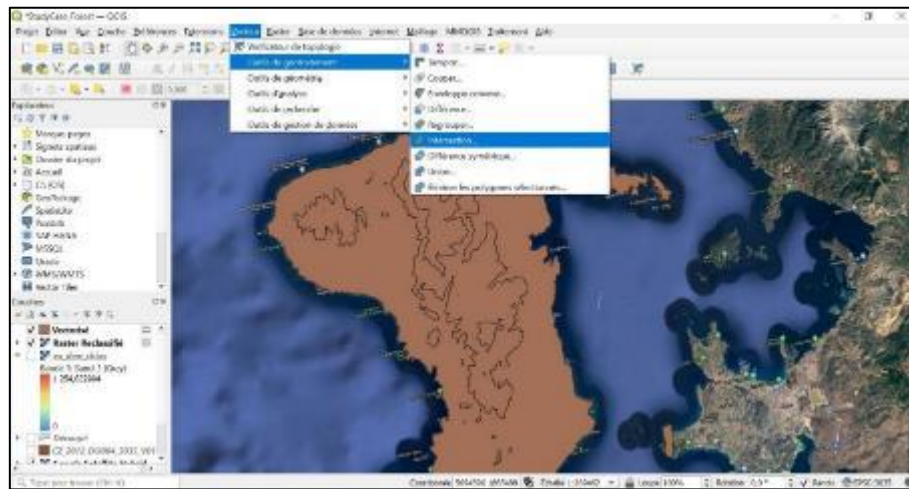


Figure 131 : Path to follow in order to use the "intersection" tool.

The result obtained then corresponds to the two merged layers, in color the LULC and the black lines the limits of the three different altitudes of the DEM (**Figure 132**).

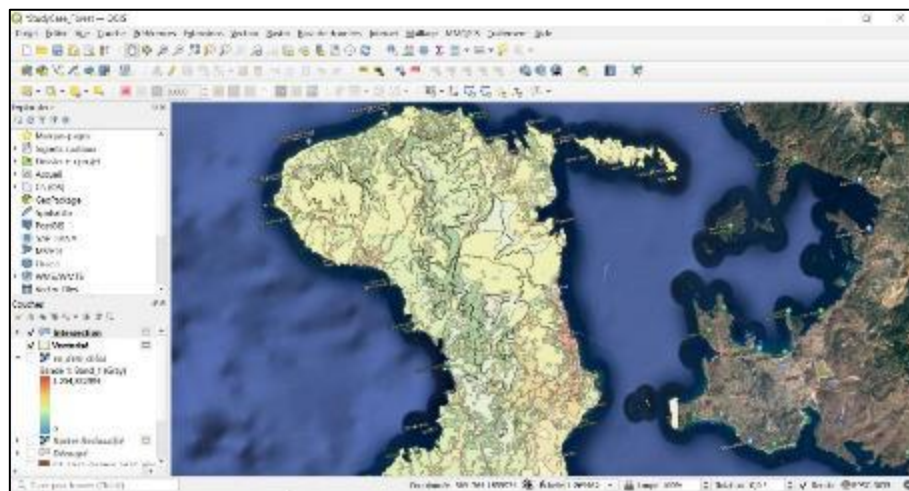


Figure 132 : The result of using the "intersection" tool merging the LULC layer and the boundaries of the DEM altitude zones.

Finally, the final step is the creation of a map representing changes in vegetation cover, whether it is a gain in forest or a reduction in forest (**Figure 133**).

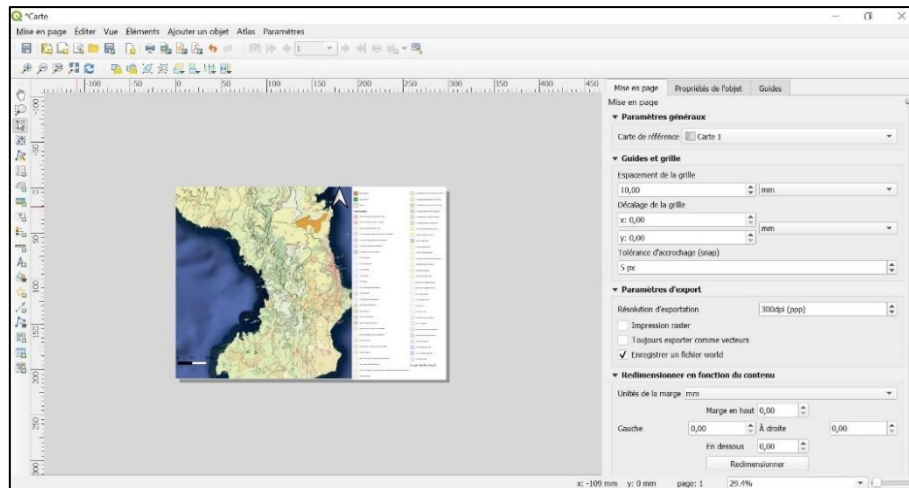


Figure 133 : Creation of the cartographic representation representing changes in vegetation cover as a function of altitude.

Finally, it is possible following this practical case to determine what are the changes in vegetation cover in the three different altitude zones. In the area closest to the sea, vegetation cover has increased, while in the highest area at higher altitudes it has decreased. On the other hand, it remains unchanged in the average altitude zone.

4.2 Health Case Study

This second **case study is intended for online data search** and the **use of online tools**. The sector studied is the European city of Brussels in Belgium. This case study is created to test the skills learned during the courses, aiming to determine the rate of people vaccinated in each neighborhood of the city. The goal is to make a preliminary study of vaccinations in order to plan a new vaccination campaign (**Figure 134**).

Where and in which range of ages should the vaccination campaign be focused ?
 What you have learned for matching Covid vaccination data and GIS visualization of webscrapped datasets ?

Figure 134 : Health Case Study Objectives, available on the FuseGI platform.

As with the first case study, the steps to follow are available on the FuseGI platform (**Figure 135**).

1. Find the *.Json map file with municipalities borders
 - ✓ *Course 4 (hint – import data)*
2. Web Scraping of population data (from wikipedia or Ministry website)
 - ✓ *Course 9 (hint – Web Scraping)*
3. Cleaning the dataset (Excel, PowerQuery) & matching the 2 datasets (population, vaccination, revenues)
 - ✓ *Course 9 (hint – clean data)*
4. Insert excel data to an attribute table
 - ✓ *Course 2, 4 (hint – attribute table)*
5. Create a simple calculation between the 2 data sets : Vaccination rate = (vaccinated people)/(municipality population)
 - ✓ *Course 2, 4 (hint – statistics, attribute table)*
6. Create map using the right scale of colours
 - ✓ *Course 6 (hint – map layout)*
7. Observe, explain and finally publish your results online :

Figure 135 : Steps to complete the health case study.

After downloading the data available on the FuseGI platform, we must add the polygon layer representing the city of Brussels and the different districts on QGIS (**Figure 136**).

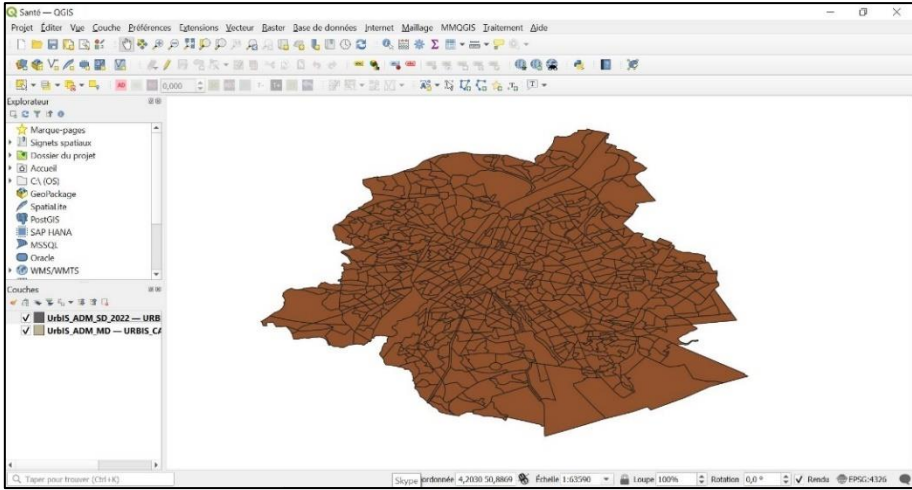


Figure 136 : Preview of the "polygon" layer added in the QGIS software.

Then, after finding the necessary data on the internet, it is possible to load this data on a spreadsheet, such as Excel, by adding the data "from the web" (**Figure 137**).

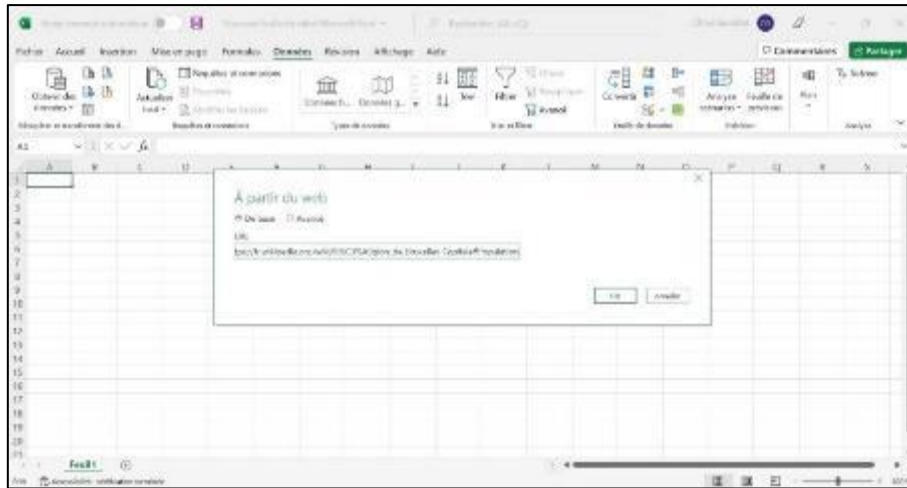


Figure 137 : Overview of loading data "from the web" into an Excel spreadsheet.

The data can then be exported to QGIS, or can be used with on-line processing tools (**Figure 138**).

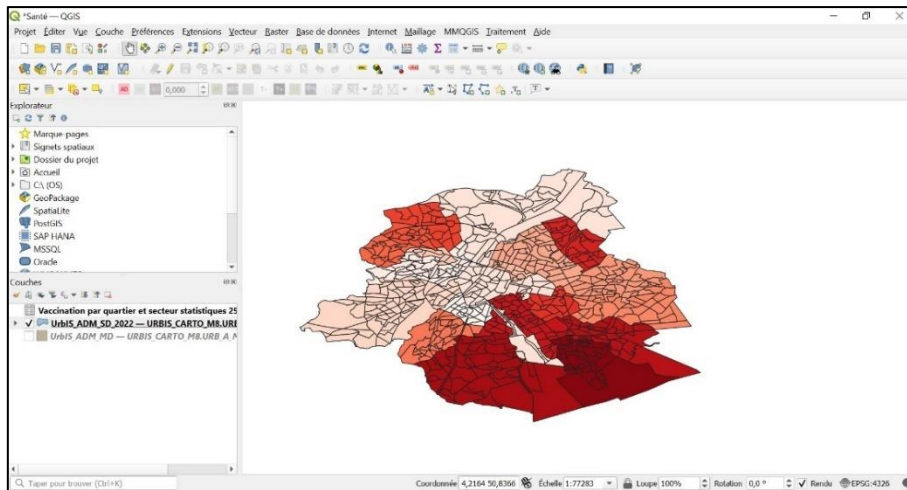


Figure 138 : Data processing using QGIS software.

Finally, the last step is the creation of the cartographic representation of the vaccination rate by neighbourhood in Brussels (**Figure 139**).

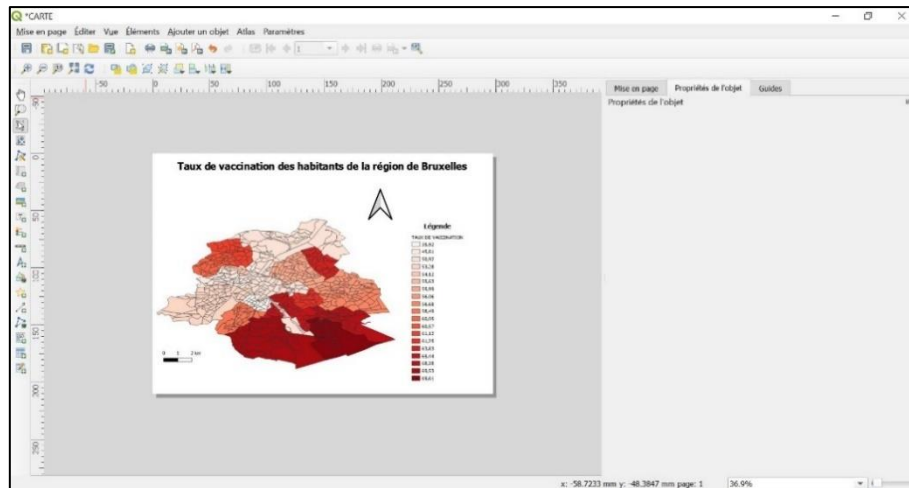


Figure 139 : Creation of the graphical representation of the vaccination rates of the inhabitants of Brussels using the QGIS software.

After making such a map, whether using QGIS or online tools, it is then possible to determine in which neighborhood it is important to carry out a new vaccination campaign.

4.3 Case Study 1 in Hydrology

This third case study is **intended to use useful tools in the case of a hydrological study**. In this exercise, users of the platform will have to assess the alteration of the coastline of a lake in Greece, which affects the residential areas and land use around it.

This case study is created to test the skills acquired during the courses, aiming to **map changes in water bodies and alterations in lake hydromorphology (Figure 140)**.

Basic question

How were the lake and its rivers modified in a 45-year period affecting the coastal area?

Figure 140 : Objective of the hydrology case study n°1, available on the platform.

The instruction for this exercise is given in the form of a succession of steps to follow **(Figure 141)**.

1. Georeference both images
 - ✓ Course 4 (hint – georeference)
2. Digitize coastline
 - ✓ Course 4 (hint – polygon)
3. Create a buffer zone of 200m starting from the coastline towards the inland area (coastal habitat zone) for both years
 - ✓ Course 5 (hint – geoprocessing)
4. Calculate difference in lake perimeter (m), lake area (m²), and buffer area (m²) among years
 - ✓ Course 2, 4 (hint – attribute table)
5. Find what kind of Land Uses (CLC lvl2) substituted the area that used to be covered by water
 - ✓ Course 5 (hint – spatial analysis)
6. Place images on DEM
 - ✓ Course 8 (hint – SAGA > Terrain Analysis) or Course 7 using GRASS
7. Deploy Hydrographic network using the DEM
 - ✓ Course 8 (hint – SAGA > Hydrology > Channels)
8. Calculate Strahler order
 - ✓ Course 8 (hint – SAGA > Hydrology > Calculate Strahler Order)
9. Define lake catchment area and all sub-basins
 - ✓ Course 8 (hint – Catchment area) or Course 7 using GRASS
10. Create a map pointing out the differences in LULC of the coastal habitats (buffer) with fully deployed hydrographic network
 - ✓ Course 6 (hint – map layout)

Figure 141 : List of steps to complete the case study, available through the FuseGI VLE platform.

After downloading the two aerial photographs of the lake dating from 1969 and 2016, you must launch the QGIS software to georeference the photographs (**Figure 142**).

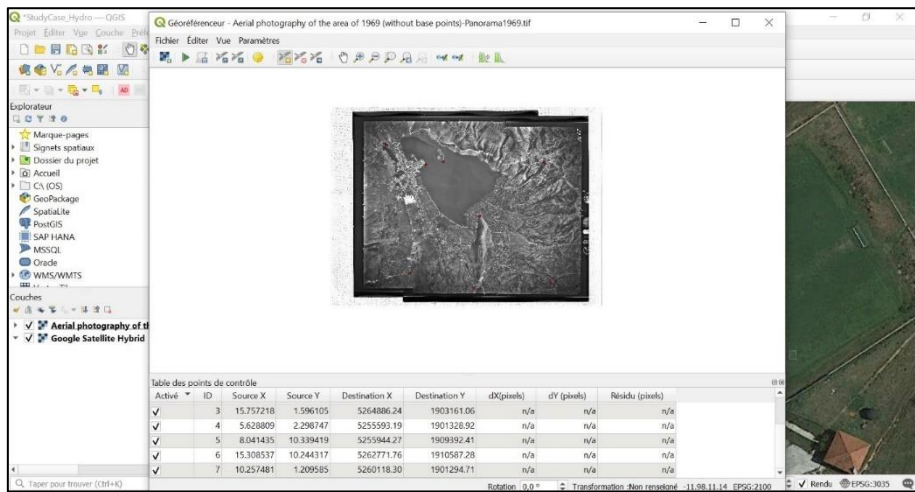


Figure 142 : Georeferencing of an aerial photograph, with QGIS software.

Georeferencing makes it possible to obtain aerial photographs of the lake at exactly the same location as the lake observed with Google Satellite (**Figure 143**).

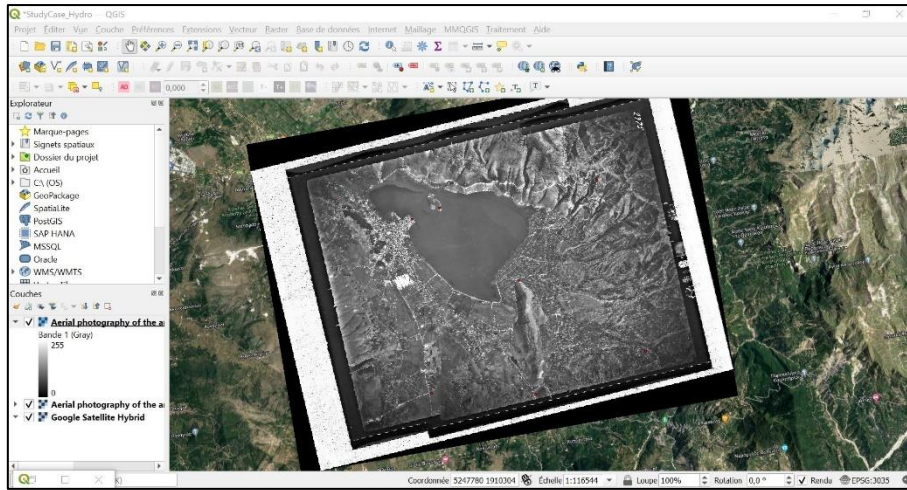


Figure 143 : Georeferencing result of aerial photography.

Then, we must digitize the shores of the lake by adding a new Shapefile layer (Figure 144).

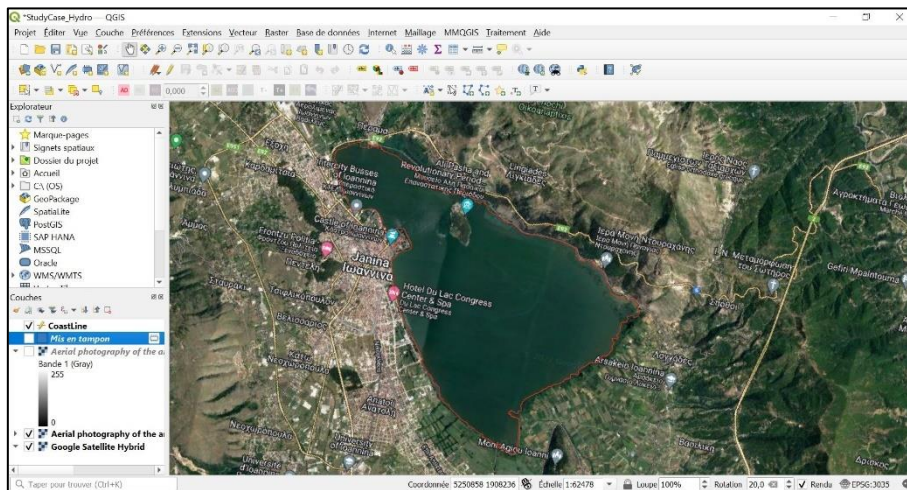


Figure 144 : Definition of the shores of the lake by creating a shapefile.

It is then possible to use the "buffer" tool to create a 200-metre buffer zone from the lake shore (Figure 145).

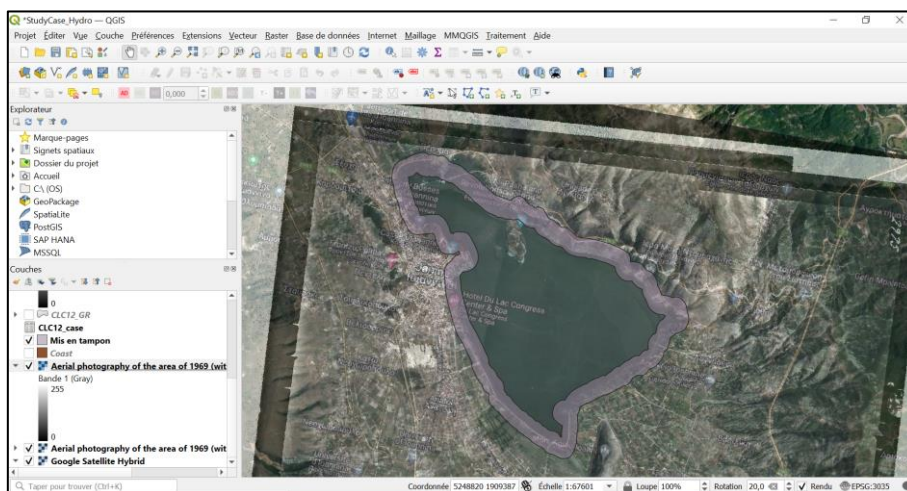


Figure 145 : The result of using the "buffer zone" tool.

Using the attribute table and the field calculator tool, it is possible to calculate the lake perimeter, lake area and buffer zone area (**Figure 146**).

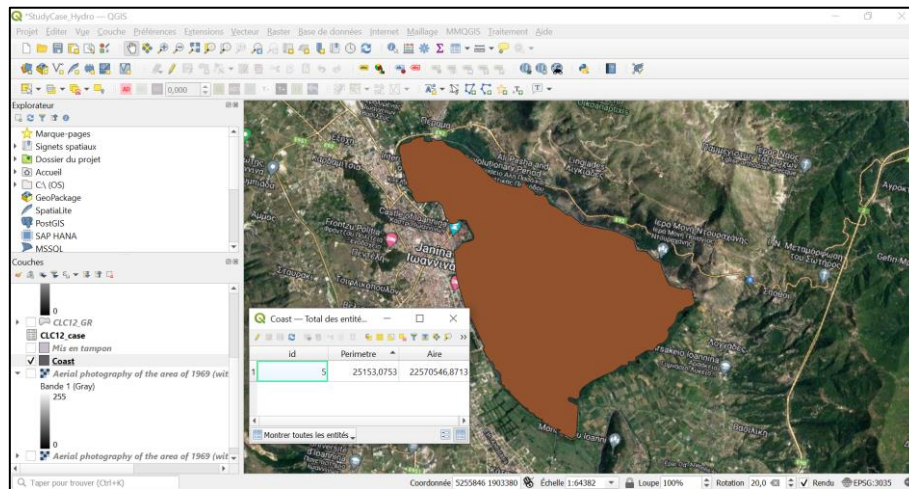


Figure 146 : Calculations of the perimeter and area of the lake, using QGIS software.

By spatially analyzing the area, it is possible to find out how the land around the lake is used over the years. Then the DEM can be added. To facilitate its use, use the "cut" tool to obtain the DEM for the lake area only and avoid excessive loading times (**Figure 147**).

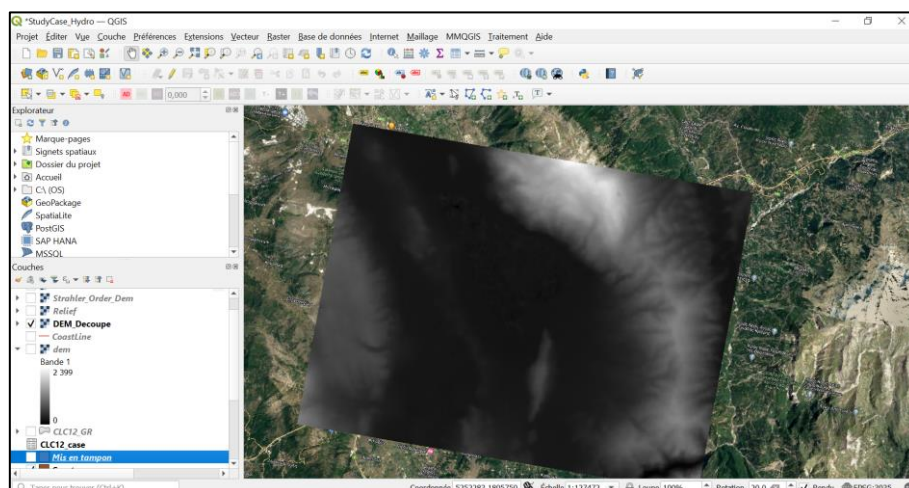


Figure 147 : Added the trimmed DEM layer in the QGIS project.

With the help of the DEM layer, it is then possible to start the more in-depth hydrological analysis, such as highlighting the hydraulic network in the area studied (**Figure 148**).

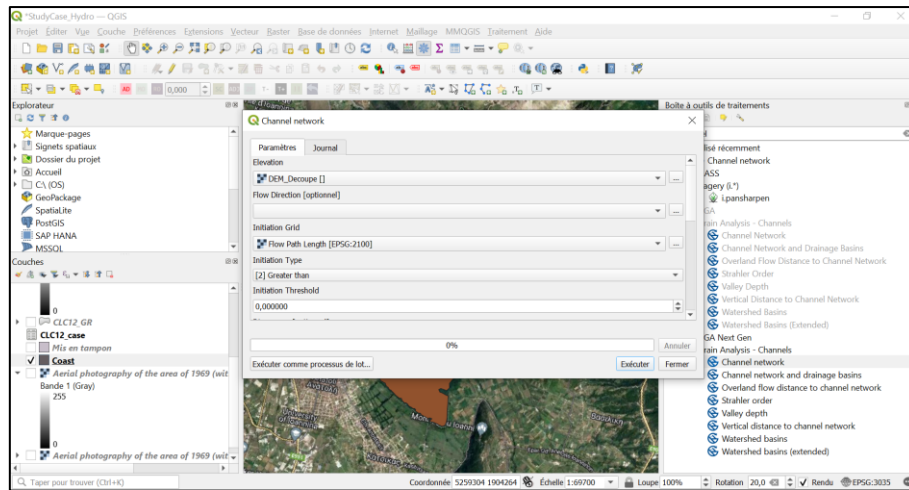


Figure 148 : Use of the tool "SAGA - channel network" to highlight the hydraulic network of the sector studied.

The hydrological study continues with the use of the SAGA tool "Strahler Order" (**Figure 149**).

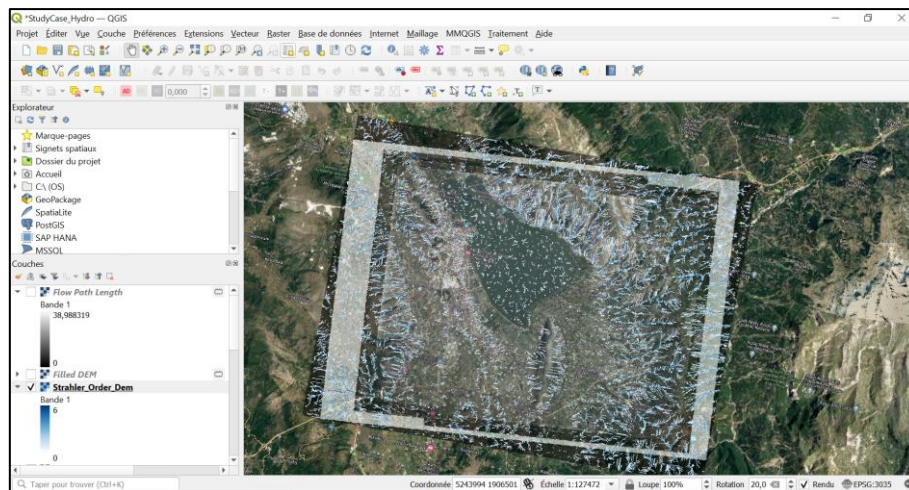


Figure 149 : Result obtained after using the "SAGA - Strahler Order" tool in the QGIS software.

And finally, we want to define the watershed of the lake as well as the sub-basins. For this, it is necessary to use a last SAGA tool available in QGIS, the tool "catchment area" (**Figure 150**).

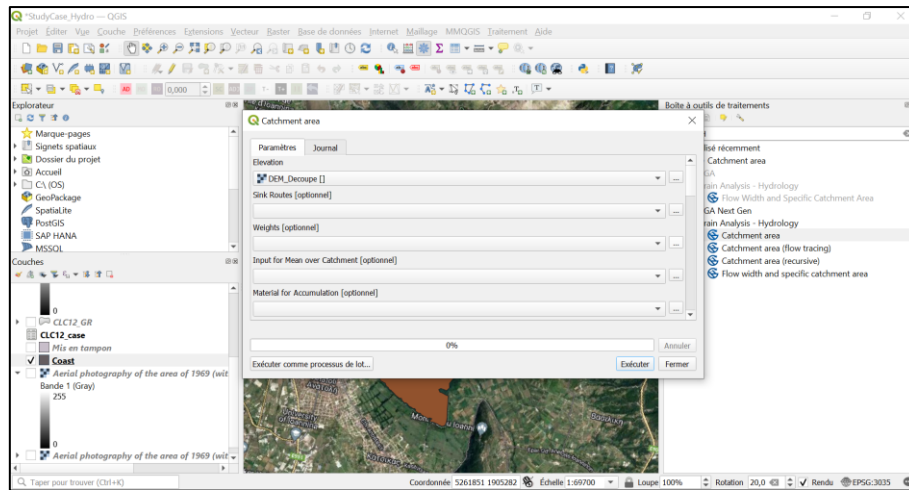


Figure 150 : Using the "SAGA - catchment area" tool in the QGIS software.

At the end of this analysis, it is possible to create a cartographic representation of the area studied (**Figure 151**).

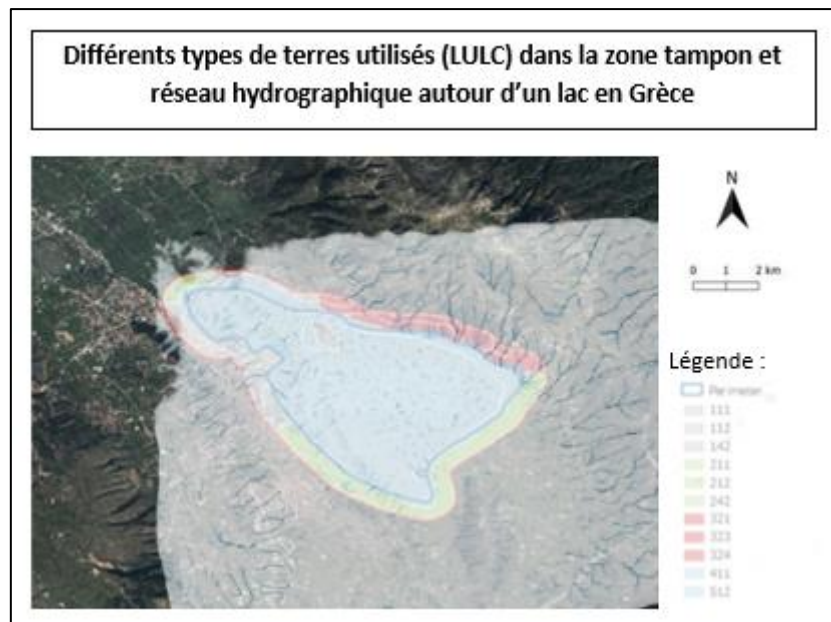


Figure 151 : Cartographic representation of the different types of land used (LULC) in the buffer zone and the river network around the lake in Greece.

4.4 Case Study 2 in Hydrology

This last **case study is intended for the handling of the attribute table**. In this exercise, users of the platform will have to prioritize rivers according to their sensitivity, using several criteria in the perspective of climate change, in the PACA region in France. To do this, you will first have to download the data from the "provided material" section on the FuseGI platform. The steps to complete this case study are also available on the platform (**Figure 152**) (**Figure 153**).

At the end of this work, we should be able to assess a degree of sensitivity (from low to high) to each section of rivers (WFD Surface Water Body), based on information provided by several existing databases, and better direct the program of measurements.

- Select the water bodies whose linear is entirely within the scope of the PACA region
Use the MDORiviere and Région_PACA tables
- Select appropriate column from existing databases or spreadsheet to meet chosen criteria
We want to cross the pressures related to the low water level of a river with the altitude of the catchment area, which are two contributory factors to strong thermal variations. The statistical processing of the monitoring data shows that the temperature range (variability) mostly characterizes the mid-mountain sectors and, to a lesser extent, the high mountain territories.
- Assign degrees for each assessment (3 numerical levels)

	Field	Evaluation	Coding
Low water pressure	low water levels	Low	1
		Medium	2
		High	3

	Field	Evaluation	Coding
Altitude of Water Body	Alt_cat	LOW	1
		HIGH	2
		MID	3

Figure 152 : List of first steps in this Hydrology 2 case study, based on the FuseGi platform.

- A cross-checking must be carried out with these two criteria in order to get three levels (low = 1, medium = 2, high = 3) in a new column and a new row (variations being amplified by low water level of the river and low water renewal):

		Altitude of Water Body		
		1	2	3
Low water pressure	1	Low	Low	Medium
	2	Low	Medium	High
	3	Medium	High	High

- The other criteria are added to the result obtained by crossing, to have a total maximum score of 10 at the end.

	Fields	Criteria	Coding
Influence of groundwater	Geol_cat	C	0
	CE_exogene	if CE_exogene and S	0
		S	+1

	Evaluation	Coding
Pressures on hydromorphology	Low influence	+1
	Medium influence	+2
	High influence	+3

	Evaluation	Coding
Pressures on riverine system	Low influence	+1
	Medium influence	+2
	High influence	+3

- Categorize the total score (number of classes and interval of your choice) to get a spatial representation of the target area.

Figure 153 : List of final steps in this Hydrology 2 case study, based on the FuseGi platform.

After opening the QGIS software and adding the region layer as well as the MDORiviere layer, it is possible to cut the MDORiviere layer in order to keep only the part concerned by our case study, i.e. the part of the PACA Region. You must then add the downloaded table by following the following path "layer", then "add a layer", then "add a spreadsheet layer". Then, in order to facilitate the processing of data between the table and the cut MDORiviere layer, it is necessary to go to the parameters of the latter and create a join between the two layers (Figure 154).

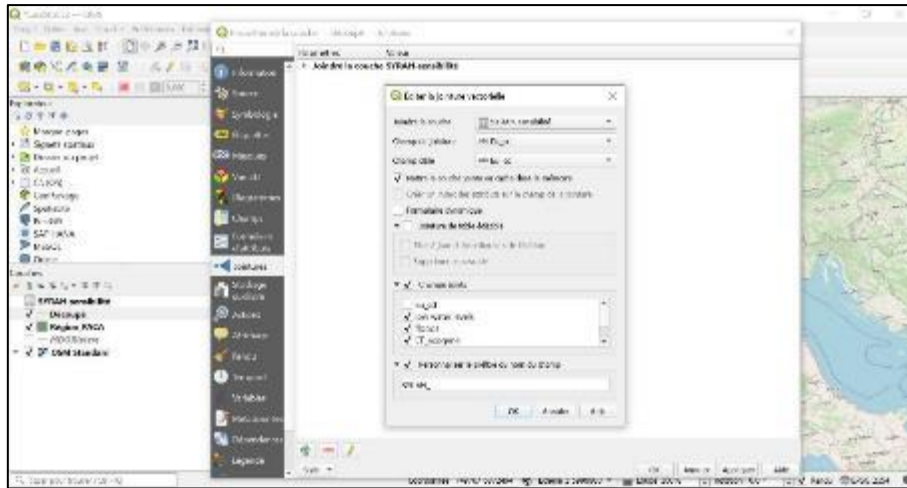


Figure 154 : Steps to join the table and the MDORiviere layer in the QGIS software.

Once the join is done, when we open the attribute table, we find both the attributes of the MDORiviere layer cut and those of the table (Figure 155).

ID	RIVER	RIVER_NAME	RIVER_CODE	RIVER_LENGTH	RIVER_WIDTH	RIVER_DEPTH	RIVER_VELOCITY	RIVER_DIRECTION	RIVER_FLOW	RIVER_VOLUME	RIVER_CAPACITY	RIVER_SENSITIVITY	RIVER_STATUS	RIVER_PRIORITY	RIVER_IMPORTANCE	RIVER_QUALITY	RIVER_HEALTH	RIVER_SECURITY	RIVER_RISK	RIVER_VULNERABILITY	RIVER_RESILIENCE	RIVER_ADAPTABILITY	RIVER_TRANSFORMABILITY	RIVER_INTEGRITY	RIVER_VITALITY	RIVER_FLOURISHING	RIVER_THRIVING	RIVER_SUSTAINING	RIVER_PERSISTING	RIVER_ENDURING	RIVER_SURVIVING
115	LOW	LOW	LOW	LOW	MEDIUM	HIGH	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
116	MEDIUM	LOW	LOW	LOW	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
117	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
118	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
119	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
120	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
121	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
122	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
123	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
124	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
125	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
126	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
127	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
128	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
129	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
130	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
131	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
132	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
133	MEDIUM	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
134	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW

Figure 155 : Preview the attribute table after joining the two layers.

It is then possible to perform all the steps of data classification thanks to the attached attribute table and to obtain the most sensitive rivers in the face of climate change (in red) and those least sensitive (in white) (Figure 156).

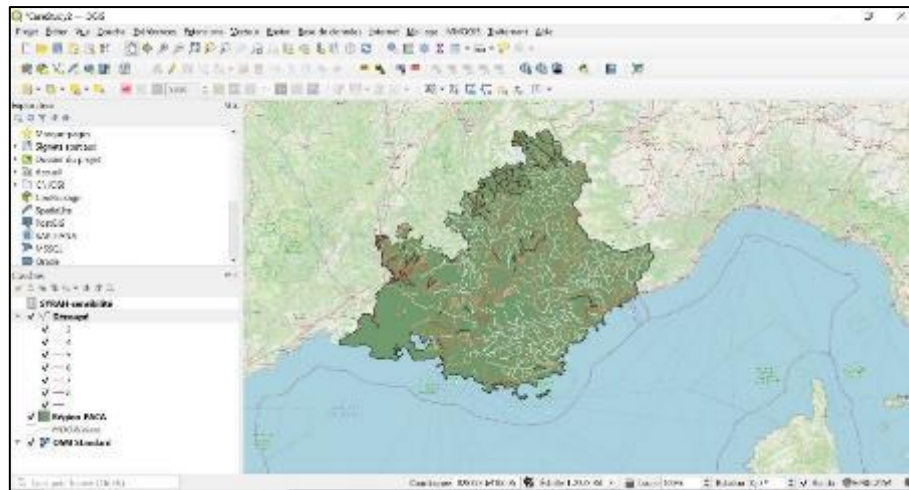


Figure 156 : Result after classification of data, in red the most sensitive rivers and in white the rivers least sensitive to climate change.

5 Innovation, Tangibility and Transferability

IO4 training toolkit assists end users to deal with geospatial data and their transformation into trustworthy and actionable information; through GeoInformatics (GI), which include a number of different technologies, processes, and methods that allow the effective acquisition, processing and analysis of accurate and up-to-date geospatial data. Concerning Quality indicators measurement, 9 training videos and an equal number of guides were developed to assist new GIS users to get familiar with commands processes and applications' usefulness and to also work as a guide for more GIS-experienced users. Two different types of modules (teaching and/ or training) are supported and more are considered (with modifications) giving the possibility for the toolkit to be included even in life-long learning courses.

Innovation

The teaching material produced contains several novel and innovative elements, which can be found from the design phase up to the teaching phase, as:

- All materials in the toolkit are novel, free of rights and created within the consortium.
- It assists the enhancement of competencies of professionals supporting digital education.
- It bridges academic and professional needs in different key environmental and health sectors.
- It covers simultaneously market skills gaps and educational/cognitive ones.
- It supports distance training novelties: different forms of communication and learning (Hybrid supported besides asynchronous through chats), two-way evaluation process, self-assessment, supplementary data provisioning, without fixed time courses but of relative duration
- It endorses different teaching methods: connection making, increased autonomy, no limits hands on practice.

Tangibility

A lot of effort was put, in order to create tangible results, since design phase of the teaching material, as:

- Has homogenous but yet flexible structure for each course within the VLE.
- Offers ability for adaptation and evolvement, i.e., adaptive international curriculum (from postgraduate to continuing education for engineers) targeting skills acquired in GIS.
- Adopts no discrimination policy with provision for inclusive and equitable online learning environment

Transferability

The main concept was to develop a tool that could easily be transferred and either adopted as it is or evolved, depending on the users' needs. Having this in mind the two major aspects were covered:

- The toolkit supports openness in all stages: the entire tool is based on freeware (QGIS) supporting openness in its entity using explicitly creative commons rights, open data, open courses and free books and manuals in the PowerPoints and in the supplementary material and operating through an open VLE platform. This also enhances the innovative character of the produced toolkit.
- This IO includes a detailed methodological approach, with rational explanation, which is easily transferable to other developers.