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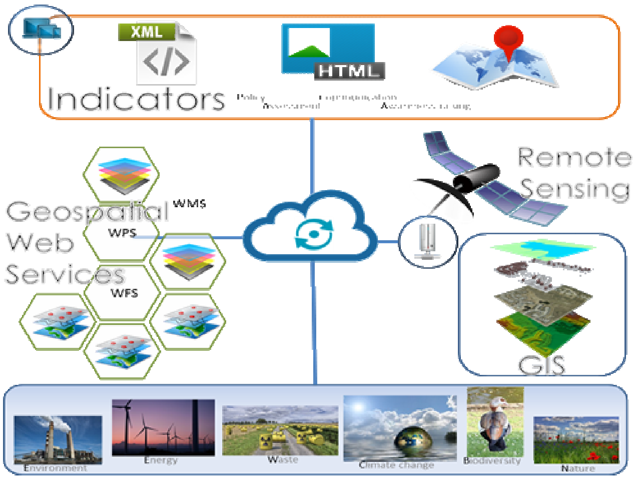

GEOINFORMATION TECHNOLOGIES FOR ENVIRONMENTAL CHANGES AND PRESSURES ASSESSMENT

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	Technological Institute of Central Macedonia
	Universita degli Studi di Trento

Environmental learning innovation for more knowledge and better jobs - EnvYJobs -

At the global level it is already known our dependence on a healthy environment and the fact that environmental problems go over national and regional borders. We are all agree that, to these kinds of challenges we can answer just through concrete and coordinated actions at EU and international level. To achieve this aim we need adequate training and access to higher and actual skills through better education and training systems. Mutual learning in field of environmental engineering between important and experimented actors in European higher education system using the exchange of good practice and implementing innovative tools and instruments is the rationale of the EnvYJobs project.

Concerning the knowledge triangle work, the EnvYJobs project starts from the idea that higher education is in the middle of a triangle formed by three important connected points: education, innovation and employability.

The project *Environmental learning innovation for more knowledge and better jobs - EnvYJobs* follows to enhance students' knowledge in environmental engineering and to make their skills and competences more attractive for stakeholders.

EnvYJobs project implementation has as principal components e-learning solutions, laboratory technologies related to the curriculum content and live laboratories which are allowing an empirical study and sociability in creating student presence for remotely accessed knowledge concerning environmental issues.

The target group of the project is composed of 120 students enrolled in the University POLITEHNICA of Bucharest, University of Trento and Saxion University of Applied Sciences. Of the total 120 students, 70 will come from the University POLITEHNICA of Bucharest - Romania, 20 from University of Trento - Italy and 30 from Saxion University of Applied Sciences - The Netherlands. Students who will attend the training session will be selected by partner universities according to a selection process established by project consortium at the beginning of the project.

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INTRODUCTION

Environmental changes are the result of human activities and interferences to the environment, as well as of natural processes. Especially, human production and consumption patterns exert environmental pressures which in turn affect the state of the environment, in terms of healthy conditions provision, resources availability and biodiversity. The above are reflected to assessment frameworks adopted by European Union and the related environmental information is expressed and assessed through special environmental indicators.

Current status on recent environmental trends and policy developments at EU and national level are reported in the Annual Environment Policy Review (EPR). According to the last ERP published in 2009 the DPSIR (Driving forces, Pressures, States, Impacts and Response) framework is used for describing the interactions between society and the environment.

There exist strong geospatial aspect on the environmental indicators and a significant relationship, interaction and overlapping among the disciplines covered by environmental sciences and Geosciences. The above justify employment of Geoinformation technologies for Environmental Changes and Pressures Assessment. These, are proved to serve as extremely significant tools for environmental processing, analysis and dissemination purposes.

Based on the above, the presented course is structured in two discrete Parts. The present Part I, which provides the appropriate fundamental background upon which

Geoinformation technologies are applied. Based on European Environment Agency (EEA), the major environmental topics, such as climate change, air pollution, biodiversity, are identified and briefly described. The prevailing frameworks for environmental pressures assessments are then presented. Finally, the established in EU level set of indicators grouped by critical environmental thematic areas, along with representative examples are completing Part I. Part II, provides, two major geoscientific technological areas that will be employed to achieve the course's objectives under DPSIR: a) Geographic Information Systems for analyzing, processing and visualizing geospatial information and b) Geospatial Semantics and Geospatial Web Services for setting the integration and interoperability dimensions.

The main objectives of this course are associated with the ability of the participants to:

- realize the importance of measuring impacts on the environment through appropriate indicators.
- study major indicators and identify their geospatial dimension
- meet the challenges arising from the utilization of geoinformation technologies for measuring indicators and assessing environmental pressures
- understand the DPSIR framework and identify the appropriate indicators for measuring environmental pressures
- apply Geoinformation related technologies to real environmental cases

CHAPTER 1

GLOBAL ENVIRONMENTAL CHANGES

1.1 General

Environmental changes are the result of human activities and interferences to the environment, as well as of natural processes. Especially, human production and consumption patterns exert environmental pressures which in turn affect the state of the environment, in terms of healthy conditions provision, resources availability and biodiversity. In this respect, the European Union (EU) established European Environment Agency (EEA), an agency charged with environmental issues in order to act as an information source for those involved in developing, adopting, implementing and evaluating environmental policy, and also the general public. Up to date environmental topics concerning EU member states are being published in EEA web site[1].

The following paragraphs provide a brief description of some of the above mentioned critical environmental issues strongly related to environmental changes.

[1] http://www.eea.europa.eu/themes

1.2 Climate Change

Time series of the average Temperature of the planet reveal an increase of more than one degree Fahrenheit during the past 100 years or so. Although such a change does not seem to be too big, the consequences related to that may lead to big impacts such as rising of sea levels, melting of glaciers, changing on rainfall patterns and growing seasons. Furthermore it may cause floods, droughts and heat waves resulting to stronger hurricanes.

In a small degree, causes of climate change may be natural, such as variations in Earth's orbit, in solar energy reaching the planet, or changes occurring in oceans and volcanoes.

Mainly these causes are considered by scientist to be coming from anthropogenic activities related to burning of heat-trapping gases, called greenhouse gases (GHG). GHGs are sourcing from burning of fossil fuels (coal, oil and gas) in electricity generation, transport, industry and households (CO_2), agriculture (CH4), land-use changes like deforestation (CO2), land filling of waste (CH4) use of industrial fluorinated gases (EEA, 2016a).

In 2009, EU related legislation aimed to implementing by 2020 the 20-20-20 targets: reducing EU GHG emissions at least 20% below 1990 levels, exploiting renewable resources for up to 20% of energy consumption and reducing 20% of primary energy use compared with projected levels. EU also proposed in 2013, a strategic plan for strengthening Europe's resilience to climate change (EEA, 2016b).

1.3 Air Pollution

Air pollution is considered a significant environmental issue affecting human health and the environment. Corrective actions taken by member states over the past decades resulted to decreased emissions of air pollutants in Europe, which resulted to improvements in air quality levels. However, a significantly high percentage of European citizens are still exposed to harmful air pollution levels due to high concentrations on major air pollutants, therefore air pollution reduction remains an important issue. In addition, due to the nature of the atmosphere the emitted pollutants may be transferred between countries and diffused elsewhere over the whole hemisphere.

Air pollution is the result of anthropogenic activities in sectors such as industry, agriculture, transportation, waste treatment etc., and/or natural processes such as volcanic eruptions, volatile organic compounds emissions from plants.

In terms of human health, almost 90% of inhabitants in Europe are exposed to pollution levels that exceed permissible thresholds and are hardly tolerable. The exposure affections depending on the duration and intensity may vary from impairing the respiratory system to premature death. Air pollutants that are considered to affect human health are particulate matter (PM), nitrogen dioxide (NO2) and ground-level ozone (O3). Beyond health damages, air pollution is responsible for serious environmental damages in ecosystems such as acidification, eutrophication and crop damage (EEA, 2016c). Finally, in economic terms for the year 2012, the cost of air pollution sourcing from industry in Europe is estimated between 59 and 189 billion Euros. It is also estimated that only 1% of the industrial facilities produce emissions to the environment and contribute that way to the 50% of the above mentioned economic damage (EEA, 2014a).

1.4 Biodiversity

A definition about Biodiversity (Levin, 2000) is extracted from the Encyclopedia of Biodiversity: *"Biodiversity comprises all the millions of different species that live on our planet, as well as the genetic differences within species. It also refers to the multitude of different ecosystems in which species form unique communities, interacting with one another and the air, water and soil."*

In the term of Biodiversity all types of genes, species and ecosystems that constitute life on Earth, are included. The anthropogenic activities, such as exploitation of forests and water resources, the agricultural activities, quarrying and constructions and the interrelated to the above climate change, have crucially affected the natural habitants causing obvious loss of biodiversity (EEA, 2016d).

In 2001, Europe had set the ambitious target of halting the loss of biodiversity by 2010, however, according to EEA assessments this target was not met. Now the target in EU level is to speed up procedures and contribute to averting global biodiversity loss and restoring degradation of ecosystem services by 2020.

1.5 Land Use

The need of billions of people for food, water, shelter etc., drive global changes to forests, farmlands, waterways, and air (Foley et al., 2005). These changes result to direct visible on the map changes in the landscape across the time, which are dependent on the way land is used. Furthermore, land is a finite resource and the way that is used affects significantly, quality of life and ecosystems and is considered as one of the principal reasons for environmental changes (EEA, 2016e).

Especially Europe, which is considered as the most intensively used continent of the planet, is a mosaic of landscapes. As member states economies are related to natural resources, land use and land resource management are key points towards resources sustainability. In any case, to conform to climate change adaptation regulations, EU policies are focused on land use practices and the related economic sectors.

From a technical point of view land use is an environmental topic that is properly studied by use of geoinformation technologies such as Geographic Information Systems (GIS) and Remote Sensing (RS). The database form the CORINE (Coordination of information on the environment) program provides valuable land cover inventories for classifications and cartographic representations (EEA, 2016f).

1.6 Water

Water resources, among others, constitute the state of the environment which is continually under threat from a variety of pressures. These pressures are forced by humans and result to freshwater ecosystems pollution, scarcity and excess, a situation known as vulnerability. The interaction between water and other critical environmental

issues such as Land use, climate change and biodiversity or sectors of human activities such as transportation, agriculture and energy, is more than obvious. In this respect EU environmental policy was initially based on ecosystems protection in terms of water quality, quantity and their role as habitats, and expressed through the Water Framework Directive (WFD) introduced in 2000 (EEA, 2016g). The WFD target seemed to have been missed by almost half of Europe's water bodies, according to assessments performed for year 2015 (EEA, 2012a). Today, a comprehensive knowledge base has been built by EEA, containing a series of reports assessing the state of Europe's water, providing valuable assistance to environmental policy makers (EEA, 2016h).

1.7 Soil

There is a complicated interaction between soil, climate change and water. Healthy soils can hold the carbon that is not drawn out of the atmosphere during the photosynthesis, thus mitigating climate change. In terms of temperature, higher values may result to more vegetation and more carbon storage, but can also result to more decomposition of the organic matter and less carbon content. In terms of water affection to carbon dioxide release in the atmosphere: low levels of oxygen in water prevents decomposition of organic matter, therefore a potential drought in such areas will increase GHG emissions and result to higher temperatures (EEA, 2016i). Of course, beyond climate change, also agriculture and forestry affect carbon storage, or release to the atmosphere (EEA, 2012b).

Soils provide the base for human and livestock food, fiber and fuels, however, they are not being considered as the same important environmental factor as air and water. For example, according to EEA (2016j), European directives lack of targets related to soils as well as valid data: a huge difference is noted between the identified (300K) and the estimated (1,5M) contaminated sites in EU. Other important problems and threats to soils in Europe include loss of top-soil due to erosion or building activities, acidification, sealing, a decline in soil biodiversity and desertification. EU actions are limited to soil assessments and analyses as well as data quality improvements in order to study causes and impacts of any soil deterioration at a continental level (EEA, 2016k).

CHAPTER 2

ENVIRONMENTAL ASSESSMENT FRAMEWORKS

2.1 Assessment Frameworks

Environmental topics, including issues discussed in previous chapter as well as sectors of human activities such as agriculture, transportation and industry, are associated with various types of indicators. Environmental indicators communicate information about progress toward environmental targets and goals. Since this information is directed to policy makers indicators have to be precisely defined. Indicators provide more quantitative information than pictures or words do, imply a metric for measuring aspects of public policy issues, and also provide information in a simple, ready to understand form as opposed to statistics or other data related sciences. Indicators are associated with a model or set of assumptions describing more complex phenomena (Hammond & World Resources Institute, 1995). Indicators are examined in detail in the next chapter. The current chapter focuses on frameworks supporting indicators as regards content framing, development, maintenance and dissemination (EEA, 2014b).

The first framework named STRESS (STress Response Environmental Statistical System) was developed by Statistics Canada and supported indicators measuring stress exerted on the environment, the effects on it and measures of policy response (Rapport & Friend, 1979; Stanners et al., 2007). OECD implemented the “pressure‐state‐response” reporting framework in the 1980s, based on STRESS. Extending this, EEA developed the DPSIR (driving force, pressure, state, impact, and response) framework to structure thinking about the interplay between the environment and socio-economic activities (EEA, 2014b) .EEA also developed the MDIAK (Monitoring, Data, Indicators, Assessments, Knowledge) framework, which considers a number of phases to link generation of information to its final use. DPSIR and MDIAK are studied separately in the next paragraphs.

2.2 The MDIAK Framework

MDIAK focuses on the environmental information itself which should be accurate in order to assist environmental policy. A number of phases are distinguished, from the generation of environmental information until its final use: a) "monitoring" of environmental parameters through observations or measurements, b) "data" refer to structured measurements for further processing and comparisons, c) "indicators" are the result of composite functions on data in order to provide answers on assessment and policy questions d) "assessments" are established by accepted indicators and e) "knowledge" is the valuable information for environmental management and actions by experts and policy makers. Figure 1 illustrates the above phases of the MDIAK chain.

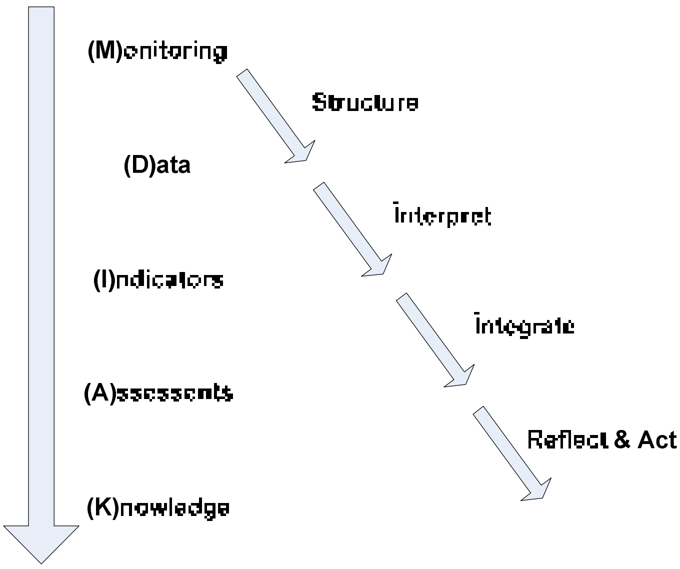


Figure 1: The MDIAK Framework

2.3 The DPSIR Framework

The DPSIR (Drivers, Pressures, State, Impact, Responses) framework was introduced by the European Environment Agency (Smeets & Weterings, 1999) to analyze the relations between environment and humans. A set of critical entities are involved to compose an abstract analysis view as shown in Figure 2 (Kristensen, 2004).

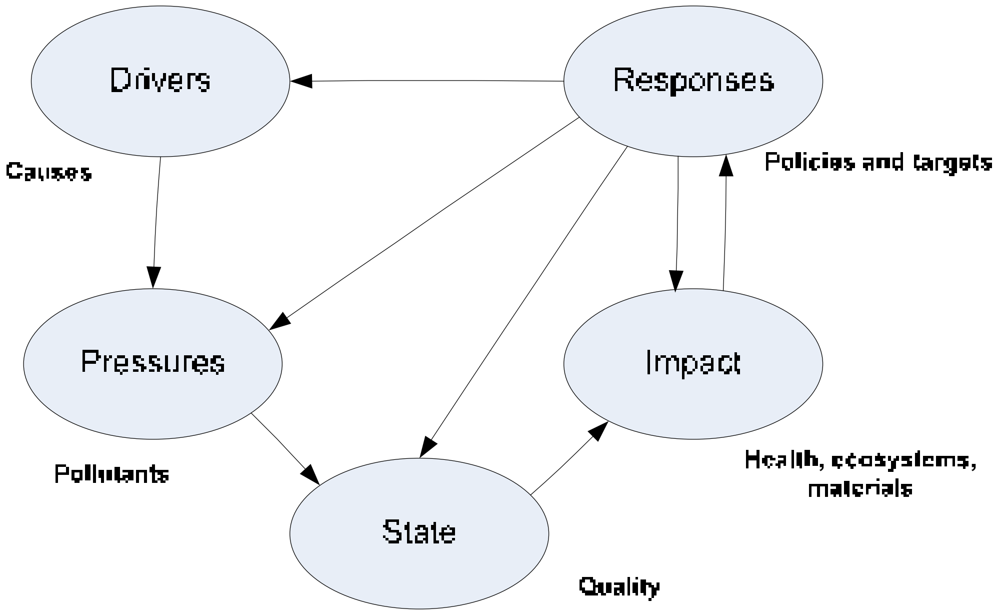


Figure 2: The DPSIR assessment framework

Drivers represent the social and economic developments causing changes which in turn exert Pressures on the environment. Consequently, the State of the environment changes, as regards the provision of adequate conditions for health, resources availability and biodiversity. This leads to Impacts on human health, ecosystems and materials (economy). The above trigger societal and political Responses that affect all other entities directly or indirectly, through adaptation or curative action.

Every single of the above defined on the DPSIR chain, entity, is associated with a variety of indicators belonging to different thematic environment-related areas. This is also a necessity for policy makers as it is obviously important to quantify the above DPSIR interactions. In this respect, Indicators associated with Drivers deal with socioeconomic variations affecting consumption and production patterns, such as for example population growth (Stanners et al., 2007). Pressure Indicators measure substances release such as emissions, physical and biological agents or land and resources use. State indicators provide quantitative and qualitative information regarding physical, biological and chemical variables such as air quality, species diversity and atmospheric compounds concentrations. Impact indicators deal with affections of the above to ecosystems, economy and human health. An example of such indicator is the population exposed to non acceptable noise levels. Finally, Response indicators refer to reactions by policy makers and the society to the aforementioned changes in the state of the environment, such as for example recycling rates (EEA, 2014b).

An interesting and representative example of the DPSIR framework application to environmental noise is presented in Figure 3.

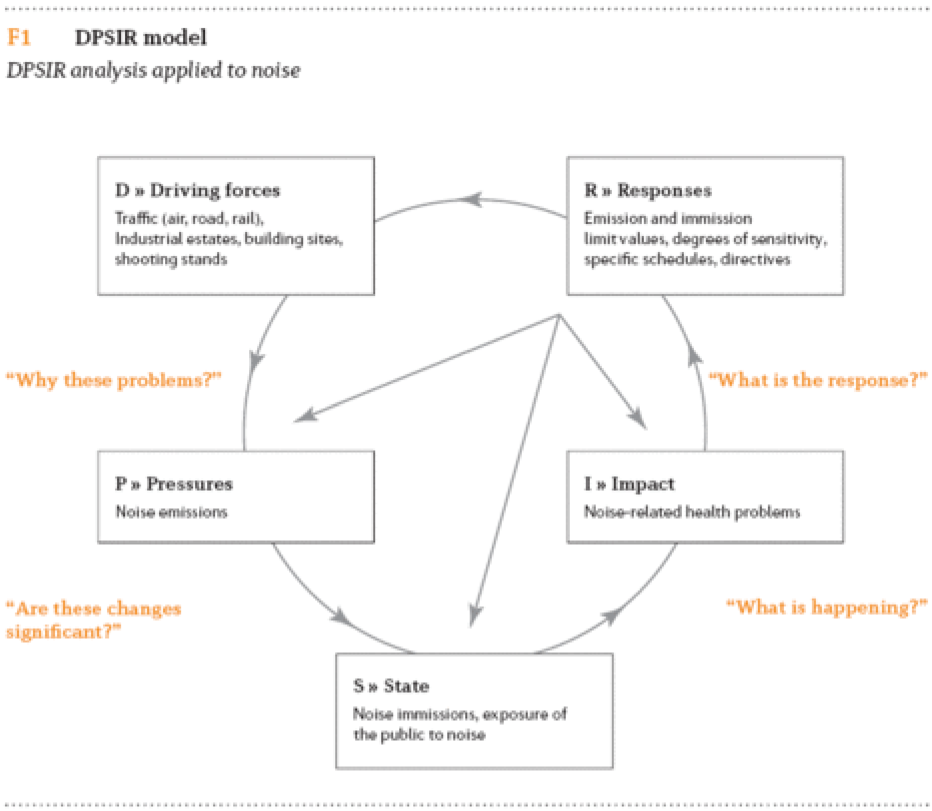


Figure 3: DPSIR analysis applied to noise[2]

According to the example noise sources such as transportation traffic, industrial activities and building sites are the driving forces for pressures exerted to the environment which in this specific example are represented by noise emissions. Noise emissions cause changes in the environment's state since people are exposed to them. As a result impacts on human health are measurable and this triggers responses from the policy makers. Responses implemented through special legislation setting permissible noise limits affect directly all of the above elements of DPSIR assessment framework.

[2] http://www.bafu.admin.ch/umwelt/status/04561/index.html?lang=en

CHAPTER 3

Environmental Indicators

3.1. General

According to European Environment Agency (EEA, 2005), *"an environmental indicator is a measure, generally quantitative, that can be used to illustrate and communicate complex environmental phenomena simply, including trends and progress over time — and thus helps provide insight into the state of the environment"*.

EEA indicators aim to support environmental policy making, and all the phases related to it such as policy frameworks design, specification of policy targets, policy monitoring and evaluation, and communication and awareness to the public (EEA, 2015a).

Environmental indicators used to be extracted from Environment Policy Review (EPR), an annual report issued by European Commission recording environmental trends and policy developments at EU and national level[3]. The 2009 EPR (EC, 2009) comprises four priority areas as specified by the 6th Environment Action Programme[4] each one containing a list of continuously updated environmental indicators: a) climate change, b) nature and biodiversity, c) environment and health and d) natural resources and waste. Until 2009, the European Commission used to publish a leaflet containing information about the trends of ten selected environmental indicators showing improvements made and actions to be taken[5]. Table 1 below presents 33 environmental indicators providing also information concerning their type according to DPSIR framework.

[3]http://ec.europa.eu/environment/archives/policyreview.htm
[4]http://ec.europa.eu/environment/archives/action-programme/
[5]http://ec.europa.eu/environment/indicators/index_en.htm

Table 1: Environmental Indicators

	Indicator	DPSIR
1	**Climate change and energy**	
1.1	Global air temperature change	S
1.2	Concentrations of CO2 in the atmosphere	P
1.3	Natural disasters linked to climate change	I
1.4	Total Kyoto greenhouse gas emissions	P
1.5	Share of energy produced from renewable energy sources in final energy consumption	R
1.6	Electricity produced from renewable energy sources	R
1.7	Combined heat and power generation	R
1.8	Energy intensity	R
1.9	Final energy consumption by transport	D
1.10	Average CO2 emissions from passenger cars	D
1.11	Cumulative spent fuel from nuclear power plants	D
2	**Nature and biodiversity**	
2.2	Conservation status of habitats by habitat group	S
2.3	Conservation status of species by taxonomic grouping	S
2.4	Landscape fragmentation	P
2.5	Topsoil organic carbon content	S
2.6	Freight transport	D
2.7	Area occupied by organic farming	R
2.8	Area under agri-environmental commitment	R
2.9	Natura 2000 area (% terrestrial area)	R
3	**Environment and health**	
3.1	Urban population exposure to air pollution by particles	S
3.2	Urban population exposure to air pollution by ozone	S
3.3	Transport noise in urban agglomerations	P
3.4	Emission projections for air pollutants	P
3.5	Air emissions of nitrogen oxides	P
3.6	Water exploitation index	P
3.7	Production of toxic chemicals	P
3.8	Production of environmentally harmful chemicals	P
3.9	Pesticides residues in food	P
4	**Natural resources and waste**	
4.1	Fish catches from stocks outside safe biological limits	S
4.2	Total waste generated	P
4.3	Municipal waste generated	P
4.4	Recycling of packaging waste	R

On March 2014 EEA established an extensive set of 137 indicators belonging in the following 13 environmental thematic groups (EEA, 2015a): 1) Air pollution, 2) Biodiversity, 3) Climate change, 4) Energy, 5) Environmental scenarios, 6) Fisheries, 7)

Green economy, 8) Household consumption, 9) Land, 10) Soil, 11) Transport, 12) Waste and 13) Water.

A core set of indicators (EEA CSI), initially introduced in 2004 by EEA, has been recently revised to adjust to new policy demands and become operational during 2014-2018 period. It consists of 42 indicators grouped into 6 thematic areas which integrate sectors exerting pressures on the environment (agriculture, forests, energy, fishery, transport).

The next paragraphs provide a brief citation of the EEA CSI indicators as these are categorized in appropriate thematic sets along with selected examples indicating the significance of Geoinformation technologies to their development. In any case, today the EEA web site offers online the indicator related information along with high quality map based capabilities, such as for example GIS web applications development (EEA, 2016l).

3.2. Air pollution, Transport and Noise

This set of indicators covers extremely important thematic areas. The status of the environment is assessed through the exceedance of air quality limits and exposure of ecosystems to acidification, eutrophication and ozone. Pressures on the environment are assessed through the emissions of air pollutants. Transport demand is a critical driving force indicator which necessitates increasing values for the response indicator measuring usage of cleaner and alternative fuels. Similarly, this set contains pressure indicators assessing pollution from industry and state indicators assessing road traffic noise limits exceedance.

Table 2: EEA Core Set of Indicators related to air pollution, transport and noise

Thematic area	Name	DPSIR
Air pollution	Emissions of main air pollutants	P
	Exceedance of air quality limit values in urban areas	S
	Exposure of ecosystems to acidification, eutrophication and ozone	S
Transport	Passenger and freight transport demand	D
	Use of cleaner and alternative fuels	R
Industry	Pollutant releases to air, water and waste from industrial facilities	P
Noise	Population exceeding ambient noise limit values (for road traffic)	S

As an example on this thematic area, the Pressures Indicator "Emissions of main air pollutants" is examined focusing on Nitrogen Dioxide (NO2) emissions sourcing from road traffic. This indicator is extremely important in urban areas with high volumes of traffic since it affects the air quality levels. Although targeted actions towards reducing emission levels have been taken in Europe over recent decades, air pollution still affects human health in a considerable degree (more than 400 000 premature deaths each year) and continues to damage vegetation and ecosystems. The levels of NO2, in 2013, have exceeded the annual EU limit value in a huge number of cases and those concerning road side monitoring locations reach 93 %. A GIS-based representation of the indicator annual values at traffic stations is shown in the following Figure 4.

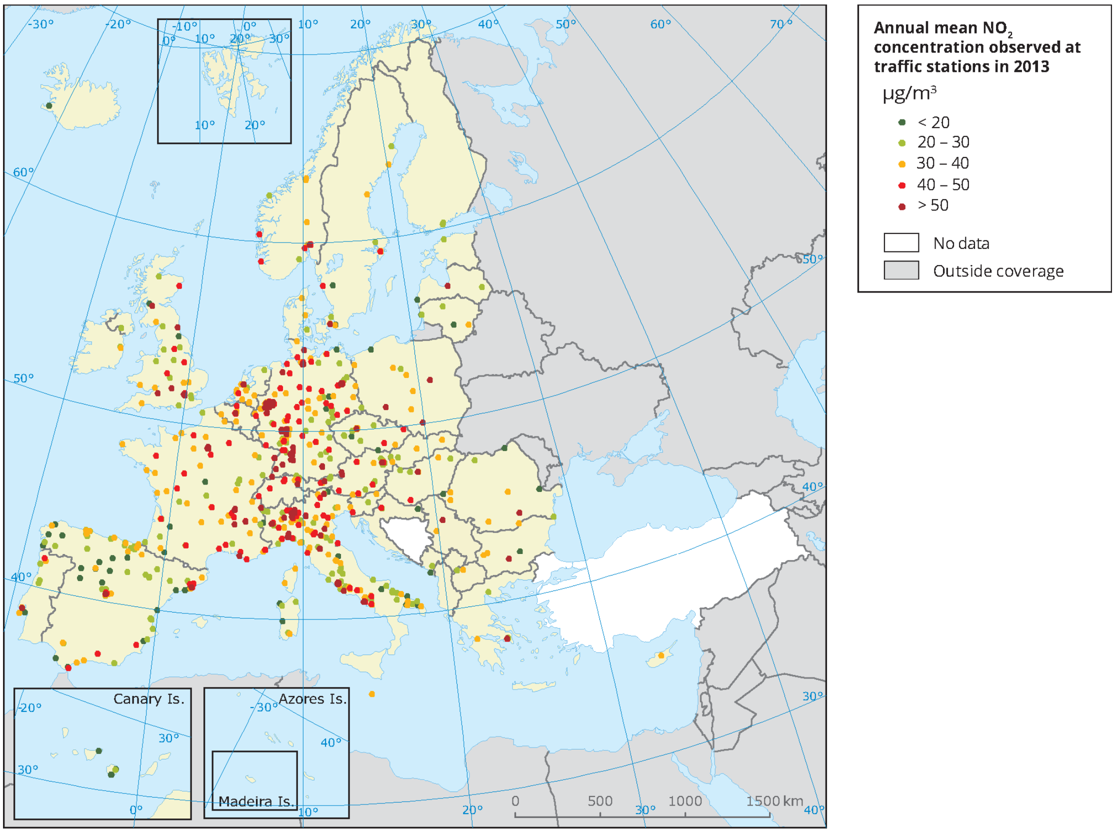


Figure 4: Annual mean NO2 concentration observed at traffic stations in 2013 (EEA, 2013)

3.3. Climate change and energy

Pressures exerted to the environment due to GHG emissions and production and consumption emissions of fluorinated gases are assessed by indicators specified in this critical thematic group. The status of the environment due to the above emissions is also assessed along with temperature measurements. Cryosphere trends, and renewable energy share are significant impact indicators of this thematic area.

Table 3: EEA Core Set of Indicators related to Climate change and energy

Thematic area	Name	DPSIR
Climate change mitigation	EU and national total greenhouse gas emission trends and projections	P
	Atmospheric greenhouse gas concentrations	S
	Production, consumption and emissions of fluorinated gases	P
Climate change impacts	Global and European temperature	S
	Cryosphere trends for European glaciers and sea ice	I
Energy	Overview of European energy system	D
	Share of renewable energy in final energy consumption	I

According to a recent report published by EEA in June 2016 (EEA, 2016m), GHG emissions in the EU-28 in 2014 have reached their lowest level since 1990, as shown in Figure 5 (EEA, 2016n).

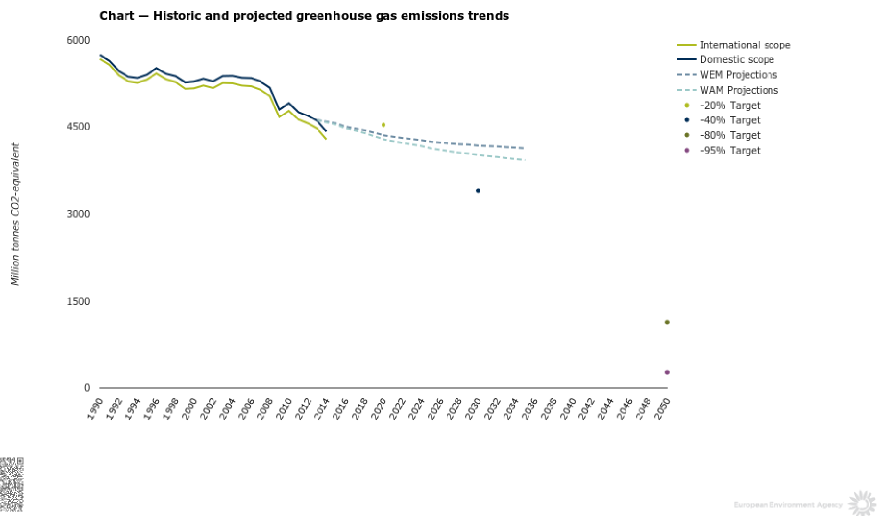


Figure 5: Historic trends and projected progress of European countries since 1990 (EEA, 2016n).

3.4. Freshwater resources

Freshwater resources set of indicators contains state indicators measuring water quality, critical concentrations (oxygen consuming substances, nutrients) and trends in ecological status. Impact indicators assess climate change impacts on water and pressure indicators respective pressures on water as shown in Table 4.

Table 4: EEA Core Set of Indicators related to Freshwater resources

Thematic area	Name	DPSIR
Water resources/ water scarcity and drought	Use of freshwater resources	P
Freshwater ecosystems	Trends in ecological status	S
Water pollution and quality	Oxygen consuming substances in rivers	S
	Nutrients in freshwater	S
Water and health	Bathing water quality	S
Climate change impacts on water	Climate change impacts on water	I
Pressures on water	Pressures on water	P

A representative example of climate change impacts on water is shown in Figure 6 and depicts water temperatures in five selected European rivers and lakes in the 20th century.

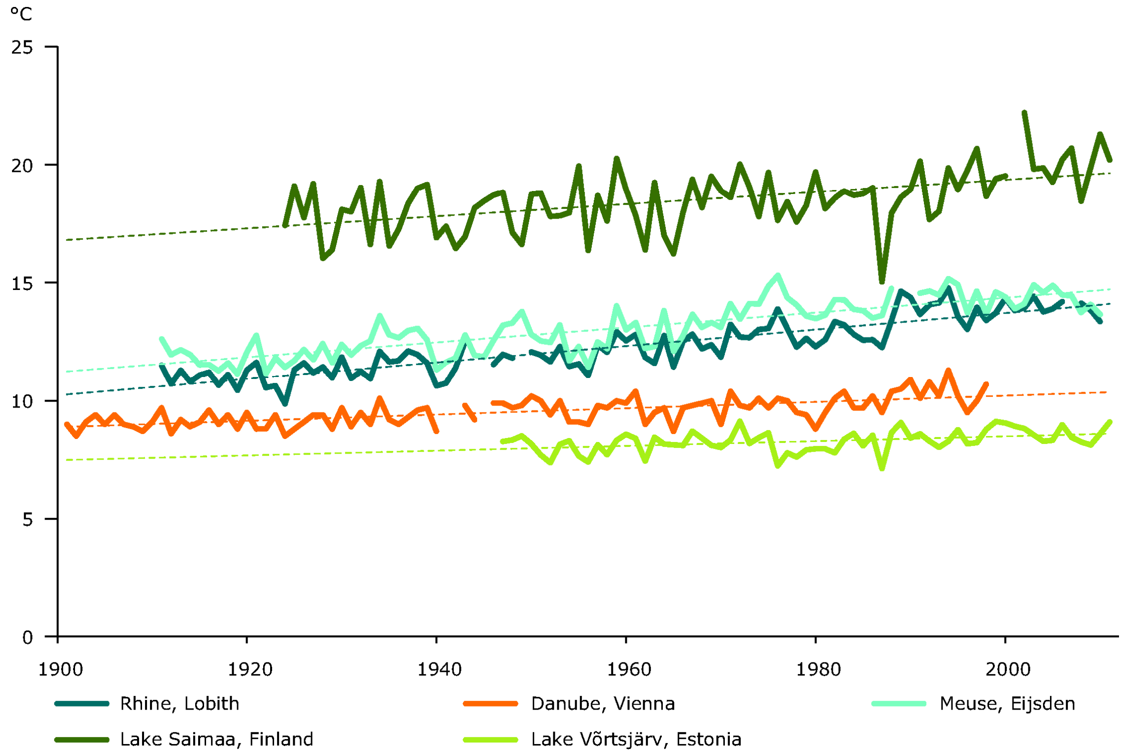


Figure 6: Annual average water temperature in River Rhine and River Meuse (1911–2010); River Danube (1901–1998), Lake Võrtsjärv (1947–2011), and average water temperature in August in Lake Saimaa, Finland (1924–2011) (EEA, 2012c)

3.5. Marine and maritime

Marine and maritime indicators measure the pressures (hazardous substances, fishing fleets) and state of the environment (nutrients, chlorophyll, fish stocks) in fisheries and transitional, coastal and marine water. They also assess impacts on the environment such as sea surface temperature and sea level rise, as shown in Table 5

.

Table 5: EEA Core Set of Indicators related to Marine and maritime

Thematic area	Name	DPSIR
Transitional, coastal and marine water quality	Nutrients in transitional, coastal and marine waters	S
	Chlorophyll in transitional, coastal and marine waters	S
	Hazardous substances in marine organisms	P
Fisheries	Status of marine fish stocks	S
	Fishing fleet capacity	P
Climate change	Sea surface temperature	I
	Global and European sea level rise	I

Figure 7 provides concentrations of dissolved inorganic nitrogen (DIN) in coastal and open waters in 2012, classified by the 80/20 percentiles of the DIN data set for the years 2007 to 2012.

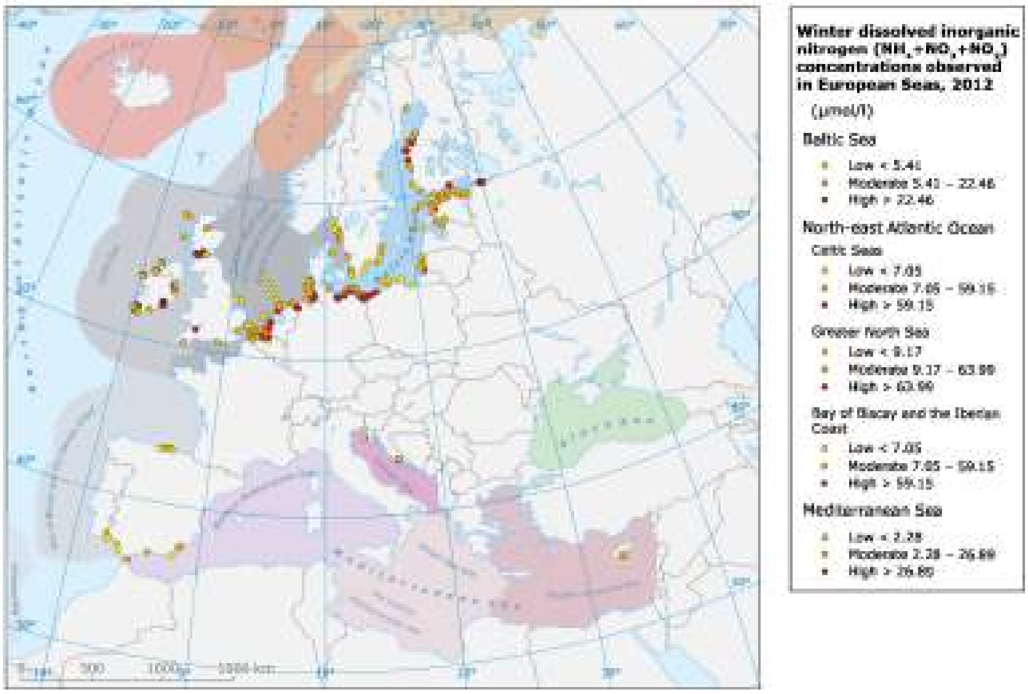


Figure 7: Winter dissolved inorganic nitrogen (DIN) concentrations in European coastal and open waters in 2012 (EEA, 2015b)

3.6. Biodiversity and ecosystems

State indicators dealing with species, a response indicator providing designated areas cover the status and trends of biodiversity. Threats to biodiversity are covered by the pressure indicator measuring land take and a new indicator dealing with the impacts of habitats and ecosystems fragmentation. Another thematic area contains indicators dealing with the responses on agricultural areas (Natura 2000) and measuring states of the forests, as shown in Table 6.

Table 6: EEA Core Set of Indicators related to Biodiversity and ecosystems

Thematic area	Name	DPSIR
Status and trends of the components of biological diversity	Species and habitats of European interest	S
	Designated areas	R
	Abundance and distribution of selected species	S
Threats to biodiversity: Habitat loss and degradation	Land take	P
	Fragmentation of habitats and ecosystems	I
Sectors – agriculture and forests	Agricultural areas under Natura 2000	R
	Forest: growing stock, increment and fellings and deadwood	S

A representative example of this set of indicators, exploiting advanced cartographical representation offered by GIS is shown in Figure 8. The map shows reduction of 'core natural/semi-natural' landscapes due to fragmentation by agricultural and/or artificial lands, both in terms of absolute area (ha) and proportionally to the 'core natural' pattern cover in 2000, for the period 2000-2006.

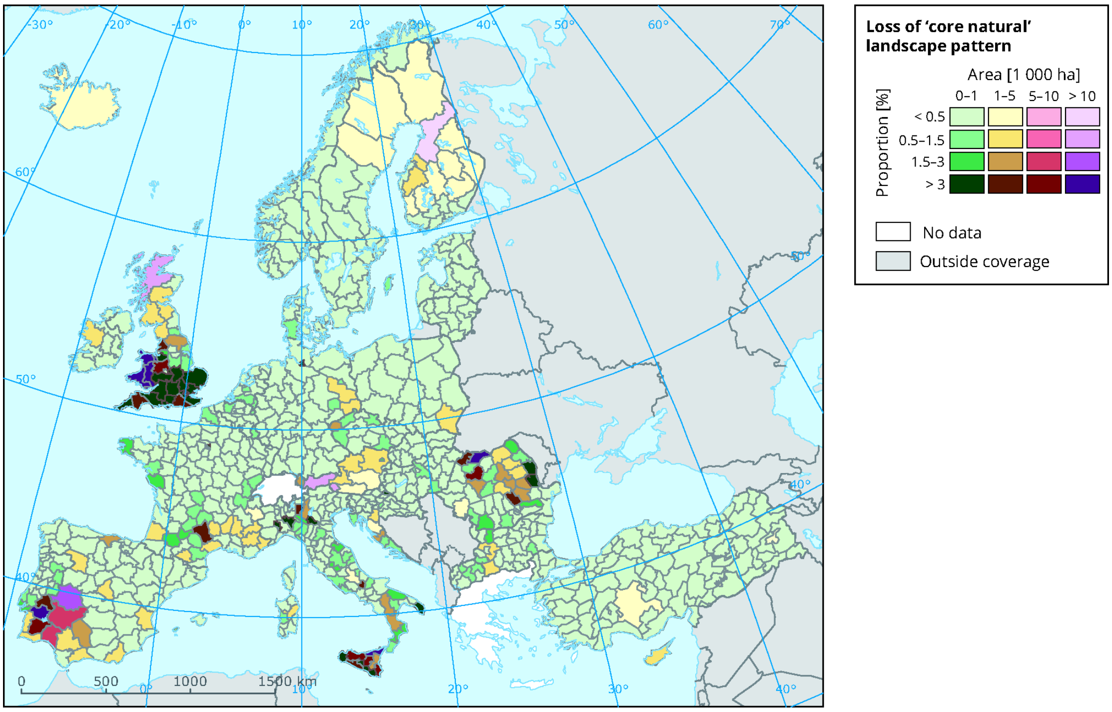


Figure 8: Loss of core natural landscape pattern (EEA, 2015c)

3.7. Waste and resources

The Waste and resources CSI covers interesting topics of waste and resource management with many new indicators. These include, waste generation which represent pressures to the environment, and waste recycling and biodegradable municipal waste reduction, which are the subsequent responses. Also new indicators, driving changes to the environment, include the decoupling of environmental pressures and impacts from the resource use.

Table 7: EEA Core Set of Indicators related to Waste and resources

Thematic area	Name	DPSIR
Waste generation	Waste generation	P
Waste recycling	Waste recycling	R
Waste diversion from landfill/ disposal	Diversion of waste from landfill	R
Household consumption	Household environmental pressure intensity	D
Energy efficiency	Total primary energy intensity	R
Decoupling of environmental pressures	Decoupling of resource use from environmental pressures	D
Decoupling of environmental impacts	Decoupling of resource use from environmental impacts	D

The graph below in Figure 9, provides waste generation values from the production side in the sectors of manufacture and services for the period 2004-2008. A significant decrease of 25% and 23% respectively is traced although the sectoral economic output increases 7% and 13% respectively. Regarding consumption, total municipal waste generation declined by 2% for the same period, despite a 7% increase in real household expenditure. Reducing waste generation in absolute terms and on the same time decoupling economic growth from resource use and environmental impacts is an EU main objective.

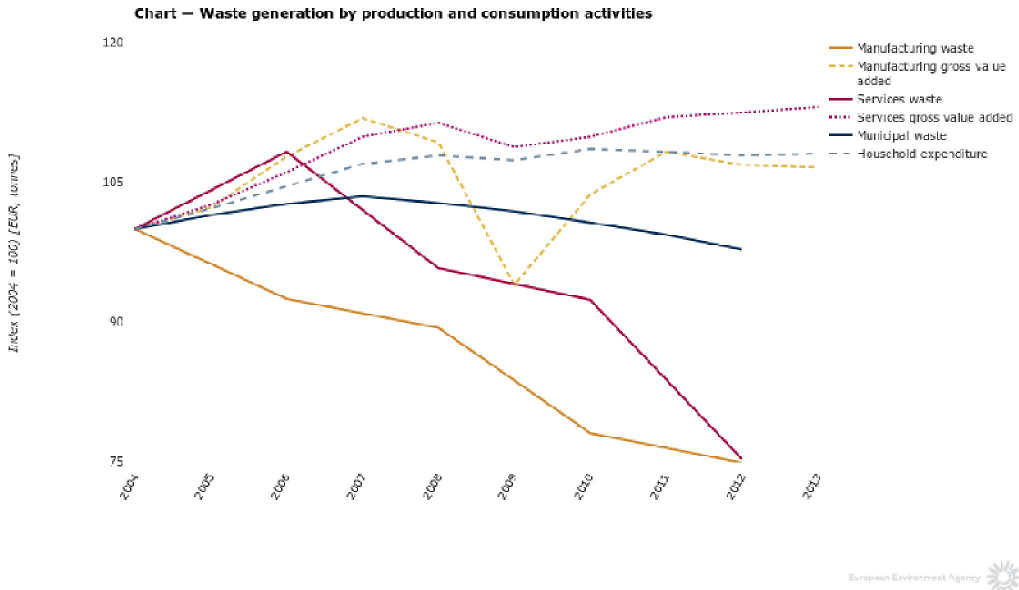


Figure 9: Waste generation by production and consumption activities (EEA, 2015d)

CHAPTER 4

GEOGRAPHIC INFORMATION SYSTEMS

4.1. Introduction to Geographic Information Systems

4.1.1. General

There are many definitions of GIS. A simple approach would define them as Information Systems dealing with geographically related data. Some selected definitions are as follows:

- *"A geographic information system is a special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines, or areas. A geographic information system manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses"* (Dueker, 1979, p 106)
- Many experts define GIS as spatial data tools. Burrough, (1986) approach GIS as *"a powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes"* while Clarke (1986) as *"automated systems for the capture, storage, retrieval, analysis, and display of spatial data."*
- According to USGS (U.S, Geological Survey) a water, earth, and biological science and civilian mapping agency *"In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations. Practitioners also regard the total GIS as including operating personnel and the data that go into the system."*
- According to ESRI, leader in GIS software supply, GIS *"lets us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends. GIS benefits organizations of all sizes and in almost every industry. There is a growing interest in and awareness of the economic and strategic value of GIS."*

GIS collect data from multiple sources with different standardizations and structures including maps, satellite images, digital products, GPS surveying measurements, data tables (Figure 10). GIS combine data and cooperate with a large number of scientific fields such as topography, cartography, photogrammetry, remote sensing and geodesy (Jankowski & Nyerges, 2001).

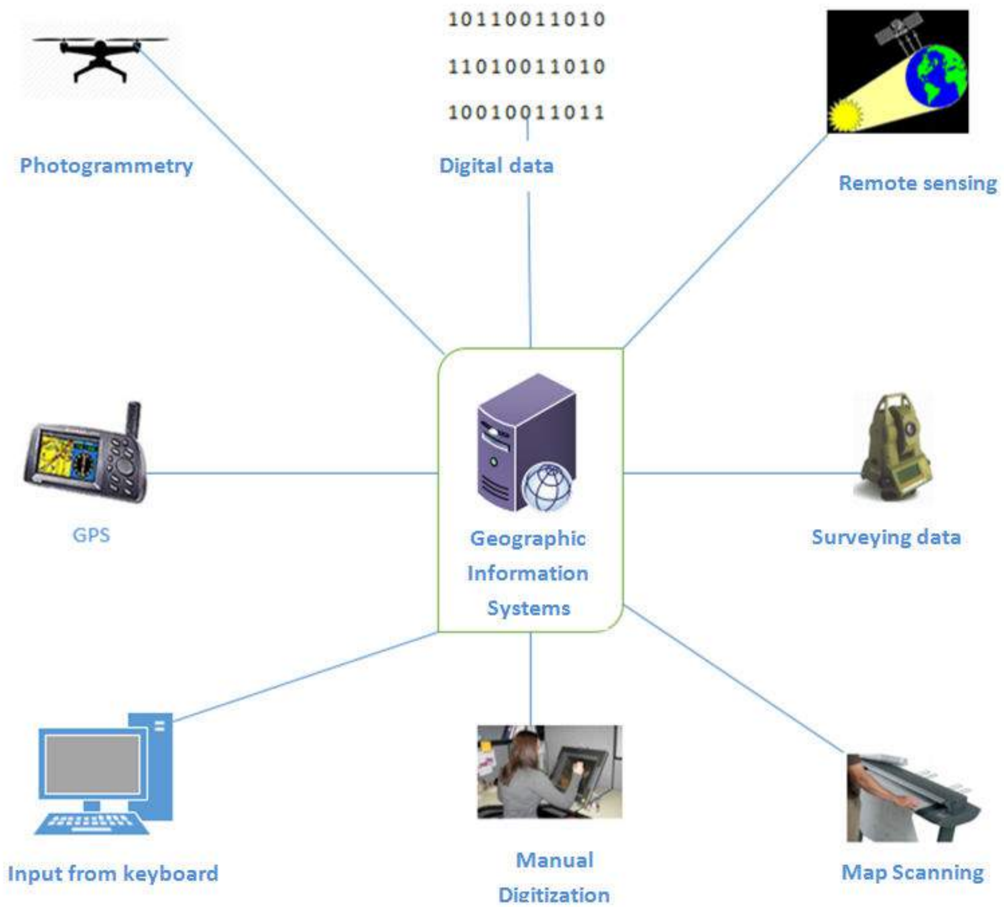


Figure 10: GIS data sources

Evolution in the field of GIS has been highly affected by the developments on Information Technology (IT). In fact, the developments in GIS technology reflect those on IT. In the beginning, GIS systems were installed in high performance computers (Mainframe GIS) and then they were evolved in GIS systems installed in desktop computers (desktop GIS). Then, in distributed systems and web services and finally in cloud technology based GIS systems (Cloud-GIS), as shown in Figure 11.

Figure 11: GIS Evolution

The associated database of a GIS system contains observations for spatially distributed features, activities or events specified in the space as points, lines or areas. A GIS processes data related to these shapes creating valuable information to provide answers for non prespecified spatial questions and analyses.

 Points: a point is a representation of an object for which we need to know its location, and not its actual shape e.g. elevation points, schools, settlements in small scales, trees etc.

 Lines: a line may symbolize many real objects e.g. rivers, roads, conduits etc.

 Polygons: Multiple sides shapes for which the surrounded area is associated with attributes e.g. lakes, municipalities, parcels etc.

4.1.2. What Questions can GIS answer

The map and the accompanied text in Figure 12 provide an overview of the questions that a GIS can answer:

- Through a GIS it is possible to identify any object spatially referenced or in other words any object that possesses coordinates. Identification is achieved via the attributes associated with the object. For example the answer in the question "What is the name of this factory?" is retrieved by a field of the attribute table associated with the spatial object of the factory
- A GIS can cooperate with other systems charged with other types of calculations/modeling/simulations in various fields of expertise. For example a GIS can cooperate with a traffic modeling software by providing transport supply in terms of road network infrastructure. It may also provide a spatial dataset of a specific scenario, e.g. a new built up area created in a rural surrounding area. This may be input to a traffic model which in turn returns the output containing predictions of traffic flows. The final output may be

represented by a GIS and the affections on traffic intensity may be visualized. It is also possible to develop a separate module inside a GIS software that will perform domain specific processes.

- Comparing two GIS projects developed over an area during two different time periods provide answers regarding the trends on this area. For example it may be visible with naked eye that a growth of an urban area is underway.
- A simple question a GIS can answer is about the coordinates of a point-building in a map. A more complicated is about the topological relationship between two separate thematic layers representing different physical objects. A GIS can locate the intersection between a river and a road revealing the spatial relationship existing between them.
- Popular answers provided by a GIS-based system are those concerning routing directions between 2 user-specified points, such as "what is the shortest route between A & B?"

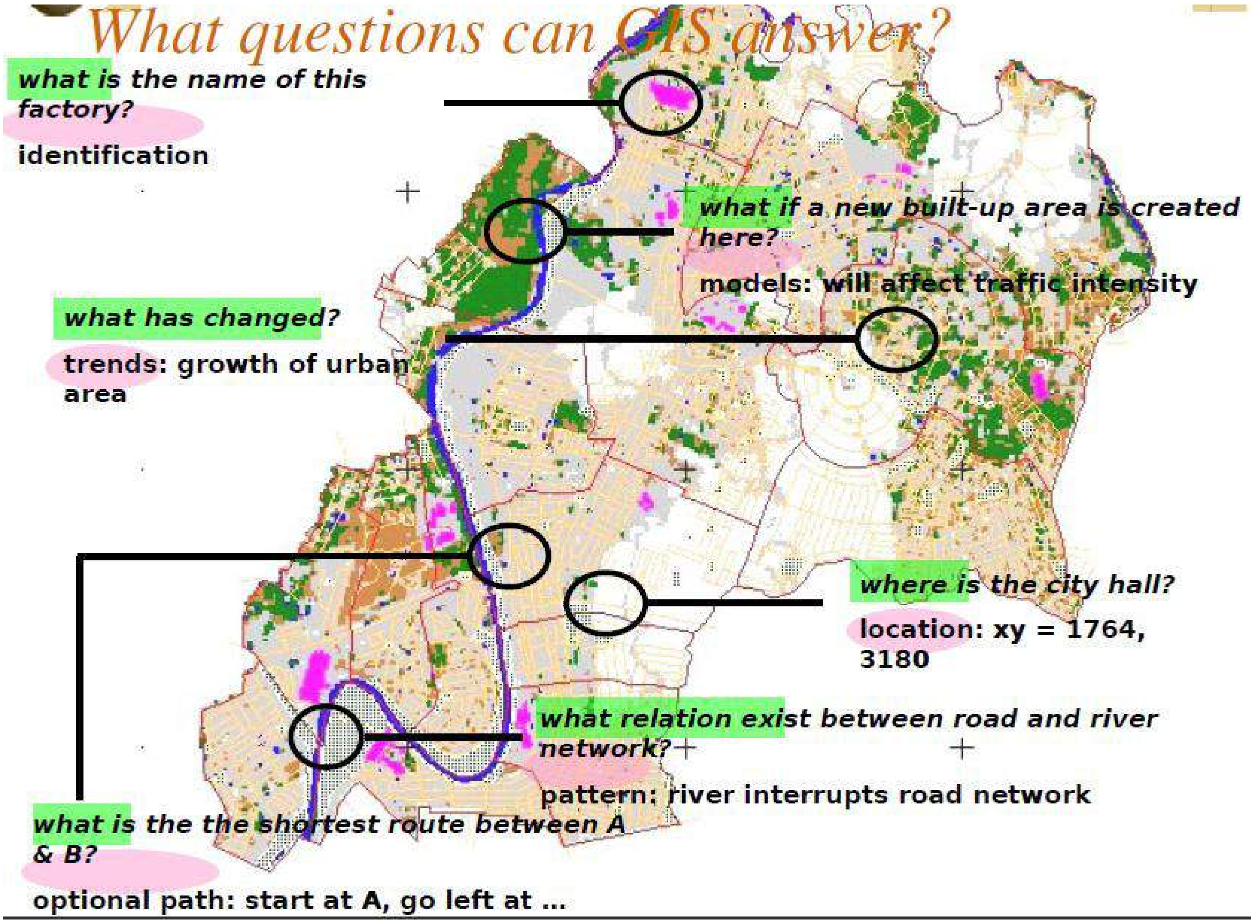


Figure 12: Questions a GIS can answer (Sambale, 2016)

4.2. Fundamental Geospatial Data Analysis

Geospatial data analysis or spatial analysis belongs to the “core” of GIS, because it deals with all procedures and methods for converting data into valuable information for both assisting decision support process and revealing patterns not directly visible. Spatial analysis may be considered as the "cooperation" between humans and computers where both play a vital role.

There are numerous analyses procedures available in GIS that may be divided into two categories:

- Fundamental
- Advanced

Fundamental procedures are considered to be useful for a wide range of applications and are available in most GIS software packages for the various data structures. Advanced procedures may be distinguished to operations of statistical and mathematical data modeling.

Regarding the fundamental spatial analysis procedures, these may be grouped into the following categories (Longley et al, 2001):

- Queries
- Measurements
- Transformations

4.2.1. Queries

In a GIS software environment the user is capable of searching for geographic objects based on descriptive characteristics (properties) even through complex expressions. This way, data of interest for each user, are revealed easily and fast, over a large dataset. Searching inside databases is performed by use of a standard for expressing queries termed SQL (Structured Query Language). All GIS software packages are already providing the capability of submitting queries through easy to use graphical interfaces. The operators employed for structuring queries are described below:

- Comparison operators

Operator	Description
< and <=	*"Less than and less than or equal to"*, may be used in expressions containing numeric, alphanumeric (considering the alphabetical order) and date, types of data
> and >=	*"Greater than and greater than or equal to"* may be used in expressions containing numeric, alphanumeric (considering the alphabetical order) and date, types of data
=	*"Equal to"*, may be used in expressions containing numeric, alphanumeric (considering the alphabetical order) and date, types of data
<>	*"Not equal to"*, may be used in expressions containing numeric, alphanumeric (considering the alphabetical order) and date, types of data
BETWEEN x AND y [NOT]	The expression "greater than or equal to x and less than or equal to y" may be replaced by the usage of a logical operator , – i.e. instead of the expression *"OBJECTID" >= 1 AND "OBJECTID" <= 10"* the expression *"OBJECTID" BETWEEN 1 AND 10"* may be used. It can also be used reversibly by utilizing the operators *[NOT BETWEEN]*
IN [NOT]	Selects records from the table when the values of a specified field is met in a specific set of values. It can also be used reversibly by utilizing the operators *[NOT IN]*
IS [NOT] NULL	Selects records form the table when there is no value in a specified field. It can also be used reversibly by utilizing the operators *[NOT BETWEEN]*
x [NOT] LIKE y	Operator LIKE can be used instead of operator = for structuring partially alphanumeric expressions. For example expression "STATE_NAME" LIKE '**Miss**%' " will return data regarding **Miss**issippi and **Miss**ouri from the layer of United States. It can also be used reversibly by utilizing operator [NOT]

- Logical operators

Operator	Description
AND	Combines two conditions together and selects records (features) that satisfy both conditions. For example *"parcel_area">100 AND "parcel_perimeter"<2000*, will search over the thematic layer of parcels those who satisfy both prerequisites, the one of area and the other of perimeter simultaneously.

Operator	Description
OR	Combines two conditions together and selects records (features) that satisfy at least one condition. For example *"parcel_area">100 OR "parcel_type"= 'agros'. This expression will return parcels that either have area more than 100 or are of type 'agros' (agricultural) or both of them*
NOT	Selects records that do not satisfy the expression. For example" NOT *"parcel_type"= 'agros', returns all parcels that are not of type 'agors'*

Some examples of submitting queries in the QGIS software environment are presented below. Two vector layers have been imported, one containing Greek municipalities and one of the CORINE land cover.

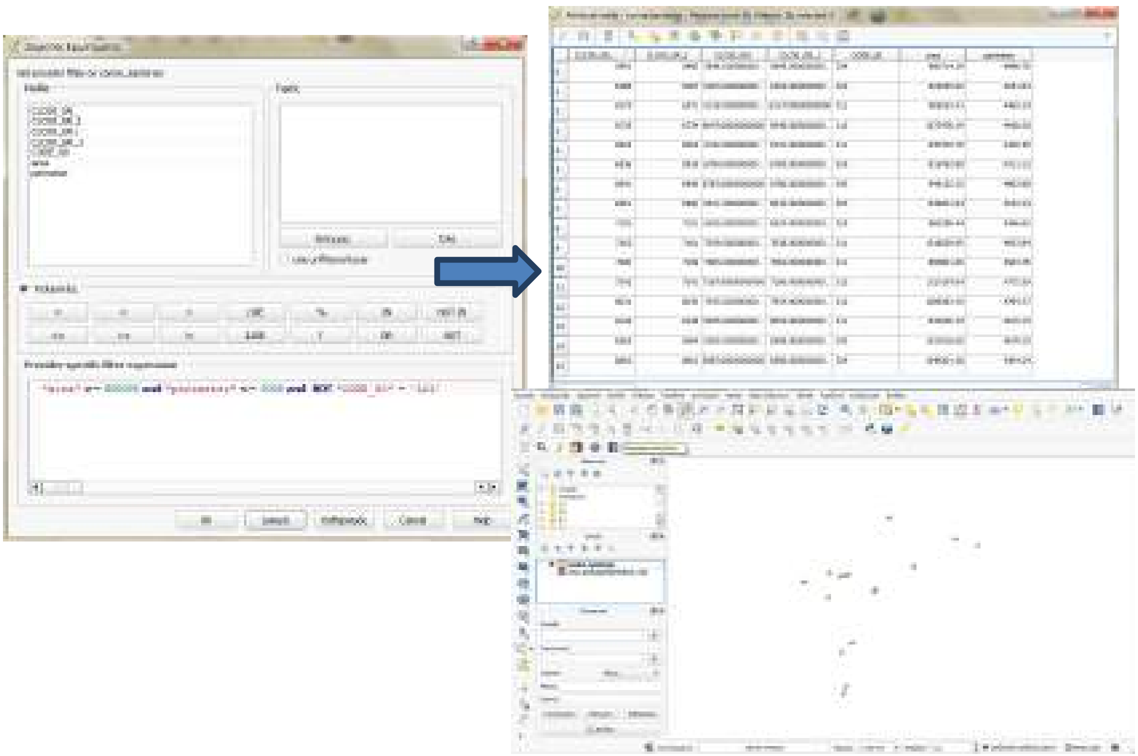


Figure 13: A display from QGIS environment – submitting a query over a vector polygon layer (CORINE)

In the example of Figure 13, a query performed, for selecting those features having area more than 800000m^2 and perimeter less than or equal to 5000m as well as not belonging to the land cover class of code 321. The result returned 16 polygons that satisfy all three conditions simultaneously. The expression employed was: "area" >= 800000 and "perimeter" <= 5000 and NOT "CODE_00" = '321'.

In the next example presented in Figure 14, a query is performed over the layer of the Greek municipalities, whose Greek name begins form the letters "ΓΑ" and are located in the mainland. The operator LIKE was employed and the expression used was: "NAME_GREEK" LIKE '___ΓΑ%' and "TYPOS" = 'MAIN'. The expression was structured with 3 underscores in the beginning in order to include in the results those municipalities who had the characters "Δ. " before their exact name, as for example happened with the municipality having the name "ΓΑΛΑΤΣΙΟΥ" that had been entered in the table as "Δ. ΓΑΛΑΤΣΙΟΥ". It should be noted that it is possible to perform much more complex queries in the database.

It is also noted that it is possible to perform mathematical operations (addition, subtraction, multiplication, division) between the fields of the attribute table of a thematic layer as well as mathematical expressions. In such cases it is first necessary to create new fields in the attribute table in order to store the results of the expressions applied.

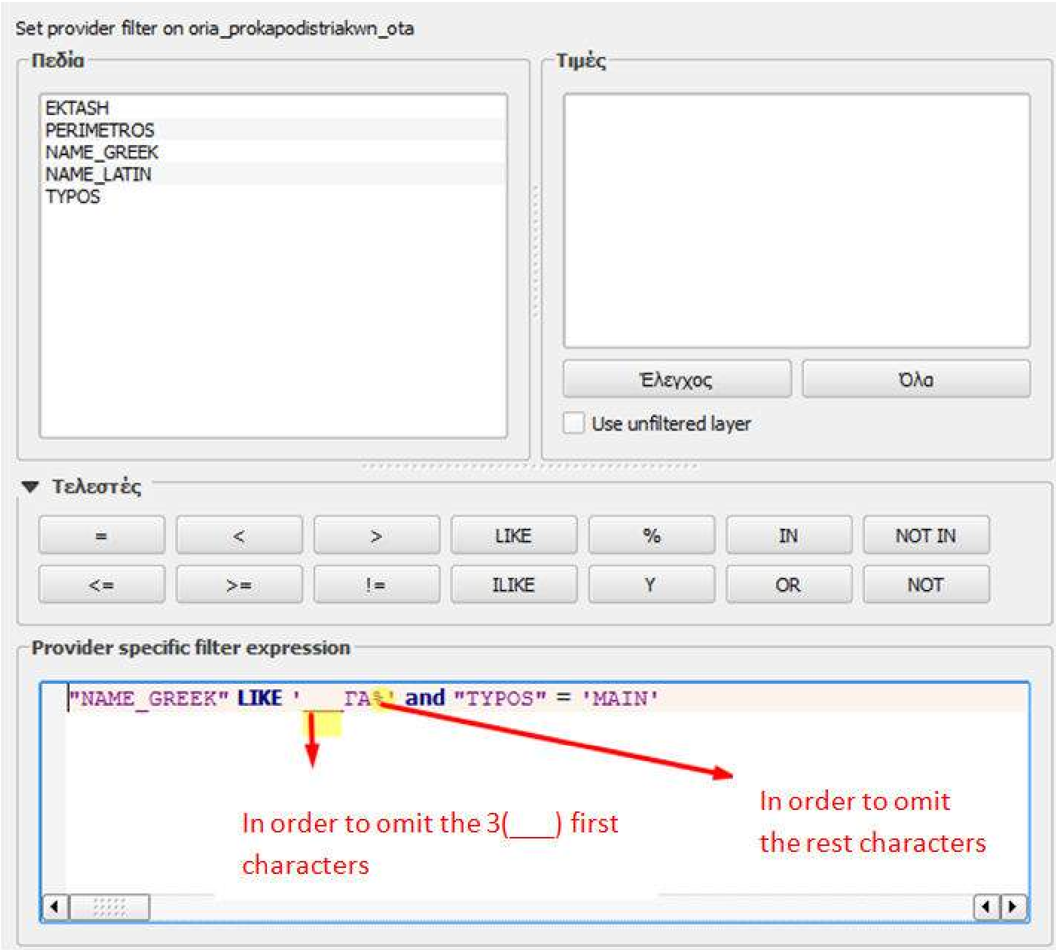


Figure 14: A display from QGIS environment – submitting a query over a vector polygon layer of the Greek municipalities

Finally, there may be structured queries that take into account the spatial relationship between two geometries, and are called spatial queries. The spatial relationships that can be expressed are the following:

- Equals – are the two geometries identical?
- Disjoint – do geometries have a common point?
- Intersect – do geometries intersect?

- Touches – do either of the geometries boundaries intersect?
- Cross – do geometries (who may be of different dimensions) have overlapping points?
- Within – is one geometry within the other?
- Contains – does one geometry completely contains the other? (opposite result of within)
- Overlaps – do geometries (who must be of the same dimension) intersection result to a different geometry (but of the same dimension)?
- Relate – are there any common points between the interiors, the boundaries and the exteriors of the geometries?

The following schemas of Figure 15, depict some of the above spatial relations.

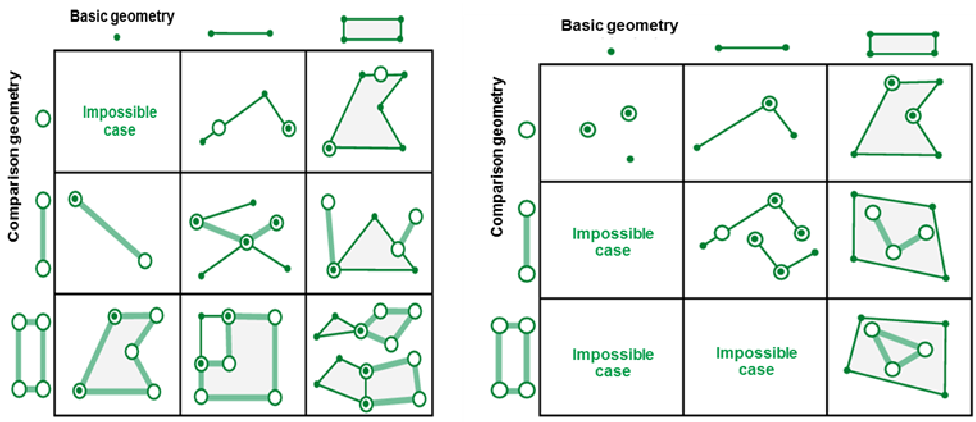


Figure 15: Schematic representation of spatial relations “Contains” and “Touch” (Longley, et.al, 2005)

In the next example we are searching for the land use polygons that are completely within the boundaries of municipality of Kastoria. To submit this query, two thematic layers are required, one of the land uses and one of the municipalities boundaries. Figure 16 shows the interface for submitting a spatial query in QGIS environment.

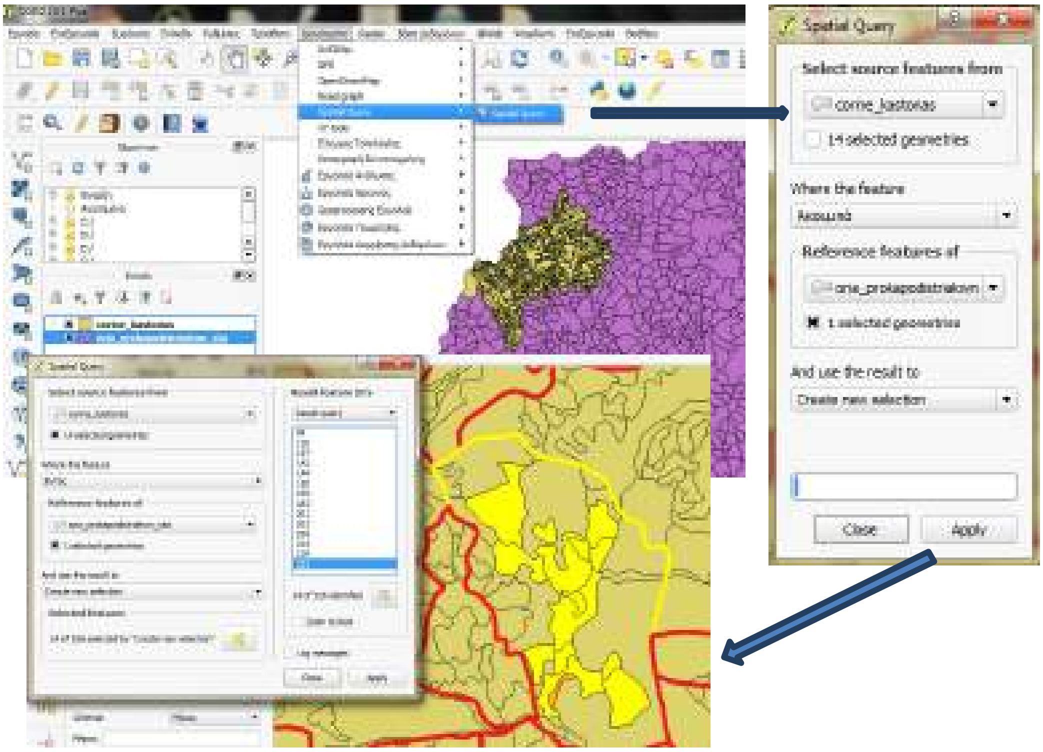


Figure 16: Display of QGIS software environment – submitting a spatial query

4.2.2. Measurements

Measurement operations allow calculating, the distance between points, line lengths, as well as areas. Usually GIS software packages employ the Eucledian distance, that is the slant distance between two points over a plane as shown in Figure 17.

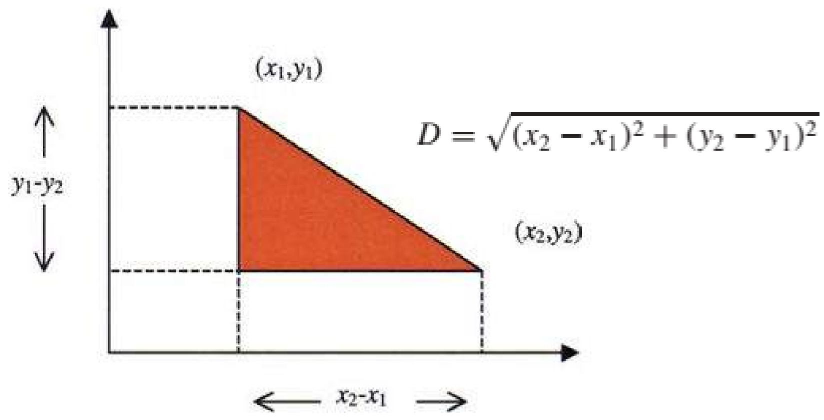


Figure 17: Eucledian distance (metric). Straight line (slant distance) between two points

Therefore the “real” distance is always greater than this measured in a GIS. In many cases the software packages provide the capability of measuring the “real” distance after defining the spheroid, as for example in QGIS.

Figure 18 presents the distance and area measurement tools of QGIS software environment – manual measurements.

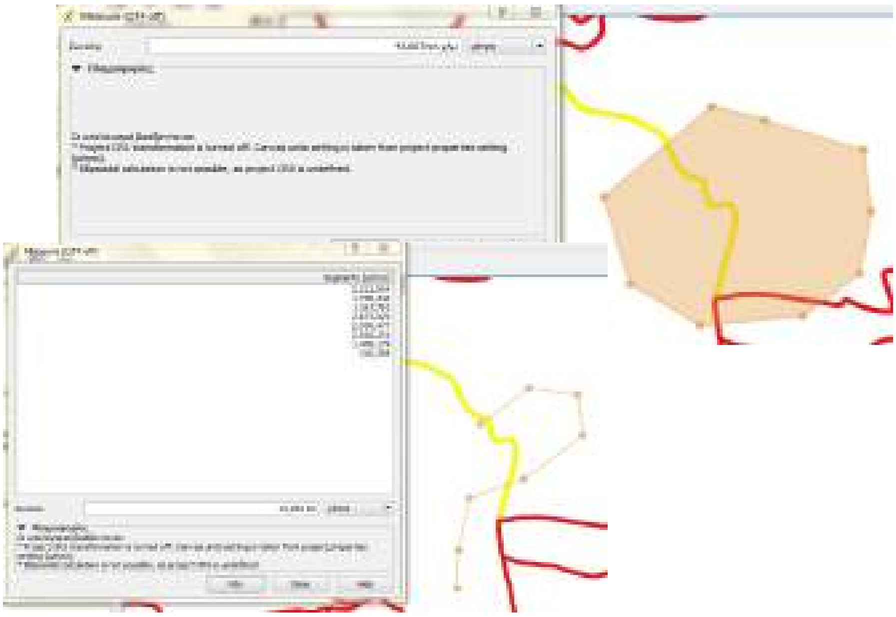


Figure 18: QGIS software display – distance and area measurement tools

It should be also noted that divergences from the reality in distance and area measurements may result from the “generalization” of reality during import of geographic objects in a system. As shown in Figure 19 the length of a line curve (e.g. a stream) is always greater than the polyline entered in the GIS.

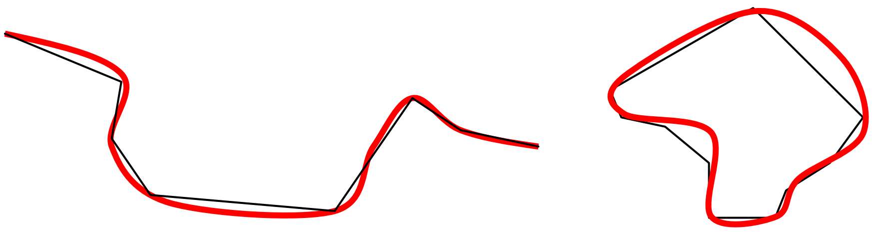


Figure 19: Schematic representation of divergences in measuring distances and areas

In addition distance and area measurements may be automatically performed in a GIS. In the attribute of a thematic layer (e.g. linear or polygonic) new fields like “length”, “perimeter” and “area” that perform the respective mathematic expression can be created. In the following example, shown in Figure 20, the area of the polygons of a vector layer is calculated.

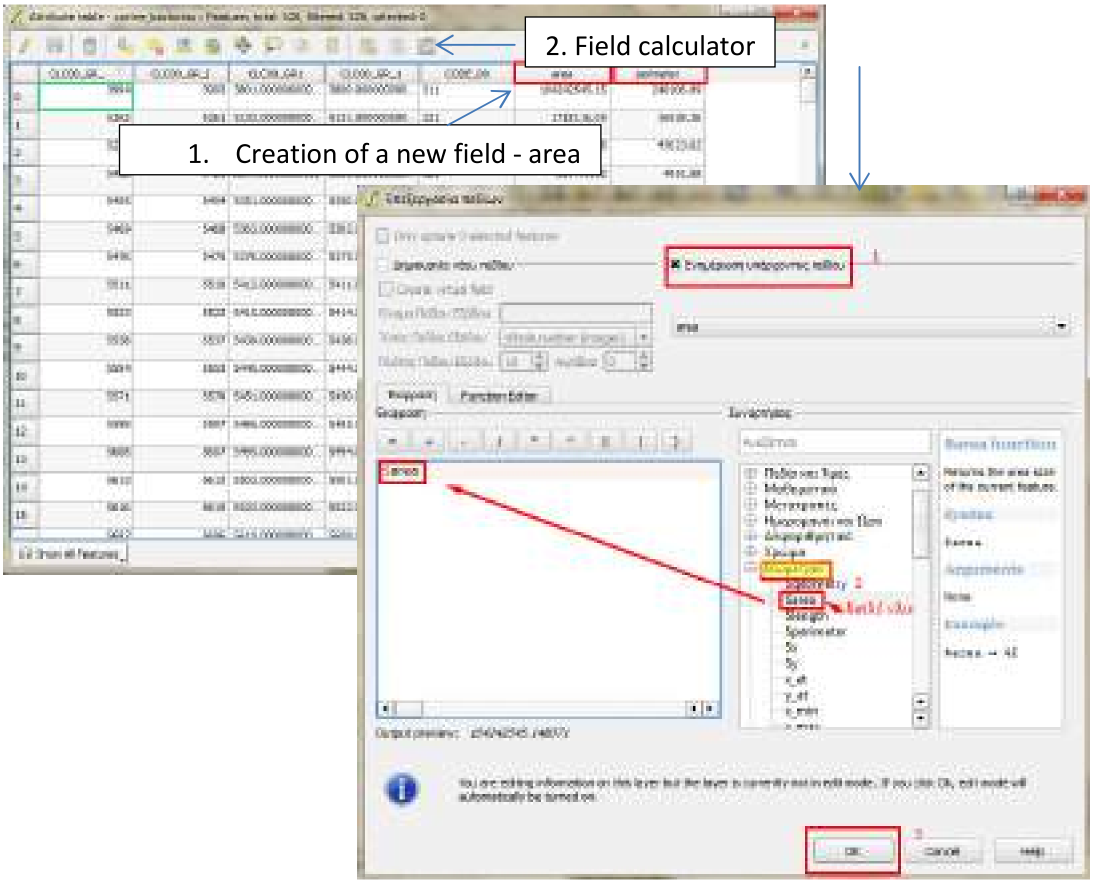


Figure 20: QGIS software display – area calculation

Finally, distance measurements can be performed automatically for a number of points of a point layer and a “target” point layer.

Other types of measurements that can be performed and concern raster files are slope and aspect. As input for such measurements, a Digital Elevation Model (DEM) is used, that is a relief representation of the terrestrial surface, i.e. for every pixel the surface elevation is recorded. DEM may come from photogrammetric methods or vector layers containing elevation data (contours and elevation points) by use of interpolation methods. There are various methods for estimating the slop and the aspect and usually the estimation value for each pixel is performed by comparing the value (elevation) of the pixel with the values of the eight adjacent pixels. Figure 21, depicts the process of estimating the slope and aspect in the QGIS software environment. The result extracted is a raster that contains the value of the slope for every pixel.

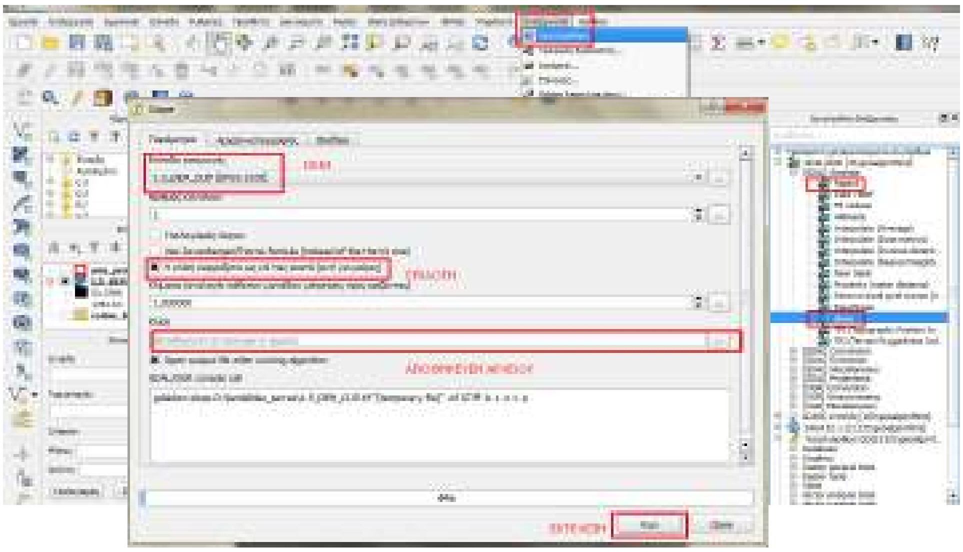


Figure 21: QGIS software display – slop calculation

4.2.3. Transformations

The following paragraphs describe procedures with transformations of spatial objects and their databases to more valuable "products", by utilizing simple methods.

1. Buffer zones creation

Buffer zones creation is a basic analysis process which aims to forming new polygons (in a thematic layer) around geographic vector objects (points, lines, polygons) of the various thematic layers. Buffer zones may be either of constant or changing width (multi-ring buffer) depending on the feature they apply to.

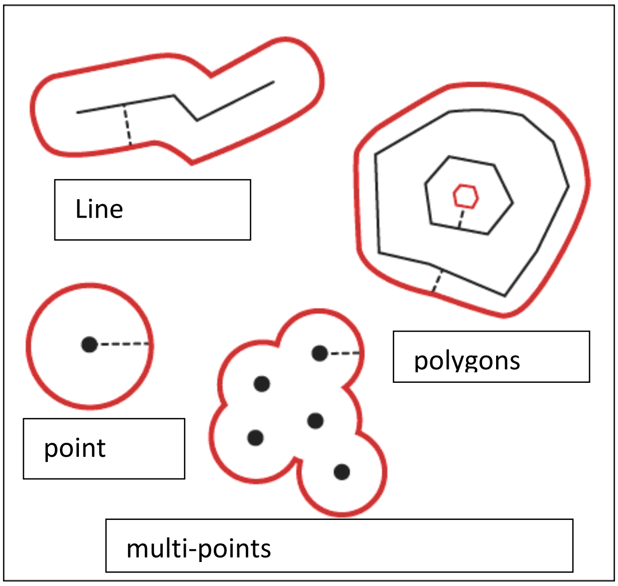


Figure 22: Schematic representation of vector data buffering procedure

It should be noted that the buffering procedure may be applied also on raster data. During this procedure a new raster file is created on which pixels are classified (receive value) considering whether they fall inside or outside the buffer distance (Figure 23).

Distance measurement from pixel center to pixel center is performed by employing Eucledian metric.

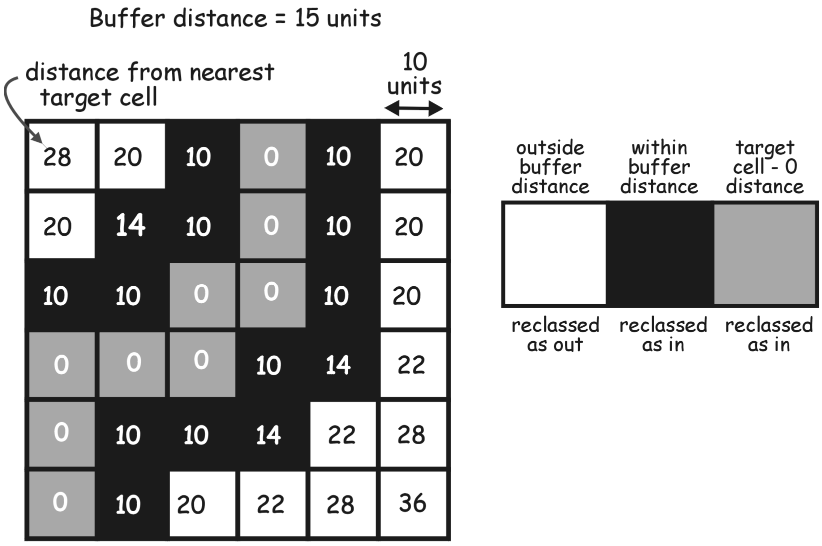


Figure 23: Schematic representation of raster data buffering procedure (source: http://www.geo.hunter.cuny.edu/aierulli/gis2/lectures/lecture5/lecture5.html).

Figure 24 illustrates the QGIS graphical interface for performing the buffer procedure in both vector and raster data as well as the procedure for searching analysis "tools".

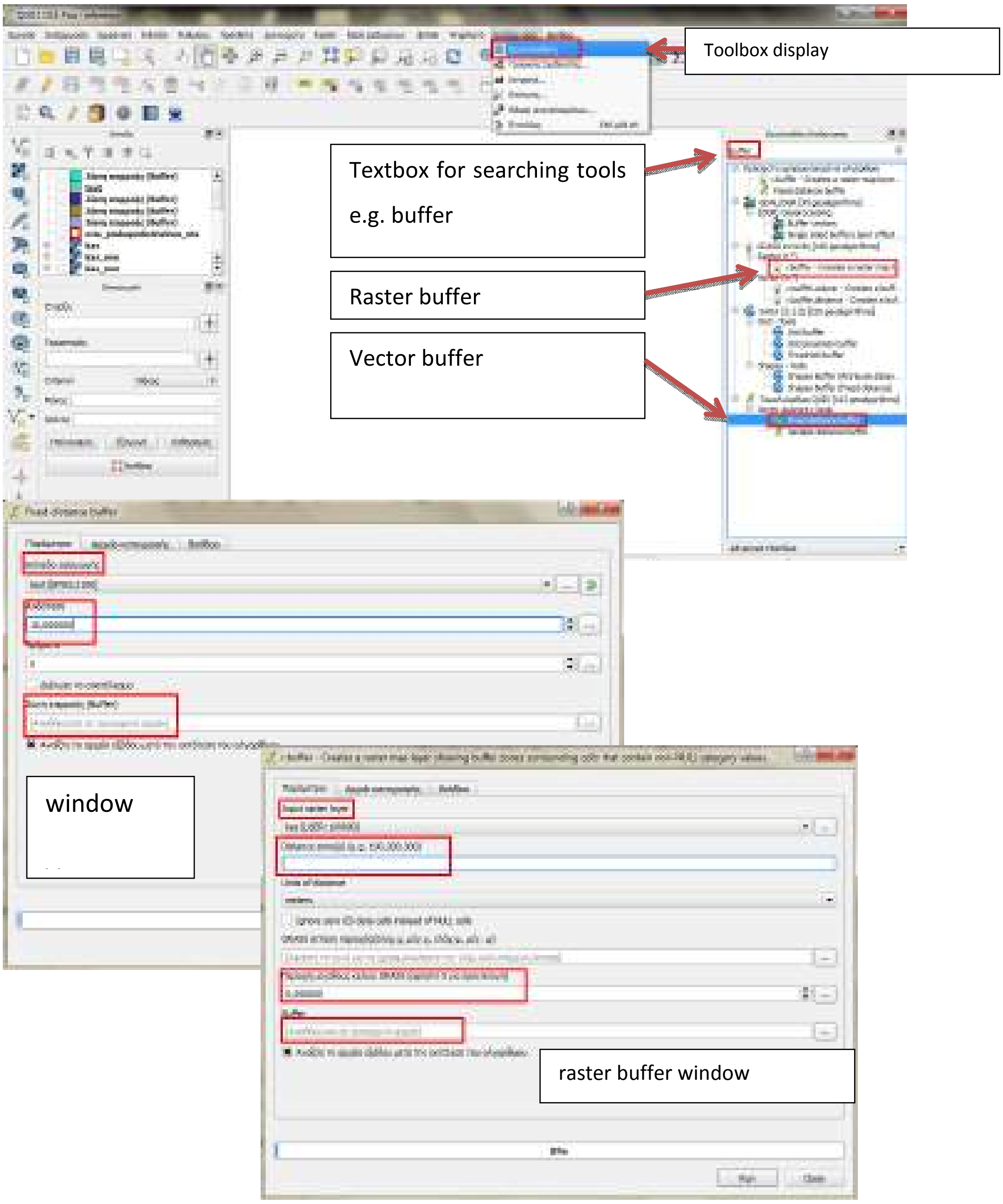


Figure 24: Representation of buffer-QGIS procedure – red frames indicate the parameters that have to be defined by the user

2. Thiessen polygons creation

This procedure creates polygons around a set of points in a way that the area surrounding every polygon is the closest to the point compared to any other point external to this area. The distance between every location and the point is measured by use of the Eucledian distance. It is noted that the Thiessen polygon creation procedure in the QGIS software environment is identified as "Voronoi polygons".

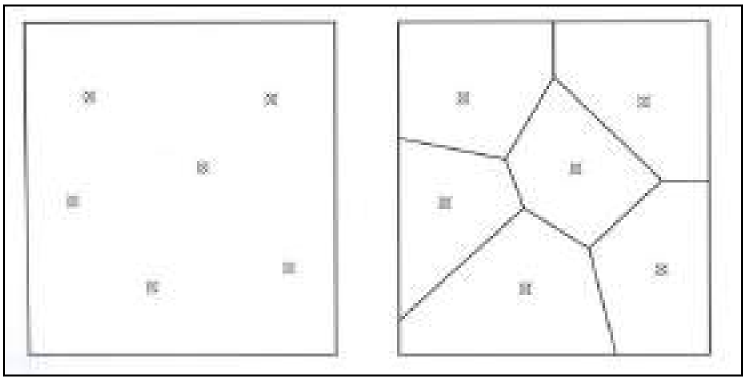


Figure 25: Schematic representation of the Thiessen procedure

3. Convex hull creation

This procedure returns a geometry that represents all the points located inside all the lines that are formed between all the points of the input geometry. A convex hull is the smallest polygon that surrounds other geometry without a concave area.

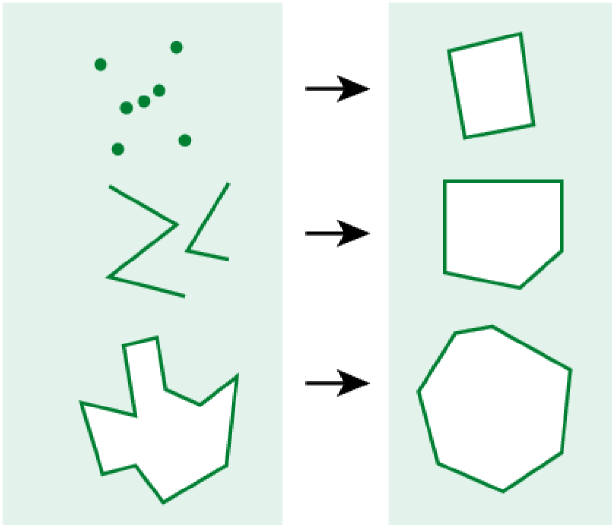


Figure 26: Schematic representation of the convex hull procedure (Longley, 2005)

4. Overlay procedure – vector data

The overlay operations create a new thematic layer (output) as a function of two or more thematic layers. In particular, the values of descriptive data of each geographical location of the new thematic layer are a function of the independent values of the imported layers associated with this location. Essentially, overlay is an extension of the Boolean algebra rules, with procedures regarding the way that the entities cover the geographical space. Overlay is mentioned either as polygons overlay or as points or lines and polygons overlay. That way a new analysis level is created which comes from the combination of spatial and non spatial data from the overlaying and the layer under cover (overlaid). Overlay procedures may be performed with thematic layers (polygon to polygon, line to polygon and point to polygon)

4.1. Union

This procedure is performed by use of logical operator OR and the new layer consists of all polygons and features of both overlaying and overlaid (covered) thematic layer

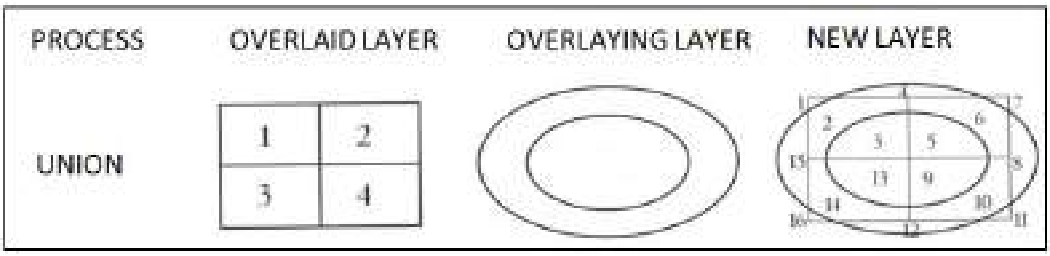


Figure 27: Schematic representation of the "Union" procedure

4.2. Intersect

The procedure is performed by use of logical operator AND, and the new thematic layer contains only those polygons and features that are common to the overlaying and the overlaid (covered) thematic layers.

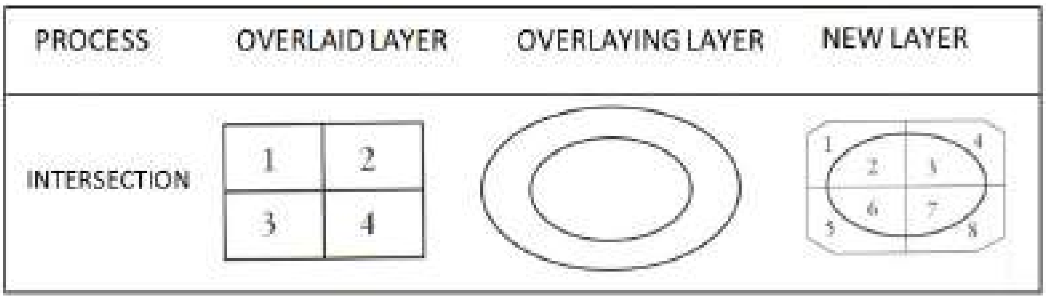


Figure 28: Schematic representation of the Intersect procedure

The following example includes the intersection between two polygon layers and specifically the layer of the Greek municipalities and the layer of CORINE land cover of municipality of Kastoria. The procedure was performed in QGIS environment and is shown in Figure 29. It is noted that the procedure is not limited in the geometric association, but also covers the descriptive data of the attribute tables of the thematic layers.

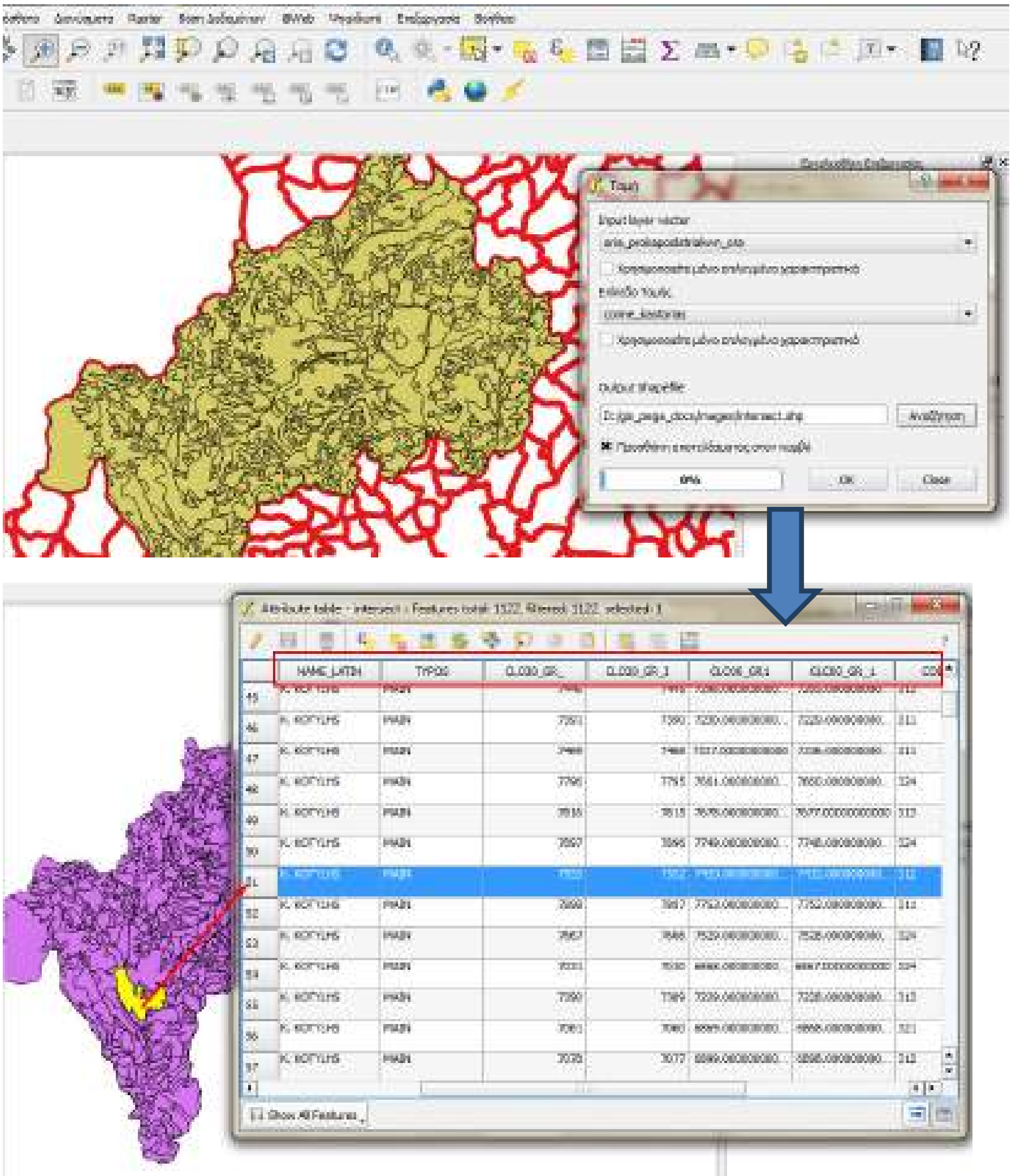


Figure 29: Representation of the “Intersection” procedure - QGIS

4.3. Symmetrical difference

The procedure is performed by use of XOR operator and the new thematic layer contains the areas that are not common to the two initial thematic layers.

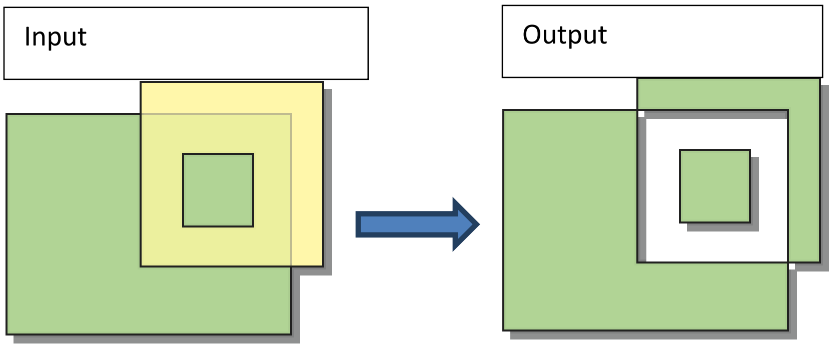


Figure 30: Representation of the “Symmetrical difference” procedure

4.4. Limitation – clip

The procedure is performed by use of NOT operator and limits the extent of the overlaid layer in the boundaries of the overlaying layer.

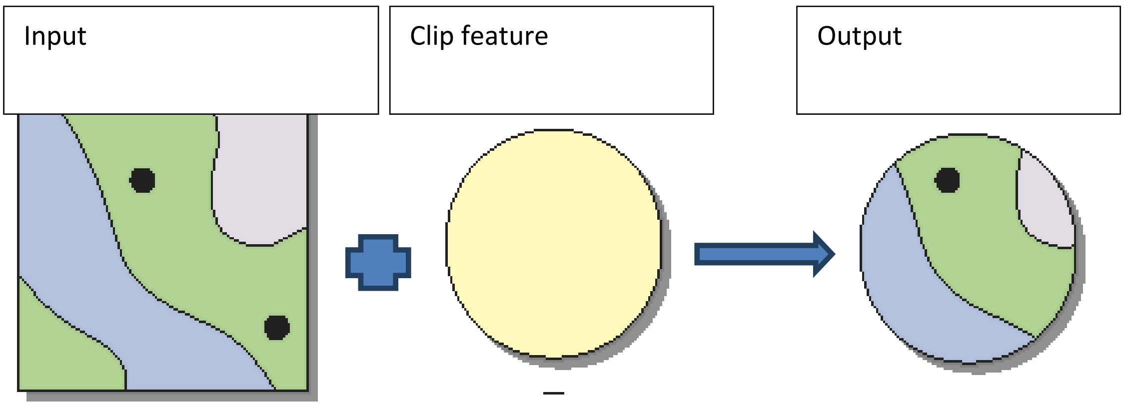


Figure 31: Representation of the “Clip” procedure

4.5. Point in polygon

Through this procedure the identification of the number of points falling to each polygon is performed. During the procedure a new polygon layer is created which in its attribute table contains a new field with the above mentioned number of points.

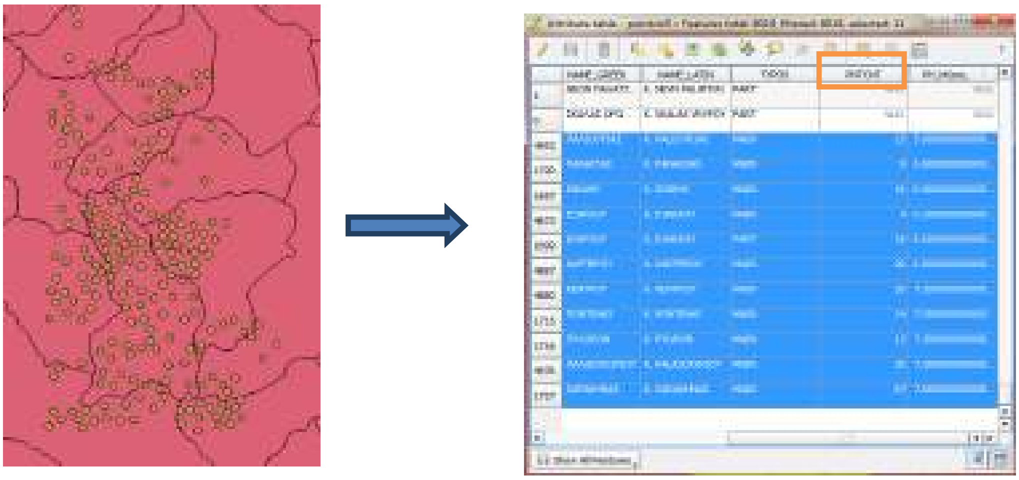


Figure 32: Schematic representation of “point in polygon” procedure

5. Overlay procedure – raster data

Overlay procedures may be also performed in raster data and result to the creation of a new raster layer where the value of each pixel is calculated according to a “relation” applied with the corresponding pixels of the imported data.

The “relation” through whom the values of the new thematic layer are calculated may be:

- Mathematic operation (e.g. multiplication)

- Statistical index (e.g. calculation of maximum value or mean)
- Boolean expression
- Comparison (>,< , =)

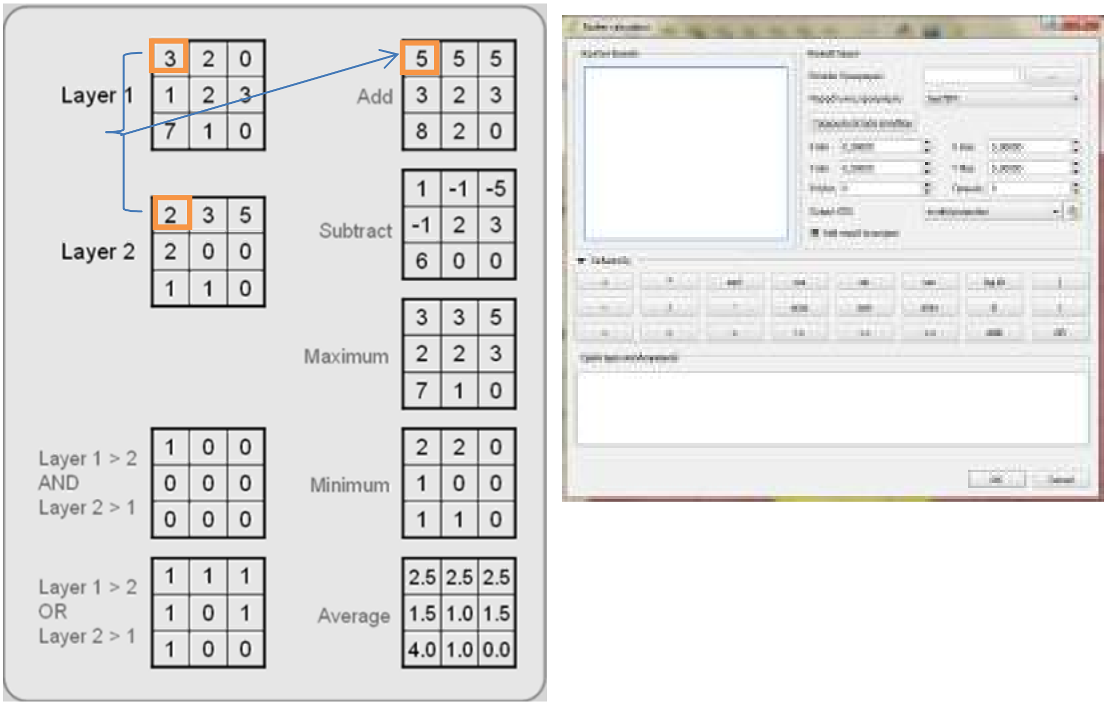


Figure 33: Schematic representation of overlaying raster data (Source: http:// giscommons.org)

6. Spatial interpolation

It is the process of estimating the value of a variable of interest (e.g. elevation, soil pH) in locations with no sample data, based on known values of the same variable in the boundaries of the study area (Burrough and McDonnell 1998). The general principle followed by the various methods that have been developed is that the "neighboring" locations have the same values for the variables under examination. For example rainfall estimation in a point of an area is similar with the values recorded on a close to the point meteorological station, as compared to a station located in greater distance. A method widely used is the Inverse Distance Weighting (IDW) method.

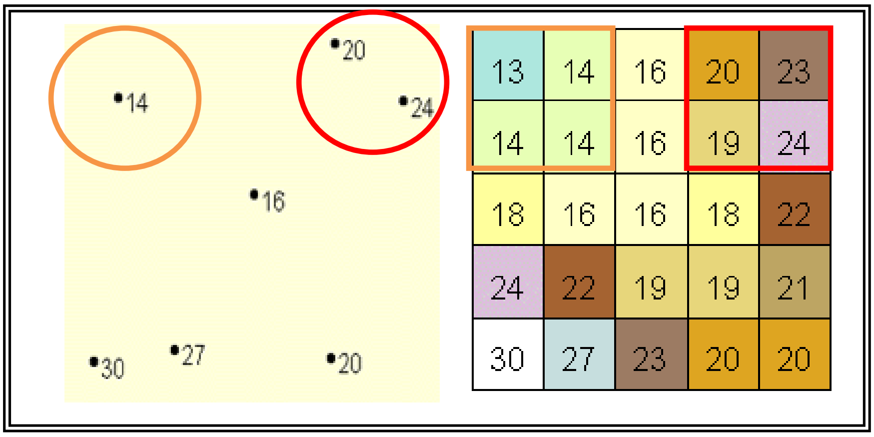


Figure 34: Schematic representation of spatial interpolation. (Source: http://resources.arcgis.com)

IDW estimates “unknown” values of a property using a weighted combination of the known values in a “specific” area of the study area, supposing that values on locations that are “closer” to the under estimation “location” are more representative as compared to “distant” values of this property (sampling points).

Figure 34 presents graphically the IDW method. In the picture we can see (on the left) that by using this method we try to estimate the value of a property (e.g. elevation) in a location where this value is not known, based on known values of this property in a specific distance. Therefore, the points that are located closer to the point under estimation will influence it more (weight). This is also represented in the following example (Figure 35).

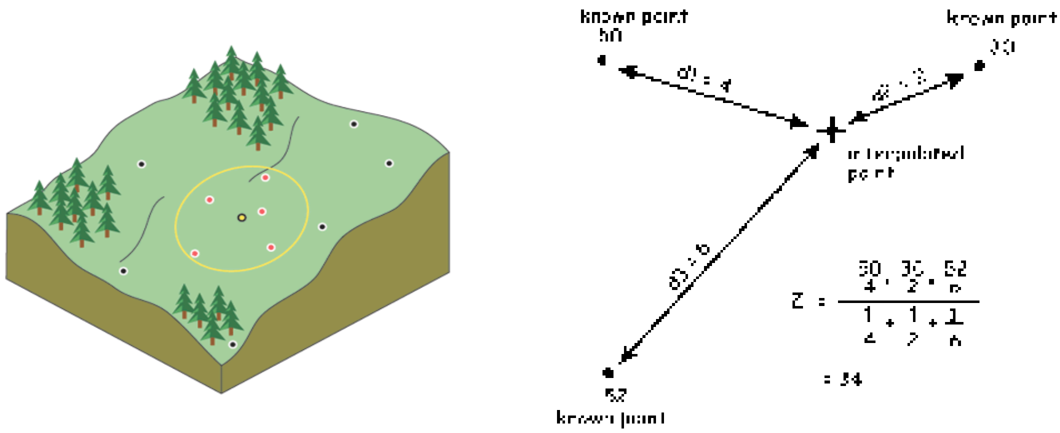


Figure 35: Schematic representation of IDW method (Source: http://resources.arcgis.com)

CHAPTER 5

Geospatial Web Technologies

5.1. Semantic Web - Ontologies

According to the– generally admitted – founder of the World Wide Web Tim Berners-Lee (1998), *"The Web was designed as an information space, with the goal that it should be useful not only for human-human communication, but also that machines would be able to participate and help. One of the major obstacles to this has been the fact that most information on the Web is designed for human consumption, and even if it was derived from a database with well defined meanings (in at least some terms) for its columns, that the structure of the data is not evident to a robot browsing the web. Leaving aside the artificial intelligence problem of training machines to behave like people, the Semantic Web approach instead develops languages for expressing information in a machine processable form*".

To better understand Semantic Web, imagine a Website containing information about artists, which has to be frequently updated with events concerning new songs, concerts etc. In order to develop and most important, to update such a website there are various approaches (Herman, 2010):

- The editors of the site are searching the web for new events. Meanwhile, they discover more and more links and they manually update the site. Soon the site becomes outdated
- The editors of the site are searching the web for new data that are published in other sites. They scan the other sites with special software in order to extract information, and they develop software in order to incorporate this information to their site. Soon the site becomes outdated again.
- The editors of the site are searching the web for new data through application programming interfaces (APIs). They have to understand programming

parameters like input, output arguments, data types etc., and they write code in order to incorporate new data. Again, the site becomes outdated.

BBC's (http://www.bbc.co.uk/music) choice is to use public datasets (e.g. Wikipedia, MusicBrainz) that are available as data and not through an API or «hidden» inside a site. Data may be extracted by use of HTTP requests or standard queries. In short, it uses the Web of Data as a Content Management System. In a way BBC uses the internet community at its whole as content editor. And this is not a secret, as shown in Figure 36.

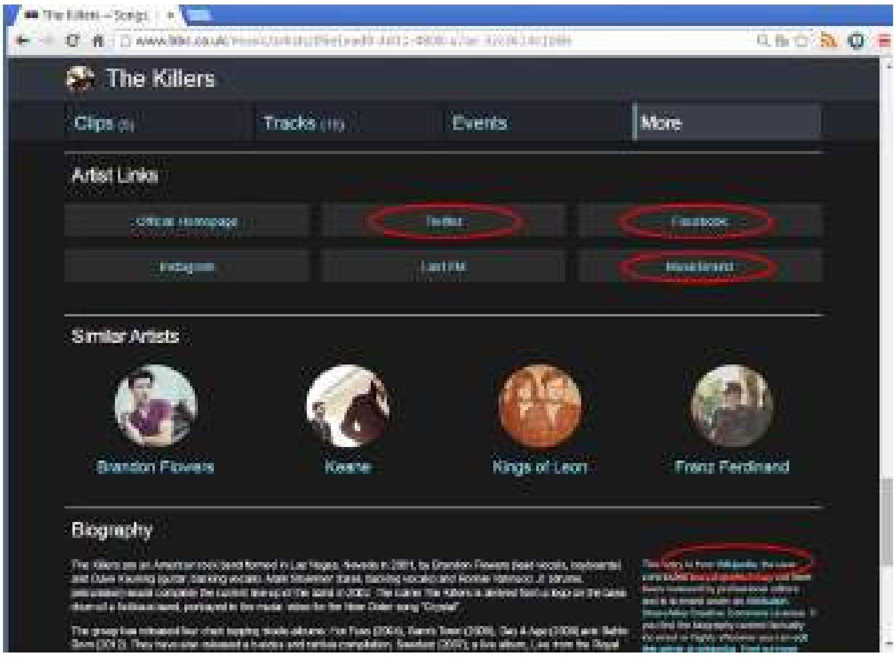


Figure 36: Exploiting the Web of Data

The World Wide Web contains many types of data: governmental, data related to health, data of general knowledge, data about companies, flights, restaurants etc. More and more applications are based on the existence and availability of these data. But frequently data are isolated like silos (Figure 37a). As an extreme case of the above metaphor, imagine a Web, where the documents are available for download but there are no hyperlinks between them. In general, data are available over the Web and are accessible through standardized web technologies, they are interconnected in the web and therefore data may be integrated in the web. All is needed is a proper infrastructure for a real Web, same way that a proper infrastructure has to be constructed in order to connect many silos between each other (Figure 37b). At this point the Semantic Web technologies are introduced (Herman, 2010).

Figure 37: a) isolated silos (source:“nepatterson”, Flickr) and b) interlinked silos (source: "kxlly", Flickr) for understanding the Web of Data

Finally, the Semantic Web is the Web of Data. Semantic Web technologies compose a set of standard technologies used to identify the Web of Data and provide a common model to machines in order to describe, search etc., data and their connections (Evangelidis et al, 2014). To manage the terms that are related to data may become a very complex job for specific knowledge areas and there is, where ontologies (vocabularies) are introduced (Herman, 2010).

In the Semantic Web, vocabularies define the concepts and the relationships used to describe an area of interest. Vocabularies are used to classify the terms that may be used in a particular application, specify potential relationships and define potential restrictions on using these terms. Practically, vocabularies may be very complex with thousands of terms, or very simple, describing only one two concepts (W3C, 2015).

The role of vocabularies in the Semantic Web is to assist data integration, in cases where ambiguities exist in the terms used for different datasets, or some extra knowledge may result to the discovery of new relationships. For example in the field of transportation, transport planners and cooperating experts use ontologies related to traffic engineering in order to represent knowledge related to volumes, speeds, levels of service etc. Users on the other side ranging from trip makers to professional drivers use other type of terminology to express for example the efficiency of transportation networks. By combining knowledge from transportation experts and users of the transport infrastructures it is possible to enable a series of intelligent applications such as decision making tools searching new infrastructures, systems monitoring the efficiency of road network etc.

The degree of vocabularies complexity depends on the applications. For some applications it may be decided not to employ even small vocabularies and to be based on the logic of the application program. For other applications it may be selected to utilize very simple vocabularies and let the Semantic Web environment make use of this extra knowledge and identify the terms. Some applications need an agreement in common terminologies without having to pass strict controls by logic systems. Some applications may need more complicated ontologies complex logic procedures. Everything depends on the requirements and the final objectives of the applications (W3C, 2015).

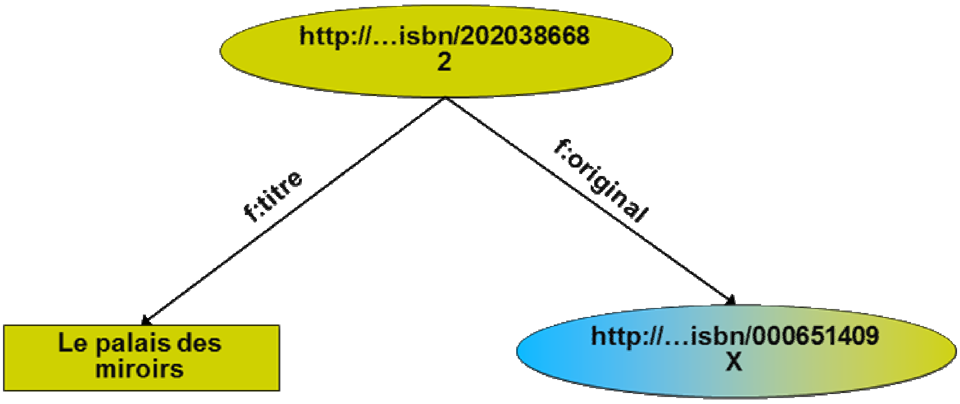
W3C provides tools for describing and defining different forms of vocabularies in a standard format, including RDF and RDF Schemas, Simple Knowledge Organization

System (SKOS), Web Ontology Language (OWL), and Rule Interchange Format (RIF). The final choice depends on the complexity and the level of strictness of a specific application (W3C, 2015).

An indicative example is as follows: a book store wants to integrate data from different publishers. Data may be imported in a common RDF model by transforming the databases of the publishers. However, a database may use the term “author”, while other database the term “creator”. In order to complete the integration an additional definition in RDF data relating the term “author” with the term “creator” has to be entered. This additional part of information is a vocabulary (or ontology), very simple though.

In a more complicated case the application may need a more detailed ontology as part of extra information. This may include an official description for uniquely identifying an entity, (for example citizens may be identified by their taxation number), the way that terms used in an application are related with terms used in other datasets, (e.g. Wikipedia), the way that a term such as ‘author” may be related with terms like for example “editor”, etc. (W3C, 2016).

For an abstract illustration of interrelated datasets, RDF graphs are used. The basic unit of an RDF graph is the triple s-p-o (subject-predicate-object) and is represented as a node-arc-node connection. A simple example of an RDF triple and its coding in RDF/XML format is shown in Figure 38 (Herman, 2010):




```
<rdf:Description rdf:about="http://…/isbn/2020386682">
    <f:titre xml:lang="fr">Le palais des mirroirs</f:titre>
    <f:original rdf:resource="http://…/isbn/000651409X"/>
</rdf:Description>
```

Figure 38: A simple RDF example

where ISBN:202038668 (subject) has predicate code ISBN:000651409 (object)

To integrate different data sources the steps that have to be followed are:

1. Creating abstract representations for every individual data set. Data become independent of their internal representations
2. Merging the resulting representations
3. Applying new queries that it was not possible to be applied in the initial individual datasets

In an ideal case, in order to crate the Web of Data, different datasets existing somewhere in the Web, of different formats (mysql, excel sheets, XHTML, etc.) with different name in the relationships between the central data entities are combined through some identical resources. In addition, by using common terminologies defined by the community (e.g. auteur, author, Person) it becomes possible to locate and retrieve new relationships. It is then possible to add more knowledge in the merged datasets such as for example a complete taxonomy of various types from a data library, geographical information etc. At this point ontologies are introduced along with additional rules and as a result it is possible to execute more dynamic queries (Figure 39).

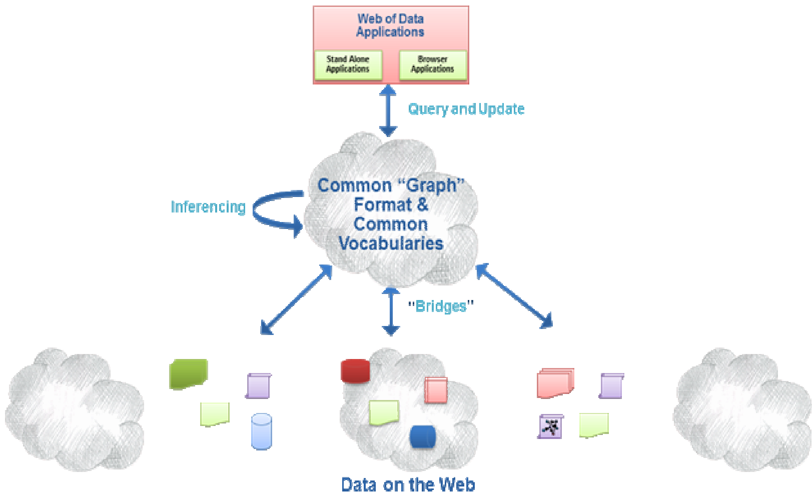


Figure 39: Creating the web of data

5.1. Markup Languages for Geospatial Data Interoperability

5.1.1. Geography Markup Language

OpenGIS® Geography Markup Language (GML) is an XML-based language for coding geospatial features. As such, it comprises the schema that describes the geospatial domain of the features as well as the actual data associated with them. Therefore, with GML it is possible a) to model systems possessing geospatial entities and b) to facilitate information exchange between geospatial transactions in the Web. Today, web clients and servers with implementations of the WFS (Web Feature Service) Interface Standard (discussed in Chapter 6) interact with GML files.

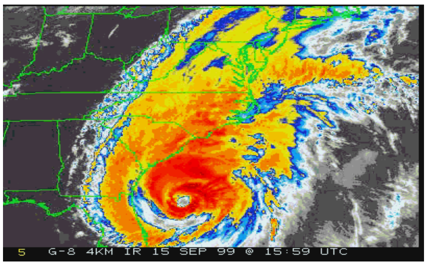
GML is based on abstract model of geography adopted by OGC and supports complex geometries, topological relationships, spatiotemporal data, coordinate reference systems, measurement units etc. The major GML characteristics are as follows [2]:

- Supports spatial and non spatial properties of the modeled objects
- It is open and vendor independent
- It is extensible
- Supports the description of geospatial application schemas
- Enables the creation and maintenance of interlinked geospatial application schemas and datasets
- Supports the transfer and storage of geospatial application schemas and datasets
- Increases the ability of sharing geospatial application schemas and the information described by them

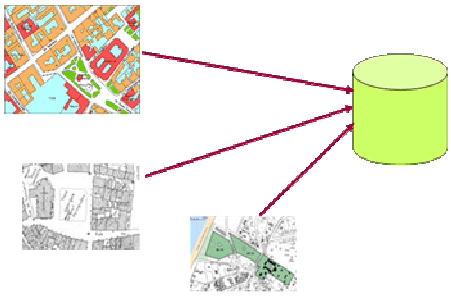
- It is a matter of those who develop the applications to decide whether the application schemas and the data will be stored in natural GML or whether GML will be used just for application and data exchange. Obviously, the first option might be adopted in newly developed systems from the scratch, while the second suits in already established systems that have to interoperate.
- GML schemas are not horizontal, neither are focused in a specific domain of expertise, however they can provide common constructions and concepts that may be employed by different application fields.

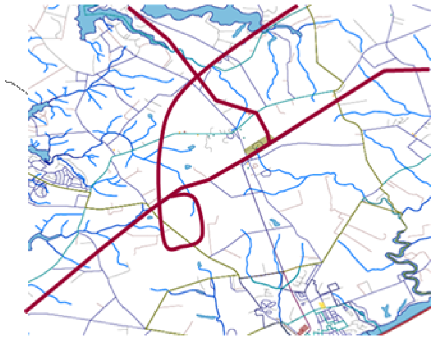
An interesting visualization of the needs and motivations that lead to GML development is presented by Lake (2005):

<ins>Response to Disasters:</ins> Data provision to multiple – geographically distributed – persons, agents and systems, is required. Participants are not only distributed but they are also autonomous.

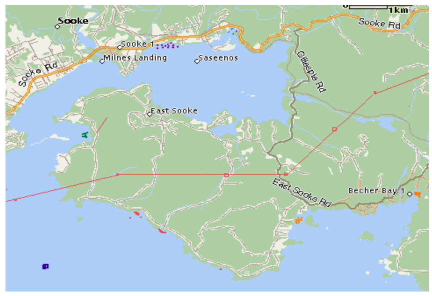


<ins>Integrated Cadastre:</ins> Municipalities share common borders, or in some cases they are merged or in other cases they are divided. Data related to cadastre may have to be used with other types of data.

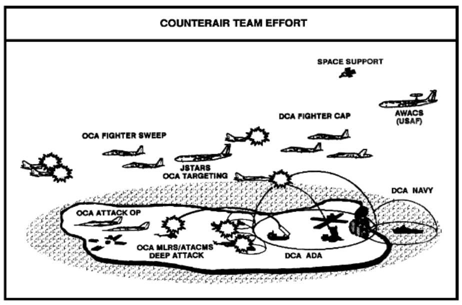




Transportation: Data related to national road network are managed by different authorities than those related to municipal road network. In addition, differentiations may be met between the descriptions of these two road networks



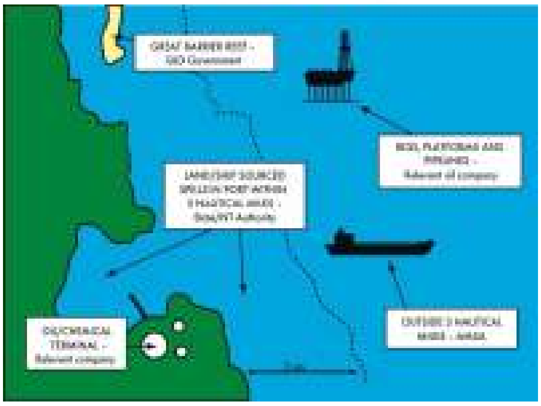
Land and Water Data Integration: Aquatic resources, electricity and gas lines crossing the boundaries of water and land, off-shore objects supported by the land, support in navigation and many other applications that require decision making from one provider and data provision to many agents



National Defense: In cases where it is important to coordinate multiple forces and there is a need for a global view of the situation, data are dynamically changing and involved units are widely distributed, data exchange in multiple direction is required

Design and Protection of Infrastructures: Multiple authorities and companies, complex structure and geometry, widely distributed stakeholders, data exchange in multiple directions, progress and development for a long period

Environmental protection: In state, national, local corporations, with distributed and autonomous stakeholders, facing dynamically changing and complex cases, when there is no knowledge of the global situation.



Location-based services: Wide variety of data sources, accurate and up to date information, widely distributed and mobile users, difficulties for service providers to create all data required, users require direct response for their individual needs

Concluding, GML contributes to Geospatial Web enablement. In an ideal case, GML absolute adoption enforces information societies to publish application schemas so that it is possible to be located, they are accessible and understandable from third parties. This way, agencies maintain the same properties of spatial features, resulting to the creation of the Web of Geospatial Data, as shown in Figure 40

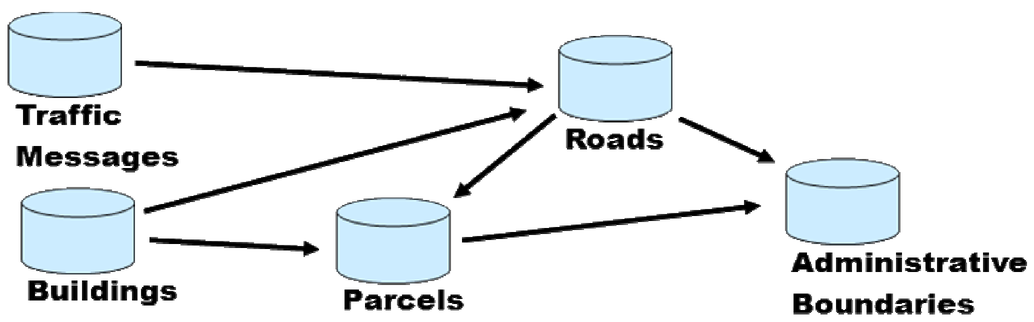


Figure 40: Web of Geospatial Data (Portele, 2003)

The above are depicted in the following example. The data model of Figure 41 illustrates a class diagram for modeling a Road class.

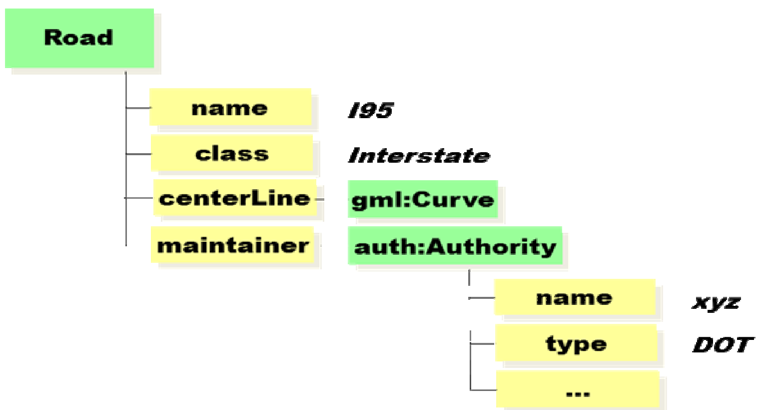


Figure 41: Road class diagram (Portele, 2003)

GML coding of the model is quite simple and is illustrated in Figure 42.

```
<Road gml:id="o.1f75dc">
        <name>I95</name>
        <class>Interstate</class>
        <centerLine>
                <gml:Curve>...</gml:Curve>
        </centerLine>
        <maintainer xlink:href="urn:x-auth:o.1f32a3"/>
</Road>
```

Figure 42: GML coding of Road class

It should be mentioned that the content concerning maintainer is modeled either as child of maintainer tag or is referenced by the property xlink:href. The link of this property may drive to the same GML document or elsewhere in the Web, highlighting that way a challenge – capability of the Web of Data

5.1.2. Keyhole Markup Language

Keyhole Markup Language (KML) is an XML based language focusing on the geographical visualization including comments on maps and graphics. Geographical visualization includes not only presenting graphics over the globe, but also controlling user navigation in terms of where to go and to look at. In this respect KML is complementary to most of the existing OGC key standards including GML, previously discussed and WFS (Web Feature Service) and WMS (Web Map Service) which are examined in the next paragraph (OGC, 2016).

The need for developing KML (Figure 43) was generated from the following facts:

a) lots of interesting data were available over the Web and

b) reasonable questions concerning these data were emerged such as:

- How accessible are these data?
- Is it possible to be viewed from the geographical – spatial perspective?
- How easy is to be shared?

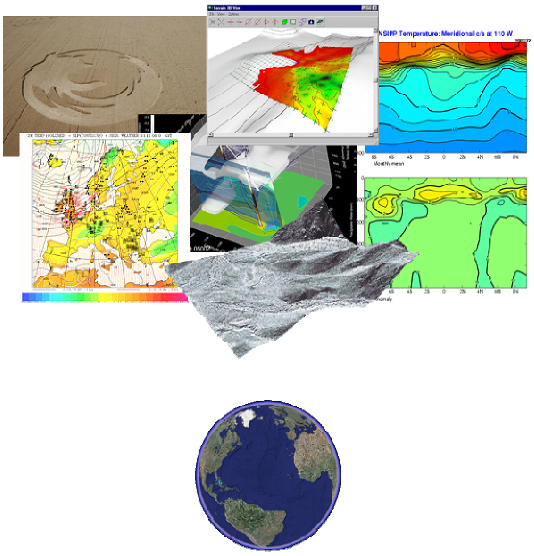


Figure 43: The need for developing KML

Finally, KML was introduced as the format for modeling and storing geographical features such as points, lines, pictures and polygons. In addition, KML files may be interlinked between each other and represent huge datasets.

As a result, KML is today the global format for representing data in Google Earth (Figure 44) and other earth browsers.

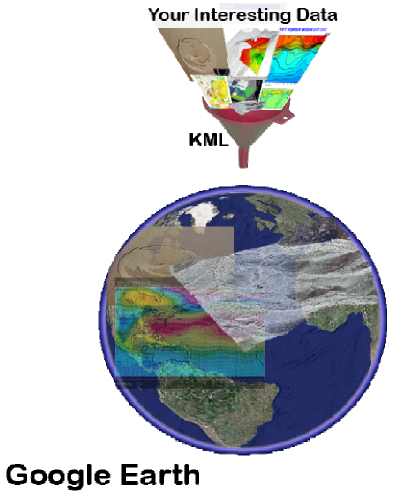


Figure 44: KML and earth browsers

KML is supported by Google which provides an interactive environment accessible by a web browser for controlling KML code (Figure 45)

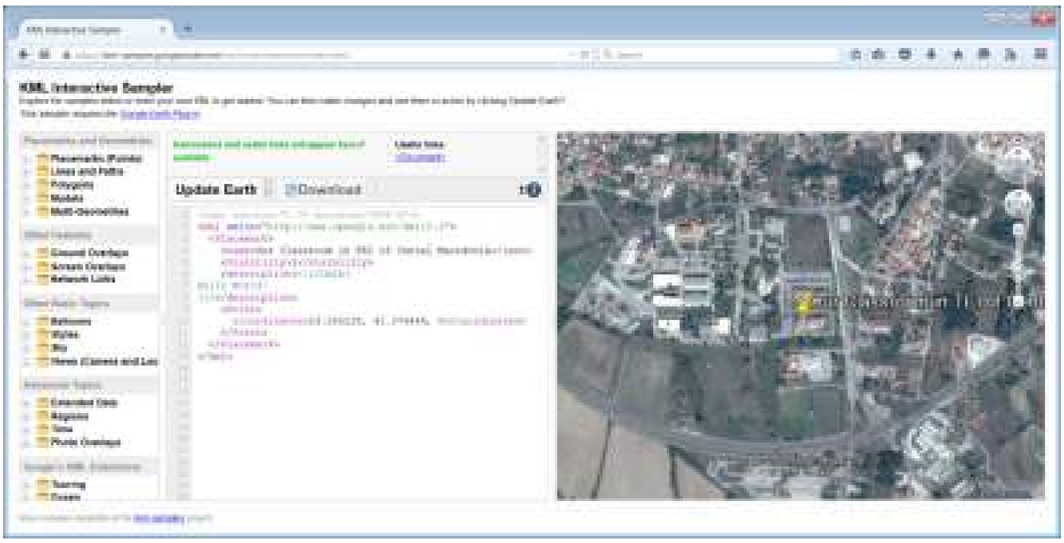


Figure 45: KML interactive sampler

For example Figure 46 depicts a simple coding of a placemark, located in the classroom where EnvYJobs videolabs will take place in Greece. This code can be written in any editor and checked through the KML interactive sampler.

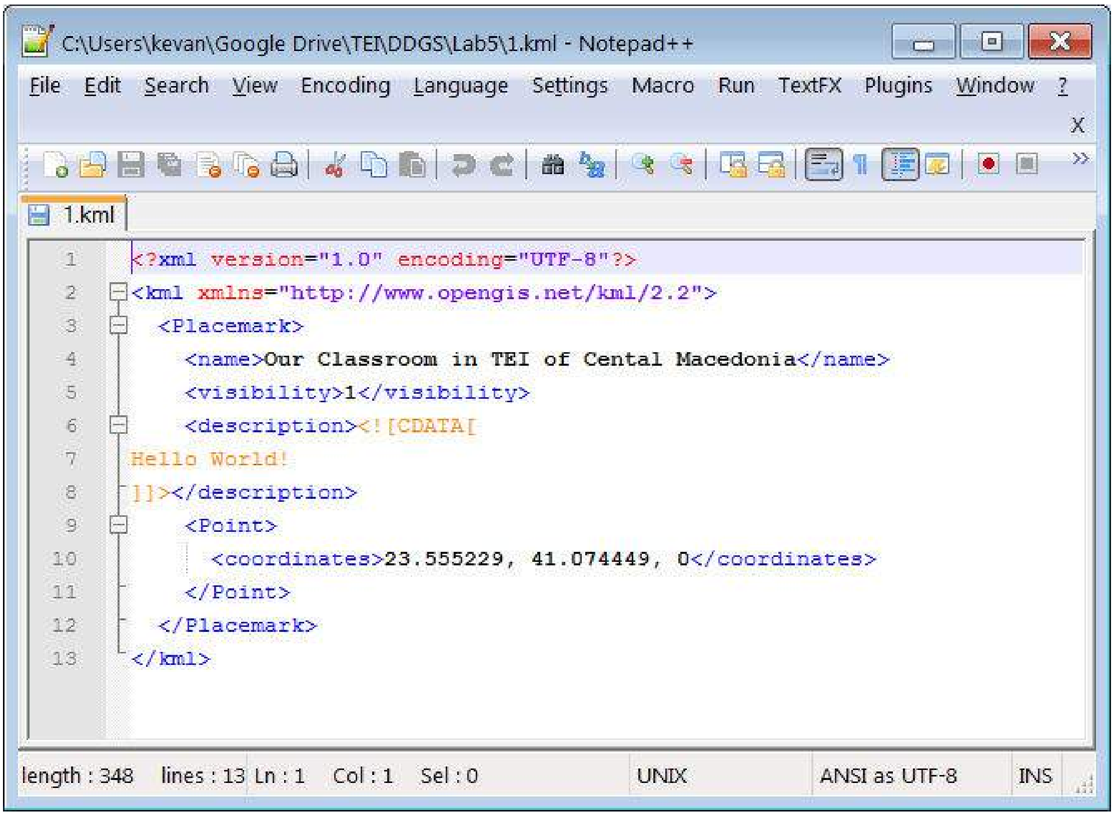


Figure 46: An example of coding in KML

5.2. Web Services and Interoperability

According to Cerami (2002) "a web service is any service that is available over the Internet, uses a standardized XML messaging system, and is not tied to any one operating system or programming language"

Practically, a web service may be implemented by use of the hypertext transfer protocol in combination with XML mark-up language that makes data transfer between machines, possible. That way Web Services allow Internet to act as a communication network between applications and not simply as a mean for sharing applications.

There are differences between a Website and a Web Service (FGDC, 2010):

- Websites provide HTML pages and forms so that users can navigate and perform operations such as searching, shopping as well as to interact with the application served by the web server. The end user interface is deployed in a web browser based on the content and the functionalities served by the web server.
- Web Services are not Websites; they are automatically invoked through a program and may be publicly available and standardized for usage by all software developers. Alternatively, they can be called through the address bar of a web browser.

For example, by typing the following URL:

```
http://api.geonames.org/postalCodeSearch?
postalcode=9015
&maxRows=10
&username=kevan
```

the web server api.geonames.org returns an XML file with information about places with postal code "9015".


```
- <geonames>
    <totalResultsCount>12</totalResultsCount>
  - <code>
      <postalcode>9015</postalcode>
      <name>St. Gallen</name>
      <countryCode>CH</countryCode>
      <lat>47.4056</lat>
      <lng>9.30933</lng>
      <adminCode1>SG</adminCode1>
      <adminName1>Kanton St. Gallen</adminName1>
      <adminCode2>1721</adminCode2>
      <adminName2>Wahlkreis St. Gallen</adminName2>
      <adminCode3>3203</adminCode3>
      <adminName3>St. Gallen</adminName3>
    </code>
  - <code>
      <postalcode>9015</postalcode>
      <name>Tromsø</name>
      <countryCode>NO</countryCode>
      <lat>69.6489</lat>
      <lng>18.95508</lng>
      <adminCode1 ISO3166-2="10">19</adminCode1>
      <adminName1>Troms</adminName1>
      <adminCode2>1902</adminCode2>
      <adminName2>Tromsø</adminName2>
      <adminCode3/>
      <adminName3/>
    </code>
  - <code>
      <postalcode>9015</postalcode>
      <name>PICO TRUNCADO</name>
      <countryCode>AR</countryCode>
```


Architectures based on open standards allow systems to “talk” between each other. This has emerged as the key approach for integrating distributed data sources and eliminating isolated systems. Architectures with components that are based on open standards allow building distributed systems in a way that these components are interlinked between together seamlessly. This also means that distributed systems may be easily upgraded and extended.

Figure 47a depicts three client/server isolated systems to which the user has to execute three different client applications in order to gain access to data, while this functionality is provided by three different server implementations. In such a case no interoperability and no reusability of the resources consumed for implementing client and server software exist. In addition, the ability of a user to transparently reach data through another external interface is very limited because data are accessible only through one given server.

Figure 47b illustrates various interoperable client/server systems. This means that client and server software resources may be reused, and that a variable and potentially wide set of servers from various vendors and organizations is available.

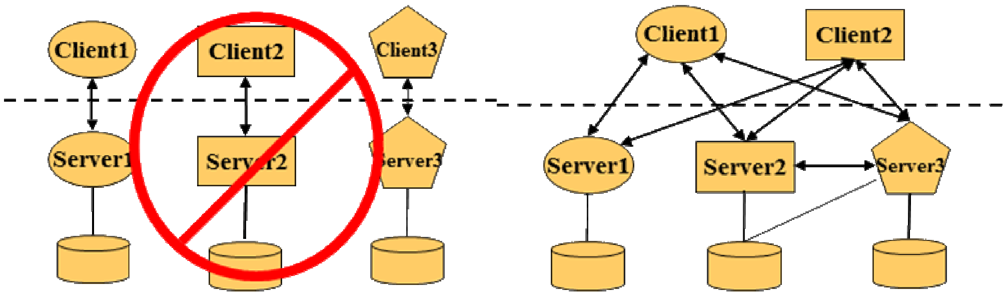


Figure 47: a) non interoperable systems and b) interoperable systems (FGDC, 2010)

Concerning geospatial information, such types of interoperable systems are crucial for developing Spatial Data Infrastructures.

5.3. OGC Geospatial Web Services

5.3.1. OGC (Open Geospatial Consortium)

OGC (Open Geospatial Consortium) is an international nonprofit organization whose mission is to create qualitative open standards to the geospatial community. These standards are developed under a unanimously process and are freely offered to anybody for use, in order to improve geospatial data interoperability worldwide. OGC standards are used in a wide variety of knowledge areas including Environment, Defense, Health, Agriculture, Meteorology, Sustainable Development and other. OGC members are coming from governmental, commercial organizations, non governmental organizations as well as academic and research organizations (OGC, 2016c).

5.3.2. Geospatial Web Services

Geospatial Web Services are services focused on geographic information. Three types of Geospatial Web Services are identified (FGDC, 2010):

1. Data Discovery Services: provide to the user the capability of searching into a metadata catalogue. Services provide all the metadata records that match searching criteria and allow view of individual records
2. Data Visualization Services – Allow the user to search, display and store geospatial data images
3. Data Access Services – Allow the user to search and obtain real geospatial data through a web client that may interact with the data

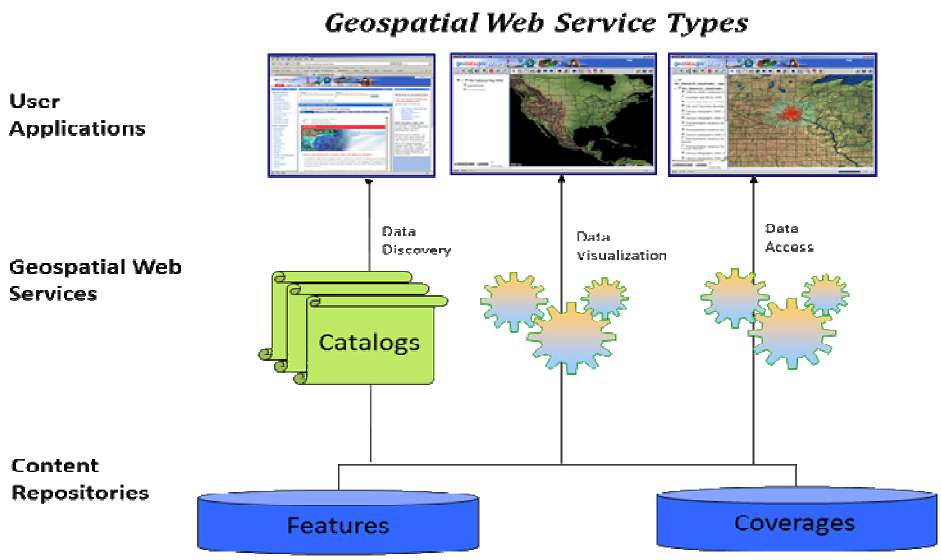


Figure 48: Types of Geospatial Web Services (FGDC, 2010)

The requests for Geospatial Web Services can be sent through a URL in a web browser. The parameters are included in the URL after a question mark (?) and are separated between each other with an ampersand (&). For example by typing in the web browser, the address:

```
http://demo.mapserver.org/cgi-bin/wms?
SERVICE=WMS
&VERSION=1.1.1
&REQUEST=Getcapabilities
```

an XML file is downloaded containing information concerning the capabilities of the server to provide maps through the WMS service..

Indicative requests specified in OGC geospatial web services include:

- GetCapabilities: request for information about the offered by the server geospatial data
- GetMap: request for getting an image file of the map of interest
- GetFeatures: request for getting geospatial features in form of coordinates
- GetFeatureInfo: request for getting the values of the attributes of a geospatial feature

In the next paragraphs the most important requests of two popular and widely used geospatial web services, are examined.

5.3.3. Web Map Service (WMS)

The OpenGIS® Web Map Service Interface Standard (WMS) provides a simple interface for submitting requests for raster maps, from one or more distributed geospatial databases. A WMS request defines the layer, the area of interest and other parameters to be processed by the map server. Response to request is one or more graphics in JPEG, PNG formats etc. that display the desired map and can be viewed in a web browser. The interface also supports the capability of specifying whether the returned graphic will be transparent so that layers form multiple servers are combined (OGC, 2016b).

The WMS service supports the requests GetCapabilities and GetMap. By typing for example a GetCapabilities type of request the user receives an XML type of file which analytically contains the specifications of the maps offered by the map server.

The following URL:

```
http://sampleserver1.arcgisonline.com/ArcGIS/services/Specialty/ESRI_StatesCitiesRiver
s_USA/MapServer/WMSServer?
&SERVICE=WMS
&VERSION=1.3.0
&request=GetCapabilities
```

returns an XML file that describes the offered capabilities as regards maps provision from a sample server belonging to ESRI. The following excerpt of the file contains in XML tags the specifications of the layer “States”

```
- <Layer queryable="1">
    <Name>0</Name>
    <Title>States</Title>
    <Abstract>States</Abstract>
    <CRS>CRS:84</CRS>
    <CRS>EPSG:4326</CRS>
  - <EX_GeographicBoundingBox>
      <westBoundLongitude>-178.217598</westBoundLongitude>
      <eastBoundLongitude>-66.969271</eastBoundLongitude>
      <southBoundLatitude>18.924782</southBoundLatitude>
      <northBoundLatitude>71.406235</northBoundLatitude>
    </EX_GeographicBoundingBox>
    <BoundingBox CRS="CRS:84" minx="-178.217598" miny="18.924782" maxx="-66.969271"
    maxy="71.406235"/>
    <BoundingBox CRS="EPSG:4326" minx="18.924782" miny="-178.217598" maxx="71.406235"
    maxy="-66.969271"/>
  - <Style>
      <Name>default</Name>
      <Title>0</Title>
    - <LegendURL width="76" height="16">
        <Format>image/png</Format>
        <OnlineResource xlink:href="http://sampleserver1b.arcgisonline.com/ArcGIS/services/Specialty
        /ESRI_StatesCitiesRivers_USA/MapServer
        /WMSServer?request=GetLegendGraphic%26version=1.3.0%26format=image/png%26layer=0"
        xlink:type="simple"/>
      </LegendURL>
    </Style>
  </Layer>
```

In order to retrieve the map a GetMap type request parameterized according to the above specifications has to be structured.

The following URL:

```
http://sampleserver1.arcgisonline.com/ArcGIS/services/Specialty/ESRI_StatesCitiesRiver
s_USA/MapServer/WMSServer?
service=WMS&
version=1.1.0&
request=GetMap&
layers=0&
styles=&
bbox=-164.765831,25.845557,-67.790980,70.409756&
width=760&
height=460&
srs=CRS:84&
format=image/png
```

returns an HTML page with png file embedded. The client server architecture is depicted in Figure 49 and their interaction through WMS service, contains the following actions:

- The client declares the parameters of his request through the web browser. The request is transformed into a composite URL address, which includes, beyond the server address, the commands and parameters of the request
- The server processes the request by parsing the command and the parameters then executing the transaction and returns the result embedded in an HTML page

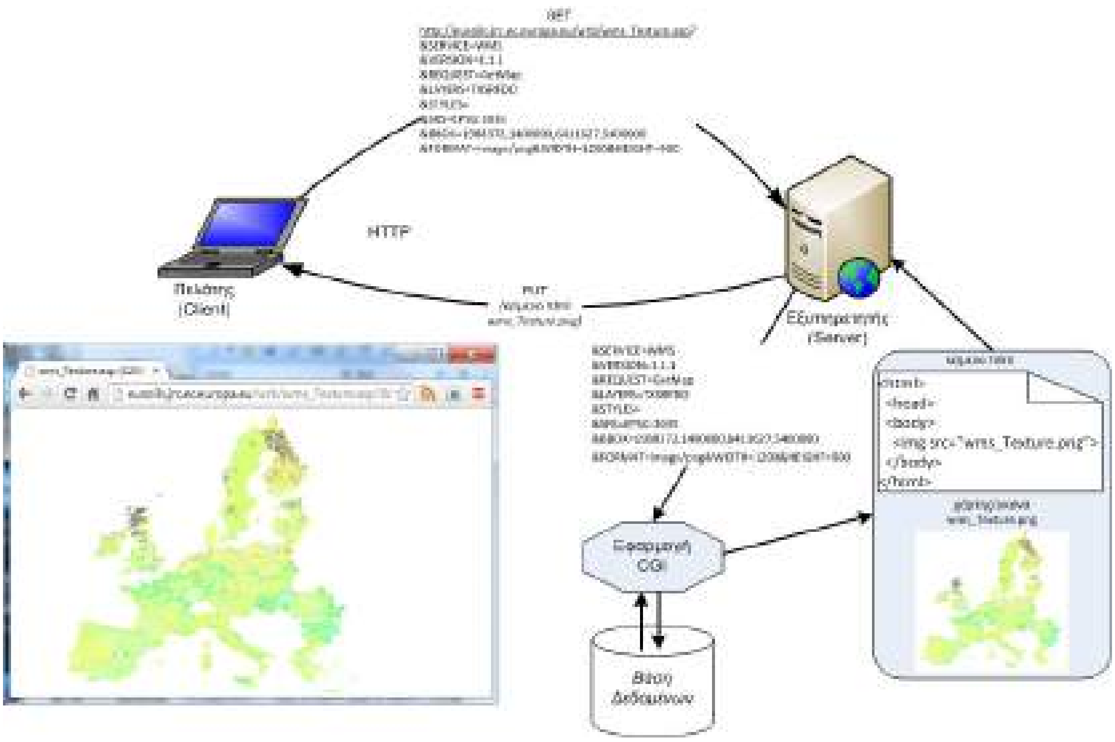


Figure 49: Client-server interaction through WMS service

5.3.4. Web Feature Service (WFS)

The OpenGIS Web Feature Service Interface Standard (WFS) defines an interface to specify requests concerning geographic features retrieval from the Web through independent to the platform calls.

The service supports requests of GetCapabilities type, similar to those of WMS service, that return XML file types with descriptions of the provided geographic features specifications.

Knowing the capabilities offered by the server and the related specifications, a GetFeatures request has to be structured for the geospatial features to be retrieved.

The following URL:

```
https://nsidc.org/cgi-bin/atlas_north?
service=WFS
&version=1.1.0
&request=GetFeature
&typename=greenland_elevation_contours
```

returns the coordinates of the contours in Greenland in GML format which is of XML type (Figure 50) and is visualized in contemporary GIS software packages (Figure 51)

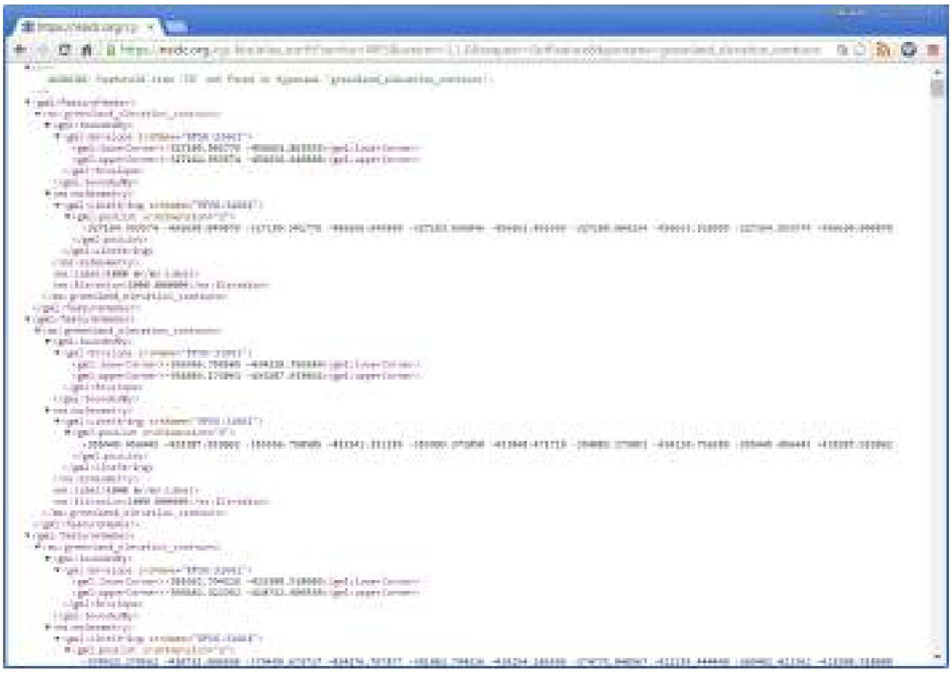


Figure 50: A GML file returned after a WFS/GetFeatures request

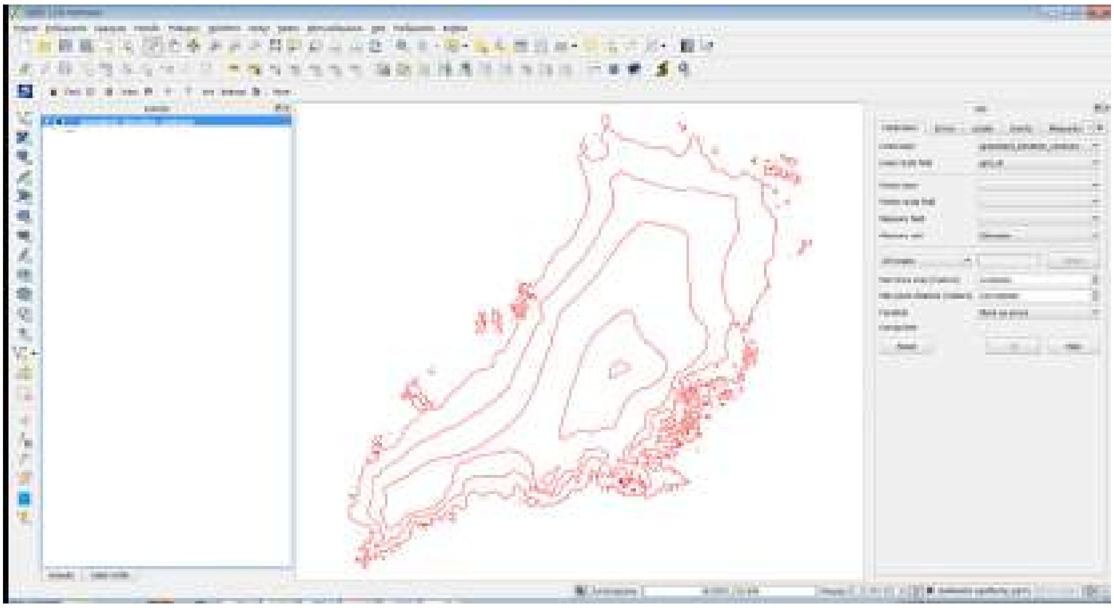


Figure 51: GML visualization in QGIS

CHAPTER 6

Geospatial Applications

6.1. Application

Geospatial Web Services were introduced in the previous chapter, and the capability of acquiring data was demonstrated, by simply submitting requests through a web browser. In this chapter free to use geospatial environmental data will be obtained from "European Soil Data Center (ESDAC)" (Panagos et al, 2012). Data will be retrieved either by a web browser or by QGIS plugins. Data will then be imported in the QGIS desktop GIS environment and major GIS functionalities will be employed to produce new processed environmentally-related thematic layers. Next step is to publish processed data through Geoserver, an open map server from OSGeo foundation and develop a simple Javascript web interface to access published data. Next paragraphs contain in detail the afore mentioned steps.

6.2. Acquiring Environmental Data

6.2.1. ESDAC

ESDAC stands for the European Soil Data Centre, a thematic centre for soil related data in Europe, aiming to serve as the reference point for soil data and to host all soil-related data and information at European level (http://esdac.jrc.ec.europa.eu/).

The ESDAC research team (Panagos et al, 2012) provides a great number of geospatial services both WMS and WFS and for this reason it is considered as the ideal repository for demonstrating an environmental geospatial application. The "Applications & Services" section of ESDAC provides a tool for working with ESDAC WMS services (Figure 52).

Figure 52: ESDAC WMS Services web interface

The interface provides searching with keywords capabilities. By clicking on WMS Openlayers option the requested map is retrieved through WMS service (**Figure 53**)

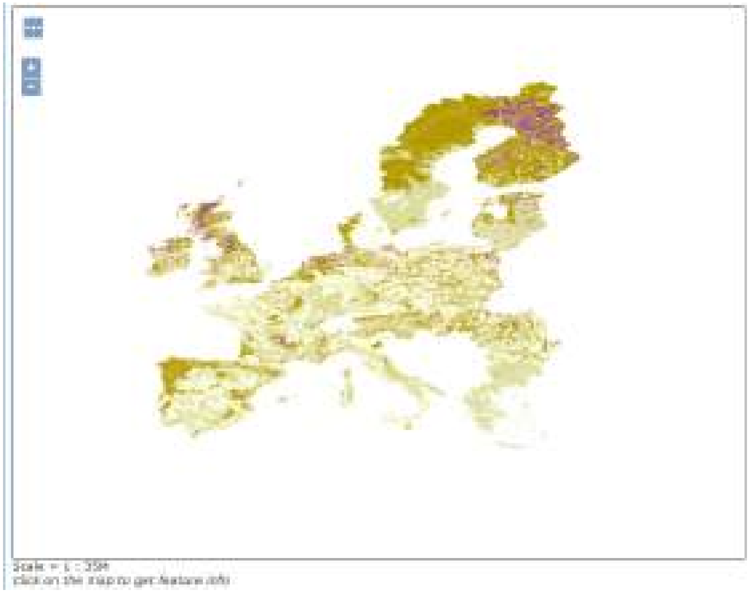


Figure 53: ESADAC map retrieved through WMS service

The map loaded in **Figure 53**, forms the following URL in the browser's address bar:

```
http://esdac.jrc.ec.europa.eu/viewer/geoserver/geonode/wms?
service=WMS&
version=1.1.0&
request=GetMap&
layers=geonode%3Aoc_top&
styles=&
bbox=-10.6152245918,31.5809474906,34.8097169992,70.0960552072&
width=800&
height=600&
srs=EPSG:4326&
format=application/openlayers
```

6.2.2. Submitting WFS requests

In order to check existence of potential WFS services that provide features (vector layers) through XML-based text files, the following URL is tested:

```
http://esdac.jrc.ec.europa.eu/viewer/geoserver/geonode/wfs?
service=WFS&
version=1.1.0&
request=GetCapabilities
```

The XML file that is returned, contains information about offered thematic layers, and among them topsoil organic carbon may be found on this, as shown in Figure 54

Figure 54: Topsoil organic carbon identified in WFS GetCapabilities XML file

The minimum parameters required for getting the vector file containing topsoil organic carbon are:

```
http://esdac.jrc.ec.europa.eu/viewer/geoserver/geonode/wfs?
service=WFS&
version=1.1.0&
request=GetFeature&
typename=geonode:oc_top
```

The above command returns an XML files containing coordinates of polygon features belonging to a category topsoil organic carbon content, and may be viewed in QGIS

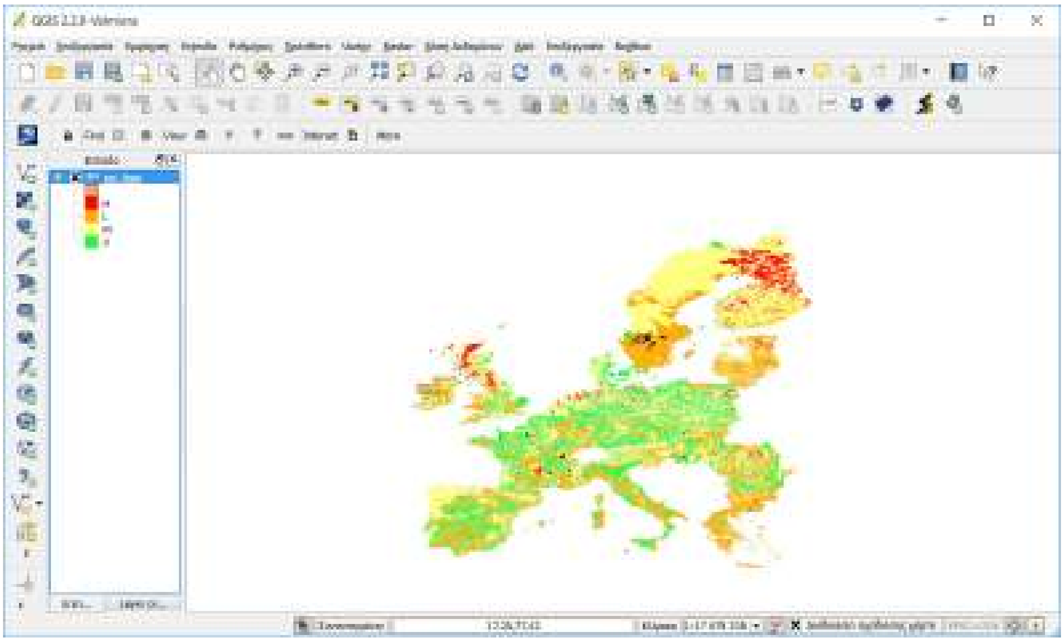


Figure 55: Visualizing XML topsoil organic carbon thematic layer in QGIS

6.2.3. Using QGIS WFS plug-in

For the purposes of the present demonstration, additional layers are retrieved from ESDAC repository by utilizing the WFS plug-in of QGIS (Figure 56):

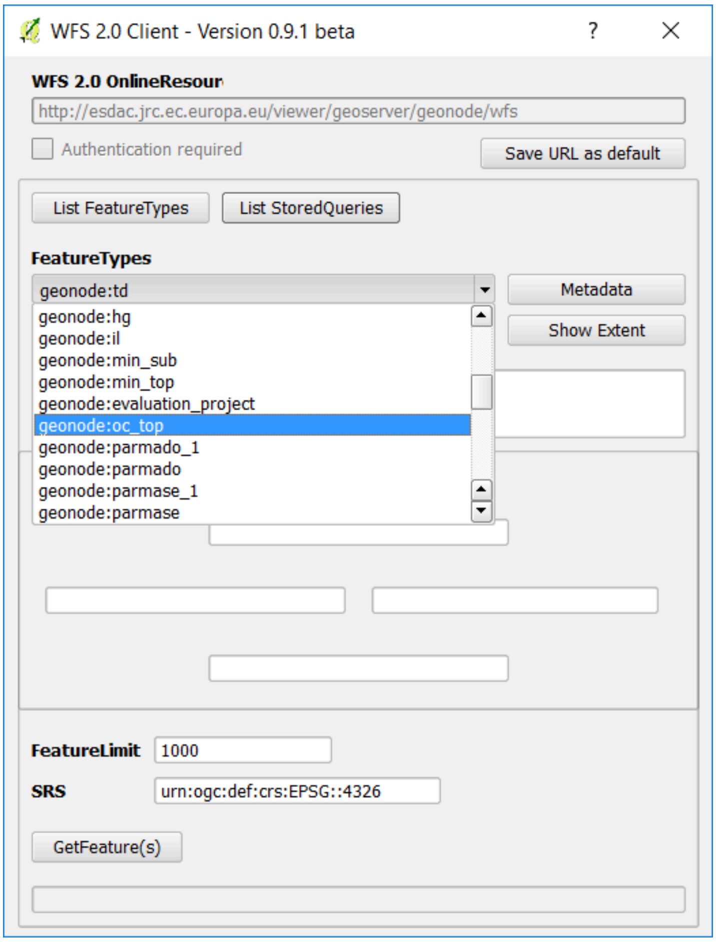


Figure 56: Employing QGIS WFS plug-in to obtain vector layers from ESDAC repository

6.3. Processes on Environmental Spatial Data

Searching inside the GML files of the layers previously acquired information describing the above spatial data may be easily extracted:

OC_TOP = Topsoil organic carbon content. The list of authorized codes and their corresponding meanings is given in the following table: OC_TOP = Topsoil organic carbon content. Code Value -------------- H = High (> 6 %) M = Medium (2 - 6 %) L = Low (1 - 2 %) V = Very low (< 1 %)
USEDO:Dominant Land Use USE-DOM: Code for dominant land use of the STU. USE DOM describes the dominant and most apparent land use for an STU. A second type of land use can be taken into account in USE SEC. The map co-ordinator must use his expert judgement to determine what are the dominant and secondary land uses for an STU, as the soil can cover extensive surfaces in regions with different agricultural practices and crops. If there is only one land use or if the variability is unknown, then the value of USE DOM must be copied to USE SEC. Land uses that do not involve much human intervention, such as wasteland, or wildlife refuse, or land above timberline, are also listed here. The list of authorised codes and their corresponding meanings is given in the following table for attributes USE-DOM : USE-DOM: Code for dominant land use of the STU Code Value -------------- 0 No information 1 Pasture, grassland, grazing land 2 Poplars 3 Arable land, cereals 4 Wasteland, shrub 5 Forest, coppice 6 Horticulture 7 Vineyards 8 Garrigue 9 Bush, macchia 10 Moor 11 Halophile grassland 12 Arboriculture, orchard 13 Industrial crops 14 Rice 15 Cotton 16 Vegetables 17 Olive trees 18 Recreation 19 Extensive pasture, grazing, rough pasture 20 Dehesa (extensive pastoral system in forest parks in Spain) 21 Cultivos enarenados (artificial soils for orchards in SE Spain) 22 Wildlife refuge, land above timberline

An environmental scenario involving major GIS processes is applied on the above.

Scenario Statement: *As good cultivation practices are considered those resulting to topsoil organic carbon with concentrations greater than 2% in arable land.*

The process of identifying arable land cultivated according to the above statement may be subdivided in the following sub-processes:

- Select areas of high or medium topsoil organic carbon content
- Select arable land areas
- Calculate intersection of the above areas

Below these sub-processes are performed:

1 Select areas of high or medium topsoil organic carbon content

To select polygon features containing high or medium values of organic carbon a simple condition is applied on the field containing organic carbon concentrations, as shown in Figure 57)

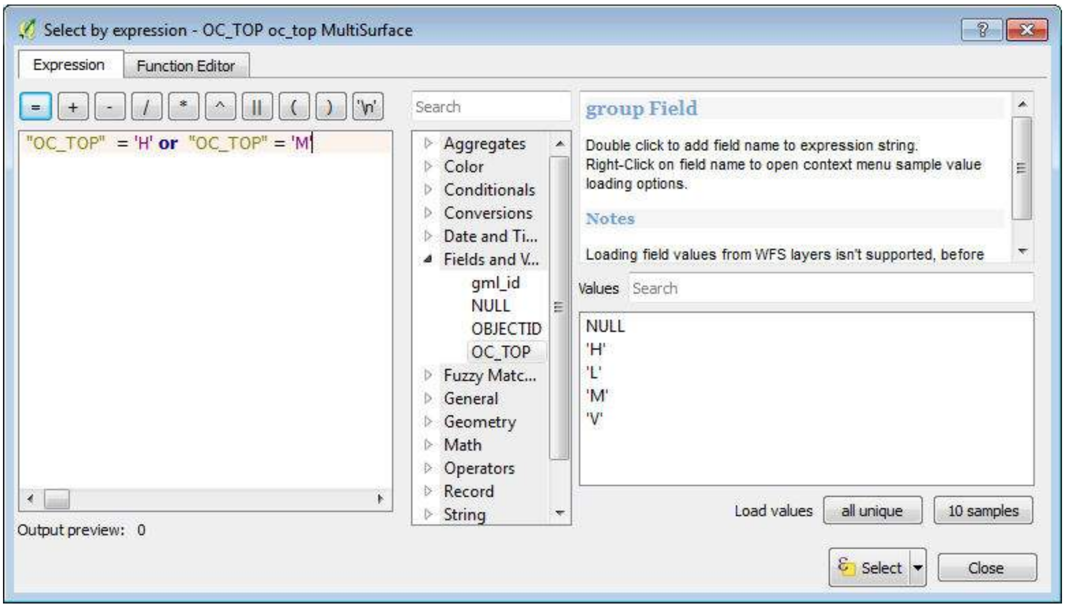


Figure 57: Selecting by organic carbon concentration

A number of 6373 out of 22960 (28%) polygons are characterized with high or medium organic carbon content (Figure 58)

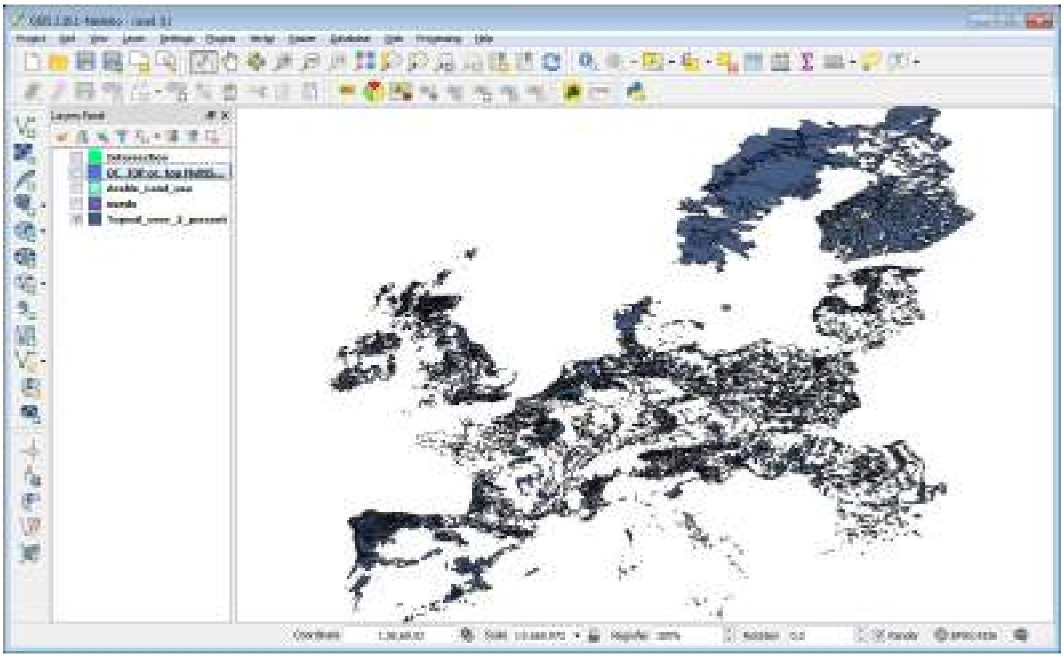


Figure 58: Organic carbon filter by High or Medium content

2 Select arable land areas

To select polygon features belonging to arable land a simple condition is applied on the field containing land use codes, as shown in Figure 59

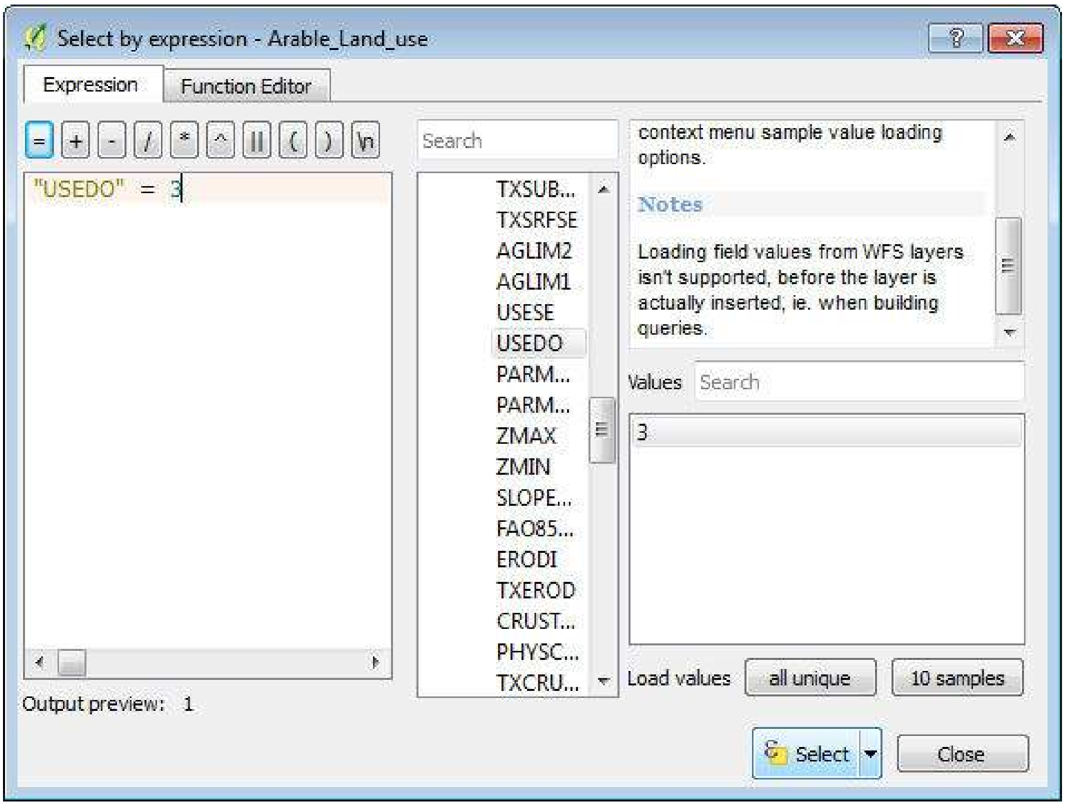


Figure 59: Selecting by land use

A number of 9029 out of 22960 land uses belong to the Arable category (Figure 60)

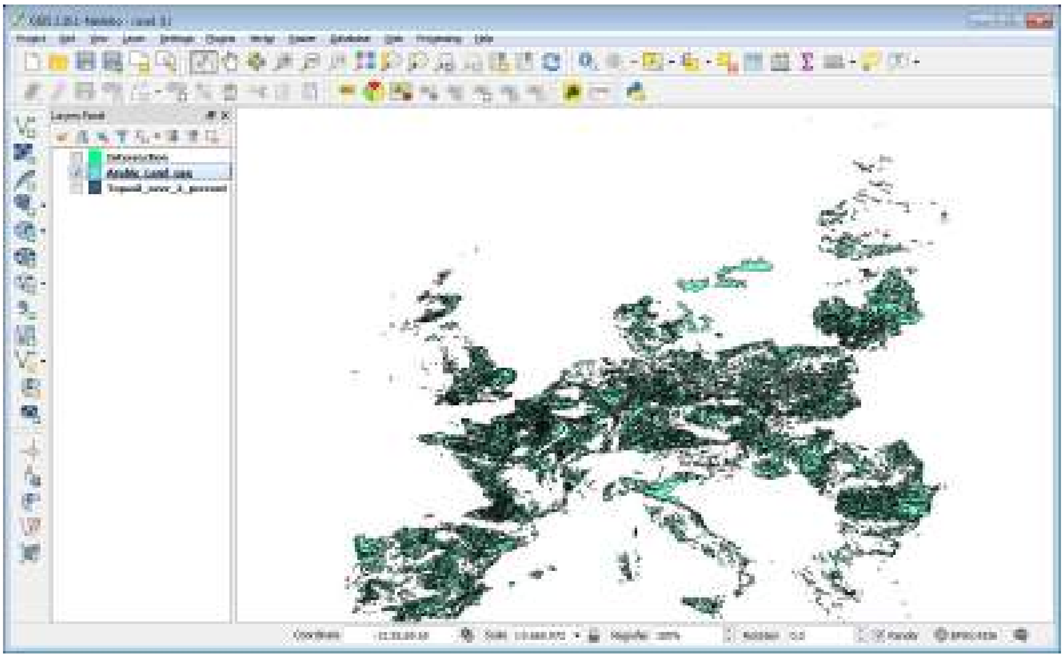


Figure 60: Land use layer filtered by arable land use

3 Calculate intersection of the above areas

QGIS provides intersection interface under vector/geoprocessing tools. Parameters include the specification of the input and the intersection layers (Figure 61). The placement of the layers is not order sensitive.

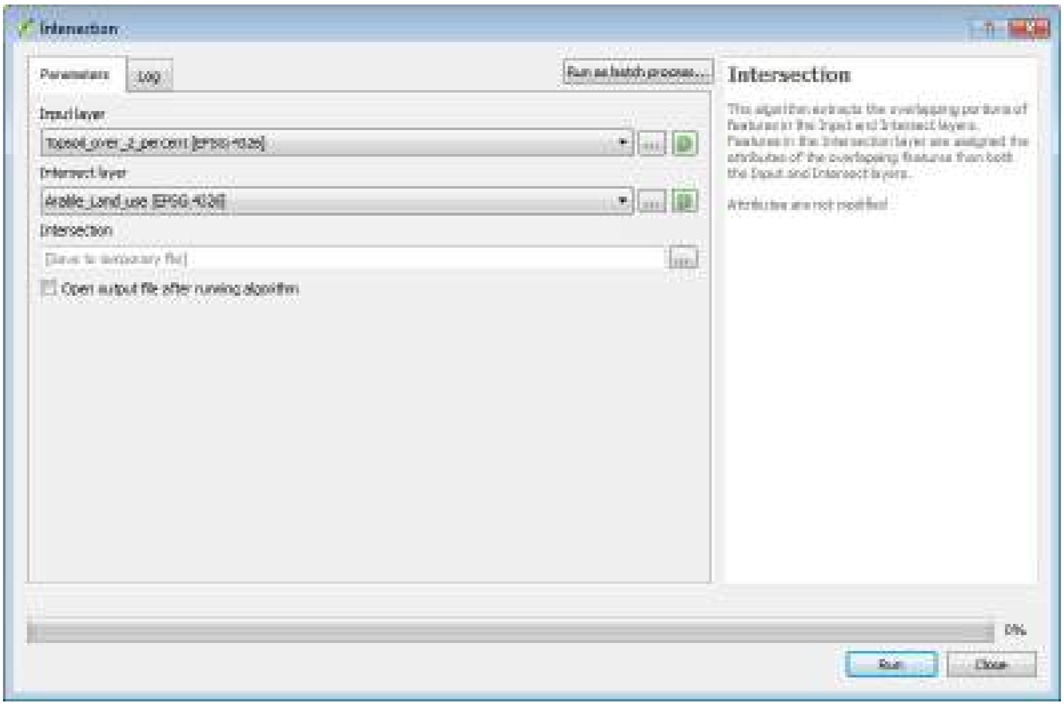


Figure 61: QGIS Intersection interface

Intersection of two polygon layers is a new polygon layer containing features that are common to both initial polygon layers. Therefore, the result will contain arable land areas having topsoil organic carbon concentrations greater than 2%, as shown in Figure 62. The result is saved as shapefile format and is given the name AL_OC.shp

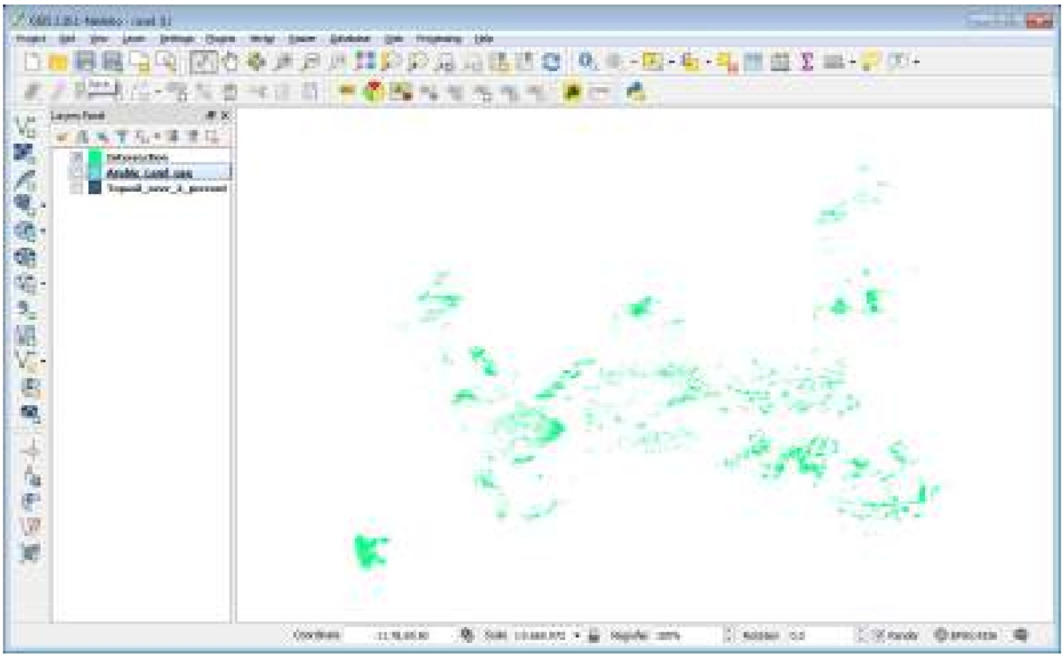


Figure 62: Arable lands with organic carbon concentrations over 2%

6.4. Creating an Environmental Web Service

6.4.1. Installing a Map Server

For the purposes of creating a geospatial environmental web service a map server has to be installed. GeoServer (http://geoserver.org/) an open source map server, for sharing geospatial data, conforming with the standards set by OGC, supported by OSGeo foundation and cooperating properly with QGIS desktop GIS, was considered as the appropriate choice.

GeoServer is free for download and usage and the installation process is quite simple. After installation with the default settings GeoServer will be responding on port 8080 of the localhost (Figure 63).

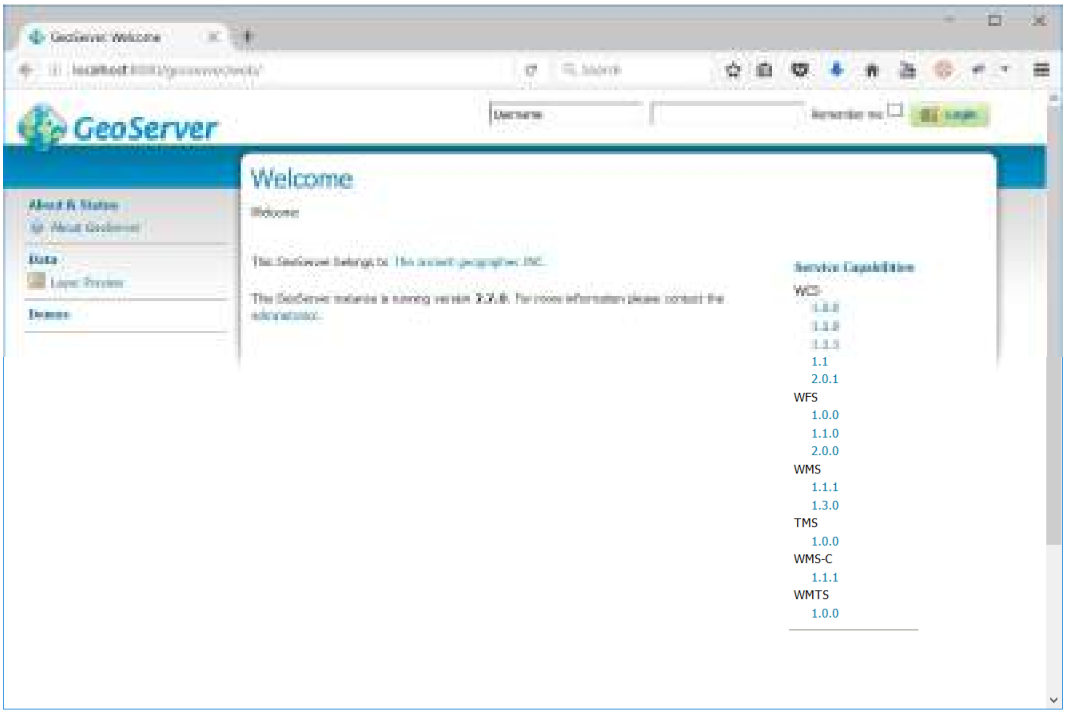


Figure 63: GeoServer installation

6.4.2. Importing and Publishing Data

The default user (login: admin, password: geoserver) will be used for the purposes of importing and publishing geospatial data previously created, in GeoServer installation responding in http://localhost:8080/geoserver/web.

Before continuing, the data previously created, concerning the arable lands with appropriate organic carbon content will have to be copied in a folder called “EnvYJobs” that will have to be created in the default Geoserver data path, as follows: “geoserver/data_dir/data/EnvYJobs”

In the path *Data ‣Workspaces* the *Add new workspace* selection will be used in order to create a Workspace with the following parameters:

Name: EnvYJobs, Namespace URI: EnvYJobs.

The EnvYJobs workspace has been created (Figure 64).

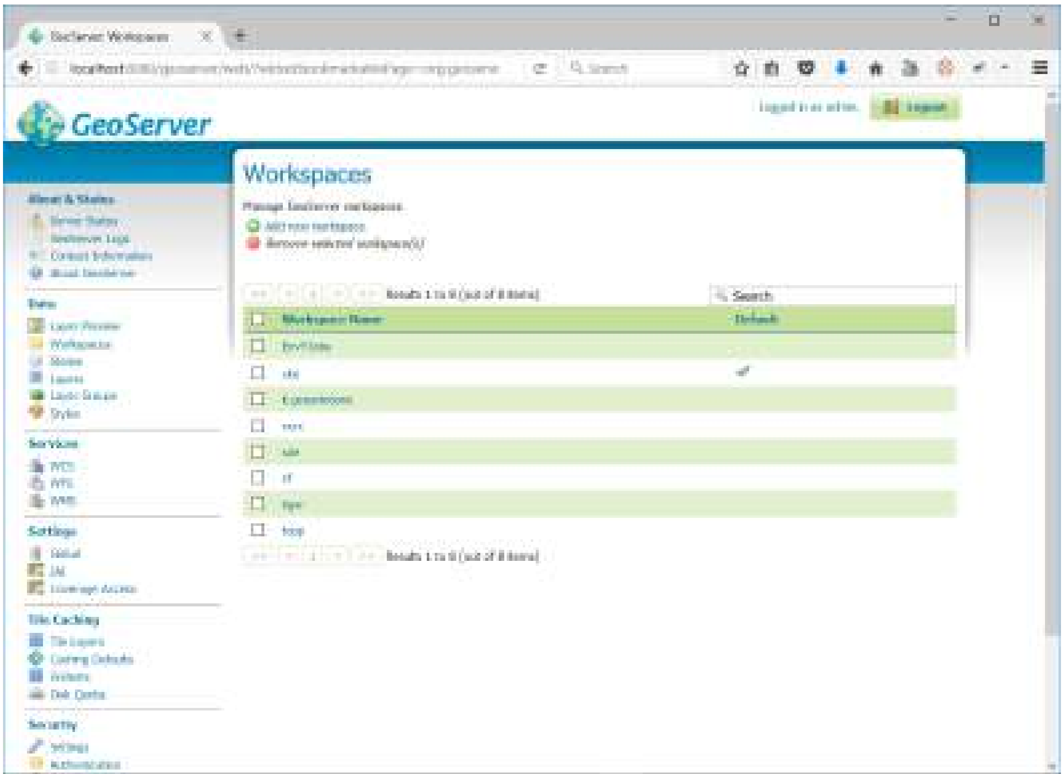


Figure 64: Creating the EnvYJobs workspace

Next step is to create a Store by navigating in *Data ‣Stores*, selecting *Add new store* of *Vector data source* Shapefile, and filling in the following parameters, as shown in Figure 65:

- Workspace: EnvYJobs
- Data Source Name: AL_OC

- Description: Arable lands with high organic carbon content
- Enabled: Checked
- Shapefile location: Browse…EnvYJobs/AL_OC.shp
- DBF charset: UTF-8

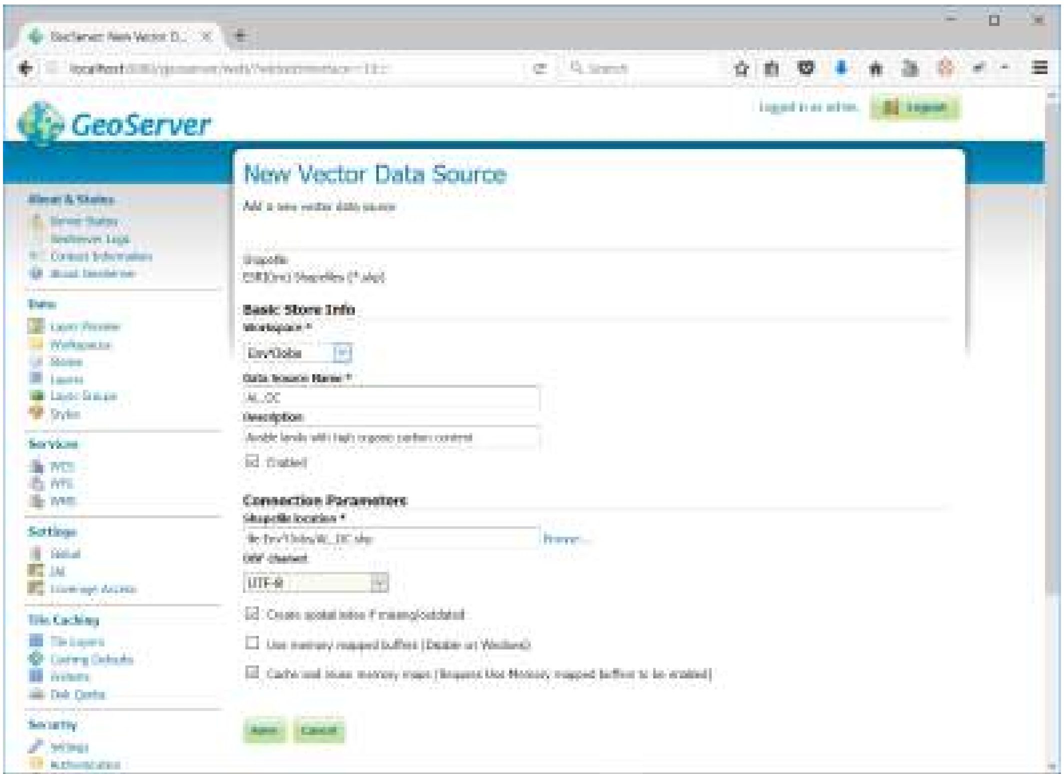


Figure 65: Creating a store for Arable lands with high organic carbon content

By saving the form of Figure 65, the choice of publishing the layer appears and the following parameters will have to be filled in:

- Enabled, Advertised: Checked
- Coordinate Reference Systems / Declared SRS / Find / Search EPSG 4326 / Click Code 4326

- Bounding Boxes: Compute from data
- Click Compute from native bounds

By saving this form a list of layers being published by GeoServer appears containing also in the last line, the EnvYJobs AL_OC layer, as shown in Figure 66.

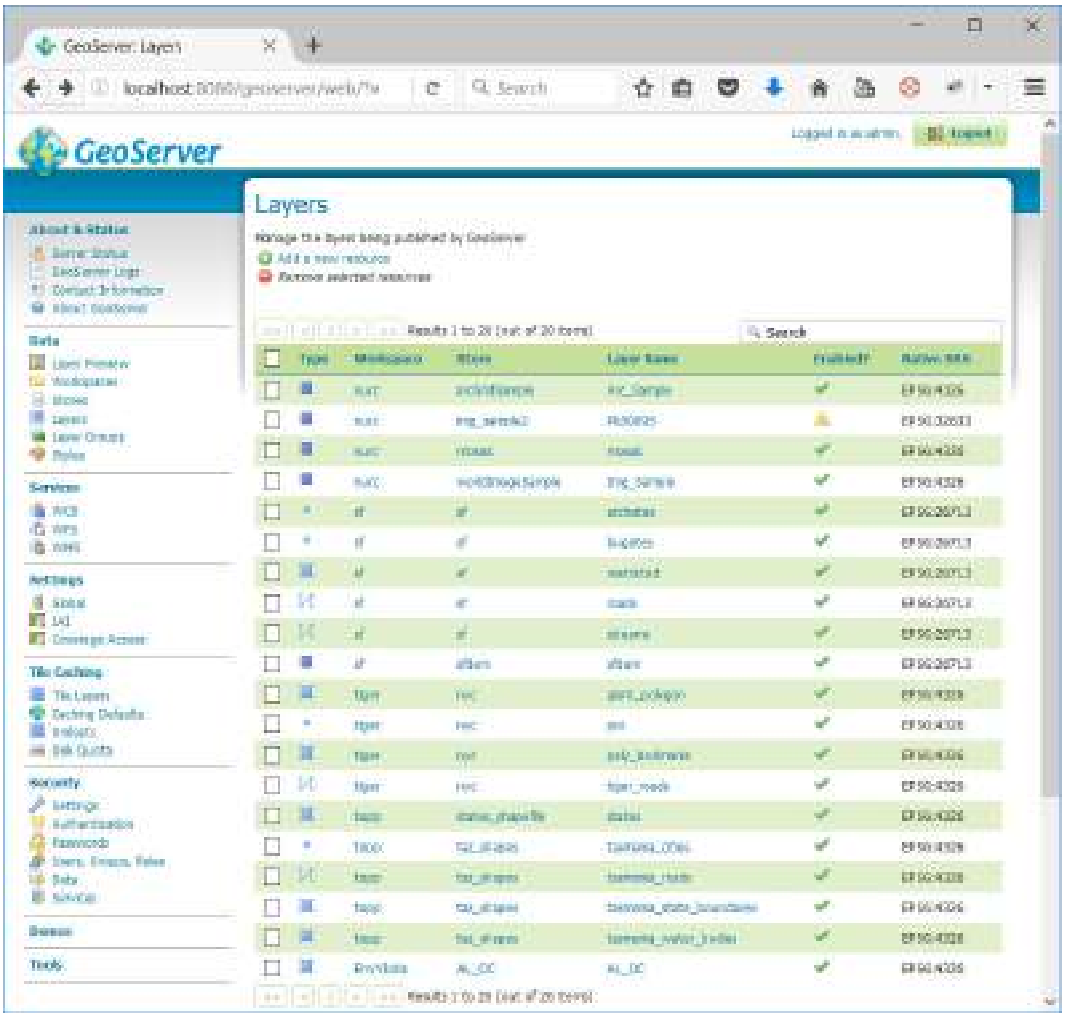


Figure 66: Layers being published by GeoServer

By navigating to *Data‣-Layer preview* and selecting the EnvYJobs AL_OC layer to be viewed through openlayers format, the final result of the layer's publish appears, as shown in Figure 67.

Figure 67: A Web Map Service of the requested layer in Openlayers format

6.5. Creating a Custom Web Application

6.5.1. Getting free and open source code

The presented case is completed with the development of an application that is connected with the layers published by GeoServer, and provides a simple web interface to list and present them. The application is written in Javascript and uses the Openlayers and the GeoExt geospatial libraries developed on top of Javascript.

This specific application is free and open source and is demonstrated in the GeoExt2 GitHub repository located in:

https://geoext.github.io/geoext2/examples/wmscapabilities/wmscapabilities.html

and is shown in Figure 68

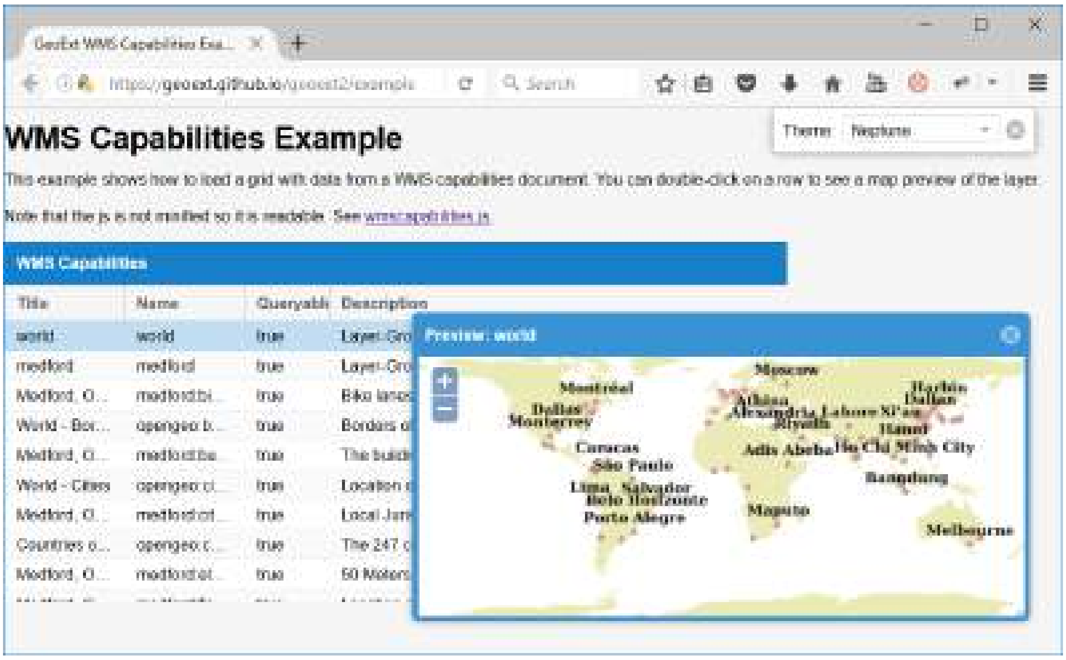


Figure 68: The application selected to be parameterized

The whole GeoExt2 Javascript Toolkit can be downloaded from:

https://github.com/geoext/geoext2

in a zip file (geoext2-master.zip).

6.5.2. Configuring a Web Server

A Web Server is required in order to publish the developed application. In the case of Windows the Internet Information Server (IIS) is incorporated in the operating system and may be easily enabled (http://www.microsoft.com/en-us/download/details.aspx?id=11093). Alternatively, or in the case of other platform, it is easy to search and install other types of web server software (e.g. Apache http://www.apache.org).

6.5.3. Parameterizing the Geospatial Application

In order to parameterize the WMSCapabilities application to work with the Web Server installed in the localhost and the GeoServer previously installed in the present work, the following arrangements have to be made:

1. The whole GeoExt2 toolkit has to be unzipped in the site folder of the Web Server (in case of IIS this is the \\inetpub\wwwroot\ folder)
2. The WMS capabilities XML file of the Geoserver installed in the localhost has to be requested through the following URL:

```
http://localhost:8080/geoserver/wms?
service=WMS&
version=1.1.0&
request=GetCapabilities
```

3. The XML WMS Capabilities file will have to be renamed as wmscap.xml and placed in the path of the Web Server geoext2-master\examples\data replacing the existing file

The application is served in the URL:

http://localhost/geoext2-master/examples/wmscapabilities/wmscapabilities.html?theme=classic

as shown in Figure 69

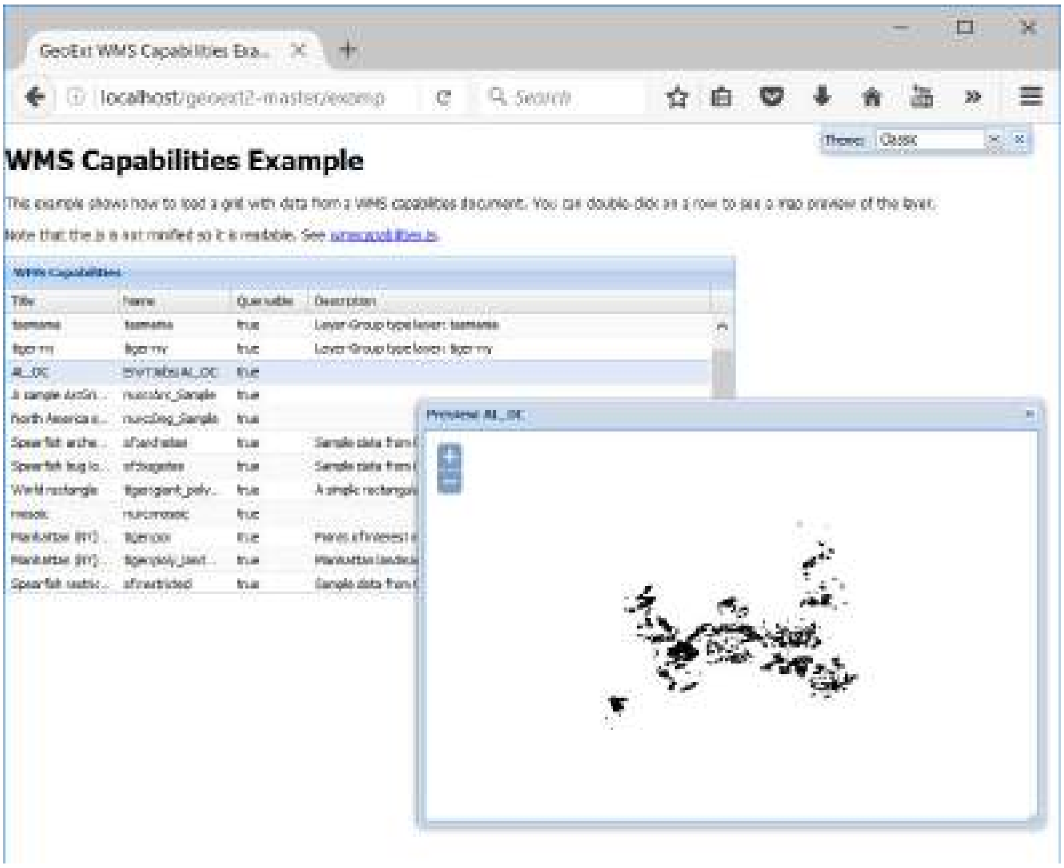


Figure 69: A web interface for viewing WMS services published by GeoServer

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