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D5.2 – The role of Remote Sensing in the three sub-sectors

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Work package / Task:

WP5 - Testing and validating the strategy based on case-based learning scenarios in 3 sub-sectors

T5.2 - Defining the role of Remote Sensing and related techniques in the scenarios

Short Description:

This report provides an overview of available remote sensing data, methods and tools relevant for the selected case-based scenarios. These data and techniques are considered as the horizontal domain that underpins the teaching/learning activities in the three sub-sectors: integrated applications, smart cities and climate change.
Remote sensing data sources and information extraction techniques/tools for the case-based scenarios are compiled in the form of interactive catalogue and made available in the Curriculum Design Tool to feed into educational structures to address the issues defined in the scenarios.

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Executive Summary

This report provides an overview of available **remote sensing data, methods and tools** relevant for the selected case-based scenarios in three sub-sectors: integrated applications, smart cities and climate change. They are considered as the common thread of these sub-sectors. The identified data and techniques are core elements that underpin and feed into case-based learning to solve the issues defined in the scenarios. The identified remote sensing data, methods and tools are listed and presented in an interactive catalogue, and the courses defined on their basis constitutes the educational offer of the Curriculum Design Tool. So that the planned traning action/event and learning activity/process can be prepared in a more **efficient and effective way**.

The most commonly identified remote sensing data in the scenarios are **optical data** (61%) followed by the **radar data** (20%). Most of the identified data (62%) are openly available (e.g. Sentinel data). Almost in half of the cases Copernicus Programme's services are indicated as a data source. The most commonly identified methods for remote sensing data processing and analysis are **time series analysis** (21%), **change detection** (17%) and **classification** (17%). The main tool identified in the selected case-based scenarios is **GIS software** (44%) followed by **remote sensing tools** (26%). The identified data, methods and tools were linked to the EO4GEO **BoK concepts**. In total, 175 unique BoK concepts were selected, which represents 16% of all concepts (1082 concepts) available in the BoK visualisation and navigation tool FindInBoK (BoK Version 2.0).

Based on the selected data, methods and tools, the following **six courses in the form of face-to-face, on-line (virtual) and blended learning** at different European Qualifications Framework (EQF) levels were specified.

a. **time series analysis** of optical data in the context of efficient planning and operation of **solar energy farms** (EQF 6)

b. **change detection** in the context of geospatial data and technologies applications for **land monitoring** (EQF 6 and 7)

c. **classification of urban vegetation** in the context of evaluation and planning of urban green structures to increase quality of life and **support ecosystem services in urban environments** (EQF 3)

d. **classification of flooded areas** in the context of **improving sustainability of cities** to storm and water (EQF 6)

e. **object-based image analysis** in the context of identification of **local heat islands** to support city planning (EQF 6 and 7)

f. **persistent scatterer interferometry** in the context of **mapping landslides** affecting Cultural Heritage sites - Baia Archaeological Park (Naples) (EQF 7)

Half of the courses (a, b, f) are planned as **academic course** and the other half (courses c, d, e) as part of **vocational and education training courses**.

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Acronyms

Acronym	Description
ARD	Analysis Ready Data
BoK	Body of Knowledge
BPMN	Business Process Model and Notation
CAMS	Copernicus Atmosphere Monitoring Service
CDT	Curriculum Design Tool
CEDEFOP	European Centre for the Development of Vocational Training
CEMS	Copernicus Emergency Management Service
CLMS	Copernicus Land Monitoring Service
CMEMS	Copernicus Marine Environment Monitoring Service
COSMO-SkyMed	Constellation of Small Satellites for Mediterranean basin Observation
C3S	Copernicus Climate Change Service
DaaS	Data as a Service
DEM	Digital Elevation Model
DIAS	Data and Information Access Services
EACEA	Education, Audio-visual, Culture Executive Agency
EARSC	European Association of Remote Sensing Companies
EC	European Commission
EO	Earth Observation (incl. Meteorology)
EO*GI	EO and GI sectors
ERS	European Remote Sensing satellite
ESA	European Space Agency
EQF	European Qualifications Framework
EU	European Union
FORLI	Fast Optimal Retrievals on Layers for IASI
FSU-EO	Department for Earth Observation, Friedrich Schiller University Jena
GEE	Google Earth Engine
GEOF	Faculty of Geodesy, University of Zagreb
GI	Geographic Information
GIB	Geografiska Informationsbyrån AB
giCASES	Knowledge Alliance project under the Erasmus+ programme of the European Commission
GIS	Geographic Information System
HR	High Resolution EO data
HRL	Copernicus High Resolution Layers
IaaS	Infrastructure as a Service
IASI	Infrared Atmospheric Sounding Interferometer
ICT	Information Computer Technology

IES	Institute for Environmental Solutions
IGiK	Institute of Geodesy and Cartography
InSAR	Interferometric Synthetic Aperture Radar
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISPRA	Italian National Institute for Environmental Protection and Research
KU Leuven	Catholic University of Leuven
LTB	Living TextBook
MODIS	Moderate Resolution Imaging Spectroradiometer
MOOC	Massive Open Online Course
MSG	Meteosat Second Generation
NASA	National Aeronautics and Space Administration
OBIA	Object-based Image analysis
OLI	Operational Land Imager
PaaS	Platform as a Service
PLUS	Paris Lodron University of Salzburg
RADAR	Radio Detection and Ranging
ROSA	Romanian Space Agency
RS	Remote Sensing
SaaS	Software as a Service
SAR	Synthetic Aperture Radar
SDI	Spatial Data Infrastructure
SNAP	SentiNel Application Platform
SPOT	Satellite Pour l'Observation de la Terre
StaMPS	Stanford Method for Persistent Scatterers
TEP	Thematic Exploitation Platform
TIRS	Thermal Infrared Sensor
TROPOMI	TROPOspheric Monitoring Instrument
UNIBAS	University of Basilicata
UPAT	University of Patras
UT-ITC	Faculty Geo-Information Science and Earth Observation, University of Twente
VET	Vocational Education and Training
VHR	Very High Resolution EO data
WARM	Water Accounting Rice Modelling
WG	Working Group
WP	Work Package

Glossary

- **Blended learning** a type of education in which students learn via electronic and online media as well as traditional face-to-face teaching.
- **Bloom's Taxonomy** is a classification of thinking or cognitive skills, which is often used in the design of educational, training and learning processes, and especially in the definition of learning outcomes. Bloom's Taxonomy consist of six levels of thinking skills, ranged from lower order thinking skills to higher order thinking skills.
- **Body of Knowledge (BoK)** is the complete set of concepts and relations between them, that make up a professional domain, (in this case EO*GI BoK) and the related learning outcomes as defined by the relevant learned society or a professional association.
- A **Course** is a unit of teaching, a set of lectures or a plan of study on a particular subject, usually leading to an exam or qualification. This unit can be used for teaching theoretical as well as practical content; depending on the specific subject of the course and its theoretical or practical nature the assessment of learners is done with an exam or through the assessment of assignments.
- The term **Earth Observation (EO) related services** is taken to mean any geo-spatial information service activity which in some way involves data coming from EO satellites (including meteorological satellites) i.e. any satellite with one or more sensors that measure parameters coming from the earth's surface or atmosphere. The involvement may be direct i.e. processing or distributing imagery or indirect i.e. consultancy based around knowledge of the imagery or its use. It starts from the point where imagery is transmitted to the ground, so it does include reception and processing of imagery but does not include construction of ground stations or the satellites delivering the data. Note that it includes all geo-spatial information services activities where satellite EO data has been used and so extends to downstream information processing of geospatial information where data being used has been derived from EO imagery possibly in combination with other data types.
- **European Centre for the Development of Vocational Training (CEDEFOP)** is one of the EU's decentralised agencies. Founded in 1975 and based in Greece since 1995, it supports development of European vocational education and training (VET) policies and contributes to their implementation.
- **European Qualifications Framework (EQF)** descriptor is defined by 8 levels of descriptors that indicate at each level the learning outcomes relevant to qualifications in any system of qualifications.

- **Geographic Information (GI)** is the data of a geographic location combined with non-spatial information (e.g. statistical data) and their representation as a map.
- **Geographic Information System (GIS)** is a computerized tool designed for storing, analysing and consulting data where geographic location is an important characteristic or critical to the analysis.
- **Knowledge** means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices related to a field of work or study. In the context of the European Qualifications Framework, knowledge is described as theoretical and/or factual.
- **Information and communication technologies (ICT)** are the infrastructure and components that enable modern computing.
- **Learning** is the process by which an individual assimilates information, ideas and values and thus acquires knowledge, know-how, skills and/or competences. (Source: Cedefop, 2008) Learning occurs through **teaching** (from a perspective of teacher, fasilitator) / **learning** (from perspective of learner, trainee) activities such as reading, reflecting, practising, networking, discussing, problem solving etc. It may take place in formal (in an organised and structured environment), non-formal (embedded in planned activities not explicitly designated as learning) or informal.
- A **Lecture** is a formal talk on a serious subject intended to display information or teach people about a particular subject (also known as lessons or classes).
- **Massive Open Online Courses (MOOC)** are free online courses available and provide an affordable and flexible way to learn new skills, advance your career and deliver quality educational experiences at scale.
- A **Module** is a collection of courses grouped because courses are runned over the same year or semester, or tackle the same topic.
- **Skill** means the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of the European Qualifications Framework, skills are described as cognitive or practical skills.
- **Training** is the organized activity aimed at transmitting and receiving information and/or instructions to improve the recipient's (learner, trainee) knowledge and/or skill. Methods of imparting training are, for example, **on-the-job training** (development through performance), **case-based methods** (analysis of an actual situation), **knowledge-based methods.**

- **Vocational Education and Training (VET)** is a key element of lifelong learning systems equipping people with knowledge, know-how, skills and/or competences required in particular occupations or more broadly on the labour market.

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1. Introduction

1.1. EO4GEO project

EO4GEO is an **Erasmus+ Sector Skills Alliance** gathering **26 partners from 13 EU countries**, most of which are part of the **Copernicus Academy Network**. Be they from academia, public or private sector, they are all active in the education and training fields of the space / geospatial sector. The project is also supported by a strong group of Associated Partners mostly consisting of associations or networks active in space/geospatial domain. The project started on January 1st, 2018, upon approval by the EU Education, Audiovisual and Culture Executive Agency (EACEA) and runs over four years.

EO4GEO **aims to help bridging the skills gap in the space/geospatial sector** by creating a strong alliance of players from the sector/community reinforcing the existing ecosystem and **fostering the uptake and integration of space/geospatial data and services**. EO4GEO works in a **multi- and interdisciplinary** way and applies innovative solutions for its education and training actions including: case-based and collaborative learning scenarios; learning-while-doing in a living lab environment; on-the-job training; co-creation of knowledge, skills and competencies; etc.

EO4GEO defines a long-term and sustainable strategy to fill the gap between supply of and demand for space/geospatial education and training taking into account the current and expected technological and non-technological developments in the space/geospatial and related sectors (e.g. ICT). The strategy is implemented by: creating and maintaining an ontology-based Body of Knowledge for the space/geospatial sector based on previous efforts; developing and integrating a dynamic collaborative platform with associated tools; designing and developing a series of curricula and a rich portfolio of teaching/learning units directly usable in the context of Copernicus and other relevant programmes and conducting a series of training actions for a selected set of scenario's in three sub-sectors - integrated applications, smart cities and climate change to test and validate the approach. Finally, a long-term Action Plan will be developed and endorsed to roll-out and sustain the proposed solutions

For more information on the project please visit http://www.eo4geo.eu/about-eo4geo/.

1.2. *Objectives of the work package*

Task 5.2 ‘Defining the role of Remote Sensing and related techniques in the scenarios’ is part of the fifth work package (WP5) of the EO4GEO project, which is titled ‘Testing and validating the strategy based on case-based learning scenarios.

The WP aims at developing case-based scenarios for three sub-sectors: integrated applications (T5.3), smart cities (T5.4) and climate change (T5.5), and testing and validating them in training actions. The case-based scenarios are designed using the curricula specified in D4.2, which are related to the business processes and occupational profiles (D4.1; Vland Sandru et al., 2020) and the teaching materials (T4.3) developed within WP4 ‘Designing GI and EO curricula in support of Copernicus’. WP5 is also using the Body of Knowledge (BoK) for EO*GI (WP2) and its collection of concepts representing knowledge and skills as well as improved and expanded tools that are based on the BoK content (WP3).

On the basis of selected case-based learning scenarios (D5.1; Krieger et al. 2020) the **training actions** will be prepared (T5.3 - 5.5) and validated (T5.6). The testing and validation will be performed by involving the training providers, the space/geospatial industry and public sector players, the end-users of the Alliance and other relevant stakeholders. The scenarios (or case studies) starts from ‘real-world’ problems and built on exploration of EO and GI techniques, in particular Copernicus data and services, to solve the problem. Therefore, remote sensing and other relevant techniques play an important role in the design of learning units. **Remote sensing data, methods and tools shall be identified and streamlined** in order to serve the case-based scenarios and feed into educational structures to solve the issues defined in the scenarios. Remote sensing and Earth Observation/Copernicus are considered as supporting or horizontal competencies needed for conducting the case-based scenarios.

The work package has the following specific objectives:

- To clearly define one or more scenarios for each of the sub-sectors, i.e. to identify a ‘real-world’ problem – e.g. ‘the timely detection of leaks in oil pipelines’ – that will be solved by using GI and EO techniques.

- To select one or more curricula which are designed in WP4 from which a selection can be made, and a learning path defined for a collaborative learning process (consisting of different steps).

- To identify such learning paths for different types of people involved: managers and decision makers, technicians, data experts, content/thematic experts, etc.

- To prepare the detailed training actions for each of the three sub-sectors with the identification of the tutors and other actors to be involved, the timeline, detailed methods, selected materials, etc.

● To conduct the training actions and to collect feedback on the learning process, and to evaluate through self-tests and other mechanisms whether the learning outcomes have been achieved.

● To draft lessons-learned from the training actions in terms of what worked well, the methods, the feasibility, the teaching materials, and scenarios described.

The method of **case-based learning** is built upon the experience of several of the consortium partners involved in the giCASES project, educational initiatives e.g. EO College and of the experience of partners at their respective universities and within their organisations. Feedback on testing and validation during learning activities will provide the necessary input to help define the action plan (WP6). The results will also be presented at dissemination events (WP7).

1.3. Objectives of the task

Remote sensing and relevant techniques shall serve the case-based scenarios defined in D5.1 and shall be used in educational structures to solve the **'real-world' problems** defined in the scenarios. The selection, acquisition, and preparation of the GI and EO data, their (pre)processing and integration, and their transformation into information readily usable for problem-solving are an important part of the teaching/learning process (Krieger et al. 2020).

Task 5.2 'Defining the role of Remote Sensing and related techniques in the scenarios focuses on collecting information about **remote sensing data sources** and their potential and limitations, identifying **analysis techniques/algorithms and tools** relevant for the case-based scenarios. In addition, specific **courses** are prepared based on identified data, methods and tools. So that the planned teaching (from a perspective of teacher, fasilitator) and learning (from perspective of learner, trainee) activities can be **prepared and carried out in a more efficient and effective way**.

The specific objectives of the task are as follows:

- ✔ **To identify remote sensing data sources** relevant to the case-based scenarios exploring the Copernicus ecosystem of core and downstream services
- ✔ **To assess the potential and limitations** of those data for the application within the scenarios (i.e. optical sensor versus radar data, spatial resolution)
- ✔ **To identify analysis techniques/algorithms** relevant to the case-based scenarios and – in case - how they need to be adapted for the scenarios
- ✔ **To iIdentify existing analysis tools** relevant to the case-based scenarios with a particular emphasis on Big Data exploration
- ✔ **To prepare detailed learning units** based on the identified data, methods and tools

1.4. Purpose of the document

This report provides an overview of available **remote sensing data, methods and tools** relevant for the selected case-based learning scenarios. These data and techniques are considered as the horizontal domain that underpins the training actions in the three sub-sectors: integrated applications, smart cities and climate change. The identified data, methods and tools are listed and described in such a way that can feed into EO4GEO educational offer.

In previous task (D5.1; Krieger et al. 2020), eleven scenarios and thirteen training actions were selected and described; three case-based scenarios in the integrated applications, three in the smart cities sub-sectors, as well as four in the climate change sub-sector. In this document the description of the case-based scenarios will be extended and complemented by providing:

- additional relevant EO/Copernicus data, specifying their potentials and limitations
- relevant data providers and EO/Copernicus data services, for example Copernicus Open Access Hub
- relevant techniques/algorithms and tools including EO4GEO EO tools and their adaptations for the scenarios
- additional missing BoK concepts
- learning material to be developed
- structure of learning courses.

In particular, methods and tools for **big data processing and analysis**, e.g. EO4GEO EO tools[1], ESA's Thematic Exploitation Platforms[2], Copernicus DIAS[3], as well as EURO DATA CUBE[4] should stay in focus. In all aspects, the relevant **BoK concepts** including identifying missing concepts will be identified. Based on the selected data, methods and tools detailed **learning units** will be prepared. Using the curricula related to business processes and occupational profiles developed in WP4 and EO4GEO tools designed in WP3, **examples of using remote sensing data, methods and tools in learning activities** for case-based scenarios will be proposed and described.

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[1] https://proba-v-mep.esa.int/eo4geo
[2] https://eo4society.esa.int/thematic-exploitation-platforms-overview/
[3] https://www.copernicus.eu/en/access-data/dias
[4] https://eurodatacube.com/

1.5. Structure of the document

This report consists of three sections. This introductory part is followed by the '**Methodology**' for preparing this document (Chapter 2). The criteria and process for selecting remote sensing data, methods and tools for case-based scenarios are summarized. In addition, a methodology for preparing the teaching/learning units to be used in training actions (T5.3-5.5) is given. The third chapter sets out the **role of remote sensing in case-based scenarios** in three sub-sectors. Most commonly identified data, methods and tools are summarized. In order **to streamline** the process of preparing teaching activities, **an interactive catalogue of selected remote sensing data, techniques/algorithms and tools** for the selected scenarios is given in the Annexes V-XIII. Data potentials and limitations are identified, and processing methods adaptations to case-based scenarios proposed. All identified data, methods and tools are linked to the relevant BoK concepts. The missing one have been identified. The last chapter provides educational offer in the form of **a set of courses**. They were prepared using the **Curriculum Design Tool** (CDT). The learning content is prepared for different levels of the European Qualifications Framework (EQF) from 3 to 7 with special emphasis put on the 'learning by doing' and vocational education and training (VET) activities.

2. Methodology

The basis for the selection of remote sensing data, methods, tools, as well as the definition of specific training actions have been eleven case-based scenarios described in the previous deliverable entitled D5.1 'Case-based learning scenarios for 3 sub-sectors' (Krieger et al., 2020). The scenarios were developed out of the collection of BPMNs and chosen according to the expertise of the partners. The decision for a specific training action was made due to the possibilities of the target group and the tutors.

The scenarios were specified stating their title, background of the learners (pre-requisites), target group, EQF level of planned training action, EO*GI profile, type of training action, learning objectives, transversal skills needed, relevant existing EO4GEO BoK concepts, relevant missing BoK concepts, content of the use case and training action, data and software needed for the scenario, learning outcomes (post-requisites). The relevant information to define the role of remote sensing in selected scenarios was identified using dedicated templates (Annex V-XIII) and collected by the project partners based on their expertise (in alphabetical order and per sub-sector; integrated applications: FSU-EO, GEOF, IES, IGiK, PLUS, ROSA, UT-ITC, smart cities: FSU-EO, GEOF, GiB, IGiK, ROSA, climate change: IGiK, UNIBAS with a support from UPAT). In addition, learners' requirements (problems to be solved) and learners' level of expertise were considered. In previous phases of the project (D4.1; Vland Sandru et al., 2020) the learners/trainees were divided into four profiles:

- ➢ EO*GI core profiles (EO*GI CorP): EO*GI students, EO*GI academics, EO*GI data experts,
- ➢ EO*GI managerial profiles (EO*GI ManP): EO*GI data experts, city planners, public authorities, managers, decision makers,
- ➢ EO*GI peripheral profiles (EO*GI PerP): city planners, public authorities, managers, decision makers,
- ➢ EO*GI complementary profiles (EO*GI ComP): managers, decision makers, technicians or administrative staff.

These profiles (target groups), together with learning objectives, learning outcomes/EQF levels, examples of RS products provided in D5.1 were the main mapping criteria between the RS data, methods, tools and the training actions to be implemented (Table 1).

Table 1 – Mapping criteria between the needed remote sensing data, methods and tools and the training actions (adapted from D5.1; Krieger et al., 2020).

Sub-sector / Partner responsible	Case-based scenario	Learning objectives / examples of remote sensing products	Training action / EQF Level (expertise in EO*GI)
Integrated applications / ISPRA	Landslide affecting Cultural Heritage sites - Baia Archaeological Park (Naples)	Students will be able to apply PSI methods to perform spatial and velocity analysis in order to detect historical and recent deformations. / Sentinel-1, ERS, COSMO-SkyMED	Academic course[5] / EQF 7 (EO*GI CorP)
	Landslides documentation supported with an EO-based service	Learners will be able to select and process EO data to derive and interpret landslide information. / Sentinel-1, -2, Pléiades	Workshop (1day)[6] / EQF 4 (EO*GI ManP)
	Geospatial data and technologies applications for monitoring land use change	Students will understand basic physical pricnciples of remote sensing, select, collect, process EO data and interprete the results. / EO data, CLMS	Academic course[7] / EQF 7 (EO*GI PerP)
	EO-based agro monitoring to support regional decision-making	Learners will be able to create a web-based map application. They will be able to understand and apply SDI. / Sentinel-1, -2, Landsat 8	Workshop[8] / EQF 6-7 (EO*GI CorP)
Smart cities / GIB	Identification of local heat islands to support city planning	Learners will be able to interpret and use EO-derived temperature maps for use in urban planning as well as identify local heat islands and analyse them in an urban planning context. / Landsat 8	Webinar[9] / EQF 4 (EO*GI PerP)
	Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban	Learners will be able to analyse and interpret different types of data in the context of planning urban green	Workshop (1 day) / EQF 4 (EO*GI PerP)

[5] Other possible training actions: internship, project work, MOOC
[6] Other possible training action: thesis
[7] Other possible training action: project work
[8] Other possible training action: summer school
[9] Other possible training action: internship

	environments	structures. / Land cover map Learners will be able to select satellite data appropiriate for land cover mapping in urban areas, classify them and analyse and visualize the results. / Sentinel-2	 Workshop (2 days) / EQF 6 (EO*GI CorP)
	Improving sustainability of cities to storm and water	Learners will be able to select and apply geodata for screening urban areas and the sensitivity to heavy rainfall events / flash floods. / Sentinel-2, LIDAR-data	Thesis[10] / EQF 6-7 (EO*GI CorP)
Climate change / UPAT	Air quality management in support of satellite-based data	Learners will be able to select EO relevant data and methods and apply them for decision-making. Learners will understand relationships among emission sources, meteorological conditions, monitoring and modelling of air pollution for practical applications. / Sentinel-3, -5, CAMS Students will be able to select, understand and analyse the relevant data and information, will be able to construct a model based on the selected data and interpret the results. / Sentinel 1, 2, 3, 5P, CAMS, MSG, Land use map	Webinar / EQF 3 (EO*GI ComP) Workshop (2 days) / EQF 5-6 (EO*GI ComP)
	Efficient planning and operation of solar energy farms	Students will be able to select, understand and analyse the relevant data and information, will be able to construct a model based on the selected data and interpret the results. / Sentinel 1, 2, 3, 5P, CAMS, C3S, MSG, Land use map	Academic course[11] / EQF 6 (EO*GI ComP)
	Impact-based weather forecast services for risk evaluation	Lerners will be able to select, understand and analyse the relevant data and information. / Sentinel 1, 2, 3, 5P, CAMS, CLMS, MSG, DEM, RADAR	Workshop[12] / EQF 3 (EO*GI ManP)
	Precision farming for vineyard	Lerners will be able to select, collect and analyse the relevant data and information, will be able to apply the data to get usefull information and understand the results. Sentinel-1,2,3, DEM, SPOT 6	Webinar[13] / EQF 3-4 (EO*GI PerP)

For learners with less technical requirements and knowledge, ready to use data (level 3) and tools have been proposed, while for the advanced learners with higher EQF unprocessed data (level 1) that require programming skills have been considered.

[10] Other possible training action: project work
[11] Other possible training action: internship

Information on **remote sensing data** has been extended to other relevant data sources based on authors' expertise and relevant references, e.g. ESA's Earth Observation Portal, collection of satellite missions and sensors by H. Kramer 2002 (Kramer, 2002). These databases allow you to look for relevant data using various categories, such as application domain. Depending on the level of knowledge of the target groups the data varied from level 1 data (reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information) to analysis ready data (ARD), e.g. Copernicus High Resolution Layers (HRL)

To ensure that the state-of-the art **methods and tools** are used in the teaching activities, the trend analysis for EO*GI sector has been analysed. This can be found in the EO4GEO deliverable 'Trends and challenges in the space/geospatial sector' (Iasillo et al., 2019). Special focus has been put on the use of processing platforms, e.g. DIAS, ESA's TEPs, and EO tools and platforms developed or extended within the EO4GEO project and listed in the deliverable 'Method, architecture and specification of the collaborative platform' (Dries et al., 2020).

BoK concepts relevant for data, methods and tools have been selected using the FindInBoK tool[14].

The collected information about remote sensing data, methods, tools and relevant BoK concepts creates a catalog with hyperlinks/permalinks (Annex V–XIII) that can be used to prepare teaching/learning materials in the next tasks (T5.3-5.5). The educational offer in the form of courses was prepared using the CDT tool (version 0.6). The information required by the tool and described in this document is presented in Table 2.

Table 2 – Course description elements and their definitions.

Title	title of a teaching/learning unit
EQF level	Information on EQF level; 8 levels of descriptors that indicate learning outcomes
Description	Description of the teaching/learning unit that builds on the identified elements of data, methods and tools; provides information on what is required for covering remote sensing related content in the foreseen training action'; general statements should be avoided
Is practical	indicates whether the teaching unit is a lecture or a 'hands on'class
Unit duration	information on how long the teaching unit lasts

[12] Other possible training action: project work
[13] Other possible training action: MOOC
[14] https://bok.eo4geo.eu/GIST

Prerequisites (at the highest course level)	information on knowledge and skills an individual must possess before learning the topic; missing BoK concepts to be indicated
Learning outcomes	skills-orientated learning outcomes: '*State what a learner is expected to know, be able to do and understand at the end of a learning process or sequence.*' (CEDEFOP, 2017); inherited from the BoK or if missing formulated using the revised Bloom's taxonomy (Annex IV)
Assessment (at the highest course level)	information on how the new knowledge and/or skills will be assessed
Bibligraphy	bibliography relevant for the learning content in APA reference style

The course elements were described by the EO4GEO partners (in alphabetical order: FSU-EO, GEOF, GIB, IES, IGiK, KU Leuven, PLUS, ROSA, UNIBAS, UT-ITC) based on their expertise. The prepared **set of learning courses** use remote sensing data, methods and tools to solve problems identified in case-based scenarios. Where applicable, relevant EO tools available at: https://proba-v-mep.esa.int/eo4geo have been selected. The courses have modular structure and can be reused in the design of educational activities.

3. The role of Remote Sensing in the three sub-sectors

The remote sensing data and techniques are the main source of geospatial data, as well as processing and analysis tools to solve the problems identified in the selected case-based scenarios in the three sub-sectors: integrated applications, smart cities and climate change. In this chapter a summary of identified data types, their potentials and limitations as well as methods and tools and their adaptation needs in the selected eleven scenarios is given. The statistics presented in this chapter were prepared by FSU-EO on the basis of the information collected by project partners (in alphabetical order: FSU-EO, GEOF, GiB, IES, IGiK, PLUS, ROSA, UNIBAS, UT-ITC) in the Annexes V-XIII. To improve the use of collected information, it is made available in the form of an interactive catalogue of RS data, methods and tools.

Most commonly identified data and data providers

The **most commonly identified data** (Figure 1) in the scenarios are optical data (61%) followed by the radar data (20%).

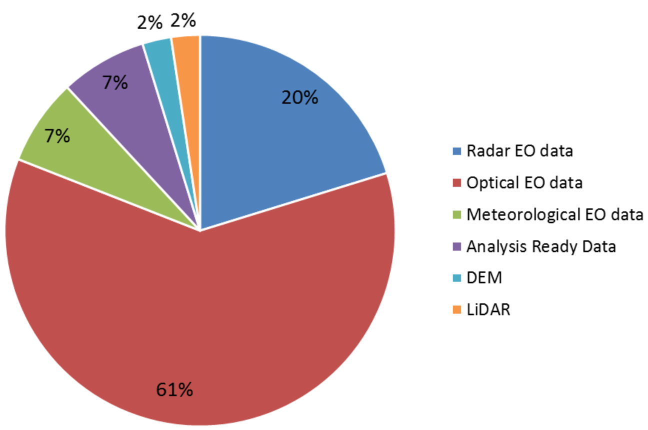


Figure 1 – Most commonly selected EO and relevant data for selected case-based scenarios.

Most of the identified data are available through an open data policy (e.g. Sentinel data) (62%). Almost in half of the cases Copernicus Programme's services are indicated as a **data source/data providers** (Figure 2). The most commonly identified data were the data acquired by the Sentinel missions that are part of the Copernicus Programme. It is the largest space data provider in the world, currently producing 12 terabytes per day (ESA, 2018). The vast majority of data and information delivered by the Copernicus space infrastructure and the Copernicus services are made freely available and accessible. Copernicus provides satellite data (images at different processing levels), but also data ready for analysis, i.e. Analysis Ready Data (ARD). Copernicus ready to use data and information can be reached through six portals: Copernicus Land Monitoring Service (CLMS), Copernicus Marine Environment Monitoring Service (CMEMS), Copernicus Atmosphere Monitoring Service (CAMS), Copernicus Climate Change Service (C3S), Copernicus

Emergency Management Service (Copernicus EMS) and Copernicus service for Security applications. Anyone can access Copernicus Data and Information Services through the DIAS or the Conventional Data Hubs.

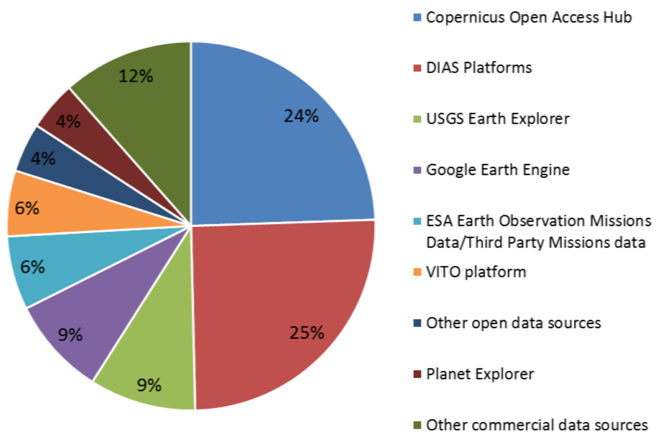


Figure 2 – Most commonly selected sources of EO and relevant data for selected case-based scenarios.

Free and open access was mentioned as the main potential of the identified EO and relevant data sets as well as its high temporal and spatial resolutions (Annex V, VIII, XI). On the other hand, the main limitations of the data identified are related to the use of data for commercial use, as well as cloud cover for optical data and complex processing for radar data.

Data available in the EO tools

The identification of mainly free and open data enables the use of EO tools in teaching/learning activities. The following datasets are currently available in the tools developed by VITO:

- ✓ Sentinel-2
- ✓ Sentinel-1 sigma0,
- ✓ Sentinel-1 coherence for selected areas
- ✓ Sentinel-3 will become available
- ✓ Sentinel 5P will become available
- ✓ PROBA-V
- ✓ Copernicus land monitoring: long time series products
- ✓ Other data if needed

Most commonly identified methods

With the emergence of a range of satellite-borne sensors, researchers now have access to stacks of dense time-series remote sensing data at high spatial and spectral resolution. In addition to advances in the technology used for remote sensing data collection, there have also been important scientific and methodological developments to enable the vast quantities of remote sensing data generated to be converted into useful information.

The most commonly identified methods for remote sensing data processing and analysis are time series analysis (21%), change detection (17%) and image classification (17%) - Figure 3. When it comes to 'Photogrammetric DEM', mainly data ready for analysis is meant. In terms of retrieval of atmospheric parameters, different satellite and ground-based air quality parameters are understood. By ‘GIS analysis’ is meant vector/raster analysis (e.g. data harmonisation, overlay analysis).

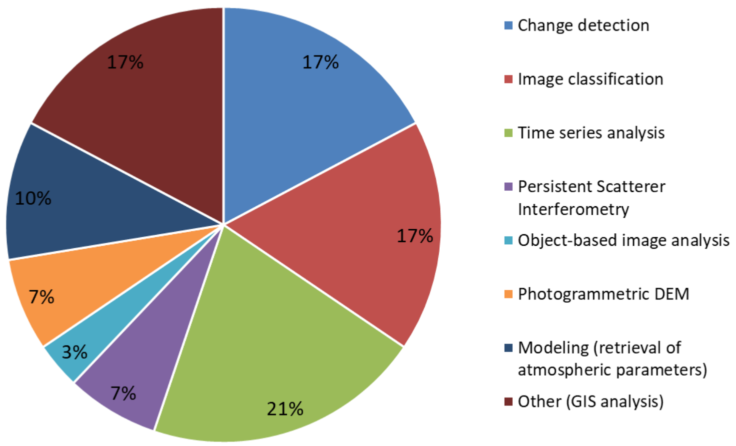


Figure 3 – Most commonly selected methods of remote sensing data processing and analysis for selected case-based scenarios.

There are many open source tools available today for processing big data relevant for all three sub-sectors. This software is made available to the public at no cost. There are different remote sensing softwares available such as tools for processing Sentinel data (e.g. Sentinel Application Platform SNAP with its dedicated Sentinel tools), tools dedicated for processing of radar data (e.g. ORFEO Toolbox, PolSARPro) and GIS tools for fusion different types of geospatial in particular vector data (e.g. QGIS, GRASS). In addition to open source software, there is a wide range of commercial remote sensing and geodata analysis software for use in each of three case-based scenarios.

Most commonly identified tools

The main tool identified in the selected case-based scenarios is the GIS software (44%) followed by remote sensing tools (26%) – Figure 4.

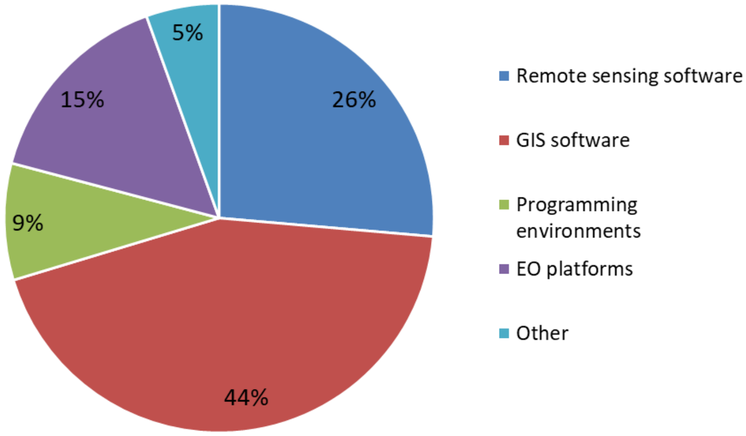


Figure 4 – Most commonly selected tools of remote sensing data processing and analysis for selected case-based scenarios.

Most identified GIS tools are open source inversely compared to remote sensing software (Figure 5).

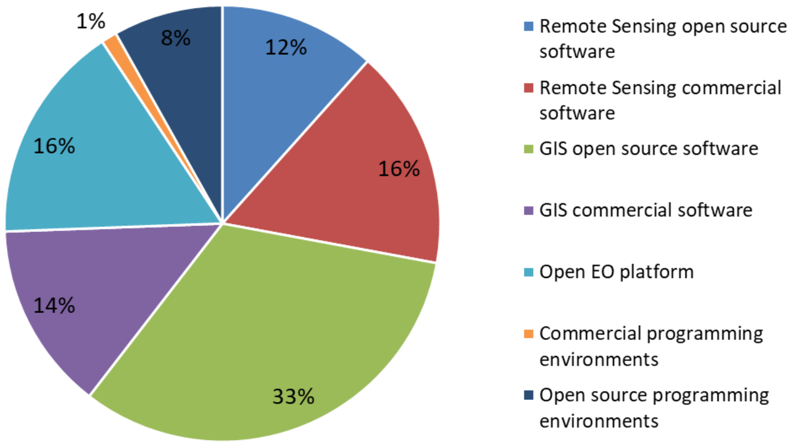


Figure 5 – Types of identified tools of remote sensing data processing and analysis for selected case-based scenarios.

Software available in the EO tools

The open source software can be easily integrated in the EO tools. Currently following tools can be used in the scenarios:

- ✓ GIS tools: QGIS
- ✓ Remote sensing tools: SNAP, Orfeo toolbox
- ✓ Programming language: R, Python, Javascript, Octave: open source matlab alternative
- ✓ Others on request

Commercial softwares can be pre-installed on Virtual Machines.

Other EO platforms can be used independently; EO tools can then be used to combine data for multiple platforms.

The identified data, methods and tools were linked to the EO4GEO BoK concepts (Annex V-XIII). In total, 175 unique BoK concepts were selected, which represents 16% of all concepts (1082 concepts) available in the BoK visualisation and navigation tool FindInBoK. Only nine concepts were identified as missing BoK concepts (including three identified in D5.1), six concepts related to specific platforms and sensors and three related to applications (crop monitoring, precision agriculture, programming link to computer science).

Most commonly annotated BoK concepts

The development of the BoK is organized in seven interconnected working groups (Stelmaszczuk-Górska et al., 2020): 'WG1 Analytical Methods and GI Foundations', 'WG2 Visualization and GI Systems', 'WG3 Spatial Data Infrastructures and Related Concepts', 'WG4 Physical Principles of Remote Sensing', 'WG5 Platforms, Sensors and Digital Imagery', 'WG6 Image Processing and Analysis', 'WG7 Thematic and Application Domains'. The concepts of WG6 were the most commonly identified concepts (24%) (Figure 6). The most frequently selected concepts reflect data types, methods and tools used in different sub-sectors. For example, in the climate change sub-sector mainly GIS tools have been selected, which is reflected in the GI WG concepts (WG1-WG3) – Chapter 3.3.3. Figure 7 presents the most commonly used BoK concepts in the form of a word cloud.

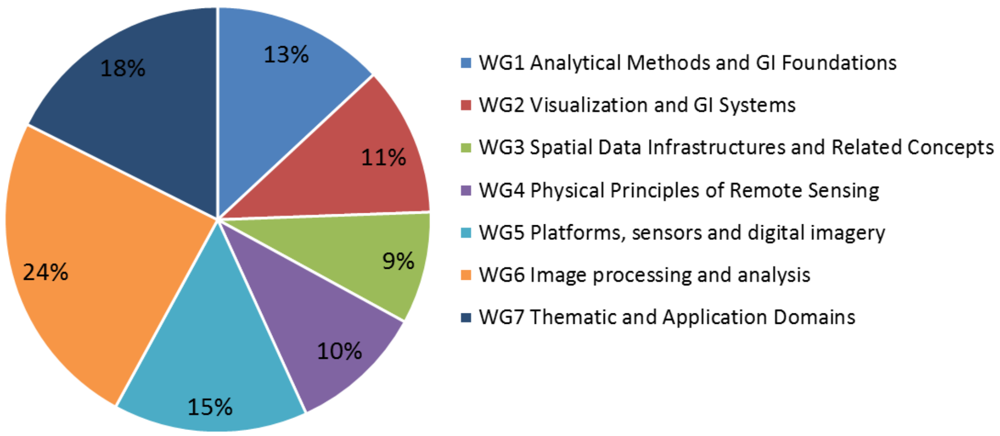


Figure 6 – Most commonly selected BoK concepts per working group (WG) for selected case-based scenarios.

Figure 7 – Most commonly selected BoK concepts in the form of a word cloud (generated using Word Cloud Generator: https://www.jasondavies.com/wordcloud/).

3.1. Integrated applications

The following four case-based learning scenarios were selected for the integrated applications sub-sector and will be implemented as part of task T5.3 coordinated by ISPRA (Krieger et al. 2020):

1. Landslide affecting Cultural Heritage sites - Baia Archaeological Park (Naples) (EQF 7)
2. Landslides documentation supported with an EO-based service (EQF 4)
3. Geospatial data and technologies applications for monitoring land use change (EQF 6)
4. EO-based agro monitoring to support regional decision-making (EQF 6-7).

Each scenario corresponds to a training action.

The case of cultural heritage affected by landslides aims at proposing a methodology to exploit Persistent Scatterer Interferometry (PSI) data and ground displacement map in Baia Archeological Park, Italy. The PSI processing will allow performing PS spatial and velocity analysis focused on the detection of historical and recent deformation. SAR interferometry is used to analyse and understand the trend of the ground deformation with respect to the subsidence phenomena starting to examine all the SAR interferometric data available and by processing the Sentinel-1 data. The detection of most affected areas leads to time series analysis of critical points, allowing to better understand the deformation pattern and its relation with the causes of their subsidence (seasonal variation, human induced activities).

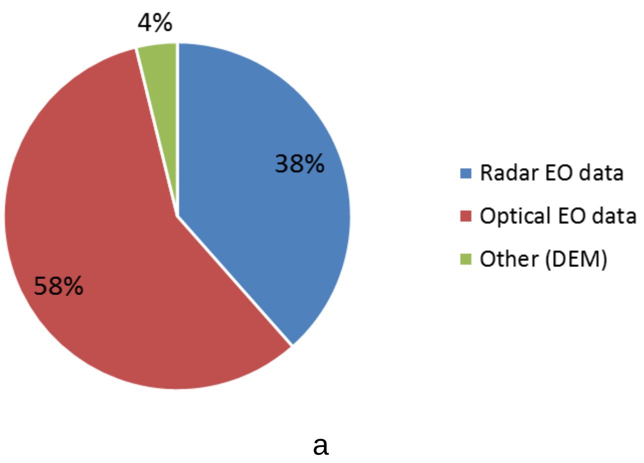
The process of documentation for landslides supported with an EO-based service is relevant for tasks of landslide mitigation, preparedness, response and recovery, e.g. hazard zone planning or eligibility checking for insurance claims. Therefore, further stakeholders rely on landslide information, e.g. infrastructure providers, insurance companies, emergency response organizations, and ultimately the public.

Another example which sustains end-user decisions is related to geospatial data and technologies applications for monitoring land use change. The aim is based on providing the tools and services needed to manage spatial remote sensing data or data collected in the field and ancillary data required to generate information about coverage and land use, as they are required for users who implement policies related to land use monitoring.

The last example is highlighting the important role of EO, which is playing an increasingly central role across the agricultural sector, from informing government policies, to support precision agriculture, and to monitor progress toward agricultural intensification for more sustainable global food supplies. The focus of the use case was to create near real time spatial maps concerning biotic risk alerts for rice cultivations.

3.1.1. Data types and data providers

For the selected case-based scenarios mainly optical data available in an open data policy are proposed (Figure 8).



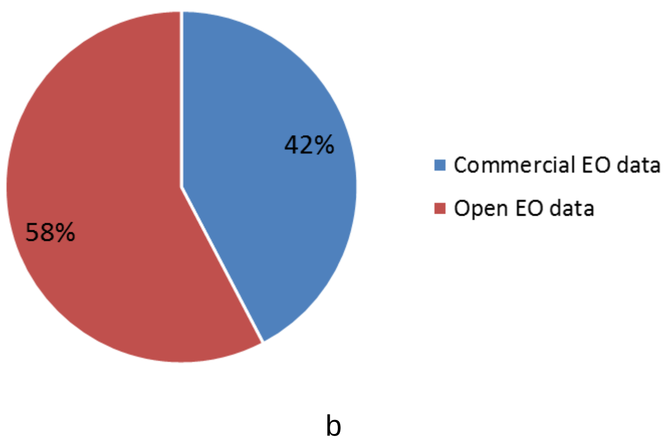


Figure 8 – Selected EO and relevant data for integrated applications sub-sector: a. in the context of acquired wavelengths, b. in the context of data access.

The Copernicus Open Access Hub, DIAS Platforms, USGS Earth Explorer and ESA Earth Observation Missions/Third Party Missions data were identified in almost 70% cases as suitable data providers (Figure 9).

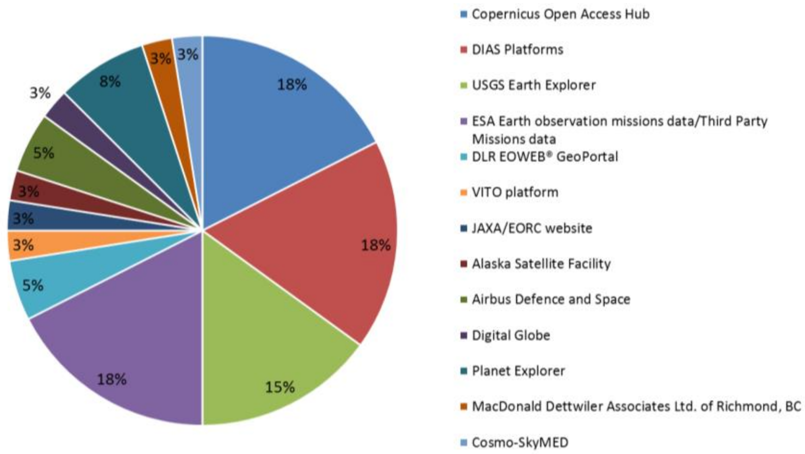


Figure 9 – Selected data providers for sub-sector integrated applications.

Optical remote sensing supports several land use/land cover analyses, due to the availability of consistent data sets for over four decades. For example, Landsat offers data since 1972, Spot is present on the orbit since the mid-1980s and MODIS since 1999. Since 2016, Sentinel 2 provides continuity of SPOT and LANDSAT image data. It contributes to ongoing multispectral observations and benefit of the Copernicus services and applications such as land management, agriculture and forestry, disaster control, risk mapping and security issues.

Satellite remote sensed data are considered effective in support of landslides inventories mapping, especially during prevention and disaster risk reduction and during an emergency response phase, when the focus is on the rapid assessment of the damages, and on the evolution of ground motion prone areas.

One of the present study cases presents landslide documentation supported with an object-based image analysis (OBIA) providing the opportunity to produce landslide maps. EO-based service. Landslide information extraction is performed with high resolution (HR) EO data (e.g. from Sentinel-2 or Landsat) and once with very high resolution (VHR) EO data (e.g. Pléiades, SPOT 6/7, Worldview 3). All these operations are made by an EO*GI analyst, a work depending on the availability of cloud-free images that may take a few weeks. Landslide in-situ mapping starts as soon as the first version of the landslide locations collection is available and finishes after the last update with the VHR landslide map occurred.

Another example is related to geospatial data applications for monitoring land use change. Land use/land cover information and the spatial distribution patterns are essential for a wide spectrum of research fields, especially urban studies and territorial planning (Stefanov et al. 2019). Land cover change involves modification of the earth surfaces and at the same time can involve an alteration in the vegetation and soil surface for urban and periurban development.

Optical as well as radar data provide a valuable information source for agriculture information. The requirement for inexpensive, synoptic information on crop areas leads to the use of satellite imagery, which has traditionally meant optical imagery. But, satellites carrying optical sensors cannot acquire data regularly in tropical regions during the rainy season. The usefulness of optical satellite imagery from the Landsat and SPOT missions for rice monitoring has therefore proved to be limited, as the main rice growing takes place during the rainy season when there is typically 90% of cloud cover. In this situation, the all-weather monitoring capability and particular instrument characteristics of Synthetic Aperture Radar (SAR) can provide a unique and timely source of data.

The focus of the fourth study case is based on an EO-based agro monitoring system to support regional decision-making. The aim was to create, manage and disseminate near real time spatialized maps concerning biotic risk alerts for rice cultivations. These risk maps are mainly obtained from the integration of assimilated EO data and statistical post-processing of crop model simulations. In particular, EO products from the European Copernicus Programme (e.g. Sentinel-1/2A data, SPOT/VEGETATION- PROBA-V (GEOV1) LAI) and NASA (e.g. MODIS and OLI data) are used along with the Water Accounting Rice Modelling (WARM) solution. Resulting risk maps are delivered through geospatial web services conveniently integrated in a web-based geoportal to allow efficient access to the rice-monitoring information.

In terms of remote sensing data sources 16 unique BoK concepts were selected representing 75% of the concepts from the WG5 (Figure 10).

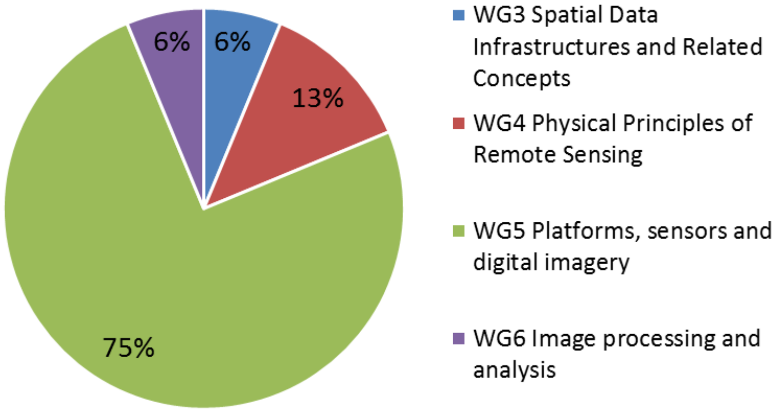


Figure 10 – Data relevant BoK concepts per working group (WG) selected for integrated applications sub-sector.

The list of selected data types their potential and limitations, data providers and relevant BoK concepts is given in Annex V.

3.1.2. Techniques/algorithms

Two of the case studies selected for the integrated applications sub-sector are related to the landslide monitoring and the other cases are related to land-use change and agro monitoring. In all of the scenarios remote sensing data are used for monitoring or before/after event data analysis. In summary, the following four relevant methods were identified: change detection, image classification, time series analysis and GIS analysis (Figure 11).

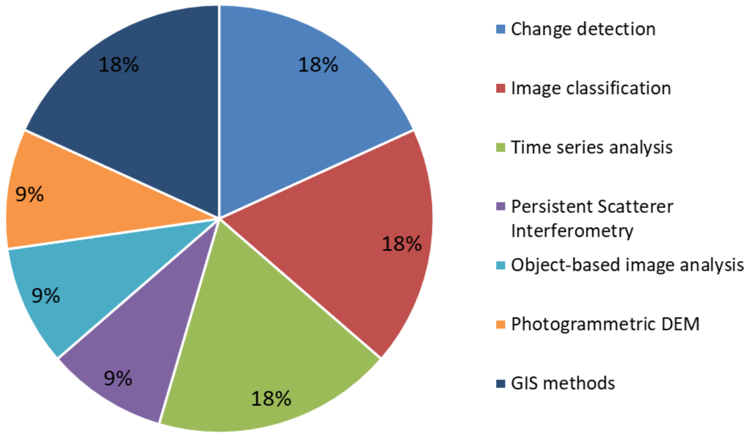


Figure 11 – Selected methods of remote sensing data processing and analysis for integrated applications sub-sector.

Synthetic aperture radar interferometry (InSAR) and specifically Persistent Scatterer Interferometry (PSI) has been a preferred approach to detect and monitor small land/object movement. SAR data is by far less affected by the weather conditions than optical data and the ability to collect the phase information allows monitoring centimeter/millimeter scale land movement. Such properties allow monitoring of even slow-moving landslides on a regular basis. Optical data can be considered as a supplemental data source to evaluate the landslide damages or changes in the environment. However, there are optical methods that use sub-pixel correlation to derive information about the landslide movement. It must be mentioned that regular data availability is crucial for early detection of landslides and the cloud-free optical data is not regularly available thus limiting the use of optical satellite data. Other optical data-based techniques include DEM generation from UAV data or spaceborne stereo imaging sensors like ASTER. The DEMs can be generated several times to observe the land movement or other changes in terrain. Object based image classification is another technique that can be used to detect landslides and also other changes that can be related to land cover or agriculture related topics. Image classification is one of the main remote sensing techniques and can be used in a majority of the selected use cases under integrated applications and often post-classification change detection is performed where the change detection is applied on independent thematic rasters. A large number of input classes can make the results difficult to interpret so the need for GIS analysis tools arises. Another useful technique is time series analysis. Time series analysis can be used to monitor a specific area of interest and to detect trends or changes in trend. To make the results publically available/viewable different web mapping approaches can be used.

A summary of the selected BoK concepts (40 selected concepts) in the context of techniques/algorithms is presented in Figure 12.

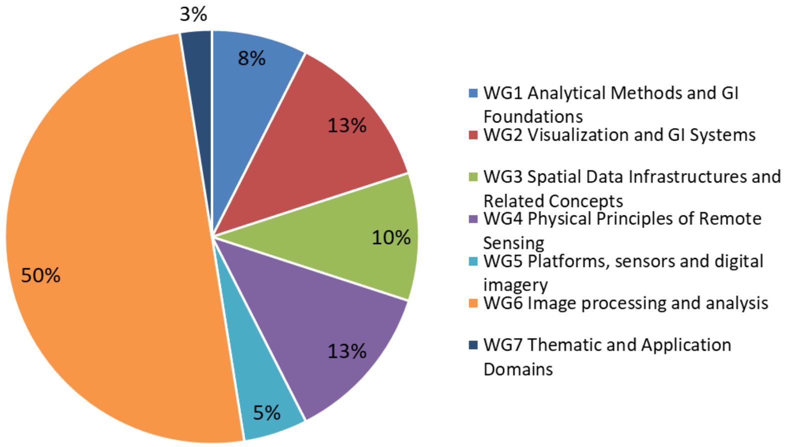
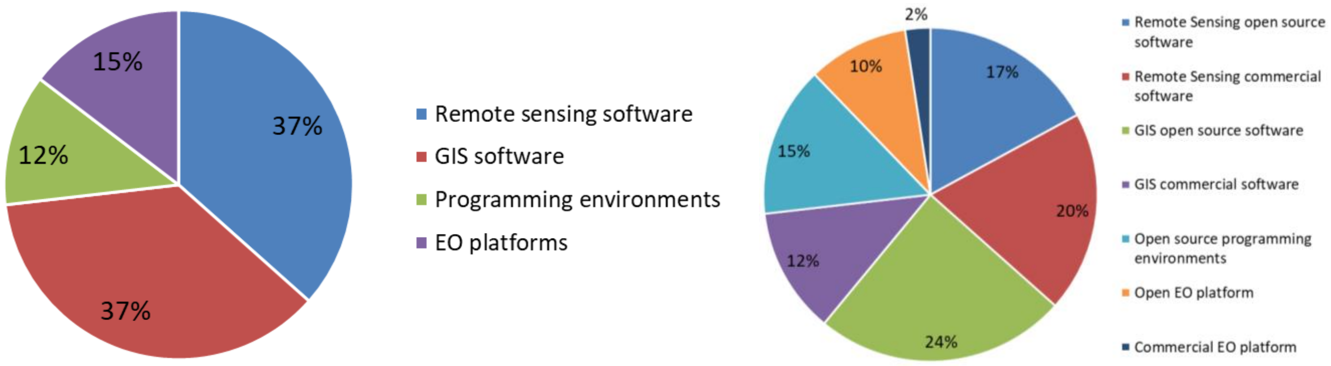


Figure 12 – Methods relevant BoK concepts per working group (WG) selected for integrated applications sub-sector.

The list of selected methods with references and adaptations needed for the selected case-based scenario as well as relevant BoK concepts is given in Annex VI.

3.1.3. Analysis tools

The analysis tools were selected taking into account the techniques/algorithms and data identified in the previous sections: 3.1.1 and 3.1.2. In general, four main remote sensing and two relevant GIS techniques/algorithms for processing selected case-based scenarios were identified. Remote sensing methods include interferometric SAR (InSAR) for SAR data, object-based image analysis classification (OBIA), change detection and time series for mainly optical data. GIS methods are interpolation and web-mapping. For complex InSAR processing, ESA's GeoHazard Thematic Exploitation Platform (G-TEP) has been selected as an analysis tool. The Food Security Exploitation Platform (FS-TEP) has been identified for agricultural applications. In addition, the GEE platform has been identified to analyse big data, for classifying or performing time series, and for detecting changes. The G-TEP platform provides Data-as-a-Service (DaaS), Infrastructure-as-a-Service (IaaS), Software-as-a-Service (SaaS) and Platform-as-a-Service (PaaS) capacities. GEE provides mainly PaaS capacities. DaaS gives the opportunity to perform catalogue queries and download data of the free data collections. IaaS provides the necessary cloud infrastructure. SaaS enables users to process data available in remote or local repositories using a number of algorithms and on-demand services, and to exploit the results. PaaS provides an application platform, or middleware, as a service on which developers can build applications. In addition, commercial and open softwares as well as programming languages dedicated to InSAR processing or EO data classification were selected. GIS softwares, web-mapping services or programming environments (Shiny) have been indicated as visualization tools. A summary of the identified analysis tools is given in Figure 13. The corresponding selected BoK concepts (13 concepts) and their distribution among the BoK WGs are presented in Figure 14.



a b

Figure 13 – Selected tools for integrated applications sub-sector: a. in the context of tool category, b. in the context of tool access.

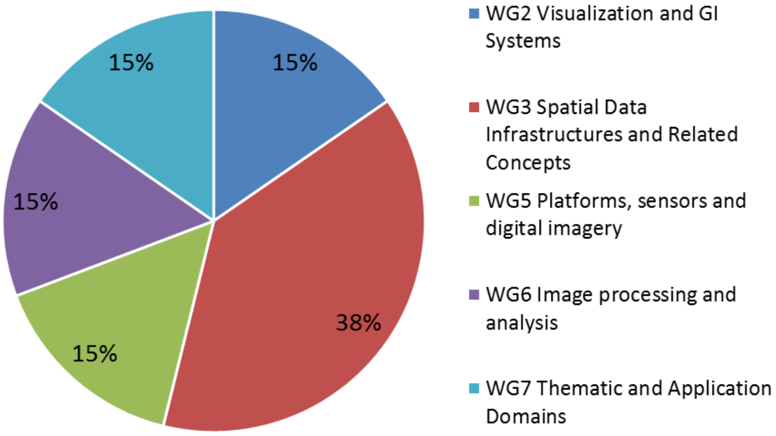


Figure 14 – Tools relevant BoK concepts per working group (WG) selected for integrated applications sub-sector.

The list of selected tools with references and relevant BoK concepts is given in Annex VII.

3.2. Smart cities

A smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business. This includes more efficient urban infrastructure, better planning of water supply and waste disposal facilities, and more efficient ways of designing city lighting and heating systems for buildings. Traditional mapping methods can hardly keep up with such rapid changes, and this slows down the successful and sustainable development of a smart city. Remote sensing methods offer new ways to collect and process city data in order to quickly obtain information for the sustainable urban development of smart cities and to meet the needs of the population living in the city. Continuous monitoring of vegetation, water bodies, farm buildings, residential buildings, sports facilities and air pollution within city limits is required for the city's maintenance and expansion plans. In this context, the following three case-based learning scenarios were selected for the smart cities sub-sector and will be implemented as part of task T5.4 coordinated by GIB (Krieger et al. 2020):

1. Identification of local heat islands to support city planning (EQF 4)
2. Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments (EQF 4 and 6)
3. Improving sustainability of cities to storm and water (EQF 6-7)

Each scenario corresponds to a training action. In case of the second scenario, two training actions will be carried out. One at EQF 4 and the other at EQF 6 level.

Satellite data from different sources can be used for the monitoring of urban areas. Medium-resolution (free and open available) optical satellite data: Landsat, Proba-V and Sentinel-2 for example, can be used to perform global spatial queries in urban areas (spectral indices calculation, classification and change detection). Wide area coverage allows for vast geographical areas to be covered with a single scene making it a cost-effective assessment tool. This data enables a long-term monitoring and the analysis of land use trends and the identification of areas of threat and environmental sensitivity, together with other open or commercial data. Data limitations are cloud-free conditions, revisit time, and insufficient spatial resolution to analyse smaller objects on the scene. On the other hand, radar data (like free and open available Sentinel-1, and commercial: TerraSAR-X, CosmoSkyMed, Radarsat-2) have no problems with cloud cover and the acquisition frequency is higher, but processing radar data is much more complex compared with optical satellite data. High-resolution satellite images, such as: WorldView 1-4, Pléiades, SPOT, GeoEye-1, RapidEye, may be used for spatial updates, settlement classification, mapping of infrastructure and service delivery, green space development and regional planning. Increased spatial accuracy allows for a more detailed planning and refinement of existing spatial environment databases. In addition to satellite imagery, there are many (free and commercial) downstream services that provide spatial data to users.

Various types of satellite data are involved in the assessment of ‘smart city concept’, being divided on different levels. On the first level are types of data such as multispectral, infrared, radar and others. The second level includes various types of remote sensing ARD data. In the third level the data fusion and geospatial analysis are performed. The fourth level is about comprehensive modelling and forecasting for decision-making support (Popov, M. et al., 2017)

For urban planning mapping and visualization, several open and commercial software tools such as GIS tools (e.g. ArcGIS, QGIS) and EO platforms and tools (e.g. Urban Thematic Exploitation Platform, Google Earth Engine, SNAP Sentinel Toolbox, ENVI) as well as software for statistical analysis (e.g. SPSS, Excel, Statistica) can be used. As GIS is a framework for gathering, managing, and analysing data, GIS software let you produce maps and other graphic displays of geographic information for analysis and presentation.

3.2.1. Data types and data providers

For smart cities sub-sector mainly very high resolution optical, commercial data were identified (Figure 15, Figure 16). As in the case of the previous sub-sector, the most commonly identified BoK concepts were those from the WG 5 (Figure 17). In summary, 33 concepts were selected.

Spatial resolution plays an important role in ensuring best quality data over wide application areas. Medium resolution satellite data can be applied to perform global spatial queries within urban environments. The wide area coverage allows for vast geographical areas to be covered with a single scene making it a cost-effective assessment tool. Landsat data enables decision-makers to assess the surface temperature, urban heat island being one of the most severe problems facing today's society. The high and very high resolution (HR and VHR) imagery allows for spatial updates, settlement classification, infrastructure and service provision mapping, green sites development, access control mechanisms and regional planning. Sentinel 2 data used in the smart cities case-based scenarios makes a significant contribution to analysis and map production with land cover mapping for up-to-date information on the effects of intense raining with high water flows and flooding and contribution to urban heat island as a basis for city planning.

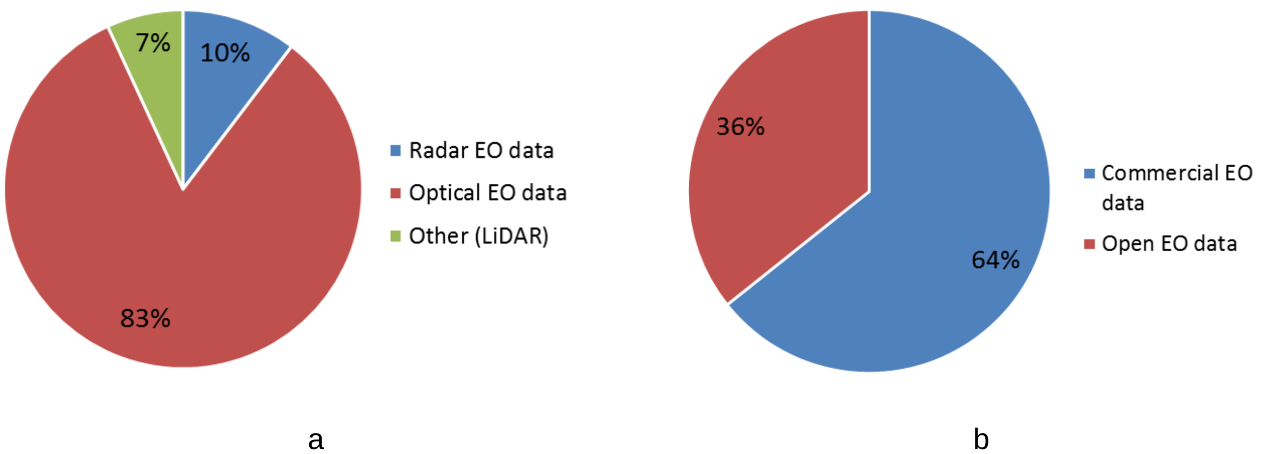


Figure 15 – Selected EO and relevant data for smart cities sub-sector: a. in the context of acquired wavelengths, b. in the context of data access.

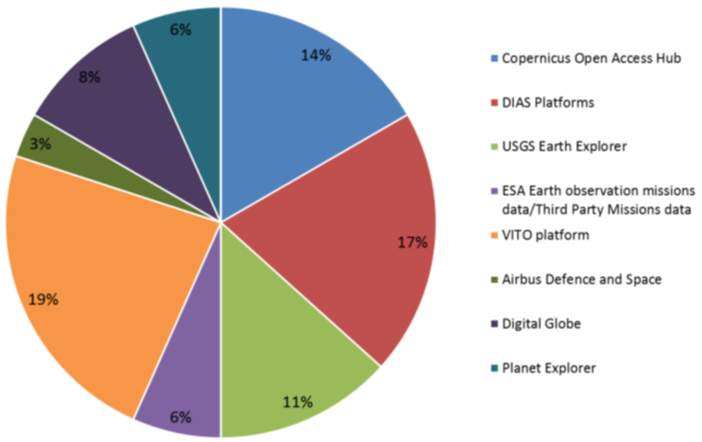


Figure 16 – Selected data providers for sub-sector smart cities.

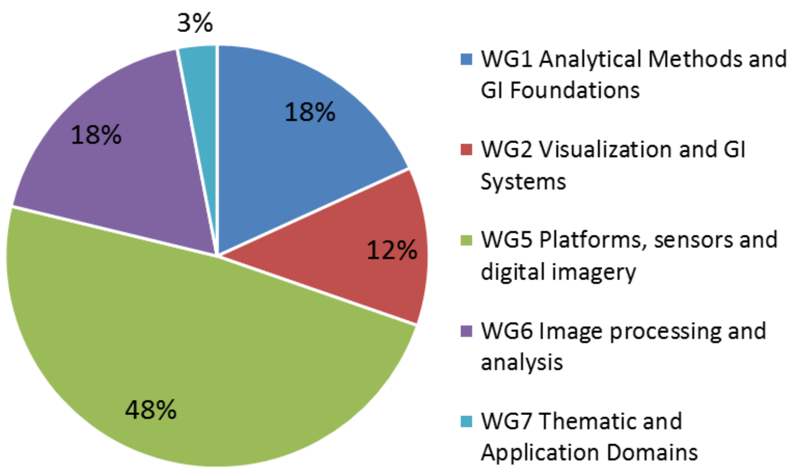


Figure 17 – Data relevant BoK concepts per working group (WG) selected for smart cities sub-sector.

The first case-based scenario, 'Identification of local heat islands to support city planning', includes the use of thermal optical satellite data to measure temperature not only at specific points, weather stations, but covering large areas. The Landsat series of satellites provides data in thermal wavelengths, with a ground resolution of 100m. In urban areas it is valuable to learn how different mixes between building constructions, green areas and impervious surfaces behave when it comes to heat even if the detail is low. The Landsat TIRS sensor measures the thermal emissivity of the surface at the satellite. To compare the sensor radiance with in-situ temperature measurements it needs to be both atmospherically corrected and adjusted for different types of land cover.

In case two, 'Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments', the green infrastructure is mapped and analysed. Several remote sensing data sources are needed to achieve good input for such analyses - from large area land cover mapping based on optical data such as Sentinel-2, to very high resolution (VHR) satellite data or aerial imagery. The city trees are very important to form ecologically functional networks for many species. Therefore elevation, specifically object heights, need to be included as input. Lidar is widely used to, with high accuracy, measure elevation and get the 3D perspective of cities. For these scales, normally LiDAR data are collected from airplanes, while drones are more common when it comes to delimited areas and more frequent measurement. Based on Lidar data, trees can be accurately outlined, including height and crown width. The trees can be stored as vector objects to be used e.g. in statistical analyses or estimation of the ecosystem services they provide. An alternative to Lidar is stereo imagery.

The 3rd case within Smart Cities, 'Improving sustainability of cities to extreme precipitation and flooding events', involves both high resolution terrain models, derived from Lidar, land cover maps originating from optical remote sensing data and finally radar satellite data for flood mapping. The approach is two-folded in this case study;

1. Mapping urban and periurban hydrologic conditions by the use of high-resolution terrain models and detailed land cover data to screen cities for areas sensitive to extreme precipitation events. Assessment of the green infrastructure and how ecosystem services can be restored to improve sustainability.

2. Using SAR data to map historical riverine flooding events to calibrate hydraulic flood models and map areas prone to riverine flooding. Flooding is normally occurring during bad weather conditions when radar is preferable due to the cloud constraints of optical satellite data.

The list of selected data types their potential and limitations, data providers and relevant BoK concepts is given in Annex VIII.

3.2.2. Techniques/algorithms

The existence of 'smart city concept' is shaped by a complex mix of technologies, social and economic factors, governance arrangements, policy and business drivers. Therefore, the implementation of the smart city concept follows different paths depending on each city's specific policies, objectives, funding and scope (EU, 2014).

One of these is mitigation of urban heat island effects, a measure which supports city planning. As an urban heat island is a typical urban phenomenon, the formation and intensity of these phenomena are related to the land cover type. The land cover surface can be described as a combination of green vegetation, water surfaces, impervious surface materials and exposed soils. Determining Land surface Temperature is a technique representative enough to derive higher air temperatures in urban areas. The highly absorbent materials found in the city and the lack of vegetation in comparison with the rural areas are the main drivers behind urban heat islands. As a basis for city planning, it was decided to start identifying local heat islands, a useful initiative for the Swedish Environmental Protection Agency as well as for the Stockholm municipality. One important solution to urban heat consists of the existence and accessibility to green areas, an actual matter which represents a fundamental component of any urban ecosystem.

The green infrastructure in urban areas is of great importance not only for suppressing heat island effects, but is also important in many other senses. Trees provide great values in ecosystem services such as improved human health, reducing levels of carbon dioxide, stormwater interception in addition to their cooling effects.

All trees are important, not only those managed by the local authorities in parks and alleys. To be analysed both in the context of green infrastructure, ecologically in habitat networks, and local calculation of different ecosystem values, trees need to be extracted to separate units in a vector layer. This involves techniques for segmentation and rule-based classification. In addition to calculation of the tree network, a habitat network involves a friction layer, various frictions depending on the species analysed. The friction layer can be achieved from a classified land cover map, based on either satellite data or aerial imagery. Ecosystem values provided by city trees demand knowledge about algorithms for each specific value, e.g. carbon dioxide reduction capabilities or stormwater interception for different tree types and sizes.

Another smart city case study is water monitoring in the municipality of Milan, where the authorities are searching for a method to better understand the ground surface movement caused by the structural defect of its collector that could affect the primary sewerage network, on the purpose of preventing damage to surface structures by detecting the movements underway. By using satellite radar interferometry, displacements are assessed over an area of interest by means of measurements of velocity, acceleration and coherence of Persistent Scatterers. Thematic maps are provided, dynamic geo-analytics and reports for monitoring the health of water and sewerage networks are prepared.

Many cities are sensitive to rainstorms and extreme weather events. Consistent mapping of impermeable surfaces and land cover is important to understand the changing hydrological conditions in urban areas. Classification of land cover maps into runoff coefficients is one of the prerequisites for hydrologic and hydraulic modelling. High resolution terrain models are derived from point-cloud Lidar and processed for hydrological modelling with raster-based breaching and filling algorithms. By the use of traditional GIS techniques like reclassification and overlay analysis, information about catchments, infiltration capacity, soils and vegetation inception can be derived.

SAR data in combination with GIS techniques to map the spatial extent and propagation of flood inundation. By the use of polarized radar, images the extent of flooding on different occasions can be mapped. This step involves processing of SAR data, raster thresholding operations and vectorization of the results. Together with maps and high-resolution terrain models, information about flood extent and water depths can be derived, and compared to normal conditions.

The methods selected for the smart cities case-based scenarios and relevant BoK concepts (25 concepts) are presented in Figure 18 and 19.

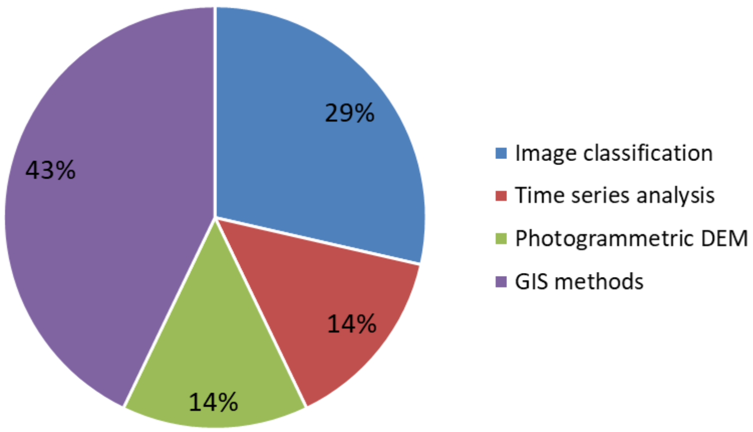


Figure 18 – Selected methods of remote sensing data processing and analysis for smart cities sub-sector.

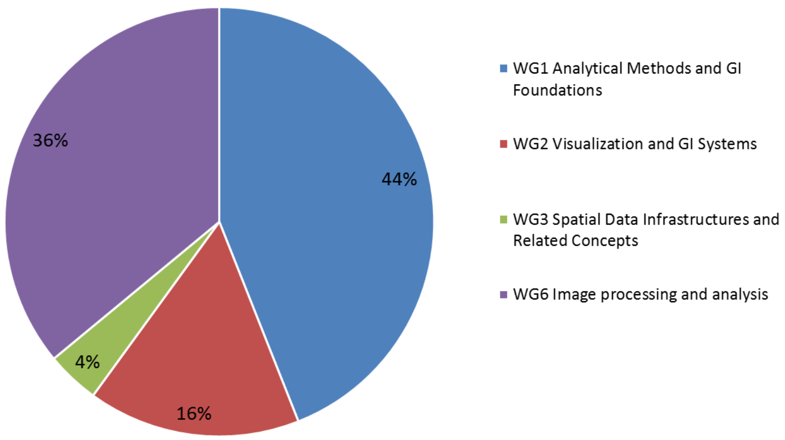
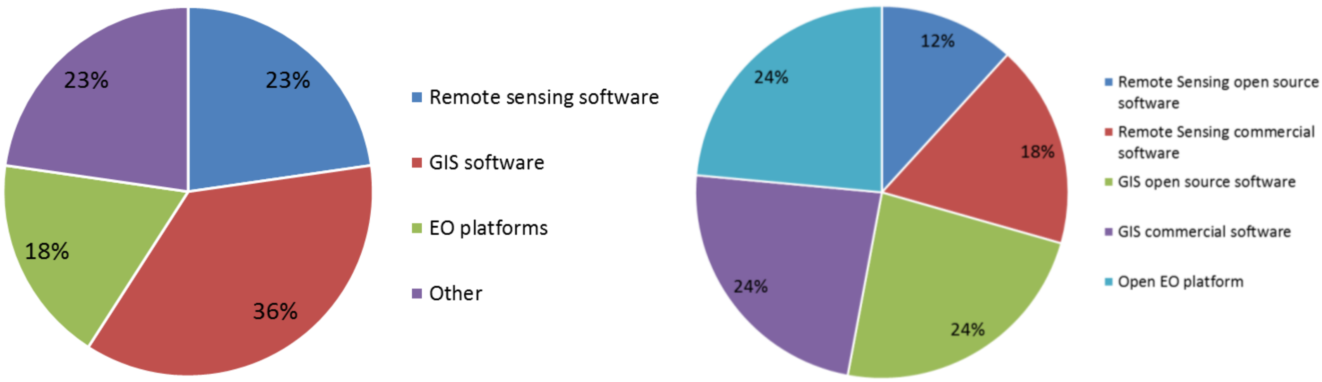


Figure 19 – Methods relevant BoK concepts per working group (WG) selected for smart cities sub-sector.

The list of selected methods with references and adaptation needed for the selected case-based scenarios as well as relevant BoK concepts is given in Annex IX.

3.2.3. Analysis tools

The analysis tools for the smart cities sub-sector have been selected taking into account the techniques/algorithms and data identified in the previous sections: 3.2.1 and 3.2.2. In general, remote sensing (23%) and GIS techniques/algorithms (36%) for processing selected case-based scenarios were identified (Figure 20). Remote sensing methods include object-based image analysis classification (OBIA), change detection and time series for mainly optical data, interpolation of Lidar point clouds and use of polarized radar images to derive flood maps. GIS methods are overlay analysis, raster calculations, raster interpolation, coordinate transformations and network analysis. The GEE platform has been identified for analysing big data. Fusion is an open-source software tool for analysing Lidar point clouds and deriving DSMs and DEMs. QGIS is an open-source GIS software with similar capabilities as ArcGIS, to be used for GIS operations. Concerning the network analyses of green infrastructure an alternative to GIS tools is to, for lower EQF levels, use stadstrad.se (other tools), a web application for analysing urban tree infrastructure.



a b

Figure 20 – Selected tools for smart cities sub-sector: a. in the context of tool category, b. in the context of tool access.

In summary, 21 BoK concepts were selected, most of them belong to WG2. (Figure 21).

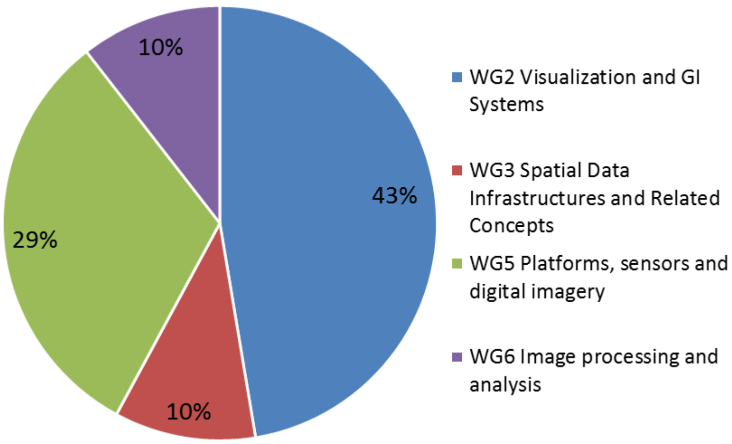


Figure 21 – Tools relevant BoK concepts per working group (WG) selected for smart cities sub-sector.

The list of selected tools with references and relevant BoK concepts is given in Annex X.

3.3. Climate change

Climate Changes cause a series of impacts on the flora/fauna and human health. Anthropogenic activities increasing the concentrations of atmospheric greenhouse gases (particularly carbon dioxide-CO_2 and methane-CH_4), have been identified, since decades, by the Intergovernmental Panel on Climate Change (IPCC) as the main source of the observed continuous increase of Earth's surface temperature which impacts on society, ecosystems, and the hydrologic cycle.

Because of the magnitude of observed and potential (environmental, economic, social, etc.) impacts, several efforts on national and international scale have been implemented in the last decades in order to better understand, foresee and mitigate climate change effects.

Climate datasets, especially those coming from satellite platforms (the only very long-term source of global data) are crucial to identify, monitor and predict these changes from the regional to the global scale. Selected scenarios, requiring observations at different spatial, temporal and spectral resolution, well represent the wide range of available datasets which are suitable for different applications from the very local to the synoptic scale.

The following four case-based scenarios were selected for the climate change sub-sector and will be implemented as part of task T5.5 coordinated by UPAT (Krieger, et al., 2020):

1. Air quality monitoring and management (EQF 3 and 5-6)
2. Solar energy forecasting for efficient planning and operation of solar energy farms (EQF 6)
3. Impact-based weather forecast services for risk evaluation (EQF 3)
4. Precision farming for vineyard (Precision viticulture) (EQF 3-4).

Each scenario corresponds to a training action. In case of the first scenario, two training actions will be carried out. One at EQF 3 and the other at EQF 5 and 6 level.

In order to provide a continuous assessment of air quality, different satellite-based observations are available depending on the scale: from very local (e.g. for city manager interested to reduce traffic impact on citizen health) to the synoptic one (e.g. for regional-national authorities in charge to design industrial/infrastructure development plans). In the first case the potential of Sentinel-5p/TROPOMI can be exploited to directly measure track pollutant like NO_2. In the second one, Copernicus Atmosphere Monitoring Service (CAMS), provides daily information (and forecast) on air pollutant (and pollens. Level 2 research products (e.g. LATMOS-FORLI) are also available, mostly based on interferometric passive optical sensors (e.g. EUMETSAT-IASI) which can be suitable for independent estimation of atmospheric chemistry at the global scale.

Similarly, the Sentinels chain and CAMS can effectively support the plan and management of solar energy farms and electrical grids. The integration of Meteosat Second Generation (MSG) data is also strategic both for estimating expected local cloud coverage (in the planning phase) and for short term forecast during solar plant management. Climate-related information, such as forecasts of air-temperature, atmospheric transparency, and wind strength, useful for renewable energy plant management are also provided by the Copernicus Climate Change Service (C3S).

The third scenario (Impact-based weather forecast services for risk evaluation) will benefit from Sentinels chain-CAMS- and MSG in order to translate forecasts and warnings coming from Meteorological and Hydrological Services, in specific risk maps depending on sectors and related expected impacts. High resolution data coming from Sentinel-1 and Sentinel-2 will also support local authorities for monitoring and damage assessment actions.

The possibility to increase and predict annual crop yields exposed to climate-dependent variations, is the subject of the last scenario (Precision farming for vineyards). Long term data analysis based on C3S data and Landsat series, can provide an assessment of the dependence of the chosen specific sector (viticulture) to long-term variations in the climate. Actions to increase crop quality and/or quantities, reducing the use of fertilizer and water, can be well supported by HR and VHR satellite sensors (e.g. Pléiades, SPOT, Sentinel-2) together with forecasts of specific meteorological conditions (e.g. for impending frosts) coming both from CAMS and C3S.

3.3.1. Data types and data providers

The scenarios selected on the base of the BPMNs described in D4.1, well emphasize the potential of EO resources (and ground data) available (most of them made available by Copernicus Services like CAMS, C3S and CLMS) at different spatial (from meters to kilometres), temporal (from minutes to several weeks) and spectral (from multi- to hyperspectral) resolutions.

In this framework active microwave sensors like SAR (and particularly Sentinel-1 constellation) provide basic and updated (e.g. deformation maps by InSAR techniques) DEMs together with (all-weather) monitoring of relevant hydrological parameters and processes (e.g. soil moisture, flood mapping, etc.).

Figure 22 presents the data relevant for the climate change case-based scenarios.

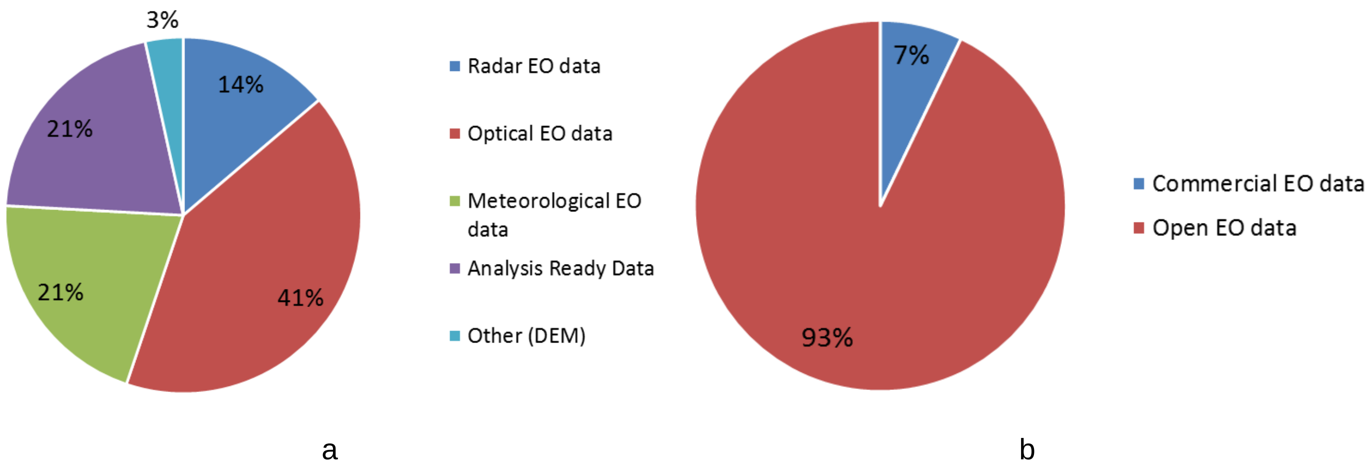


Figure 22 – Selected EO and relevant data for climate change sub-sector: a. in the context of acquired wavelengths, b. in the context of data access.

Access to the data is guaranteed by different platforms (like Copernicus DIAS) and by Copernicus Services which also provides ground data and level-2 products (Figure 23).

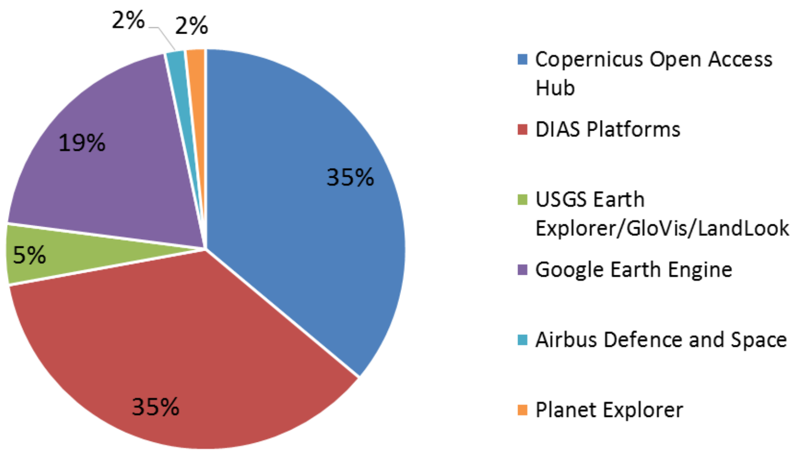


Figure 23 – Selected data providers for sub-sector climate change.

For this sub-sector, 47 concepts were selected, most of them belong to WG7 (Figure 24).

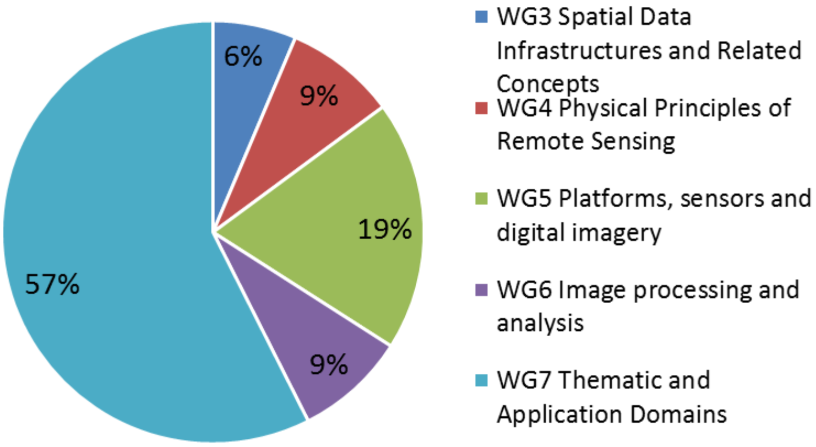


Figure 24 – Data relevant BoK concepts per working group (WG) selected for climate change sub-sector.

The list of selected data types their potential and limitations, data providers and relevant BoK concepts is given in Annex XI.

3.3.2. Techniques/algorithms

Techniques and algorithms for climate change related applications have been identified mostly based on information from deliverables 4.1 and 5.1. Looking at the four identified use cases, different observational and analysis techniques are required.

As far as the Air quality monitoring and management scenario is concerned, together with the analysis of daily concentration of main pollutants (and pollens) provided by CAS, long-term time-series analysis are required in order to identify the relative significance of observed changes as well as to identify trends and pollution sources for mitigation actions planning. To this aim the downscaling from synoptic to very local scale EO data and their cross-correlation analysis with ground-based measurements will be of paramount importance in order to discriminate from large scale (e.g. climatological) and very local (e.g. traffic, intensive breeding, etc.) pollutant sources as well as to evaluate the overall social and economic impacts (e.g. on public health).

As far as the second scenario (Solar energy forecasting) long-term time-series analysis of cloud cover (mostly form EO satellites) and related yearly solar insolation (modelled, possibly supported by ground and atmospheric calibration measurements) will be the base (together with static parameters related to orography, exposition, etc.) for preliminary cost/benefit analyses in the evaluation of plants locations and productivity. Specific algorithms to translate daily weather (and cloud coverage) forecast bulletins in terms of expected energy production will be fundamental for system operation and maintenance planning.

For the third scenario (Impact-based weather forecast services for risk evaluation), the appropriate integration of multi-satellite and ground-based observations can provide the major benefits. To this aim suitable (temporal and spatial) re-scaling and interpolation algorithms will allow to fully benefits from available observational data for each specific risk to be evaluated. For instance, the coupling of adverse weather forecasts (e.g. heavy precipitations) with the estimate of soil wetness (achievable at different space-time scales from active and passive EO microwave sensors) will allow to dynamically update traditional flood risk models. Similarly, change-detection algorithms, applied to data coming from both, optical and active microwave EO sensors, will be required to support landslide risk monitoring and, more in general, all damage assessment evaluations after most hydrological adverse events. For all these applications reference fields (providing expected values and 'normal' variability of each parameter) should be computed on the base of multi-annual observations.

For the fourth scenario (Precision farming for vineyards), time series analysis of available EO observations will be required in order to try to establish correlations among phonological cycle changes and annual crop yields. This learning phase will help to identify suitable spectral/temporal indicators for an early detection of possible deviation and consequent losses mitigation actions. The analyses of classical (or new) spectral vegetation growth indicators based on VHR EO data, will help to address targeted actions devoted to increase crop quality and/or quantities, reducing the use of fertilizer and water. Also, in this case algorithms suitable for integrating multi-source and multi-scale observations (satellite and ground based measurements, weather forecast analyses, etc.) will be crucial even for the early identification (and prevention by appropriate mitigation actions) of potentially devastating events (e.g. impending frosts) in the very short term.

A summary of the identified methods is presented in Figure 25.

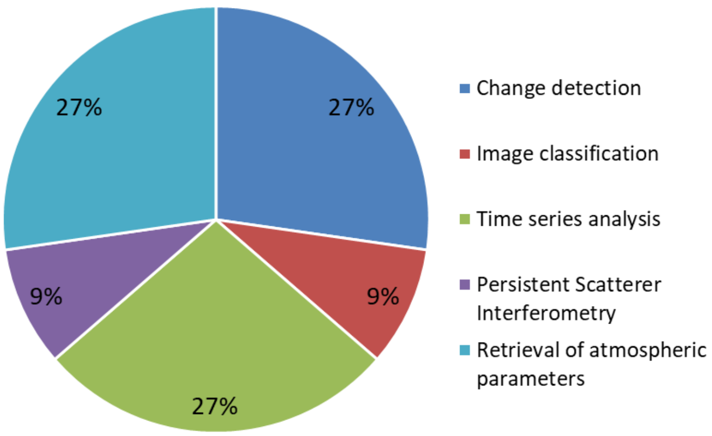


Figure 25 – Selected methods of remote sensing data processing and analysis for climate change sub-sector.

For this sub-sector, 66 relevant BoK concepts were selected, most of them belong to WG6 (Figure 26).

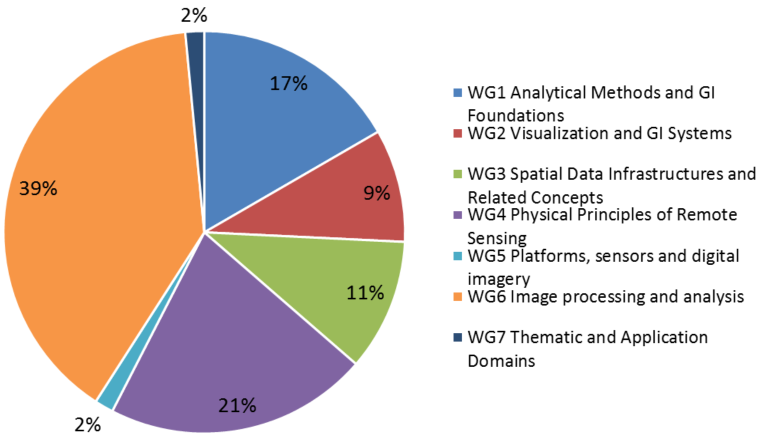


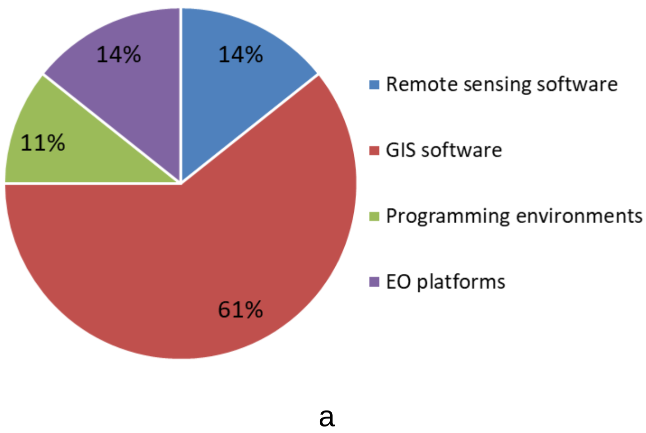
Figure 26 – Methods relevant BoK concepts per working group (WG) selected for climate change sub-sector.

The list of selected methods with references and adaptation needed for the selected case-based scenario as well as relevant BoK concepts is given in Annex XII.

3.3.3. Analysis tools

The analysis tools for the climate change sub-sector are generally common to all the other sub-sectors as far as basic image data and GIS processing are concerned. More refined tools are available to directly process level-1 data particularly for inversion processes devoted to extract chemical parameters from interferometric sensors like IASI or hyperspectral which are not usually required for the selected applications which can benefits directly of available level-2 products.

A summary of the identified tools is given in Figure 27.



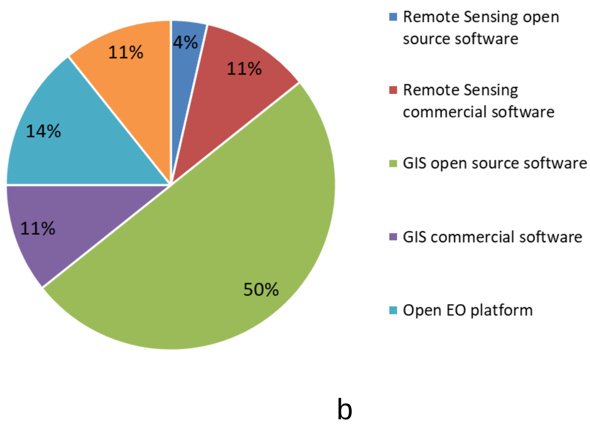


Figure 27 – Selected tools for smart cities sub-sector: a. in the context of tool category, b. in the context of tool access.

The selected BoK concepts (7 concepts) are presented in

Figure 28.

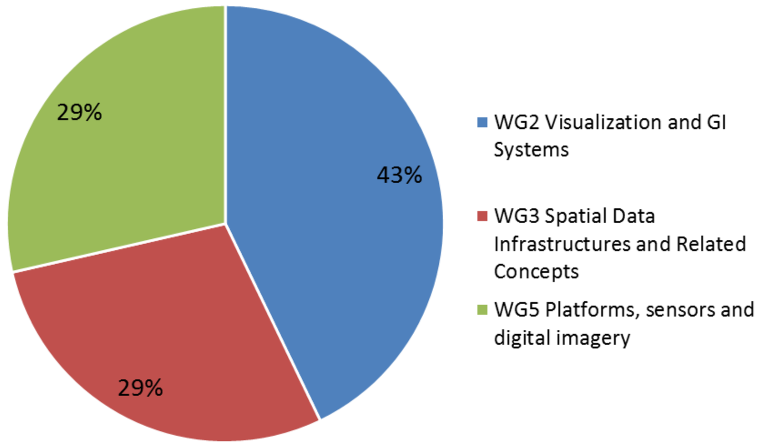


Figure 28 – Tools relevant BoK concepts per working group (WG) selected for smart cities sub-sector.

The list of selected tools with references and relevant BoK concepts is given in Annex XIII.

4. Detailed learning units

Six learning courses were prepared based on the characteristics of identified remote sensing data, methods and tools. The courses were prepared using the Curriculum Design Tool (CDT) developed by the EO4GEO project partner, Universitat Jaume I (UJI). The modular structure of the CDT educational offer will allow partners to re-use the courses in preparation for the training actions.

When developing the learning units for the planned training actions in the tasks 5.3-5.5, the focus was on the most frequently chosen data products and services and the most commonly used processing methods. Regarding the tools, the EO tools developed by the EO4GEO project partner VITO will be used when appropriate.

As outlined in Chapter 3, the most commonly identified data products among the selected case-based learning scenarios are openly available high resolution optical and radar data (Sentinels). The most commonly identified processing methods are time series analysis, change detection and image classification. These data product types and processing methods form a base in the learning courses (section 4.1 – 4.3). Additionally, the user needs specified in the EARSC taxonomy, i.e. monitor, map, forecast, assess, detect (EARSC, 2015), were considered. The relevant techniques that cover terms such as monitor, map, assess, detect are object-based image analysis (OBIA) and persistent scatterer interferometry (PSI).

The courses were adapted to each scenario taking into account different EQF levels. The designed courses are:

g. time series analysis of optical data in the context of efficient planning and operation of solar energy farms (EQF 6) - chapter 4.1

h. change detection in the context of geospatial data and technologies applications for land monitoring (EQF 6 and 7) - chapter 4.2

i. classification of urban vegetation mapping in the context of evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments (EQF 3) - chapter 4.3

j. classification of flooded areas in the context of improving sustainability of cities to storm and water (EQF 6) - chapter 4.4

k. object-based image analysis in the context of identification of local heat islands to support city planning (EQF 6 and 7) - chapter 4.5

l. persistent scatterer interferometry in the context of mapping landslide affecting Cultural Heritage sites - Baia Archaeological Park (Naples) (EQF 7) - chapter 4.6.

Half of the courses (a, b, f) are planned as academic course and the other half (c, d, e) as potential part of a VET training with a special focus on practical exercises.

The elements of course description are provided in Table 2, Chapter 2 ‘Methodology’.

4.1. Time Series Analysis

This proposed detailed course on Time Series Analysis is planned as an academic course for a selected case-based scenario entitled “Efficient planning and operation of solar energy farms” (climate change sub-sector) and consists of six teaching/learning units in the form of blended learning (Figure 29):

1. Lecture: Time series analysis concept and basic methods: Theory and Principles
2. Practicals: Modelling and forecast global solar radiation time-series
3. Lecture: Fundamentals of optical remote sensing methods and instruments: Theory and Principles
4. Practicals: Cloud coverage detection and forecast from space
5. Practicals: Time Series Analysis: Tools and Practice on ground, satellite and NWP data
6. Practicals: Application examples: Practice

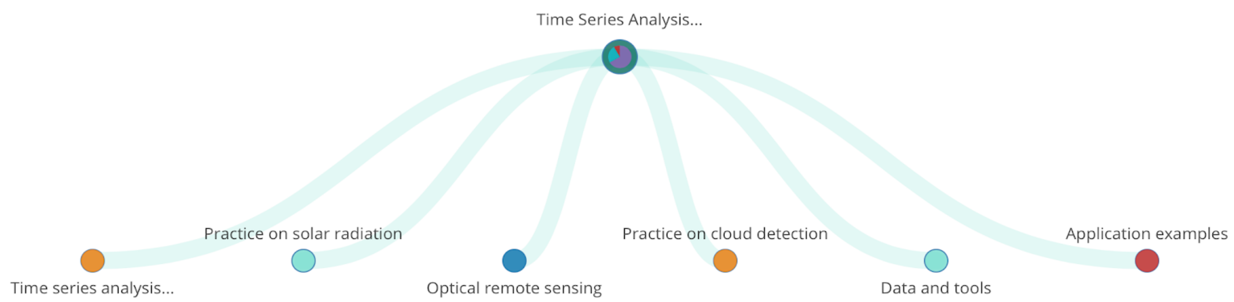


Figure 29 – Academic course on Time Series Analysis at EQF 6.

This course is available at: https://eo4geo-cdt.web.app/detail/Gj20qry2wziOTL9cnOgI.

Title
Course: Time Series Analysis of optical data

EQF: 6

Description
This is an EQF 6 course for upper secondary level students and other complementary professionals (managers, decision makers, technicians, administrative staff) who want to acquire professional skills in basic time-series analysis. Fundamentals of statistics and time-series data analysis will be provided together with practical tools devoted to fully implement applications based on EO (from satellites and at ground) and weather forecast data. It consists of lectures and

practicals. The course will particularly emphasize the study of time evolution of selected parameters (e.g. in terms of stationarity, trends, seasonality, cross-correlations) in order to allow forecasts of their expected value and variability in selected geographic areas and period of the year. The combined use of multi-parametric time-series will be introduced and applied to a specific scenario.

Course duration: 1 semester

Prerequisites
Basics of fundamental of mathematics and statistics at high school level (EQF 5)
Basic science and geography on Sun-Earth system and solar daily/annual cycle
Basic knowledge of computer use and basic processing and visualization tools.

Learning outcomes
Demonstrate knowledge on time series analysis concept and basic and advanced methods.
Demonstrate knowledge on limits of each selected approach and how to benchmark their performance
Demonstrate knowledge on when and how to apply specific time-series analysis approach
Apply time-series analysis tools with simple (synthetic and real) data set
Demonstrate knowledge on solar radiation cycles in standard atmospheres
Demonstrate knowledge on the impact of variable atmospheric conditions in perturbing theoretical model
Demonstrate knowledge on theoretical basis of optical remote sensing
Select appropriate EO sensors/platforms
Perform optical satellite time-series data analysis using STEP/SNAP chain and Google Engine tools
Select and apply methods for appropriate data integration
Apply multi-parametric, multi-source, multi-scale time-series analysis methods
Plan and apply project on optimal solar plant site selection and running

Assessment
Project-based (work report, 75%), presentation (25%)

Bibliography
George E. P. Box, Gwilym M. Jenkins (1976). Time series analysis: forecasting and control, Holden-Day, 1976.

George E. P. Box, Gwilym M. Jenkins, Gregory C. Reinsel (2013). Time series analysis: forecasting and control, Wiley 2013

Tamer Khatib, Azah Mohamed, K. Sopian (2012). A review of solar energy modelling techniques. Renewable and Sustainable Energy Reviews 16, 2864– 2869

Steven D. Miller, Matthew A. Rogers, John M. Haynes, Manajit Sengupta, Andrew K. Heidinger (2018). Short-term solar irradiance forecasting via satellite/model coupling. Solar Energy 168, 102–117

Gordon Reikard, Clifford Hansen (2019). Forecasting solar irradiance at short horizons: Frequency and time domain models. Renewable Energy 135, 1270-1290

James B. Campbell and Randolph H. Wynne (2011) Introduction to Remote Sensing. The Guilford Press, 2011; 662 pages.

Charles Elachi, Jakob J. van Zyl (2006). Introduction to the physics and techniques of remote sensing. Wiley Series in Remote Sensing and Image Processing, Vol. 28. John Wiley & Sons, 2006, 584 pages

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Title

Lecture: Time series analysis concept and basic methods: Theory and Principles

Description

This lecture gives the basic theoretical background of time-series analysis theory and principles. The objective of the lecture is to explain and present classical and advanced time-series analysis and forecast methods. Methods to evaluate performance of forecasts will be also provided.

Lecture duration: 2x3 hours

Learning outcomes:

Demonstrate knowledge on time series analysis concept and basic and advanced methods.
Demonstrate knowledge on limits of each selected approach and how to benchmark their performance
Demonstrate knowledge on when and how to apply specific time-series analysis approach

Bibliography

George E. P. Box, Gwilym M. Jenkins (1976). Time series analysis: forecasting and control, Holden-Day, 1976.

George E. P. Box, Gwilym M. Jenkins, Gregory C. Reinsel (2013). Time series analysis: forecasting and control, Wiley 2013

Mahmoud Ghofrani and Musaad Alolayan (2018). Time Series and Renewable Energy Forecasting (a review) http://dx.doi.org/10.5772/intechopen.70845, in Time Series Analysis and Applications. Edited by Nawaz Mohamudally. IntechOpen. DOI: 10.5772/intechopen.68262

Title

Practicals: Modelling and forecast global solar radiation time-series

Description

The objective of this 'hands on' class is to introduce the clear-sky (standard atmospheres) model for solar radiation (horizontal illuminance, direct normal and diffuse irradiance) at the Earth surface. Time-series of so modelled parameters and others measured at ground (e.g. air-temperature, relative humidity, pressure, etc.) relevant to the selected scenario, will be used for practicing time-series analysis and forecast methods.

Practicals duration: 2x2 hours

Learning outcomes:

Apply time-series analysis tools with simple (synthetic and real) data set
Demonstrate knowledge on solar radiation cycles in standard atmospheres
Demonstrate knowledge on the impact of variable atmospheric conditions in perturbing theoretical model

Bibliography

Wind Field and Solar Radiation Characterization and Forecasting (2018). Perez R. (editor). Green Energy and Technology. Springer, Cham.

Boland, J. (2008). Time series modelling of solar radiation. In Modeling Solar Radiation at the Earth's Surface (pp. 283-312). Springer, Berlin, Heidelberg. (https://link.springer.com/chapter/10.1007%2F978-3-540-77455-6_11)

Title

Lecture: Fundamentals of optical remote sensing methods and instruments: Theory and Principles

Description

This lecture gives the theoretical fundaments of optical remote sensing and related instruments.

Lecture duration: 3x2 hours

Learning outcomes

Demonstrate knowledge on theoretical basis of optical remote sensing
Select appropriate EO sensors/platforms

Bibliography

James B. Campbell and Randolph H. Wynne (2011) Introduction to Remote Sensing. The Guilford Press, 2011; 662 pages.

Charles Elachi, Jakob J. van Zyl (2006). Introduction to The Physics and Techniques of Remote Sensing. Wiley Series in Remote Sensing and Image Processing, Vol. 28. John Wiley & Sons, 2006, 584 pages

P Cracknell; Ladson W B Hayes (2007). Introduction to remote sensing. Taylor & Francis, Pages 335.

Title

Practicals: Cloud coverage detection and forecast from space

Description

This is a practical class that introduces methods for cloud detection and long-term analysis of cloud coverage by using meteorological satellites. It will offer the opportunity to practice with time-series of satellite data and related products as well as with specific data analysis and visualization tools in STEP/SNAP and Google Engine environment

Practicals duration: 2x2 hours

Learning outcomes

Perform optical satellite time-series data analysis using STEP/SNAP chain and Google Engine tools

Bibliography

Jedlovec, G. (2009). Automated detection of clouds in satellite imagery. Advances in Geoscience and Remote Sensing, 303-316.

Voyant, C., Haurant, P., Muselli, M., Paoli, C., & Nivet, M. L. (2014). Time series modeling and large scale global solar radiation forecasting from geostationary satellites data. Solar Energy, 102, 131-142.

Andronache, C. (Ed.). (2018). Remote Sensing of Clouds and Precipitation. Springer. (https://www.springer.com/gp/book/9783319725826)

Stephens, G. L., & Kummerow, C. D. (2007). The remote sensing of clouds and precipitation from space: A review. Journal of the Atmospheric Sciences, 64(11), 3742-3765.

https://navigator.eumetsat.int/product/EO:EUM:DAT:MSG:CLAI

https://www.eumetsat.int/website/home/Satellites/GroundSegment/Safs/NumericalWeatherPrediction/index.html

https://wui.cmsaf.eu/safira/action/viewDoiDetails?acronym=CFC_METEOSAT_V001

http://step.esa.int/main/

Ttitle

Practicals: Time Series Analysis: Tools and Practice on ground, satellite and NWP data

Description

This practicals give an overview of the applications of time-series analysis methods to heterogeneous data set required in the selected scenario. In particular observations (punctual) from ground station, from EO platforms and from NWP (Numerical Weather Forecast) analyses will be considered in order to deal with multi-scale real data often requiring interpolation and/or kriging to fill gaps in the space/time domain.

Practicals duration: 3x2 hours

Learning outcomes

Select and apply and possible solutions dealing with real multi-source multi-scale data
Select and apply methods for appropriate data integration

Bibliography

Cano D., Monget J.-M., Albuisson M., Guillard H., Regas N., Wald L., 1986. A method for the determination of the global solar radiation from meteorological satellites data Solar Energy, 37, 1, 31-39.

Rigollier C., M. Lefèvre, L. Wald, 2004. The method Heliosat-2 for deriving shortwave solar radiation from satellite images, Solar Energy 77(2), pp. 159-169, 2004, doi 10.1016/j.solener.2004.04.017

Z. Qu, B. Gschwind, M. Lefevre, and L. Wald (2014). Improving HelioClim-3 estimates of surface solar irradiance using the McClear clear-sky model and recent advances in atmosphere composition. Atmos. Meas. Tech. 7, 3927–3933, doi: 10.5194/amt-7-3927-2014

Sujan Ghimire, Ravinesh C. Deo, Nathan J. Downs, Nawin Raj (2019). Global solar radiation prediction by ANN integrated with European Centre for medium range weather forecast fields in solar rich cities of Queensland Australia. Journal of Cleaner Production, 216, 288-310

Dazhi Yang (2018). Kriging for NSRDB PSM version 3 satellite-derived solar irradiance. Solar Energy Volume 171, 1, Pages 876-883

https://solrad-net.gsfc.nasa.gov/

https://www.eumetsat.int/website/home/Data/Products/Atmosphere/index.html?lang=EN

https://cds.climate.copernicus.eu/#!/home

Title
Practicals: Application examples (3x2)

Description
This hands-on class teaches the use of time series-analysis methods in the specific scenario of solar plant optimal site selection and running. Time series of global, direct, and diffuse irradiations on horizontal surface, and direct Irradiation on normal plane for clear-sky conditions will be first simulated than compared with real data obtained from different data sources. For a specific region optimal sites will be selected and for one of them a simulation of solar plant management and running will be attempted by using multi-parametric forecasts.

Practicals duration: 3x2 hours

Learning outcomes
Apply multi-parametric, multi-source, multi-scale time-series analysis methods
Plan and apply project on optimal solar plant site selection and running

Bibliography
Tamer Khatib, Azah Mohamed, K. Sopian (2012). A review of solar energy modelling techniques.

Renewable and Sustainable Energy Reviews 16, 2864– 2869

Rigollier C., M. Lefèvre, L. Wald, 2004. The method Heliosat-2 for deriving shortwave solar radiation from satellite images, Solar Energy 77(2), pp. 159-169, 2004, doi 10.1016/j.solener.2004.04.017

Z. Qu, B. Gschwind, M. Lefevre, and L. Wald (2014). Improving HelioClim-3 estimates of surface solar irradiance using the McClear clear-sky model and recent advances in atmosphere composition. Atmos. Meas. Tech., 7, 3927–3933, doi:10.5194/amt-7-3927-2014

https://atmosphere.copernicus.eu/solar-energy

https://navigator.eumetsat.int/product/EO:EUM:DAT:0022

User Guide to the CAMS Radiation Service
https://atmosphere.copernicus.eu/sites/default/files/2020-03/CAMS72_2018SC1_D72.4.3.1_2019_UserGuide_v1.1.pdf

4.2. Change Detection

This change detection course is planned as an academic course for a selected case-based scenario entitled 'Geospatial data and technologies applications for monitoring land use change' (integrated applications sub-sector). The academic course consists of six teaching/learning units in the form of blended learning (Figure 30):

1. Lecture: Introduction to remote sensing
2. Practicals: Change detection with optical data
3. Practicals: Change detection with SAR data
4. Practicals: Land use/Land cover change detection
5. Practicals: Change detection of urban areas
6. Practicals: Change detection in agriculture

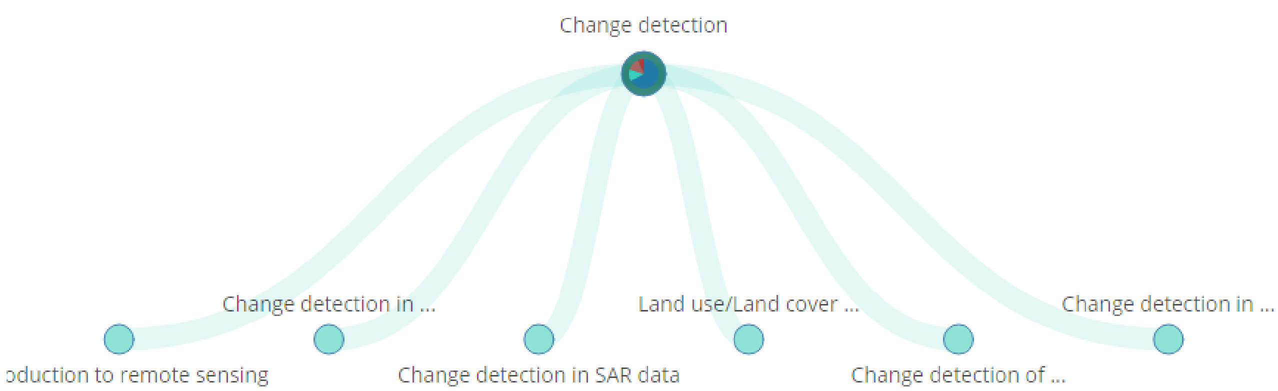

Figure 30 – Academic course on change detection at EQF 6 and 7.

This course is available at: https://eo4geo-cdt.web.app/detail/Ij3beI009aSF0fu4zs3N.

Title
Course: Change detection using optical and radar data

EQF: 6 and 7

Description
This is an academic course. Its overall objective is to conduct land use and land cover change as required in the various policies.
The course provides information on the tools and services needed to manage spatial remote sensing data or data collected in the field and ancillary data required to generate information about coverage and land use, as they are required for users who implement policies related to land use monitoring.

Change detection is a technique to determine changes in particular features of an object over a specific interval of time. Its main aim is to provide quantitative and qualitative information of deviations and their spatial distribution including category, amount and areas of changes occurred.

Course duration: 1 semestre

Prerequisites
[IP1-1] Data manipulation
[GIST] Geographic Information Science and Technology
[GD2-2] Remote sensing
[IP3-4] Image classification
[IP] Image processing and analysis
[IP3] Image understanding
[IP3-13] Visual interpretation
[PS1-2-2-1-3] Hyperspectral Radiometers
[GD] Geospatial Data

Learning outcomes
Demonstrate knowledge on fundamental physical principles of remote sensing
Demonstrate knowledge on remote sensing data acquisition, storage, and processing.
Demonstrate knowledge on conceptual understanding of using software for remote sensing image processing and analysis
Demonstrate knowledge on optical data
Process optical data
Apply and compare change detection methods
Explain and outline the advantages of radar sensors
Explain how radar images are used for specific applications
Demonstrate advantages and disadvantages of radar remote sensing over optical
Apply polarimetry and interferometry
Demonstrate knowledge on different types of LULC on a defined area on optical and SAR data
Discuss and explain land degradation trends that occurred at an interval of 10 years in a given area
Compare land use/cover change products
Demonstrate knowledge and apply change detection by: conducting image subtraction between two dates using QGIS, creating multi-date Landsat layer stacks, identifying and analysing changes in land cover
Select data and change detection method for processing remote sensing data for an urban area
Perform change detection
Demonstrate knowledge on change detection methods for agriculture
Process time series data for crop monitoring
Apply, evaluate and compare thematic indices for a period of 10 years crop monitoring

Assessment
Project-based (report 25%), presentation (25%) and exam (50%)

Bibliography
Lillesand, T., Kiefer, R.W., Chipman, J., 2015. Remote sensing and image interpretation. John Wiley & Sons.

Jensen, J. R. (2007). Remote Sensing of the Environment. An Earth Resources Perspective. Second Edition, pp. 592, Pearson Prentice Hall, USA. ISBN 0-13-188950-8
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McHarg, I. L. 1969. Design with nature. Garden City, NY: American History Press.
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Mitchell, A. 2005. The ESRI guide to GIS analysis, Volume 2: Spatial measurements and statistics. Redlands, CA: ESRI Press.
Osullivan, D. and Unwin, D. 2003. Geographic information analysis. New York: Wiley.
Ripley, B. D. 1988. Statistical inference for spatial processes. Cambridge: Cambridge University Press.
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Worboys, M. and Duckham, M. (2004) GIS: A computing perspective. Boca Raton, FL: CRC Press
Worboys, M. F. 1992. A generic model for planar spataial objects. International Journal of Geographical Information Systems, 6, 353-372.
Smith, J. (1997) Introduction to geodesy: The history and concepts of modern geodesy. New York: Wiley.

Title
Lecture: Introduction to remote sensing

Description
This lecture gives an overview of remote sensing fundamentals, data, methods, tools and applications.

Lecture duration: 3x2 hours

Learning outcomes
Demonstrate knowledge on fundamental physical principles of remote sensing
Demonstrate knowledge on remote sensing data acquisition, storage, and processing
Demonstrate knowledge on conceptual understanding of using software for remote sensing image processing and analysis

Bibliography
Canada Centre for Remote Sensing, Fundamental of Remote Sensing, Tutorial
Gergel, S., Turner, M., (2017), Learning Landscape Ecology, A practical guide to concepts and techniques, Springer-Verlag, New York;
Kairu, E., 1982.An Introduction to Remote Sensing, in GeoJournal;

Goodchild, M. F. (1992). Geographical information science. International Journal of Geographical Information Systems, 6(1):31–45

Title
Practicals: Change detection with optical data

Description
This 'hands on' class gives an overview of change detection methods and tools using optical remote sensing data.
It introduces the basic terminology and change detection methods, e.g. multi-band images, classical change detection differencing methods through spectral change vectors or transform analysis.

Practicals duration: 3 x 2 hours

Learning outcomes
Demonstrate knowledge on optical data
Process optical data
Apply and compare change detection methods

Bibliography
Campbell, J., Wynne, R, 2011, Introduction to remote sensing, 5th ed. New York: Guilford Press;
Collet, C., Chanussot, J., Chedi, K. 2006. Multivariate image processing: methods and applications. wiley, Hoboken, NJ;
Ridd, M., Liu., J., 1998. A comparison of four algorithms for change detection in an urban environment," Remote Sens. Environment, vol. 63, no. 2, pp. 95–100;
Bovolo, F., et all. 2012. A Framework for Automatic and Unsupervised Detection of Multiple Changes in Multitemporal Images," IEEE Trans. Geosci. Remote Sens., vol. 50, no. 6, pp. 2196–2212
Nielsen, A., 2007. The Regularized Iteratively Reweighted MAD Method for Change Detection in Multi- and Hyperspectral Data," IEEE Trans. Image Process., vol. 16, no. 2, pp. 463–478

Title
Practicals: Change detection with SAR data

Description
This 'hands on' class gives an overview of change detection methods and tools using radar remote sensing data. Synthetic aperture radar (SAR) data have gained increasing importance in change detection applications, because SAR is an active sensor, operating without regard to weather, smoke, cloud cover, or daylight.
The processing steps of change detection mainly include image preprocessing, generation of the difference image, detection of the change information, and evaluation of the detection result.

Practicals duration: 3x2 hours

Learning outcomes
Explain and outline the advantages of radar sensors
Explain how radar images are used for specific applications
Demonstrate advantages and disadvantages of radar remote sensing over optical

Apply polarimetry and interferometry

Bibliography

Simard, M.; Degrandi, G.; Thomson, K.P.B.; Benie, G.B. 2002. Analysis of speckle noise contribution on wavelet decomposition of SAR images. IEEE Trans. Geosci. Remote Sens.
Köstli, K.P.; Beard, P.C. 2003. Two-dimensional photoacoustic imaging by use of Fourier-transform image reconstruction and a detector with an anisotropic response. Appl. Opt.
Ikuta, C.; Zhang, S.; Uwate, Y.; Yang, G.; Nishio, Y. 2015 A novel fusion algorithm for visible and infrared image using non-subsampled contourlet transform and pulse-coupled neural network. In Proceedings of the International Conference on Computer Vision Theory and Applications, Lisbon, Portugal

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Title
Practicals: Land use/Land cover change detection

Description
This 'hands on class' gives an overview of change detection methods for mapping land cover (LC) and land use (LU) changes. In addition, the common Land Cover Classification Systems are introduced and implemented.

Practicals duration: 6x2 hours

Learning outcomes
Demonstrate knowledge on different types of LULC on a defined area on optical and SAR data
Discuss and explain land degradation trends that occured at an interval of 10 years in a given area
Compare land use/cover change products
Demonstrate knowledge and apply change detection by: conducting image subtraction between two dates using QGIS, creating multi-date Landsat layer stacks, identifying and analysing changes in land cover

Bibliography

Erle E, Pontius R (2007) Land-use and land-cover change. In: Cleveland CJ (ed) Encyclopaedia of earth environmental information. Coalition, Washington
Lu D, Mausel P, Brondizio E, Moran E (2004) Change detection techniques. Int J Remote Sens 25(12):2365–2407

Title
Practicals: Change detection of urban areas

Description
This 'hands on' class gives an overview of change detection methods using remote sensing data of urban areas. Additionally, the students will select and apply the methods to detect changes in urban areas.

Practicals duration: 3x2 hours

Learning outcomes
Select data and change detection method for processing remote sensing data for an urban area

Perform change detection

Bibliography

Nielson, A., Conradsen, K., Simpson, J. 1998, Multivariate alteration detection (MAD) and MAF post processing in multi-spectral bi-temporal image data: new approaches to change detection studies. Remote Sensing of Environment: 64: 1–19.
Mas, J. F. 1999. Monitoring land-cover change: a comparison of change detection techniques. International Journal of Remote Sensing: 20: 139–152.
Pilon, P. G., Howarth, P. J., Bullock, R. A., Adeniyi, P. O. 1988, An enhanced classification approach to change detection in semi-arid environments. Photogrammetric Engineering and Remote Sensing: 54: 1709–1716.
Singh, A. 1989. Digital change detection techniques using remotely-sensed data. International Journal of Remote Sensing: 10: 989–1003.

Title
Practicals: Change detection in agriculture

Description
This 'hands on class' gives an overview of change detection methods using remote sensing data in agriculture. Moreover, the students will select and apply the methods to detect changes in agriculture.

Practicals duration: 3x2 hours

Learning outcomes
Demonstrate knowledge on change detection methods for agriculture
Process time series data for crop monitoring
Apply, evaluate and compare thematic indices for a period of 10 years crop monitoring

Bibliography

J. Chen, J. Chen, H. Liu, and S. Peng, (2018). ''Detection of cropland change using multi-harmonic based phenological trajectory similarity,'' Remote Sens., vol. 10, no. 7, p. 1020
M. D. Nellis, K. P. Price, and D. Rundquist,2009. ''Remote sensing of crop- land agriculture,'' in The SAGE Handbook of Remote Sensing, vol. 1. Univ. of Nebraska–Lincoln, Nebraska: Papers in Natural Resources, pp. 368–380
Ennouri, K., Kallel, A., 2019. Remote Sensing: An Advanced Technique for Crop Condition Assessment, in Mathematical Problems in Engineering

4.3. Classification (EQF 3)

The classification method will be part of a workshop entitled 'Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments' and will last for 5 or 7 days. The participants will come from different organisations related to the topic:

- local administrations & municipalities - management level (A)
- administrations, municipalities & service providers - technical experts (B)
- academia /VET (C)

The workshop is planned as a face-to-face workshop[15] and has the following structure (Figure 31):

1. Course: Context analysis
2. Course: Problem, objectives & stakeholder analysis
3. Course: Ecosystem services provided by urban greenery and trees
4. Course: Vegetation and land classification in urban areas
    a. Lecture: Vegetation indices
    b. Lecture: Satellite imagery - availability and specifications
    c. Lecture: Land cover classification
    d. Practicals: Project work
5. Course: Visualisation & presentation of results
6. Course: Validation of remote sensing products

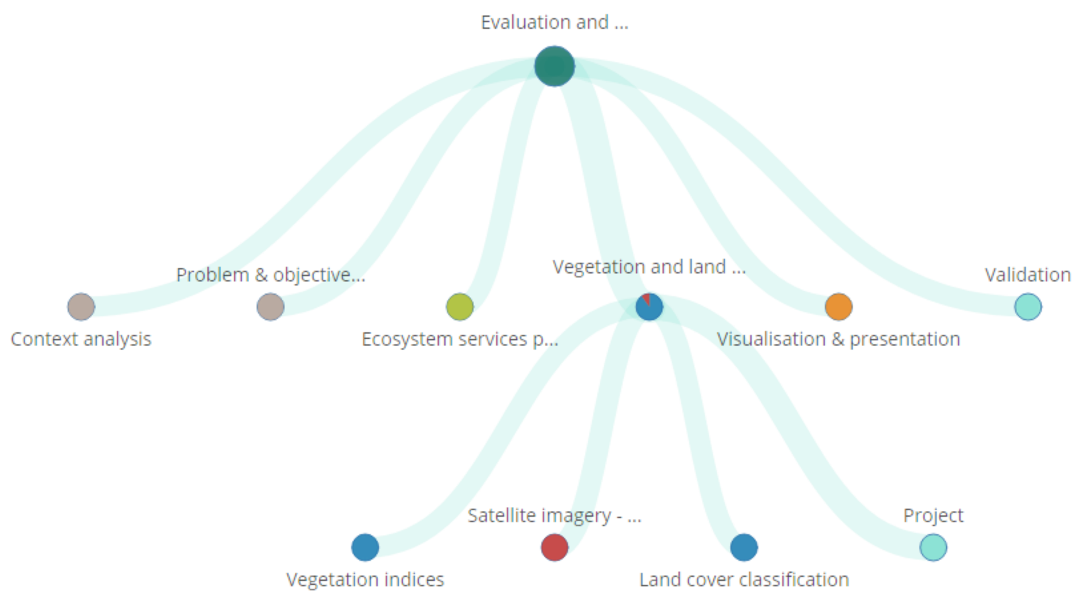

Figure 31 – Module on classification at EQF 3.

This module is available at: https://eo4geo-cdt.web.app/detail/3wtWUjTxXH4B8QP3C5tL.

Title
Module: Evaluation and planning of urban green structures

EQF: 3

Description
Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments

[15] An on-line alternative because of COVID-19 pandemic is also considered

Workshop duration: 5 days

Learning outcomes
Explain the policy framework
Explain the root causes of a problem, possible strategies for solutions, and the stakeholders involved
Demonstrate knowledge on suitable satellite data
Demonstrate knowledge on vegetation indices
Choose and collect suitable satellite data
Discuss, select and compute vegetation indices
Create a vegetation classification
Evaluate classification accuracy
Discuss and choose reference data

Assessment: Group assignments

Title
Course: Context analysis

EQF: 3

Description
Prior to initiating detailed analytical work with stakeholder groups, it is important that those involved in the identification or formulation of projects are sufficiently aware of the policy, sector and institutional context within which they are undertaking their work. Key documents that should be referenced would include the EC's Policy Papers and relevant National Government policy documents, such as Sector Policy documents.
Attendance: A, B, C

Course duration: 0,5 day

Learning outcomes
Explain the policy framework

Bibliography
https://europa.eu/capacity4dev/dear-programme/documents/europeaid-project-cycle-management-guidelines

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Title
Course: Problem & objectives & stakeholder analysis

EQF: 3

Description
Problem analysis: Problem analysis identifies the negative aspects of an existing situation and establishes the 'cause and effect' relationships between the identified problems. It involves three main steps: 1. Definition of the framework and subject of analysis; 2. Identification of the major

problems faced by target groups and beneficiaries (What is/are the problem/s? Whose problems?); and 3. Visualisation of the problems in form of a diagram, called a 'problem tree' or 'hierarchy of problems' to help analyse and clarify cause–effect relationships. Objectives analysis: Analysis of objectives is a methodological approach employed to: • Describe the situation in the future once identified problems have been remedied; • Verify the hierarchy of objectives; and • Illustrate the means-ends relationships in a diagram to identify strategies for interventions. Stzakeholder analysis: Any individuals, groups of people, institutions or firms that may have a significant interest in the success or failure of a project (either as implementers, facilitators, beneficiaries or adversaries) are defined as 'stakeholders'. A basic premise behind stakeholder analysis is that different groups have different concerns, capacities and interests, and that these need to be explicitly understood and recognized in the process of problem identification, objective setting and strategy selection.
Attendance: A, B, C

Course duration: 1 day

Learning outcomes
Explain the root causes of a problem, possible strategies for solutions, and the stakeholders involved

Bibliography
https://europa.eu/capacity4dev/dear-programme/documents/europeaid-project-cycle-management-guidelines

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Title
Course: Ecosystem services provided by urban greenery and trees

EQF: 3

Description
The values provided by the green infrastructure are often overlooked in the early stages of planning processes. That, and the fact it is often difficult to estimate and argue for green values in comparison to other values with a more commercial direction, demands for an easy way to visualise green values at early stages. These could be used for calculating costs for compensation. To define different classes of physical coverage of the Earth's surface
Attendance: awareness level A (2 days), B+C (0,5 day); partly joint working groups

Course duration: 0,5 day, 2 days

Title
Course: Vegetation and land classification in urban areas

EQF: 3

Description
The course gives an overview of EO based classification of vegetation. The course includes topics like satellite data availability, different sensors, spectral band combinations, and vegetation

indices. The course includes a project to perform land and vegetation cover classification in an urban area.
Attendance: B, C

Course duration: 2 days
The values provided by the green infrastructure are often overlooked in the early stages of planning processes. That, and the fact it is often difficult to estimate and argue for green values in comparison to other values with a more commercial direction, demands for an easy way to visualise green values at early stages. These could be used for calculating costs for compensation. to define different classes of physical coverage of the Earth's surface
Attendance: awareness level A (2 days), B+C (0,5 day); partly joint working groups

Prerequisites
[IP1-3] Geometric correction
[IP1-7] Radiometric correction
[IP1-4] Image enhancement
[IP1-1] Data manipulation

Learning outcomes
Demonstrate knowledge on suitable satellite data
Demonstrate knowledge on vegetation indices
Choose and collect suitable satellite data
Discuss, select and compute vegetation indices
Create a vegetation classification
Evaluate classification accuracy
Discuss and choose reference data

Title
Lecture: Satellite imagery - availability and specifications

EQF: 3

Description
Overview of different satellite systems and sensors, suitable for mapping of vegetation, Focus on availability and resolution - spatial, radiometric, spectral and temporal.

Lecture duration: 2 hours

Bibliography
Campbell, J.B., & Wynne, R.H. (2011). Introduction to remote sensing. Guilford Press, New York-London

Learning outcomes
Demonstrate knowledge on suitable satellite data

Title
Lecture: Vegetation indices

EQF: 3

Description
Theoretical background on how parameters like chlorophyll and water content in vegetation are reflected spectrally in different wavelengths. Derivation of different vegetation indices Spectral indices are calculated based on digital brightness values.

Lecture duration: 2 hours

Learning outcomes
Demonstrate knowledge on vegetation indices

Title
Practicals: Project work

Description
Project. Perform land cover and vegetation classification in an urban area using Sentinel- 2 data. Project includes collection of reference data for training and validation. Project report shall include chosen methodology cartographic product, accuracy assessment and discussion.

Practicals duration: 0,5 day

Learning outcomes
Choose and collect suitable satellite data
Discuss, select and compute vegetation indices
Create a vegetation classification
Evaluate classification accuracy
Discuss and choose reference data

Title
Course: Visualisation & presentation

EQF: 3

Description
Visualisation and presentation of information products adapted to the workflow of stakeholders. This unit addresses mapping methods and the variations of those methods for specialized mapping and visualization instances, such as thematic mapping, dynamic and interactive mapping, Web mapping, mapping and visualization in virtual and immersive environments, using the map metaphor to display other forms of data (spatialization), and visualizing uncertainty. Analytical techniques used to derive the data employed in these graphic representations are discussed in Knowledge Area AM Analytical Methods and Unit DN2 Generalization and aggregation.
Attendance: A, B, C

Course duration: 0,5 day

Assessment: presentation, feedback from users

Title
Course Validation of remote sensing products

EQF: 3

Description
The validation approach provides guidance on how the delivered products will be evaluated by defining suitable indicators. Validation concerns two aspects: technical quality assessment and user validation. The quality assessment is performed according to e.g. INSPIRE Data Specifications. The data quality elements considered are: (i) Completeness, (ii) Logical Consistency, (iii) Positional Accuracy, (iv) Thematic Accuracy, (v) Temporal quality and (vi) Usability. The user validation considers the impact of the information product(s) on the workflow of the user and the relevance for problem solving.

Course duration: 0,5 day

4.4. Classification (EQF 6)

This proposed detailed course on Flood mapping using Hydrology Exploitation Platform (H-TEP) is prepared for a case-nased scenario entitled 'Improving sustainability of cities to storm and water' and consists of six learning units of blended learning (Figure 32):

1. Lecture: Water indices from optical images
2. Lecture: Interaction of microwaves with matter
3. Lecture: Mapping water with microwaves
4. Lecture: Water frequency mapping
5. Lecture: Tools for water mapping with SAR
6. Practicals: Hydrology Exploitation Platform (H-TEP): introduction and hands on

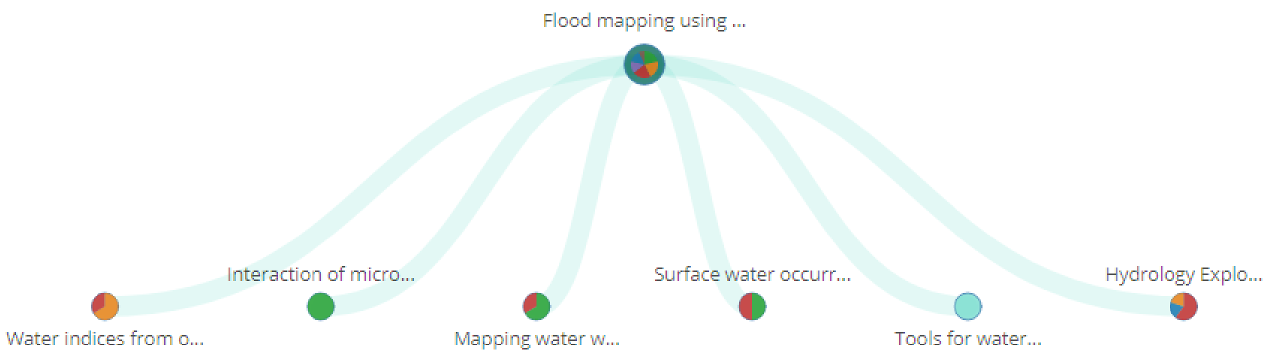

Figure 32 – Course on Flood mapping using Hydrology Exploitation Platform at EQF 6.

This course is available at: https://eo4geo-cdt.web.app/detail/3jsPswpijVewCa9tDY7E

Title
Course: Flood mapping using Hydrology Exploitation Platform (H-TEP)

EQF: 6

Description
This is a course for EO*GI students at the master and bachelor level or EO*GI specialists with a basic knowledge on radar remote sensing that aims at introducing and testing a fully automatic processing chain for flood mapping using Hydrology Exploitation Platform (H-TEP). It consists of traditional and on-line (blended learning) lectures and practicals.
Floods are more and more frequent phenomena in our environment. Due to the appearance of extreme heavy rains resulting from anthropogenic climate change, rivers occur from their natural riverbeds and excessive surface water runoff takes place. As a result, residential areas are flooded, causing significant casualties and financial losses.
Remote sensing data can provide a synoptic and systematic view of large areas and provide useful information on the extent and dynamics of floods. In particular, radar remote sensing has demonstrated its usefulness in emergency response for flood mapping and monitoring. This course will introduce water mapping with microwaves, from explaining the interaction of microwaves with matter and pre-processing of radar data to hands-on mapping flooded areas. For that, the Hydrology Thematic Exploitation Platform (HTEP) will be introduced. In addition, methods using optical sensors will be presented and discussed.

Course duration: 18 hours

Prerequisites
[PP] Physical principles
[PS1-2] Passive Sensors
[PS1-3] Active Sensors
[AM] Analytical Methods
[IP1-3] Geometric correction
[IP1-7-3-1] Converting DN to TOA reflectance
[IP1-7-1] Atmospheric correction
[CF5b] Elements of geographic information
[AM10-1] Problems of large spatial databases
[PS3-4] Properties of digital imagery
[PP1-6-9] The Water Cycle

Learning outcomes
Demonstrate knowledge on water indices using optical images
Explain differences between optical and radar remote sensing
Explain terms: scattering, emission, dielectric properties, surface roughness, polarimetry
Explain the microwaves interaction with water
Explain methods of surface water occurrence mapping
Select method for surface water occurrence mapping
Select tool for water mapping with SAR
Process and analyse SAR data using H-TEP
Produce water map and flood frequency map

Assessment
Short tests and quizzes during the training

Bibliography

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http://hydrology-tep.github.io/documentation/quick-start-manual/qsm8.html
https://eo-college.org/courses/echoes-in-space/
https://eo-college.org/resource/hydrosphere_applications/
RUS Webinar: Flood Mapping with Sentinel-1 - HAZA01
http://www.un-spider.org/sites/default/files/IWG_SEM_EmergencyMappingGuidelines_v1_Final.pdf
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Couclelis, H. (1992) People manipulate objects (but cultivate fields): Beyond the raster-vector debate in GIS. In A. U. Frank, I. Campari, and U. Formentini, (Eds.), Theories and methods of spatio-temporal reasoning in geographic space. (65-77). Berlin: Springer Verlag
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Mennis, J. L., Peuquet, D.J., and Qian, L. (2000). A conceptual framework for incorporating cognitive principles into geographical database representation. International Journal of Geographical Information Science, 14, 501-520.
Peuquet, D. J. (1994). Its about time: A conceptual framework for the representation of temporal dynamics in geographic information systems. Annals of the Association of American Geographers, 84, 441-61.
Sinton, D. (1978) The inherent structure of information as a constraint to analysis: Mapped thematic data as a case study. In Dutton, G. (Ed.), Harvard Papers in GIS #7. Cambridge, MA: Harvard University.
Yuan, M. (1999) Use of a three-domain representation to enhance GIS support for complex spatiotemporal queries. Transactions in GIS, 3, 137-159.

Title

Lecture: Water indices from optical images

Description

This lecture gives a theoretical overview of current status of detecting, extracting, and monitoring water surface using optical remote sensing.
A straightforward and effective way to extract water (classify water and non-water areas) is to use water indices, which are calculated from mulit-spectral data using two or more bands. Many indices have been developed to extract surface water areas or flood inundation extent, in this lecture the indices will be presented and compared.

Lecture duration: 1,5 hours

Learning outcomes

Demonstrate knowledge on water indices using optical images

Bibliography
Huang, C., Chen, Y., Zhang, S., Wu, J. (2018). Extracting, and Monitoring Surface Water from Space Using Optical Sensors: A Review. Reviews of Geophysics 56, 2, p. 333-360. https://doi.org/10.1029/2018RG000598
Wang, Z., Liu, J., Li, J., Zhang, D.D. (2018). Multi-Spectral Water Index (MuWI): A Native 10-m Multi-Spectral Water Index for Accurate Water Mapping on Sentinel-2. Remote Sens., 10, 1643. https://doi.org/10.3390/rs10101643

Title
Lecture: Interaction of microwaves with matter

Description
This lecture introduces principles of microwave remote sensing and its theoretical background of scattering processes.
The objective of this lecture is to explain the basic scattering mechanism that occurs between microwaves and matter.

Lecture duration: 1,5 hours

Learning outcomes
Explain differences between optical and radar remote sensing
Explain terms: scattering, emission, dielectric properties, surface roughness, polarimetry

Bibliography
Henderson, F. M. & Lewis, A. J. (ed.) (1998). Principles & Applications of Imaging RADAR. Manual of Remote Sensing. Third Edition, Volume 2. John Wiley & Sons, USA.

Title
Lecture: Mapping water with microwaves

Description
This lecture explains why the microwaves are of particular interest to map water. In this session measurement techniques for water monitoring are presented, giving a vast range of examples and explaining the underlying principles.

Lecture duration: 2x1,5 hours

Learning outcomes
Explain the microwaves interaction with water

Bibliography
Henderson, F. M. & Lewis, A. J. (ed.) (1998). Principles & Applications of Imaging RADAR. Manual of Remote Sensing. Third Edition, Volume 2. John Wiley & Sons, USA.

Title
Lecture: Surface water occurrence mapping

Description
This lecture explains the methods for surface water occurrence mapping.
This session gives an overview of mapping methods for the frequency of occurrence of water on the land surface over a given time period.

Lecture duration: 2x1,5 hours

Learning outcomes
Explain methods of surface water occurrence mapping
Select method for surface water occurrence mapping

Bibliography
Henderson, F. M. & Lewis, A. J. (ed.) (1998). Principles & Applications of Imaging RADAR. Manual of Remote Sensing. Third Edition, Volume 2. John Wiley & Sons, USA.

Title
Lecture: Tools for water mapping with SAR

Description
This lecture gives an overview of existing tools for water mapping with SAR.

Lecture duration: 1 hour

Learning outcomes
Select tool for water mapping with SAR

Bibliography
https://step.esa.int/main/toolboxes/sentinel-1-toolbox/
https://hydrology-tep.eu/#!
https://www.harrisgeospatial.com/Software-Technology/ENVI-SARscape

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Title
Practicals: Hydrology Exploitation Platform (H-TEP): introduction and hands-on

Description
This 'hands on' class introduces the Hydrology Exploitation Platform (H-TEP). Currently, the flood monitoring application provides the following possible output results: water masks, reference mask, water frequency map, flood maps, flood frequency map and maximum floodable area.
In the hands-on part, the water masks and flood frequency map using Sentinel-1 data are generated. In addition, the results refinement using high resolution Sentinel-2 optical data is implemented.

Practicals duration: 4x2 hours

Learning outcomes
Process and analyse SAR data using H-TEP
Produce water map and flood frequency map

Bibliography
http://hydrology-tep.github.io/documentation/quick-start-manual/qsm8.html
http://www.un-spider.org/sites/default/files/IWG_SEM_EmergencyMappingGuidelines_v1_Final.pdf

4.5. Object-based Image Analysis (OBIA)

This proposed on-line course on Object-based Image Analysis (OBIA) and is the GEOBIA Summer School. It can be part of the case-based scenario entitled 'Identification of local heat islands to support city planning' and consists of four learning units (Figure 33):

1. Lecture: Introduction to OBIA
2. Practicals: OBIA in eCognition
3. Practicals: OBIA in QGIS and Orfeo toolbox
4. Practicals: Practical example: Urban heat islands.

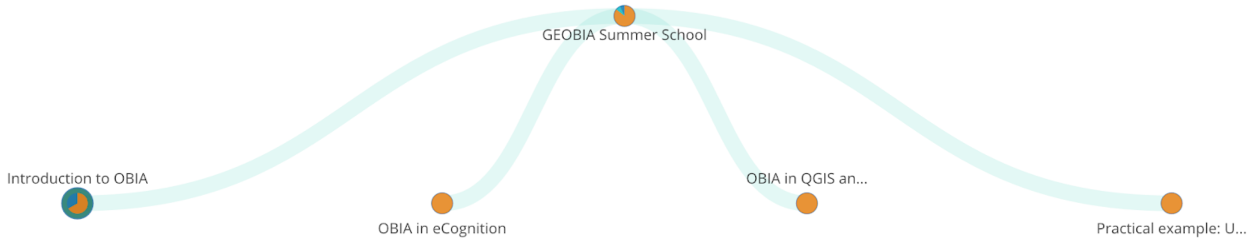

Figure 33 – Summer school on Object-based Image Analysis at EQF 6 and 7.

This course is available at: https://eo4geo-cdt.web.app/detail/D2akSkYfUWQTkYMgrYFS

Title
Course: GEOBIA Summer School

EQF: 6 and 7

Description
The description of summer school on object-based image analysis (OBIA) is based on the structure of the GEOBIA Summer School, which is held in June 2020. The summer school brings together a varied audience from students and young professionals and applies distance learning approaches given current travel restrictions. Participants will be introduced to OBIA in a series of lectures and practicals and then apply the acquired knowledge and skills in project work. The assessment of the contributions of participants is based on the assessment of their project work.

The overall goal of this summer school is to provide participants with an in-depth understanding of the object-based image analysis (OBIA) method. The summer school starts with the introduction of the main drivers and advantages of OBIA.The main segmentation methods together with their advantages and disadvantages are presented. In addition, supervised and rule-based classification methods used to assign the objects obtained through segmentation to the classes of interest are introduced. Both proprietary and open-source software for applying OBIA in different remote sensing applications will be presented.

In the following, the core lectures and practicals for introducing summer school participants to the subject of OBIA are introduced (these are only part of what is covered by the summer school). These learning units cover:

- Introduction to OBIA,
- OBIA in eCognition,
- OBIA in QGIS and the Orfeo toolbox,
- Practical example: Urban heat islands.

Summer school duration: 4x 1,5 hour

Prerequisites: principles of remote sensing techniques and data
[PS3] Remote Sensing data and imagery
[PS1-2-1] Spectrometers
[IP1-4] Image enhancement
[IP1-4-1] contrast stretching
[IP3-13] Visual interpretation
[IP3-4] Image classification

Learning outcomes
Describe the main advantages of object-based image analysis methods
List the main segmentation methods used to group similar pixels into homogeneous objects
Identify physical, semantic and spatial properties used to assigned objects to the target classes
Explain the advantages and limitations of rule-based classification methods
Apply multi-resolution segmentation for regionalising an optical image into segments
Implement a classification scheme for assigning image objects
Apply the conditional probability method to assign objects to classes of a classification scheme
Apply edge-based segmentation for dividing an optical image into segments
Implement a classification scheme for assigning image objects
Apply the maximum likelihood method to assign objects to classes of a classification scheme
Identify requirements to EO information for the evaluation of an urban heat island problem of an urban area
Develop and implement an object-based image analysis workflow for a specific application context

Assessment
Individual assignment (50%) and written exam (50%)
Oral presentation and written report on the project work conducted during the summer school

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Title
Lecture: Introduction to OBIA

Lecture duration: 1,5 hours

Description: The general principle of OBIA and the main steps of an OBIA workflow are introduced. This introduction covers segmentation techniques and classification approaches.

Learning outcomes
Describe the main advantages of object-based image analysis methods
List the main segmentation methods used to group similar pixels into homogeneous objects
Identify physical, semantic and spatial properties used to assigned objects to the target classes
Explain the advantages and limitations of rule-based classification methods

----
Title
Practicals: OBIA in eCognition

Practicals duration: 1,5 hours

Description: This hands-on session introduces eCognition as a tool for defining rule sets to assign objects to target classes.

Prerequisites:
[IP3-7] Object-based image analysis (OBIA)
[IP3-7-1] Class modelling
[IP3-5] Image segmentation
[IP3-13-1] Elements (cues) of interpretation
[IP3-7-4] Spatial features

Learning outcomes:
Apply multi-resolution segmentation for regionalising an optical image into segments
Implement a classification scheme for assigning image objects
Apply the conditional probability method to assign objects to classes of a classification scheme

----
Title
Practicals: OBIA in QGIS and Orfeo Toolbox

Practicals duration: 1,5 hours

Description: OBIA cannot only be performed with proprietary tools, but also with open source tools. These tools are introduced in this training unit and differences with the proprietary solutions are discussed.

Prerequisites:
[IP3-7] Object-based image analysis (OBIA)
[IP3-7-1] Class modelling
[IP3-5] Image segmentation
[IP3-13-1] Elements (cues) of interpretation
[IP3-7-4] Spatial features

Learning outcomes:
Apply edge-based segmentation for dividing an optical image into segments
Implement a classification scheme for assigning image objects
Apply the maximum likelihood method to assign objects to classes of a classification scheme

----
Title
Practical example: Urban heat islands

Practicals duration: 1,5 hours

Description: This training unit introduces a specific case study where the OBIA method is applied in the context of Urban heat islands. Starting from choosing the appropriate satellite images and a study area, the example covers the workflow of segmentation, classification and interpretation of the results.

Prerequisites:
[IP3-5-6-1] Multi-resolution segmentation
[IP3-5-1] Edge-based segmentation
[IP3-4-3] Classification schemes (taxonomies)
[IP3-4-2-2] Maximum likelihood
[IP3-4-2-1] Conditional probability

Learning outcomes:
Identify requirements to EO information for the evaluation of an urban heat island problem of an urban area
Develop and implement an object-based image analysis workflow for a specific application context

Bibliography
Blaschke, T., Lang, S., & Hay, G.J. (2008). Object-Based Image Analysis - Spatial Concepts for Knowledge-Driven Remote Sensing Applications. New York: Springer
Blaschke, T. (2010). Object based image analysis for remote sensing. ISPRS Journal of Photogrammetry and Remote Sensing, 65, 2-16
Blaschke, T., Hay, G.J., Kelly, M., Lang, S., Hofmann, P., Addink, E., Queiroz Feitosa, R., van der Meer, F., van der Werff, H., van Coillie, F., & Tiede, D. (2014). Geographic Object-Based Image Analysis – Towards a new paradigm. ISPRS Journal of Photogrammetry and Remote Sensing, 87, 180-191

4.6. Persistent Scatterer Interferometry (PSI)

This proposed detailed academic course on Persistent/Permanent Scatterer Interferometry is a proposal for the case-based scenario entitled ‘Landslide affecting Cultural Heritage sites - Baia Archaeological Park (Naples)’ and consists of seven main learning units of blended learning (Figure 34):

1. Lecture: Interpretation of time series data
2. Lecture: Differential SAR Interferometry: Theory and Principles
3. Lecture: Persistent Scatterer Interferometry: Theory and Principles
4. Lecture: Persistent Scatterer Interferometry: Tools
5. Practicals: Introduction to SNAP-StaMPS workflow

6. Lecture: Application examples: Theory
7. Practicals: Application examples: Practice

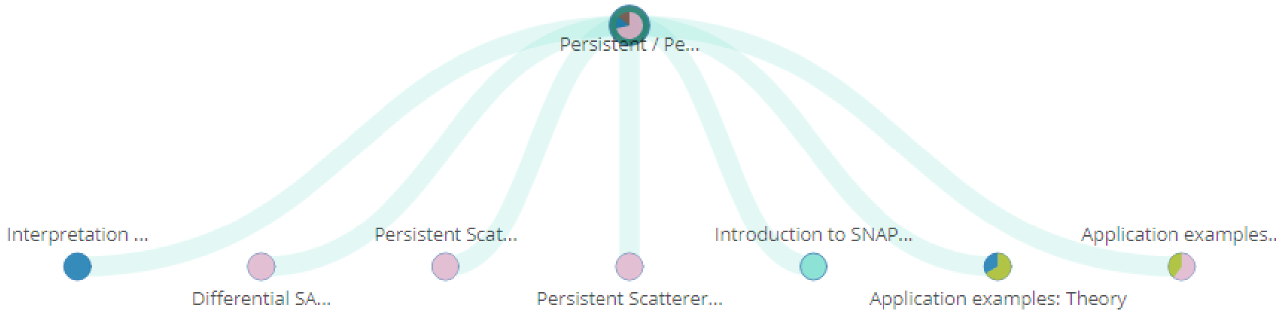

Figure 34 – Academiccourse on Persistent/Permanent Scatterer Interferometry at EQF 7.

This course is available at: https://eo4geo-cdt.web.app/detail/6N6haxAADaM6VMbikqWy

Title
Course: Persistent/Permanent Scatterer Interferometry

EQF: 7

Description

This is an academic course for students (specialists) at the master level that aims at designing and applying fully automatic processing chain for land deformation monitoring using Persistent Scatterer Interferometry (PSI) and the European Space Agency (ESA) SentiNel Application Platform (SNAP) and Stanford Method for Persistent Scatterers (StaMPS) via EO platform.
Persistent scatterer interferometry (PSI) is an advanced Differential SAR Interferometry method. Using so-called persistent scatterers (PSs) in a relatively large stack of interferograms, a deformation on ground can be measured. PS approach allows the estimation of deformation time-series related to point-wise, high coherent scatterers on the ground based on processing long sequences of SAR data.

Course duration: 1 semester

Prerequisites
Radar Physical Principles
Principles of Interferometry
Interferometry (Data processing)
Analytical Methods
Basic functions of PSI tools
Introduction to Sentinel-1 Toolbox (S1TBX)

Learning outcomes
Explain and compare different time series analysis methods
Explain the fundamentals of Differential SAR Interferometry
Discuss advantages of SAR techniques over traditional measuring techniques
Discuss limitations of interferometric measurement
Explain differences between DInSAR and PSI

Select optimal sensor and acquisition parameters for SAR deformation monitoring
Select optimal PSI tool/software/hardware
Perform SAR data processing using SNAP-StaMPS workflow
State application examples of PSI methods for deformation monitoring
Apply PSI method for landslides monitoring
Measure deformation using SAR data

Assessment
Project work report (75%) and presentation (25%)

Bibliography
Hanssen, R.F. (2001). Radar Interferometry: Data Interpretation and Error Analysis. Remote Sensing and Digital Image Processing. New York. Kluwer Academic Publishers. ISBN 0-7923-6945-9.
Henderson, F.M. & Lewis, A.J. (ed.) (1998). Principles & Applications of Imaging RADAR. Manual of Remote Sensing. Third Edition, Volume 2. John Wiley & Sons, USA. ISBN-10: 0471294063
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Maitre, H. (ed.) (2008). Processing of Synthetic Aperture Radar Images. London. John Wiley & Sons. ISBN 978-1-84821-024-0.
Massonnet, D., Feigl, K.L. (1998). Radar interferometry and its application to changes in the Earth's surface. Rev. Geophys. 36, 441-500. https://doi.org/10.1029/97RG03139

Title
Lecture: Interpretation of time series data

Description
This lecture gives an overview of time series data analysis methods with a special focus on trend recognition and clustering approaches.
Time series of remote sensing data can be based on series of raw digital numbers (DN) reflectance values or on variables commonly derived from the original data prior to analysis. Analysis of this data allow us to identify trends, identify anomalies or to identify changes or clustering of time series displacement data.

Lecture duration: 2x1,5 hours

Learning outcomes:
Explain and compare different time series analysis methods

Bibliography
Kuenzer, C., Dech, S., & Wagner, W. (2015). Remote sensing time series revealing land surface dynamics: Status quo and the pathway ahead. Remote Sensing Time Series (pp. 1-24): Springer

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Title
Lecture: Differential SAR Interferometry: Theory and Principles

Description
This lecture gives an advanced theoretical background of the Differential SAR Interferometry (DInSAR).
The objective of the lecture is to explain and present advantages of SAR techniques over traditional measuring techniques as well as limitations of interferometric measurements including different factors that can impact the result or the process of DInSAR.

Lecture duration: 1,5 hours

Learning outcomes:
Explain the fundamentals of Differential SAR Interferometry
Discuss advantages of SAR techniques over traditional measuring techniques
Discuss limitations of interferometric measurement

Bibliography
Massonnet, D., Feigl, K.L. (1998). Radar interferometry and its application to changes in the Earth's surface. Rev. Geophys. 36, 441-500. https://doi.org/10.1029/97RG03139

Title
Lecture: Persistent Scatterer Interferometry: Theory and Principles

Description
This lecture gives an advanced review of the differences between Differential SAR Interferometry (DInSAR) and Persistent Scatterer Interferometry (PSI).
The objective of the lecture is to explain and present differences between DInSAR and PSI, optimisation of SAR deformation measurement as well as explain optimal sensor and acquisition parameters including different factors that can impact the result or the process of PSI (e.g. natural sources of error, different atmospheric phenomena) for SAR deformation monitoring using PSI. Furthermore, the main principles of the PSI algorithm are presented.

Lecture duration: 3 x 1,5 hours

Learning outcomes:
Explain differences between DInSAR and PSI
Select optimal sensor and acquisition parameters for SAR deformation monitoring

Bibliography
Crosetto, M., Monserrat, O., Cuevas-González, M., Devanthéry, N., & Crippa, B. (2016). Persistent scatterer interferometry: A review. ISPRS Journal of Photogrammetry and Remote Sensing, 115, 78-89.
Ferretti, A., C. Prati, and F. Rocca, 2001. Permanent scatterers in SAR interferometry, IEEE Transactions on Geoscience and Remote Sensing, 39(1):8–20.

Title
Lecture: Persistent Scatterer Interferometry: Tools

Description
This lecture gives an overview of different software solutions for PSI calculations and estimations. In addition, this lecture informs about hardware specifications needed for processing.

Lecture duration: 1,5 hours

Learning outcomes
Select optimal PSI tool/software/hardware

Bibliography
https://www.gamma-rs.ch/no_cache/software.html
http://homepages.see.leeds.ac.uk/~earahoo/stamps/
https://github.com/mdelgadoblasco/snap2stamps
https://www.harrisgeospatial.com/Software-Technology/ENVI-SARscape
https://eo4society.esa.int/resources/geohazards-exploitation-platform-g-tep/

Title
Practicals: Introduction to SNAP-StaMPS workflow

Description
This is a practical class that introduces the SNAP-StaMPS workflow.
This hands-on guide you from the import and preprocessing of SAR data in the SENTINEL-1 Toolbox (S1TBX) over the generation and analysis of interferograms to the export to StaMPS and to further PSI processing and export of the results to Google Earth.

Practicals duration: 3 x 3 hours

Learning outcomes
Perform SAR data processing using SNAP-StaMPS workflow

Bibliography
http://eoscience.esa.int/landtraining2018/files/materials/D3B2_Stamps_S1_PS_Exercise_2018.pdf
http://homepages.see.leeds.ac.uk/~earahoo/stamps/StaMPS_Manual_v4.1b1.pdf
https://github.com/mdelgadoblasco/snap2stamps

Title
Lecture: Application examples: Theory

Description
This lecture gives an overview of the applications of PSI methods for deformation monitoring.

Lecture duration: 2x1,5 hours

Learning outcomes
State application examples of PSI methods for deformation monitoring

Bibliography
Ferretti, A. (2014). Satellite InSAR data: reservoir monitoring from space. EAGE publications.

Zhao, C., & Lu, Z. (2018). Remote sensing of landslides—A review. Remote Sensing, 10, 279. doi:10.3390/rs10020279

Title
Practicals: Application examples: Practice

Description
In this hands-on unit you will learn how to monitor landslides using SAR data and Persistent Scatterer Interferometry (PSI) technique. Using an example of Cultural Heritage sites - Baia Archaeological Park, landslides activities will be measured. This hands-on gives insights into the interpretation of the results, e.g. velocity maps, time-series displacements. For this purpose, the SENTINEL-1 Toolbox (S1TBX) in the SentiNel Application Platform (SNAP), StaMPS and visualisation tools will be used.

Practicals duration: 5 x 2 hours

Learning outcomes
Apply PSI method for landslides monitoring
Measure deformation using SAR data

Bibliography
https://github.com/mdelgadoblasco/snap2stamps
http://homepages.see.leeds.ac.uk/~earahoo/stamps/StaMPS_Manual_v4.1b1.pdf
http://step.esa.int/main/doc/tutorials/

5. Summary and next steps

Task 5.2 entitled ‘Defining the role of Remote Sensing and related techniques in the scenarios’ focused on analysing, collecting and streamlining information about remote sensing data sources and their potential and limitations, analysis techniques/algorithms, tools and knowledge and skills (Body of Knoweldge concepts) relevant to case-based scenarios, as well as providing a summary of what is available and applicable in the EO4GEO EO tools developed by the project partner VITO. This information was provided in the form of an interactive catalogue of selected remote sensing data, techniques/algorithms and tools for the three sub-sectors and selected in previous task (T5.1) case-based scenarios that can be used in subsequent tasks (T5.3-5.5). The EO4GEO tools and the streamlined data, methods, tools and concepts makes the design of the courses more efficient. In addition, educational offers for the most commonly selected remote sensing data, methods and tools for the learning case-based scenario, i.e. time series analysis, change detection, classification, object-based analysis and persistant scattererr interferometry, in the form of five courses and one module were specified in the Curriculun Design Tool. The modular structure of the prepared courses allows you to re-use their content in the detailed design of forthcoming teaching activities. The single training actions will be implemented and integrated in the educational offers that are developed in WP4 ‘Design and development of curricula in support of Copernicus’.

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EU. (2014). Mapping Smart Cities in the EU. Retrieved from https://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOL-ITRE_ET(2014)507480_EN.pdf

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Stelmaszczuk-Górska, M. A., Aguilar-Moreno, E., Casteleyn, S., Vandenbroucke, D., M. Miguel-Lago, Dubois, D., Lemmens, R., Vancauwenberghe, G., Olijslagers, M., Lang, S., Albrecht, F., Belgiu, M., Krieger, V., Jagdhuber, T., Fluhrer, A., Soja, M. J., Mouratidis, A., Persson, H. J., Colombo, R. & Masiello, G. (2020). Body of Knowledge for the Earth Observation and Geoinformation sector – A Basis for Innovative Skills Development. ISPRS Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. (*in press*)

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7. ANNEX I: Template: Role of remote sensing in the scenarios - DATA

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations

8. ANNEX II: Template: Role of remote sensing in the scenarios - METHODS

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links/ References

9. ANNEX III: Template: Role of remote sensing in the scenarios - TOOLS

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading

10. ANNEX IV: Revised Bloom's taxonomy (Hofer et al., 2020)

Lower Levels | Higher Levels

1 remember	2 understand	3 apply	4 analyze	5 evaluate	6 create
choose	cite	apply	analyse	assess	add to
define	classify	build	arrange	check	build
find	compare	calculate	choose	choose	change
identify	contrast	choose	classify	compare	choose
list	deliver	classify	compare	decide	combine
locate	demonstrate	construct	differentiate	defend	compile
name	discuss	correlate	distinguish	determine	construct
recognize	estimate	demonstrate	examine	estimate	convert
relate	explain	develop	find	evaluate	create
remember	illustrate	identify	install	explain	design
select	indicate	illustrate	list	interpret	develop
state	interpret	implement	order	judge	devise
write	outline	interpret	prioritize	justify	discuss
	relate	model	query	measure	estimate
	report	organise	research	prioritize	manage
	review	perform	select	recommend	model
	understand	plan		select	modify
		relate		test	plan
		represent		validate	process
		select			produce
		solve			propose
		teach			revise
		use			solve
					test
					transform

11. ANNEX V: Integrated applications: Data

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
Landslide affecting Cultural Heritage sites - Baia Archaeological Park (Naples)	Sentinel 1A-B	Copernicus Open Access Hub Alaska Satellite Facility DIAS Platforms	[PS] Platforms, sensors and digital imagery [PS1-3] Active Sensors [PS1-3-1-1] Imaging Radar [PS2-2-3-3] Acquisition modes [PS3-7] Processing levels [PS3-7-2] SAR data [PS4] Satellite and Airborne Sensors and Missions Databases [GD11] Satellite and shipboard remote sensing [IP5-3-1] Data and information access service (DIAS)	free and open available, long term monitoring together with other open data	complex processing of data
	ERS	ESA EARTH ONLINEa		free and open available, long term monitoring together with other open data	complex processing of data
	COSMO-SkyMED	For scientific use: ESA 3rd Party Missions		high resolution	complex processing of data, commercial use
	TerraSAR-X	for science: EOWEB for other users: Airbus Defence and Space		high resolution	complex processing of data, commercial use
	Radarsat 2	For scientific use: ESA 3rd Party Missions		high resolution, full polarization (quadpol data)	complex processing of data, commercial use
	ENVISAT-ASAR	ESA EARTH ONLINEa		free and open available, long term monitoring together with other open data	complex processing of data

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
	ALOS-PALSAR	JAXA webpage Preprocessed data		application under vegetated areas	only limited amount of available open data
Landslides documentation supported with an EO-based service	Sentinel 1A-B	Copernicus Open Access Hub DIAS Platforms	[PP1-1-2] Electromagnetic spectrum [PP1-3-4] Spectral Signature of Vegetation, Water, Soil [PS3-4-2] Spatial resolution [PS3-7-2] SAR data [PS1-3] Active Sensors [PS4] Satellite and Airborne Sensors and Missions Databases [IP5-3-1] Data and information access service (DIAS) [PS1-2] Passive Sensors [PS3-7-1] Optical data [PS2-2-3-3] Acquisition modes [PS3-7] Processing levels	free and open available, long term monitoring together with other open data	complex processing of data
	Sentinel 2A-B	Copernicus Open Access Hub DIAS Platforms USGS EarthExplorer		free and open available, long term monitoring together with other open data	if very very detailed analysis is required (spatial resolution 10 m) cloud-free condition is needed revisit time
	Pléiades Spot 6/7	Airbus Defence and Space For scientific use: ESA 3rd Party Missions		high resolution	commercial use cloud-free condition is needed
	WorldView1,2,3 GeoEye	Digital Globe (https://discover.digitalglobe.com/)		high resolution	commercial use cloud-free condition is needed
	Deimos1&2	For scientific use: ESA 3rd Party Missions		high resolution	commercial use cloud-free condition is needed
	Planet (Dove, SkySat)	Planet Explorer For scientific use: ESA 3rd Party Missions		high resolution	commercial use cloud-free condition is needed

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
	TanDEM-DEM	EOC Geoservice (DLR)		high resolution	
Geospatial data and technologies applications for monitoring land use change	Sentinel 2A-B	Copernicus Open Access Hub DIAS Platforms USGS EarthExplorer	[PS4] Satellite and Airborne Sensors and Missions Databases [PS1-2] Passive Sensors [PS3-7-1] Optical data [PS] Platforms, sensors and digital imagery [PS3-7-2] SAR data [PS1-3] Active Sensors [PS1-3-1-1] Imaging Radar [PS2-2-3-3] Acquisition modes [PS3-7] Processing levels [IP5-3-1] Data and information access service (DIAS)	free and open available, long term monitoring together with other open data	if very detailed analysis is required (spatial resolution 10 m) cloud-free condition is needed revisit time
	Landsat 8	USGS EarthExplorer		free and open available, long term monitoring together with other open data	if very detailed analysis is required (spatial resolution 30 m) cloud-free condition is needed revisit time
	Planet Labs	Planet Explorer		high resolution	commercial use cloud-free condition is needed
	Sentinel 1A-B	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	complex data processing, for land cover applications
EO-based agro monitoring to support regional decision-making	Sentinel 1A-B	Copernicus Open Access Hub DIAS Platforms	[PS1-3] Active Sensors [PS1-3-1-1] Imaging Radar [PS3-7-2] SAR data [PS4] Satellite and Airborne Sensors and Missions Databases [PS1] Remote sensing sensors [PS3] Remote sensing data	free and open available, long term monitoring together with other open data	complex processing of data
	Sentinel 2A-B	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	if very detailed analysis is required (spatial resolution 10 m) cloud-free condition is needed revisit time

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
		USGS EarthExplorer	and imagery [PS2-2-3-3] Acquisition modes [PS3-7] Processing levels [IP5-3-1] Data and information access service (DIAS) [PS1-2] Passive Sensors [PS3-7-1] Optical data		
	Landsat 8 OLI	USGS EarthExplorer		free and open available, long term monitoring together with other open data	if very detailed analysis is required (spatial resolution 30 m) cloud-free condition is needed revisit time
	Proba-V	VITO-EODATA		free and open available, long term monitoring together with other open data, large swath	resolution of 300 m
	MODIS 250 m	USGS EarthExplorer		free and open available, long term monitoring together with other open data	resolution of 250 m
	Planet Labs	Planet Explorer		very high resolution temporal and spatial	commercial use cloud-free condition is needed

12. ANNEXVI: Integrated applications: Methods

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links/ References
Landslide affecting Cultural Heritage sites - Baia Archaeological Park (Naples)	InSAR, in particular Persistent Scatterer Interferometry	[IP1] Image pre-processing [IP1-5] Interferometry [PP2] Radar Principles [PP2-3] Detecting Microwaves/SAR Image formation [PP2-3-11-2] Permanent Scatterer Interferometry [PP2-3-7] SAR Geometric Configuration [PP2-3-8] Terrain Reflectivity and geometric distortions	No adaptations needed Need to understand the importance of topography w.r.t acquisition direction in SAR images (SAR Geometry)	Ferretti, A., C. Prati, and F. Rocca, (2001). Permanent scatterers in SAR interferometry, IEEE Transactions on Geoscience and Remote Sensing, 39(1):8–20. Ferretti, A. (2014). Satellite InSAR data: reservoir monitoring from space. EAGE publications.
	Sub-pixel correlation (in case of optical data)	[IP1-3-1] Orthorectification [IP1-3-2-1] Image co-registration [PS3-7-1-2-1] Orthophotos [AM13-5] Raster resampling [IP3-11-1] Change detection [IP3-11] Time series analysis	No adaptations needed. Approach available in COSI-Corr software	Leprince, S., Barbot, S., Ayoub, F., & Avouac, J. P. (2007). Automatic and precise orthorectification, coregistration, and subpixel correlation of satellite images, application to ground deformation measurements. *IEEE Transactions on Geoscience and Remote Sensing*, *45*(6), 1529-1558. Lacroix, P., Bièvre, G., Pathier, E., Kniess, U., & Jongmans, D. (2018). Use of Sentinel-2 images for the detection of precursory motions before landslide failures. *Remote Sensing of Environment*, *215*, 507-516.

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links/ References
Landslides documentation supported with an EO-based service	Classification: object-based image analysis (OBIA)	[IP3-4] Image classification [IP4-2-1] Accuracy assessment [IP3-7-4] Object-based image analysis (OBIA)	No adaptations needed.	Blaschke, T. (2010) Object based image analysis for remote sensing. ISPRS J. Photogramm. Remote Sens., 65 (1), pp. 2-16 Zhao, C., & Lu, Z. (2018). Remote sensing of landslides-A review. Remote Sensing, 10, 279. doi:10.3390/rs10020279
	Photogrammetric DEM	[PS3-4-2-6] Very high resolution data [IP1-3] Geometric correction [IP1-3-1] Orthorectification [IP1-3-1-2] Photogrammetric principles [IP3-3-1] DEM generation [IP1-3-1-1] DEM generation with 'Structure-from-Motion'	No adaptations needed.	Rusnák, M., Sládek, J., Buša, J., & Greif, V. (2016). Suitability of digital elevation models generated by UAV photogrammetry for slope stability assessment (case study of landslide in Svätý Anton, Slovakia). Acta Scientiarum Polonorum. Formatio Circumiectus, 15(4), 439. Fourniadis, I. G., Liu, J. G., & Mason, P. J. (2007). Landslide hazard assessment in the Three Gorges area, China, using ASTER imagery: Wushan–Badong. *Geomorphology*, *84*(1-2), 126-144.
Geospatial data and technologies applications for monitoring land use change	Classification Change detection Bi-temporal change detection	[CV4-1] Thematic mapping [IP3-4] Image classification [IP3-5] Image segmentation [IP3-2] Computer vision [IP3-11-1] Change detection	No adaptations needed.	M. J. Canty (2014). Image Analysis, Classification and Change Detection in Remote Sensing: With Algorithms for Python, 4th Edition, CRC Press, 2006-08-30. ISBN: 0849372518 Serra, P., Pons, X., & Sauri, D. (2003).

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links/ References
	Post-classification change detection			Post-classification change detection with data from different sensors: some accuracy considerations. *International Journal of Remote Sensing*, *24*(16), 3311-3340.
	Time series analysis Satellite Image Time Series (SITS) based change detection	[IP3-2] Computer vision [IP3-11-1] Change detection [IP3-11] Time series analysis [IP1-3-2-1] Image co-registration [IP2-1] Data fusion [IP3-11-3] Dynamic Time Warping [IP3-11-2] Cube-based time series analysis	No adaptations needed.	Gómez, C., White, J. C., & Wulder, M. A. (2016). Optical remotely sensed time series data for land cover classification: A review. ISPRS Journal of Photogrammetry and Remote Sensing, 116, 55-72. Ienco, D., Interdonato, R., Gaetano, R., & Minh, D. H. T. (2019). Combining Sentinel-1 and Sentinel-2 Satellite Image Time Series for land cover mapping via a multi-source deep learning architecture. ISPRS Journal of Photogrammetry and Remote Sensing, 158, 11-22.
EO-based agro monitoring to support regional decision-making	Classification Change detection Post-classification change detection Accuracy Assessment	[CV4-1] Thematic mapping [IP3-4] Image classification [IP3-5] Image segmentation [IP3-2] Computer vision [IP4-2-1] Accuracy assessment	No adaptations needed.	D'Andrimont, R., Lemoine, G., Van der Velde, M., & Corbane, C. (2017). Harnessing big data for agricultural monitoring: combining remote sensing, open access data and crowdsourcing. In Proc. Of the 2017 Conference on Big Data from Space (BiDS'17), https://doi. org/10.2760/383579. Torbick, N., Chowdhury, D., Salas, W., & Qi, J. (2017). Monitoring rice
	Time-series	[CV4-4] Visualization of temporal geographic data	No adaptations needed.	

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links/ References
		[IP3-2] Computer vision [IP2-1] Data fusion [IP3-11-3] Dynamic Time Warping [IP3-11-2] Cube-based time series analysis [IP3-1-2-1] Soil-adjusted Vegetation Index (SAVI) [IP3-1-2-3] Normalized Difference Vegetation Index (NDVI) [TA3-1-1-3-3] Vegetation indices		agriculture across Myanmar using time series Sentinel-1 assisted by Landsat-8 and PALSAR-2. Remote Sensing, 9(2), 119. Phung, H. P., Nguyen, L. D., Thong, N. H., Thuy, L. T., & Apan, A. A. (2020). Monitoring rice growth status in the Mekong Delta, Vietnam using multitemporal Sentinel-1 data. Journal of Applied Remote Sensing, 14(1), 014518. Weiss, M., Jacob, F., & Duveiller, G. (2020). Remote sensing for agricultural applications: A meta-review. Remote Sensing of Environment, 236, 111402 Chauhan S., Darvishzadeh, R. Boschetti M., Pepe M., Nelson, A., (2019). Remote sensing-based crop lodging assessment: Current status and perspectives. ISPRS journal of photogrammetry and remote sensing, 2019. https://doi.org/10.1016/j.isprsjprs.2019.03.005
	Interpolation	[AM13-3] Interpolation [DM3-2] The raster model [AM13-4] Vector to raster and raster-to-vector	No adaptations needed.	Aliyev, R. Z. (2018). SPATIAL DATA INTERPOLATION. International Journal of Medical and Biomedical Studies, 2(4).

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links/ References
	Web Mapping	[DA4] Database design [WB7] Web application development elements [WB7-3] Web application frameworks and geoportal frameworks [WB5] Application development via Data Integration [CV4-5] Dynamic and interactive displays [CV4-6] Web mapping	Needed functionality should be selected	Leaflet JavaScript mapping library https://leafletjs.com/ OpenLayers JavaScript mapping library https://openlayers.org/ D3.js JavaScript library for interactive data visualisation https://d3js.org/ GeoNode Open Source Geospatial Content Management System http://geonode.org/ Mapbender web-based geoportal framework https://www.osgeo.org/projects/mapbender/

13. ANNEX VII: Integrated applications: Tools

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
Landslide affecting Cultural Heritage sites - Baia Archaeological Park (Naples)	GeoHazards Exploitation Platform (G-TEP)	[CV] Cartography and Visualization [GD11-4] Ground verification and accuracy assessment [GD11-3] Algorithms and processing [GD] Geospatial Data	https://eo4society.esa.int/resources/geohazards-exploitation-platform-g-tep/
	SNAP Sentinel Application Platform - Software	[DA2-8] Commercial and open source software [GD11-3] Algorithms and processing [IP1-5] Interferometry [PS3-6-11] Software related formats [PS3-6] Data Formats	http://step.esa.int/main/doc/tutorials/
	STAMPS Stanford Method of Persistent Scatterer - Software packages (PSI Processing)		http://homepages.see.leeds.ac.uk/~earahoo/stamps/

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
	GAMMA (PSI processing)		https://www.gamma-rs.ch/no_cache/software.html
	ENVI-SARScape (PSI Processing)		https://www.harrisgeospatial.com/Software-Technology/ENVI-SARScape
	Doris (Delft object-oriented radar interferomtric software)		http://doris.tudelft.nl/
	Orfeo Toolbox (OTB)		https://www.orfeo-toolbox.org/
	PolSARPro		https://earth.esa.int/web/polsarpro
	The InSAR Scientific Computing Environment (ISCE)		https://github.com/isce-framework/isce2
	MATLAB for R shiny and STAMPS	[DA2-8] Commercial and open source software [GD11-3] Algorithms and processing	
	R with R shiny		https://shiny.rstudio.com/

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
	GIS Softwares (ArcGIS, Idrisi, SAGA GIS, ILWIS, QGIS)	[CV] Cartography and Visualization [GD] Geospatial Data [PS3-6-11] Software related formats [PS3-6] Data Formats [DA2-8] Commercial and open source software	https://en.wikipedia.org/wiki/List_of_geographic_information_systems_software https://www.harris.com/solution/envi https://clarklabs.org/terrset/idrisi-gis/ http://www.saga-gis.org/en/index.html https://www.itc.nl/ilwis/ https://qgis.org/en/site/
Landslides documentation supported with an EO-based service	GeoHazards Exploitation Platform (G-TEP)	[IP4-2-1] Accuracy assessment [TA6-2-2] Vulnerability assessment	https://eo4society.esa.int/resources/geohazards-exploitation-platform-g-tep/

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
	Google Earth Engine (GEE)	[GD] Geospatial Data [PS3-6-11] Software related formats [PS3-6] Data Formats [GS1] Legal aspects	https://earthengine.google.com/
	GIS Software (ArcGIS, Idrisi, SAGA GIS, ILWIS, QGIS)	[CV] Cartography and Visualization [GD] Geospatial Data [PS3-6-11] Software related formats [PS3-6] Data Formats [DA2-8] Commercial and open source software	https://en.wikipedia.org/wiki/List_of_geographic_information_systems_software https://www.harris.com/solution/envi https://clarklabs.org/terrset/idrisi-gis/ http://www.saga-gis.org/en/index.html https://www.itc.nl/ilwis/ https://qgis.org/en/site/
Geospatial data and technologies applications for monitoring land use change	Remote Sensing commercial software (TNT GIS, ERDAS IMAGINE, eCognition, ENVI)	[PS3-6-11] Software related formats [PS3-6] Data Formats [DA2-8] Commercial and open source software [CV] Cartography and Visualization	https://geospatial.trimble.com/products-and-solutions/ecognition https://www.microimages.com/ https://www.hexagongeospatial.com/products/power-portfolio/erdas-imagine
			https://en.wikipedia.org/wiki/Remote_sensing_software
			https://en.wikipedia.org/wiki/Remote_sensing_softwar

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
			e
	Remote Sensing free software: SNAP Sentinel Application Platform, QGIS, Orfeo Toolbox (OTB)		https://step.esa.int/main/toolboxes/snap/
	Google Earth Engine (GEE)	[GD] Geospatial Data [PS3-6-11] Software related formats [PS3-6] Data Formats [GS1] Legal aspects	https://earthengine.google.com/
EO-based agro monitoring to support regional decision-making	GIS Software (ArcGIS, PostGIS) e.g. ArcGIS Online	[CV] Cartography and Visualization [GD] Geospatial Data	https://en.wikipedia.org/wiki/List_of_geographic_information_systems_software
	Sen2Agri	[GD] Geospatial Data [PS3-6-11] Software related formats [PS3-6] Data Formats [TA7-5-2] Copernicus Programme	http://www.esa-sen2agri.org/

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
	Remote Sensing Software TNT GIS, ERDAS IMAGINE, eCognition)	[PS3-6-11] Software related formats [PS3-6] Data Formats [DA2-8] Commercial and open source software [CV] Cartography and Visualization	https://en.wikipedia.org/wiki/Remote_sensing_software https://www.microimages.com/ https://www.hexagongeospatial.com/products/power-portfolio/erdas-imagine
	Food Security Exploitation Platform (FS-TEP)	[CV] Cartography and Visualization [IP4-2-1] Accuracy assessment [TA6-2-2] Vulnerability assessment	https://eo4society.esa.int/resources/food-security-exploitation-platform-fs-tep/
	Python	[GD11-3] Algorithms and processing	https://jupyter.org/ Python raster processing module Rasterio https://rasterio.readthedocs.io/ Python module for work with shapefiles - Shapely https://shapely.readthedocs.io/ Python module for spatial analysis - Pysal https://pysal.org/

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
	Java Script		GeoPandas python module for data visualisation and analysis https://geopandas.org/ GDAL the core of many geospatial libraries https://gdal.org/ Snappy is SNAP python module https://senbox.atlassian.net/wiki/spaces/SNAP/pages/19300362/How+to+use+the+SNAP+API+from+Python Turf is JavaScript module for web based geospatial analysis https://turfjs.org/ Satellite Image Time Series Analysis For Remote Sensing Data Cubes in R: https://rdrr.io/github/e-sensing/sits/f/vignettes/sits.Rmd
	R		

14. ANNEX VIII: Smart cities: Data

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
Identification of local heat islands to support city planning	Landsat 8 TIRS	USGS EarthExplorer USGS GloVis USGS LandLook, Sentinel2Look	[AM10-1,2] Problems of large spatial databases; [AM10-2] Data mining approaches [AM13-6] Coordinate transformations [CV4-1] Thematic mapping [CV4-3] Multivariate displays [CV4-4] Visualization of temporal geographic data [CV4-5] Dynamic and interactive displays [IP1-1-1] Image subset [IP1-1-2] Layer stack [IP3-1] Band maths [IP3-13] Visual interpretation [PS1-2] Passive Sensors [PS3-7-2] SAR data [PS1-3] Active Sensors [PS2-2] Moving Platforms [PS3-2] Digital image terminology [PS3-3] Data storage	free and open available, long term monitoring together with other open data	cloud-free condition is needed revisit time spatial resolution (for detailed analysis)
	Sentinel-2 Sentinel-3	Copernicus Open Access Hub USGS EarthExplorer VITO - Copernicus Land Monitoring Service (CLMS): The Copernicus Atmosphere Monitoring Service (CAMS) DIAS Platforms		free and open available long term monitoring together with other open data Sentinel-2: spatial resolution: 10, 20 and 60 m; revisit time: 10 days at the equator with one satellite, and 5 days with 2 satellites	cloud-free condition is needed (for Sentinel-2 data) revisit time spatial resolution (for detailed analysis)
	Proba-V	VITO - Copernicus Land Monitoring Service (CLMS): DIAS Platforms		free and open available long term monitoring together with other open data Proba-V: spatial resolution: 300m/600m; revisit time: providing global coverage every two days	cloud-free condition is needed spatial resolution (for detailed analysis)

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
			[PS3-4] Properties of digital imagery [PS3-6] Data Formats [TA3] Land Monitoring ***Missing:*** ***[PS4 -1] Missions*** ***[PS4-1-1] Copernicus mission*** ***[PS4-1-2] Landsat missions*** ***[PS4-2] Satellite Sensors*** ***[PS4-2-1] Sentinel-2 MSI*** ***[PS4-2-3] Landsat TM(+)***		
Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments (EQF 4)	Lidar data		[AM10-1,2] Problems of large spatial databases; [AM10-2] Data mining approaches [CV4-1] Thematic mapping [CV4-3] Multivariate displays [CV4-4] Visualization of temporal geographic data [CV4-5] Dynamic and interactive displays [IP1-1-1] Image subset [IP1-1-2] Layer stack	Accurate elevation high resolution DEM	Commercial, non-repetitive
	Sentinel-2	Copernicus Open Access Hub USGS EarthExplorer VITO - Copernicus Land Monitoring Service (CLMS): The Copernicus Atmosphere Monitoring Service (CAMS) DIAS Platforms		free and open available long term monitoring together with other open data Sentinel-2: spatial resolution: 10, 20 and 60 m; revisit time: 10 days at the equator with one satellite, and 5 days with 2 satellites	cloud-free condition is needed (for Sentinel-2 data) revisit time spatial resolution (for detailed analysis)

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Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
	Proba-V	VITO - Copernicus Land Monitoring Service (CLMS):	[IP3-1] Band maths [IP3-13] Visual interpretation [PS1-2] Passive Sensors [PS1-3-2-1-1] Laser profilers (LiDAR) [IP1-7-3-2] Lidar point clouds [PS2-2] Moving Platforms [PS3-2] Digital image terminology [PS3-3] Data storage [PS3-4] Properties of digital imagery [PS3-6] Data Formats [AM6-2] Interpolation of surfaces [PS3-6-10] .LAZ format [TA3] Land Monitoring	free and open available long term monitoring together with other open data Proba-V: spatial resolution: 300m/600m; revisit time: providing global coverage every two days	cloud-free condition is needed spatial resolution (for detailed analysis)
	SPOT satellites, WordView-1-4,GeoEye-1, RapidEye	Satellite Imaging Corporation, Geoimage, Digital Globe		high resolution revisit time	commercial use cloud-free condition is needed
Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments (EQF 6)	Sentinel-2	Copernicus Open Access Hub USGS EarthExplorer VITO - Copernicus Land Monitoring Service (CLMS): The Copernicus Atmosphere Monitoring Service (CAMS) DIAS Platforms	[AM1-2] Analytical approaches [AM4] Basic analytical operations [AM10] Data mining [PS4] Satellite and Airborne Sensors and Missions Databases [IP5-3-1] Data and information access	free and open available, long term monitoring together with other open data Sentinel-2: spatial resolution: 10, 20 and 60 m; revisit time: 10 days at the equator with one satellite, and 5 days with 2 satellites	cloud-free condition is needed (for Sentinel-2 data) revisit time spatial resolution (for detailed analysis)

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
	Proba-V	VITO - Copernicus Land Monitoring Service (CLMS):	service (DIAS) [PS1-2] Passive Sensors [PS3-7-1] Optical data [PS2-2-3-3] Acquisition modes	free and open available long term monitoring together with other open data Proba-V: spatial resolution: 300m/600m; revisit time: providing global coverage every two days	cloud-free condition is needed spatial resolution (for detailed analysis)
	SPOT satellites, WordView-1-4, GeoEye-1, RapidEye, Planet Labs	Satellite Imaging Corporation, Geoimage, Digital Globe, Planet Explorer		high resolution revisit time	commercial use cloud-free condition is needed
Improving sustainability of cities to storm and water	Lidar data		[CV4-1] Thematic mapping [CV4-3] Multivariate displays [CV4-4] Visualization of temporal geographic data [CV4-5] Dynamic and interactive displays [IP1-1-1] Image subset [IP1-1-2] Layer stack [IP3-1] Band maths [IP3-13] Visual interpretation [PS1-2] Passive Sensors [PS1-3-2-1-1] Laser profilers (LiDAR)	accurate elevation high resolution DEM	Commercial, non-repetitive
	Sentinel 2	Copernicus Open Access Hub USGS EarthExplorer The Copernicus Atmosphere Monitoring Service (CAMS) The Copernicus Climate Change Service (C3S) VITO - Copernicus Land Monitoring Service (CLMS): DIAS Platforms		free and open available, long term monitoring together with other open data	cloud-free condition is needed spatial resolution (for detailed analysis)

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
	Pléiades	Airbus Defence and Space	[IP1-7-3-2] Lidar point clouds [AM6-2] Interpolation of surfaces [PS3-6-10] .LAZ format	high resolution stereo image possibility	commercial use cloud-free condition is needed
	Planet Labs	Planet Explorer		high resolution	commercial use cloud-free condition is needed
	Sentinel 1	Copernicus Open Access Hub USGS EarthExplorer DIAS Platforms		free and open available, long term monitoring together with other open data	complex processing of data
	TerraSAR-X		[PS] Platforms, sensors and digital imagery [PS3-7-2] SAR data [PS1-3] Active Sensors [PS1-3-1-1] Imaging Radar [PS2-2-3-3] Acquisition modes [PS3-7] Processing levels [IP5-3-1] Data and information access service (DIAS) [TA3] Land Monitoring	high resolution	commercial use
	CosmoSkyMed	For science: ESA 3rd Party Missions		high resolution	complex processing of data, commercial use
	Radarsat-2	For scientific use: ESA 3rd Party Missions		high resolution	complex processing of data, commercial use
	SPOT satellites, WordView-1-4, GeoEye-1, RapidEye	Satellite Imaging Corporation, Geoimage, Digital Globe,		high resolution	commercial use cloud-free condition is needed

15. ANNEX IX: Smart cities: Methods

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links
Identification of local heat islands to support city planning	Time series Overlay analysis	[IP3-11] Time series analysis [IP3-11-3] Dynamic Time Warping [CV4-4] Visualization of temporal geographic data [AM4-3] Overlay [AM13-5] Raster resampling [AM11] Network analysis [AM4-4] Neighborhood analysis [AM5-3] Spatial cluster analysis [AM6-2] Analysis of surfaces [AM4-2] Buffers	No adaptations needed	Kuenzer, C., Dech, S., & Wagner, W. (2015). Remote sensing time series revealing land surface dynamics: Status quo and the pathway ahead. Remote Sensing Time Series (pp. 1-24): Springer; Sakoe, H., & Chiba, S. (1978). Dynamic programming algorithm optimization for spoken word recognition. IEEE transactions on acoustics, speech, and signal processing, 26, 43-49;
Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments (EQF 4)	Vector/raster analysis	[AM13-4] Vector-to-raster and raster-to-vector [DM4-4] Application models based on vector data [IP3-4-7-2] Support vector machines (SVM) [AM13-5] Raster resampling		Cortes, C., & Vapnik, V. (1995). Support-vector networks. Machine Learning, 20, 273-297
Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments (EQF 6)	Classification (Land cover)	[AM14-3] Classification and transformation of attribute measurement levels [IP3-4-3-1] Land cover classification system (LCCS) [IP3-4-3-1] Classification schemes (taxonomies)		Douglas, D., and Peucker, T. (1973). Algorithm for the reduction of the number of points required to represent a digitized line or its caricature. The Canadian Cartographer, 10:2, 112-122. McMaster, R. (1992) Map

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links
		[AM4-1] Reclassification and selection operations		generalization in digital cartography. Washington DC: Association of American Geographers. Topfer, F. and Pillewizer, W. (1966). The principles of selection. The Cartographic Journal, 3, 10-16. Weibel, R. and Jones, C.B. (1998). Computational perspectives on map generalization, GeoInformatica, 2(4), 307-314. Di Gregorio, A., & Jansen, L.J. (2000). Land cover classification system: LCCS: classification concepts and user manual. In. FAO, Rome, Italy: Food and Agriculture Organization of the United Nations Rome
Improving sustainability of cities to storm and water	Classification	[AM14-3] Classification and transformation of attribute measurement levels [IP3-4-3-1] Land cover classification system (LCCS) [IP3-4-3] Classification schemes (taxonomies) [IP3-4] Image classification [IP1-4] Image enhancement		Jensen, J. R. (2005). Introductory digital image processing: a remote sensing perspective (3rd ed.). Upper Saddle River, N.J.: Prentice Hall, p. 255.
	Data harmonisation	[CV2-1] Data sources for mapping [CV2-2] Data processing [CV2] Data considerations		

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed	Relevant links
	DEM	[IP1-3-1-1] DEM generation with 'Structure-from-Motion' [IP3-3-1] DEM generation		Westoby etal. (2012). ‘Structure-from-Motion’ photogrammetry: A low-cost, effective tool for geoscience applications. Geomorphology, 179, 300-314. doi:https://doi.org/10.1016/j.geomorph.2012.08.021

16. ANNEX X: Smart cities: Tools

Case-based scenario	Relevant existing analysis tools/platforms (From 4.1, 5.1 + any other relevant, + information commercial/open source)	Relevant BoK concepts (From 5.1 + Bok T2.3 including identifying missing concepts)	Link/further reading
Identification of local heat islands to support city planning	GIS Software (ArcGIS, QGIS)	[GIST] Geographic Information Science and Technology [DA1-5] Overview on Software engineering [DA1-7] Software design and construction [DA2-8] Commercial and open source software [PS3-6-11] Software related formats [DA1-8] Software and data lifecycle, archiving	https://www.caliper.com/maptitude/gis_software/default.htm) (https://developers.arcgis.com/labs/what-is-arcgis/) (https://www.deskbright.com/excel/what-is-excel/)
	DIAS/Google Earth Engine (GEE)	[IP5-3-1] Data and information access service (DIAS)	https://www.copernicus.eu/en/access-data/dias https://www.google.com/earth/outreach/learn/introduction-to-google-earth-engine/
	Urban Exploitation Platform (U-TEP)	[IP5-3-1] Online processing [GD10-2] Platforms and sensors	https://eo4society.esa.int/resources/urban-exploitation-platform-u-tep/ https://www.dlr.de/eoc/en/desktopdefault.aspx/tabid-11882/20871_read-53736
Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments (EQF 4)	GIS Software (ArcGIS, QGIS)	[GIST] Geographic Information Science and Technology	Bailey, T.C. and Gatrell, A.C. 1995. Interactive spatial data analysis. Harlow: Longman. Burrough, P. A. and McDonnell, R. 1998. Principles of geographical information systems. Oxford: New York: Oxford University Press. Cliff, A. D., and Ord, J. K. 1981. Spatial processes:

			Models and applications. London: Pion Press. Cressie, N. 1991. Statistics for spatial data. Chichester, England: John Wiley. Fotheringham, A. S., Brunsdon, C., and Charlton, M. 1999 Quantitative geography: Perspectives on spatial data analysis. London: Sage. Fotheringham, A. S., Brunsdon, C., and Charlton, M. 2002. Geographically weighted regression: The analysis of spatially varying relationships. New York: Wiley. Haining, R. 2003. Spatial data analysis: Theory and practice. Cambridge University Press.
	Urban Exploitation Platform (U-TEP) ?	[IP5-3-1] Online processing [GD10-2] Platforms and sensors	https://eo4society.esa.int/projects/urban-tep/
	Stadsträd.se		https://info.stadstrad.se/
	Excel		https://www.deskbright.com/excel/what-is-excel/
Evaluation and planning of urban green structures to increase quality of life and support ecosystem services in urban environments (EQF 6)	Remote sensing softwares (ENVI, Erdas Imagine, eCognition)	[DA2-8] Commercial and open source software [DA3-1] Major geospatial software architectures [DA] Design and Setup of Geographic Information Systems	
	SNAP Sentinel Application Platform - Software	[GD2-2] Remote sensing [PS2-2-2-3-2-3-3-1] Interferometric Wide Swath Mode [GD10-2] Platforms and sensors [PS2-2-3] Spaceborne platforms and systems [PS2-2-3-2] Type of satellite orbits [PS3-4-3] Radiometric resolution [PS3-4] Properties of digital imagery	Jackson W.M (editor), (2009). Manual of Remote Sensing: Earth Observing Platforms & Sensors, 3th ed. Lavender, S., Lavender, A. (2017). Practical Handbook of Remote Sensing, CRC Press, Taylor & Francis Group, Boca Raton, US. A Canada Centre for Remote Sensing Remote Sensing Tutorial, Fundamentals of Remote Sensing, Retrieved from https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/ear

			thsciences/pdf/resource/tutor/fundam/pdf/fundamentals_e.pdf Campbell, J.B., Wynne, R.H. (2003). Introduction to Remote Sensing, Fift edition, The Guilford Press, New York, US. Lavender, S., Lavender, A. (2017). Practical Handbook of Remote Sensing, CRC Press, Taylor & Francis Group, Boca Raton, US. Campbell, J.B., Wynne, R.H. (2003). Introduction to Remote Sensing, Fift edition, The Guilford Press, New York, US. A Canada Centre for Remote Sensing Remote Sensing Tutorial, Fundamentals of Remote sensing, Retrieved from https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/resource/tutor/fundam/pdf/fundamentals_e.pdf
	GIS Software (ArcGIS, QGIS)	[GIST] Geographic Information Science and Technology	
Improving sustainability of cities to extreme precipitation and flooding events	SNAP Sentinel Application Platform - Software	[GD2-2] Remote sensing [PS2-2-2-3-2-3-3-1] Interferometric Wide Swath Mode [GD10-2] Platforms and sensors [PS2-2-3] Spaceborne platforms and systems [PS2-2-3-2] Type of satellite orbits [PS3-4-3] Radiometric resolution [PS3-4] Properties of digital imagery	Jackson W.M (editor), (2009). Manual of Remote Sensing: Earth Observing Platforms & Sensors, 3th ed. Lavender, S., Lavender, A. (2017). Practical Handbook of Remote Sensing, CRC Press, Taylor & Francis Group, Boca Raton, US. A Canada Centre for Remote Sensing Remote Sensing Tutorial, Fundamentals of Remote Sensing, Retrieved from https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/resource/tutor/fundam/pdf/fundamentals_e.pdf Campbell, J.B., Wynne, R.H. (2003). Introduction to Remote Sensing, Fift edition, The Guilford Press, New York, US.

			Lavender, S., Lavender, A. (2017). Practical Handbook of Remote Sensing, CRC Press, Taylor & Francis Group, Boca Raton, US. Campbell, J.B., Wynne, R.H. (2003). Introduction to Remote Sensing, Fift edition, The Guilford Press, New York, US. A Canada Centre for Remote Sensing Remote Sensing Tutorial, Fundamentals of Remote sensing, Retrieved from https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/resource/tutor/fundam/pdf/fundamentals_e.pdf
	Whitebox tools	[DA4-1] Modeling tools [AM] Analytical Methods	
	GIS Software (ArcGIS, QGIS)		
	SWMM toolbox (EPA)	[GC1] Theory of Geocomputation and complex systems [GC2] Spatial simulation modelling	
	MIKE Urban	[GC2] Spatial simulation modelling	
	Hydrology Exploitation Platform (H-TEP)	[TA3-3-1-1] Lake Surface Water Temperature	https://eo4society.esa.int/resources/hydrology-exploitation-platform-h-tep/

17. ANNEX XI: Climate change: Data

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
Air quality monitoring and management (EQF 3)	Sentinel 3	Copernicus Open Access Hub DIAS Platforms	[PS] Platforms, sensors and digital imagery [PS1-2] Passive Sensors [PS2-2-3-3] Acquisition modes [PS4] Satellite and Airborne Sensors and Missions Databases [PP1-8-1] Satellite orbits: (quasi)Polar, Geostationary, Molnyia, Non-rotating, Sun-Syncronous, etc.) [GD] Geospatial Data [GD2-2] Remote sensing [IP5-3-1] Data and information access service (DIAS) [PS3-7] Processing levels [PS3-6] Data Formats [TA1] Atmosphere Monitoring [TA1-1] Air quality [TA1-3] Ozone layer and UV radiation [TA1-4] Emissions and	free and open available, long term monitoring together with other open data	spatial resolution (for detailed analysis)
	Sentinel 5P	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	cloud-free condition is needed spatial resolution (for detailed analysis)
	Copernicus Atmosphere Monitoring Service (CAMS)	Copernicus Open Access Hub DIAS Platforms			

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
			surface Fluxes [TA1-5] Climate forcing		
Air quality monitoring and management (EQF 5/6)	Sentinel 1A-B	Copernicus Open Access Hub DIAS Platforms Google Earth Engine	[PS] Platforms, sensors and digital imagery [PS1-2] Passive Sensors [PS2-2-3-3] Acquisition modes [PS4] Satellite and Airborne Sensors and Missions Databases [PP1-8-1] Satellite orbits: (quasi)Polar, Geostationary, Molnyia, Non-rotating, Sun-Syncronous, etc.) [GD] Geospatial Data [GD2-2] Remote sensing [IP3-11-2] Cube-based time series analysis [GD11] Satellite and shipboard remote sensing [IP5-3-1] Data and information access service (DIAS) [PS3-7] Processing levels [PS3-6] Data Formats [IP5-3] Online processing [PP1-4-10] Retrieval of	free and open available, long term monitoring together with other open data	
	Sentinel 2A-B	Copernicus Open Access Hub DIAS Platforms Google Earth Engine		free and open available, long term monitoring together with other open data	
	Sentinel 3	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	spatial resolution (for detailed analysis)
	Sentinel 5P	Copernicus Open Access Hub DIAS Platforms Google Earth Engine		free and open available, long term monitoring together with other open data	cloud-free condition is generally needed spatial resolution (for detailed analysis)

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
	Meteosat Second Generation	Eumetsat-Operational Portal (EOP)	atmospheric parameters (vertical profiles of temperature and main chemical constituents) by inversion (e.g. by Empirical Orthogonal Function Methodology) of radiances measured from satellites [TA1] Atmosphere Monitoring [TA1-1] Air quality [TA1-3] Ozone layer and UV radiation [TA1-2] Solar energy [TA1-2-1] planning solar energy installations [TA1-4] Emissions and surface Fluxes [TA1-5] Climate forcing [TA2-1-1-1] impact projections on flood frequency and water availability [TA2-1-1] mitigate effects of changing precipitation patterns [TA2-10] Global users [TA2-2-1-3] past and future climate normals [TA2-2] Agriculture and Forestry [TA2-3-1] assessing the	free and open available, long term monitoring together with other open data	
	Copernicus Atmosphere Monitoring Service (CAMS) NOAA-SURFRAD (140 US ground stations) https://www.esrl.noaa.gov/gsd/renewable/surfrad.html	Copernicus Open Access Hub DIAS Platforms			

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
			weather risks to insured assets [TA2-4-1] assessing and designing urban infrastructure appropriate for extreme weather conditions [TA2-4-1-1-1] energy-relevant climate indicators [TA2-4-1-1] forecast models for intense rainfall, heat waves, extreme air pollution [TA2-4-1-1] historical, seasonal forecasts and projections of climate indicators [TA2-5-1-1-1] climate-health indicators [TA2-5-1-1] maps and forecasts of temperature, heat-wave frequency and climate-health indicators [TA2-8-1] facilitating ongoing and long-term adaptation of the tourism sector to a changing climate [TA2-8-1-1] tourism-relevant climate indicators [TA2-9-1-1] climate-biodiversity indicators		

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
			[TA2-9-1] assessing biodiversity and ecoystem services [TA2] Climate Change Monitoring TA4-3] Coastal and marine environment [TA4-4] weather, seasonal forecasting and climate		
Solar energy forecasting for efficient planning and operation of solar energy farms	Sentinel 1A-B	Copernicus Open Access Hub DIAS Platforms Google Earth Engine	PS1-3] Active Sensors [PS3-7-2] SAR data [PP2-3-11] Interferometry (InSAR) [PS] Platforms, sensors and digital imagery [PS1-2] Passive Sensors [PS2-2-3-3] Acquisition modes [PS4] Satellite and Airborne Sensors and Missions Databases [GD] Geospatial Data [GD2-2] Remote sensing [IP3-8-2] Radiative transfer modelling [IP3-11-2] Cube-based time series analysis [IP5-3-1] Data and	free and open available, long term monitoring together with other open data	
	Sentinel 2A-B	Copernicus Open Access Hub DIAS Platforms Google Earth Engine		free and open available, long term monitoring together with other open data	cloud-free condition is needed
	Sentinel 3	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
	Sentinel 5P	Copernicus Open Access Hub DIAS Platforms Google Earth Engine	information access service (DIAS) [IP5-3] Online processing [PP1-6-5] Thermal infrared radiation transfer in the atmosphere [PS3-7] Processing levels [PS3-6] Data Formats [TA1-2] Solar energy [TA1-2-1-1] historic irradiance time series	free and open available, long term monitoring together with other open data	cloud-free condition is needed spatial resolution (for detailed analysis)
	Meteosat Second Generation	Eumetsat Operational Portal (EOP) SOLEMI - Solar Energy Mining (DLR)		free and open available, long term monitoring together with other open data	
	Copernicus Climate Change Service (C3S)	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	
	Copernicus Atmosphere Monitoring Service (CAMS)	Copernicus Open Access Hub DIAS Platforms https://atmosphere.copernicus.eu/catalogue#/		free and open available, long term monitoring together with other open data	
Impact-based weather forecast services for risk evaluation	Sentinel 1A-B	Copernicus Open Access Hub DIAS Platforms	[PS1-3] Active Sensors [PS3-7-2] SAR data [PP2-3-11] Interferometry (InSAR) [PS] Platforms, sensors	free and open available, long term monitoring together with other open data	

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
		Google Earth Engine	and digital imagery [PS1-2] Passive Sensors [PS2-2-3-3] Acquisition modes [PS4] Satellite and Airborne Sensors and Missions Databases [GD] Geospatial Data [GD2-2] Remote sensing [IP3-8-2] Radiative transfer modelling [IP3-11-2] Cube-based time series analysis [GD11] Satellite and shipboard remote sensing [IP5-3-1] Data and information access service (DIAS) [IP5-3] Online processing [PS3-7] Processing levels [PS3-6] Data Formats [PP1-4-10] Retrieval of atmospheric parameters (vertical profiles of temperature and of main chemical constituents) by inversion (e.g. by Empirical Orthogonal Function Methodology) of radiances		
	Sentinel 2 A-B	Copernicus Open Access Hub DIAS Platforms USGS EarthExplorer Google Earth Engine		free and open available, long term monitoring together with other open data	cloud-free condition is needed
	Sentinel 3	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	
	Sentinel 5P	Copernicus Open Access Hub DIAS Platforms Google Earth Engine		free and open available, long term monitoring together with other open data	
	Copernicus Climate Change Service (C3S)	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
	Copernicus Atmosphere Monitoring Service (CAMS)	Copernicus Open Access Hub DIAS Platforms https://atmosphere.copernicus.eu/catalogue#/	measured from satellites [PP1-6-5] Thermal infrared radiation transfer in the atmosphere	free and open available, long term monitoring together with other open data	
	CFSR: Climate Forecast System Reanalysis	Copernicus Open Access Hub DIAS Platforms		free and open available, long term monitoring together with other open data	
Precision farming for vineyard (Precision viticulture)	Sentinel 1-AB	Copernicus Open Access Hub DIAS Platforms Google Earth Engine	PS1-3] Active Sensors [PS3-7-2] SAR data [PP2-3-11] Interferometry (InSAR) [PS] Platforms, sensors and digital imagery [PS1-2] Passive Sensors [PS2-2-3-3] Acquisition modes [PS2-3-1] Field spectroradiometers [PS4] Satellite and Airborne Sensors and Missions Databases [GD] Geospatial Data [GD2-2] Remote sensing [IP3-11-2] Cube-based time series analysis [GD11] Satellite and	free and open available, long term monitoring together with other open data	complex processing of data
	Sentinel 2-AB	Copernicus Open Access Hub DIAS Platforms USGS EarthExplorer Google Earth Engine		free and open available, long term monitoring together with other open data	cloud free condition is needed revisit time spatial resolution (for detailed analysis)
	Sentinel 3	Copernicus Open Access Hub		free and open available, long term monitoring together with other open data	cloud-free condition is needed spatial resolution (for detailed analysis)

Case-based scenario	Relevant Remote Sensing data	Data providers	Relevant BoK concepts	Data potentials	Data limitations
		DIAS Platforms	shipboard remote sensing [IP5-3-1] Data and information access service (DIAS) [IP5-3] Online processing [PS3-7] Processing levels [PS3-6] Data Formats [PP1-4-10] Retrieval of atmospheric parameters (vertical profiles of temperature and of main chemical constituents) by inversion (e.g. by Empirical Orthogonal Function Methodology) of radiances measured from satellites		
	Landsat 8 TIRS	USGS EarthExplorer Google Earth Engine		free and open available, long term monitoring together with other open data	cloud free condition is needed revisit time spatial resolution (for detailed analysis)
	SPOT 6	Airbus Defence and Space		high resolution	commercial use cloud free condition is needed
	Planet Labs	Planet Explorer		high resolution	commercial use cloud free condition is needed
	DEM				

18. ANNEX XII: Climate change: Methods

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed
Air quality monitoring and management (EQF 3)	Apply satellite-derived and ground-based data into air quality planning	[DM5-2] Modelling time aspects [GD] Geospatial Data [GD2] Data Collection [no] Mathematical models of uncertainty: Probability and statistics [PP1-6-1] Structure and chemical-physical composition of Earth's atmosphere	Adaptation required depending on the availability of local ground and (open)social data
Air quality monitoring and management (EQF 5/6)	Air pollution remote sensing from space	[AM6] Analysis of surfaces [AM8] Geostatistics [IP2] Data assimilation [PP1-4-9] Line-by-line radiative transfer models [PP1-4-10] Retrieval of atmospheric parameters (vertical profiles of temperature and of main chemical constituents) by inversion (e.g. by Empirical Orthogonal Function Methodology) of radiances measured from satellites	Adaptation required depending on the availability of local ground and (open)social data
	https://atmosphere.copernicus.eu/training		No adaptation required
Solar energy forecasting for efficient planning and operation of solar energy	Solar energy forecasting	[IP4-3-1] Cloud cover percentage [PP1-3-6] Spectral Signature of Clouds	No adaptation required

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed
farms	NOTE: books of Kleissl and Kariniotakis	[IP4-3-1] Cloud cover percentage [PP1-1-10] Solar constant and solar insolation [PP1-6-2] Absorption and scattering of solar radiation in the Atmosphere	
Impact-based weather forecast services for risk evaluation	time-series and change detection analyses/algorithms	[AM5-7] Multi-criteria evaluation [CV4-4] Visualization of temporal geographic data [DM5-2] Modelling time aspects [IP3-11] Time series analysis [IP3-11-1] Change detection [IP3-11-2] Cube-based time series analysis [IP3-11-3] Dynamic Time Warping	No adaptation required
	Integration of optical and microwave satellite data with ground-based weather information and forecast analysis InSAR, in particular Persistent Scatterer Interferometry (for landslides)	[AM5-5] Analyzing multidimensional attributes [AM5-7] Multi-criteria evaluation [AM13-3] Interpolation [AM13-4] Vector to raster and raster-to-vector conversions [AM13-5] Raster resampling [AM14-1] Scale and generalization [CF5-8] Spatial integration [CV4-1] Thematic mapping [CV4-5] Dynamic and interactive displays [CV4-6] Web mapping [DA4] Database design [DM3-2] The raster model [IP1] Image pre-processing [IP1-3] Geometric correction [IP1-3-1] Orthorectification [IP1-5] Interferometry [IP2] Data assimilation [IP2-1] Data fusion [IP2-3] Data integration [IP1-3-2-1] Image co-registration	Adaptation required depending on the availability of local ground and (open) social data

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed
		[IP3-3-1] DEM generation [IP1-3-1-3] RPC correction [IP3-4] Image classification [IP3-5] Image segmentation [IP3-7] Object-based image analysis (OBIA) [IP4-2-1] Accuracy assessment [PP1-3-4] Spectral Signature of Vegetation, Water, Soil [PP1-3-7] Composition of spectral signatures (Linear Mixing) [PP2] Radar Principles [PP2-3] Detecting Microwaves/SAR Image formation [PP2-3-11-2] Permanent Scatterer Interferometry [PP2-3-8] Terrain Reflectivity and geometric distortions [PS3-7-1-2-1] Orthophotos [WB7] Web application development elements [WB7-3] Web application frameworks and geoportal frameworks [WB5] Application development via Data Integration	
	time-series and change detection analyses/algorithms	[AM5-7] Multi-criteria evaluation [CV4-4] Visualization of temporal geographic data [DM5-2] Modelling time aspects [IP3-11] Time series analysis [IP3-11-1] Change detection [IP3-11-2] Cube-based time series analysis [IP3-11-3] Dynamic Time Warping	No adaptation required
Precision farming for vineyard (Precision viticulture)	Classification	[AM13-3] Interpolation [AM13-4] Vector to raster and raster-to-vector conversions	Adaptation required depending on the availability of local ground data

Case-based scenario	Relevant technique/algorithm	Relevant BoK concepts	Adaptations needed
		[CV4-1] Thematic mapping [DA4] Database design [DM3-2] The raster model [GC3-4] Pattern recognition [IP1-3-2-1] Image co-registration [IP1-7-6] Field spectroscopy reference data [IP2-1] Data fusion [IP3-1] Band math [IP3-1-1-1] Vegetation fraction [IP3-1-1-2] LAI (Leaf Area Index) [IP3-1-2-1] Soil-adjusted Vegetation Index (SAVI) [IP3-1-2-3] Normalized Difference Vegetation Index (NDVI) [IP3-2] Computer vision [IP3-4] Image classification [IP3-5] Image segmentation [IP4-2-1] Accuracy assessment [TA3-1-1-3-3] Vegetation indices [WB7] Web application development elements [WB7-3] Web application frameworks and geoportal frameworks [WB5] Application development via Data Integration	
	time-series and change detection analyses/algorithms	[CV4-4] Visualization of temporal geographic data [DM5-2] Modelling time aspects [IP3-11] Time series analysis [IP3-11-1] Change detection [IP3-11-2] Cube-based time series analysis [IP3-11-3] Dynamic Time Warping	No adaptation required

19. ANNEX XIII: Climate change: Tools

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
Air quality monitoring and management (EQF 3)	Open software for mapping and visualization	[DA2-8] Commercial and open source software [CV] Cartography and Visualization [GD] Geospatial Data [PS3-6-11] Software related formats [PS3-6] Data Formats [CV2-2] Data processing	https://sentinel.esa.int/web/sentinel/toolboxes/sentinel-3 https://atmospherictoolbox.org http://step.esa.int/main/
Air quality monitoring and management (EQF 5/6)	Python	[GD11-3] Algorithms and processing [CV2-2] Data processing	
	Mapping and visualization GIS Software (ArcGIS, Idrisi, SAGA GIS, ILWIS, QGIS)	[CV] Cartography and Visualization [GD] Geospatial Data [PS3-6] Data Formats [CV2-2] Data processing	https://sentinel.esa.int/web/sentinel/toolboxes/sentinel-2 https://en.wikipedia.org/wiki/List_of_geographic_information_systems_software https://www.harris.com/solution/envi https://clarklabs.org/terrset/idrisi-gis/ http://www.saga-gis.org/en/index.html https://www.itc.nl/ilwis/ https://qgis.org/en/site/ http://step.esa.int/main/
	Google Earth Engine	[CV] Cartography and Visualization [GD] Geospatial Data [PS3-6] Data Formats [GD11-3] Algorithms and processing	Developer's Guide

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
		[CV2-2] Data processing	
Solar energy forecasting for efficient planning and operation of solar energy farms	Python	[GD11-3] Algorithms and processing [CV2-2] Data processing	
	R		
	Mapping and visualization GIS Software (ArcGIS, Idrisi, SAGA GIS, ILWIS, QGIS)	[CV] Cartography and Visualization [GD] Geospatial Data [PS3-6] Data Formats [CV2-2] Data processing [GD11-3] Algorithms and processing	https://en.wikipedia.org/wiki/List_of_geographic_information_systems_software https://www.harris.com/solution/envi https://clarklabs.org/terrset/idrisi-gis/ http://www.saga-gis.org/en/index.html https://www.itc.nl/ilwis/ https://qgis.org/en/site/ http://step.esa.int/main/
	Google Earth Engine		Developer's Guide
Impact-based weather forecast services for risk evaluation	Open software for mapping and visualization	[DA2-8] Commercial and open source software [CV] Cartography and Visualization [GD] Geospatial Data [PS3-6] Data Formats [CV2-2] Data processing	https://sentinel.esa.int/web/sentinel/toolboxes/sentinel-3 https://sentinel.esa.int/web/sentinel/toolboxes/sentinel-2 https://atmospherictoolbox.org http://step.esa.int/main/
	Google Earth Engine		Developer's Guide

Case-based scenario	Relevant existing analysis tools/platforms	Relevant BoK concepts	Link/further reading
Precision farming for vineyard (Precision viticulture)	Remote Sensing Softwares Remote Sensing free software: SNAP Sentinel Application Platform, QGIS, Orfeo Toolbox (OTB) Remote Sensing commercial software (TNT GIS, ERDAS IMAGINE, eCognition, ENVI)	[DA2-8] Commercial and open source software [GD] Geospatial Data [PS3-6-11] Software related formats [PS3-6] Data Formats	http://step.esa.int/main/doc/tutorials/ https://geospatial.trimble.com/products-and-solutions/ecognition https://www.microimages.com/ https://www.hexagongeospatial.com/products/power-portfolio/erdas-imagine
	GIS Software (ArcGIS, Idrisi, SAGA GIS, ILWIS, QGIS)		https://en.wikipedia.org/wiki/List_of_geographic_information_systems_software https://www.harris.com/solution/envi https://clarklabs.org/terrset/idrisi-gis/ http://www.saga-gis.org/en/index.html https://www.itc.nl/ilwis/ https://qgis.org/en/site/
	Google Earth Engine	[DA2-8] Commercial and open source software [CV] Cartography and Visualization [GD] Geospatial Data [PS3-6] Data Formats [CV2-2] Data processing	Developer's Guide