Co-funded by the Erasmus+ Programme of the European Union

SDI and EO Education and Training for North Africa

Project ref. number:
No. 610328-EPP-1 -2019-1-BE-EPPKA2-CBHE-JP

D1.4 Specification of project curriculum in SDI and EO

Author(s)/Organisation(s)/Partner number:

Glenn Vancauwenberghe & Lisa Lacroix (KU Leuven)

Work Package / Task:

WP1 – Preparing the environment for curriculum design

T1.4 - Specification of project curriculum

Short Description:

This report introduces the SEED4NA project curriculum on Spatial Data Infrastructures (SDI) and Earth Observation (EO).

Keywords:

Curriculum design, Spatial Data Infrastructures (SDI), Earth Observation (EO)

Table of Contents

1. Introduction

1.1. The SEED4NA project

For many of the societal and environmental challenges that governments are facing, decision-makers strongly rely on spatial and earth observation data, to better target, monitor, and assess their actions and interventions. These data are now becoming more and more available through the establishment of data infrastructures and platforms, which aim to improve access to, sharing and use of data. The effective use of these data requires that professionals in the public, private and academic sector have the relevant knowledge and skills on spatial data infrastructures (SDI), earth observation (EO) and related technologies. This means that higher education institutions must have the knowledge and capacities to provide modern education to their students and offer professionals the right training programmes to raise the overall level of expertise in SDI & EO.

Initiatives to promote and coordinate the sharing of EO and spatial data are also emerging in the region of Northern Africa, at the local, national and regional level. Despite the growing availability and accessibility of data, there still are several barriers and challenges hindering the uptake and use of these data in policy making and implementation. Among these barriers and challenges is a lack of skills and knowledge on SDI and EO among practitioners, decision-makers and other key stakeholders. Therefore, it is essential that academic institutions in the North African countries raise their capacities regarding SDI and EO.

The main objective of SEED4NA is to improve the quality of higher education in North Africa in the fields of SDI and EO, and to enhance its relevance for the labour market and society through the development of new and innovative SDI/EO curricula. The SEED4NA project aims to: 1) develop the required knowledge, skills and competencies on SDI & EO within partner universities; 2) help introducing modern SDI & EO courses in engineering and agriculture/forestry studies; 3) implement supporting relevant vocational training programmes; 4) help partner universities to support the development of SDI in their country and 5) promote a European approach to SDI & EO.

SEED4NA will result in the establishment of capable, well-trained pools of experts within the involved North African academic institutions, which will introduce a modern approach in academic and VET education on SDI & EO in their respective countries, thereby becoming promotors of SDI development and EO use.

1.2. Specification of project curriculum in SDI and EO

WP1 of the SEED4NA project deals with the specification of a project curriculum on SDI and EO and the adaptation of this project curriculum to the needs of HEIs and stakeholders in North Africa. The work package has the following specific objectives:

- To analyse the present curricula with regard to GI and EO at HEI's in partner countries
- To analyse and collect existing learning material at HEI's at program countries;
- To identify SDI and EO stakeholders requirements regarding knowledge and skills requested by new and existing professionals;
- To design a curriculum on SDI and EO adapted to the needs of local HEIs and stakeholders

Task 1.4 of SEED4NA deals with the specification and adaptation of the project curriculum in SDI and EO. This will be done based on the results of analyses of existing SDI/EO education in Europe and in North Africa, and an in-depth assessment of the skills requirements of SDI/EO stakeholders and practitioners in North Africa.

This deliverable 'Specification of project curriculum in SDI and EO' (D1.4) present the main components of an education curriculum in SDI and EO. A next deliverable of the project (D1.5) will look into the adaptation of this curriculum to the needs and interests of the stakeholders in the four partner countries of the project (Algeria, Egypt, Morocco and Tunisia).

1.3. Structure of the document

This report is structured as follows. After this introductory chapter, the next chapter provides an analysis of existing SDI/EO curricula at the four European universities participating in SEED4NA: Twente University (the Netherlands), Bochum University of Applied Sciences (Germany), KU Leuven (Belgium) and University of Zagreb (Croatia). Chapter three of this report focuses on some EO/SDI curricula offered at other universities in Europe, including two multi-partner (joint) programmes supported by the Erasmus+ Program. In chapter four, we identify the common components across these programmes, and use these as a basis to propose a core curriculum on SDI and EO. In the fifth chapter, we present the main conclusions of this report and some recommendations on how to adapt the proposed curriculum to local needs of partner universities in North Africa.

2. Existing SDI/EO education at SEED4NA universities

In this chapter, we present and discuss the curricula on SDI/EO offered at the European SEED4NA universities, i.e. University of Twente, Bochum University of Applied Sciences, KU Leuven and University of Zagreb. At all four universities, there's one main program at MSc level dealing with SDI and EO subjects, while Bochum University of Applied Sciences and University of Zagreb also offer a BSc program in which SDI and EO topics are covered.

2.1. MSc in Geo-information Science and Earth Observation (University of Twente)

The Master in Geo-Information Science and Earth Observation focuses on skills relevant for GIS and Earth observation sciences, but also data sciences are covered. During the program, students learn how to collect, transform and integrate data and use these for developing, innovative and sustainable solutions useful for tackling real-world problems.

2.1.1. Overall structure

During the Master's in Geo-Information Science and Earth Observation, students have to collect a total of 120 EC in the time frame of two years. The content of the curriculum depends on two main choices to be made by the students:

1. At the start of the program, students have chose among seven specialisations, covering specific domains in geo-information sciences and earth observation:
    - Applied Remote Sensing for Earth Sciences
    - Natural Hazards and Disaster Risk Reduction
    - Geoinformatics
    - Geo-information Management for Land Administration
    - Natural Resources Management
    - Urban Planning and Management
    - Water Resources and Environmental Management

2. In addition to the compulsory courses, which also depend on the specialisation students choose, they also have to select several elective courses. Most of these elective course are available to everyone, no matter of the specialisation. In total there are more than 15 elective courses. Students can also choose to do an internship at a company or research institute.

The first year of the program is divided into four quartiles:

- During the first quartile, the students learn the basics of Geo-Information Sciences, which consists of three separate courses.
- During the second quartile, the students take two compulsory courses of the specialisation they have chosen
- In the third quartile, the students combine the course on 'Global challenges and local action' with one compulsory course from their specialisation
- During the fourth quartile, the students take one compulsory courses of their specialisation with one elective courses.

- Parallel to these courses, the students can also take an academic skills courses to gain the necessary skills required to do scientific research in geo-information science and earth observation.

Table 1 shows the common modules and courses of the program.

Common courses	Courses	ECTS
Basics of Geo-Information Science and Earth Observation 14 ECTS	GIS & RS for geospatial solutions	4
	Geospatial Data: Concepts, Acquisition and Management	5
	Geospatial Analysis and Interpretation	5
Global challenges, local action 7 ECTS	Global Challenges, Local Action	7
Academic skills 4 ECTS	Academic skills	4

Table 1 Common courses of the MSc program at University of Twente

The specialisation courses for each of the seven specialisations are shown in table 2. Throughout the different quartiles, students have to follow four courses of the specialisation they have chosen.

Specialisation courses	Courses	ECTS
Applied Remote Sensing for Earth Sciences	Spectral Data Processing	7
	Spectral Geology	7
	Geological Remote Sensing	7
	Field Measurements and Validation	7
Geoinformatics	Acquisition and Exploration of Geospatial Data	7
	Scientific Geocomputing	7
	Extraction, Analysis and Dissemination of Geospatial Information	7
	Image Analysis	7
	Integrated Geospatial Workflows	7
Geo-information Management for Land Administration	Land Information Systems and Models	7
	Organising Land Information	7
	Responsible Land Administration	7
	Cadastral Data Acquisition Technologies and Dissemination Methods	7
Natural Hazards and Disaster Risk Reducation	Introduction to Disaster Risk and Data Input for Hazard Modelling	7
	Physically-based Hazard Modelling	7
	Data-driven Hazard Modelling	7

	Disaster Risk Management	7
Natural Resources Management	Earth Observation for Natural Resources Management	7
	Natural Resources Management Fundamentals	7
	From Data to Geo-information for Natural Resources Management	7
	Environmental Monitoring and Modelling for Natural Resources Management	7
Urban Planning and Management	Building Inclusive and Competitive Cities	7
	Planning Sustainable Cities	7
	The Compact City	7
	Risk-sensitive urban planning studio	7
Water Resources and Environmental Management	Earth Observation of Water Resources	7
	Hydrological and Environmental Cycles	7
	Observing and Modelling Surface Water in a Changing World	7
	Shades-of-Blue: Earth Observation of Coastal and Inland Waters	7

Table 2 Specialisation courses of the MSc program at University of Twente

In addition to their specialisation, students also have to selected several elective courses, which are presented in table 3. In their second year, they can do an internship at a company or research institute, to gain practical experience. The internship is optional, students can also decide to take elective courses equivalent to the internship credits.

Elective courses	Courses	ECTS
Electives	Water, climate and cities	5
	Catchment Hydrology and Surface Water	7
	Geo-Journalism	7
	3D Modelling for City Digital Twins based on Geospatial Information	7
	Advanced Image Analysis	7
	Big Geodata Processing	7
	Digital Twin for Water, Energy and Food Security	7
	Entrepreneurship: a Bridge to Geospatial Innovation	7
	Drinking water, sanitation and hygiene for improved health	5
	Economics and Finance for Geosciences	7
	Geo-Health	7
	Geophysics – imaging the unseen	7
	Intra Urban Spatial Patterns and Processes	7
	Land Change Modelling	7

	Land Use and Transport Interaction	7
	Laser Scanning	7
	Spatio-temporal Analytics and Modelling	7
	Species distribution and environmental niche modelling	7
	Statistics for spatial and spatio-temporal data	7
	Forest monitoring and carbon stock estimation with multi-source remote sensing in the context of climate change	7
	Water and carbon dynamics in ecosystems	7
	Weather Impact Analysis	7

Table 3 Table 3 Elective courses of the MSc program at University of Twente

During the second year of the program, the students mainly work on their MSc research proposal and MSc thesis, combine with some elective courses (and optionally an internship).

Thesis	Courses	ECTS
Thesis	MSc Research Proposal and Thesis Writing	45

Table 4 Thesis module of the MSc program at University of Twente

2.1.2. Relevant courses

The Master in Geo-Information Science and Earth Observation at University of Twente includes several courses that are closely related to the core topics of SDI and EO, which are central in the SEED4NA curriculum. In the table below we present a selection of the most relevant courses, including information on the learning outcomes they aim to achieve.

Courses	Learning outcomes
GIS & RS for geospatial solutions	- Apply the geospatial problem solving approach to address a specific geospatial problem. - Build a geospatial data processing workflow and apply appropriate methods for data acquisition, management and analysis, including the integration of data and analysis functions. - Explain how contextual and cultural differences can influence the collection and analysis of geospatial data, and the presentation of geo-information to a target audience.
Geospatial Data: Concepts, Acquisition and Management	- Explain the relevant concepts in geo-information science for the acquisition, management and retrieval of geospatial data using geo-databases. - Define spatial reference systems, coordinate systems and projections for geospatial data and apply relevant transformations for data integration with an emphasis on images. - Explain electromagnetic radiation and the main processes of its interaction with the Earth surface and atmosphere. - Apply atmospheric correction and image enhancement techniques to a remote sensing dataset to prepare for information extraction. - Explain visualization principles and apply them for the interpretation and communication of geospatial data products (maps, graphs and remote sensing images).

Geospatial Analysis and Interpretation	- Classify spatial analysis functions and apply appropriate analysis operations on a geospatial dataset. - Apply standard image analysis and change detection techniques to extract spatial and temporal information from a geospatial dataset. - Identify the impact of geospatial data handling on data quality and implement standard quality assessment procedures.
Global Challenges, Local Action	- Explain global challenges and trends and how their impacts differ across geographic areas, critically reflect on institutional frameworks/global agreements related to the global challenges addressed in the keynote lectures. - Critically reflect on the capacity of geo-spatial data, methods and tools in addressing specific global challenges. - Apply knowledge and skills acquired in preceding courses to analyse global challenges and trends and their effects at the local/regional level. - Jointly analyse, synthesize and communicate on the local and/or regional effects of a selected global challenge. - Apply professional skills (oral communication, formulating an argument, scientific debate) and (ethical) values needed (justice, responsibility, reasonableness, respect, honesty) for working in international and interdisciplinary teams and environments. - Reflect on international and interdisciplinary differences when co-developing local actions (context-specific strategy, plan, indicators, policy recommendation) to address global challenges.
Spectral Data Processing	- Understand the principles of a higher-level programming language and apply these to scripting. - Construct, adapt and troubleshoot scripts in an (online) processing platform. - Operate an online processing platform to compute useful Earth surface parameters. - Evaluate the quality of image processing results and judge its influence on image interpretation. - Criticize remote sensing methods in terms of suitability for a specific application.
Acquisition and Exploration of Geospatial Data	- Design basic database structures for the storage of geospatial data using model-driven architecture principles. - Make informed decisions on: the appropriate sensor or source, and methods for data acquisition, including field surveys, Web Services available through Spatial Data Infrastructures, crowdsourcing and Web-scraping. - Analyse geospatial data resources and describe their usefulness in terms of spatial, temporal, and attribute quality using statistics and calculus concepts. - Apply cartographic design principles in either exploration or presentation of geospatial data. - Use or modify algorithms written in Python, C++, Matlab, R or Spatial SQL as part of acquisition and exploration of geospatial data tasks.

Scientific Geocomputing	- List and memorize the basic syntax of the programming language - Explain mathematical notions in well-structured algorithms and understand their computational complexities - Apply the knowledge of algorithmics and literate programming in code development to solve problems with spatial components - Use spatial databases to load, curate and otherwise manipulate spatial data in database management systems - Use the notions of scientific data visualization and web mapping to demonstrate the outputs of their programs to increase understandability and interpretability - Read and analyze code that other programmers developed - Critically evaluate and fix program logic and correctness through reading, back-tracking, testing and debugging cycles - Develop programs to analyze spatial data in raster and vector formats using dedicated libraries - Learn new programming libraries, from scratch, without direct help from instructors and use those libraries in designing and formulating their solutions
Extraction, Analysis and Dissemination of Geospatial Information	- Plan a photogrammetric mission with a focus on quality aspects of the results. - Utilize image orientation procedures for the generation of topographic products such as maps and Digital Terrain Models. - Assess requirements from an application perspective to select appropriate graphic representations to map changes. - Determine the requirements of 3d viewing environments, and explain the application of depth cues. - Explain the principles of web architectures and web services requirements for web/cloud applications. - Explain the role of Open Standards and use them for the creation and consumption of GeoWebservices. - Create GeoWebservices and associated web mapping clients for information dissemination - Evaluate and analyse the uncertainty of spatial datasets and model outputs, and choose the appropriate option to design an effective uncertainty visualization.
Image Analysis	- Develop an image processing chain using non-linear filters and mathematical morphology operations for automatic information extraction from images in the context of a given problem. - Choose and apply a segmentation method to a given image and describe the uncertainty of the obtained result - Make informed decisions on the best classification and/or change detection method for a given set of images and a specific problem - Apply orthorectification to derive orthophoto - Make informed decisions on appropriate image matching method for a given type of data and problem - Explain the basic principles of radar images and utilize them for geospatial information extraction. - Evaluate attribute and scale uncertainty and relate it to the quality of derived orthophotos, accuracy of resulting image classification, and matching

Integrated Geospatial Workflows	- Analyse the quality of structured and semi-structured data sources and apply coding solutions for the storage, querying and curation of this data, appropriate for specific application contexts. - Apply semantic information integration through knowledge formalisation, semantic enrichment, exploratory querying and data mining. - Construct interoperable and reproducible geospatial workflows based on process modelling methods and workflow languages. - Create webservices and visualise their content systematically. - Make informed decisions on the infrastructural system design for enabling meaningful data integration on the web.
Earth Observation for Natural Resources Management	- Examine environmental indicators estimated with Earth Observation data (crop yield and water use, plant species diversity, forest cover) according to the scale of observation and information requirements. Exploration helps students to uncover their Earth Observation data and analytics needs in natural resources management. - Compare multispectral broadband, hyperspectral narrowband, thermal infrared, SAR and LiDAR data for crop yield and water use, plant species diversity and forest cover estimation, based on their spatial, temporal, radiometric and spectral resolution. Earth Observation data needs should align with the scale of observation. - Choose multispectral broadband, hyperspectral narrowband, thermal infrared, SAR and LiDAR metrics for crop yield and water use, plant species diversity and forest cover estimation, by considering their effectiveness, reliability, validity, efficiency. and usability. Earth Observation analytics needs should align with the information requirement. - Create analysis-ready Earth Observation data with data portals like Google Earth Engine. Cloud-computing environments and other data portals are increasingly used by the Earth Observation community to manage the large volume of Earth Observation data. - Derive statistical properties of Earth Observation data with hypothesis-testing in the R software environment. Inferential statistics help you to get to know your data before applying more advanced analytical techniques. - Design a technical workflow to acquire and process Earth Observation data. The technical workflow is the final roadmap to Earth Observation data and techniques.
Earth Observation of Water Resources	- Derive essential water and energy variables from Earth Observation data. - Apply the concepts of radiative transfer theory in the optical, thermal and microwave parts of the electromagnetic spectrum for water and energy cycles. - Collect, process, and visualize essential water and energy variables from Earth observation data supplied via the world wide web and through satellite broadcasts. - Apply a calibration/validation protocol and calculate statistical error metrics for quantitative accuracy assessment of derived water and energy variables.
Advanced Image Analysis	- Explain the impact of sample size and various sampling methods on the classification performance - To analyze and quantify the effect of different hyperparameters on classification results - Assess the strengths and weaknesses of the traditional machine learning and deep learning methods taught in the course - Apply the advanced image analysis methods taught in the course to classify both single-date and multi-temporal images in support of addressing environmental and societal problems - Critically interpret the classification results obtained using advanced image analysis methods

Table 5 Selection of relevant courses offered at University of Twente

2.2. BSc Geoinformatics (HSBO)

The bachelor's degree program in geoinformatics at Bochum University of Applied Sciences combines areas of geosciences - such as geodesy or geography - with computer science methods. The program aims to prepare students to use geodata in a targeted, effective and sustainable manner. The focus of the program is on the management and analysis of spatial data with special IT applications and software development. The program – 210 ECTS – is offered in German.

2.2.1. Overall structure

The BSc Geoinformatics program offered at HSBO combines six types of modules

- Basic 'General' modules, such as Geography, Informatics, Mathematics and Physics
- Basic 'Geo-informatics' modules, such as Introduction to Geo-Information Science, , Basics of cartography, Basic models of geoinformatics, and Databases and Spatial analysis methods, and Remote Sensing
- Specialised Modules on 'Software-Engineering, including Programming languages, Algorithms and data structures, Software Engineering, and Internet Techniques and Web-based GIS Technology
- Specialised Modules on 'Geodata Management' such as Enterprise GIS, (Geo-) Databases, Norms and Standards, 3D Models and their application, and Spatial analysis methods
- Specialised Modules on Surveying, such as Geodetic acquisition methods for geo-informaticians, Land Management & Cadastral Land Register, and Property valuation
- 'Key competences' modules, such as Introduction to Studying, English, law and administration and Project Management.

Table 6 shows the six basic 'general' modules, including courses on mathematics, CAD, computer sciences, physics, geography and other.

Basic 'general' modules	Courses	ECTS
Mathematics I	Mathematics I	10
Geometric-graphical basics	CAD	5
	Descriptive Geometry	
Mathematics II	Mathematics II	5
Fundamentals of computer science	Fundamentals of computer science	5
Statistics for geoinformaticians	Error theory equalisation	10
	Calculation	
Natural sciences for geo-informatics specialists	Physics	5
	Geography	

Table 6 Basic general modules of the BSc Geoinformatics program at HSBO

The program also contains several so-called basic geo-informatic modules, in which the foundations and core elements of geo-informatics are addressed. An overview of these modules and the associated courses is given in table 7. Among these modules and courses are 'Introduction to Surveying', 'Introduction to Geo-informatics', 'Programming languages', 'Basic models of geo-informatics' and others.

Basic geo-informatics modules	Courses	ECTS
Introduction to Surveying	Introduction to Surveying	6
Introduction to Geo-Information Science	Introduction to Geo-informatics	6
Programming languages	Programming languages	10
Basics of cartography	Basics of cartography	5
Algorithms and data structures	Algorithms and data structures	5
Basic models of geoinformatics	Computer graphics for GIS	10
	Digital elevation models	
	Basic models of geoinformatics	
Databases	Databases – Geodatabases	5
Spatial analysis methods	Spatial analysis with GIS	5
	Geostatistics	

Table 7 Basic geo-informatics modules of the BSc Geoinformatics program at HSBO

These basic geo-informatics modules are complemented with more specialised geo-informatics modules, which cover three main domains: Software Engineering, Geodata Management and Surveying. In table 8, the list of specialised geo-informatics modules and courses is presented.

'Specialised' geo-informatics modules	Courses	ECTS
Remote sensing	Introduction to remote sensing	5
	Digital Image Processing	
Norms and standards	Norms and standards	5
	Official Geodata	
Internet Techniques and Web-based GIS Technology	Internet technology and web programming	10
	Web-based GIS	
	Geodata Infrastructures	
Geodetic acquisition methods for geo-informaticians	Geodetic acquisition methods for geo-informaticians	5
Land Management & Cadastral Land Register	Land Management	5
	Real Estate Cadastre	

Software Engineering	Software Engineering	5
Geodetic reference systems and positioning	Geodetic reference systems and positioning	5
Selected topics of Programming	Selected topics of Programming	5
Enterprise GIS	Enterprise GIS	5
3D Models and their application	Virtual Reality	5
	Specialised 3D Models	
Advanced module in software engineering	GIS Development Environments	10
	Software Development Project	
Advanced module in in geodata management	Big GeoData	10
	Geodata Management Project	
Advanced module in remote sensing	Advanced methods of remote sensing	5
Advanced module in property valuation	Property valuation	5
Compulsory elective courses from other subject areas	Compulsory elective module	5

Table 8 Specialized geo-informatics modules of the BSc Geoinformatics program at HSBO

The BSc program also consists of several overarching modules, which provide an introduction to studying and cover key competences such as specialised English, Project Management and Business Administration. The three overarching modules and the courses they include are shown in table 9.

Overarching modules	Courses	ECTS
Introduction to Studying	Learn to study	3
	Spreadsheet calculation for engineering applications	
	Rhetoric and presentation techniques	
Key competences I	Specialised English	5
	Legal and administrative studies	
Key compétences II	Project Management	5
	Practical Business Administration	
	Technology Assessment and Sustainability	

Table 9 Overarching modules of the BSc Geoinformatics program at HSBO

Finally, the program also contains a module on 'practical work and thesis', which includes an internship, the bacherlor thesis and a colloquium for the bachelor thesis (see Table 10).

Practical modules	Courses	ECTS
Practical work & thesis	Internship	15
	Bachelor thesis	12
	Colloquium for bachelor thesis	3

Table 10 Practical modules of the BSc Geoinformatics program at HSBO

2.2.2. Relevant courses

There are several courses on topics related to SDI and EO in the BSc Geoinformatics program at HSBO. Since these courses can inspire and support the development of the SEED4NA curriculum, an overview of the most relevance courses and the associated learning outcomes is provided in table 11.

Courses	Learning outcomes
Introduction to remote sensing	- knowledge of collecting and processing geodata - in-depth knowledge of the analysis and interpretation of geodata - skills for networking different specialist areas - analyze, structure and formulate technical problems
Advanced methods of remote sensing	- knowledge of collecting and processing geodata - in-depth knowledge of the analysis and interpretation of geodata - in-depth knowledge of applications at the interface to neighboring disciplines - increased development of skills for networking different specialist areas - analyze, structure and formulate technical problems
Norms and standards	- knowledge of important geoinformatics standards and norms - handling of standards and standard documents. - application of conceptual data modeling and the derivation of concrete products and formats - transfer of formally structured and English-language standards to concrete implementations in data modeling, formats and interfaces - ability to develop additional standards and use them for use cases
Official Geodata	- knowledge of the geoinformation available within the framework of SDIs - skills to assess the quality of information and use it in an application-related manner - skills in understanding model-based concepts of geospatial base data and geospatial data infrastructures
Web-based GIS	- to implement client- and server-side web mapping applications; - to estimate the effort required to set up and operate web mapping applications and simple industry models and portals.
Geodata Infrastructures	- knowledge of essential technical and organizational measures for the development of interoperable geodata infrastructures; - competence to participate in the structural development of geodata infrastructures

Geodata Management Project	- ability to design and implement GIS-related technical concepts - competence in realizing multidimensional data models including versioning - knowledge in the development of specialist applications with user interfaces, role models and quality assurance measures - ability to convert existing geodata into a uniform database using ETL processes and to update it regularly and automatically.

Table 11 Selection of relevant courses of the BSc Geoinformatics program at HSBO

2.3. MSc Geoinformatics (HSBO)

Bochum University of Applied Sciences also has an Master's degree program in Geoinformatics, which provides a scientific and research-oriented education that qualifies students for work in functional and management positions in the private sector, public administration and research and development. The MSc Geoinformatics program has 90 ECTS and covers 3 semesters.

2.3.1. Overall structure

The programme consists of five types of modules:

- In-depth basic modules (compulsory)
- Subject-related elective modules
- General elective modules
- Comprehensive modules (compulsory)
- Thesis (compulsory)

Students have to take at least ten of the proposed modules in the first two semesters (first year of the programme), for a total of 60 ETCS. In the third semester, they work on their Master thesis, for another 30 ECTS.

The five compulsory modules of the MSc program are presented in table 12. There are three compulsory modules on geoinformatics topics – Modelling spatial data, Mathematical methods for Geocomputation and Geodata Infrastructure – which are complemented with a module on 'Sustainability and Corporate Management and the Thesis module.

Compulsory modules	Courses	ECTS
Modelling spatial data	Modelling spatial data	5
Mathematical Methods for Geocomputation	Discrete mathematics	5
	Formal specification	
Geodata Infrastructure	Development and organization of information infrastructures	5
	Geodata quality and automated checking	
Sustainability and Corporate Management	Introduction to the Sustainability Debate	5
	Corporate Governance	

Thesis	Master thesis	25
	Colloquium for the master thesis	5

Table 12- Compulsory modules of the MSc Geoinformatics program at HSBO

On geo-informatics topics, students should also choose among different elective modules, which are presented in table 13: Development of Geoinformation Products, Spatial Decision Support, Advanced Methods of Software Engineering, Artificial Intelligence and Programming and Integration of Sensors.

Subject-related elective modules	Courses	ECTS
Development of Geoinformation Products	Design of geo-information products	5
	GI-Project	
Spatial Decision Support	Decision support models	5
	Modeling and simulation of dynamic spatial processes	
Advanced Methods of Software Engineering	Software design	5
	Architecture for distributed geospatial applications	
Artificial Intelligence	Artificial Intelligence	5
Programming and Integration of Sensors	Programming of sensors and microcontrollers	5
	Sensor integration	

Table 13 Subject-related elective modules of the MSc Geoinformatics program at HSBO

In addition to the subject-related elective modules there also are more general or interdisciplinary elective modules. The International Summer School is one of these, as well as Modelling and Processing of Point Clouds, Interdisciplinary BIM Seminar and Fundamentals of BIM-based collaboration (as shown in table 14).

Interdisciplinary elective modules	Courses	ECTS
Modelling and Processing of Point Clouds	Processing of point clouds	5
	Simulation and visualization of infrastructure models	
Interdisciplinary BIM Seminar	Interdisciplinary BIM Seminar	5
Fundamentals of BIM-based collaboration	Fundamentals of BIM-based collaboration	5
International Summer School	International Summer School	5

Table 14 Interdisciplinary elective modules of the MSc Geoinformatics program at HSBO

2.3.2. Relevant courses

Also in HSBO's Master program on Geoinformatics there are several courses on topics related to SDI and EO. A selection of relevant courses is presented in table 15. For the design of the SEED4NA curriculum, these courses will be used as an important foundation.

Courses	Learning outcomes
Modelling spatial data	- competence in building and interpreting conceptual data models - ability to independently create data models - competence in recognizing modeling limitations and ability to make necessary additions to be recorded in specifications for models - ability to structure even complex models with UML editors, and formulate and exmine OCL constraints - knowledge of basic concepts of the Semantic Web - ability to create ontologies using the Web Ontology Language (OWL). - knowledge of the Resource Description Framework (RDF) and knowledge graph skills ("Knowledge Graphs") in suitable notations - ability to classify data according to Barners-Lee's 5-star rating
Development and organization of information infrastructures	- knowledge of selected information infrastructures (e.g. GovData, CODE-DE, Google Earth Engine) and skills relevance, target systems, role models and basic processes for these infrastructures. - ability to independently research and use geodata as well as to independently publish and update geodata in selected information infrastructures. - ability to represent essential characteristics of selected license models (e.g. data license Germany, Creative Commons) and ability to use data correctly in accordance with the licensing - competence to independently obtain suitable licenses for a given purpose - knowledge of the legal basis of important information infrastructures (INSPIRE Regulations, geoinformation laws of the federal and state governments, e-government law)
Geodata quality and automated checking	- competence in defining geodata requirement profiles for new products or services - knowledge of typical data life cycles - competency in creating appropriate data management plans that include aspects of data quality, access control and archiving. - ability to define requirements-specific measures for quality assurance of geospatial data and the technical implementation of simple quality assurance measures - knowledge of the boundary conditions and design principles that need to be taken into account for the user and - needs-based design of information technology products (cognitive aspects, design recommendations, legal requirements, etc.)
Architecture for distributed geospatial applications	- knowledge of common architectural concepts and the ability to evaluate their suitability for specific application contexts. - Ability to design and document service and event-oriented architectures for simple distributed geospatial applications - knowledge of common standards and technologies for implementing service and event-oriented architectures and ability to use them in your own projects

Table 15 Selection of relevant courses of the MSc Geoinformatics program at HSBO

2.4. MSc Geography (KU Leuven)

At KU Leuven modules and courses on GI, SDI and EO are offered in the context of two broader Master programmes at the university: the Master of Geography and the Master of Bioscience Engineering. The most integrated programme on GI/SDI/EO is the Master of Geography, jointly organised by KU Leuven and the Vrije Universiteit Brussel (VUB). The master aims to provide students the tools to grapple with real-world problems at different spatial scales, including a deeper understanding of geographical problems and methods, knowledge of theoretical debates within the discipline, and practical training in the use of geographical techniques.

2.4.1. Overall structure

The full programme of the Master of Geography comprises 120 ECTS, and consists of core courses on human-environment interactions and research methods in geography (27 ECTS), compulsory courses within a chosen specialisation (36 ECTS), a number of specialised electives in the field (27 ECTS), and a master's thesis (30 ECTS).

For their specialisation, students have to select a combination of two out of four modules:

- Earth and Climate: this specialisation focuses on terrestrial ecosystems and environmental changes, emphasising timely and relevant research topics in the geosciences like global warming, ice-climate interaction, soil and water conservation, long-term landscape development, natural hazards and risk assessment.
- Society and Space: in a strongly urbanised world there is a growing need to understand social, economic, cultural, and political dynamics of urban areas better. This specialisation focuses on the social and political issues of the current era of globalisation.
- Geo-information Sciences: within this specialisation students become acquainted with new approaches and techniques for acquiring, managing, analysing and mapping spatial data.
- Mixed Methods: students explore the latest research methods in geography, both quantitative and qualitative.

In table 16, we provide the content of the programme, focusing on courses dealing with GI, EO and related topics. This also includes two so-called reorientation courses, for students that did not take such courses in there previous education.

Modules	Courses	ECTS
Common basis courses	Environmental change	6
	Introduction to Remote Sensing	3
	Research Seminar	3
	Geography of Development	6
	Environmental and Resource Economics	6
Geo-information sciences	Advanced Earth Observation Techniques	3
	GIS Programming	6
	Remote Sensing of the Environment	3
	Geospatial Information Technologies	6

Internship	Internship	15
Strengthening modules	Remote Sensing of Vegetation, Soil and Water Systems	6
	Machine Learning and Inductive Inference	4
	Advanced Land-Climate Dynamics	3
	Introduction to Programming	4
	Web Technologies	3
	Urban Studies	4
Reorientation courses	Introduction to GIS	3
	Introduction to Geoprocessing	3

Table 16 Courses of the MSc Geograpghy at KU Leuven

In the MSc Programme Bioscience Engineering – and some other MSc programmes – a separate courses on 'Earth Observation' (5 ECTS) is offered, which also is relevant to the SEED4NA curriculum.

2.4.2. Relevant courses

In table 17 a selection is shown of the most relevant courses at KU Leuven, i.e. courses that could inspire and support the design of the SEED4NA project curriculum on SDI and EO.

Courses	Learning outcomes
Introduction to GIS	- have knowledge of different spatial data models and how these models are implemented in GIS software; - have a proper understanding of how raster GIS and vector GIS software is used for spatial problem solving; - master the concept of map algebra and how this concept is applied for multi-criteria analysis; - be able to define an entity-relationship model for structuring a database and to translate the E-R model into a relational data model; - be able to define a flowchart for solving a particular spatial problem, making use of available GIS functions; - have developed the practical skills to perform spatial analysis using raster or vector GIS software.
Introduction to Remote Sensing	- have a good knowledge of the characteristics and the use of important sensors for terrestrial earth observation; - be familiar with a variety of techniques for image classification, their potential for land-use/land-cover mapping, and the conditions that should be fulfilled for applying these techniques; - master alternative methods for change detection and be able to choose a proper method depending on the type of application; - be able to apply standard earth observation techniques for producing land-use/land-cover information at different scale levels; - be able to assess the accuracy of a classifier and compare classification results obtained with alternative methods for image interpretation

Introduction to Geoprocessing	- to be familiar with the basic concepts of programming that are specifically applicable to the processing and analysis of spatial data - to work out a solution strategy to analyze spatial data, based on a general scientific problem - to write program codes that allow for processing and analyzing spatial data (incl. time series). - to develop simple programming applications in existing GIS software.
Earth Observation	- understanding the various types of Earth observation techniques and how they are used in different applications - gain insight in the electromagnetic spectrum and its relation with incoming and outgoing radiation to and from the Earth - gain insight in which sensors can be used for various types of remotely sensed Earth observations and which platforms carry Earth observing sensors - gain insight in the basic image characteristics required for various Earth applications, over land, ocean and atmosphere - gain insight in the principles and operational missions in the field of optical remote sensing, thermal remote sensing and microwave remote sensing - gain insight in the processing and distribution of Earth observation data.
Advanced Earth Observation Techniques	- have a good understanding of different methods for sub-pixel classification and be aware of the difficulties involved in properly applying these techniques; - have knowledge of different ways of including contextual information in the image interpretation process; - have gained insight into how land use can be inferred from remote sensing data using spatially explicit approaches; - be able to properly assess the accuracy of image interpretation results; - be aware of the most important sources for obtaining information on the state-of-the-art of earth observation research in order to expand the knowledge acquired during the course; - be able to apply advanced earth observation techniques for producing land-use/land-cover information at different scale levels; - be able to define an appropriate strategy for mapping land-use/land-cover, taking into account the characteristics of the study area, the data available and the requirements of the applications (class definition, scale level); - be able to critically report about results obtained and compare/relate these results to previous work by other researchers.
GIS Programming	- be familiar with geoprocessing tools and toolboxes in ArcGIS Pro; - have a basic understanding of Python and of programming concepts and troubleshooting techniques that are common to most programming languages; - be able to assemble geoprocessing tools into scripted models for solving GIS problems and for setting up complex geoprocessing workflows in the ArcGIS Pro environment; - know how to customize GIS software, extend its functionality and make optimal use of geospatial software libraries.
Remote Sensing of the Environment	- have a good knowledge of the characteristics and the use of important sensors for earth observation of environmental events; - be familiar with the variety of remote sensing techniques available for measuring natural and anthropogenic events and phenomena, and the conditions that should be fulfilled for applying these techniques; - have a good understanding of different methods offered by passive optical and active radar remote sensing for environmental studies; - master different methods for change detection and be able to choose one or several proper method(s) depending on the type of application;

	- be aware of the most important sources for obtaining information on the state-of-the-art of earth observation research, in order to expand the knowledge acquired during the course; - be able to objectively compare results obtained with alternative methods for image interpretation; - be able to critically report about results obtained and compare/relate these results to previous work by other researchers; - be able to apply the learned techniques with open-source software and programming languages
Geospatial Information Technologies	- become profoundly knowledgeable about geospatial database technology and its relationships with Geographic Information Systems; - acquire specialized skills related to working with and managing (object-)relational geospatial databases using PostgreSQL/PostGIS-software by means of an elaborated tutorial emphasizing the Structured Query Language (SQL; - acquire thorough knowledge of the rationale and concepts of Spatial Data Infrastructures (SDI); - acknowledge the organizational dimension of SDI; - acquire thorough knowledge of the technical components of SDI: (i) geospatial data repositories, (ii) metadata catalogues, (iii) access services and (iv) technical standards regarding (i), (ii) and (iii); - learn to interact with SDI to discover, explore and exploit geodatasets; - learn how to contribute to SDI through data modelling and standardization, database and metadata compilation and publication, service development.
Remote Sensing of Vegetation, Soil and Water Systems	- get acquainted with the principles of remote monitoring of vegetation, soil and water systems, and with the application of earth observation technology in terrestrial system monitoring and modelling. - understand and explain advanced approaches of digital earth observation in the context of plant-biophysical system and process assessment - attain a thorough understanding of, and proficiency in, the utilization of advanced tools, instruments and procedures for the non-invasive study of vegetation, soil and water systems.

Table 17 Selection of relevant MSc courses at KU Leuven

2.5. BSc Geodesy and Geoinformatics (University of Zagreb)

The University of Zagreb has a BSc Program on Geodesy and Geoinformatics, which aims to prepare students for participation in cadastral and land registration procedures, for the production and maintenance of topographic, cartographic, and land geoinformation systems, for measuring the sizes needed to define the size, position, shape, contours, and changes of any part of the Earth and land, and for solving practical land surveying tasks.

2.5.1. Overall structure

During six semesters, students acquire basic knowledge and skills on the establishment of geodetic networks, geodetic surveys, the processing and visualization of data thus obtained, land information management, and geoinformation systems management. Most semesters consists of a mix of obligatory courses and optional courses.

An overview of the obligatory courses per semester is presented in table 18. Per semester students are enrolled in between 5 and 7 courses.

Semesters	Courses	ECTS
Semester 1	Mathematical Analysis	5
	Analytical Geometry and Linear Algebra	5
	Physics	5
	Basics of Geoinformatics	5
	Geodetic Instruments	5
	Engineering Graphics in Geodesy and Geoinformatics	3
	Physical Education	0
Semester 2	Computer Geometry	5
	Programming	5
	Land Surveying	5
	Field Measurements	5
	Vector Analysis	3
	Basics of Statistics	4
	Physical Education	0
Semester 3	Information Society	3
	Analysis and Processing of Geodetic Measurements	5
	Databases	5
	Differential Geometry	5
	Geodetic Plans	5
	Principles of Land Register Law	2
	Physical Education	0

Semester 4	Cartography	5
	Geodetic Reference Frames	5
	Cadastre	5
	Photogrammetry	5
	Geoinformation Modelling	5
	Physical Education	0
Semester 5	Professional Project	3
	Satellite Positioning	5
	Engineering Geodetic Bases	5
	Remote Sensing	5
	Land Development	5
Semester 6	Engineering Geodesy	5
	State Survey	5
	Map Projections	5
	Hydrographic Survey	5
	Final Exam	2

Table 18 Obligatory courses of the BSc Geodesy and Geoinformatics at University of Zagreb

Students have to complement these obligatory courses with some optional courses, which deal with various topics. A selected of the most relevant optional courses is given in table 19.

Optional courses	Courses	ECTS
Optional courses	Open Geoinformation	2
	Algorithms in Geoinformation Systems	3
	Geoinformation Manipulation	5
	Geoinformation Quality	5
	Geoinformation Infrastructure	5
	Management in Geodesy and Geoinformatics	3
	Web Cartography	3

Table 19 Optional courses of the BSc Geodesy and Geoinformatics at University of Zagreb

2.5.2. Relevant courses

The BSc Geodesy and Geoinformatics program of University of Zagreb entails a set of courses dealing with SDI, EO and related topics. In table 20, an overview is provided of several relevant courses and the associated learning outcomes.

Courses	Learning outcomes
Geoinformation Infrastructure	- Describe and use key and utility registers and other databases of economic and public utility infrastructure - Distinguish and use geoinformation services - Explain Spatial Data Infrastructure and its parts - Describe and distinguish levels of spatial data infrastructure - Use Geoinformation infrastructure
Open Geoinformation	- Describe licenses for open and free spatial data and software. - Identify and discuss advantages and disadvantages of open geoinformation for modern society. - Estimate quality and applications of open geoinformation datasets and software. - Participate in projects for collecting open geoinformation and developing geoinformation software. - Find and plan usage or application of open geoinformation and software.
Remote Sensing	- Applying knowledge in determining, defining and solving spatial problems of high complexity. - Evaluation, interpretation and synthesis of relevant information. - Presenting scientific contents and stances in written and oral form. - Applying mapping of geographical contents, georeferencing. - Applying corresponding maps and cartographical methods in analysis and presentation of the results. - Applying corresponding skills needed for acquiring and interpretation of creation conclusions which include relevant socially, scientific and ethical theme. - Problem solving related to qualitative and quantitative geographic information.

Table 20 Selection of relevant courses of the BSc Geodesy and Geoinformatics at University of Zagreb

2.6. MSc Geodesy and Geoinformatics (University of Zagreb)

The University of Zagreb also offers a 2-year Master's program on Geodesy and Geoinformatics, which consists of two majors – Geodesy and Geoinformatics – with different compulsory courses to be followed. The program, which was introduced in the academic year 2008/2009, counts for 120 ECTS.

2.6.1. Overall structure

The program is structured around four semesters. In the first three semesters, there are different compulsory courses for each major, which need to be complemented – for 12 ECTS per semester – by elective courses, common to both majors. In the third and especially fourth semester, students work on their master thesis, in which they apply their acquired knowledge and skills to perform research and/or execute practical work.

Table 21 shows the obligatory courses per semester for the major in geoinformatics. Each of the first three semesters, has three obligatory courses. The fourth semester is fully dedicated to the thesis.

Semesters	Courses	ECTS
Semester 1	Spatial Databases	6
	Spatial Management Support	6
	Computer Cartography	6
Semester 2	Advanced Remote Sensing	6
	Geoinformation Systems	6
	Spatial Data Analysis	6
Semester 3	Integrated Systems in Geomatics	6
	Image Survey	6
	Geovisualisation	6
	Diploma Thesis	30
Semester 4	Diploma Thesis	30

Table 21 Obligatory courses of the MSc Geodesy and Geoinformatics at University of Zagreb

In addition to these obligatory courses, students also have to select several optional courses in the first semesters. A selection of

Optional courses	Courses	ECTS
Optional courses	Application of Remote Sensing	6
	Complex Analysis	6
	Academic English	6
	GIS in Application	6
	Programme Engineering in Geomatics	6
	Cartography and New Technologies	6

Table 22 Optional courses of the MSc Geodesy and Geoinformatics at University of Zagreb

2.6.2. Relevant courses

In the major 'Geoinformatics' of the MSc Geodesy and Geoinformatics there are several courses that are addressing the core subjects of SEED4NA, i.e. SDI and earth observation. An overview of these courses, including their learning outcomes is provided in table 23. The course on GIS in Application especially focuses on how geospatial data and GIS are used in different sectors. The course 'Advanced Remote Sensing' follows after the basic course on Remote Sensing offered earlier in the learning path. The course on Spatial Databases covers different aspects of spatial databases and their management, and is – to a certain extent – relevant to SDIs. Finally, there's also a course on Application of Remote Sensing.

Courses	Learning outcomes

GIS in Application	- know the ways of introducing GIS in large systems (enterprises). - know how to choose the optimal GIS technology for a specific purpose - know how to assess the quality of spatial data and their suitability for targeted GIS - know the implementation of GIS in different fields of application. - lead the creation of GIS from the initial conceptual model to the final realization.
Advanced Remote Sensing	- carry out and analyze feature highlighting processing on multisensory digital recordings. - analyze the quality of the scene mapping by a modulation transfer function (MTF) recording system and to determine the real spatial resolution on the recordings of the analyzed system. - describe and know how to use Johnson's criteria for detection, recognition and identification of objects of interest on multisensory digital recordings. - perform supervised pixel-based classification of digital multisensor images. - define and analyze digital image segmentation. - create and analyze the confusion matrix and evaluate the accuracy of the supervised classification. - describe the methods and technology of aviation multisensor systems for reconnaissance and interpretation.
Application of remote sensing	- Describe the basic terms and principles of remote research - Describe the useful physical features of part of the electromagnetic radiation used in remote sensing. - Distinguish the most important methods of thematic interpretation in remote research. - Differentiate and argue the application of remote research methods in various fields of science and human activity. - Define terms: unsupervised and supervised classification. - Analyze the specifics of the thematic interpretation for selected professional areas. - Draw conclusions about the quality and persuasiveness of the results of interpretation and processing of digital images.
Spatial Database	- distinguish a monolithic desktop GIS from a spatial database - classify spatial data models according to their functionality - create a database of spatial data using open international standards - illustrate spatial data indexing methods using examples that integrate multiple disciplines - apply and compare computer geometry algorithms in spatial databases - evaluate the capabilities of spatial databases for storing and processing multidimensional objects

Table 23 Selection of relevant courses of the MSc Geodesy and Geoinformatics at University of Zagreb

3. Existing SDI/EO curricula at other EU universities

In this chapter, we present and discuss the structure and content of existing SDI and EO curricula offered at European universities. The curricula included in this chapter all include both SDI and EO subjects and therefore are good practices in integrating SDI and EO in a single curriculum.

3.1. Master in Geospatial Technologies (UJI, IFGI, UNL)

The Master in Geospatial Technologies, supported by the EC Erasmus+ programme, is a cooperation of three European universities: University of Münster (UM - Germany), Universitat Jaume I (UJI - Spain) and Universidade Nova de Lisboa (UNL - Portugal). Aim of the MSc program is to prepare students to exploit new technologies to support environmental and societal decision-making.

3.1.1. Overall structure

The Master in Geospatial Technologies is a three-semester program in which courses are offered at the three partner universities.

- The first semester offers two different learning paths, one focused more on statistics, data modelling, and GI basics (offered by UNL) and one focused more on informatics, new media and GI basics (offered by UJI).
- The second semester provides basic and advanced courses in GIScience, complemented with courses on more transversal competences (project management, research methods). All courses take place at UM.
- The third semester is fully focused on the Master thesis, which usually is close linked to ongoing research projects of the three participating universities.

Table 24 shows the three modules and six courses offered at UNL during the first semester of the program. These deal with the Foundations of GIS, advanced topics in GIS and analytical tools. Within the module on advanced topics there's a dedicated course on Remote Sensing.

Modules	Courses	ECTS
Module 1: Foundations of Geographic Information Science	Geographic Information Science	**7,5**
Module 2: Advanced Topics in Geographic Information Science I (*1 of 2 courses to be selected*)	Spatial Analysis and Visualization	7,5
	Remote Sensing	7,5
Module 3: Analytical Tools	Spatial Statistics	5
	Geospatial Datamining	5
	Group Project Seminar on Programming and Analysis	5

Table 24 Modules of the first semester at UNL of the MSc Geospatial Technologies

During the first semester, courses also are offered at UJI (Spain) where the focus is more on (advanced) informatics & data analytics, complemented with courses on the basics of GI. There's a course on 'Spatial Data Services, Sources, Standards and Infrastructures' in the second module, and a course on EO and Remote Sensing in the module on GI basics.

Modules	Courses	ECTS
Module 1: Foundations of Informatics	Programming	4
	Databases and Data Management	3
	Artificial Intelligence and Machine Learning	3
Module 2: Advanced Informatics and Data Analytics	Data Science	4
	Development of Applications for Geographic Data Exploration and Visualization	5
	Spatial Data Services, Sources, Standards and Infrastructures	3
Module 3: GI basics	Geographic Information Systems: Desktop to Web	3
	Geographic Information Systems applications and trends	2
	Earth Observation and Remote Sensing	3

Table 25 Modules of the first semester at UJI of the MSc Geospatial Technologies

During the second semester all courses take place at Universiry of Münster in Germany. The four modules and their courses are shown in table 26. Three of these moduels deal with Geographic Information Science (foundations, advanced topics & applied topics), while the fourth module focuses on transferable skills.

Modules	Courses	ECTS
Module 4: Foundations of Geographic Information Science II	Core Topics in Geographic Information Science	2
	GI Forum	1
	GI Forum Discussion Group	1
Module 5: Advanced Topics in Geographic Information Science II (*2 of 5 courses to be selected*)	Location-based services	5
	Spatial cognition	5
	Study project	5
	Programming in GI	5
	Reference Systems	5
Module 6: Applied Topics in Geographic Information Science	From data to knowledge	5
	Applied topics	5
Module 7: Transferable Skills	Project management/GeoMundus conference	3
	Research methods in GI Science	3

Table 26 Modules of the second semester at UM of the MSc Geospatial Technologies

The third semester fully focuses on the MSc thesis and its different components (seminar, thesis, defense), which are shown in table 27.

Modules	Courses	ECTS
Thesis	Master thesis seminar	2
	Master thesis including defense	28

Table 27 Modules of the third semester of the MSc Geospatial Technologies

3.1.2. Relevant courses

Table 28 shows the learning outcomes of the two most relevant courses of the MSc Geospatial Technologies program, i.e. 'Spatial Data Services, Sources, Standards and Infrastructures' and 'Earth Observation and Remote Sensing'.

Courses	Learning outcomes
Spatial Data Services, Sources, Standards and Infrastructures	- understand server limitations when serving geospatial data. - know the basic concepts of RRI and the implications of not considering them. - know the existence of other infrastructures, linked to previous data sources and standards. - know the existence of new data sources and the importance of obtaining representative data to address a problem with a reduced or low level of bias. - know the existence of established standards from other communities and practices. - be able to manage and view live data feeds. - being able to select the right type of service to share geospatial data. - know how to optimize the geospatial service for better server performance, depending on client-side usage. - know how to exemplify and visualize geospatial data using geospatial services. - be able to find and evaluate the suitability of new data sources.
Earth Observation and Remote Sensing	- describe the types of measurements in Remote Sensing and explain why satellite images can be used for Earth observation to produce geographic information - work on their own to develop a project to produce information based on satellite imagesor other sources of remote sensing imagery - select the satellite and sensor that is best suited for use in the production of different types of information on different spatial scales - describe and apply algorithms for classifying spectral, spatial and temporal patterns in satellite images in order to derive information - assess and interpret the error within information derived from satellite images - describe and evaluate the socio-economic benefits of remote sensing

Table 28 Selection of relevant courses of the MSc Geospatial Technologies

3.2. Copernicus Master in Digital Earth

The Copernicus Master in Digital Earth is an international Erasmus Mundus Joint Master Degree Program, involving three European universities: Paris-Lodron University Salzburg (PLUS), University of South Brittany (UBS) and Palacky University Olomouc (UP) . The study program aims to combine broad-based advanced Geoinformatics, Earth Observation, Remote Sensing, Cartography, Geovisualisation, Computer Science with a applied emphasis on use cases with Copernicus data and services within the main Copernicus domains under a generic Digital Earth vision.

3.2.1. Overall structure

In the first year, which is completed at PLUS, the focus is on Earth observation and Geoinformatics. In year two, there are two specialization tracks, on Geodata Science & AI4EO (at UBS) and on Geovisualisation and Geocommunication (at UP).

Table 29 shows the common modules of the program, which mostly are offered in the first year (module 1-5). In addition to these core modules, students can also participate in short intensive programmes and internships, and have to select among some elective courses.

Compulsory Modules	Courses	ECTS
Module 1: Orientation project ***6 ECTS***	Copernicus in Digital Earth (EO*GI)	1
	Spatial Thinking & Modelling	2
	Career Development & ePortfolio	1
	Scientific Methods and Writing	2
Module 2: Space-Time Models & Representations (*selected courses for 6 ECTS*) ***6 ECTS***	Geovisualisation and Advanced Cartography	6
	Systems Thinking in Spatial Representations	3
	Design of Geospatial Data Models	3
Module 3: Digital Earth Observation & Technologies ***12 ECTS***	Advanced Remote Sensing	6
	Copernicus Hubs and Institutions	3
	Digital Earth: Big Earth Data Concepts	3
Module 4: Spatial Image Analysis ***6 ECTS***	Object-Based Image Analysis	3
	Analysis and Modelling (Remote Sensing)	3
Module 5: Integrated Applications ***12 ECTS***	Project Management	3
	Practice Software Development	3
	Application Development (Earth Observation)	6
Short Intensive Programmes ***3 / 9 ECTS***	International Summer School I	3
	International Summer School II	3
	Blended Intensive Programme	6

Elective subjects **6 / 12 ECTS**	Elective courses	6 / 12
Internship ***12 /18 ECTS***	Skills-based Internship – Work Placement	12
	Collaborative Research – Work Placement	12 /18
Master Thesis ***21 ECTS***	Master's exam	3
	Thesis	18

Table 29 Common modules of the Copernicus MSc in Digital Earth

The specialization track on Geovisualization and Geocommunication consists of two main modules, one one geovisualization and one on geocommunication, and several electivec courses, of which students have to select two.

GeoVIS modules	Courses	ECTS
Module 1: Geovisualisation ***15 ECTS***	Systematic Geovisualisation	6
	Advanced Methods of Geovisualisation	6
	Design in Geovisualisation	3
Module 2: Geocommunication ***9 ECTS***	Cognitive Cartography	3
	Web Cartography	6
UPOL electives (2 courses to be selected) ***6 ECTS***	3D Visualisation	3
	Cartographic Project	3
	Desktop Publishing in Cartography	3

Table 30 Modules of the specialization track on 'Geovisualization and Geocommunication'

The specialization track on Geodata Science & AI4GEO consists of two modules. A first module deals with the fundamentals of data sciences, the other module on AI for Earth Observation.

GeoData Science Modules	Courses	ECTS
Module 1: Fundamentals of Data Science ***15 ECTS***	Machine Learning	6
	Foundations of Deep Learning	3
	Big Data	6
Module 2: Artificial Intelligence for Earth Observation ***15 ECTS***	Efficient Remote Sensing Image Processing	6
	Deep Learning for Computer Vision	3
	Geospatial Data Analytics Project	6

Table 31 Modules of the specialization track on 'GeoData Science & AI4GEO'

3.2.2. Relevant courses

In table 32 a selection is shown of the most relevant courses at KU Leuven, i.e. courses that could inspire and support the design of the SEED4NA project curriculum on SDI and EO.

Courses	Learning outcomes
Advanced Remote Sensing	- understand the larger space policy context of satellite Earth observation with a particular focus on the Copernicus programme - familiarise with advanced methods, tools and techniques of remotely sensed imagery; - master image analysis tools and methods to a degree to be confident in tackling 'real-world' application scenarios; - apply specific image acquisition techniques (VHR optical data, Radar data, Lidar, UAV) - perform image pre-processing (calibration, filtering, and pre-classification) - conduct spatial image analysis using image segmentation, advanced classifiers (both physical-model based and statistical) and assess the quality of the results.
Copernicus Hubs and Institutions	- have a better understanding of the EU space programme - get in contact with these initiatives enabling further networking and potential career options; - experience and discuss implementation of Copernicus data with key players in Europe.
Digital Earth: Big Earth Data Concepts	- understand current trends of big data in remote sensing and its background - apply new concepts and approaches.
Analysis and Modeling (Remote Sensing)	- compile small hands-on experiments and/or comparative methodological studies - evaluate different tools in terms of availability, applicability and suitability and recommend a responsible usage and parametrisation - apply various analysis techniques with a focus on image data - understand and explain a specific analysis process in an appropriate methodological depth - remember and relate fundamental tools and methods in the field of remote sensing and image analysis
Design of Geospatial Data Models	- provision of background theories and their application in hands on experiences. - definition of data models - definition of data models based on UML - General Feature Model (GFM) as metamodel for the definition of geospatial data models - a quick introduction to XML - how to implement data models in XML - an introduction to the Geography Markukp Language (GML)

Table 32 Selection of relevant courses of the Copernicus Master in Digital Earth

3.3. Master Applied Geoinformatics (PLUS)

University of Salzburg also offers its own MSc program on Applied Geoinformatics, which aims to qualify students to join the growing field at the intersection of digital technologies and spatial sciences. Students are trained and prepared to become active worldwide in the geospatial domain and other domains, in different sectors (government, industry, academia, NGO or self-employed).

3.3.1. Overall structure

The master's programme in Applied Geoinformatics comprises seven modules with a total number of 90 ECTS points. This also includes 12 ECTS points assigned for elective courses and a mandatory internship. The master's thesis is worth an additional 30 ECTS points, resulting in a total of 120 ECTS. An overview of the seven modules and their courses is provided in table 30.

Modules	Courses	ECTS
Module 1: Propedeutics and Elective courses ***15 ECTS***	Electives (subjects recommended in orientation interview)	12
	Orientation and Introduction	1
	Scientific Methods and Writing	2
Module 2: GIScience: Theory and Research Methods ***6 ECTS***	Lectures in GIScience	2
	GIScience: Theory and Concepts	4
Module 3: Methods in Geoinformatics (3 courses to be selected) ***18 ECTS***	Advanced Remoted Sensing	6
	Multivariate Statistics | Spatial Statistics | Geostatistics	6
	Geovisualization and Advanced Cartography	6
	Geodata Acquisition	6
	Spatial Simulation	6
	Location Based Services	6
Module 4: Spatial Analysis and Modelling ***6 ECTS***	Methods in Spatial Analysis	2
	Analysis and Modelling	4
Module 5: Geo-Application Development ***12 ECTS***	Basics of Software Development	3
	Practice Software Development	3
	Application Development	6
Module 6: Spatial Data Infrastructures ***12 ECTS***	Design of Geospatial Data Models	3
	OpenGIS: Standards, Architectures and Services	3
	SDI Services: Implementation	6
Module 7: - I3 Project ***12 ECTS***	Interdisciplinary/Integrated/Interactive Project	12
Internship ***9 ECTS***	Internship	9
Master Thesis ***30 ECTS***	Master thesis	28
	ePortfolio	1
	Master's exam	1

Table 33 Modules of the MSc Applied Geoinformatics (PLUS)

3.3.2. Relevant courses

The program offers several courses on topics related to SDI and EO. Interesting to notice is that there's a dedicated module on SDIs, which consists of three courses: 'SDI Services: Implementation', ' OpenGIS: Standards, Architectures and Services' and 'Design of Geospatial Data Models'.

Courses	Learning outcomes
OpenGIS: Standards, Architectures and Services	- introducing the conceptual strategies, organizational requirements and legal frameworks for leveraging the advantages of Open GIS. - providing the organizational, legal and technical foundation for accessing, using and delivering geographic information in harmonized spatially enabled distributed IT service infrastructures. - learn how to utilize open, shared GIS resources like INSPIRE and Open-Government data - foster the students' understanding and ability to design and use Open GIS data structures, workflows and processes leveraging open information repositories.
Design of Geospatial Data Models	- provision of background theories and their application in hands on experiences. - definition of data models - definition of data models based on UML - General Feature Model (GFM) as metamodel for the definition of geospatial data models - a quick introduction to XML - how to implement data models in XML an introduction to the Geography Markukp Language (GML)
SDI Services: Implementation	- organizing and sharing GI resources - understand the principles and techniques of spatial data organization and apply these principles and techniques to design and build spatial databases (e.g. Oracle Spatial, Postgres PostGIS, ArcSDE etc.); - understand the concept of spatial data infrastructures; give examples of organizing spatial information in geoportals at organizational, enterprise, national, regional and global levels (e.g. ArcGIS Online) - publishing GI content and tools over the web: map services, data services, and analytical services; (e.g. ArcGIS Server, Geoserver Open Source) - discuss and define the interoperability needs beyond technical issues like direct access and industry standards on a legal, semantical and organizational level
Advanced Remoted Sensing	- understand the larger space policy context of satellite Earth observation with a particular focus on the Copernicus programme - familiarise with advanced methods, tools and techniques of remotely sensed imagery; - master image analysis tools and methods to a degree to be confident in tackling 'real-world' application scenarios; - apply specific image acquisition techniques (VHR optical data, Radar data, Lidar, UAV) - perform image pre-processing (calibration, filtering, and pre-classification) conduct spatial image analysis using image segmentation, advanced classifiers (both physical-model based and statistical) and assess the quality of the results.

Table 34 Selection of relevant courses of the MSc Applied Geoinformatics

4. Proposal for a SEED4NA curriculum on SDI and EO

In the previous two chapters an overview and analysis was provided on existing SDI/EO curricula currently provided at various higher education institutions in Europe. We looked into the relevant curricula at the four European universities participating in SEED4NA and into several curricula provided at other European universities, in which SDI and EO subjects were integrated. In this chapter we propose the building blocks of a SEED4NA curriculum on SDI and EO, which will serve as a basis for the curriculum projects that will be implemented at the partner universities.

4.1. SEED4NA curriculum on SDI and EO

Taken into consideration the setup and experiences of existing curricula on SDI/EO, we propose to structure the SEED4NA curriculum on SDI and EO around five main components. The structure of the curriculum and the five components are shown in figure 1. The five main components are:

I. GI, SDI and EO for geospatial solutions
II. Spatial Data Infrastructures
III. Earth Observation
IV. Applications of SDI and EO
V. Emerging technologies

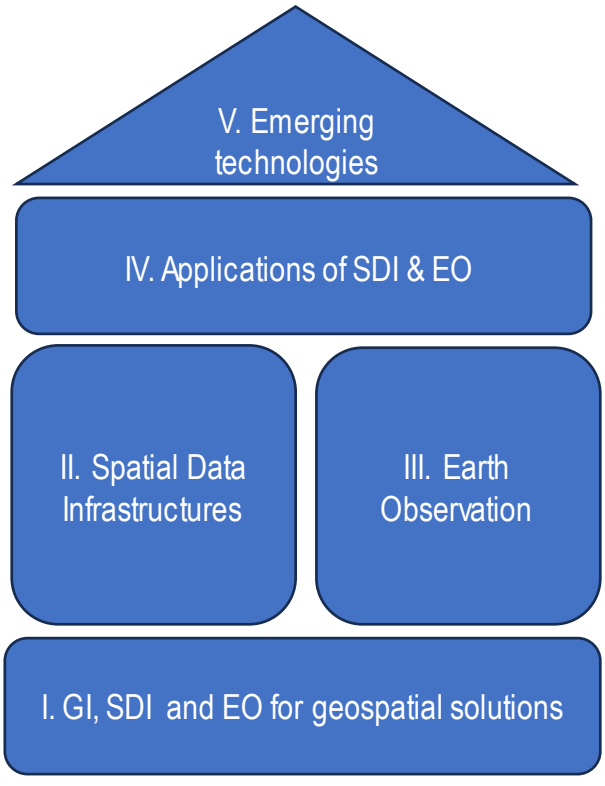

Figure 1 Building blocks of the SEED4NA curriculum

'GI, SDI and EO' provides the foundation of the curriculum, on which the two core blocks are built: 'Spatial Data Infrastructures' and 'Earth Observation'. Integration of the two core topics takes place in the building block on SDI/EO Applications, which looks at the application and integration of SDI and EO in addressing key societal challenges. Finally, there's a 'future-oriented' building block on new and emerging technologies.

In the following sections, we briefly present the content of these building blocks. Further detailing of the building blocks and their content and structure will be done by taking into consideration the needs of the SEED4NA partner universities and local stakeholders in Algeria, Morocco, Egypt and Tunisia. This adaptation process and its result will be presented in a separate deliverable.

4.2. GI, SDI and EO for geospatial solutions

The building block on 'GI, SDI and EO for geospatial solutions' aims to introduce GI(S), Spatial Data Infrastructure and Earth Observation' as key enablers of geospatial solutions. This building block will cover the entire 'geospatial' value chain, from acquiring and collecting geospatial data, over processing and managing the data, and towards sharing, analysing and visualizing the data for turning them into geospatial solutions to problems and challenges into society.

The core components of this building block – which could also be the basis for structuring it into different modules and courses – include:

- Foundations of GI, SDI & EO
- Data acquisition
- Databases & data management
- GI Programming
- Data analysis
- Geovisualization
- Geo-information products & services
- Data quality

In table 35 an overview is provided of existing courses in curricula offered at European universities related to each of these components. These courses could inspire the further development of these components as part of the SEED4NA curriculum, from determining learning outcomes to preparing and implementing teaching activities and assessing students.

Components	Related courses
Foundations of GI, SDI & EO	- GIS & RS for geospatial solutions (UT, MSc GIS and EO) - Geographic Information Science (MSc Geospatial Technologies) - Core Topics in Geographic Information Science (MSc Geospatial Technologies) - From data to knowledge (MSc Geospatial Technologies) - Spatial Thinking & Modelling (Copernicus Master in Digital Earth) - GIScience: Theory and Concepts (PLUS, MSc Applied Geoinformatics)
Data acquisition	- Geospatial Data: Concepts, Acquisition and Management (UT, MSc GIS and EO) - Acquisition and Exploration of Geospatial Data (UT, MSc GIS and EO) - Geodata Acquisition (PLUS, MSc Applied Geoinformatics)

Databases & data management	- Databases – Geodatabases (HSBO, BSc Geoinformatics) - Geodata Management Project (HSBO, BSc Geoinformatics) - Spatial Databases (UZ, MSc Geodesy and Geoinformatics) - Databases and Data Management (MSc Geospatial Technologies)
GI Programming	- GIS Programming (KU Leuven, MSc Geography) - Introduction to Geoprocessing (KU Leuven, MSc Geography) - Programming (MSc Geospatial Technologies) - Programming in GI (MSc Geospatial Technologies)
Data analysis	- Geospatial Analysis and Interpretation (UT, MSc GIS and EO) - Spatial analysis with GIS (HSBO, BSc Geoinformatics) - Extraction, Analysis and Dissemination of Geospatial Information (UT, MSc GIS and EO) - Spatial Analysis and Visualization ((MSc Geospatial Technologies) - Methods in Spatial Analysis (PLUS, MSc Applied Geoinformatics)
Geovisualization	- Geovisualisation (UZ, MSc Geodesy and Geoinformatics) - Development of Applications for Geographic Data Exploration and Visualization ((MSc Geospatial Technologies) - Spatial Analysis and Visualization (MSc Geospatial Technologies) - Geovisualisation and Advanced Cartography (Copernicus Master in Digital Earth) - Systematic Geovisualisation (Copernicus Master in Digital Earth) - Advanced Methods of Geovisualisation (Copernicus Master in Digital Earth) - Design in Geovisualisation (Copernicus Master in Digital Earth)
Geo-information products and services	- Design of geo-information products (HSBO, MSc Geoinformatics) - Location-based services (MSc Geospatial Technologies)
Data quality	- Geoinformation Quality (UZ, BSc Geodesy and Geoinformatics) - Geodata quality and automated checking (HSBO, MSc Geoinformatics)

Table 35 Components of the building block on 'GI, SDI & EO for geospatialtial solutions'

For each of these components, we believe it's especially useful to address the relevance and importance of SDI and EO, rather than providing a very detailed knowledge and understanding of each of them. In some cases, these components already will be tackled earlier in the educational career or learning path. But an overall understand of the value chain of turning raw data into location-enabled decisions, products and/or services is recommended, prior to introducing the core building blocks on SDI and EO.

4.3. Spatial Data Infrastructures

The building block on 'Spatial Data Infrastructures' covers all the core aspects and components of Spatial Data Infrastructures. It starts with an introduction and discussion of each of these components, combined with real examples of SDIs in different parts of the world. Since standards and interoperability are key to the development and implementation of SDIs, these also should be covered. This also applies to data modelling, SDI services and the non-technological aspects of SDIs.

The core components of this building block – which could also be the basis for structuring it into different modules and courses – include:

- Spatial Data Infrastructures: components & practices
- Standards and interoperability
- Spatial data modelling
- SDI Services
- Organisational and institutional aspects of SDIs

Components	Related courses
SDI: components & practices	- Geodata Infrastructures (HSBO, BSc Geoinformatics) - Geospatial Information Technologies (KU Leuven, MSc Geography) - Geoinformation Infrastructure (UZ, BSc Geodesy and Geoinformatics)
Standards and interoperability	- Norms and standards (HSBO, BSc Geoinformatics) - Geospatial Information Technologies (KU Leuven, MSc Geography) - Spatial Data Services, Sources, Standards and Infrastructures (MSc Geospatial Technologies) - OpenGIS: Standards, Architectures and Services (PLUS, MSc Applied Geoinformatics)
Spatial data modelling	- Modelling spatial data (HSBO, MSc Geoinformatics) - Geospatial Information Technologies (KU Leuven, MSc Geography) - Geoinformation Modelling (UZ, BSc Geodesy and Geoinformatics) - Design of Geospatial Data Models ((Copernicus Master in Digital Earth) - Design of Geospatial Data Models (PLUS, MSc Applied Geoinformatics)
SDI services	- Web-based GIS (HSBO, BSc Geoinformatics) - Extraction, Analysis and Dissemination of Geospatial Information (UT, MSc GIS and EO) - Geospatial Information Technologies (KU Leuven, MSc Geography) - Spatial Data Services, Sources, Standards and Infrastructures (MSc Geospatial Technologies) - OpenGIS: Standards, Architectures and Services (PLUS, MSc Applied Geoinformatics) - SDI Services: Implementation (PLUS, MSc Applied Geoinformatics)
Organisational and institutional aspects of SDIs	- Official Geodata (HSBO, BSc Geoinformatics) - Development and organization of information infrastructures HSBO, (MSc Geoinformatics) - Geospatial Information Technologies (KU Leuven, MSc Geography) - Open Geoinformation (UZ, BSc Geodesy and Geoinformatics) - OpenGIS: Standards, Architectures and Services (PLUS, MSc Applied Geoinformatics)

Table 36 Components of the building block 'Spatial Data Infrastructures'

4.4. Earth Observation

The SEED4NA curriculum also contains a building block on Earth observation, which covers all core aspects of EO, from the principles of remote sensing, over the different – types of – satellites, sensors and imagery, to image processing and analysis and platforms for accessing EO data. In line with this, the core components of this building block include:

- Principles of remote sensing
- Satellites, sensors & imagery
- Image processing and analysis
- EO platforms

In table 37 we provide an overview of the already existing courses offered at European HEIs on each of these components. Important to notice is that many of these courses cover multiple of these components. Often, curricula rather make a distinction between introductory/basic courses and 'advanced' courses on remote sensing and EO.

Components	Related courses
Principles of remote sensing	- Geospatial Data: Concepts, Acquisition and Management (UT, MSc GIS and EO) - Introduction to remote sensing (HSBO, BSc Geoinformatics) - Advanced methods of remote sensing (HSBO, BSc Geoinformatics) - Introduction to Remote Sensing (KU Leuven, MSc Geography) - Remote Sensing of the Environment (KU Leuven, MSc Geography) - Earth Observation (KU Leuven, MSc Bioscience Engineering) - Remote Sensing (UZ, BSc Geodesy and Geoinformatics) - Advanced Remote Sensing (UZ, MSc Geodesy and Geoinformatics) - Earth Observation and Remote Sensing (MSc Geospatial Technologies) - Digital Earth: Big Earth Data Concepts (MSc Geospatial Technologies) - Advanced Remote Sensing (UZ, MSc Geodesy and Geoinformatics) - Remote Sensing of the Environment (KU Leuven, MSc Geography)
Satellites, sensors & imagery	- Introduction to Remote Sensing (KU Leuven, MSc Geography) - Earth Observation and Remote Sensing (MSc Geospatial Technologies) - Advanced Remoted Sensing (PLUS, MSc Applied Geoinformatics) - Advanced Earth Observation Techniques (KU Leuven, MSc Geography)
Image processing and analysis	- Spectral Data Processing (UT, MSc GIS and EO) - Digital Image Processing (HSBO, BSc Geoinformatics) - Advanced Remoted Sensing (PLUS, MSc Applied Geoinformatics) - Image Analysis (UT, MSc GIS and EO) - Object-Based Image Analysis (Copernicus Master in Digital Earth) - Analysis and Modelling (Remote Sensing) (Copernicus Master in Digital Earth)
EO platforms	- Earth Observation (KU Leuven, MSc Bioscience Engineering) - Advanced Remoted Sensing (PLUS, MSc Applied Geoinformatics)

Table 37 Components of the building block 'Earth Observation'

4.5. Applications of SDI and EO

In addition to the core building blocks on SDI and EO, the SEED4NA curriculum also includes a seperate building block on applications of SDI and EO, i.e. on SDI and EO to support and enable applications in different fields and domains. The overall aim of this building block is to introduce students into the use of SDI and EO for providing – geospatial – solutions to key challenges in different domains of society. The building blocks consists of an – introductory – component, in which a general look is provided how SDI/EO could enable solutions in many domains. In addition to these, there are also components on specific fields or domains, such as natural resources management, water management, spatial planning, land administration, etc.

The proposed components of this building blocks include:

- SDI and EO applications
- Natural Resources Management
- Water Management
- Spatial Planning
- Land Administration
- Natural Hazards and Disaster Risk Reduction
- Cities & local government

In the existing curricula on SDI/EO, we noticed courses on each of these components are provided at different universities, which could support the further development of these components as part of SEED4NA.

Components	Related courses
SDI and EO Applications	- Global Challenges, Local Action (UT, MSc GIS and EO) - Introduction to the Sustainability Debate (HSBO, MSc Geoinformatics) - Advanced Remote Sensing (UZ, MSc Geodesy and Geoinformatics) - GIS in Application (UZ, MSc Geodesy and Geoinformatics) - Application Development (Earth Observation) (Copernicus Master in Digital Earth) - Design of geo-information products (HSBO, MSc Geoinformatics) - Location-based services (MSc Geospatial Technologies)
Natural Resources Management	- Earth Observation for Natural Resources Management (UT, MSc GIS and EO) - Natural Resources Management Fundamentals (UT, MSc GIS and EO) - From Data to Geo-information for Natural Resources Management (UT, MSc GIS and EO) - Environmental Monitoring and Modelling for Natural Resources Management (UT, MSc GIS and EO) - Remote Sensing of Vegetation, Soil and Water Systems (KU Leuven, MSc Geography)
Water Management	- Water, climate and cities (UT, MSc GIS and EO) - Earth Observation of Water Resources (UT, MSc GIS and EO) - Hydrological and Environmental Cycles (UT, MSc GIS and EO) - Observing and Modelling Surface Water in a Changing World (UT, MSc GIS and EO) - Shades-of-Blue: Earth Observation of Coastal and Inland Waters (UT, MSc GIS and EO) - Catchment Hydrology and Surface Water (UT, MSc GIS and EO)

	- Remote Sensing of Vegetation, Soil and Water Systems (KU Leuven, MSc Geography)
Spatial Planning	- Intra Urban Spatial Patterns and Processes (UT, MSc GIS and EO) - Building Inclusive and Competitive Cities (UT, MSc GIS and EO) - Planning Sustainable Cities (UT, MSc GIS and EO) - The Compact City (UT, MSc GIS and EO) - Risk-sensitive urban planning studio (UT, MSc GIS and EO)
Land Administration	- Land Information Systems and Models (UT, MSc GIS and EO) - Organising Land Information (UT, MSc GIS and EO) - Responsible Land Administration (UT, MSc GIS and EO) - Cadastral Data Acquisition Technologies and Dissemination Methods (UT, MSc GIS and EO) - Land Management (HSBO, BSc Geoinformatics) - Real Estate Cadastre (HSBO, BSc Geoinformatics) - Cadastre (UZ, BSc Geodesy and Geoinformatics)
Natural Hazards and Disaster Risk Reduction	- Introduction to Disaster Risk and Data Input for Hazard Modelling (UT, MSc GIS and EO) - Physically-based Hazard Modelling (UT, MSc GIS and EO) - Data-driven Hazard Modelling (UT, MSc GIS and EO) - Disaster Risk Management (UT, MSc GIS and EO)
Cities & local government	- Intra Urban Spatial Patterns and Processes (UT, MSc GIS and EO) - Water, climate and cities (UT, MSc GIS and EO) - Building Inclusive and Competitive Cities (UT, MSc GIS and EO) - Planning Sustainable Cities (UT, MSc GIS and EO) - The Compact City (UT, MSc GIS and EO) - Urban Studies (KU Leuven, MSc Geography)

Table 38 Components of the building block 'Applications of SDI and EO'

4.6. Emerging technologies

As 'closure' of our SEED4NA curriculum, we propose the inclusion of a separate building block on 'Emerging technologies', which looks into new technologies in the geospatial domain. Looking at the existing curricula, we discovered three technological developments that are covered in multiple curricula: artificial intelligence, big data and 3D and digital twins. We proposes these as the three core components of the building block on 'Emerging technologies'. In table 38 we identify existing courses related to each of these three components.

Components	Related courses
Artificial intelligence	- Artificial Intelligence (MSc Geoinformatics) - Artificial Intelligence for Earth Observation (Copernicus Master in Digital Earth)
Big data	- Big GeoData (HSBO, BSc Geoinformatics) - Big Geodata Processing (UT, MSc GIS and EO) - Big Data (Copernicus Master in Digital Earth)

3D & Digital Twins	- 3D Modelling for City Digital Twins based on Geospatial Information (UT, MSc GIS and EO) - Digital Twin for Water, Energy and Food Security (UT, MSc GIS and EO) - Specialised 3D Models (HSBO, BSc Geoinformatics)

Table 39 Components of the building block 'Emerging technologies'

5. Conclusion

The aim of this deliverable was to introduce and present the core building blocks and components of the SEED4NA curriculum on SDI and EO. The design of this curriculum was inspired by existing curricula on SDI and EO at the European universities participating in SEED4NA and some other curricula on SDI/EO offered in Europe. In total nine different curricula on SDI/EO were identified, of which the overall structure and content was presented and investigated. The most relevant courses were highlighted, as they could be of great value for the development and implementation of the SEED4NA curriculum on SDI and EO.

Based on this investigation of existing curricula and the way they are structured, a proposal for a SEED4NA curriculum on SDI and EO was made, consisting of five main building blocks: GI, SDI and EO for geospatial solutions, Spatial Data Infrastructures, Earth Observation, Applications of SDI and EO, and Emerging technologies. For each of these building blocks we also identified several key components, as well as existing courses on each component.

The next step now is to adapt and further specify this curriculum to the needs of the stakeholders in North Africa, and in each of the four SEED4NA partner countries (Egypt, Algeria, Morocco & Tunisia) in particular. This will be done by taking into consideration the needs and stakeholders of these stakeholders, and of the experts involved in the design and delivery of SDI/EO education at the partner universities of SEED4NA. Later in the project the SEED4NA curriculum will be the basis for the development and implementation of updated and new courses at the eight partner universities.