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Structuring Thesis Topics within the Copernicus Master in Digital Earth: Preparing Alumni for Future-Oriented Careers in the Space Industry

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Abstract

The Copernicus Master in Digital Earth (CDE), a joint European Master of Science, co-funded by the Erasmus Mundus programme, addresses the growing demand for geospatial experts by equipping students with advanced skills in Earth observation, geoinformatics, geovisualisation and geodata science. We propose a unified master's thesis framework that encompasses development strategy, geospatial datasets, implementation mode, geographic scope, and application domains, aiming to bridge theory and practice while fostering innovative and research-driven education. Compulsory internships linked to thesis projects strengthen academia-industry collaboration, enabling students to address societal challenges such as climate change, green transition and digital transformation. The CDE programme has produced numerous joint publications, dedicated industry partnerships and even start-ups, with alumni excelling in academia, industry and public service. By uniting research, education and industry, the CDE exemplifies a role model for educating geospatial professionals in the broader scope of global challenges.

1. Introduction

The European Commission emphasises optimising the benefits space brings to society and the economy, as outlined in the Space Strategy for Europe (EC, 2023). Surveys, policy documents, and blueprint skills projects have highlighted a growing demand for qualified geospatial experts (Hofer et al., 2020). The Copernicus Master in Digital Earth (CDE), co-funded by the Erasmus Mundus Joint Master (EMJM) programme, addresses this need by equipping students with advanced technical and research skills to potentially improve geospatial services (Brunner-Maresch et al., 2023).

The CDE is a two-year, full-time integrated European Master of Science programme that qualifies individuals to lead initiatives, projects, and institutions, translating Copernicus data and Earth Observation (EO) services, both remote sensing and in-situ, into management decisions within a broader digital Earth vision. The programme's interdisciplinary approach ensures that students acquire a robust foundation in EO and GeoInformatics (GI) during the first year of study at Paris-Lodron University of Salzburg in Austria, before specialising in one of two advanced tracks during the second year: GeoData Science or GeoVisualisation and Geocommunication. The former is conducted at the University of South Brittany (UBS) in France, while the latter is at the Palacký University Olomouc (UPOL) in the Czech Republic. This structure enables students to gain deep expertise in their chosen area while maintaining a strong generalist geospatial skill set, making them highly adaptable professionals in a rapidly evolving field.

Accredited as a fully recognised EMJM programme by the Agency for Quality Assurance and Accreditation Austria (AQ Austria), the CDE maintains the highest academic standards. The joint degree is delivered through a consortium led by the University of Salzburg in collaboration with UBS and UPOL. Additionally, numerous associated academic and industry partners contribute to the programme, ensuring a rich learning experience that integrates theoretical and applied knowledge.

CDE welcomes applicants from diverse backgrounds in the geospatial disciplines, including (but not limited to) geography, geoinformatics, remote sensing, data science, geology, environmental sciences, urban and regional planning, civil engineering, and computer science. The programme is designed to attract both young graduates at the start of their careers and professionals looking to enhance their expertise in EO and GI. Graduates of the programme have gone on to successful careers in academia, government agencies, private sector enterprises, and even entrepreneurial ventures.

Master's thesis projects play a key role in introducing students to academic research and practical problem-solving in EO and GI. They serve as a bridge between learned knowledge and its application, enabling students to tackle real-world challenges. Aligned with the programme's objectives, these projects equip students with cutting-edge expertise and leadership skills, ensuring they are prepared for impactful careers in academia, industry and public service. By integrating hands-on research with strong industry linkages, CDE fosters innovation and positions its graduates as key actors in addressing global challenges.

2. Joint Currilculum and Unified Master's Thesis Structure

CDE builds on joint teaching and unique research expertise in applied geospatial methodology, computer science, and geovisualisation coordinated by the University of Salzburg. Several international associated partners from academia and in-

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dustry provide added value to faculty and students (CDE Partners, 2025). The joint curriculum (see Figure 1) is designed to provide students with technical and transversal skills in digital Earth observation. In this context, the Book of Knowledge (Lemmens et al., 2022) and Bloom's Taxonomy (Anderson and Krathwohl, 2001) have been integrated into modules and course development.

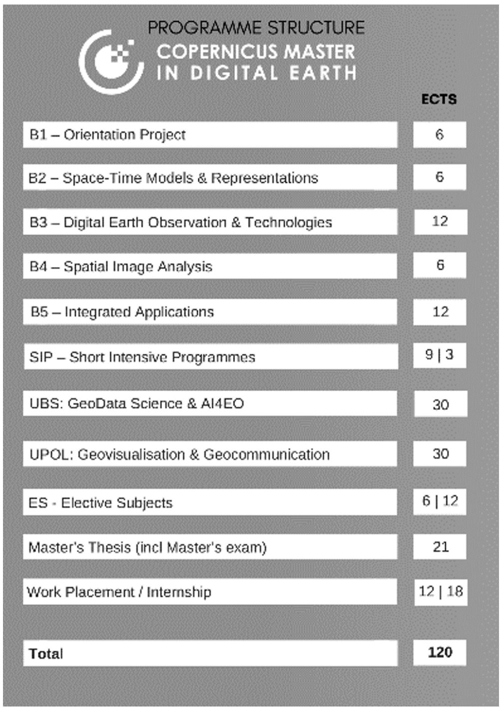


Figure 1. CDE curriculum.

The Erasmus Mundus Joint Master curriculum is structured to ensure a balanced and comprehensive learning experience, maintaining a total of 30 ECTS per semester. The programme framework supports a broad-based yet specialized education in Geoinformatics, EO, remote sensing, cartography, geovisualisation, and computer science, with a strong applied emphasis on Copernicus data and services within the digital Earth framework. The curriculum underwent revisions in 2023, ensuring its continuous alignment with technological advancements and industry needs. The latest 2023 curriculum governs the current programme structure (Curriculum, 2023). The third semester is dedicated to specialisation at one of the designated partner universities, typically leading to a master's thesis aligned with the chosen track in the final semester. A compulsory work placement is conducted either as a full-time engagement during semester breaks or as an equivalent part-time experience.

The success of this joint degree framework (Geodata Science, Geovisualisation and Geocommunication) emphasises the importance of a unified structure for master's thesis projects, reflecting the programme's commitment to fostering high-quality research and skill development. A standardised approach ensures that thesis topics align with both academic rigor and the practical demands of the geospatial industry (Brunner-Maresch et al., 2024). Given that the programme offers two distinct specialisation tracks, a unified structure is essential in maintaining coherence across different academic pathways. This ensures that students, regardless of their specialisation, adhere to a common set of guidelines for research methodology, data handling, and application relevance.

The unified structure also strengthens the integration of research and education by offering consistent guidelines that benefit both students and supervisors. It facilitates collaboration among the three universities and industry partners, ensuring that thesis topics address key societal challenges, such as climate change and digital transformation, while aligning with the latest advancements in EO and GI (Lang et al., 2021). Additionally, the Programme board, composed of representatives from all consortium universities, oversees critical academic decisions, including specialisation track assignments, work placement approvals, and thesis supervision protocols, ensuring academic consistency and fairness across the joint degree framework.

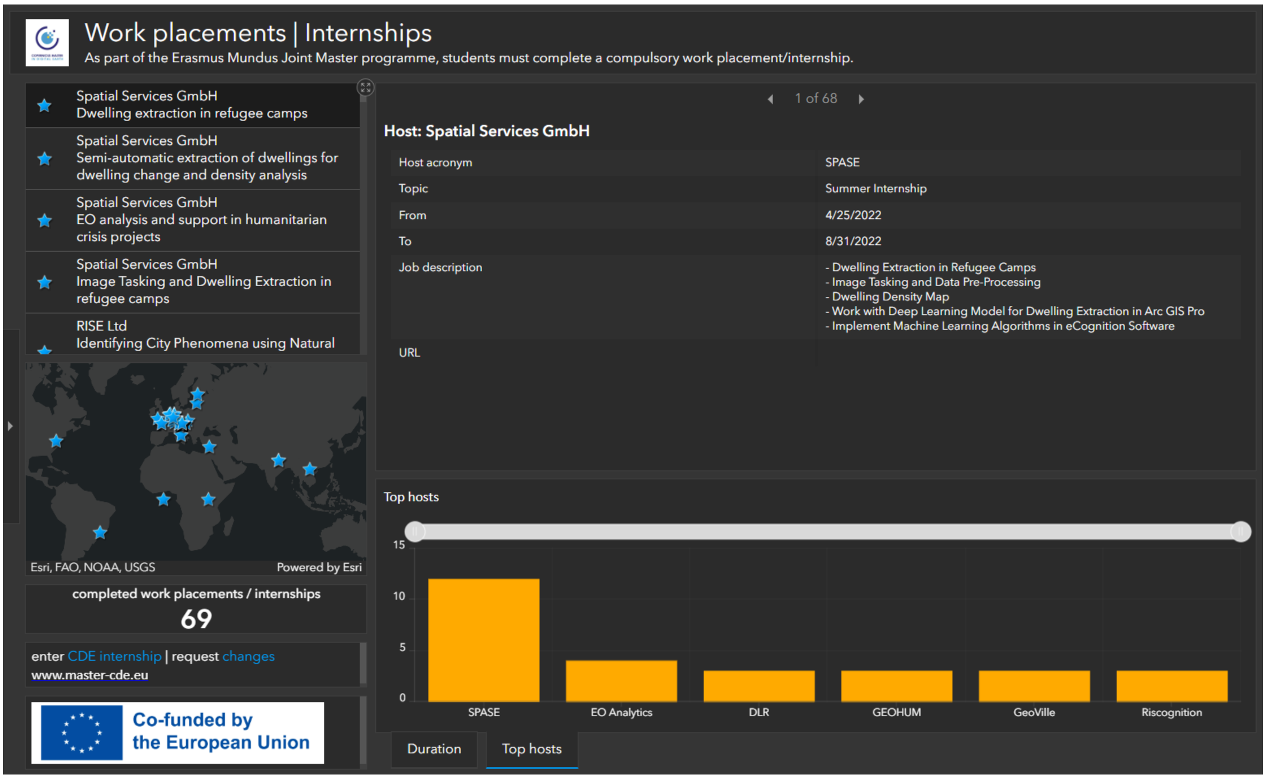
3. Academia – Industry Cooperation

CDE integrates compulsory skills-based internships and collaborative research work placements, ensuring that students gain industry exposure and apply their academic knowledge in real-world settings (Dashboard, 2025b) (Dashboard, 2025a). The professional internship, valued at 12 ECTS, spans at least eight weeks and is equivalent to full-time employment. Students opting for a research-oriented placement engage in a twelve-week collaborative work placement, worth 18 ECTS, align it with their Master's Thesis. This setup fosters practical learning and enhances employability by allowing students to develop technical and professional competencies while gaining insight into industry trends and requirements.

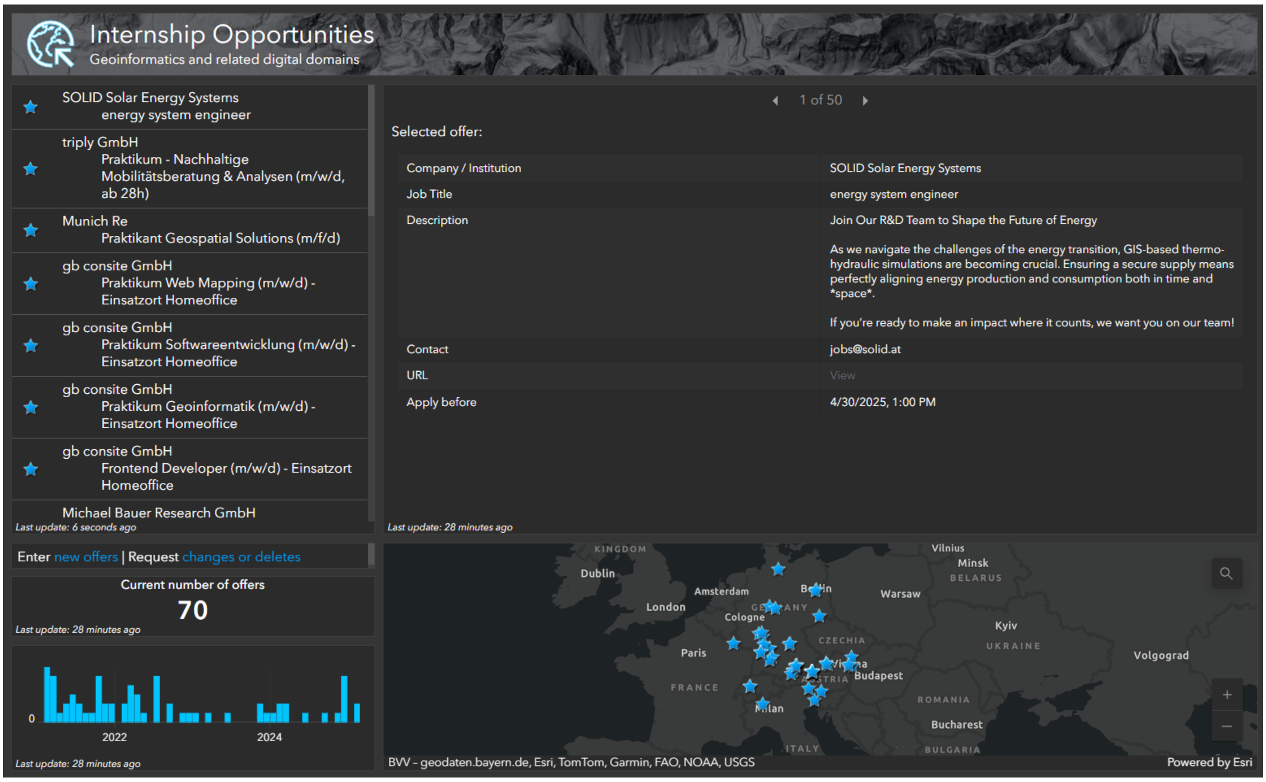
Internships are completed at pre-approved institutions, including both academic and non-academic partners, encouraging industry engagement and ensuring that students apply their expertise in practical settings. The Programme Board plays a key role in overseeing placement approvals, ensuring alignment with academic and professional standards. These placements provide students with invaluable experience, bridging the gap between theoretical knowledge and real-world application. By participating in work placements at organisations specialising in Earth observation, geoinformatics and related disciplines, students enhance their professional networks and future employment prospects.

A defining feature of the collaborative research work placement is its close integration with the master's thesis. Students undertaking this option work in research-focused environments, such as consortium partners or external research institutions, and contribute to ongoing scientific projects. These placements are structured to lead to joint research publications, further strengthening the connection between academia and industry. The emphasis on research-oriented placements ensures that students remain at the forefront of innovation, engaging with cutting-edge developments in digital Earth and geospatial technologies.

The added value of these internships and placements is highlighted by both students and employers. Students benefit from an applied learning experience that refines their technical skills, professional adaptability, and problem-solving abilities. For employers, hosting CDE interns provides an opportunity to integrate fresh perspectives and emerging geospatial techniques into their workflows while identifying potential future employees. Screenshots of the CDE work placement dashboard and internship opportunities Dashboard (see Figures 2.(a) and 2.(b)) illustrate available opportunities and placement distributions for the latest four intakes, demonstrating the programme's commitment to fostering academia-industry collaboration on a global scale.



(a)



(b)

Figure 2. Overview of the (a) work placement and (b) internship opportunities dashboards.

4. Master's Thesis Categorisation

As a core element of the CDE programme, master's theses demonstrate students' ability to conduct independent research in EO and GI. The program offers an integrated co-supervision framework, ensuring students receive guidance from multiple experts. To enhance thesis quality and relevance, a structured approach has been introduced, categorised into five main com-

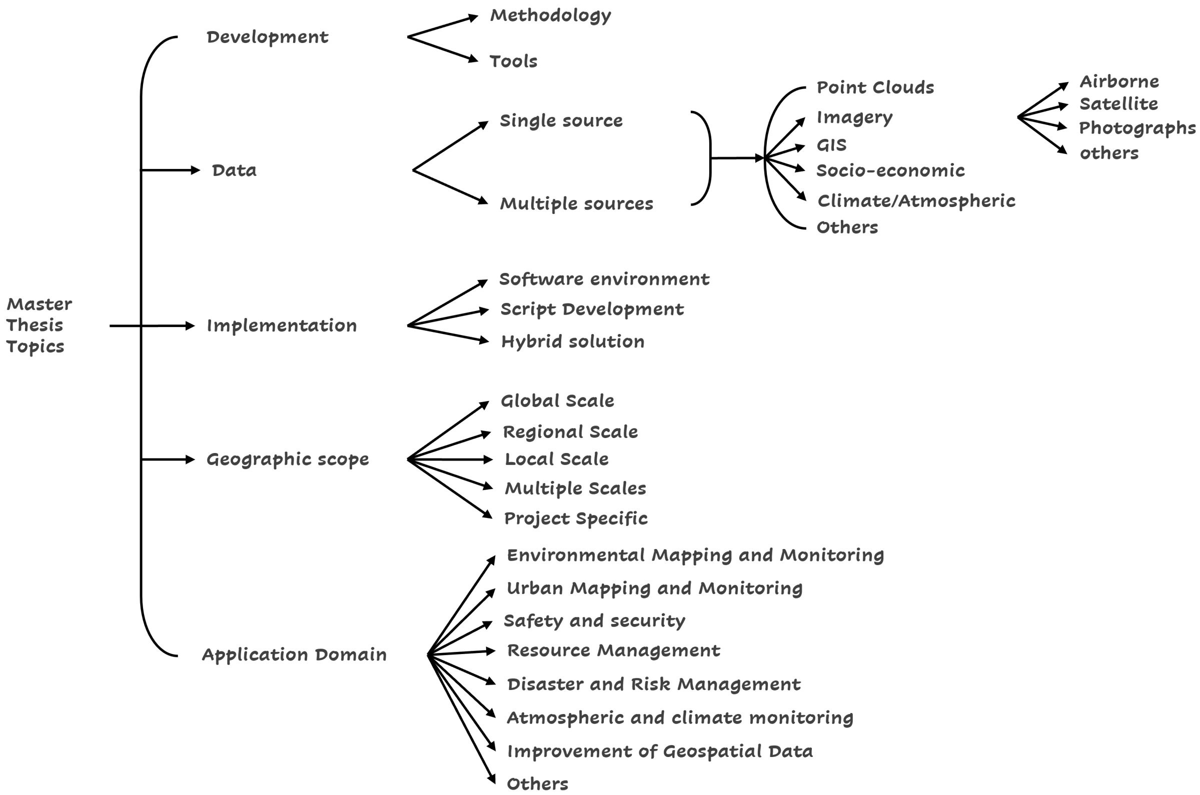
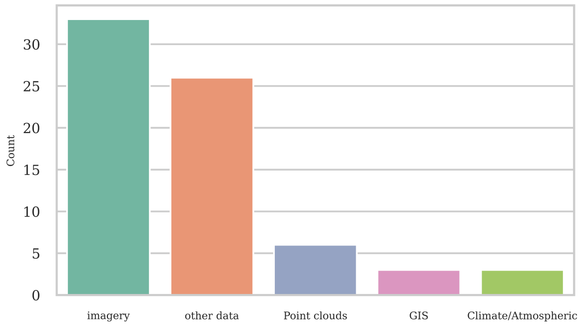


Figure 3. CDE master's thesis topics' components and categories.

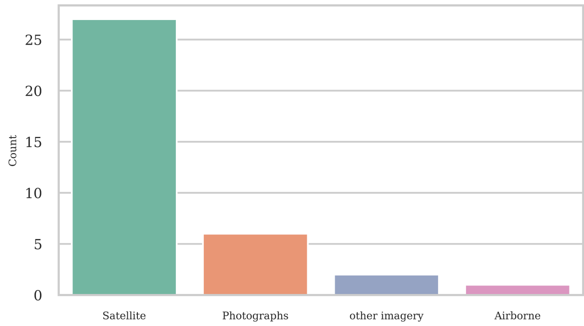
ponents as depicted in the diagram of Figure 3. They can be listed in the following:

- **Development** part of the topic that focuses on methodological advancements and the design or improvement of technical workflows conducted during the thesis project. This component is further divided into two main subcategories: methodology, which refers to the scientific approach and research strategy adopted, such as supervised learning, simulation modelling and time-series analysis, among countless others. The second subcategory is tools, referring to the software, libraries and platforms developed or adapted to implement the work. The latter can be Python tools, QGIS plugins and web-based applications. In general, development is the most important component since it leads to concrete solutions that can be prototypes, decision-support tools, workflows for data processing, and tools integration within existing operational systems in institutional or commercial settings.
- **Data** component that emphasises the diversity of EO and GI datasets employed. Subcategories include point clouds from LiDAR or photogrammetry and imagery with further classification into airborne, spaceborne, and photographs sources. It also includes GIS Data (vector/raster-based spatial databases) and climate/atmospheric data referring to outputs from weather models or in-situ sensor networks. Projects may utilise single or multiple data types, allowing comparative analyses, data fusion strategies, or integrated modelling approaches.
- **Implementation** section reflecting the applied dimension of the thesis work, focusing on how the work is executed and delivered. It includes three subcategories: writing a script, where students develop custom code or scripts for data processing, analysis and visualisation. The second subcategory consists of using interactive software, which involves exploiting existing platforms and tools to carry out the research. Lastly, scripting can be combined with interactive tools as a hybrid solution to create more adaptable and efficient workflows. This categorisation allows flexibility in methodological approaches while maintaining a clear focus on practical applicability.
- **Geographic Scope** outlines the spatial context of the research. Master thesis projects may operate at a global, regional, and local scale, each offering different analytical challenges and potential impact. Additionally, a multiple scope category is included for theses that integrate analyses across different spatial levels, such as comparing urbanisation patterns across multiple cities. A further project-specific category is available for work that is not explicitly location-based, such as simulation environments, games and algorithm development emphasising flexibility and innovation within the GI framework.
- **Application Domains** underscore the societal and market-driven relevance of the conducted master thesis research. Categories include: environmental mapping and monitoring, urban mapping and monitoring, atmospheric and climate monitoring, risk and disaster monitoring, resource management, safety and security and improvement of geospatial Data. These domains allow students to align their research with policy priorities, commercial needs and global development goals.

This structuring ensures that students can align their research with current scientific and industry needs, promoting innova-



(a)



(b)

Figure 4. Distribution of different (a) data types and (b) imagery types.

tion and interdisciplinary solutions. The categorisation has resulted in impactful outcomes such as joint research publications, industry collaborations, high-profile conference presentations, and startups, illustrating the programme's success in bridging academia and real-world application.

5. Results and Impact

This section presents an overview of the measurable outcomes and long-term impact of the CDE programme. It focuses on analysing feedback collected through a dedicated alumni and student survey, complemented by internal programme statistics and performance indicators. The charts and visualisations provided illustrate the distribution and frequency of selected categories within the structured components of master's theses, as outlined in the previous section (see Figure 3). This includes data on methodological approaches, types of datasets used, implementation strategies, spatial contexts, and thematic application domains. These results are used to assess the effectiveness of the master's thesis core components in equipping graduates with the skills and opportunities necessary to thrive in the geospatial domain. In doing so, we aim to highlight the theses' contribution to bridging the gap between higher education, research, and the job market.

5.1 Analysis and Discussion

The analysis of the structured master's thesis components, based on survey data collected from the latest four CDE student intakes, provides valuable insights into the diversity and focus areas within the programme. These results align with the structured categorisation model presented in the previous section, offering a quantitative perspective on how students apply and interpret the five core components (Data, Development, Implementation, Geographic Scope, and Application Domains) in their thesis research.

In terms of data types used (see Figure 4.(a)), imagery dominates with 33 instances, reflecting the central role of EO-derived raster data in geospatial research. This is consistent with the strong emphasis within the CDE curriculum on remote sensing and EO analysis. Other data types follow closely (26 instances), which include a range of composite and student/project-defined datasets. The prevalence of this category demonstrates that students are not restricted by predefined options but are encouraged to explore, integrate, or even generate new data sources. Point clouds, GIS data, and climate/atmospheric data were used less frequently, yet still represent important, specialized areas of research.

A more detailed look at the imagery subcategory (See Figure 4.(b)) confirms that satellite imagery is by far the most used imagery type (27 out of 36 imagery-related projects), highlighting the accessibility and analytical richness of data from various missions, particularly freely available Sentinel missions provided by the European Space Agency (ESA). Photographic sources likely from UAVs and ground surveys accounted for six projects, while airborne imagery and other imagery types had a marginal presence. This breakdown reflects the practical realities of data availability and cost, with satellite platforms offering scalable, free, and open-access data.

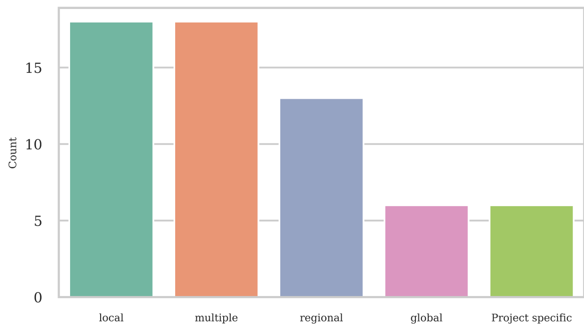


Figure 5. Distribution of different geographic scope.

The Geographic Scope distribution (see Figure 5) reveals a relatively balanced approach among different spatial levels. Local and multiple scope projects (18 each) dominate, illustrating a strong interest in addressing highly localised issues while also conducting comparative and multiscale studies. Regional and global studies are also represented, albeit less frequently, due to the complexity and data requirements associated with such scales. Interestingly, six projects were categorised as project-specific, including work that does not involve a physical geography component, such as software prototyping, simulations and educational tools. This confirms that the CDE programme successfully accommodates projects that do not rely on spatial analysis, further underscoring its methodological flexibility.

Implementation-related components are shown in Figures 6 and 7. The results reflect a wide spectrum of technical strategies adopted by students. In Figure 6, a notable majority (31 responses) fall under a general category of other implementation

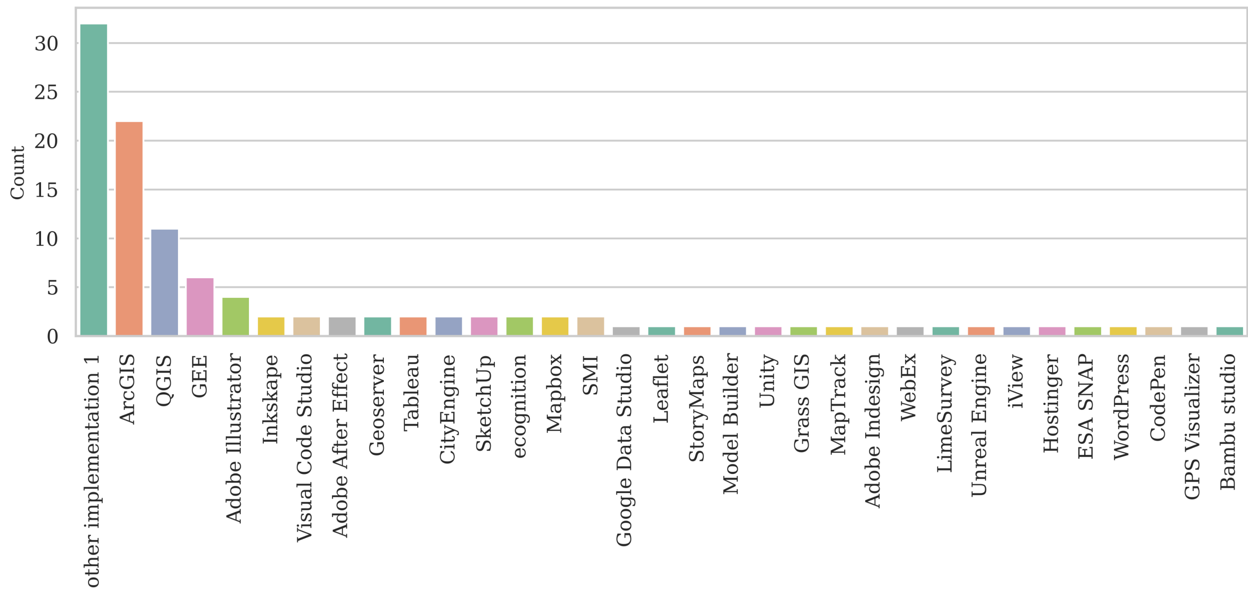


Figure 6. Distribution of different software environments.

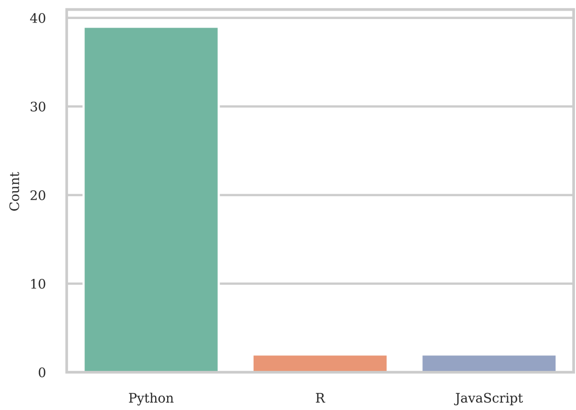


Figure 7. Distribution of different programming languages.

strategies, suggesting a significant diversity in software usage and combinations. Specific software environments such as ArcGIS, QGIS, GEE, Adobe Illustrator, and advanced visualisation or web development tools such as Leaflet, Unity and SketchUp were often used in combination, highlighting an integrative approach to geospatial implementation. Figure 7 confirms that Python is the dominant programming language used for script-based implementation (37 responses), indicating the high relevance of open-source scripting in data processing, automation, and model development. Other scripting languages like R and JavaScript appear minimally, often in multi-language projects, which points to the versatility and interoperability of different tools in student workflows.

Finally, Figure 8 illustrates the thematic distribution of application domains. The most prominent themes are environmental mapping and monitoring, urban mapping and monitoring and disaster and risk management, confirming that student research often aligns with global priorities and sustainability targets. Other domains, such as improvement of geospatial Data, atmospheric and climate monitoring as well as resource management indicate a more specialised but impactful engagement. The security and safety and other domains categories reflect further thematic diversity, including emerging and unconventional applications.

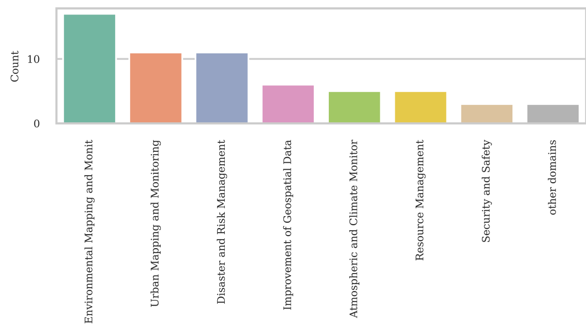


Figure 8. Distribution of different application domains.

Taken together, these findings affirm the adaptability and interdisciplinary nature of the CDE master's thesis framework. The high incidence of other responses across multiple charts, particularly for data types, implementation tools, and application domains, reflects a deliberate openness in the CDE educational model. Rather than constraining students to predetermined paths, the programme fosters autonomy, creativity, and exploration. This is especially critical in the context of a rapidly evolving geospatial industry, where adaptability and innovation are key competencies. Students are empowered to tailor their projects to personal interests, current research trends, or professional aspirations, often exploiting the programme's strong industry ties and international network of collaborators.

The Development component of the thesis framework, while not accompanied by a quantitative chart in this analysis, remains a central pillar in student projects. It encompasses the methodological and algorithmic core of the thesis work, reflecting how students design or innovate within the geospatial domain. Due to the inherently qualitative and multidimensional nature of this component, defining rigid subcategories proved challenging. Nevertheless, some recurring methodological directions have emerged across cohorts. These include the development or integration of Artificial Intelligenece (AI) frameworks, Map Animations and 3Dimensional (3D) Visualisations, as well as advanced techniques such as eye-tracking, time series modeling, and semantic enrichment. Other notable approaches involve data fusion, climate modelling, and a variety of object-related methods spanning from feature extraction to object detection, classification, counting, and recognition. Methods such as change detection, image enhancement, data augmentation, and map compilation are also prevalent. Finally, more comprehensive strategies, such as geospatial analysis and spatial synthesis, indicate the integration of multiple analytical perspectives. This diversity not only enriches the research landscape within the CDE but also equips students with transferable and forward-looking technical skills.

The results also validate the robustness of the thesis categorisation framework presented in this paper. By encouraging students to define their work through multiple lenses (methodological development, data integration, implementation strategy, geographic relevance, and societal impact), the framework promotes holistic thinking and practical problem-solving. It serves both as a scaffold for student learning and as a valuable evaluation tool for curriculum development. These insights are essential for the ongoing evolution of the CDE programme and may serve as a model for other interdisciplinary graduate programmes in the geospatial sciences.

5.2 Outcome impact

CDE alumni (CDE Career Paths, 2025) are highly skilled professionals equipped for careers in academia, industry, and public service. The programme's unique emphasis on collaborative research and structured thesis development has led to significant academic and professional outcomes. Notably, it has produced 45 joint publications (CDE Student–Faculty Research Publications, 2025), a number that continues to grow, reflecting the scholarly quality and relevance of the thesis work. Furthermore, the program has fostered an expanding professional network that spans multiple institutions and sectors.

Further demonstrating its collaborative and transdisciplinary nature, several CDE students have completed their master's thesis research through trilateral cooperation between the main coordination university (University of Salzburg), a partner specialisation university (UPOL or UBS depending on their specialization track), and a third institution. Among these partners is the University of Strasbourg's ICUBE-SERTIT laboratory. As a pioneer in transforming satellite data into geo-information with societal impact, SERTIT offers services in rapid mapping, risk and reconstruction, surface water monitoring, forestry and land use planning. Their integration of cutting-edge technologies, such as big data analytics, machine learning, and EO-based geo-information systems, provides a robust foundation for thesis work on disaster management, urban planning, and environmental monitoring. LISTIC (Laboratory of Computer Science, Systems, Information and Knowledge Processing) in France is another example, where students have explored machine learning for early detection of natural hazards through modality translation using EO data.

Another notable partner is the United Nations University – Institute for Environment and Human Security (UNU-EHS). Through this collaboration, CDE students engage in research on systemic risk, disaster risk reduction, and climate change adaptation, connecting environmental hazards to broader societal and developmental dynamics. The relevance and rigor of such research has even led to extended cooperation beyond graduation, with some students being offered consultancy roles and PhD positions within UNU. Other examples include master thesis partnerships with leading space agencies such as the German Aerospace Center (DLR), focusing on water quality derived from hyperspectral EO time series.

Individual success stories further highlight the programme's impact. A CDE graduate was awarded the prestigious Karl-Kraus Young Talent Award 2024 by the German Society for Photogrammetry, Remote Sensing and Geoinformation (DGPF). His thesis was recognized for its innovative approach and contribution to precision agriculture. His participation in the DGPF's annual conference and subsequent award underscore the academic excellence cultivated within the CDE framework.

The entrepreneurial outcomes of the programme are equally notable. Some alumni have translated parts of their thesis work into innovative ventures, founding the startups Wematics and Termatics. Wematics (WeMatics, 2025) offers tailored Earth observation services for urban planning, emergency response, and climate adaptation, leveraging EO data, GIS, and custom analytics to empower decision-makers. Termatics (Termatics, 2025), on the other hand, emerged from a thesis focused on terrain visualization and semantic enhancement and now delivers high-performance 3D mapping and immersive geospatial applications for science communication and urban development. These startups exemplify how thesis-driven research within CDE can catalyse entrepreneurial innovation and applied geospatial solutions.

By uniting research, education, and industry, the Copernicus Master in Digital Earth stands as a role model for training geospatial professionals capable of addressing global challenges. The program fosters not only academic excellence but also real-world impact through its integrative approach, empowering graduates to contribute meaningfully across scientific, policy, and commercial domains.

6. conclusion

The CDE offers a distinctive, harmonised approach to geospatial education, combining academic structure with practical relevance. Through its unified thesis framework, strong ties to research and industry, and emphasis on interdisciplinary methods, the program enables students to address real-world challenges with scientific rigor and innovation. The diversity and impact of the thesis outcomes, ranging from joint publications and institutional collaborations to award-winning research and entrepreneurial ventures, highlight the programme's success in preparing professionals who are both technically skilled and globally engaged. As such, CDE represents a compelling model for training the next generation of digital Earth experts.

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