

Enhancing Capacity Building in Earth Observation: Education and Training Tools for Sustainable Development Goals (SDGs) by European Regions

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ABSTRACT

This article highlights the contributions of the NEREUS Earth Observation Working Group (EO WG) experts in aligning the United Nations Sustainable Development Goals (SDGs) with the innovative use of Earth Observation (EO) tools and methodologies. By enhancing capacity building skills and sharing best practices across European regions, the EO WG demonstrates the transformative potential of regional expertise in tackling global sustainability challenges. The EO WG underscores how EO training tools and methodologies support critical SDGs, including sustainable cities and communities (SDG 11), climate action (SDG 13), life below water (SDG 14), and life on land (SDG 15). This group of experts shares EO tools and methodologies implemented on practical use cases. These cases are designed to address both local priorities and global challenges following a bottom-up approach, reinforcing the role of regional stakeholders in shaping EU and global space sustainability agendas (NEREUS, 2023).

Keywords: policy, regional governance, regions, Earth Observation (EO), sustainability, geospatial technologies, Sustainable Development Goals (SDGs), capacity building

Mejora de la capacidad de observación de la Tierra: herramientas de educación y formación para los Objetivos de Desarrollo Sostenible (ODS) por regiones europeas

RESUMEN

Este artículo destaca las contribuciones de los expertos del Grupo de Trabajo de Observación de la Tierra (GTOT) de NEREUS para alinear los Objetivos de Desarrollo Sostenible (ODS) de las Naciones Unidas con el uso innovador de herramientas y metodologías de Observación de la Tierra (OT). Al mejorar las capacidades y compartir las mejores prácticas entre las regiones europeas, el GTOT demuestra el potencial transformador de la experiencia regional para abordar los desafíos de la sostenibilidad global. El GTOT subraya cómo las herramientas y metodologías de capacitación en OT apoyan ODS cruciales, como ciudades y comunidades

sostenibles (ODS 11), acción climática (ODS 13), vida submarina (ODS 14) y vida de ecosistemas terrestres (ODS 15). Este grupo de expertos comparte herramientas y metodologías de OT implementadas en casos prácticos. Estos casos están diseñados para abordar tanto las prioridades locales como los desafíos globales siguiendo un enfoque ascendente, reforzando el papel de los actores regionales en la configuración de las agendas de sostenibilidad espacial de la UE y globales (NEREUS, 2023).

Palabras clave: política, gobernanza regional, regiones, observación de la Tierra (OT), sostenibilidad, tecnologías geoespaciales, Objetivos de Desarrollo Sostenible (ODS), desarrollo de capacidades

加强地球观测领域的能力建设：欧洲各地区 面向可持续发展目标的教育与培训工具

摘要

本文重点阐述了NEREUS地球观测工作组(EO WG)的专家在将联合国可持续发展目标(SDGs)与地球观测(EO)工具及方法的创新应用相结合方面所作的贡献。通过加强能力建设并分享欧洲各地区的最佳实践，该工作组展示了区域专业知识在应对全球可持续发展挑战方面所具有的变革潜力。工作组强调了地球观测培训工具与方法如何支持关键的可持续发展目标，包括可持续城市和社区(SDG 11)、气候行动(SDG 13)、水下生物(SDG 14)以及陆地生物(SDG 15)。该专家组分享了在实际应用案例中实施的地球观测工具与方法；这些案例采用自下而上的方式，旨在同时应对地方优先事项与全球挑战，从而强化了区域利益攸关方在影响欧盟及全球空间可持续发展议程中的作用(NEREUS, 2023)。

关键词：政策，区域治理，区域，地球观测，可持续性，地理空间技术，可持续发展目标，能力建设

Introduction: Enhancing Regional Empowerment in Europe—The Added Value of EO Training Tools for the SDGs

In recent years, one of the most important aspects of European space policy has been the role of inter-

regional and intraregional cooperation at the pan-European level. With the tense geopolitical situation and the impacts of global warming reaching local and regional levels, European regions are adopting a more strategic approach towards the use of space and capacity building initiatives. In this context, sev-

eral European regions (e.g., the Azores, Portugal; Hesse, Germany; Occitanie, France; and Catalonia, Spain)—the level next to the national state—have launched their own regional space strategies, while others defined data exploitation strategies, adopted Regional Government Resolutions for the creation of a multidisciplinary working group on space technologies (Veneto region), or integrated the use of space into their regional Smart Specialisation Strategies (S3) (Região Autónoma dos Açores, n.d.; Hessian Ministry of Economics, Energy, Transport and Housing, 2023; Occitanie Region, n.d.; Institut d’Estudis Espacials de Catalunya, 2024; Veneto Region, n.d.a; Foray, 2015).

Although regional empowerment in the European space sector has received less attention, European regions are among the main users and procurers of space technologies, data, applications, and services, substantially impacting their economy, development, and growth.

In this respect, it is worth mentioning that the United Nations Sustainable Development Goals (SDGs) provide a global framework for addressing environmental, social, and economic challenges, which is linked also with the needs and goals of European regions (United Nations Department of Economic and Social Affairs, 2023). These regions face challenges such as climate adaptation, urban growth, and biodiversity preservation. Local and regional governments are essential for achieving the 2030 Agenda. A recent report by the OECD (2024) states that at least 105

out of the 169 SDG targets depend on their active engagement. Furthermore, in 2021, subnational governments accounted for 55% of public investment in OECD countries, highlighting their pivotal role in infrastructure development and the advancement of sustainability. Moreover, the proximity of regional authorities to citizens enables the development of tailored Earth Observation tools that can effectively address these challenges.

On this basis, this original work of the Earth Observation Working Group, comprising regional EO experts under NEREUS, the Network of European Regions Using Space Technologies (NEREUS, n.d.a.), aims to (a) highlight the relevance of the UN SDGs objectives to the needs of regional and local stakeholders, (b) demonstrate the potential of EO for sustainable regional development, and (c) showcase regional leadership in achieving SDGs. These experts come from both government and academia/research sectors, illustrating the successful outcomes from their interaction and emphasizing the university’s enhanced role in the transition from industrial to knowledge-based society (Cai & Etzkowitz, 2020).

This article highlights how regional space ecosystems—comprising authorities, universities, research centers, and other stakeholders—focus on citizen needs by implementing training programs and knowledge-sharing platforms as key components of EO capacity building. These initiatives help ensure that users across different sectors are skilled in interpreting and applying

EO data, fostering data-driven decision-making. Continuous learning and adaptation are also necessary to keep pace with advancements in EO technologies, further emphasizing the importance of sustained capacity-building efforts.

As environmental challenges grow in complexity, the ability to monitor, analyze, and respond to these issues using Earth Observation (EO) data has become indispensable. As emphasized by Masó et al. (2023), the use of EO data is relevant to compute the indicators defined by the SDGs at a high level of granularity. This approach is useful, for example, in order to detect “hot spots” at the regional scale, where traditional statistical reporting often fails to capture the diversity of local conditions.

In this context, capacity building refers to developing skills, training methodologies, tools, and infrastructure that enable regional stakeholders—governments, research institutions, private companies, and local communities—to effectively use EO data in decision-making processes (NASA Earth Science Division, 2022). European regions are adopting a more strategic approach towards the use of space and capacity building initiatives, but the widespread adoption of EO data by local and regional authorities still faces significant technological and organizational challenges (Filippi & Aiello, 2025). The research identifies a critical need for targeted capacity building to bridge the gap between space-based innovation and everyday public policy management.

EO capacity building is an important step for regions to equip their ecosystems with the right skills and knowledge to effectively use advanced EO tools and methodologies. As a result, local authorities and communities are better positioned to implement adaptive strategies that address both local and global challenges, such as climate resilience, urban planning, and natural resource management. Policymakers can leverage EO insights to make more informed decisions, enhance the quality of life, and address regional priorities and achieve the United Nations SDGs. In this regard, international evidence confirms that EO-based solutions can be significantly more cost-effective than traditional ground-based monitoring, with the potential to reduce data collection costs (Caribou Space, 2020).

To this end, the UN SDGs are highly relevant to regions as they address interconnected global challenges—such as climate change, urbanization, and biodiversity loss—that also appear at local and regional levels. Regions are at the forefront of implementing solutions, as they are directly responsible for managing resources, urban planning, and environmental conservation while addressing the needs of their citizens (NEREUS et al., 2018). Finally, this article aims to illustrate the link between regional and international cooperation, which is essential for aligning local actions with broader global objectives, and to highlight the role of regions as proving grounds for shaping future UN agendas.

Through the analysis of specific use cases, the article demonstrates how capacity building tools and methodologies in the EO sector address regional needs and challenges linked with the UN SDGs framework. Moreover, the presentation of regional EO training tools and methodologies highlights their innovative contribution to decision-making and policy development processes, specifically in the following SDGs: Industry, Innovation, and Infrastructure (SDG 9); Sustainable Cities and Communities (SDG 11); Climate Action (SDG 13); Life Below Water (SDG 14); and Life on Land (SDG 15).

In this respect, feedback from the Earth Observation Working Group (EO WG) demonstrates the transformative potential of regional collaboration by showcasing capacity-building initiatives and the use of EO tools and methodologies to present solutions to the UN SDGs.

Regional Best Practices and UN SDGs

The Veneto GNSS Network as a Model for Precision Positioning and Capacity Building to Foster Innovation (SDG 9)

Despite SDG 9 (Industry, Innovation, and Infrastructure) primarily addressing developing countries in response to global challenges (e.g., Africa's infrastructure deficit; United Nations Economic Commission for Africa [UNECA], 2022; IS-Global, n.d.) related to economic development, technological progress, and

infrastructure gaps, its overarching goal is to replace traditional industrialization methods with sustainable models. This shift aims to build resilient infrastructure and foster innovation, making SDG 9 relevant to all countries.

In the Veneto region, for several years, a collaborative effort between the Centre of Studies and Activities for Space (CISAS) "G. Colombo" at the University of Padova and regional authorities has resulted in the establishment of a robust GNSS network comprising almost 30 permanent stations (CISAS, n.d.; Veneto Region, n.d.b.).

The GNSS network in Veneto is essential for precise positioning and navigation across various sectors, particularly given the region's challenges with seismic activity and land subsidence. Accurate monitoring is crucial for risk mitigation, while positioning applications in precision farming and land surveying require real-time, high-accuracy data to ensure efficient operations. In recent years, the network has enabled centimetric-level accuracy in most agricultural applications, reducing operational errors and improving resource efficiency in fertilization and irrigation. Ongoing innovation enhances the GNSS network's capabilities, ensuring continuous improvements in accuracy, accessibility, and efficiency. Advanced methodologies such as RTK, PPP, and Galileo HAS support local needs and serve as a model for interregional and international collaborations. These innovations can be scaled to other regions, reinforcing their long-term impact and driving technological progress.

Aligned with SDG 9 of the 2030 Agenda, the network strengthens infrastructure resilience, supports predictive maintenance, and fosters technological innovation. It promotes sustainable industrialization by optimizing logistics, transportation, and resource management. Furthermore, by improving connectivity and reducing disaster risk, it contributes to safer and more efficient urban and rural development.

The network delivers Real-Time Kinematic (RTK) corrections using multi-constellation capabilities, including GPS, GLONASS, Galileo, and BeiDou, with upgrades underway for Galileo and BeiDou. RTK corrections are broadcast to professional users via the Networked Transport of RTCM via Internet Protocol (nTRIP). Advanced methodologies like the Master Auxiliary Concept (MAC) and Nearest Site (NRT) ensure optimal correction delivery based on user location. Meanwhile, ongoing research on Precise Point Positioning (PPP) and Galileo HAS continues to improve both accuracy and accessibility.

The actual total number of registered RTK users to the regional network is over 2,000. The average number of new registered RTK users is 30 on a monthly basis. According to statistics on users' type, the network is used mainly for precision farming (75%), land surveying (20%), and scientific/research aim (5%).

This initiative supports several UN SDGs, with a focus on fostering innovation. The Veneto GNSS network serves as an innovative model for re-

gional and international partnerships, with future developments demonstrating the potential for continued innovation and transferability across Europe and beyond.

Harnessing Earth Observation Capacity Building Tools for Achieving Sustainable Cities: A Focus on SDG 11

China's rapid urbanization driven by economic growth has led to severe air pollution, with two-thirds of cities failing to meet air quality standards. Particulate matter (PM) has become the major pollutant due to the shift from coal burning, while nitrogen oxides (NO_x) have remained stable but may increase with growing motorization; Beijing's air pollution control efforts offer hope for improving air quality amid rapid development and increasing vehicle use (Hao et al., 2005). By 2050, nearly 70% of the world's population is projected to live in cities (World Health Organization, 2020). In response to rapid urbanization and its associated challenges, the UN SDG 11 was established. This SDG aims to create sustainable cities and communities by ensuring inclusivity, resilience, and environmental sustainability in urban areas.

Across Europe, regional efforts to integrate EO tools into policymaking are paving the way for innovative solutions to urban challenges such as urban illumination, air pollution, heat islands, land-use change, and environmental degradation. The following examples highlight this common challenge at the local and regional levels, how the work

of the Earth Observation Working Group (EO WG) is reflected through capacity building, and the impact on regional policies. Across Europe, the EO WG experts have identified a number of EO tools and methodologies that support the achievement of sustainable cities and provide tangible solutions to diverse urban challenges. The overwhelming number of case studies submitted for this particular SDG underscores the urgent need for improved urban development.

A key example comes from municipalities in France. Artificial night light (ANL) significantly impacts nocturnal biodiversity, even at low intensities. The challenge lies in balancing necessary urban illumination with ecological preservation. In collaboration with biodiversity and lighting experts, Cerema, a well-known French research centre based in Brittany region, has utilized satellite imagery to map ANL and its pressure on ecosystems, particularly focusing on France's urban and peri-urban regions. Data sources, such as LuoJia-01 satellite imagery, combined with local street lighting and tax data, enable detailed mapping of light emissions. This integration made it possible to identify and quantify the main contributors who significantly affect nocturnal ecological corridors. Recent work by Cerema has shown that these satellite-derived radiance maps can be used operationally by municipalities to identify priority areas for reducing ANL and to support biodiversity-friendly lighting strategies (Cerema, 2024). These maps inform regional policies, aiding municipalities

like Nice and Aix-Marseille in creating Dark Infrastructure—a network of dark corridors connecting biodiversity habitats. By integrating geomatics, biodiversity expertise, and urban planning skills, this project supports energy-efficient and biodiversity-conscious lighting strategies (Figure 1). Future work aims to create a national ANL map to enable broader implementation across Europe, facilitating cross-border ecological protection. By identifying habitat cores and potential dark corridors, the method supports the design of a territory-scale nocturnal ecological network, enabling municipalities to integrate biodiversity needs into lighting renovation strategies.

Another example focuses on the rise of particulate matter (PM2.5) pollution in Greece, which was exacerbated by the increased biomass burning during the financial crisis, addressing health and environmental challenges. To tackle this, researchers at the University of Patras and NILU (Norwegian Institute for Air Research) developed a deep learning-based forecasting model to predict urban air pollution exceedances. This model integrates historical PM2.5 measurements from a dense network of calibrated low-cost sensors with meteorological and atmospheric composition data from the Copernicus Atmosphere Monitoring Service (CAMS). Using a long short-term memory (LSTM) neural network, the system predicts pollution episodes and provides early warnings to local authorities and vulnerable populations (Figure 2). The model's operational use in the Municipality of Thermi (in the greater area

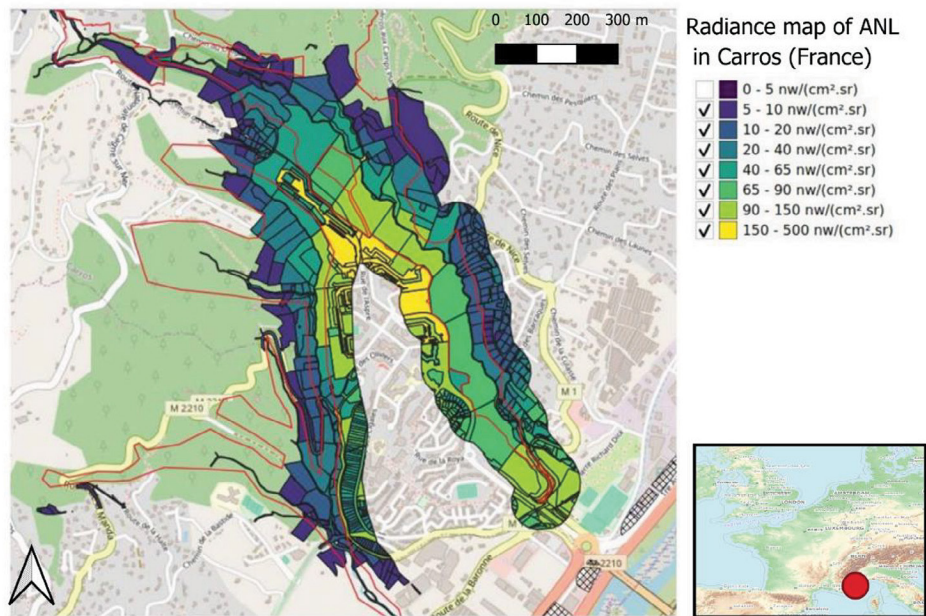


Figure 1. Radiance Map of ANL in Carros (France)

Note. Map of radiance on private and public plots around Carros biodiversity interest area (Carros, France). Source: Adapted from Cerema. Background map © OpenStreetMap contributors.

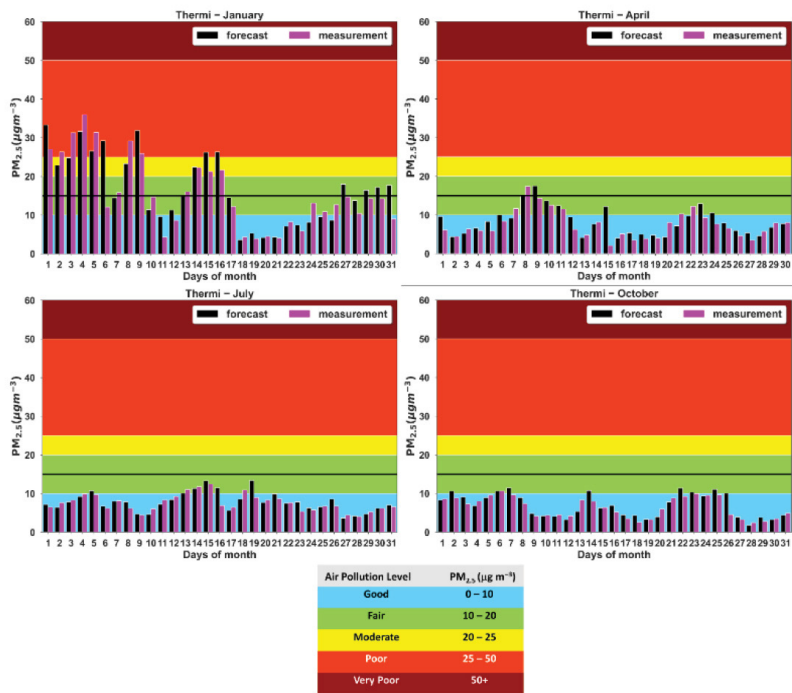


Figure 2. PM_{2.5} concentrations in Thermi (Greece)

Note. Daily average forecasted and measured denoted with black bars PM_{2.5} concentrations during January, April, July and October 2023 at Thermi (Greece). Courtesy of Laboratory of Atmospheric Physics, Physics Department, University of Patras.

of Thessaloniki), Greece, highlights its potential for widespread adoption, enabling municipalities to implement emission control strategies and protect public health. The operational prototype demonstrated its ability to forecast intra-day PM_{2.5} exceedances above the WHO daily limit of 15 µg/m³, offering timely alerts that enable municipalities to activate preventive measures. Since air pollution affects urban populations, particularly vulnerable groups like children and the elderly, the model is aligned with municipal efforts to reduce the adverse environmental impact and integrate measures into national and EU policies. The forecasting system is already used as a decision-support tool, providing daily predicted concentration levels and exceedance probabilities to local authorities, who can then plan short-term emission-reduction actions and public advisories. By implementing air quality monitoring and forecasting, it also meets the 2030 Agenda and calls for integrated solutions to environmental challenges achieving multiple goals simultaneously, from public health to climate resilience.

Moving on, urban vegetation mitigates climate change impacts by improving air quality, enhancing carbon storage, and reducing urban heat islands. However, detailed vegetation mapping has been limited by the spatial resolution of traditional datasets. The Green Urban Sat project, co-funded by CNES, the French Space Agency, addresses this limitation using stereoscopic Pléiades imagery. In Nancy, France, researchers have developed methods to discriminate vertical vegetation layers

and classify formations such as isolated trees, narrow bands of vegetation, and woods. The methodology integrates supervised satellite image classification, Digital Surface Models derived from tri-stereoscopic imagery, and spatial analysis rules to extract detailed vegetation features. A wide range of quantitative indicators—including vegetation height, canopy diameter, NDVI, and Leaf Area Index (LAI)—are generated to characterise vegetation structure and assess ecosystem services in different urban contexts. The resulting datasets, structured as detailed vector layers enriched with multiple attributes, are made accessible through dedicated platforms (e.g., Green City Lab), facilitating their integration into planning workflows. The project demonstrates how Very High Resolution (VHR) imagery supports municipalities in identifying areas needing ecological enhancement. The methodology's replicability across European cities holds promise for scaling this innovative approach.

Experts from Cerema (Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban Planning) in urban planning and ecological transition also used Local Climate Zones (LCZ) to address urban heat islands (UHI). Leveraging high-resolution satellite imagery from Pleiades and SPOT missions, this approach divides urban areas into homogeneous units based on their climatic behaviour (Figure 3), enabling city planners to identify and mitigate heat vulnerability. The LCZ maps provide actionable insights into urban morphology, land use, and socio-economic vulnerability,

supporting measures like vegetation planting, de-soiling, and urban design adaptation. Adopted by over 30 French cities and transferable globally, this tool empowers local authorities to combat climate challenges effectively while fostering international collaboration for

sustainable urban resilience. LCZ mapping can also provide derived indicators such as imperviousness, vegetation rates, and socio-economic vulnerability indexes when fine-scale data are available, allowing a more comprehensive assessment of heat-risk exposure.

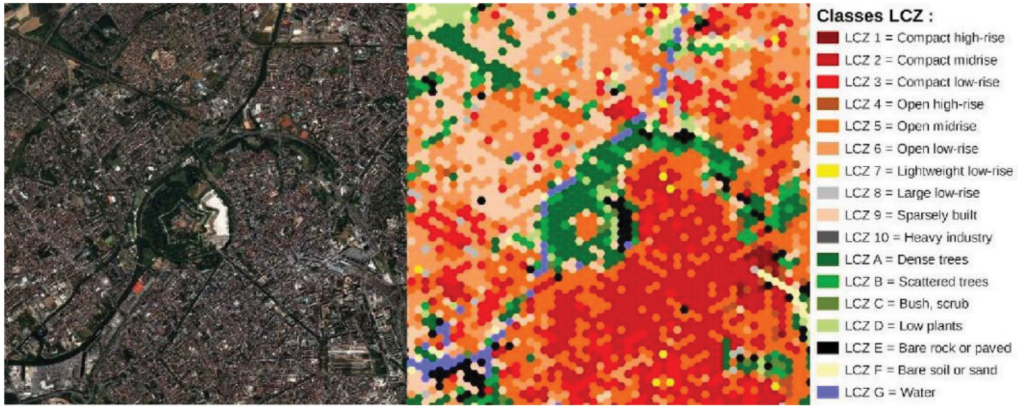


Figure 3. Satellite data of Lille and LCZ identification, France

Note. Pleiades satellite image of Lille—France (left) and associated LCZ mapping (right). © CNES 2020, Distribution Airbus DS.

In Subcarpathia, Poland, land fragmentation and low soil productivity have led to the abandonment of agricultural land, threatening food security and economic resilience. Traditional cadastral data lacks the granularity needed for effective land management. To address this, the Subcarpathian Office of Surveying and Agricultural Areas has adopted Copernicus Land Monitoring Service (CLMS) data to analyze land cover changes at the village level (Corine Land Cover 6-yearly and Land Cover 2015–2019). By integrating CLMS raster data with orthomosaic imagery and custom algorithms, the office has been able to identify priority areas for land consolidation and revitaliza-

tion. This methodology has improved the planning of sustainable agricultural policies, providing actionable insights for policymakers and farmers. Future plans include scaling this approach to support national agricultural development initiatives. The Subcarpathian Office has incorporated this methodology into its standard workflow for agricultural land-development planning, and its potential for adoption at national level has been recognised as a pilot model for sustainable rural-development policy in Poland.

In the Azores Autonomous Region, a comprehensive land-cover and land-use (LCLU) mapping initiative seeks to balance territorial develop-

ment with ecological preservation. The project uses Copernicus Sentinel-1 and Sentinel-2 satellite data to monitor ecosystems and urban landscapes (Figure 4). This integrated approach enables the production of high-resolution, up-to-date LCLU maps and detailed characterisation of terrestrial ecosystems. The resulting datasets empower local stakeholders with actionable insights for managing land use sustainably, directly contributing to SDG 11's goal of sustainable cities. These outputs provide decision-makers with a comprehensive and dynamic understanding of land-use patterns, enabling the

identification of critical areas subject to change, degradation, or development pressure. The results, including detailed geospatial datasets and thematic maps, are directly applicable to a wide range of stakeholders, such as urban planners, environmental agencies, and agricultural managers. This project highlights the critical role of EO tools in aligning regional policies with broader sustainability frameworks. Moreover, the methodology shows strong potential for transfer to similar island regions grappling with urban and environmental challenges.

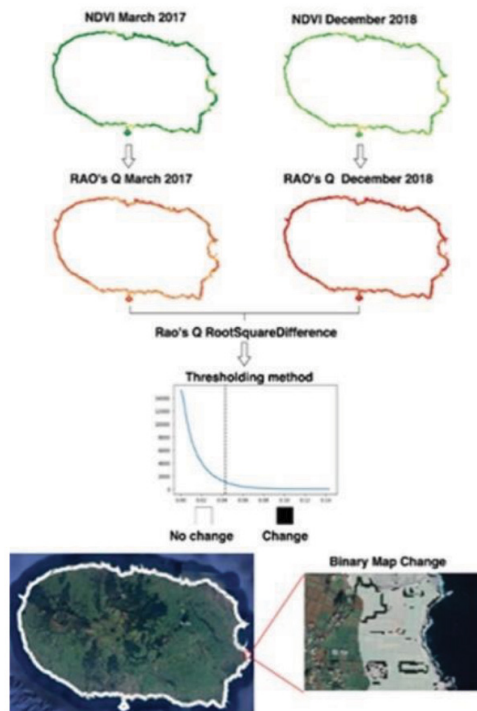


Figure 4. LU/LC changes analysis in Azores Islands (Portugal)

Note. Example of Land Cover/Land Use changes analysis in Azores Islands (Portugal). Reprinted from Tassi & Gil (2020), "A Low-cost Sentinel-2 Data and Rao's Q Diversity Index-based Application for Detecting, Assessing and Monitoring Coastal Land-cover/Land-use Changes at High Spatial Resolution, Journal of Coastal Research, Special Issue No. 95. Source: ResearchGate.

In the Veneto region, the challenge of controlling land consumption—a pressing issue in one of Europe’s most urbanized areas—has driven innovative uses of EO tools. With land consumption exceeding 11%, monitoring land-use change is essential for aligning regional policies with SDG 11 and EU targets for zero net land consumption by 2050. Tools such as the LandTrendr algorithm and Dynamic World datasets enable the rapid detection of land transformations (Figure 5). LandTrendr is an algorithm developed by NASA to analyse time-series Landsat images in order to monitor changes in land cover. The algorithm uses image processing techniques to detect tempo-

ral trends and discontinuities in land cover, which may be indicative of natural or anthropogenic changes. Dynamic World is a global land cover dataset with near real-time resolution of 10 m, based on Sentinel-2. Besides these algorithms, data from Sentinel-1 are used in order to verify changes in land cover map. This initiative supports efficient urban governance by providing insights into territorial evolution. Its implementation requires knowledge of remote sensing, regional policies frameworks, and basic coding skills. The use of these methodologies has significantly enhanced land use monitoring processes, positioning Veneto as a model for sustainable urban management.



Figure 5. LULC changes in Veneto Region (Italy)

Note. Analysis with LandTrendr algorithm of soil changes in Veneto Region (Italy) along the new regional motorway “Pedemontana SPV.” Image produced using Google Earth Engine. Map data: 2023.

Regional Challenges and Case Studies in Support of Climate Action (SDG 13)

The 2019–2020 Australian bushfires, exacerbated by extreme heat and drought conditions associated to climate change, destroyed vast areas of land, impacted biodiversity, and caused immense human and economic losses (Driscoll et al., 2024). In response to the growing

climate crisis, SDG 13 was established to promote urgent action through mitigation and adaptation strategies while fostering international cooperation (United Nations, n.d.a.).

Space-based solutions, and in particular EO tools and methodologies developed by European regions, are playing a pivotal role in supporting this SDG. Several initiatives in Europe

highlight the diverse ways EO contributes to monitoring and mitigating climate change impacts, particularly in the context of forest monitoring, extreme weather events, policy assessment, and educational platforms on global environmental change (Poirier et al., 2024).

For example, in Catalonia, the Institut d'Estudis Espacials de Catalunya (IEEC) and the Universitat Politècnica de Catalunya (UPC) have developed advanced methods for forest biomass estimation and forest ecosystems monitoring, particularly through satellite-based data from the European Space Agency (ESA) Copernicus program, Sentinel-1 and Sentinel-2, as well as GEDI and other sensors. These tools enable the quantification of forest biomass and its temporal evolution (Giménez et al., 2024), which is crucial for monitoring climate change effects such as deforestation, forest biomass degradation, forest fires, or insect outbreaks. By applying artificial intelligence (AI) algorithms and remote sensing data processing techniques, researchers can assess the impact of climate change on forest ecosystems with greater precision. The knowledge generated from this monitoring provides governments and organizations with the information required to assess the effectiveness of policies and implement more targeted interventions for forest restoration.

In a similar vein, Veneto region has leveraged satellite imagery from the Copernicus Sentinel-2 mission to address the damage caused by extreme meteorological events, such as the Vaia

storm of 2018 (Motta et al., 2018; Vaglio Laurin et al., 2021; Battisti et al., 2023). Using statistical models, multiresolution segmentation, and supervised classification techniques with fuzzy logic, based on “knn” classifier, the region has produced highly accurate maps of the affected forest areas (Figure 6). This geospatial data has been instrumental for local authorities and stakeholders in planning environmental restoration and managing financial resources for forest recovery, ensuring that policies are aligned with the region's long-term environmental goals. As a result of the mapping, the total surface area damaged by wind-thrown trees in the Veneto region was approximately 12,227 ha (Various Authors, 2024). The detail of the dataset has been published in the Veneto region geoportal.

Another example in Catalonia comes from the Centre of Geographic Information Systems and Remote Sensing (SIGTE) of the University of Girona, which has developed the Edu-sat platform (<https://www.edu-sat.com/?lang=en>), a web-based educational tool designed to engage young audiences with the potential of remote sensing technologies by providing access to near-daily Sentinel satellite imagery via the EO Browser application. The platform offers interactive resources to explore satellite images and their applications in monitoring global environmental changes through nine specific case studies, including forest fires, glacier regression, and volcanic eruptions. Through Edusat, students gain practical knowledge of the Copernicus program and are equipped to critically

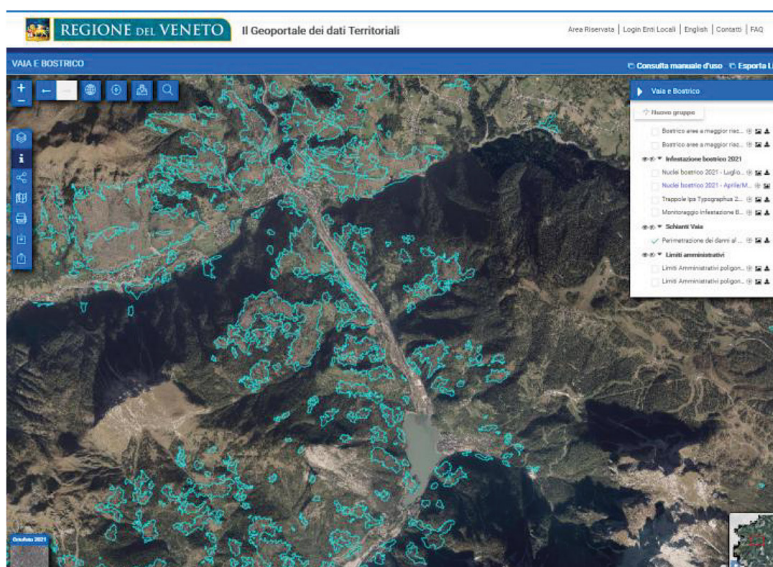


Figure 6. Forest damages in Veneto Region (Italy)

Note. Detection of wooden areas affected by Vaia storm in Veneto Region (Italy) through combined GIS procedures. Screenshot taken from Veneto region geoportal. Dataset licensed under CC BY 4.0.

assess the environmental impacts of human activities. The effectiveness of this approach is demonstrated by its recent adoption by the Catalan Government as a key resource for STEAM-space education. The platform also aims to empower educators with tools to integrate EO technologies into the curriculum, thus fostering the next generation of climate-conscious citizens who can contribute to sustainable development.

At a broader level, the SDGs-EYES Horizon project (<https://sdgs-eyes.eu>), coordinated by the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) in Italy, is addressing the fragmentation of SDG monitoring efforts by integrating data from Copernicus and other EO services. This project focuses on SDG indicators related to climate (SDG 13), ocean (SDG 14), and land (SDG 15), aiming to pro-

vide decision-makers with accurate and reliable information. By combining satellite data, in-situ observations, and advanced data analytics, SDGs-EYES is developing tools to support EU policy needs. A primary example of its real-world application is the collaboration with institutional stakeholders such as, among others, the Italian State Forestry Corps (“Carabinieri Forestali”) and ISPRA (Italian Institute for Environmental Protection and Research). These partnerships ensure that the tools developed—such as those for multi-hazard monitoring and improved carbon cycle quantification—directly address observational gaps in current environmental policies. These tools enhance the capacity of stakeholders to assess and act upon climate-related challenges effectively. Within the framework of SDG 13 (Climate Action), the project’s

methodology is particularly significant as it enables the concrete estimation of specific indicators for SDG 13.

Another notable example is the French platform “Applisat” (<https://www.applisat.fr>), managed by the General Commission for Sustainable Development (CGDD) with the support from Cerema, as part of the French Satellite Applications Plan (2023–2027), which promotes the use of satellite-derived data for local authorities and government services in order to address environmental challenges, including climate change. In addition to the website, the platform relies on a professional community that brings together various stakeholders to promote the use of satellite applications for territorial development and facilitate the exchange of knowledge and experiences. Specifically, Applisat also provides, for the climate domain, methodologies for monitoring urban heat islands and carbon footprints, leveraging high-resolution imagery to support local decision-makers in implementing resilient urban planning and mitigation strategies.

POS2IDON: Leveraging Earth Observation and Machine Learning for Advancing Marine Pollution Detection and Supporting SDG 14

The Great Pacific Garbage Patch—the vast accumulation of plastic waste in the Pacific Ocean—is one of the most visible examples of ocean pollution, estimated to cover 1.6 million sq. kilometers, significantly affecting marine life and ecosystems (The Ocean Cleanup,

n.d.). Through SDG 14, the UN recognized that oceans are vital for climate regulation and biodiversity, and that urgent action was needed to protect them.

Water serves as a critical nexus linking various sectors, including agriculture, aquaculture, and wastewater management, with profound implications for ecosystem health and human well-being. Satellite imagery reveals the global scale of coastal eutrophication trends, emphasizing the pervasive influence of water across different regions. 19 out of 23 regions of NEREUS are maritime, coastal, and outermost areas (NEREUS, n.d.b.). The following example from the NEREUS EO WG illustrates efforts on sustainable maritime management. By fostering collaboration and transparency through open-source code, the EO WG showcases best practices coming from outermost regions, such as the Azores.

Life Below Water is vital for the Azores, an archipelago deeply connected to the ocean. Marine biodiversity, fisheries, and tourism are key to the region’s economy and environment. Protecting marine ecosystems through conservation, responsible fishing, and pollution reduction ensures a sustainable future. In a significant advancement for achieving SDG 14, “Conserve and sustainably use the oceans, seas and marine resources for sustainable development,” the Azores have recently established the largest Marine Protected Area (MPA) network in the North Atlantic, covering 287,000 square kilometers. The Regional Government of the Azores emphasized that its decision,

made through a science-based and participatory process, to protect 30% of its seas serves as an example that other regions should follow to ensure the future health of the planet (Blue Azores, n.d.).

In this respect, the Associação para o Desenvolvimento do Atlântico International Research Centre (AIR Centre) has developed POS2IDON, an innovative tool for detecting floating marine debris and other ocean features (Figure 7). Leveraging machine learning models, including Random Forest, XG-Boost, and Unet, POS2IDON processes Sentinel-2 satellite imagery to identify features indicative of marine plastic pollution. The tool's pipeline integrates data acquisition from the Copernicus Data Space Ecosystem to detect suspicious aggregation zones, as demonstrat-

ed during a major debris event in the Gulf of Honduras in 2020. By enabling the classification of debris aggregation zones, the tool provides actionable insights for policymakers, aquaculture stakeholders, and environmental clean-up initiatives. This methodology relies on advanced programming skills, particularly in Python and Julia, and integrates spectral data from sources like the MARIDA library to achieve high classification accuracy. The output includes detailed classification maps that support long-term seasonal analysis and post-disaster management, guiding cleanup efforts and assessing debris inputs to marine environments. Future enhancements include developing a user-friendly web platform, broadening accessibility and impact.

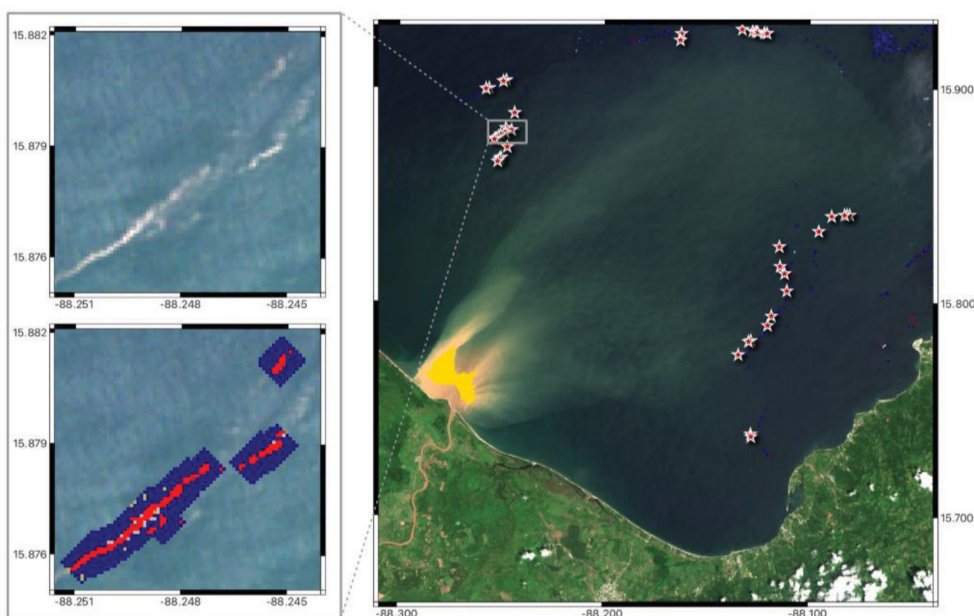


Figure 7. Plastic Debris detection in Honduras Gulf

Note. The tool POS2IDON (PT) applied to a major plastic debris event in the Gulf of Honduras (September 18, 2020). Likely presence of marine debris (red pixels and stars). Source: AIR Centre. Contains modified Copernicus Sentinel data.

Leveraging Copernicus Regional Platform and AI Tools for Earth Observation Capacity Building to Support SDG 15

The Amazon Rainforest, often referred to as the “lungs of the Earth,” is experiencing severe deforestation, with vast areas being cleared for agriculture purposes, particularly cattle ranching and soy farming (WWF, n.d.). This widespread deforestation threatens biodiversity, accelerates climate change, and disrupts the livelihoods of indigenous communities.

Terrestrial ecosystems play a pivotal role in supporting human life, accounting for more than half of the global GDP and holding significant cultural and economic significance (United Nations, n.d.b.). SDG 15 was established to halt biodiversity loss, combat desertification, and promote sustainable land use by addressing key threats such as deforestation, land degradation, and the loss of species. It emphasizes the importance of protecting terrestrial ecosystems for present and future generations.

Despite incremental progress in sustainable forest management and the expansion of protected areas, the bulk of improvements remains modest, severely impacting citizens. While many of the previous use cases apply also to SDG 15 on land, however the EO WG experts, with the following two examples, present in a more evident way how capacity building skills in EO are part of the solution at a global scale.

In the Brittany region, IRISPACE, a research institute, through

the Copernicus Regional platform (<https://copernicus-regional.irispace.fr>), addresses the challenge of low awareness among local and regional authorities about the potential of Copernicus program data for territory management. The platform supports both EO acculturation and the regional industrial ecosystem by promoting the use of free and commercial satellite data, such as Sentinel-2 images, through accessible tools like the Sinergise API and open-source web clients. This initiative aims to build the skills needed for web mapping and development, thus enabling stakeholders to better leverage EO tools for regional planning. The Copernicus Regional platform, developed in collaboration with Geo-Bretagne partners, hosts a catalogue of EO resources and was expanded in March 2024 with automated tools that generate environmental indicators at the municipal level. The platform's success has led to the development of commercial services like Littosat, demonstrating how public EO acculturation can bridge the gap between regional authorities and the specialized space industry. Going forward, it is essential to gather user feedback and secure resources for ongoing maintenance and platform animation.

Some of the partners involved in the FIRE-RES project, in particular the University of Padua, have developed a comprehensive pan-European mapping system that uses EO data to provide informative data layers that can be used to mitigate wildfire risks, supporting SDG 15. The research work used satellite imagery, including Senti-

nel-1 and Sentinel-2, radar backscatter from ALOS-2 (radar backscatter and DSM), combined with AI-driven analysis through an ensemble of machine learning algorithms trained on 49 distinct bioclimatic and spectral features, to produce maps of vegetation structure variables. These data were subsequently employed to estimate canopy fuel maps and fuel model maps, which are critical for fire behaviour modelling. Outputs include raster maps at around 100 m resolution detailing aboveground biomass (Pirotti et al., 2023), canopy base height, and canopy bulk density (Kutchartt et al., 2024a), validated using an independent dataset of ground-truth plots. These raster layers were integrated through a Pan-European Fuel Map Server (Kutchartt et al., 2024b; Figure 8), supporting stakeholders such as civil protection and forest services to

improve wildfire risk assessment and management. A tool for ground validation, the FIRE-RES Geo-Catch mobile application (Kutchartt et al., 2023), enables users to upload geotagged and oriented photos from their smartphone, supporting cross-validation of the fuel model map. These services are highly findable, accessible, interoperable, and reusable. The infrastructure for processing remote sensing data is based in the R environment and is essential for the replicable implementation of the workflow and the production of the final datasets. The initiative aligns with regional and national policies, aiming to inform strategies for forest management and wildfire mitigation, with plans for finer resolution mapping and integration into local geospatial infrastructures to maximize impact.

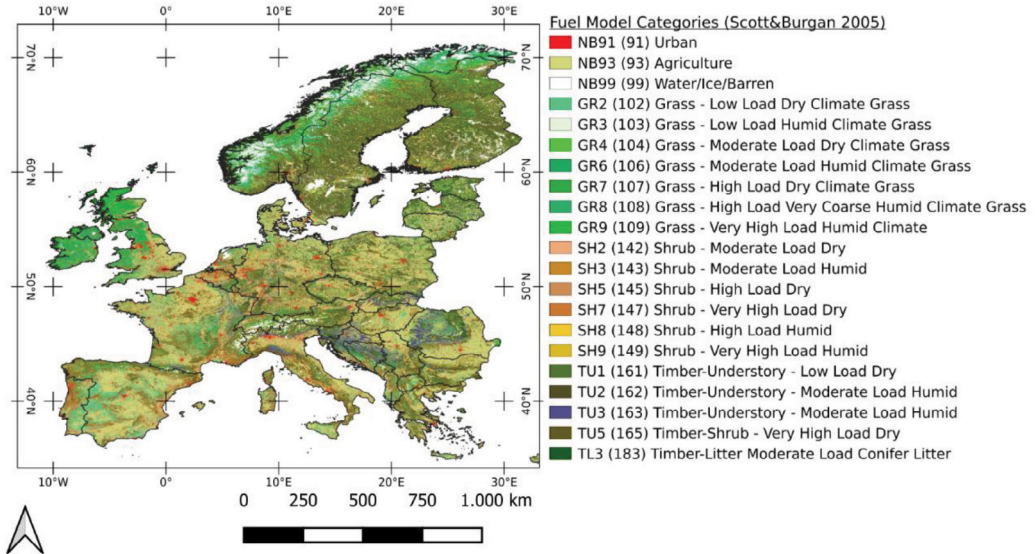


Figure 8. Pan European map of fuel model classification

Note. FIRE-RES project. A Pan European map of fuel model classification (Kutchartt et al., 2024b) using the Scott and Burgan (2005) nomenclature.

Conclusions

All previous use cases by the Earth Observation Working Group (EO WG) highlight the transformative role of EO tools and methodologies in advancing the United Nations Sustainable Development Goals (SDGs). The group's work underscores how EO tools support critical SDGs, including climate action (SDG 13), life below water (SDG 14), life on land (SDG 15), and sustainable cities and communities (SDG 11). Each one of these tangible use cases addresses more than one or even two SDGs, showcasing their broad and advanced applicability to different regional and global needs.

Furthermore, the impact of EO on the environment, public health, and citizens' wellness is becoming increasingly evident. By monitoring air quality, urban heat islands, and pollution patterns, EO tools help policymakers design healthier living environments and reduce exposure to environmental hazards, addressing targeted mitigation strategies.

Reflecting the triple helix model, the EO WG fosters collaboration and shares knowledge and expertise across European regions. The group exemplifies how regional innovation and capacity building can address global sustainability challenges.

However, achieving a more inclusive and advanced use of EO technologies across all European regions requires sustained awareness-raising efforts and coordinated investments. The critical role of regions in driving prog-

ress toward the SDGs underscores the need for a well-coordinated approach to capacity building, one that involves collaboration between public and private entities across different regions. By investing in capacity building, Europe not only enhances its ability to meet SDGs but also fosters innovation and economic growth within the space sector. As described, these contributions showcase the capacity of EO technologies to offer sustainable solutions not only to the needs of regional and local stakeholders, but also to the global community.

Future challenges include ensuring long-term funding for regional EO initiatives, fostering interoperability among EO platforms, and bridging the digital divide to ensure equal access to EO tools across all European regions.

By continuing to invest in EO capacity building and fostering cross-regional collaboration, European regions can become global frontrunners in the use of space technologies for sustainable development. This collective effort will not only strengthen Europe's leadership in EO but also ensure that space-based solutions drive real and measurable progress toward the UN SDGs.

In conclusion, it is essential to emphasize that this group represents only a selection of European regions—members of NEREUS—that actively leverage space technologies and participate in capacity-building initiatives. These regional efforts are not isolated but are referenced and interconnected at the EU level through NEREUS. Notably, the EO WG members play a key role in utilizing space technologies and

advancing capacity-building practices. By promoting EO capacity building skills, the EO WG aims at fostering resilience and contributing to a sustainable future for Europe and beyond.

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