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An integrated EU Space for Climate Action: success stories of European satellite applications in supporting the EU Green Deal

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Abstract

Space data constitute an indispensable resource for comprehending, monitoring, mitigating, and adapting to climate change, playing a pivotal role in facilitating the green ecological transition in Europe and beyond. Over the past decades, European space capabilities have proved instrumental in addressing the diverse challenges posed by climate change in the region, while advancing the objectives of the EU Green Deal and the UN 2030 Sustainable Development Goals. Given the acknowledgement of space activities and data within the EU policy framework, this paper aims to amplify their efficacy and demonstrate their invaluable contributions to Europe's climate resilience by showcasing real-life examples. The description of specific successful stories where Earth Observation and space data contribute to enhancing climate resilience in Europe will be put under the spotlight, to showcase the instruments and technical capabilities currently available, as well as the methods and examples to maximise their potential.

Keywords: *EU Green Deal, space applications, climate change, Earth Observation*

1. Abbreviations

C3S	Copernicus Climate Change Service
CAMS	Copernicus Atmosphere Monitoring Service
CLMS	Copernicus Land Monitoring Service
EGD	European Green Deal
EGNOS	European Geostationary Navigation Overlay Service
EO	Earth Observation
ESA	European Space Agency
EU	European Union
EUSPA	European Union Agency for the Space Programme
GNSS	Global Navigation Satellite System
GOVSATCOM	Governmental Satellite Communications
IRIS²	Infrastructure for Resilience, Interconnection & Security by Satellites
SAR	Synthetic Aperture Radar
UN	United Nations

2. Introduction

The growing visibility of the effects of a changing climate placed, in recent years, low-carbon and climate-neutral goals as focus objectives in Europe, urging institutions as well as the scientific community for advanced knowledge and tools to analyse, predict and mitigate the impact of anthropogenic activity on Earth.

Space technologies have long played a role in monitoring Earth's climate, but can we truly say that their full potential to support sustainable development is today universally recognised?

Within the European Union and its Member States, the connection between space technologies and sustainable objectives has been recently supported and often included in green legislations and policies [1].

Based on research developed by the European Space Agency (ESA) and the European Space Policy Institute (ESPI) in 2024, the word "space" is present in some of the EU's climate policies, most of the time mentioning the Copernicus Programme, while all ESA Members States have at least one reference to space in their national climate policies [1].

Even if mentioned, the role of space solutions is not always accurately reflected or effectively integrated into sustainable actions by businesses, national governments or public authorities within the European Union.

Despite the potential of space solutions to move towards a green transition, the data presented by the European Union Agency for the Space Programme

(EUSPA) industry consultation published in the "EU Space for Green Transition" report of 2023 [2] showed a clear lack of awareness of this applicability. The results of the stakeholder consultations revealed that only 14% of the interviewees already use space data in their operations, and only 7% use space data in their operations relative to environmental topics [2].

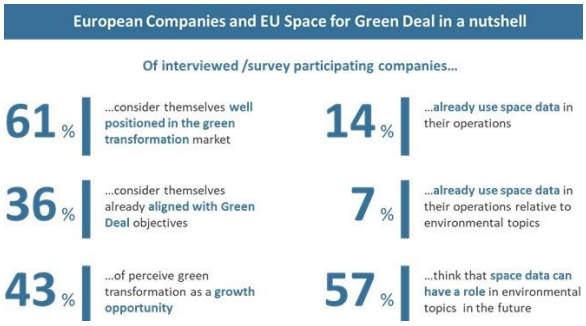

Fig. 1 Summary of the results of stakeholder consultations (interviews and surveys).

Source: EU space for green transformation: A new tool for companies to monitor their sustainability targets (Issue1).

While satellites could offer significant potential for supporting sustainable activities and Green Deal objectives, various factors, including complexity, costs, regulatory challenges, and lack of knowledge and awareness limit their adoption.

The results of the EUSPA report revealed that even if almost all the consulted companies are currently not leveraging EU space data to reach green transformation objectives, they expressed their interest in discovering more about all the available possibilities and solutions.

The intention of this paper is therefore to review the sustainability objectives set by the European Union within the European Green Deal and match space solutions which support its goals. By presenting some pivotal use cases, this paper will also serve as a guideline to showcase real-life examples where space solutions have been successfully leveraged to meet sustainable objectives and raise awareness of the many benefits the EU Space Programme has to offer to reach ultimately sustainable development.

3. *European Green Deal: Roadmap for a sustainable development*

Based on the concepts of sustainability and protection of European natural capital, combined with legal and financial guidelines, the European Green Deal (EGD) aims to "transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use." [3].

Since its implementation back in 2019, the combination of actors, factors, and policies required the maximum synergy to move towards its objectives, which target several key areas that make up the Green Deal:

- Increase EU's climate ambition for 2030-2050, with the goal to reduce greenhouse gas emissions by 55% by 2030 and reach climate neutrality in 2050.
- Supply clean, affordable and secure energy, to decarbonise the Region and support the development and uptake of new energy supplies, focusing on renewable sources.
- Mobilising industry for a clean and circular economy, transforming the industrial sectors' value chains towards sustainable processes and fair resource use.
- Building and renovating in an energy and resource-efficient way, moving buildings towards energy efficiency and boosting the construction sector.
- A zero-pollution ambition for a toxic-free environment, monitoring, reporting, preventing, and providing remedies to pollution.
- From "Farm-to-Fork": a fair, healthy and environmentally friendly food system, supporting more sustainable farming and food production activities.
- Accelerating the shift to sustainable and smart mobility, increasing access to more affordable, accessible and cleaner alternatives to current mobility habits.

Regionally deepening the Paris Agreement [4] and focusing on creating a climate-resilient Union and transitioning to a greener economy, the objectives set in the EGD aim to transform key sectors, from energy, transportation, and agriculture, to industry while boosting economic growth and improving the quality of life for European citizens.

A Just Transition Mechanism was established to assist and protect regions and countries by supporting the transition to low-carbon activities, re-skilling of workers and access to financial support to facilitate investments into new sustainable projects [3]. This spirit is encapsulated within the Green Deal collection of goals and targets, intentions and objectives, a success which will depend on the elaboration and effective implementation of several strategies and regulations within the single Member States and at the Union's level. The objectives set in the EGD are aimed to inspire change, transforming the narrative by which we approach economic growth and development, within an efficient and sustainable perspective supported by accurate data for more informed decisions.

The EGD in its introductory part affirms how, to achieve all its objectives, the EU should also promote and

invest in digital transformations and tools as they are "essential enablers of the changes" [3]. Although the EU Green Deal does not directly address space applications and Earth Observation capabilities, it acknowledges the significance of data-driven decision-making and monitoring as essential components for supporting evidence-based policies, relying on science and research.

4. *European space solutions for sustainable objectives*

Since 2021, the connection between space solutions and sustainable priorities has been strengthened by new synergies. The establishment of EUSPA, thus the enlargement of the scope of activities including all the branches of the EU Space Programme, from Copernicus to Galileo and EGNOS, provided new approaches also related to the promotion and maximisation of space data uses to reach sustainable objectives in different market segments [5]. In addition, the EU Climate Law released in the same year provided legal guidance to the strategies included in the EU Green Deal, representing a leap forward in the role of space solutions in supporting the achievement of the Union's sustainability priorities.

The EU Climate Law legally bound the EU member states to its climate targets set in the EGD and specified how the Commission "should ensure a robust and objective assessment based on the most up-to-date scientific, technical and socioeconomic findings […] as well as the Earth Observation data provided by the European Earth Observation Programme Copernicus" [6]. EU Space data and programmes are today a vital part of the appraisal and further response to climate change. EU's Galileo, EGNOS and Copernicus programmes continuously and accurately gather objective and reliable data that contributes to the assessment of essential Climate Variables, monitoring the state of the climate, biodiversity loss, ocean health, and ozone depletion to mention some, and providing long-time, high-quality, and verified data sets accessible to everyone free of charge. If we examine their role within the context of a more sustainable society, companies and businesses benefit from a myriad of possible applications of EU space data, which can translate not only into more sustainable economic activities but also into cost reduction and increased efficiency, a more skilled workforce and more qualified job offers [2].

Copernicus [7] Europe's advanced Earth Observation system is a precious tool for the EU sustainability priorities. Providing real-time and forecast information products, as well as informed mapping in numerous sectors from agriculture, biodiversity protection, and renewable energy development, contributes to numerous Green Deal objectives, such as zero pollution, clean energy, and the farm-to-fork strategy [8]. Earth Observation data provided by the Copernicus Land Monitoring Service (CLMS) with the Sentinel-1 C-band SAR satellite [9] collects crucial information on land cover and uses supporting informed and accurate mapping of regions and the nature of their soil. Farmers can develop a more precise farming strategy, saving resources, and public authorities are supported in their land registry and urban control activities, which are crucial during emergencies.

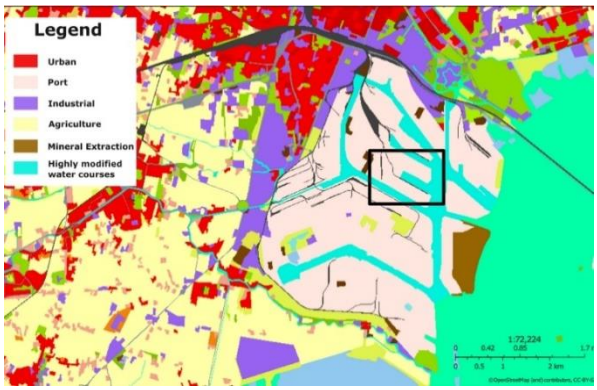

Fig. 2 Copernicus Land Monitoring Service Coastal Zones product image of the Harbour of Marghera (IT) showing the different land cover and land use categories (2018).

Source: Copernicus Land Monitoring Service

The Copernicus Climate Change Service (C3S) [10] provides past, current and future projections on our climate and its changes, crucially supporting EDG's climate ambitions, while the Copernicus Atmosphere Monitoring Service (CAMS) [11] delivers data about air quality tracking industries compliance to emission targets, supporting EGD's climate objectives, but also "Mobilising industry for a clean and circular economy" and "A zero-pollution ambition for a toxic-free environment" targets. CAMS data help address the risks related to climate change, such as extreme weather events, drought, and floods, supporting the development of all the effective strategies related to Disaster and Risk Management and assisting public authorities and municipalities.

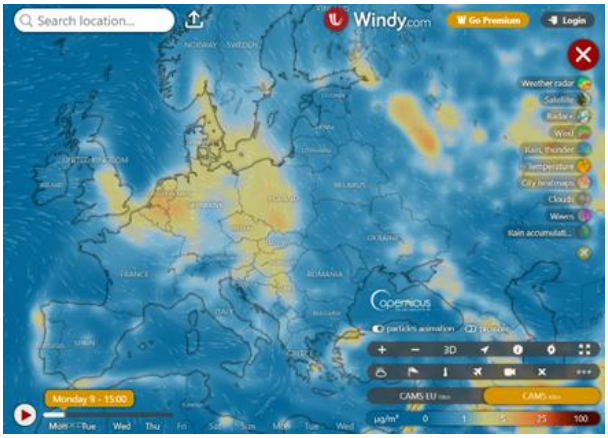

Fig. 3 NO2 concentrations in Europe, 9 September 2024. Source: Windy.com

Green urban development strongly relies on geospatial data. Galileo [12] data and services are crucial for Smart cities and "Accelerating the shift to sustainable and smart mobility" objectives. Galileo data supports city administrators and urban planners in improving the local traffic management system, reducing congestion, fuel consumption and emissions, by optimising routes for vehicles and public transport. Those services are also crucial for green energy objectives, enabling an efficient placement of renewable energy infrastructures for example, by locating the best area where to develop wind farms or place solar panels [13].

EU GOVSATCOM [14] systems facilitate the gathering and dissemination in real-time of all the vital data which support all the EU Green Deal objectives: communication data, EO data, positioning, navigation and timing data (PTN) and many more. By doing so, they stimulate local economies, promote sustainable regional development and economic growth, optimise supply chains and logistics, and also support real-time security priorities, civil protection and law enforcement.

EU communication satellites bridge the digital divide by enhancing connectivity: they support the EU Green Deal objectives which aim to ensure that all regions, including remote and rural, can benefit from the green transition [13].

The new IRIS^2 (Infrastructure for Resilience, Interconnectivity and Security by Satellite) constellation will be crucial to secure reliable connectivity in the whole European Region [15] supporting the EU Green Deal objective of "no person and no place left behind" [16].

5. *Space 4 EU Green Deal: examples of Success Stories*

Knowledge sharing and awareness raising are fundamental, and in the following section, the study will focus on providing real-life examples of how space can successfully support the European Green Deal objectives by presenting technologies and ways through which we can unlock the full potential of space solutions for Earth's challenges.

1) North Sea: Planning offshore wind energy in the Digital Twin of the Sea [17]

Planning offshore wind energy projects in the North Sea is complex, as it involves the understanding of currents, wind patterns, and marine ecosystems, making sure the wind farms are placed in the best location, to be both efficient and safe. The Ministry of Infrastructure and Water Management of the Netherlands back in 2022, had as a key point on the agenda the development of an offshore wind farm in the Dutch part of the North Sea. On this occasion, the ambitions of sustainable use of the sea had to meet with the interests of all the different stakeholders involved: shipping lanes and commerce, energy corridors, marine protection, and aquaculture, to mention some. To overcome this challenge, a Digital Twin of the Sea was developed, in collaboration with the Breda University of Applied Sciences, a government-funded higher education institute in the Netherlands. The Maritime Spatial Planning simulation platform developed a digital replica of the North Sea which was able to simulate spatial plans. The Copernicus data were an important contributor to its development. The free and open-access data provided by the Copernicus Marine Service were integrated into the replica with models and data visualisation, creating an effective and accurate digital twin. This new multi-user platform was vital for policymakers and professionals to better understand the local marine ecosystem and nature, as well as develop accurate planning and mapping for offshore wind power development in the North Sea. This use case represents an important example of how space solutions can assist in reaching the EGD objective of "Supply clean, affordable and secure energy" supporting at the same time the climate ambitions to reach climate neutrality and environmental and marine ecosystem protection.

2) Space-enabled shuttles: a step in the autonomous direction [18]

In the bustling streets of Lyon, France, in the last few years, a new wave of transportation emerged. To respond to the increasing urban congestion, the city of Lyon has explored since 2019 a smarter and greener mobility solution. The public transport authority SYTRAL, teamed up with two French companies Keolis Group and NAVYA, leading to the development of a new cost-effective way to encourage public transportation using GNSS data.

Fig. 4 Cutting-edge multi-sensor technology
Source: Navya Safety Report 2019

The new autonomous vehicles supported by satellite navigation, are freely accessible and circulate regularly every day, offering a cost-effective alternative in the city. Thanks to the navigation system, the position of the vehicles is constantly monitored assisted with detection systems such as cameras and sensors. The introduction of the new system allowed the city to overcome the challenges related to urban mobility and pollution rates which characterised rush hours and lunchtime in Lyon, connecting offices in the business parks with the nearby tram station. This innovation is also part of the EU-funded project Autonomous Vehicles to Evolve to New Urban Experience (AVENUE) thanks to which more autonomous vehicles have been deployed in other European cities in the past years, in the cities of Geneva, Copenhagen and Luxembourg [19]. This particular use case is another crucial example of how space solutions are supporting the EGD targets: this example supports the "A zero-pollution ambition for a toxic-free environment" objective, as well as the one of "Accelerating the shift to sustainable and smart mobility", and is overall supporting the target of reaching its climate ambitions related to the reduction of greenhouse gas emissions.

3) WatchITgrow: smart agri-resource management [2]

Resources (water, pesticides etc.) are often used extensively in crops. This usually generates high costs for farmers as well as creates damage to the soil and its products.
In 2023 in Belgium, potato cultivation has achieved an output of around 50 tonnes per hectare, with a maximum output which is expected to double this number. This higher supply might be the result of a better, more sustainable and effective management of the crops, as well as a constant and accurate monitoring of the unexpected changes in the climate in the region, which is very often affected by strong floodings. To support farming development in the region, a Flemish independent research organisation, VITO, has partnered with Belgapom, the Belgian potato trade & processing industry, to develop WatchITgrow.

This Copernicus-based system, entirely dedicated to the Belgian potato industry, is a geo-information platform which relies on data from the Sentinel-1 and Sentinel-2 satellites of the Copernicus Programme, which provides crucial data and information on the state and growth of crops, yields and harvest dates estimates, fundamentally supporting local farmers. This system is also complemented with more data from other satellites, drones, weather and soil measurements.

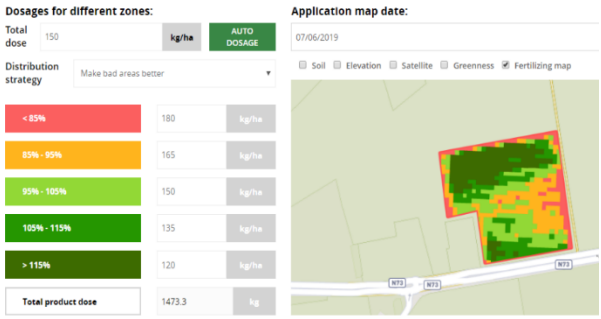

Fig.5 A print screen of an application map for variable rate Nitrogen fertilization created with WatchITgrow.
Source: VITO Remote Sensing Website.

As the EGD sets important targets for water, pesticides, and fertiliser usage in agriculture, this use case provides fundamental inputs on the role of space solutions in supporting those targets and transitioning towards a healthier food supply, thus supporting the EGD's Farm-to-fork objectives.

5. Conclusions

The European space ecosystem operates within a harmonious interplay of missions and expertise, where the technical knowledge of the European Space Agency (ESA), the private companies and start-ups, universities and research centres, combined with the legislative framework of the European Union, synergistically integrate space for climate action in the region.

Through research and development initiatives, data sharing access, and policy support, the close partnership among European space actors fosters capacity building and aligns technologies with green transition objectives. A profound complementarity, which underscores a shared commitment to leverage space assets for sustainable initiatives and accelerate the utilisation of satellites and data to tackle climate challenges, ultimately supporting Europe's green future. The exploration conducted in this paper aims to showcase the opportunities the European space sector currently offers to support sustainable development, presenting some pivotal use cases that aim to explain and bring closer technologies to solutions, tools to challenges, and demonstrate their great interoperability. Despite this potential, we have seen how minimally space solutions are integrated to meet sustainable objectives, and how today, the crucial need to raise awareness meets with the imperative to foster cross-sectoral partnerships and research. Innovation will shape future developments towards green and sustainable societies. An innovation which will not only be limited to the uptake of new technologies but also changes within societies, politics, economies and their respective nature. How citizens, decision-makers, businesses, and other important stakeholders will accelerate all those innovation cycles will play a crucial role in possible future scenarios of a sustainable and climate-resilient Europe.

We have seen how space data and technologies can be of great support for farmers to develop sustainable crop management, or to support decision-makers to find the best location for wind farms. The opportunities offered by space solutions can be infinite when combining new minds and ideas, knowledge and expertise, which can boost new perspectives and activities.

To bring closer services and users: this is the key action to consider implementing to support this integration. Develop new sharing platforms, networks of understanding and engagement activities which can raise awareness and support a new dialogue based on multidisciplinarity inspiring new perspectives on space technologies and data.

The dissemination of stories and case studies that explain with simple details how to integrate these technologies and which data can be freely used can be a crucial way to overcome limited awareness and knowledge. A model which Eurisy has embraced as a core feature of its activities and mission, and which aspires to continue to promote within its community and beyond.

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