Baumgart *et al. Sustainable Earth* (2021) 4:6
https://doi.org/10.1186/s42055-021-00045-6

Sustainable Earth

RESEARCH Open Access

Space for the Sustainable Development Goals: mapping the contributions of space-based projects and technologies to the achievement of the 2030 Agenda for Sustainable Development

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Abstract

Progress towards the achievement of the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development in many ways presupposes the utilisation of science, technology and innovation. Many sustainability-oriented projects across industries make use of space-based technologies and services to contribute to the Goals. Among others, satellite-based Earth observation, positioning, navigation and communication services are used in an array of sectors ranging from monitoring environmental conditions and changes to supporting search and rescue missions. In order to illustrate contributions to the SDGs, space agencies and other institutions have aligned their projects to the SDG framework. This study attempts a more holistic, aggregate mapping of such alignments to gauge which SDGs benefit the most and from space-based projects and technologies, as opposed to those benefiting the least. The results demonstrate that the number of contributing projects varies significantly across the Goal spectrum, as does the share of the various technologies involved, with particular focus on industrial development, hunger elimination, and improved healthcare. Nevertheless, the range of application of space-based technologies is wide and highlights the relevance of space to support the transition towards a sustainable future.

Keywords: Space-based technologies, Space contributions, Aggregate mapping, Sustainable development goals, Space agencies

Introduction

In September 2015, the United Nations General Assembly adopted a set of global objectives, the Sustainable Development Goals (SDGs), as part of the 2030 Agenda for Sustainable Development (henceforth 2030 Agenda), a roadmap for future generations to inherit a more sustainable and thriving planet [55]. The 17 SDGs, building on the three pillars of sustainability, namely, economy, society, and the environment [53], cover a wide range of socioeconomic and environmental themes ranging from gender equality to sustainable management of natural resources (Fig. 1).

The SDGs are a globally recognizable symbol and a banner under which the various initiatives for sustainable development can assemble and re-brand themselves. To make these high-level objectives translatable at the policy level and facilitate the implementation of strategies, policies, and initiatives for the achievement of the SDGs, 169 Targets were identified to underpin the Goals. These Targets provide a platform to identify policies and other initiatives that aim at the various individual aspects that constitute the SDGs, and therefore translate high-level values into actionable regional and

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local needs. To further enable policymaking for the achievement of the SDGs, a set of 231 unique indicators, with one or more corresponding to each Target, were selected to foster monitoring of progress made. The relevance of the indicators is assessed regularly [56].

Although the SDGs were compiled as a set of goals that are to be achieved globally in cooperation between all United Nations Member States and all stakeholders, the actual implementation most often takes place at the national level. UN Member States have devised their own national action plans for the implementation of the SDG framework.

Likewise, reporting of the progress towards the achievement of the SDGs is largely a matter of national policy [56]. Even though this might seem counterintuitive considering the otherwise universal approach of the 2030 Agenda, it is precisely this principle that allows for national policymakers to develop strategies that reflect local needs and circumstances. At the same time, facilitating collaboration between national statistical systems and the relevant international and regional organizations enhances data reporting channels and helps to secure harmonization and consistency of data and statistics [56]. Eventually, through a specific process of the Voluntary National Reviews, the progress is reported back to the United Nations through the High-Level Political Forum. Linking back to the structure of the SDG framework, it is the existence of the Targets that enables the implementation of the framework at national level and therefore, allows for UN Member States to adjust their approaches according to their individual priorities.

The implementation at UN Member State level can also benefit from the interlinkages that exist in the 2030 Agenda. Due to the interconnectedness of the SDGs, the achievement of the 2030 Agenda requires addressing multiple goals simultaneously since the achievement of one goal may depend upon and affect the achievement of other goals. The SDGs were thus designed to build upon each other, multiplying the effect of one action to contribute to the achievement of other SDGs, thereby creating a spill-over effect across the objectives. Nevertheless, the effectiveness of strategies for the implementation of the 2030 Agenda, be they at the national or international level, relies significantly on extensive collaboration on a national and institutional level as well as on the combined use of a range of political and technological tools, as is reflected in SDG 17: Partnership for the Goals.

The role of space technologies, services, applications and policies

The United Nations recognizes the role of Earth observation (EO) and geolocation [provided, notably, by Global Navigation Satellite Systems (GNSS)] in supporting

Fig. 1 The Sustainable Development Goals

the achievement of the SDGs [55]. Orbiting in space, EO satellites equipped with specialized sensors provide data on vast and remote areas of the Earth, improving our knowledge of, for example, the atmosphere, land, oceans, ice extent and ecosystems. Geolocation and in particular, GNSS, is used to incorporate position information to data and provide location-based services to both humans and machines (e.g. drones or self-driving cars). Geolocation is central and ubiquitous in advanced industrial society, being widely employed in all modes of transport (road, aviation, maritime, etc.), fleet management, high-precision and consumer applications, provision of time information in critical national infrastructures, as well as scientific applications such as measuring the impact of space weather on the Earth, of earthquakes and climate change on human communities, among others. In addition to EO and GNSS that are mentioned specifically in the 2030 Agenda for Sustainable Development, an array of equally important space-based technologies, such as satellite telecommunications (SatCom), already contribute to several SDGs and associated Targets.

The authors of this article recognize that there are multiple classification schemes possible for outer space technologies, services, applications and policies (henceforth *space technologies*) (see for example: [4, 15, 16]), all of them equally valid. For this analysis only the predefined set of space-based categories have been selected as indicated below. The selection was made so that all projects considered in this paper could be easily accommodated within these categories. They are also wide enough to maintain full functionality even in case of future extension of the database:

- **Earth observation (EO)** "is the gathering of information about the planet Earth's physical, chemical and biological systems. It involves monitoring and assessing the status of, and changes in, the natural and man-made environment" [18], through remote sensing means. A very commonly used example would be meteorological satellites. Although the definition allows for both in-situ and satellite information gathering, in this paper, the term 'Earth observation' is used only in reference to satellites.
- **Global Navigation Satellite Systems (GNSS)** are composed of constellations of Earth-orbiting satellites that broadcast their locations in space and time enabling the determination of the position and navigation information by receivers [54]. GNSS can be used in all forms of transportation and play a critical role in telecommunications, land surveying, law enforcement, emergency response, precision agriculture, mining, finance, and scientific research, among other applications.
- **Satellite communication** (SatCom) relies on communications satellites that relay signals with voice, video and data to and from one or multiple locations. While Earth-based alternatives to space technologies are sometimes possible, space-based technologies can often reduce infrastructure requirements and offer more cost-effective service delivery options, especially for broadcasting and to provide communication services to remote or isolated communities [64].
- **Space science** is a scientific area occupied with the observation and analysis of natural phenomena that occur in outer space, as well as the development of relevant technologies. It encompasses disciplines such as astronomy and astrobiology [13].
- **Space exploration** "covers the broad range of technologies associated with enabling successful activities in space, from mission operations to in-situ resource utilization" [34]. For this paper, *Space exploration* corresponds to the exploration of the solar system and includes human spaceflight. Robotic spacecrafts (uncrewed exploration) are sent to celestial bodies in the solar system, notably to prepare for crewed missions (human spaceflight).
- **Technology transfer** is the "mechanism by which the accumulated knowledge developed by a specific entity is transferred wholly or partially to another one to allow the receiver to benefit from such knowledge" ([51], p.13). This transfer of knowledge is commonly referred to as *spin-off.*
- **Other**: This category refers to activities that are undertaken by space actors (e.g. space agencies) which could not be assigned to one of the categories above.

This classification has served its purpose very well with only 3% of the 506 solutions analyzed falling under the *Other* category. It is worth noting that among the solutions examined, often more than a single technology is employed. For instance, precision farming may use EO, GNSS as well as SatCom. Solutions may therefore fall under more than one category.

Several efforts have been made to highlight the importance of space in supporting the 2030 Agenda, either through progress monitoring or direct contributions to its achievement. Yet, such efforts have focused mainly on the areas of EO and GNSS. One of the first of such studies was the one carried out jointly by the United Nations Office for Outer Space Affairs (UNOOSA) and the European Global Navigation Satellite Systems Agency (GSA) [62]. This study, which focuses on a specific subset of the existing literature (see section 2 for more information), showed that synergies between EO and GNSS could lead to increased contributions to the

SDGs. Since then, several other studies have been released, such as the European Space Agency (ESA) SDGs Portal. ESA has published and maintains a catalogue of solutions showcasing the wide spectrum of what the various space projects can do in support of the 2030 Agenda. Likewise, UNOOSA, following its vision of ‘bringing the benefits of space to humankind’, has been working on identifying solutions and matching them with the SDGs. In this way, it is actively raising awareness and promoting space technologies for the SDGs [63]. Furthermore, UNOOSA provides access to the benefits of space by supporting the development of the space sector through its ‘Access to Space for All’ initiative and a range of capacity-building activities.

Objectives, methodology and research limitations

Objectives

This article aims to provide a comprehensive review of space-related projects that contribute to the achievement of the SDGs with the objective of mapping the distribution of contributions against each SDG and, if possible, against each individual Target. The authors’ goal was to identify which projects and which national or international entities are reported in the literature to make the most substantive contributions to the achievement of the SDGs, and where, across the SDG framework, gaps are most prevalent.

A series of sub-objectives are pursued throughout this article. One of them is the intention to identify which projects, or rather space technologies, are associated with the highest as well as lowest number of Goals and/or Targets. Through this approach, insights can be gained into the question of which space technologies have so far demonstrated the highest potential in contributing to the achievement of the SDGs. Conversely, this article also explores which SDGs and Targets exhibit the highest or lowest number of associated projects, thus highlighting the main areas of contributions, or lack thereof.

The study attempts to respond to a combination of quantitative and qualitative questions with a vision to develop a more holistic understanding of the overall contributions of space to the achievement of the SDGs. While a recent UNOOSA/GSA study indicates that almost 40% of the Targets benefit directly from EO and GNSS [62], it was limited in its scope to EO and GNSS services offered by the projects of the European Union (EU). The estimate hence portrays only a limited scope of space technologies rather than encompassing a multitude of providers globally.

The research questions examined in the study are as follows:

- RQ1: Does the number of projects differ significantly among the SDGs? If yes, why?
- RQ2: Which SDGs/Targets exhibit the highest/lowest number of contributing projects?
- RQ3: Which projects are associated with the highest number of SDGs/Targets?
- RQ4: Which space-based technologies are the most prevalent per SDG/Target? Why?
- RQ5: Which space-based technologies are the most prevalent in contributing projects? Why?

Using these questions as a base and the existing literature as a guide, the authors developed a set of hypotheses regarding the distribution of contributions of the various space technologies to the achievement of the SDGs.

This study endeavours to fill some of the gaps and improve the understanding of space contributions closer to their actual extent. Nonetheless, it is limited in its scope as the sources considered are not exhaustive (see section 2.3). Moreover, space contributions to the SDGs are constantly increasing with the invention of new applications, the adoption of new tools, and the deployment of new projects. The authors hope to overcome this temporal limitation of research by advocating for the launch and continuation of long-term, comprehensive initiatives to keep relevant available information up to date with developments in the space sector. Such initiatives would ensure the widespread adoption of mapping of projects against the SDG framework and specific measures to increase the use of space technologies for the 2030 Agenda, as discussed more elaborately in sections 4 and 5.

Methodology

In order to assess the variety of contributions of space technologies, the authors followed an archival-based approach. Initially, a literature review was conducted for the purpose of identifying sources that explore contributions of projects based on EO, SatCom, and navigation, as well as non-technological space-related activities such as capacity-building, education, and research. Several sources, ranging from official space agency publications to online databases, linking space-related activities with the SDGs were reviewed and compiled into a single comprehensive list. The relevant projects were identified mainly through archival review of both offline (books, reports, other documents) and online sources (websites, presentations, databases, other online sources). The sources reviewed were, except for one German language source, written in English.

Due to inherent limitations with regard to the design of the research (see section 2.3), only sources authored by institutions directly involved in, or responsible for, space-based projects and space-related activities were taken into consideration, and among those sources, only those explicitly aligning projects with the SDGs at a Goal or Target level were considered eligible for inclusion in the final compilation. Additionally, the institutions considered as sources operate at either national or international level, are linked to one or more UN Member States and are officially recognized by the latter. Any entities included in the list that are not national or international space agencies and related institutions, were not utilized as sources, but included as identified partners to source-institutions in one or more of the identified projects. Lastly, official publications of UN Member States and relevant publications by international intergovernmental bodies were used as additional sources to derive links between space-based projects and the achievement of the SDGs.

In order to establish a cohesive approach to the research objective, a set of definitions regarding the research subjects have been developed as indicated below.

An *institution* indicates an organization with an established structure and physical premises. This term refers to entities that are responsible for the commission, development, execution and/or funding of space-related projects. This category includes national and multinational space agencies, international organizations involved in space exploration, as well as their lead private sector partners or prime contractors. Furthermore, consortia of institutions with established structure and long-term objectives, regardless of the permanency of their premises, are also considered for the scope of this study as individual institutions. Examples of the latter are the Committee of Earth Observation Satellites and the International Charter 'Space and Major Disasters'. The terms *institution* and *entity* are used interchangeably in the main body of the study.

A project is a planned undertaking with clear and established objectives, initiated by one or more institutions. Projects may be hosted in institutional premises, in the field, or have no physical premises. For the purpose of this paper, this term is interpreted as any type of activity, initiative, programme or technological innovation facilitated by space research and technology. Such projects contribute to the achievement of the SDGs on a Goal or Target level (indicated henceforth as *project/solution alignment*). The study has not taken into consideration any categories or typologies that the source-institutions may have adopted when referring to their projects; any initiative that fulfils the selection criteria of the study has been included in the project list, regardless of the respective label attached to it by the source-institution (e.g. initiative, programme, project). Moreover, projects falling under the umbrella of wider initiatives (i.e. subprojects under larger projects) have also been included as individual projects. Such an example would be the case of EO4SD and EO4SD Eastern Partnership, both of which have been included in the study as individual projects. This approach was adopted under the assumption that most subprojects have identifiable goals, often separate from the goals of the respective umbrella project, and therefore their contributions to the achievement of the SDGs should be recorded separately. The terms *project* and *solution* are used interchangeably in this study.

In total, 1542 project alignments were considered. The main body of projects that were included in the database were aligned to the SDG framework at a Target level, with the majority originating from the European Space Agency's (ESA) SDGs Portal database [14]. At a Goal level, principal sources of space-related contributions include the Earth Observation Handbook [39] and the International Partnership Programme (IPP) report of the UK Space Agency [50]. Other documents, including conference presentations of the Japan Aerospace Exploration Agency (JAXA) [25], the German Aerospace Center (DLR) [12] and the Canadian Space Agency [6] further expanded the list of projects. In addition, European Global Navigation Satellite Systems (EGNSS) and Copernicus contributions previously compiled by UNOOSA [62] have also been incorporated. Table 1 presents a complete list of the sources used for the mapping of space projects contributing to the achievement of the SDGs. In general, only official publications have been used in this study. In the case of the Indian Space Research Organisation (ISRO), however, no official publication could be found, but alignments of ISRO projects to the achievement of the SDGs have been mapped by an unofficial online source. Therefore, in order to ensure authenticity of the data, ISRO has been asked for confirmation of these alignments.

As this paper focuses on the relationships between projects, SDGs, and Targets, the most effective way to represent and analyse the information was deemed to be using a graph database [42]. Graph databases are designed to treat the relationships between data (relationships) as equally important to the data themselves (nodes). It is intended to hold data without constricting it to a pre-defined model [35] embedding the relationships as natural part of the database structure, making it easier to understand them and to extract the information contained in the nodes and relationships in an efficient manner.

The Neo4j graph database management system [36] was used in combination with the R programming language, enabling the authors to analyse the project alignments in detail. A visualisation of the compiled data was created. The project alignments were clustered into

Table 1 List of sources utilised for the mapping of space-related contributions to the SDGs

Institution	Source title	Source type	Reference
Algerian Space Agency	*Monitoring and estimation of the Sustainable Development Goal (SDG) 15 by remote sensing tools, assessment of land productivity change (sub-indicator 15.3.1)*	Conference presentation	[3]
Bolivarian Agency for Space Activities	*Space Activities in Venezuela*	Conference presentation	[49]
Canadian Space Agency	*Space supports the Sustainable Development Goals*	Conference presentation	[6]
China National Space Administration	*China space solutions for the realization of the SDGs*	Conference presentation	[67]
Committee on Earth Observation Satellites, European Space Agency	*Satellite Earth Observations in Support of the Sustainable Development Goals*	Report	[39]
European Space Agency	*SDGs Portal*	Online database	[14]
German Aerospace Center	*Space Research and Technology: Key Driver* for Development	Conference presentation	[12]
German Aerospace Center	*DLR Nachhaltigkeit. Bericht 2016/17*	Report	[10]
German Aerospace Center	*Booth guide for the International Astronautical Congress 2018 in Bremen*	Congress brochure	[9]
Group on Earth Observation	*GEO Wetlands Projects*	Website	[19]
Indian Space Research Organisation	*Contribution by ISRO towards SDGs*	Document	[24]
Italian Space Agency	*ASI's Survey to contribute to the achievement of the Sustainable Development Goals*	Conference presentation	[40]
Japanese Aerospace Exploration Agency	*JAXA's Activity for Sustainable Development Goals (SDGs)*	Conference presentation	[25]
National Aeronautics and Space Administration	*EO4SDGs*	Conference presentation	[26]
National Institute of Aeronautics and Space of Indonesia	*Enhancing the role of Space for the SDGs in Indonesia*	Conference presentation	[46]
Netherlands Space Office	*Earth Observation and Sustainable Development Goals in the Netherlands*	Report	[38]
South African National Space Agency	*Earth observation services for Monitoring Agricultural Production in Africa*	Website	[47]
UK Space Agency	*International Partnership Programme:* Project overview	Report	[50]
United Nations Office for Outer Space Affairs, European Global Navigation Satellite System Agency	*EGNSS and Copernicus: Supporting the Sustainable Development Goals*	Report	[62]

categories and synergies between space technologies were subsequently explored (see Fig. 2 for visualization of the database).

To gain further insights on the data and provide a platform for their interpretation, a set of qualitative analysis methodologies were used. Initially, the SDGs were evaluated against RQ2 in order to identify the answers to the question. The three SDGs with the highest number of related project alignments and the three with the lowest number of project alignments, along with SDG 17 (for further information about the justification behind the choice of SDG 17, see section 4), were selected to be analysed qualitatively.

The exact text of the Targets of each of the aforementioned SDGs was inserted in a qualitative analysis tool, NVivo [43], to analyse the content. Initially, the Target text of each SDG was visualised through the word cloud function of NVivo to measure the frequency with which different words appear within the text of each SDG. Word clouds are "visual representations of a set of words, typically a set of tags, in which attributes of the text such as size, weight or colour can be used to represent features (e.g. frequency) of the associated terms" ([23], as cited in [7]). In this study, the entirety of the text of the Targets was included in word clouds. Connectors and transition words were removed automatically from the process and the word clouds were created at the level of exact words. Apart from the original word frequency query of each individual SDG, queries for combinations of SDGS were also run (e.g. combined text

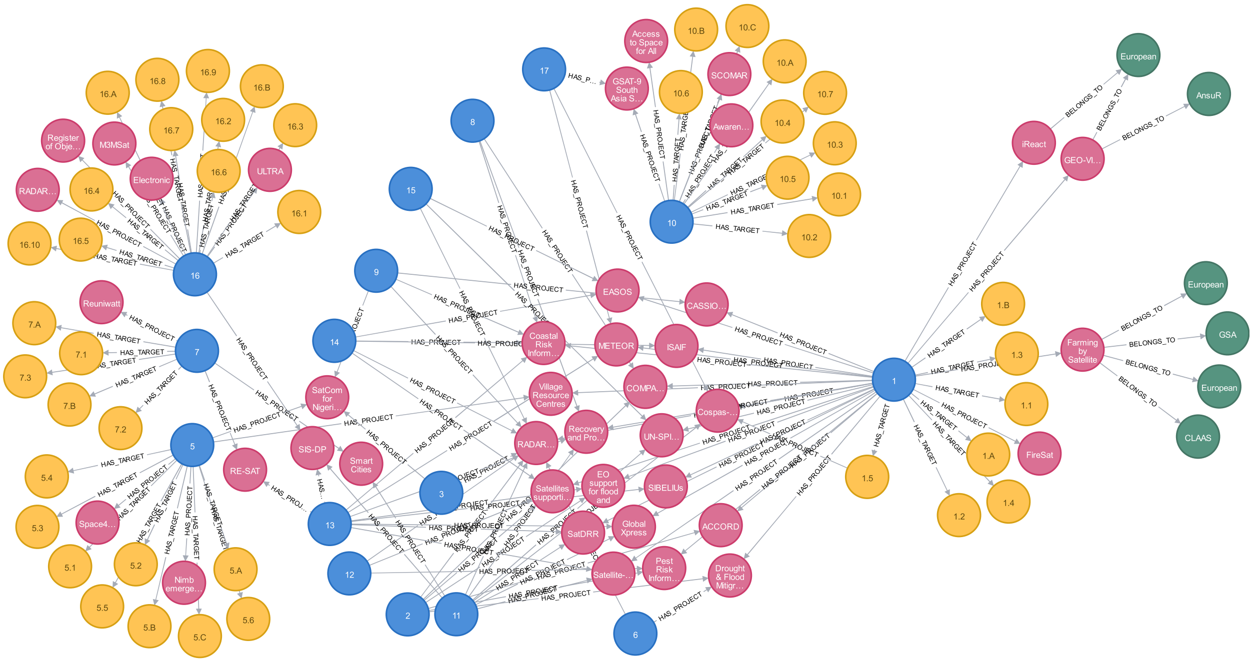


Fig. 2 Extract from the database in pictorial form. The database contains nodes (coloured circles) which are connected by relationships (arrows). Each relationship includes a tag to describe the relationship type (e.g. BELONG_TO), which facilitates more intuitive queries to the database. The nodes are coloured according to their types; in the figure, the colour code is as follows: Green = Institutions; Red = Projects; Blue = SDGs; Yellow = Targets

of the three SDGs with the highest number of project alignments; combined text of the three SDGs with the highest number of project alignments).

Subsequently, utilising insights from the word clouds, the text was subjected to content analysis [37] to identify patterns in the content and the phrasing of the Targets that could provide insights on the linkages between the SDGs and space contributions. The selected approach for the analysis consisted of the development of a tagging system: tagging of words or phrases and grouping of tagged text according to themes selected by the authors. The construction of the tagging system was based on the evaluation of Target excerpts (henceforth *items*) according to *actionability*. For the scope of this study, *actionability* of an item is defined as the level at which the examined text enables, supports and/or promotes conceptualization and implementation of targeted items within a specific, well-defined context. Actionability is understood as a spectrum and is therefore by definition complicated to break down into distinct categories. For the purpose of this article, actionability has been broken down to a set of Likert scale nodes as shown in Fig. 3.

The content of the Targets was tagged according to the aforementioned levels of actionability, based on several criteria, including but not limited to level of generality of language, references to specific action plans, and level of specificity of objectives. The different SDGs were compared against each other, as well as in groupings, with the aim to draw conclusions about the relationship between the number of project alignments and the content/phrasing of the Targets of each SDG.

Several other tags were introduced, such as the distinction of target groups between general and specific. All references to specific individual or groups of

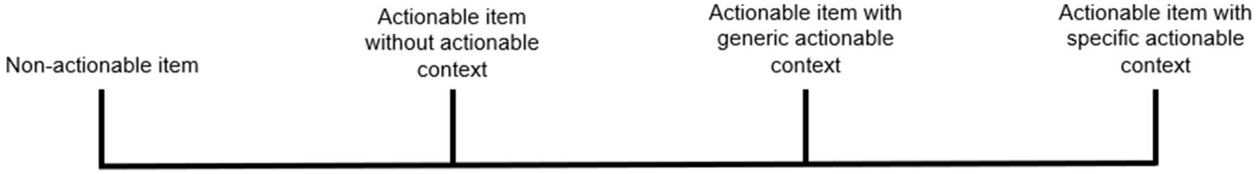


Fig. 3 Actionability spectrum in Likert scale form. The nodes identified in the spectrum range from *Non-actionable item* (minimum level of actionability) to *Actionable item with specific actionable context* (maximum level of actionability)

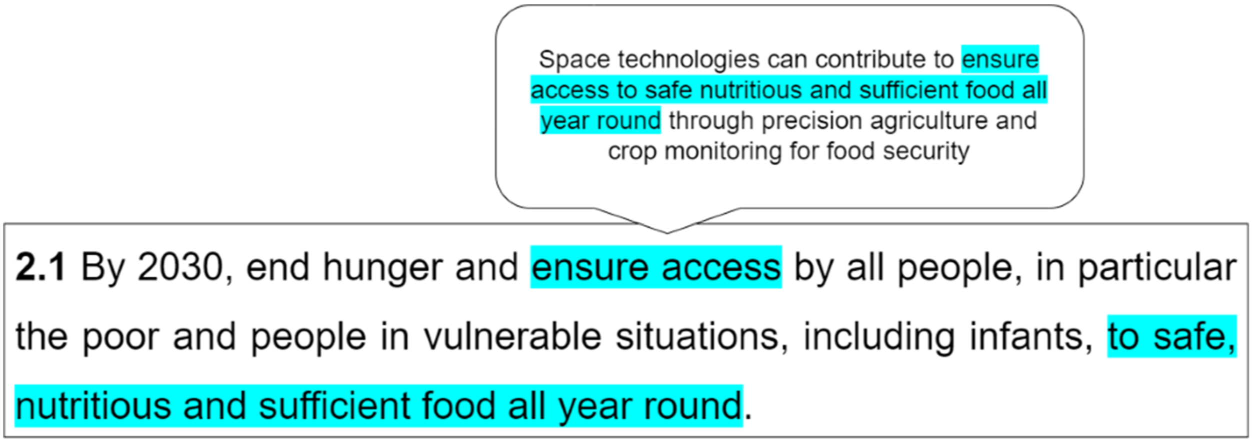
recipients of the benefits, or guidelines that the Targets make provisions for were tagged as specific target groups. The rest, and more generic mentions to target groups were tagged as generic. Furthermore, the entirety of the content of the Targets was examined under a space expert lens to identify instances of potential contributions of space to the SDGs. More specifically, each item was cross-referenced with existing space technologies and/or solutions in order to ascertain the potential of space to provide services relevant to each notion included in each Target.

Figure 4 illustrates the approach to the identification of items that have potential to receive contributions from space. In this example, Target 2.1 was tagged once with *potential space references*. As the process of identifying items that might have the capacity to receive space contributions relied on the individual and cumulative expertise of the authors regarding existing technologies and their potential uses, it is not all-encompassing; potential space references might not have been included and constant technological advancement calls for regular updates of the study (for more information, see section 2.3).

Obstacles to research and other limitations

One issue faced during the compilation of space contributions was the differentiation of projects that directly contribute to the achievement of the SDGs and those whose contribution is limited to monitoring of the progress made towards the achievement of Targets at an indicator level. Further implication was that some of these monitoring contributions could be considered as policy-informing and thus indirectly contributing to the actual achievement of the SDGs. This difficulty therefore reinforced the authors' initial position of only taking project alignments' contributions into consideration without attempting to make such alignments themselves.

The additional challenge was the complexity exhibited by the alignments. Individual projects were often aligned with the achievement of multiple SDGs or Targets – the latter at times including more than 15 instances of alignment. The projects vary widely in size and scope, but, as alignments were taken from the source, the projects were not weighted regarding which SDG's achievement is supported most distinctly. It was consequently not possible to determine, what the main area of each space contribution is. To overcome the above problem as well as the issue of presenting the plethora of data in tabular form, further steps in data preparation were considered necessary. At a Target level, the list of project alignments was again carefully reviewed and evaluated as either a direct or an indirect contribution. Direct contributions were considered to be those whose impact immediately benefits the achievement of a specific Target. While indirect contributions also conduce to the achievement of a Target, such contributions are merely viewed as implicit side benefits of the primary objective of the projects. From this perspective, projects that help farmers improve their crop yield can be viewed as having both direct but also indirect implications. A direct contribution to Targets 2.3 or 2.4 as an increased food production is the direct consequence, while poverty reduction would be considered a side effect of increased agricultural efficiency as an indirect contribution to Target 1.1. The authors acknowledge that this approach is bound to be subjective and simultaneously emphasize that the process of labelling contributions as either direct or indirect was carried out without the involvement of reporting institutions and in the absence of available official information. Consequently, this categorization does not necessarily reflect the opinion of the reporting



Space technologies can contribute to ensure access to safe nutritious and sufficient food all year round through precision agriculture and crop monitoring for food security

2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.

Fig. 4 Illustration of the tagging process for potential space references. The highlighted text is considered one space reference. The bubble indicates the justification for the inclusion of the example as a potential space reference institutions, however, it was nevertheless deemed important as to give insights into the wide distribution of contributions across the SDG spectrum and to render the data intelligible.

At last, two more limiting aspects require further clarification. First, the authors do not claim completeness of the mapping. Since the goal was to investigate and aggregate those space contributions that were publicly reported by institutions, only those alignments found in official publications were included. Projects conducted by the listed institutions, as well as of other institutions that were not quoted, may very well have contributed to the achievement of the SDGs, however, since their alignment was not described explicitly in official publications, they could not be used for this study. Secondly, it should be emphasized that the following mapping reflects the status quo of current space contributions to the achievement of the SDGs and not the potential thereof. The fact that some SDGs or Targets seem to be less supported by space technologies may eventually change, sooner or later. Furthermore, in order to avoid possible misinterpretations, it is important to take into consideration that, due to the nature of this research, all projects are equally weighted. Consequently, some Targets that are connected to only a few space projects may appear to be supported less than other Targets. However, the few contributing space projects might be of considerable scale and complexity. The likelihood of such obstacles should be borne in mind when reviewing the following research results.

It is important to mention that as content analysis “more than any other research method, is inextricably tied to human intellectual abilities” ([27], p.209), subjective interpretation is an inherent part of the approach. In this study, and in particular regarding space reference tagging, the authors have an inherent understanding of how space contributes to sustainable development and the identification of such potential references might be influenced by such insights. One such example would be the case of trafficking: even though the connection between space technology and trafficking might not seem obvious, monitoring through satellites is quite prevalent in projects combatting trafficking (see for example: [5, 61]). As the authors are aware of this fact, the word *trafficking* was identified and used as a potential space reference.

Results

The study database includes 506 unique projects and 389 unique institutions. While all SDGs exhibited at least one project alignment, this is not the case at a Target level; only 100 out of the 169 Targets exhibited at least one project alignment. It is worth noting that, as the projects examined have been aligned to the components of the SDG framework by the source-institutions, the project alignments may happen at different levels, namely either the Target or the Goal level. To avoid misinterpretations of the original alignment processes, this study examined the project alignments at their original level as provided by the source-institutions.

Space-related projects, the Targets, and the SDGs are highly interconnected. The 506 examined projects have, in total, 1542 connections to different SDGs and Targets, which means that, on average, each project contributes to more than three SDGs or Targets. The number of project alignments varies significantly across projects. Answering RQ3, with connections to 28 different Targets, the project with the highest number of project alignments is a SatCom project named *ECO (Every Child Online)*.

Correspondingly, some SDGs have more connections to projects than others, as it can be seen in Fig. 5, where connections either to the Targets or directly to the SDGs are shown. Addressing RQ1 and RQ2, the highest number of project alignments is towards SDG 9: Industry, Innovation and Infrastructure, while the SDG with the lowest number of project alignments is SDG 5: Gender Equality. After SDG 9, with more than 100 project alignments each, follow SDG 2: Zero Hunger, SDG 3, and SDG 17. Besides SDG 5, SDGs with fewer than 50 project alignments include SDG 16: Peace, Justice and Strong Institutions and SDG 10: Reduced Inequalities. It should be noted that SDG 17, which is a unique Goal within the SDG framework, due to its focus on cooperation for the achievement of the rest of the SDGs, exhibits a significantly high number of project alignments. This result is quite interesting, yet expected, considering the nature of SDG 17, which is discussed further in section 4.

The analysis has also considered the technologies to understand their distribution within each SDG, either directly or to the Targets. Overall, EO and SatCom tend to be the most prevalent technologies. EO alone accounts for 457 out of the 1542 project alignments (approximately 30% of the total), while SatCom accounts for 448 (over 26%). These numbers indicate a single utilisation of EO or SatCom without any combinations. When considering projects that utilise a combination of technologies, the aforementioned numbers increase dramatically: the rate of EO in combination with other technologies reaches over 35% of the total alignments, while SatCom in combination with other technologies represents over 33% of the alignments. Both technologies – EO and SatCom – combined represent only 1% of the total alignments.

Figure 6 illustrates the distribution of contributions of the different technologies to each SDG (see RQ4), at both the Target (6.A) and the Goal level (6.B), as well as aggregated view of Goal and Target level (6.C). To avoid double-counting of cases, each project that employs a

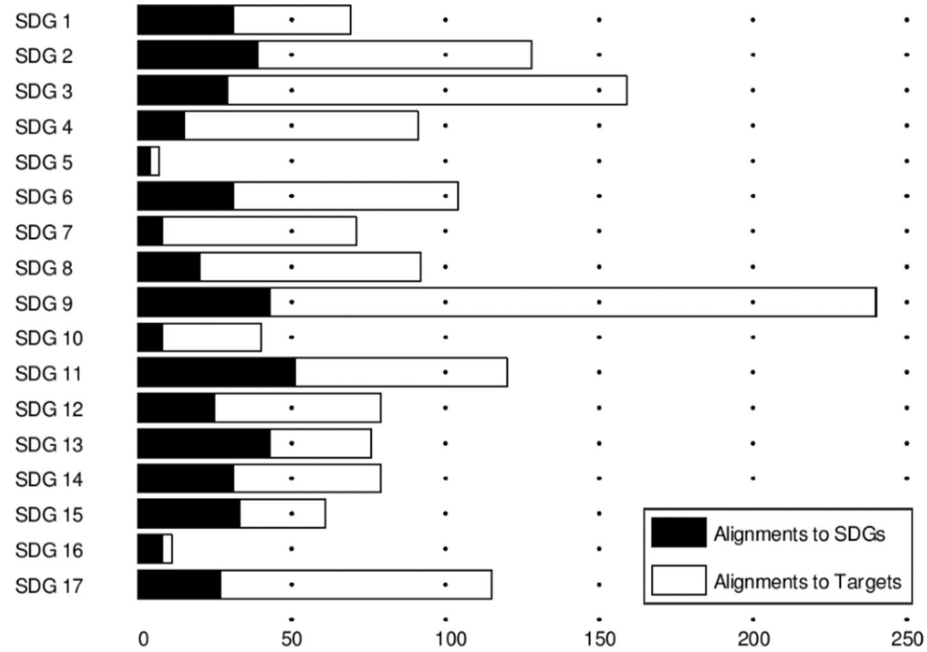


Fig. 5 Number of project alignments per SDG. The graph shows the number of alignments to each SDG (alignments provided at SDG level, not at Target level) and the alignments directly to Targets

combination of technologies is counted as one project alignment in total. Therefore, if, for example, a project uses three different technologies, their contribution (project alignment for each technology) will be divided by three. As can be seen in Fig. 6, some SDGs exhibit clear prevalence of specific technologies, while in others this prevalence is not quite as distinct. In Fig. 6.A, two technologies prevail, followed by a set of others of a similar level in terms of number of project alignments. SatCom stands out as the technology with the most alignments at Target level (466), followed by EO with 277. GNSS, Space Exploration, and Technology Transfer follow with a similar number of alignments (approximately 115). However, when considering the alignments at SDG level (Fig. 6.B), EO is the most represented technology with 268 alignments, followed by GNSS with 58 alignments, and SatCom with 50. Figure 6.C considers all the technologies that are present in the project alignments and groups them by SDG.

The same technology can be applied in different manners, in response to different needs which shape the way in which the technology is integrated in the solution. 211 projects, out of a total of 506 in the database, are relevant to only one SDG, which was an unexpected outcome considering the interlinkages between SDGs. Furthermore, despite the differences in the perceived impact of each project alignment on the achievement of its respective target SDG, this study does not adopt a weighted approach in assessing such differences; each project alignment is counted as one contribution.

Regarding RQ5, it can be observed that the number of space technologies mobilized in the projects varies. Nevertheless, as Fig. 7 shows, more than three quarters of the projects considered in this study made use of only one space technology, while 22% were based on some combination of space technologies. EO and SatCom were by far the most commonly used technologies with either of them contributing to more than a third of the total number of projects, whereas the use of GNSS, technology transfer, space exploration, space science, and other technologies was less prevalent. However, despite the fact that GNSS contributes little by itself, it constitutes a component of three space technology combinations that exhibit a comparably high degree of contributions, namely in combination with EO and SatCom. The most commonly used technology combination was EO and GNSS followed by space exploration and technology transfer (Fig. 7).

Figure 8 shows the number of items tagged with the various actionability tags (non-actionable item; actionable item without actionable context; actionable item with generic actionable context; actionable item with specific actionable context) per SDG. The cumulative count of tagged items appears to be a rough indication of the tendency of an SDG to receive contributions from space. All three SDGs with the highest number of

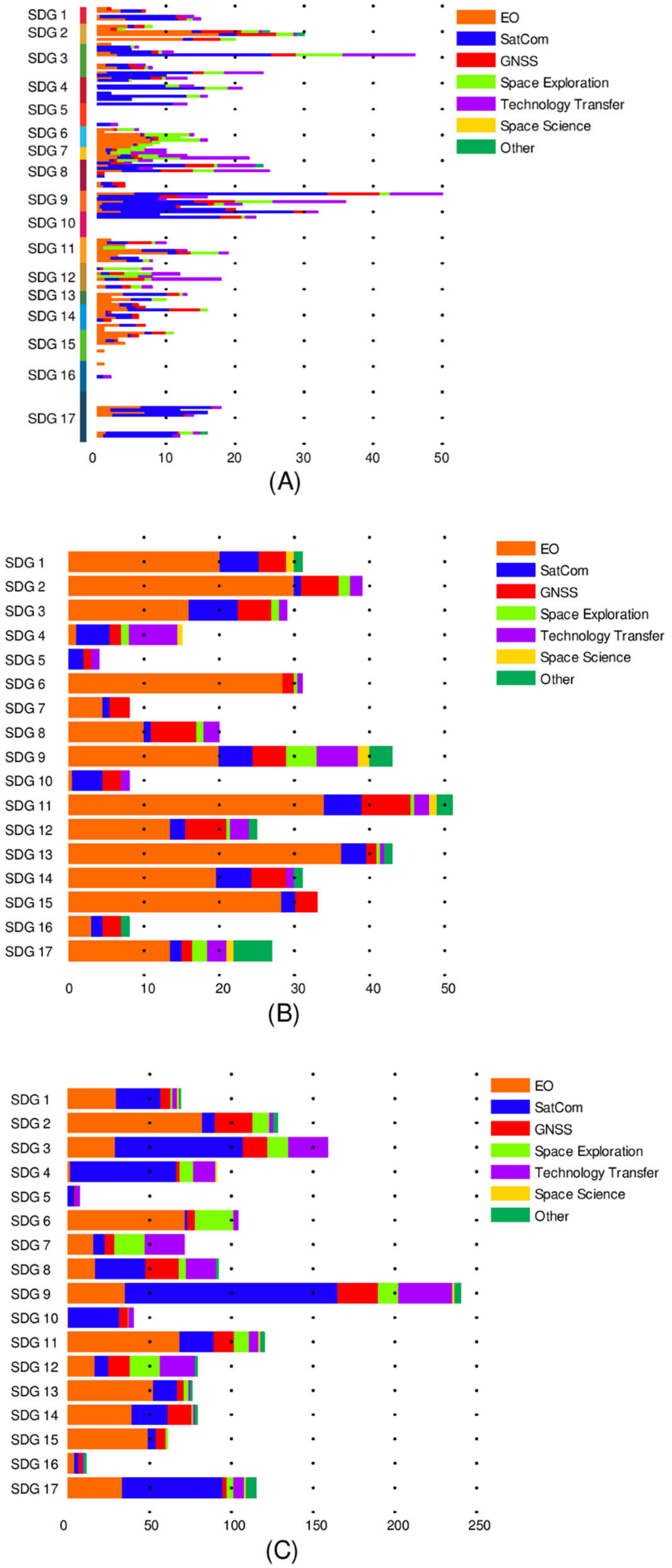


Fig. 6 Share of the various technologies for each SDG at Target level (6.A), Goal level (6.B) and aggregated view of Target and Goal level (6.C)

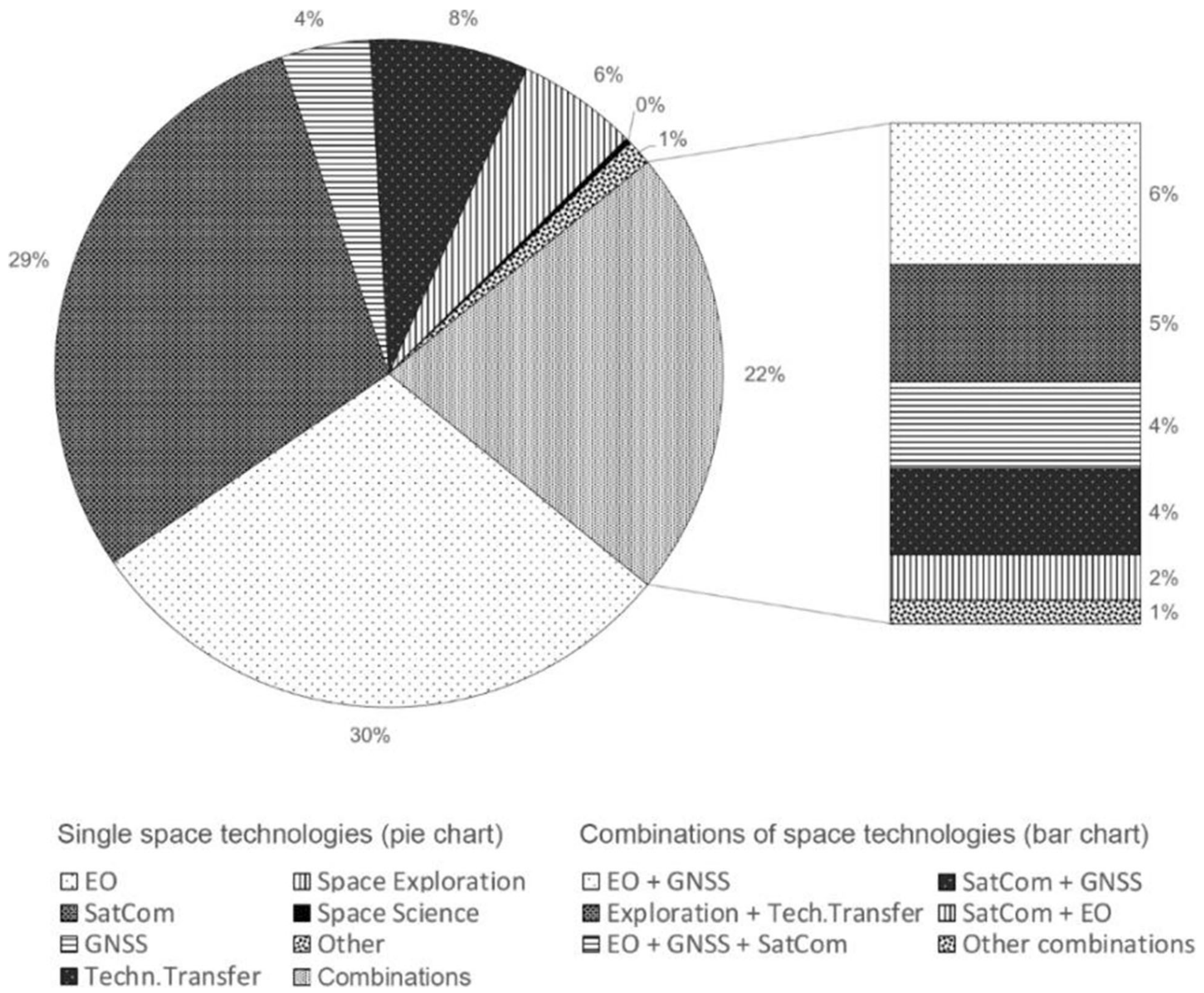


Fig. 7 Breakdown of the contributions of individual space technologies (pie chart) and combinations thereof (bar chart) to the sum of projects. Combinations that make up less than 1% of all combinations are summarized in the category “Other combinations”. Percentages in parentheses are relative to the sum of technology combinations. The percentage values have been rounded to the nearest integer

project alignments, as well as SDG 17, exhibit higher numbers of tagged items when compared to the three SDGs with the lowest number of project alignments. It is noteworthy, however, that there seems to be no direct correlation between the number of project alignments and that of the tagged items. For example, as evident in Fig. 5, SDG 9 exhibits a higher number of project alignments in comparison to SDG 2; yet SDG 2 exhibits a higher number of tagged items under the actionability theme than SDG 9. Nevertheless, overall, both SDG 2 and SDG 9 show a higher number of tagged items than any of the three SDGs with the lowest number of project alignments.

This relationship is also illustrated, in a more evident fashion, in Fig. 9, that shows the number of items tagged with the target group specificity tags (generic target group; specific target group) per SDG. The cumulative count of tagged items under the target group specificity theme appears to be more strongly relevant to the project alignment number than the actionability theme.

Similarly, the cumulative count of tagged items under the two themes combined appears indicative of whether an SDG will receive a significant number of contributions or not (Fig. 10).

The content analysis was concluded with the tagging of items that could have indicated potential for space contributions (*potential space references*). As these references tended to be more contextual rather than individual words in sequential order (see Fig. 4), the tagging approach utilized was based on *coverage*. Coverage “indicates how much for the source content is coded at [each] node” [44]. It takes the form of percentage of the

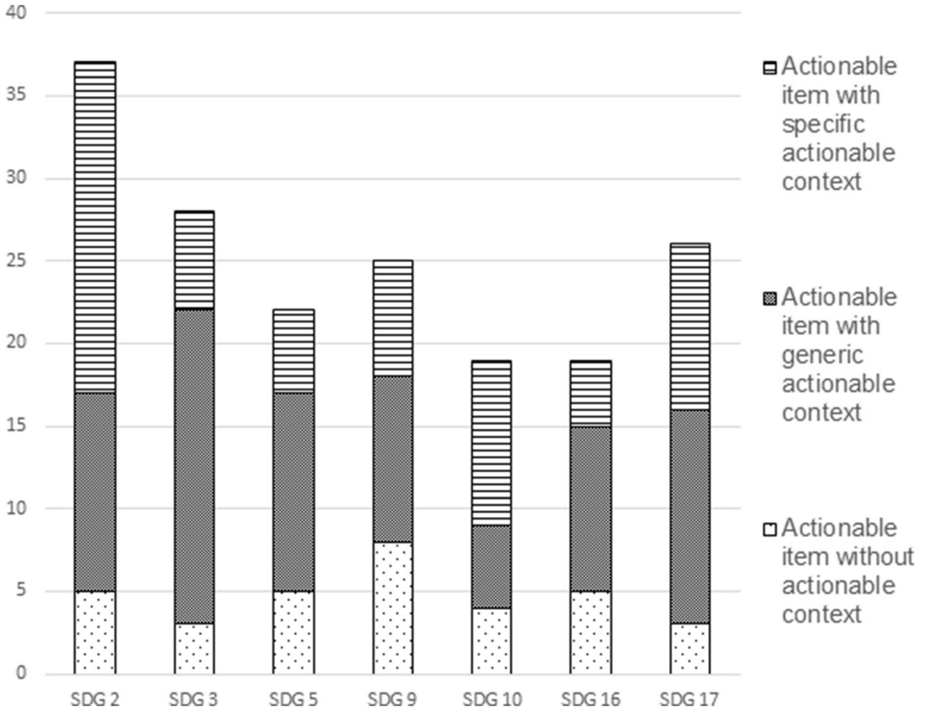


Fig. 8 Actionability disaggregated by tag. The graph indicates absolute numbers of items, not weighted in terms of individual SDG word count. As there were no instances of non-actionable items, this category is not included in the figure

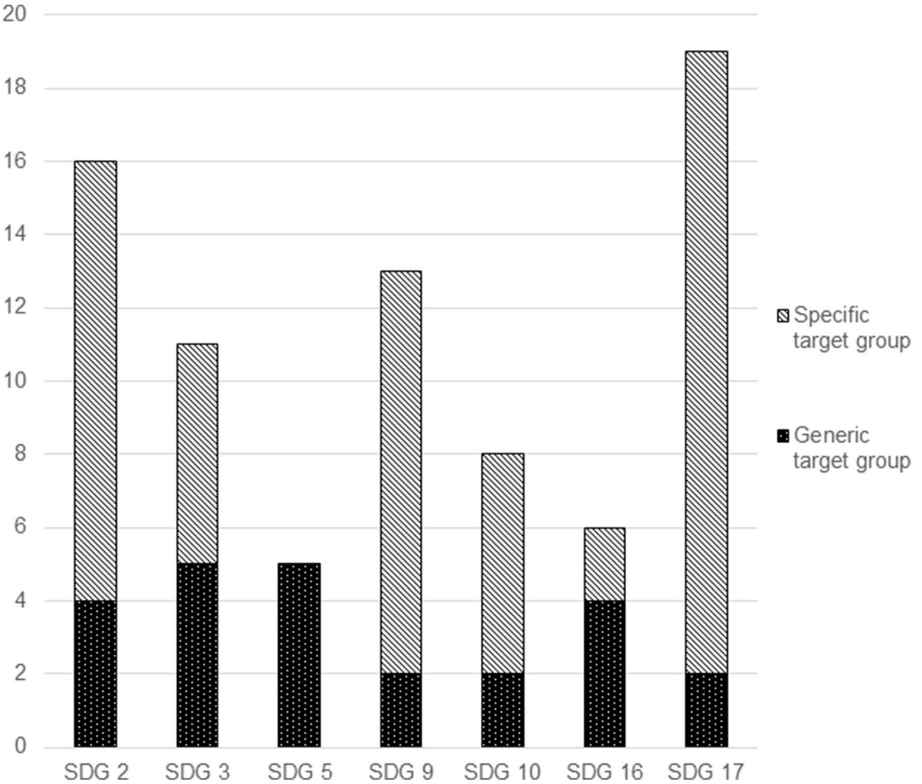


Fig. 9 Specificity of target groups by tag. The graph indicates absolute numbers of items, not weighted in terms of individual SDG word count

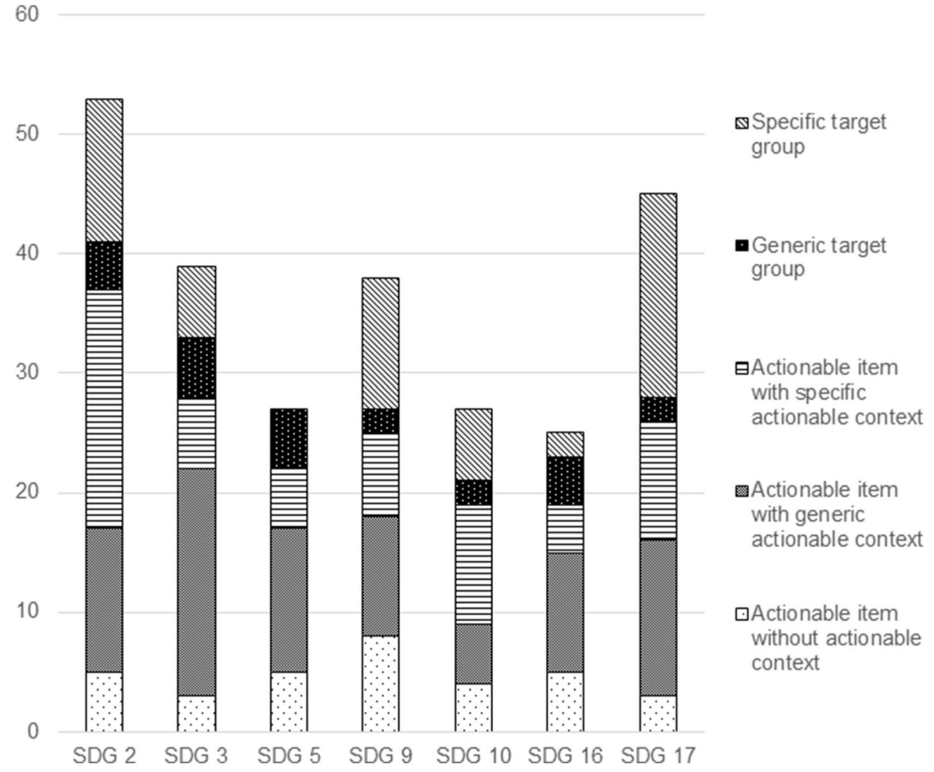


Fig. 10 Actionability and target group specificity by tag. The graph indicates absolute numbers of items, not weighted in terms of individual SDG word count. As there were no instances of non-actionable items, this category is not included in the figure

overall source content and is calculated by NVivo based on the relevant tagged items. Additionally, the overall word count for each SDG was calculated, as well as the word count of items tagged with the potential space reference tag. Figure 11 illustrates the different components mentioned above, namely space reference coverage, overall word count per SDG, and space reference word count per SDG. In order to enrich the results and make them more intelligible, the authors calculated and included in Fig. 11 the ratio of space reference word count per SDG to overall word count per SDG (*word count ratio*).

Discussion

Exploring the results presented in section 3, it becomes clear that the role that space can play in the achievement of the SDGs is prominent. Space contributes to all 17 SDGs, even though the distribution of project alignments is uneven, with SDGs 5, 10, and 16 being the ones that benefit less overall. A potential explanation behind this uneven distribution can be traced to the actual content and wording of the different SDGs.

As seen in section 3, content analysis is a powerful tool to explore relationships between project alignments and SDGs and Targets. Innumerable approaches to content analysis of the SDGs can be followed; in this paper, the authors decided to explore the notions of actionability, target group specificity, and potential space references. The reason behind this choice of themes lies in the wording of the SDGs. As mentioned in the methodology section (section 2.2), the content of the SDGs was run through the word cloud function of NVivo to explore potential themes, overlaps, and differences. During that process, the comparative results of two combinations of SDGs, namely the group of SDGs with the highest number of project alignments (group A) and that of those with the lowest number of project alignments (group B), produced a very interesting insight (Fig. 12).

As illustrated in Fig. 12, the prevalent language used differs significantly between the two groups. Although both groups exhibit a clear focus on developed and developing countries, the means and thematic pathways proposed are very different. While group A made more use of more technology-oriented words, such as *infrastructure*, *research*, *industrial*, and *access*, group B focused more on institutional structures, with the use of words such as *institutions*, *policies*, and *economic*. This disparity led the authors to the selection of the three themes presented in the methodology (section 2.2).

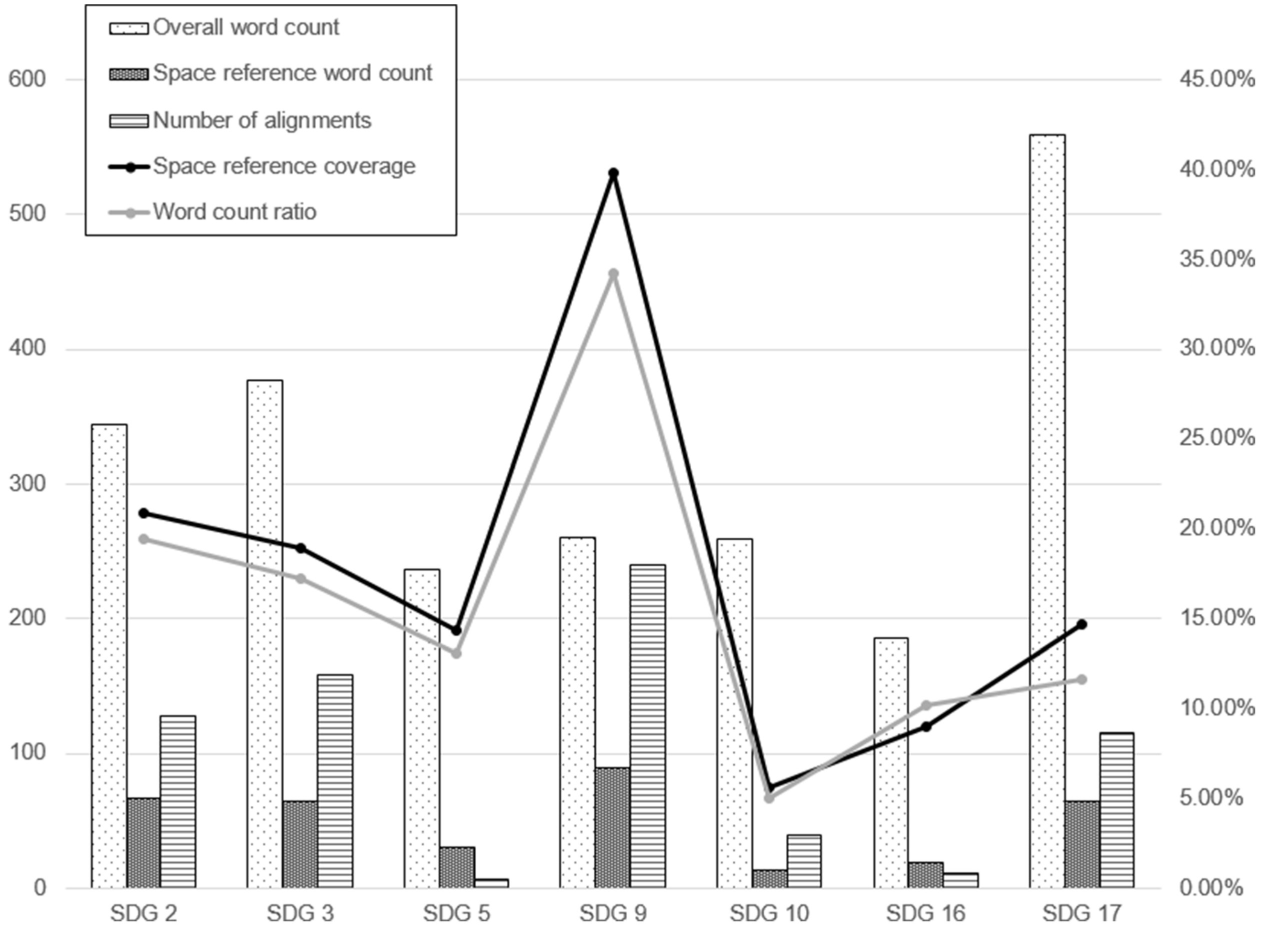


Fig. 11 Percentage of SDG coverage of potential space references in terms of word count. The graph shows the overall word count and potential space reference word count as absolute numbers and ratio, as well as the number of project alignments per SDG

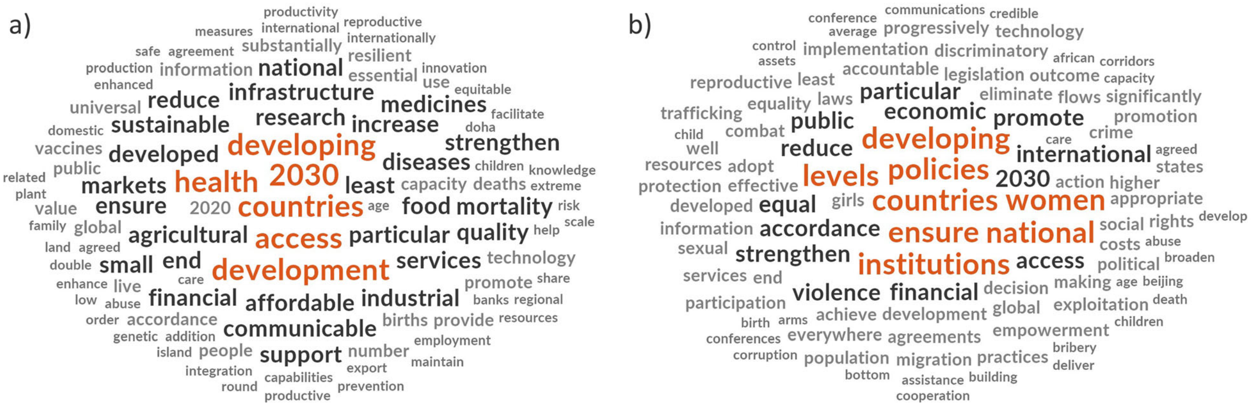


Fig. 12 Word clouds generated for a) the three SDGs with the most (SDG 2, 3, and 9) and b) the three SDGs with the fewest project alignments (SDGs 5, 10, and 16), using NVivo [43]

Interpreting group A as more working level and actionable from a space technology perspective as opposed to group B, the authors explored whether this perception could be derived from the linguistic context provided in the content of the SDGs. As explained in the results (section 3), from an actionability perspective, even though a generic relation seems to exist, no direct correlation could be deduced. Similar results derived also from the target group specificity analysis.

Nevertheless, the comparison of the potential space reference word count ratio with the number of project alignments per SDGs resulted in much stronger correlation, with SDGs with higher word count ratio tending to exhibit more project alignments. Even though the relationship between the two parameters is not direct, it could indicate either gaps in the mapping of space contributions, the existence of potential niches to expand the implementation of space-based projects, or both.

At this stage, it is important to acknowledge the existence of SDG 17: Partnership for the Goals, as it has been a staple aspect of the interpretative approach that this study has adopted. From the perspective of space contributions to the 2030 Agenda, the existence of SDG 17 is pivotal, as it brings in the element of international cooperation. International cooperation is essential in the processes involved in the development and implementation of space-based projects, as space technology is in general an international endeavour that requires extensive multilateral cooperation. Therefore, the cooperation reflected in the SDG 17 plays a fundamental role in the development of space technologies, affecting deeply the contributions of space to the 2030 Agenda in a circular way (Fig. 13).

Fig. 13 Schematic representation of the circular interaction between the 2030 Agenda, international cooperation (SDG 17) and the development of space technologies

Throughout this paper, SDG 17 has been consistently included in the analysis, intended to be used as a basis for comparison to enhance the interpretation of results. The reason behind the role that SDG 17 plays in this study lies in the fact that, as mentioned earlier, SDG 17 constitutes a very particular case within the SDG framework. As the only SDG formulated differently than the rest of the Goals, in both content and actual format aspects, SDG 17 is also unique in terms of content as it is the only SDG that refers to other SDGs and the wider SDG framework. SDG 17 calls for the development of partnerships for the achievement of the 2030 Agenda and does not constitute a stand-alone objective like the other Goals. It exhibits a circular approach to the interpretation of the 2030 Agenda, acting as the connector between the different building blocks of the SDG framework, using international cooperation as the binding agent. This uniqueness of SDG 17 is also evident in its format, being the only SDG that categorises its Targets into thematic areas with subtitles. SDG 17 has alignments to Targets 17.6, 17.7, 17.8, 17.9, 17.16, and 17.17, which correspond to the thematic areas of T*echnology*, *Capacity-Building* and *Systemic Issues*. The other two thematic areas of SDG 17, namely *Finance* and *Trade*, do not exhibit any alignment.

As is evident in the case of SDG 17, the content of the SDGs impacts the type of projects that are aligned to each Goal, and this impact also affects the potential of space to contribute to the achievement of the 2030 Agenda. Yet, there are other factors at play that should be considered when discussing the role that space plays in the attainment of the SDGs.

When examining the share of the space technologies contributing the most to the SDGs (see RQ4), the largest contributions by far are those of SatCom and EO. Several factors may affect this distribution and, acknowledging the complexity of the issue, the authors have identified a set of potential causes that, although likely simplifying the situation for the sake of fostering discussion, may provide interesting insights.

1. *Versatility*

Versatility indicates the variety of different uses that can be made of the same technology. Specifically, SatCom is an enabler and integral part for many solutions; for instance, a solution like tele-medicine uses SatCom to transmit the data gathered by different instruments (such as a sonographer) to a location where this data can be analysed by experts [28]. Furthermore, SatCom provides the interconnectivity layer making telemedicine accessible in remote areas. As more and more devices rely on internet connection availability, interconnectivity everywhere becomes increasingly essential, enabling the development and implementation of applications that were not possible before. The space solutions landscape associated with SatCom will change in the near future, as the deployment of satellite mega constellations, including constellations to support the deployment of 5G, will be a catalyst for the proliferation of new solutions.

For what concerns EO, the variety of sensors that can be accommodated in a satellite (or a constellation of satellites) to monitor the Earth allows for very different applications ranging from weather monitoring [41] to measuring subsidence of buildings or dams [31, 48] and monitoring of assets to ensure the fulfilment of international obligations, namely addressing any state obligations that stem from international law [32].

However, the versatility rationale may apply also to technology transfer, as spin-offs of the different technologies, such as miniaturization of computers, permeate our daily lives. An illustrative example would be the Apollo Guidance Computer (AGC) that was developed for the Apollo programme and had to be miniaturized to fit in a very small space and weigh as little as possible, compared to its contemporary computers occupying entire rooms. The production of the AGC computer started the trend of processor miniaturization, effectively meaning that all integrated circuits are part of the Apollo legacy, as the first integrated circuit was created to meet NASA's specifications for reduced weight and increased computing power [33]. Despite the omnipresence of integrated circuits, however, it is not obvious at first sight that, for example, a fridge is somehow related to the Apollo program.

2. *Availability*

The availability of specific technologies may be able to explain why they are used more prominently. The term *availability* is a mix of different aspects, and therefore a complex issue to analyse. Initially, the number of assets that can be categorized under a certain space technology could be a good indicator of availability. In the case of satellites, in most cases it is possible to assign a satellite to a single category and it is easy to quantify how many of them fall under a certain technology. To analyze the

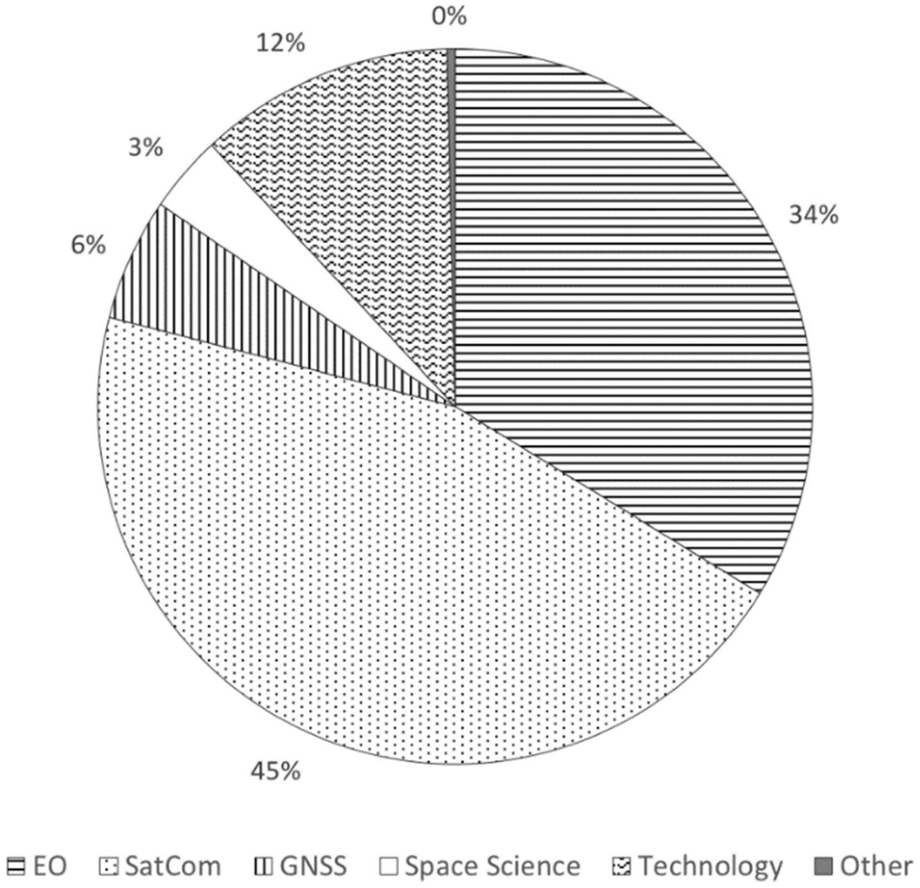


Fig. 14 Share of technologies used by the operational satellites in orbit, as of March 2020

relationship between the number of satellites using a particular space technology and the prevalence of that space technology within the project alignments, data from the Register of Objects Launched into Outer Space (henceforth *Register*, maintained by UNOOSA [65]) has been used. The Register contains data on the *Function of the space object* which can be used to count satellites belonging to each technology, although occasionally the labels used might not correspond directly to specific technologies. A combination of data from the Register and the database of the Union of Concerned Scientists [52] has been used to illustrate the proportion of the various technologies used by operating satellites (Fig. 14). Nevertheless, the availability hypothesis appears to be valid only when the capacity of a solution can increase with the addition of more satellites of the same type (e.g. by increasing the frequency of images taken over a certain area). Conversely, the availability hypothesis does not apply to GNSS constellations, as the addition of extra satellites of the same type increases the resilience of the service but does not provide additional precision.

While there is a positive correlation between the number of satellites and the use of the technologies shown in Fig. 14, this correlation is difficult to establish for technology transfer, space science and space exploration, as the latter are not reliant upon assets as easily quantifiable as satellites. Therefore, finding the proxy for establishing the correlation becomes more complex, with the definition of assets for those categories often encompassing different things such projects, patents or policies. In the case of technology transfer, there is some degree of information tracked by dedicated organizational units within the space agencies (technology transfer offices), which allows for an order of magnitude. For example, ESA has "spun-off" over 150 projects during the last 10 years, yet, the total number of ESA projects in the database of this study is 258 and 54 are listed under technology transfer.

Moreover, certain policy aspects might have a positive or negative effect related to availability. For example, the application of intellectual property rights to data, services or technologies, might restrict or increase their availability. Likewise, the development and enforcement of policies and regulations related to the use of certain technologies might increase or decrease their availability, as they might artificially create or hamper markets for the technology. For instance, the EU Directive 2005/35/EC of 7 September 2005 in article 10.2 (a) "tracing discharges by satellite monitoring and surveillance" ([17], L 255/14) specifically refers to satellite monitoring, which increased the demand for Earth Observation. Similarly, policy recommendations can be made to encourage the use of space technologies for the achievement of the SDGs.

So far, the paper has focused on single technologies, however, a significant share of space-based technologies is being used in some combination, highlighting the importance of synergies between the various technologies. As shown in Fig. 7, about a quarter of contributing projects involve a combination of two or more technologies, with EO and GNSS being the most common of such combinations, followed by space exploration and technology transfer. These results originate from the fact that EO and GNSS are complementary technologies as seen in the common integration of Copernicus EO with GNSS [62]. A variety of projects integrate space-based measurements, such as EO imagery, with in-situ measurements based on satellite navigation, either directly or indirectly. The use of both data sources allows for complementation or validation of scientific measurements [1]. Another common area of application of a combined EO and GNSS approach is its utilization during search and rescue (SAR) operations, enhancing situational awareness as well as optimizing the localisation of and navigation to affected sites in remote areas or at sea [21, 29]. Both types of applications are highly relevant in the context of the SDGs, for example in the monitoring of environmental conditions or agricultural yields [2, 30], or in the prevention of deaths due to natural disasters or maritime accidents [20, 22, 29]. In the case of space exploration and technology transfer, the connection between the two can be explained by the adaptation of technologies used in space exploration for the use on Earth through technology transfer, such as air and water recycling methods used onboard the International Space Station and can be modified and transferred for use on Earth [8, 45].

Another aspect of the discussion on space contributions to the 2030 Agenda that has been brought to the surface through this analysis is the topic of potential niches. As revealed by the content analysis, several SDGs exhibit a "hidden" capacity to receive significantly more space contributions than currently reported. A prime example is SDG 5, one of the SDGs identified as one of the Goals with the lowest number of project alignments. The space reference word ratio of SDG 5 was calculated as only slightly lower than SDG 3, which is counted among the top three SDGs with the highest number of project alignments, and even higher than SDG 17. Two hypotheses support this outcome as rationale: i) SDG 5 may benefit from a significantly higher number of future projects than it does currently as it incorporates several gender-related thematic areas that are eligible to be served by space technologies, or ii) SDG 5 already benefits from a significant number of projects that have not been included in this study because they have not been officially mapped against the SDG framework. These hypotheses are likely to apply to all SDGs with a relatively high space reference word ratio.

To illustrate these hypotheses, we can consider the cases of tele-medicine and tele-education. Tele-medicine makes a direct contribution to the increased access to health services (SDG 3) and through this, it has an indirect, yet significant impact on sexual and reproductive rights, which are related to SDG 5. Similarly, tele-education has a direct and obvious connection to SDG 4, yet it is pivotal for women's empowerment as it enables access of women not only to education, but also to professional skills and, consequently, market and employment opportunities. Specifically, in the case of already existing projects, potential connections to SDG 5 could be incorporated and highlighted by targeting specific groups.

Rephrasing the description of a project to incorporate clearer wording about SDG-related outcomes, as in the case of tele-medicine explored earlier, can go a long way to increase visibility of space contributions to the 2030 Agenda. Considering the existing potential of space contributions, explicitly aligning projects with SDGs will enhance further the understanding of policy makers with regard to the role of space technologies for sustainable development and will allow access to a wider toolbox for policy-making targeting SDGs, particularly those with a low number of project alignments.

In conjunction with updating the description of projects, increased efforts on mapping of projects against the SDG framework would allow for expanded public awareness on the role of space in addressing global issues encapsulated in the 2030 Agenda, as well as improved monitoring of the distinct uses of space-based technologies and applications for the achievement and progress monitoring of the SDGs and the Targets. To achieve these objectives, relevant actors are encouraged not only to map their projects against the SDG framework but also to incorporate the use of space technologies into policy plans for the achievement of the SDGs, at regional, national or local levels.

Through incorporation of space technologies into national policy, states would further foster the design, development, and implementation of space projects targeting the SDGs. Such initiatives would incentivise institutions to explore novel approaches to help achieve the objectives of the 2030 Agenda, by for example, focusing on niches within SDGs with underexploited potential to receive space contributions (e.g. SDG 5).

Lastly, another indirect way for states to promote the acknowledgement of space contributions to the 2030 Agenda is to ensure the submission of comprehensive and detailed information about the functions of their launched satellites when they register them in the Register to facilitate the mapping of space contributions. By supporting the maintenance of a comprehensive and official database on space objects, states enable in-depth research on space contributions to sustainable development, which in turn can not only guide the development of new projects on relevant topics, but also support policymaking for the achievement of the 2030 Agenda.

Conclusions

Space-based projects can play a key role in the urgent global endeavour to achieve sustainable development. The variety of technologies these projects employ as well as their wide spectrum of application render them suitable to address all 17 SDGs and a significant number of the Targets of the 2030 Agenda. Nevertheless, the achievement of some SDGs benefits more from space-based projects than that of others. This study shows that technology-oriented SDGs 2, 3, and 9 were the ones most supported by projects, whereas institutional structure or policy-oriented SDGs 5, 10, and 16 were shown to be the least supported. Similar to the number of project alignments per SDG, the contribution of the various technologies and their combinations vary significantly per SDG and Target, with SatCom and EO taking the lead, which can be attributed to both their diverse nature and respective degree of availability. As emphasized earlier, the observation that some SDGs and Targets have only few contributions or exhibit a complete absence thereof, ought not be equated with an actual lack of contributions by space-based projects, but rather a lack of contributions mapping. Nevertheless, the results of this study serve as a general indicator of the distribution of contributions of space-based projects to the achievement of the SDGs.

While space technologies can make substantial contributions to the process towards the achievement of the 2030 Agenda, mapping of projects against the SDG framework is still fragmented and relevant attempts have been few and far between. It is important though to promote and expand such ventures to raise awareness and acknowledge the contribution of space. To this aim, space-related entities across all levels and geographical location should connect their activities to the international frameworks, and particularly the 2030 Agenda.

In support of the objective to increase mapping rates, UNOOSA, as the entity that "represents the United Nations in promoting international cooperation in the exploration and peaceful uses of outer space for economic, social and scientific development" [60], has organised several activities under the so-called Space4SDGs thematic umbrella [66]. The United Nations/Austria Symposium on Space for the Sustainable Development Goals, Stronger Partnerships and Strengthened Collaboration, which was held in Graz, Austria, 17–19 September

2018, discussed extensively the interlinkages between the space sector and the global agendas, and particularly the use of space-derived products and services for the 2030 Agenda [11, 57]. Interestingly, one of the main recommendations that came out of the UN/Austria Symposium was that "space agencies incorporate the 2030 Agenda for Sustainable Development into their goals, with a view to raising awareness and increasing the visibility of the space contribution" ([57], p.11). Subsequently, riding on the momentum created by the UN/Austria Symposium, UNOOSA in cooperation with the China National Space Administration organised the UN/China Forum on Space Solutions: Realizing the Sustainable Development Goals, in Changsha, China, 24–27 April 2019 [11, 58]. Similarly to the UN/Austria Symposium, participants of the UN/China Forum noted the importance of "space technology […] to the attainment of all Sustainable Development Goals and that more awareness raising efforts should be made to inform people of the benefits that outer space could bring" ([58], p.4), as well as that "more work was to be done by the United Nations and Governments in raising awareness about the Goals, in particular the targets and indicators associated with each Goal" ([58], p.5).

Efforts to promote the use of space for sustainable development continue, as the United Nations Member States are discussing the "Space2030" Agenda [59], which is still in draft status. However, in its current form, the "Space 2030" Agenda is considered "as a comprehensive and forward-looking strategy for reaffirming and strengthening the contribution of space activities and space tools to the achievement of global agendas, addressing long-term sustainable development concerns of humankind. It also contributes to charting the future contribution of the Committee to the global governance of outer space activities" ([59], p.2) and emphasizes that "space tools are highly relevant for the attainment of the global development agendas, in particular the 2030 Agenda for Sustainable Development and its goals and targets, either directly, as enablers and drivers of sustainable development, or indirectly, by providing essential data for the indicators used to monitor the progress towards achieving the 2030 Agenda" ([59], p.3).

It is important to note that although space is a very important instrument that contributes significantly to the achievement of the 2030 Agenda, under no circumstances should it be understood as a panacea. It should be considered as but one of many means and methods in the sustainable development toolbox and be utilised accordingly.

Space agencies and other stakeholders are actively working in the mapping of space solutions against the SDG framework. The number of project alignments is expected to increase in the future, and therefore, a revision of this analysis may be required.

Acknowledgements
The views expressed herein are those of the authors and do not necessarily reflect the views of the United Nations. The authors would like to thank the United Nations Office for Outer Space Affairs for providing a supporting environment for the development and completion of this article. Special thanks are due to Mr. Luc St-Pierre for his support, feedback and comments that made this endeavour possible, as well as to Ms. Nathalie Ricard, for her feedback.

Authors' contributions
All authors contributed equally to the development and completion of this article.

Funding
No funding was received for this study.

Availability of data and materials
The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 28 December 2020 Accepted: 12 November 2021

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