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Coordinated Capacity Development to Maximize the Contributions of Space Science, Technology, and its Applications in Support of Implementing Global Sustainable Development Agendas—A Conceptual Framework

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ABSTRACT

Space science, technology, and its applications have the potential to make essential contributions to the implementation of global development agendas which encompass the 2030 Agenda for Sustainable Development, the Sendai Framework for Disaster Risk Reduction, and the Paris Agreement on Climate Change. Member States of the United Nations are ultimately responsible for implementing the development agendas at the national level. The use of Earth observation tools can provide timely and reliable input data to the Global Indicator Framework to directly follow-up and review some of the sustainable development goals 169 targets. The continued user of these tools gives Member States the capability to evaluate the effectiveness of actions taken to reach specific targets and to report on progress achieved or shortcomings that need to be addressed. For many countries, capacity development is an essential factor for making optimal use of solutions offered by space activities. A large number of stakeholders, including international, regional, and national entities, are providing relevant capacity development activities. This article provides a pragmatic conceptual framework for improved collaboration and coordination of capacity development to assist Member States to fully utilize the contributions of space science, technology, and its applications to implement the global development agendas and to benefit society. The proposed coordination of capacity development needs to be integrated into an overall results-based management approach for optimizing the use of space science, technology, and its applications in support of global development agendas.

1. Introduction

Achieving sustainable development has been called the greatest present challenge for humankind. The global development agendas, including the 2030 Agenda for Sustainable Development [1], the Sendai Framework for Disaster Risk Reduction [2], and the Paris Agreement on Climate Change [3] were adopted in 2015 to provide guidance for Member States of the United Nations to achieve progress toward economic, social, and environmental sustainable development. The 2030 Agenda for Sustainable Development, the most universal of the global development agendas, is based on a set of 17 sustainable development goals (SDGs), 169 associated targets, and a comprehensive indicator framework to stimulate firm action in all critical areas of importance for the sustainability and the well-being of humanity and the planet [4].

It is well known that it will require transformational rather than evolutionary efforts to implement the global development agendas. Space technology as used in this study refers to remote observation

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of land and sea surfaces to gather imagery and other data of value in weather and crop forecasting, resource management, environmental monitoring, and other applications are expected to make essential contributions to this effort [5]. Earth observation (EO) refers to civil space-based EO and its applications. Satellite observation by agencies of the Committee on Earth Observation Satellites (CEOS) are based on a systematic overview of present and planned EO satellite missions and their instruments. The EO data, global positioning systems, and geographic information systems—collectively referred to in this article as geospatial technologies (GSTs)—can play a vital role in the efficient planning, implementation, and monitoring toward realizing the SDGs. However, their use remains largely marginal. It is important to note that "leave no one behind" is a key principle of the 2030 Agenda for Sustainable Development. The Global Framework Indicators to follow-up and review the SDGs' 169 targets have been set to be disaggregated by gender, age, income, geography, occupation, and other aspects of social identity. With this in mind, in the present study, we primarily focus on cooperation and coordination in capacity building on the use of space technology for providing reliable input data for indicators where the use of GSTs makes direct contributions.

Promoting and upscaling the use of GSTs for implementing the SDGs is only possible if two conditions can be fulfilled: (1) Ensuring that all countries have access to EO data, software tools, and services and (2) Ensuring that all countries have access to EO-based analysis ready data (ARD) that is openly available and is fit for purpose for SDG monitoring and reporting that their user organizations can trust and comfort in using the data along with software tools. As defined by CEOS, the ARD are the satellite EO data that have been processed to a minimum set of requirements and organized into a form that allows immediate value-adding without additional user effort [6].

EO researchers and nongeospatial specialists need to know that EO data available to them is trustworthy for their specific application. Considering this need, the CEOS Cal/Val Working Group portal provides support to worldwide activities on calibration and validation and specifically ensures the standardization of sensor intercalibration [7]. The overall goal is to increase the measurement of all the sensors supported by this system and increase the interoperability between EO platforms. On the access to EO data, tools, and services, in the recent past, several initiatives have taken place to collate and provide free access to EO data from long-term archived and from some current satellite missions and to develop methodologies that are aimed at providing case studies as well as cost-free access to advanced spatial analysis tools to support real-time decision-making. Some important initiatives in this direction include the Committee of EO Satellites developing data cubes [8] and other future data architectures through the Working Group on Information System and Services [9], the Group on Earth Observation (GEO) developing its result-oriented Global Earth Observation System of Systems (GEOSS) to allow discovering and accessing EO resources and reproducible knowledge with a specific initiative called Earth Observations for SDGs [10], the World Meteorological Organization (WMO) setting up regional climate centers to support national meteorological and hydrological services with climate information and prediction products for climate services as well as its designated Global Producing Centers for Long-Range Forecasts [11], the Infrastructure for Spatial Information in the European Community [12], the United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP) SDG Data Portal [13], and the United Nations Committee of Experts on Global Geospatial Information Management [14], to name a few.

On the global capacity development front, some important initiatives that provide opportunities for capacity development courses in conjunction with their own activities include the:

- United Nations Office for Outer Space Affairs (UNOOSA) promoting the establishment of six Regional Centers for Space Science and Technology Education, affiliated to the United Nations, to build capacity in developing parts of the globe [15];
- CEOS establishing its Working Group on Capacity Building and Data Democracy (WGCapD) [16];
- Virtual Laboratory for Training and Education in Satellite Meteorology (VLab), established by WMO and the Coordination Group for Meteorological Satellites (CGMS) [17];
- WMO Capacity Development Strategy to engage global and regional centers and the WMO Global Campus for a collaborative network of capacity building institutions and services [18];
- GEO Working Group on Capacity Development supporting GEO flagships, initiatives, community activities, and regional GEO's [19];
- Food and Agriculture Organization (FAO) Capacity Development Portal [20];
- Scientific and Technical Advisory Group of the United Nations Office for Disaster Risk Reduction [21]; and
- Global initiatives by Faculty of Geo-Information Science and Earth Observation of the University of Twente [22].

International nongovernment professional societies, initiatives that provide diverse opportunities for capacity development at the global level include the:

- Institute of Electrical and Electronic Engineers (IEEE) [23] and
- International Society for Photogrammetry and Remote Sensing (ISPRS) [24].

In the private sector, companies such as ESRI [25] also carry out capacity building activities, whereas at the regional level, capacity building activities are carried out by institutions such as the:

- Asia Pacific Regional Space Forum (APRSAF) [26];
- South Asian Association for Regional Cooperation Disaster Management Centre (SAARC-DMC) [27]; and
- UN-ESCAP annual Ministerial Conferences for enhancing awareness of the rapidly growing GSTs and their applications in societal benefit areas [28].

Capacity development in space science, technology, and its applications has been provided to Member States of the United Nations since the beginning of the space age, under the overall framework of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and the United Nations Programme on Space Applications with the intent of making to share space benefits available to all countries, independent of their levels of economic development [29]. Evidently, much has been achieved since 1959 when COPUOS was established by the United Nations General Assembly, and space activities are today recognized as an essential element to support public infrastructures, providing a wide range of benefits to society. In 2019, more than 90 countries have assets deployed in outer space, and practically all countries are using space science, technology, and its applications in one form or another. Many of these benefits are available free of charge to all countries in the world, including signals provided by the Global Navigation Satellite Systems (GNSSs) and data and products provided by hundreds of meteorological and EO satellites [30].

However, many countries continue to lack sufficient national capacities to use the EO data and applications for the benefit of society, and there is therefore a continuing need for the capacity development, which is provided by many stakeholders, including the aforementioned ones. In fact, it can be observed that the many opportunities for capacity development provided by these

stakeholders are in many cases overwhelming. While many countries have benefitted from a wide range of capacity development activities, they have not been able to build lasting institutional capacity from the training and education provided to them. There are many reasons for this depending on the particular situation, which varies with time, of each concerned country.

The reasons may include:

- Insufficient coordination among stakeholders providing capacity development, resulting on the one hand in a duplication of efforts and on the other hand in a lack of addressing potentially more important needs.
- Lack of a coordinated, integrated strategy for capacity development related to space activities, which would guide all these stakeholders.
- Lack of a coordinated results-based management framework to measure the success of capacity development interventions (such as indicator frameworks and competency frameworks), despite that fact that some of these frameworks are in place, more effort needs to be done to improve the follow-up and review processes by incorporating tailored user experiences.
- An oversupply of capacity development offers from many different stakeholders without coordination among national stakeholders who are to receive capacity development, overwhelming those countries with repeated or not adequate training thus leading to suboptimal results.
- Lack of a national strategy on how to make sustainable use of capacity development provided to the country.
- Lack of a national strategy and framework to retain trained staff and to place them in the best possible roles to make optimal use of their knowledge.

More efficient and effective capacity development on the use of space science, technology, and its applications is essential, and Member States need to be supported to make the fullest possible use of it. As pointed out under Thematic Priority 7 on “Capacity Building for the 21st Century” developed by COPUOS in preparation for the UNISPACE+50 [31], one of the important ways to solve the above issues is to devise methods to enhance existing partnerships and forge new ones to strengthen and deliver targeted capacity development [30]. In this article, we propose a pragmatic conceptual framework to facilitate coordination/cooperation of EO capacity development activities at the national, regional, and global scales, through collaborative efforts of international organizations, regional partners, including space agencies, capacity building institutions along with professional national, regional, and international nongovernment societies.

The article is organised as follows. Section 2 gives a brief overview of challenges in capacity development efforts on the use of GSTs for achieving the SDGs. Section 3 analyzes existing capacity development efforts made globally by various players and reviews gap areas in present day capacity building/development approaches. In Section 4, we discuss the need for a coordinated capacity development program to fill-in the gap areas. Section 5 describes the proposed conceptual framework. In Section 6, we describe in detail the functional aspects of a Space Capacity Development Advisory Board which is an important component of the proposed framework. Our conclusions are given in Section 7.

2. Challenges in capacity development on geospatial technologies

Many case studies have already revealed the benefit of using GSTs for measuring progress toward achieving SDG targets [32]. The subject of GSTs is a rapidly growing field with its heterogeneous connections to a variety of fundamental sustainable development themes (water, food, forest, coasts, urban infrastructure, etc.). As mentioned earlier, the GSTs exploit the combined application of remote sensing data, global positioning systems, ground observations network data, and geo-information science systems to support progressive SDG implementation. Challenges in capacity development in the GSTs are in (1) understanding the complex sequence of data acquisition, processing and fusing data/information. These data/information come from disparate sources, which include long-term archived satellite data from the past missions and also from satellites in operation currently in a highly heterogeneous environment from the viewpoint of spatial, spectral, polarizations, and radiometric resolutions of their sensors. This calls for subject experts from diverse disciplines to provide training and education to bring out information from satellite and *in situ* data to be combined with other existing information, (2) storing, retrieving, and analysing big data arising out of the past and current space missions and integrating these with other disparate spatial and/or nonspatial data sources that include an emerging wealth of data from citizens through smart mobile technology and wireless networks along with advanced data visualization tools for end-user interpretation, and (3) the ultimate issue lies in developing human and institutional resources to be self-sufficient, capable of converting the wealth of available data into information and from information into knowledge with the ARD for actionable information or services aimed at realizing SDGs targets.

In most cases, the majority of trainees are young and curious mid-career professionals who would wish to build their career on any training undertaken, and also decision-makers who wish to learn new technologies and applications to resolve their current national issues. However, as Teillet et al. put it, a large section of the EO user community comes from national administration and government policy-making sectors who prefer to receive “plug-and-play” data utilization services, rather than an exhaustive theoretical understanding and case study illustrations [33]. Nevertheless, to develop self-sufficient institutions in the developing countries, there should be a robust nucleus of individuals who understand why and how the technology works and can adapt it for specific applications and even evolve it to meet their specific needs.

3. Existing capacity development: efforts and gaps

Capacity development (CD) is an effort to strengthen skills and abilities on the individual, organizational, and institutional levels. Impact of capacity development can be ensured when support is provided to create an enabling environment to ensure the conditions are in place to apply the acquired knowledge and skills. We shall address significant efforts made by various stakeholders to promote space data-based solutions and the shortcomings that hinder the overall results-based implementation of these efforts.

Efforts: With increased utilization of EO data derived from space in national and regional development, it is important to increase awareness of the value of EO data products and services and include support to locate and access data, products, and tools to user communities. Realizing this, global organizations, UNOOSA, WMO, GEO, and CEOS have established capacity building working groups, networks, and/or activities to promote their efforts and have made national and regional capacity development as one of their priority objectives.

The GEO has initiated capacity building efforts, applying a holistic approach to capacity development, to assist developed and developing countries through thematic flagships, initiatives, and community activities as well as establishing regional GEO's—AfriGEO, AmeriGEO, AO GEO, and EuroGEO—to better understand and use the resources of the GEOSS. In collaboration with

CEOS and other national and international organizations, GEO conducts several training programs in Africa, Latin America and the Caribbean, Asia, the Pacific, and Europe. The training programs address the priorities identified by the countries of each region. Common objectives are (i) “the promotion, collaboration, and coordination among the GEO members in each continent, to realize a future wherein decisions and actions, for the benefit of the region, are informed by coordinated, comprehensive, and sustained EO and information, (ii) engage with end users, particularly policy-makers and decision-makers, to understand information needs for evidence-based policy-making and to raise awareness on the value of EO in meeting those needs; and (iii) showcase the use of EO in reaching the goals and targets of the SDGs, the Sendai Platform on Disaster Risk Reduction, and the Paris Agreement on climate change”. The capacity development efforts range from training programs that leverage resources from established capacity building activities of collaborating organizations to co-development of needed interventions with users and results in increasing individual and institutional, technical, and human capacity. Space agencies, CEOS, GEO, WMO, and UN and associated regional training centers provide access to data, software tools, training, and disseminate case studies to showcase the use of EO data to engage institutional users worldwide. These groups also aim to enhance cooperation at regional and national levels by focusing on country-specific requirements to develop EO plans, Spatial Data Infrastructures, as necessary, and establishing national GEO structures.

The CEOS mandated its WGCapD to undertake a variety of activities to promote four of CEOS's priorities: (1) “provide wider and easier access to EO data, (2) increase the sharing of software tools such as the use of open source software and open systems interface, (3) enhance data dissemination capabilities and transfer relevant technologies to end users, and (4) undertake intensive capacity building, education, and training (including awareness and outreach) for enabling end users to gather all the information needed to use EO products and services and for increasing communication on achieved results”. The WGCapD carries out its activities through national and regional face-to-face workshops that include virtual presentations delivered remotely, webinars, massive open on-line courses (MOOCs), and educational and training materials available on the websites of its space agency members [34]. It also leverages resources from established capacity building activities and resources of collaborating organizations.

Along similar lines, the WMO has evolved its capacity building programs to reach more developing countries by taking advantage of existing EO and ground-based solutions with current day innovative technologies through web-based training calendars, data products and services, and training resources available through WMOLearn [35]. The WMO-CGMS VLab focuses on training operational meteorologists to use the latest satellite data through their regional training centers.

Independently, there are six regional Centers, affiliated to the UNOOSA, established at different times since 1995 that strengthen human resources in developing countries through education and training to develop and apply space science and technology for sustainable development in their respective regions. The underlying mandate is to empower the participants in training activities of the Centers with sufficient field knowledge such that they would be able to handle their country's developmental requirements in using GSTs, especially for the management of natural disasters, without the need for outside expertise. As a result of the preparations for the UNISPACE+50 commemoration, UNOOSA was identified by the United Nations COPUOS as a mechanism to implement Thematic Priorities 6 and 7, dealing with resilience to disasters and capacity building, respectively. To support these priorities, UNOOSA uses the activities of the United Nations Platform for Space-based Information for Disaster Management and Emergency Response and of its Programme on Space Applications and leverages activities of Regional Support Offices provided by institutions of member states and of other collaborating institutions.

Similarly, professional societies such as ISPRS have set up specific technical commissions on remote sensing and spatial information sciences to explore recent research advancements in applying these technologies and technical commissions on education and outreach to learn modern methodologies for effective knowledge transfer in both face-to-face and web-based training in GSTs.

Mandated by the General Assembly, the United Nations Statistical Commission identified in March 2016, a global indicator framework comprising 230 indicators to monitor the SDGs' 169 targets. Reflecting Agenda 2030's guiding principle of “leaving no one behind”, indicators are set to be disaggregated by gender, age, income, geography, occupation. and other aspects of social identity [36].

According to the Inter-Agency and Expert Group on the Sustainable Development Goal Indicators (IAEG), including FAO, the success of the SDGs rests to a large extent on an effective monitoring, review, and follow-up process [37].

A robust follow-up and review mechanism for the implementation of the 2030 Agenda for Sustainable Development requires a solid framework of indicators and statistical data to monitor progress, inform policy, and ensure accountability of all stakeholders. The global indicator framework developed by the IAEG was adopted by the General Assembly on 6 July 2017 and is contained in the Resolution (A/RES/71/313) adopted by the General Assembly on “Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development” [38].

The High-level Political Forum, United Nations central platform for follow-up and review of the 2030 Agenda for Sustainable Development and the SDG, provides for the full and effective participation of all States Members of the United Nations and States members of specialized agencies [39]. Ultimately, the UN has identified custodian agencies for each of the 17 SDGs and Sendai Framework indicators. For example, FAO is one of the major organizations with [20]implementation responsibility for Goal 2, Zero Hunger.

In fact, FAO is the custodian UN agency for 21 SDG indicators. In particular under Goal 2, “End hunger, achieve food security and improved nutrition, and promote sustainable agriculture”, FAO has the custodianship of Indicators: 2.3.1 Volume of production per labor unit by classes of farming/pastoral/forestry enterprise size; 2.4.1 Proportion of agricultural area under productive and sustainable agriculture [40].

Under Indicator 2.4.1, the area under productive and sustainable agriculture captures the three dimensions of sustainable production: environmental, economic, and social. The measurement instrument—farm surveys—will give countries the flexibility to identify priorities and challenges within the three dimensions of sustainability. Sustainable agriculture is at the heart of the 2030 Agenda and is the first fundamental step to securing zero hunger. This indicator will measure progress toward SDG Target 2.4. While many of the SDGs address issues related to agriculture, SDG indicator 2.4.1 is fully dedicated to it. Space data-based solutions are and can be an important component in the development of geospatial information and EO data inputs into the global indicator framework for the implementation of other SDGs as well. Space data-based solutions are and can be an important component of the solution to address the SDGs and Sendai Framework.

Gaps: Despite these and other organizational efforts, familiarization of new technologies and open data policies, and extensive

capacity building efforts made several challenges remain. The most critical one is expert trainer resources and funding availability to deliver effective capacity building to use rapidly evolving GSTs to address the large and growing demands across the globe. In most cases, outside of leveraging existing resources, the training efforts are undertaken independently. This has led to duplication of efforts and to missed opportunities to build upon the capacity and save overall capacity development cost and effort. Also, despite all these training efforts at various capacity development levels, many developing countries still neither have the ability to employ geospatial information for their national development nor have the capacity to skillfully manage natural disasters, in particular risk reduction and mitigation plans and adaptation to the impacts of climate change on sustainable development. It is also challenging to inform the institutions to potential trainees about training opportunities because of lack of repository of large lists of trainees contact information, which are now collected and maintained independently by these organizations.

Another gap in today's capacity development is the lack of awareness of space-based innovations as essential drivers for achieving the required capacity to explore new and ever-growing GSTs and tools for sustainable development goals. In its preparations for UNISPACE+50, the COPUOS has proposed actions under its Thematic Priority 7 to overcome this gap. Those actions described in the following paragraphs are taken into account in the conceptual framework to facilitate coordination/cooperation of capacity development activities proposed in this article.

The General Assembly, in its resolution 73/6 of 26 October 2018, "noted with appreciation that the preparatory process and the high-level segment of UNISPACE+50 had resulted in documents aimed at articulating a comprehensive, inclusive and strategically oriented vision on strengthening international cooperation in the exploration and peaceful uses of outer space, in which space is seen as a major driver of and contributor to the achievement of the SDGs for the benefit of all countries. The General Assembly invited the Committee to continue to develop, on the basis of the results of the UNISPACE+50 process, a 'Space2030' Agenda and implementation plan and to submit it to the Assembly for its consideration in 2020" [38]. The "Space2030" Agenda and implementation plan will be a "comprehensive and forward-looking strategy for reaffirming and strengthening the contribution of space activities and space tools to the achievement of global agendas" and contributing to chart the future contribution of the Committee to the global governance of outer space activities.

The Space2030 Agenda is expected to emphasize that the seven Thematic Priorities developed by the Committee in the context of UNISPACE+50 represent a comprehensive approach to addressing key areas and collectively serve to determine the core objectives of the future work of the Committee and its subcommittees and the Office for Outer Space Affairs in the areas of, among others, international cooperation toward "capacity-building for the twenty-first century (Thematic Priority 7)".

Efforts to facilitate coordination/cooperation of capacity development activities include exploring new innovative and effective approaches to develop overall capacity as a fundamental pillar for global space governance. This priority necessitates in turn accomplishment of four pillars: (a) quality assured learning opportunities, (b) adoption of new curriculum advances and training practices, (c) exploiting the advanced web services of present day technologies for sharing platforms and tools, and (d) standardization of certification and credit systems for uniformity across the globe for training programs. These pillars are to be developed based on the analysis of present day capacity of the nations and regions. The results of this analysis will be used to develop a plan for long-term sustainability of capacity development, as shown in Fig. 1.

The benefits of coordinated capacity development between space agencies, CEOS, GEO, and the UN (COPUOS and OOSA) to maximize the contributions of space science, technology, and its applications in support of implementing global sustainable development agendas are many. Some of these are in (1) reducing duplication efforts and building of synergies; (2) managing optimally financial and expert resources by pooling, possibly through sharing the budget and coordinated arrangement of subject matter expertise that includes identifying trainers who can effectively communicate in the region/country specific languages. Inclusion of national and international professional societies like the IEEE, ISPRS as partners would be an added advantage, especially for identifying subject experts on national and region-specific themes; (3) sharing software tools and methodologies developed by various agencies and initiating joint research on innovative solutions needed for country-specific projects and requirements; (4) sharing resource lists of trainees from cooperating organizations and developing a mechanism to communicate on capacity development programs to maximize the results from the effort; and (5) highlighting clearly the roles of each player and their connected geospatial information regional and global services in terms of data warehousing or web portals to provide clearly synergetic resources from the users' point of view.

4. Framework for coordinated capacity development

The proposed conceptual framework to address the above challenges and take a concrete first step to coordinate space-based capacity development activities is illustrated in Fig. 2. This coordinated capacity development (CCD) framework includes four distinct phases: harmonizing, planning, executing, and delivering. Each of these phases are described below.

Harmonization phase: It is fundamental to harmonize coordination among capacity building/development working groups of the global organizations and institutions UNOOSA, WMO, GEO, and CEOS as well as regional organizations and professional societies connected with geospatial information and technologies. For example, in the context of the Asia Pacific region, organizations, such as UN-ESCAP, Asia-Oceania GEO (AOGEO,) APRSAF, the Association of Southeast Asian Nations, and SAARC-DMC as well as space agencies the region and International NGOs may possess the knowledge of the regional institutional capacity development needs, current status, and required actions to implement SDGs in this region.

An essential component of the harmonization of past and current capacity development efforts that would also provide quantitative results-based tracking and management of future capacity development activities is "a common database that records the capacity development interventions in each country conducted by all the contributing organizations. Such a database would identify synergies and duplications and would allow countries themselves to review what capacity development they have already received, how they could best utilize those interventions in the framework of their national capacity development strategies, and help in defining needs for the future. The WMO Country Profile Database could be an example or core of such a capacity development database". It is acknowledged that development of the database would be a considerable effort requiring some dedicated resources [41]. However, it would be a difficult task to harmonize, analyze, and evaluate capacity development efforts without a procedure to record capacity development interactions, on which future capacity development activities could be planned more efficiently and effectively.

Planning phase: To make coordinated capacity building effective, it is essential to set up a Space Capacity Development

Fig. 1. Basic pillars of increasing coordinated capacity development. SDG, sustainable development goal; CD, capacity development.

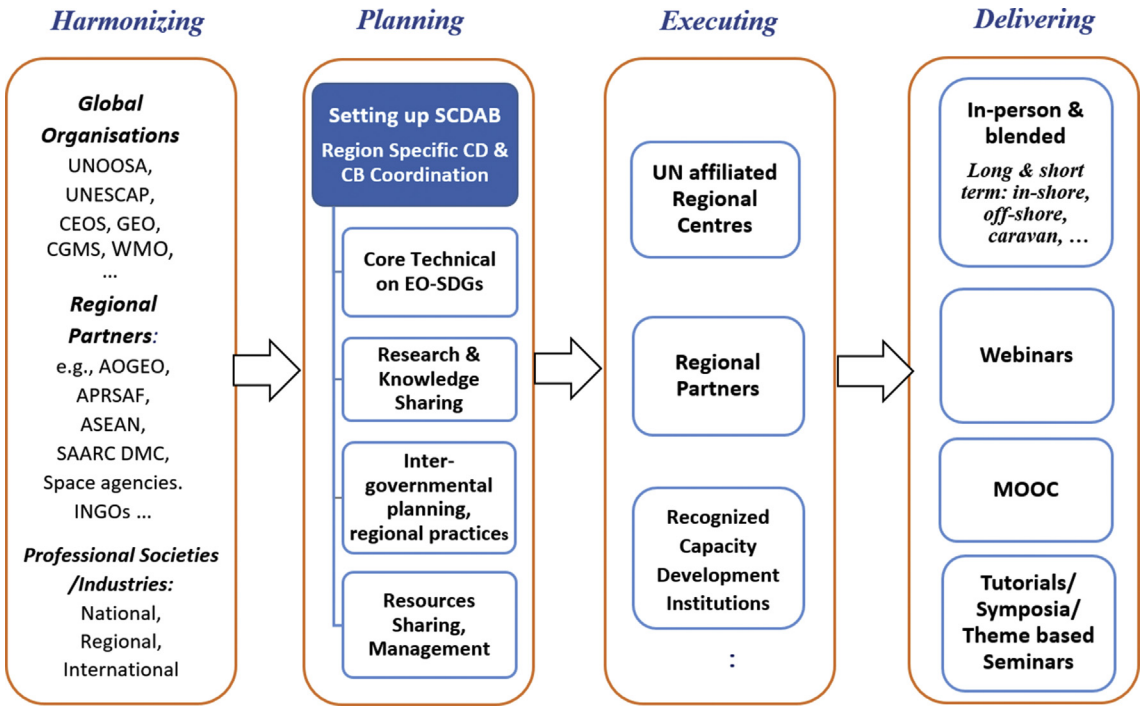

Fig. 2. The proposed framework for coordinated capacity development. UN-ESCAP, the United Nations Economic and Social Commission for Asia and the Pacific; UNOOSA, United Nations Office for Outer Space Affairs; WMO, World Meteorological Organization; GEO, Group on Earth Observation; CEOS, Committee on Earth Observation Satellites; SCDAB, Space Capacity Development Advisory Board; APRSAF, Asia Pacific Regional Space Forum; ASEAN, the Association of Southeast Asian Nations; SAARC-DMC, South Asian Association for Regional Cooperation Disaster Management Centre; INGOs, International NGOs; MOOC, massive open on-line course; SDG, sustainable development goal; EO, Earth observation.

Advisory Board (SCDAB). As mentioned earlier, there should be a dedicated team of individuals who understand why and how EO and related technology works and can adapt it for specific applications and even evolve it to develop self-sufficient institutions in developing countries. This board may have its core members from global and regional organizations. The board would draft overall plans and may include *ex officio* representatives from the professional societies. The main objective of the SCDAB would be to assess region-specific requirements in realizing the SDG implementation. There is a need to connect the global level efforts for SDG follow-up and review with the bottom up (country-level) efforts on data collection, monitoring, reporting, and implementation. It would also identify a subgroup of experts for regional curricula development and co-development interventions needed for short-term and long-term capacity building programs.

The curricula, which would be developed by members of participating organizations, should comprise (a) core technical support for SDGs for which the use of EO has direct applicability in providing on the SDG targets and indicators building on the work that has been done by organizations such as GEO and CEOS in this area, (b) research and knowledge sharing, (c) intergovernmental planning and regional practices, and (d) resources pooling and management. Co-development intervention needs would be identified and worked between technical experts and users [42]. The curriculum development experience of UNOOSA and WMO and the co-development experience by multiple space agency/international development assistance organizations would be very valuable in this effort.

While preparing its Action Plan report on space applications for SDGs in the Asia and the Pacific regions, the UN-ESCAP defined three action areas to define the scope of implementation: “capacity building and technical support, research and knowledge-sharing, and intergovernmental discussions and regional practices” [43]. All three areas need specific attention to achieve overall capacity development and hence are adapted here. These three areas are further described from a capacity development point of view as follows:

(i) *Building core technical competence:* The development of human capacity and provision of technical tools to support selected methodologies is the core-training element for reaching each of the SDGs. The objective is to develop capacity and provide technical support to access, analyze, and utilize EO data and information, particularly for countries in the regions with special needs and those with limited capacity to use space applications. Some key elements to provide such competence to be considered by the SCDAB include the following:
   a. Establish technical know-how on how to access EO data and other ancillary information and methodologies related to space applications;
   b. Build the required understanding of a work plan toward developing standards on spatial scales, understand that there are temporal variations in the data because of EO instruments calibration while in operation and intrinsic characteristics of features being observed; and
   c. Provide technical solutions by blending space data with disparate data sources which include traditional data sources comprising administrative data, national statistics, survey data, etc. along with data from crowdsourcing and other digital innovations and past geospatial data platforms to evolve evidence-oriented decision support.

(ii) *Building "Research and knowledge-sharing":* It is equally important to keep Research and knowledge-sharing (RKS) activities in parallel to evolve newer technologies that allow new possibilities of applications with space data. Specifically, the RKS is expected to
   a. provide basic knowledge and deep insight on present day exploitation of space data and advanced technologies to manage sustainable development;
   b. overcome or minimize barriers that hinder full utilization of space information, including historical analysis of experiences to develop informed future recommendations;
   c. engage subject experts, professional trainers, and resource material on space data exploitation; and
   d. involve youth and mid-career professionals in stimulating research and promote innovations by entrepreneurs through competitions like hackathons and support scientific projects.

(iii) *"Intergovernmental discussions and regional practices":* Connecting capacity building efforts with the end-user community is vital to the success of the SDGs implementation. To this end, existing regional practices for handling critical situations may need to be assessed for modifications through raising awareness, training, and building capacity at the decision-making level. Efforts have been constantly made, for instance, by the UN-ESCAP Regional Ministerial Conferences, to bring all the countries in the Asia-Pacific region to bring awareness of the needs and benefits of space solutions in implementing the SDGs. Specific capacity development plan must include:
   a. Collate best practices and hard efforts made on space EO data democracy, in particular to specific regional cooperation;
   b. increase awareness on advantages and existing barriers to access space solutions at national and regional governmental levels;
   c. enthuse senior decision-makers with sufficient success stories on space-based decision-making process and also raise importance of building a long lasting impact to build the required institutional capacity with trained staff;
   d. initiate work plan with existing intergovernmental mechanisms, and explore sharing with international and technical organizations to share multitemporal satellite imagery and ancillary information in coherent with the thematic areas identified in the Plan of Action and the SDGs of Agenda 2030; and
   e. promote private and commercial entities to support and continue Governments' access to satellite data and products for sustainable development.

As an illustration in employing these three steps proposed here, we provide a curriculum design for capacity development in SDG 2: Zero Hunger in Section 6.

Execution Phase: During the execution of planned capacity development, it is important to take note of contributions made by globally recognized capacity building centers and institutions that have proven record of building human resources. Some of these include the UN-affiliated Regional Centers, WMO, the VLab network, GEO flagships, initiatives, community activities, and regional GEO's engaged in capacity development, CEOS WGCapD, and associated space agencies engaged in capacity building such as CNES,[1] DLR,[2] ESA,[3] GISTDA,[4] INPE,[5] ISRO,[6] NASA,[7] SANSA[8], and UK Space Agency also global academic knowledge institutes such as the University of Twente can provide necessary platform of execution plan of regional capacity building for UN-SDGs. The reason is straightforward in that these have already well established facilities and upgrade time-to-time to carry out long-term training that would definitely support to training the trainers for the region in future. They have well-developed curriculum design and also follow good practices for effective knowledge transfer both in short-term or long-term programs with either face-to-face or online methods and co-development interventions as well. Their strong connectivity with essential organizations from public and private sectors is an added advantage to pool continued effort of establishing institutional capacity development.

Deliverables: Many different methods exist to undertake the proposed capacity development based on the needs of the individuals, organizations, and institutions. Co-development of interventions will be used to ensure the needs are jointly understood and sustainable capacity improvements achieved. In-person as well as in-person combined with live streaming can be used for long-term and short-term courses, off-shore, and/or caravan training may be needed to efficiently cover the countries at the regional scale [44]. This could include both model courses that can be adapted and reproduced in all regions and structured self-explanatory courses following the e-content generation methods suitable for MOOC. Collaborations would include exchanging good practices and online problem solving techniques. Additionally, time-to-time exposure on advanced methods through global webinar series on selected topics, distance education schemes with sufficient self-learning illustrations on the use of space applications for implementing the SDGs are required to deliver the proposed capacity development. Occasional opportunities are to be explored for exchange of ideas and promotion through discussions and tutorials in international conferences and symposia conducted in

[1] National Centre for Space Studies (CNES), France.
[2] German Aerospace Centre (DLR), Germany.
[3] European Space Agency (ESA), France.
[4] The Geo-Informatics and Space Technology Development Agency (GISTDA), Thailand.
[5] The National Institute for Space Research (INPE), Brazil.
[6] The Indian Space Research Organization, India.
[7] The National Aeronautics and Space Administration (NASA), USA.
[8] The South African National Space Agency (SANSA), South Africa.

coordination with national and international professional societies. Short-term or long-term projects could be used to co-develop a tailored intervention when needed.

5. Functional aspects of the SCDAB

As mentioned earlier, the SCDAB plays a pivotal role in bringing out all issues related to coordinated capacity development and exploring solutions to these for successful implementation of the framework. In particular, the SCDAB will set up guiding principles to establish resources in terms of theme-oriented human experts and training materials to monitor methods to attract professionals in large to maximize the participation and also resolve conflicts, if any, across all the stakeholders. The SCDAB will also take the responsibility of analyzing the potential of regional and local levels for implementing the SDGs and propose tailor-made solutions to capacity building curricula and infrastructural development. It should also keep in mind efforts made in the past on results-based management [32] and study gap areas in implementing its elements. This necessitates leadership of the capacity development networks of UNOOSA, WMO, GEO, CGMS, and CEOS to nominate managerial and technical experts as points of contact who have extensive experience in capacity development programs for different regions. The overall functional elements for the SCDAB can be envisaged in two distinct aspects: Managerial Path and Technical Path, as shown in Fig. 3.

5.1. Managerial path

The Managerial Path has many building blocks to arrive at *guiding principles*. This begins with first setting up procedures for promoting collaboration with high clarity for engaging all partnering organizations/NGOs to build the concept of CCD. This is fundamental to successfully link different organizations, as many of these have already defined capacity building/development in their annual work plans in their theme priorities. In particular, these principles should address the following specific areas.

(a) *Engaging in Partnerships:* As shown in framework (Fig. 2), many like-minded and theme-oriented professional societies, government line departments, space agencies, and regional bodies/forums are to be invited to join hands with the international organizations for the common requirement of SDGs implementation. This requires a detailed plan of engagement for each of these stakeholders for their role in overall achievement of capacity development programs in local, national, and regional scales. In addition, a careful evaluation of the current status of progress in understanding and implementing all those SDGs for which GSTs can offer the most value and with direct applicability at national and regional levels is to be surveyed. Such an effort should leverage existing follow-up and review processes including the annual UN High Level Political Forum and national voluntary reviews and reports submitted annually as part of this process. The results of the survey should be used to plan the strategy of the capacity development needed to maximize the effort of training on gray areas, rather than wasting time and resources over the established goals in these levels. Some government organizations, development agencies, and banks, NGOs, and private industries dealing with GSTs are potential sponsors for these programs. A guiding approach for meeting the human and financial resources needed is to be prepared.

(b) *Managing the resources:* Resources are needed and often insufficient for subject matter experts and training participants to participate in training programs. For training programs motivated to provide skills development in participants, short courses (duration running from one week to a maximum of 8 weeks) should have sufficient human experts who have zeal and sense of great commitment besides their authoritative expertise on the training theme. To this, an approach is needed to mobilize funding sources to meet the expenditure of the travel and material cost for participants and subject matter experts. Co-development of methods and services for SDG reporting requires multiyear funding both of the subject–matter experts and users

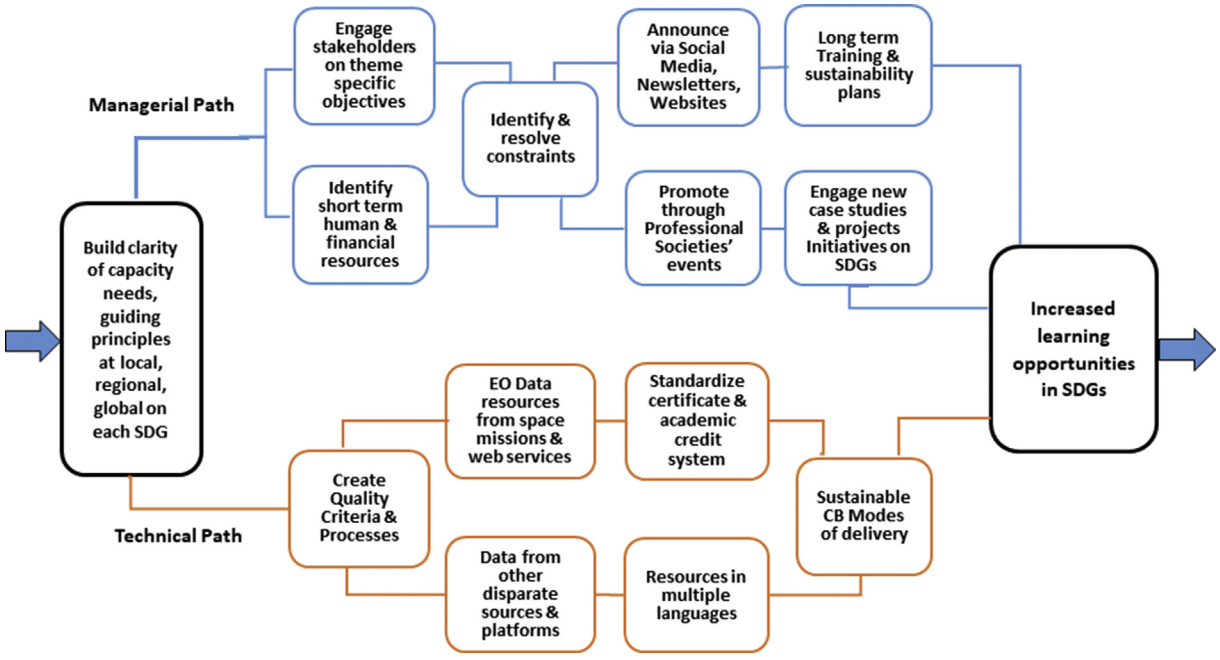

Fig. 3. Functional element of Space Capacity Development Advisory Board. SDG, sustainable development goal; EO, Earth observation.

involved in co-development. It is also important that SCDAB work out mechanisms to insist upon member states to provide funding support to sustain the trained knowledge beyond the pilot studies.

(c) *Planning long-term training programs:* Long-term courses beyond 8 weeks may be entrusted with institutions/organizations already well established globally. Engaging countries in trainings is yet another approach while ensuring geographic breadth of activities and relevance. These establishments have their own human and financial resources supported by their parent governments and/or the associated organizations. These courses may typically run for 9 months to 1 year to provide postgraduate certificates, providing a possibility of supporting higher education (M.Sc., M. Tech., or Ph.D.) to mid-career professionals. Even though they may have committed education curricula approved by their expert education program committees like board of studies, these organizations can be asked to include special theme-oriented topics as part of their training programs. The expertise from a pooled trainers' database can be asked to provide from time-to-time lectures either through web-based training or one-to-one interaction mode when the experts gather on specific theme-oriented Symposia or Conferences in which the long-term participants can benefit by attending and interacting with these experts.

(d) *Identifying constraints and solutions:* Be it engaging multiple organizations and/or human and financial resources sharing, it is important that anticipatory risk areas and constraints be identified, and means of resolving these issues diplomatically are defined. At this point of time, it is not envisaged that the proposed framework is likely to replace many of the ongoing capacity development programs already in place initiated by the global organizations. Subsequently, with all global and regional partners engaging within this framework positively, there is a possibility of smooth transition from individual to coordinated effort. A good effort may be required to resolve any conflicts or constraints that may arise across these partners. Therefore, the SCDAB may need to identify most likely constraints and work out ways and means of solving these issues.

(e) *Reaching the potential participants:* The present day social media, e.g. Facebook, twitter, and alike, can provide a far reach to inform potential participants about upcoming training and education programs. The capacity building/development programs of global organizations, CEOS, CGMS, GEO, WMO, and UNOOSA have a large network of participants through their long programs in various regions of the globe with corresponding lists of training participants. Many of these organizations also circulate newsletters and also flash the new programs in their dedicated websites to inform their programs in advance. Pooling all the potential participants by theme will attract their attention to participate and benefit from the programs.

(f) *Engagement with professional societies:* Partnership with professional societies of remote sensing and associated applications domains and statistical communities from global to national level as well as national mapping agencies and line ministries as key stakeholders will help in building capacity on statistical practices for the purposes of follow-up and review of the SDGs. This will help build processes, mechanisms, and human capacity to include EO in national development plans and to integrate them with national statistical accounts to improve the measuring, monitoring, and achievement of the SDGs. These partnerships and collective efforts can support broader societal ownership of the Goals and Targets to strengthen the effectiveness and accountability of their implementation. These groups may further benefit in promoting the objectives of the CCD effort, as these have a strong regional and global networking of members comprising largely students and mid-career professionals. These societies also promote scientific initiatives through their own resources which attract academia globally, thereby paving way for newer and innovative elements in future technologies and their applications.

5.2. Technical Path

Given the diversity of training programs undertaken by various stakeholders, there are four major areas to be addressed on the technical aspect of the programs. These are briefly discussed below.

a. *Ensuring quality criteria in training:* The development of required curriculum design for each of the SDGs is to be prepared in line with internationally accepted quality assurance (QA) standards on education and training. Though these standards may have some differences, their objectives can be brought under six dimensions, as identified in the QA literature, namely: *relevance, quality of content and design, effectiveness, efficiency, impact, and sustainability.* Besides this, there are many reports on best practices in training and education shared by experienced trainers of global training and education organizations and professional societies on lessons learnt from their previous programs. All the expert human resources persons are to be aligned to follow these standard operating procedures for best results and sustainability of the programs.

b. *Ensuring EO-based ARD and other data resources:* As mentioned earlier, there has been considerable effort already made in providing EO data from space missions through web portals. These web portals also facilitate the users to add their data from other platform sources (from ground measurements, drones, and smartphones) as part of their web services. Such service applications have increasingly become the most sought after elements from users perspectives and are to be made part of the training program.

c. *Developing resources in multiple languages:* Trainers may need to teach in and training material may need to be translated into multiple regional languages. The ability to replicate the training material in multiple languages can tremendously reduce the cost of making, as for example, in the case of e-learning training contents. For long-term courses, trainees are typically trained in the primary language of the courses, which in most cases is English. The initiative of WMO, for example, has led to the COMET Translation Resource Center [45], which offers resources to guide your own translations to expand the availability of training materials. The SCDAB may need to evaluate the present mechanisms that exist for such translational services to implement the global training of SDGs.

d. *Standardizing certificate and credit sharing:* It is expected that a large contingent of training participants could be researchers and mid-career professionals who aspire to take further higher education. They could be interested to know if the CCD will support granting credit to them for their educational experiences gained through its programs for another institution. This would call for standardization of a certificate and credit sharing system that would be accepted by national and global academic institutions.

e. *Delivering sustainable training services:* SCDAB could work out possible ways of engaging partnering teams to co-develop training materials and courses suited to the SDGs. It has always been a challenge to stakeholders to manage participants

from multicultural, multiethnic environments with different educational systems to effectively transfer knowledge. In such cases, co-development is expected to provide fruitful results in terms of supporting shared knowledge and experience, thereby allowing stronger partnerships, resolving gap areas, and developing innovative approaches.

6. Example of capacity development for SDG 2: zero hunger

As mentioned earlier in Section 5, the planning phase consists of, other than resources management, the curriculum design and development covering three major components: core technology, research and knowledge sharing, and intergovernmental and regional practices. The UN-ESCAP suggests these components as part of plan of action on Space applications for sustainable development. In this Section, these are addressed to prepare the course design for SDG 2 Zero Hunger, as a case study.

The prime motive of the Goal on Zero Hunger is to end hunger by achieving food security and improved nutrition and by promoting sustainable agriculture. This motive can further be studied under three subgoals: food production, agroecosystem resilience, and precision agriculture (according to Target 2.4). Some of the indicators to effect these are (a) losses from natural disasters, by climate and nonclimate related events and (b) crop yield gap (actual yield vs attainable yield from the current crop year).

As mentioned in Section 5, the curriculum design and development should be composed of three subtitles: core technical, research and knowledge sharing, and intergovernmental practices. In the following, we describe a possible set of topics for training on these subgoals—with emphasis given to those topics where the EO-based ARD plays a significant role in addressing the indicators of specific SDG themes and where additional data are needed to complement the EO ARD as well as on the use of existing case studies, tools, and services.

(i) Food production

Core technical: The training component should include technical discussions on (a) food production capacity for seasonal forecasting and its impact, (b) techniques for real-time monitoring of weather from EO meteorological data assimilated with ground based measurements, (c) mapping tools for optimal infrastructure requirements such as food storage, warehousing, etc. and associated socioeconomic parameters to ascertain local and regional demands and distribution strategies.

Research & knowledge sharing: Theme experts further provide updated knowledge on advanced techniques being explored for enhanced estimation of food production. These may include (a) statistical and empirical modeling techniques for crop productivity and pest and insect outbreaks using agrometeorological information, (b) satellite-based observation and mapping techniques for land use, soil quality, and productivity for appropriate crops, and (c) demand mapping for crop productivity against population density to learn food security needs in vulnerable areas.

Intergovernmental practices: Different nations in each region follow different practices on the above methods. It is important to bring awareness of such activities as international GEOGLAM, GFOR, and regional forums like APRSAF, Interregional Smart Agricultural Forum and their functional aspects wherein there is a possibility for sharing good practices across the nations in the regional and global levels. There are international nongovernment organizations such as ISPRS that conduct special topical meetings through their technical commissions. Sharing practices that are used and seasonal forecasting regionally across borders can be beneficial.

(ii) Precision agriculture

Core technical: The training component should include technical discussions on (a) Basics of Precision Agriculture and its benefits, advances in unmanned aerial vehicles (UAVs), and vehicle mounted instrumented systems for achieving location-based monitoring agricultural conditions together with high resolution satellite-based imaging systems.

Research & knowledge sharing: Theme experts further provide state-of-art technologies on the models and methods of applying GSTs from UAS, GNSS, and satellite-based systems and new technologies for precision agriculture monitoring.

Intergovernmental practices: The integration of satellite-based EO and GNSS, a variety of other data from *in situ* and airborne data sources combined with other digital innovations. The nations in each region can share their food security models in terms of harmonizing food-safety systems, activities of their national centre of excellence in food safety research and collaboration, and enhancing domestic food testing capabilities.

(iii) Agroecosystem resilience

Core technical: The training component should include technical discussions on how (1) EO data can be exploited for multihazard early warning and damage assessment (flood, drought) and (2) decision support tools for drought monitoring and early warning systems.

Research & knowledge sharing: Researchers and subject matter experts may share knowledge on (a) developing soil nutrients map for ecosystem management and (b) mainstream climate information for ecosystem resilience (livestock, aquaculture, fisheries, and alternate livelihoods).

Intergovernmental practices: The topics can include intergovernmental policies and data for sharing experiences and findings from drought management systems for regional policy directions and modes of enhancing cooperation in regional early warning and alert networking systems and share the required information and data to reduce risk of transboundary disasters such as floods, cyclone, and dust storms.

For each of these areas, methods developed to integrate EO with statistical reporting systems could be integrated and lessons shared across governments using these reporting systems.

7. Discussions and conclusions

The 2030 Agenda for sustainable development calls for new strategies to build the capacity for developing and developed nations to meet the expectations and achieve the overall commitment of these nations to the move for transforming the world to a better living place. Even though there have been efforts made by several international government and nongovernment organizations including professional societies, there are many shortcomings in making the expected impact in communities to achieve the above objectives progressively. It is often debated in many national and international forums that the progress of implementing the SDGs in many parts of the globe is rather slower than it should be in realizing the objectives. This cannot be achieved without joint effort by all stakeholders engaged in capacity development to make a way forward in improving the current situation. A conceptual approach is essential to define this joint effort.

The proposed framework plans to harmonize the effort of all stakeholders together through a Space Capacity Development Advisory Board. The board with experienced officials having strong commitment would work out strategies of engaging both government and nongovernment experts as resource people for capacity

development. It is important to bring expertise in multiple languages for effective knowledge transfer where English is not official language. When we have experts from different educational background, quality assurance in training material and learning pedagogies should be ensured. We define possible functional aspects of this board to analyze existing gaps in both technical and managerial perspectives and propose possible solutions for increasing the benefits of the coordinated capacity development initiative. The objectives should include long-term train-the-trainers program and short-term awareness and skills development goals in overall training strategies, combined with the creation of an organizational enabling environment to bring sustainable effort in building the human resources capacity. Special effort can be made to promote GSTs for SDGs through funding innovative scientific initiatives and also competitive programs such as hackathons to arouse interest in undergraduate students to sustain future needs of human capacity development.

This framework is expected to reduce duplicate efforts and support building of synergies, effective management of financial and expert resources, and sharing and joint research on software tools and methodologies developed by various agencies and partners of organizations; this would generate a set of innovative solutions needed for the country-specific projects and requirements and highlighting clearly the roles of each organization and their connected geospatial information regional and global services to avoid conflicts of interest. It is important that though regional-dependent, the training curriculum design for each sustainable development goal would be developed to cover technical core competence, resources for knowledge sharing, and intergovernmental practices. The design for three goals is given as illustrations.

The proposed coordination of capacity development needs to be integrated into an overall results-based management approach for optimizing the use of space science, technology, and its applications in support of global development agendas, such as the one proposed in Ref. [32]. The proposed conceptual framework would take a concrete first step to coordinate space-based capacity development activities.

Declaration of competing interest

None.

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Appendix A. Supplementary data

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