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ConnectinGEO

Coordinating an Observation Network of Networks EnCompassing saTellite and IN-situ to fill the Gaps in European Observations

Deliverable D2.3
Proposal of EVs for selected themes

Version 1

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Document control page

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Executive Summary

The ConnectinGEO methodology for the identification of Essential Variables (EVs) starts at societal goals, associated targets, and indicators and identifies those variables that are essential for quantification of the indicators. This methodology is applied in this document to the seventeen Sustainable Development Goals (SDGs) accepted in 2015 by the United Nations. These SDG have been associated with ~170 specific Targets. Approximately, 240 Indicators have been proposed as reporting cards to measure progress towards the targets (the definition of the targets and indicators is in advanced draft and the exact number can be different depending on the exact version of the available documents and may vary in the future). A careful review of all of the proposed indicators shows that, in the current formulation of them, most of them are solely based on social and economic statistic data, while only around 15% requires data that can be obtained by Earth observation procedures.

The review utilizes the concept for the GEOSS Knowledge Base, which supports GEO's effort "to connect the demand for sound and timely environmental information with the supply of data and information about the Earth that is collected through observing systems and made available by the GEO community." The result of the review is a set of recommendations to GEO helping "to unlock the power of Earth observations".

The GEO 2015 Ministerial declaration "affirms that GEO and its Earth observations and information will support the implementation of, inter alia, the 2030 Global Goals for Sustainable Development". Nevertheless, this document concluded that GEO needs to initiate a process to define complimentary EO based indicators that increase the representation of environmental aspects in the monitoring of progress towards the targets and SDGs. Without such environmental indicators it can be doubted that the efforts to reach the SDGs will be an effective road to more sustainability. It also has to be doubted that the current set of proposed indicators will correctly measure the intended progress towards more dignity and sustainability. The importance of EO and geospatial information on both the natural and built environment for a number of goals is underlined here. Examples of SDG Targets, where a better integration of Earth observations into the indicators, and the use of geospatial information are those mainly focusing on human dependencies on natural resources and environmental impacts of human activities, i.e.:

- Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 3: Ensure healthy lives and promote well-being for all at all ages
- Goal 6: Ensure availability and sustainable management of water and sanitation for all
- Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 13: Take urgent action to combat climate change and its impacts
- Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

On the one hand, GEO Societal Benefit Areas (SBAs) can contribute to the design of EO based indicators useful for SDG targets. Importantly, the community processes in several

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SBAs to identify relevant EVs can be a template for an expert-based approach to develop indicators based on available sets of EVs. More specifically, the Essential Biodiversity Variables (EBVs) and Ecosystem Variables (ESV) can be used as basis to design new indicators more related to EO measurements for:

- SDG 3: human health is closely linked to the conservation of biodiversity and ecosystem functions and services, consequently some of EBVs can be used to formulate additional SDG 3 indicators in support to SDG3 targets. As described in Section 4.2, some of these EBV can be extracted by EO as direct measurements or proxies.
- SDG6, SDG 13, SDG 14 and SDG 15: habitat extent, connectivity and fragmentation and changes, along with land cover/use changes can be used to extract indicators trends useful for supporting related SDGs targets. As an example, coastal habitat and changes over time can contribute to coastal erosion mapping from EO data in support to SDG Target 14.2. Major contribution can be provided to all set of SDG Targets 15.

More coverage need to be included for the EO data into the definition of the SDGs. As an example, ConnectingGEO considers that the way Goal 13: *Take urgent action to combat climate change and its impacts* is translated into indicators excludes the use Earth observation for monitoring climate change. This goal has to take into account that the United Nations Framework Convention on Climate Change (UNFCCC) is the primary international, intergovernmental forum for negotiating the global response to climate change and also the overlap with the IPPC. The approach taken to Goal 13 is avoiding consideration of climate change monitoring and rather focusing on monitoring the impact of governmental decisions and policies for mitigation, adaptation, impact reduction and early warning for climate change. This moves Goal 13 and its targets and indicators away from the Earth observation domain. As discussed in Section 3, there is a need for a complementary set of indicators for sustainable development for Goal 13 that links environmental changes to an overall sustainability metrics. For these indicators, EOs and the ECV will be crucial.

The review of the set of EVs developed in several GEO communities provided in D2.2 revealed that there is considerable overlap between EVs identified by different communities. In particular, the core set of EVs common to several communities should be considered for complementary SDG indicators.

On the other hand, the use of EO data is completely new in the some communities involved in processes facilitating progress towards the SDGs. As an example, the World Bank community has focused mainly on economical and social issues measured with aggregated socioeconomic data, even thou a growing recognition remote sensing cannot be separated from monitoring progress. In particular, this will help in spatially disaggregated data in the way the UN recommends. GEO can take an important role in supporting these communities with complementary indicators derived from Earth observation data.

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1. Introduction

The vision in the GEO Strategic Plan 2016-2025 about implementing GEOSS considers that GEO needs to work "to connect the demand for sound and timely environmental information with the supply of data and information about the Earth that is collected through observing systems and made available by the GEO community". To achieve such a goal, GEO must work "to unlock the power of Earth observations by facilitating their accessibility and application to global decision-making within and across many different domains".

GEOSS and its infrastructure must evolve in order to meet current and emerging needs by:
- extending the user audience to **decision-makers and the general public**;
- placing **additional focus on the accessibility and usability of Earth observation resources** to improve our scientific understanding of the Earth processes, and enhance our predictive capabilities **that underpin sound decision-making**;
- providing a service framework **to engage partners and user communities** in evolving the current infrastructure to enable **collaborative tools for co-creation of products** and services suitable for effective exploitation by user communities;
- evolving the current system of systems component based architecture with **an open systems platform** that is flexible, sustainable and reliable for data access, integration and use, and the delivery **of knowledge-based products and services**.

To support GEO vision and strategic objectives, it is necessary to move from a data-centric system to a more information and knowledge-centric system. This is possible by applying the so-called DIKW paradigm: as depicted in Figure 1, this is about *understanding and connecting*. Information is an added-value product generated by understanding data and working out relations among them and with physical and/or social phenomena. Understanding information and working out valuable patterns generates knowledge, in turn.
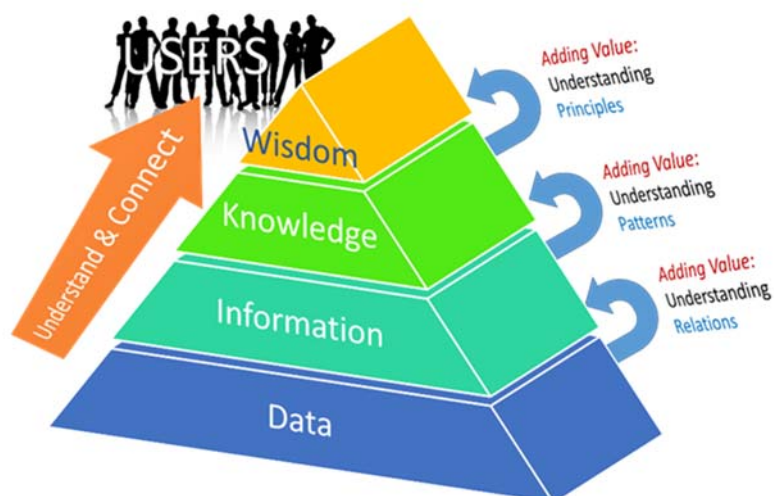
Figure 1. The DIKW pattern

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Elements and processes characterizing the linkage between data and knowledge in GEOSS are showed by Figure 2. Entities to be considered for generating knowledge from Earth Observation (and non-EO) data include: GEOSS Essential Variables, Environmental Priority Indicators; Environmental and socio-economic indexes; Sustainable Development Goals and Targets. Two paths are possible and both valuable: (a) generate knowledge from existing datasets; (b) identify the datasets that are necessary to underpin the knowledge required by GEOSS users.
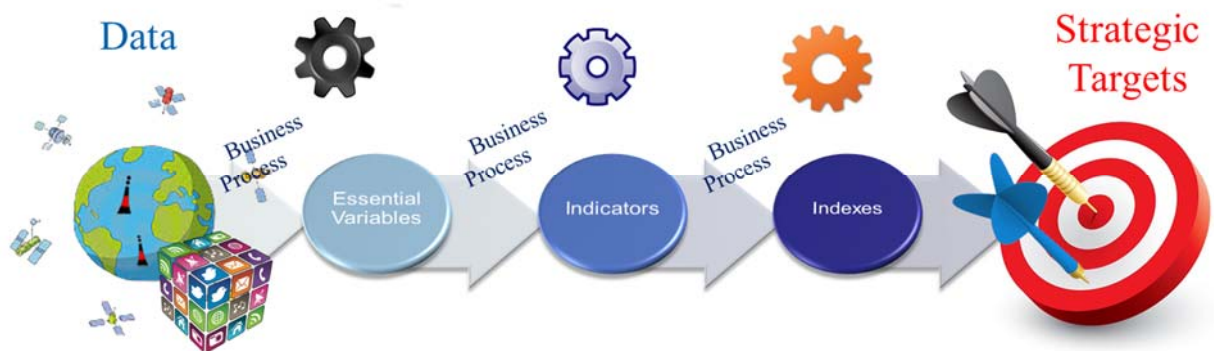
Figure 2. GEOSS approach to generate information and knowledge from Earth Observations

The GEO Foundational Task GD-09 on the new GEOSS Knowledge Base is asked to consider all these elements and methodologies in the concept and implementation of the Knowledge Base to evolve the current GEOSS Software Ecosystem into a GEOSS Social Ecosystem. The GEO Model Web initiative will strongly support this evolution.

In such evolutionary processes, the first step is the most important one. Therefore, to recognize and promote the generation of Essential Variables in GEOSS is of paramount importance. This first step must be underpinned and promoted by entire GEOSS Community (i.e. 8 SBAs), as well as the GCI and the DAB, in particular.

1.1.   Scope of this document

The concept of Essential Variables (EVs) is increasingly used in Earth observation communities to identify those variables that have a high impact and should have priority in designing, deploying and maintaining observation systems and making data and products available. The community associated with GCOS was one of the first one to develop a full set of Essential Climate Variables (EVS). Other examples of communities that have applied the concept with different levels of maturity are several communities engaged in observations of the oceans, biosphere, and water cycle. A detailed description of the current status of the EV deliberations in the GEO societal benefit and thematic areas is provided by the ConnectinGEO deliverable 2.2.

Most of the communities give current feasibility and cost efficiency a high value in the process of identifying their EVs. To a large extent, this limit the EV sets to the area of high feasibility in the impacts versus feasibility diagram, while the area of low feasibility, high impact is underrepresented (see the discussion on the ConnectinGEO deliverable 2.1). Moreover, this "expert-based" approach to EVs does not provide a link to societal benefits as an inherent aspect but rather constructs this link a posteriori.

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ConnectinGEO developed a complementary "goal-based" methodology that takes societal goals and targets as a priori information. In general, these sets of societal goals and targets come with associated indicators that are used as reporting cards for the targets and as planning tools to support the design of actions that ensure progress towards the targets. The ConnectinGEO methodology provides the link between indicators and EVs. The details are described in ConnectinGEO deliverable 2.1.

In this report, we compile in Section 2 the different sets of EVs developed by several GEO communities and provide examples of how these EVs can be linked to Earth observations. The section provides lists for these sets of EVs. For several selected EVs, it also shows the way in which observational requirements can be defined and then available dataset that meet these requirements can be discovered.

In Section 3, we use the example of the United Nations' Sustainable Development Goals (SDGs) to illustrate the ConnectinGEO methodology. The link between the SDGs and the SDG targets is included in the data model. The targets are linked to indicators, and in the ConnectinGEO methodology, the indicators are analysed to identify those indicators that require environmental observations for quantifications. As a result, a list of corresponding Essential Variables is developed. The current list of proposed indicators are found to be mainly of statistical nature requiring socio-economic data for quantification. Therefore, in Section 3 it is proposed that GEO develops a complimentary set of indicators that bring in environmental aspects of sustainability. This is consistent with a number of comments on the SDG metrics provided by scientific communities. Once the list of EVs is completed, observational requirements can be defined, and these requirements are then available for a search for available datasets.

In Section 4, the relation between SDGs, Targets and Indicators is further explored and put into practice by proposing the full list of indicators that ConnectinGEO considers can be expressed using Earth Observation and can be link with existing or future EVs. In particular the SDGs 2, 6 and 15 are related to three Essential Biodiversity Variables (EBVs) that are also used in Ecosystems: Species Distribution, Habitat Structure and Soil Moisture.

The ConnectinGEO methodology is implemented in the GEOSS Knowledge Base. In Section 1.2, we give a brief summary of the data model of the GEOSS Knowledge Base that applies to goals, targets, indicators, EVs and observational requirements.

1.2.   GEOSS Knowledge Base

Until 2015, the GEOSS User Requirements Registry (URR) was the primary place to collect information on Earth observations requirements and the application and users that depended on these observations. A Ministerial guidance provided to GEO during the Ministerial Summit in 2014 requested that GEO "develop a comprehensive interdisciplinary knowledge base defining and documenting observations needed for all disciplines and facilitate availability and accessibility of these observations to user communities." In response to this guidance, the URR has been transformed and extended into the Socio-Economic and Environmental Information Needs Knowledge Base (SEE-IN KB).

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The contents of the SEE IN KB reflect the knowledge, information, and data needs of a wide range of applications and users. The data model of the SEE-IN KB is based on unstructured objects (Figure 3). Each entity in the SEE-IN KB is an object. Objects can belong to one or more groups. With the group concept, new groups can be introduced as needed. A group is defined by a set of attributes selected from a master set of attributes (the ontology). Examples of attributes are Variable, Resolution, Latency, Accuracy, etc. Each attribute comes with a specified domain taken from a master set of domains. Examples of domains are an interval of real number, a list of variables, or a list of specific terms. Groups also are associated with rules for how members of the group can act and interact with other objects. A special group are Links (which are also objects). Links define the relationship between two objects in the same or two different groups. This link concept is used to capture connectivity. With the group concept, new groups can be introduced as needed."
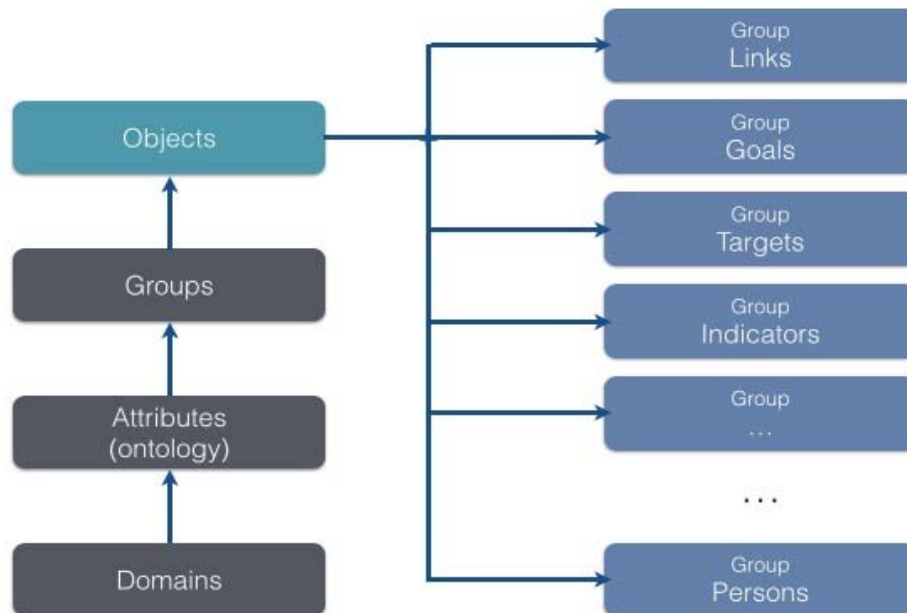
Figure 3. Main elements of the data model of the SEE-IN KB. The dark-gray boxes define the domains for attributes, the ontology, and the known groups. Each entity in the SEE-IN KB is an object, which are registered in an inventory, where the entity is associated with one or more groups. Details on the object are provided in the body of object, depending on the group membership. The objects in the Link group capture the connectivity and relationships between object."

The groups inherited from the URR include User Types, Applications, Requirements, Research Needs, Infrastructure Needs, Technology Needs, Capacity Needs, and Links. Additional groups include, among others, Persons, Models, Services, Datasets, Essential Variables, Variables, and several groups for various types of gaps.

The concept of Essential Variables (EVs) is implemented in the SEE-IN KB. Based on the results of Task 2.1 in the ConnectinGEO WP2, rules are made available to link societal goals (such as the Sustainable Development Goals, SDGs) to EVs.

Existing set of EVs can be linked to societal goals and benefits. The results of the review of EV developments in the GEO SBAs will be published in the SEE-IN KB. The lists of EVs provided in Section 2 below will be transformed into the data model of the SEE-IN

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KB and published there. The lists provided in Section 3 are already in the data model of the SEE-IN KB and publication is in progress.

This SEE-IN KB provides the core of the GEOSS Knowledge Base, which - among others - adds the capability of conducting gap analyses to the SEE-IN KB. The GEOSS Knowledge Base also "facilitate availability and accessibility of these observations to user communities," as requested in the Ministerial guidance.

The SEE-IN KB serves as the primary source for "user needs" in ConnectingGEO and will be utilized for at least one of the gap analysis approaches in the ConnectinGEO methodology. Moreover, the outcomes of the ConnectinGEO gap analysis will be published in the SEE-IN KB. The information in the SEE-IN KB will not be part of the Observation inventory but will be used later on in the project to compare offerings (data) with needs and determine the gaps. Also it will be used to set priorities.

It is mentioned here that the SEE-IN KB is developed as open-source software with community participation. It is a constantly evolving knowledge base and both information contents and rules can be updated through web-based interfaces. Guests can view and search all contents. Users can sign up and request editing authority. The SEE-IN KB has several options for users to publish objects in all available groups, establish new groups and develop rules for queries and analyses.

2. Synergies and Synthesis

The total number of EVs reviewed within ConnectinGEO in the frame of Work Package 2 is 147 (see Table 1 below). Some of the EVs are actually not just a single variable, but a cluster of several ones. These variables are grouped here in seven of the new GEO Societal Benefit Areas (SBAs), namely Biodiversity and Ecosystem Sustainability, Disaster Resilience, Energy and Mineral Resources Management, Food Security and Sustainable Agriculture, Public Health Surveillance, Sustainable Urban Development, Water Resources Management, plus Climate as a cross-cutting thematic area in the new GEO Work Plan Strategy. Within those GEO SBAs we have further regrouped those variables in the following 11 themes (adopted for the ConnectinGEO workshop "Towards a sustainability process for GEOSS Essential Variables", Bari, 11-12 June 2015): Agriculture, Biodiversity, Climate (and Carbon cycle), Disasters, Ecosystems, Energy, Health, Human Settlements, Oceans (and Marine Ecosystems), Water and Weather.

The community that has defined the highest number of EVs is currently the Climate one, led by the Global Climate Observing System (GCOS), covering – with its ECVs (Essential Climate Variables) – one third of the total number. Moreover most of the ECVs are relevant to the other GEO SBAs or themes. Others communities already working on a mature set of EVs are Weather (led by WMO and GAW) and Ocean, led by the Global Ocean Observing System (GOOS). The EV discussion and related work is growing fast in the Biodiversity and Energy communities, while in other areas, like Agriculture, Disasters, Ecosystems, Health, and Urban Development, the work on specific EVs is still in the initial stage. Fortunately, they can rely also on several EVs already identified in some areas that are relevant also to others. Table 1 is a tentative list synthetizing in a synoptic way this complex situation. The result is a long (and complex) table, which highlights the duplications and possibilities for synergies among different communities.

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It is evident that out of the 147 EVs listed, many are relevant to more than one area. In particular, the most often listed variable (12 times) is Temperature, in the three different systems' components (air, water and soil). Then there is Carbon (at least 11 times) in its different forms, like CO2 in the air, CO2 partial pressure in water, and all the relevant different stages of the carbon cycle in the different system components. The next variable is Pressure, again related to different systems' components, like atmosphere, sea and water chemical composition. Subsequent variables are (again in different system components) Wind, Solar Irradiance, Precipitation, Humidity, as well as some water specific variables, like Ocean Acidity and Oxygen. It is evident that the majority of these variables are related to the Climate (and Weather) and Water (particularly Ocean) areas. In particular, most of the ECVs are relevant to other GEO SBAs, and a couple of them (Temperature and Precipitation) are virtually relevant to all of the new GEO SBAs, being affected by, and affecting (directly or indirectly and at different level), all of the following areas: Agriculture, Biodiversity, Climate, Ecosystems, Disasters, Energy, Health, Water, Weather, and also Urban Development.

On the other side, if we approach the issue starting with the themes, we can see, for instance, that a theme like Ecosystems, which is still in an initiation stage for what concern the definition and identification of specific EVs, can rely on a number of EVs already available from other areas, which are of direct relevance. This is also recognized by the Ecosystem community, which is indeed starting their EV analysis from the available EVs list (see the ConnectinGEO Deliverable 2.2 for more details).

This suggests that each community working on the identification of the variables essential for their purposes should first review all the EVs currently available and the related documentation, including the synthesis work done in ConnectinGEO, mainly in the Deliverables 2.1, 2.2 and the present document. This will allow to take stock of the work already done and concentrate the efforts on those variables that are cross-cutting different domains and check if the requirements are the same; in this way it will be easier to advocate for further improvements, in terms of methodologies, accuracy, spatial and temporal sampling, etc., on a small number of key variables.

Table 1. Synthesis of EVs status

GEO New SBA (+ Climate)	Themes (according to the Bari's Workshop)	EV name	Domain and/or system component	Status of EV discussion (initial, medium, advanced)	Relevant communities, conventions, others initiatives	Other relevant GEO SBAs
Biodiversity and Ecosystem Sustainability	**Biodiversity**			Advanced	GEOBON, CBD, Ramsar Convention	
		Genetic composition (Co-ancestry, Allelic diversity, Population genetic differentiation, Breed and variety div.)				
		Species populations (Species distribution, Population abundance, Population structure by age/size class)				

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GEO New SBA (+ Climate)	Themes (according to the Bari's Workshop)	EV name	Domain and/or system component	Status of EV discussion (initial, medium, advanced)	Relevant communities, conventions, others initiatives	Other relevant GEO SBAs
		Species traits (Phenology, Body mass, Natal dispersion distance, Migratory behaviour, Demographic traits, Physiological traits)				
		Community composition (Taxonomic diversity, Species interactions)				
		Ecosystem function (Net primary productivity, Secondary productivity, Nutrient retention, Disturbance regime)				
		Ecosystem structure (Habitat structure, Ecosys. extent and fragmentation, Ecosys. composition by functional type)				
Biodiversity and Ecosystem Sustainability	**Ecosystems**			Initial (starting with other available EVs)	GECO, GEO-GNOME, Belmont forum	
Climate	**Climate (and Carbon cycle)**			Advanced	GCOS, UNFCCC, WMO, GAW	
		Air temperature	Atmosphere (Surface)			Agriculture, Biodiversity & Ecosystems, Disasters, Health, Weather, Water? Urban dev.?
		Wind speed and direction	Atmosphere (Surface)			Biodiversity & Ecosystems, Disasters, Energy, Weather
		Water vapour	Atmosphere (Surface)			Weather
		Pressure	Atmosphere (Surface)			Weather
		Precipitation	Atmosphere (Surface)			Agriculture, Biodiversity & Ecosystems, Disasters, Energy, Health, Water,

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GEO New SBA (+ Climate)	Themes (according to the Bari's Workshop)	EV name	Domain and/or system component	Status of EV discussion (initial, medium, advanced)	Relevant communities, conventions, others initiatives	Other relevant GEO SBAs
						Weather, Urban dev.?
		Surface radiation budget	Atmosphere (Surface)			Agriculture, Biodiversity & Ecosystems
		Temperature	Atmosphere (Upper-air)			Weather
		Wind speed and direction	Atmosphere (Upper-air)			Weather
		Water vapour	Atmosphere (Upper-air)			Weather
		Cloud properties	Atmosphere (Upper-air)			Weather
		Earth radiation budget (including solar irradiance)	Atmosphere (Upper-air)			Weather
		Carbon dioxide	Atmosphere (Composition)			
		Methane, and other long-lived greenhouse gases	Atmosphere (Composition)			
		Ozone and Aerosol, supported by their precursors	Atmosphere (Composition)			
		Sea-surface temperature	Ocean (Surface)			Biodiversity & Ecosystems, Ocean, Weather
		Sea-surface salinity	Ocean (Surface)			Ocean
		Sea level	Ocean (Surface)			Biodiversity & Ecosystems, Ocean
		Sea state	Ocean (Surface)			Ocean
		Sea ice	Ocean (Surface)			Ocean
		Surface current	Ocean (Surface)			Weather
		Ocean colour	Ocean (Surface)			Ocean
		Carbon dioxide partial pressure	Ocean (Surface)			Ocean
		Ocean acidity	Ocean (Surface)			Biodiversity & Ecosystems, Ocean
		Phytoplankton	Ocean (Surface)			Biodiversity & Ecosystems, Ocean
		Temperature	Ocean (Sub-surface)			Ocean
		Salinity	Ocean (Sub-surface)			Ocean

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GEO New SBA (+ Climate)	Themes (according to the Bari's Workshop)	EV name	Domain and/or system component	Status of EV discussion (initial, medium, advanced)	Relevant communities, conventions, others initiatives	Other relevant GEO SBAs
		Current	Ocean (Sub-surface)			Ocean
		Nutrients	Ocean (Sub-surface)			Ocean
		Carbon dioxide partial pressure	Ocean (Sub-surface)			Ocean
		Ocean acidity	Ocean (Sub-surface)			Ocean
		Oxygen	Ocean (Sub-surface)			Biodiversity & Ecosystems, Ocean
		Tracers	Ocean (Sub-surface)			Ocean
		River discharge	Land			Biodiversity & Ecosystems, Water
		Water use	Land			Agriculture, Health, Urban Dev., Water
		Groundwater	Land			Agriculture, Water
		Lakes	Land			Agriculture, Water
		Snow cover	Land			Water, Weather
		Glaciers and ice caps	Land			Water, Weather
		Ice sheets	Land			Water, Weather
		Permafrost	Land			Water, Weather
		Albedo	Land			Weather
		Land cover (including vegetation type)	Land			Weather
		FAPAR	Land			
		LAI	Land			
		Above-ground biomass	Land			
		Soil carbon	Land			Agriculture
		Fire disturbance	Land			Agriculture, Biodiversity & Ecosystems, Disasters
		Soil moisture	Land			Agriculture, Biodiversity & Ecosystems, Weather
Climate	**Weather**			Advanced	WMO, GAW	
		Atmospheric pressure				Climate
		Wind speed and direction				Biodiversity &

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GEO New SBA (+ Climate)	Themes (according to the Bari's Workshop)	EV name	Domain and/or system component	Status of EV discussion (initial, medium, advanced)	Relevant communities, conventions, others initiatives	Other relevant GEO SBAs
						Ecosystems, Climate
		Air temperature				Agriculture, Biodiversity & Ecosystems, Climate, Disasters, Health, Water, Urban dev.
		Relative humidity				Biodiversity & Ecosystems, Climate
		All Global Numerical Weather Prediction (NWP) variables (e.g., PBL + Tropopause height) and others yet to be determined by WMO/GAW.				Climate
		Aerosols (aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron), speciation and chemical composition, Aerosol Optical Depth (AOD) at multiple wavelengths, AAOD, water content, ratio of mass to AOD, vertical distribution of extinction).				Climate
		Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO2 (surface and column), CH4, CO2, N2O, HCHO, HOx, Clx, ClO, BrO, OClO, ClONO2, HDO, CFCs, HCFCs, HFCs, Rn, SF6)				Climate
		Others: Actinic flux, fire radiative power, land proxies, lightning, dry and wet deposition,				Climate

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		pollen (key species), OCS				
Disaster Resilience	Disasters			Initial	Sendai Framework	
Energy and Mineral Resources Management	Energy			Initial	IRENA, IEA	
		Ocean (fixed and floating offshore wind, wave, tidal, currents, OTEC)	Ocean			Ocean
		Temperature (sea-surface, sub-surface and deep-sea)	Ocean			Biodiversity & Ecosystems, Ocean, Weather
		Bathymetry	Ocean (Renewable energy)			Ocean
		Current (speed, direction)	Ocean (Renewable energy)			Ocean
		Tidal (min, max, sea surface elevation)	Ocean (Renewable energy)			Ocean
		Wave (height, direction, period)	Ocean (Renewable energy)			Ocean
		Wind speed and direction	Ocean (Renewable energy)			Ocean
		Land use, Land cover (including urbanization, hydrology, grid description)	Onshore wind			Climate, Biodiversity & Ecosystems
		Elevation (Orography)	Onshore wind (Renew.En.)			
		Land surface temperature	Onshore wind (Renew.En.)			Agriculture, Biodiversity & Ecosystems, Climate, Disasters, Health, Weather, Water? Urban dev.?
		Land use, Land cover	Onshore wind (Renew.En.)			Agriculture, Bidiversity & Ecosystems, Climate
		Surface air temperature	Onshore wind (Renew.En.)			Agriculture, Biodversity &

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						Ecosystems, Climate, Disasters, Health, Weather, Water? Urban dev.?
		Surface atmospheric pressure	Onshore wind (Renew.En.)			
		Surface humidity	Onshore wind (Renew.En.)			
		Urbanization	Onshore wind (Renew.En.)			Biodiversity & Ecosystems, Climate, Disasters, Urban Dev.
		Wind speed and direction	Onshore wind (Renew.En.)			Biodiversity & Ecosystems, Climate, Disasters, Weather
		Elevation (Orography)	Solar energy			
		Cloud cover	Solar energy (Renew.En.)			Climate, Weather
		Land use, Land cover	Solar energy (Renew.En.)			Agriculture, Bidiversity & Ecosystems, Climate
		Precipitation	Solar energy (Renew.En.)			Agriculture, Biodiversity & Ecosystems, Climate, Disasters, Health, Water, Weather, Urban dev.?
		Solar Surface Irradiance and its components (global, direct, diffuse)	Solar energy (Renew.En.)			Agriculture, Climate, Weather
		Surface air temperature	Solar energy (Renew.En.)			Agriculture, Biodiversity & Ecosystems, Climate, Disasters, Weather
		Surface humidity	Solar energy (Renew.En.)			
		Urbanization	Solar energy (Renew.En.)			Agriculture, Biodiversity & Ecosystems, Climate, Disasters, Urban Dev.

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GEO New SBA (+ Climate)	Themes (according to the Bari's Workshop)	EV name	Domain and/or system component	Status of EV discussion (initial, medium, advanced)	Relevant communities, conventions, others initiatives	Other relevant GEO SBAs
Food Security and Sustainable Agriculture	**Agriculture**			Medium	GEOGLAM	
		Crop Area				
		Crop Type				
		Crop Condition				
		Crop Phenology				
		Crop Yield (current and forecast)				
		Crop Management and agricultural practices				
Public Health Surveillance	**Health**	Weather/climate		Initial	WHO	
		Famine early warning				
		Short term forecasting of communicable diseases				
Sustainable Urban Development	**Human Settlements**			Initial	UN-HABITAT, Sendai Framework	
Water Resources Management	**Water**			Advanced	GOOS, IOCCP, WMO	
		Precipitation				Agriculture, Biodiversity & Ecosystems, Climate, Disasters, Energy, Health, Weather, Urban Dev.?
		Evaporation and evapotranspiration				Climate
		Snow cover				Climate
		Soil Moisture/Temperature				Climate
		Groundwater				Climate
		Runoff/streamflow/river discharge				Climate
		Lakes/reservoir levels and aquifer volumetric change				Climate
		Glaciers/ice sheets				Climate
		Water quality				Agriculture, Biodiversity & Ecosystems,

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GEO New SBA (+ Climate)	Themes (according to the Bari's Workshop)	EV name	Domain and/or system component	Status of EV discussion (initial, medium, advanced)	Relevant communities, conventions, others initiatives	Other relevant GEO SBAs
						Health, Urban dev.
		Water us/demand (agriculture, hydrology, energy, urbanization)				Agriculture, Biodiversity & Ecosystems, Health, Urban dev.
	Oceans (and Marine Ecosystems)				GOOS, IOCCP, WMO	
		Sea Level Pressure	Physical (Surface)			Climate, Weather
		Surface Wind	Physical (Surface)			Climate, Weather
		Surface Current	Physical (Surface)			Biodiversity & Ecosystems, Climate, Weather
		Sea Ice	Physical (Surface)			Biodiversity & Ecosystems, Climate
		Sea Level	Physical (Surface)			Biodiversity & Ecosystems, Climate, Disasters
		Sea State	Physical (Surface)			Climate
		Sea Surface Salinity	Physical (Surface)			Biodiversity & Ecosystems, Climate
		Sea Surface Temperature	Physical (Surface)			Biodiversity & Ecosystems, Climate, Weather
		Upper-Air	Physical (Surface)			Climate, Weather
		Ocean Color	Physical (Surface)			Biodiversity & Ecosystems, Climate
		Carbon Dioxide Partial Pressure	Physical (Surface)			Climate
		Ocean acidity	Physical (Surface)			Biodiversity & Ecosystems, Climate
		Oxygen	Physical (Surface)			Biodiversity & Ecosystems, Climate
		Tracers	Physical (Surface)			Climate, Weather

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		Current	Physical (Sub-surface)			Biodiversity & Ecosystems, Climate
		Salinity	Physical (Sub-surface)			Biodiversity & Ecosystems, Climate
		Temperature	Physical (Sub-surface)			Climate
		Carbon Dioxide partial pressure	Physical (Sub-surface)			Climate
		Ocean acidity	Physical (Sub-surface)			Climate
		Oxygen	Physical (Sub-surface)			Climate
		Tracers	Physical (Sub-surface)			Climate
		Current	Physical (Sub-surface)			Climate
		Global Ocean Heat Content	Physical (Sub-surface)			Climate
		Oxygen	Biogeochemical			Climate
		Macro Nutrients: NO3, PO4, Si, NH4, NO2	Biogeochemical			Climate
		Carbonate System: DIC, Total Alkalinity, pCO2 and pH (at least 2 of 4)	Biogeochemical			Climate
		Transient Tracers: CFC-12, CFC11, SF6, tritium, 3He, 14C, 39Ar	Biogeochemical			Climate
		Suspended particulates (POC, PON or POM) and PIC ++ laboratory, beam attenuation, backscatter, acidlabile, beam attenuation	Biogeochemical			Climate
		Particulate Matter Export: POC export, CaCO3 export, BSi export	Biogeochemical			Climate
		Nitrous Oxide	Biogeochemical			Climate
		Carbon-13: 13C/12C of dissolved inorganic carbon	Biogeochemical			Climate
		DOM: Dissolved organic matter, DOC, DON, DOP	Biogeochemical			Climate
		Chlorophyll	Biology and Ecosystems			Climate
		Coral Cover	Biology and Ecosystems			Climate
		Mangrove Area	Biology and Ecosystems			Climate
		Harmful Algal Blooms (HABs)	Biology and Ecosystems			Climate

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GEO New SBA (+ Climate)	Themes (according to the Bari's Workshop)	EV name	Domain and/or system component	Status of EV discussion (initial, medium, advanced)	Relevant communities, conventions, others initiatives	Other relevant GEO SBAs
		Zooplankton (biomass/abundance)	Biology and Ecosystems			Climate
		Salt Marsh Area	Biology and Ecosystems			Biodiversity & Ecosystems
		Large marine vertebrates: abundance/distribution	Biology and Ecosystems			Biodiversity & Ecosystems
		Seagrass Area	Biology and Ecosystems			Biodiversity & Ecosystems
		Tags and Tracking of species of value/large marine vertebrates	Biology and Ecosystems			Biodiversity & Ecosystems
		Zooplankton (Krill)	Biology and Ecosystems			Biodiversity & Ecosystems

3. Linking SDGs to Essential Variables

To illustrate the importance of the Indicators for the sustainable development, we will cite Marianne Fay (the chief economist for climate change at the World Bank) in a recent presentation to the Open Plenary of the Technical Committee of the OGC celebrated in Washington DC on March the 7th 2016. She said "some time ago, I wanted *sustainability* as the third World Band goal but at that time we could not include it because we did not had no idea on how to define indicators for it".

This recognized the importance of the work on sustainable indicators that the UN is doing now for the SDG.

In D2.1, the methodology to link societal goals to EVs was discussed and is applied here to the Sustainable Development Goals (SDGs) accepted in 2015 by the United Nations (see https://sustainabledevelopment.un.org/sdgs). The seventeen goals are listed in Table 2. For each goal, a set of targets has been defined. In total, 170 targets have been agreed upon (Table 3). Progress towards these targets is measured with indicators (see https://sustainabledevelopment.un.org/topics/indicators). The global SDG indicator framework was developed by the Inter-Agency Expert Group on SDG Indicators. A proposal for the framework has been submitted to the United Nations Statistical Commission in February 2016 (see http://unstats.un.org/sdgs/iaeg-sdgs/ga-briefing-28-Jan-2016/). This framework includes a list of 228 indicators (see http://unstats.un.org/unsd/statcom/47th-session/documents/2016-2-IAEG-SDGs-E.pdf).
It is expected that this framework will be adopted by the UN Statistical Commission in March 2016. Therefore, the proposed 228 indicators (Table 4) have been used to identify those indicators that either depend on EOs for quantification or would benefit from additional information derived from EOs.

The information on SDGs, Targets, Indicators, and the links to Essential Variables has been published in the GEOSS Knowledge Base using the data model briefly described in

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Section 1.2. The tables mentioned above were generated based on the contents in the GEOSS Knowledge Base.

Note that on February 19, 2016, a revised version of the list of indicators has been submitted to the United Nations Statistical Commission, which now has 240 proposed indicators. The contents in the GEOSS Knowledge Base will be updated once the final list of accepted indicators is available. At that point in time, the identification of Essential Variables for SDG monitoring will be revised.

It is clear that out of the 228 indicators, only a small fraction has a direct dependency on, or benefit of, EOs in the classical sense. The SDG indicator framework is to a large extent focusing on statistical variables related to human activities and human conditions. These variables are inherently social or economic in their nature.

It is mentioned here that in the preparatory discussion of the SDGs, an effort has been made to integrate the environment into the SDGs and the indicators. In particular, UNEP (2013) proposed three approaches to the integration of societal and environmental goals and indicators that would represent environmental developments. Below, Figure 4 shows these three approaches. Most of the 17 SDGs are social, economic, or social and economic, while only very few integrate environmental aspects. Therefore, most of the targets fall into the classes of "social" and "economic," while the number of targets that are purely environmental or integrated is small.

A number of scientific communities have raised concerns about the environment not sufficiently represented in both the SDGs and the indicators proposed to monitor progress towards the targets. For example, Griggs et al. (2013) put a strong emphasis on safeguarding the Earth's life-support system, on which present and future generations depend. Lu et al. (2015) point out that a review of the proposed SDGs conducted by ICSU showed that addressing climate change, food and water security, and health requires coordinated global monitoring and modeling of many factors. The currently proposed indicator framework has not sufficiently integrated the environmental aspects of sustainable development.

Based on the notion that sustainable development requires the functioning Earth's life-support system (Griggs et al., 2013), it is proposed here to develop a set of complementary indicators that bring environmental aspects to the monitoring of SDG targets. The underlying concept for this could be the "safe operating space for humanity" introduced by Rockstrom et al. (2009). This proposal will be communicated to the GEO Initiative GI-18 "Earth Observations in Service of the 2030 Agenda for Sustainable Development.

It is also noted here that geospatial data is of high relevance for the monitoring of progress towards the SDG targets. For example, Goal 1 would benefit from poverty maps and improved information on human and infrastructure losses during disasters. Crowd-sourcing, citizen scientist and big data analyses combined with geospatial representation can address the current gaps. For Goal 2, geospatial information on crop yields, irrigation, vulnerability, soil characteristics, flood risk and other environmental characteristics would be important inputs for more elaborate monitoring.

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For a number of goals, information on the built environment is crucial. For example, Goals 3 and 4 would benefit from information on health facilities and educational facilities, respectively. Goal 9 fully depends on information on all public services. Monitoring progress towards Goal 6 depends to a large extent on information of all aspects of the water cycle and particularly the terrestrial part of the water cycle.

The Goals 12, 13, 14, and 15 all address environmental aspects of sustainable development, but the current indicators do not fully utilize the available EOs. There is an important role for GEO in complementing the current indicators with comprehensive data and products, including geospatial products directly relevant for the monitoring of the targets for these goals.

Table 2. List of the seventeen SDGs

Name	Short Description	Description
Sustainable Development Goal 1	No Poverty	End poverty in all its forms everywhere
Sustainable Development Goal 2	Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Sustainable Development Goal 3	Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages
Sustainable Development Goal 4	Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Sustainable Development Goal 5	Gender Equality	Achieve gender equality and empower all women and girls
Sustainable Development Goal 6	Clean water and Sanitation	Ensure availability and sustainable management of water and sanitation for all
Sustainable Development Goal 7	Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all
Sustainable Development Goal 8	Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Sustainable Development Goal 9	Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Sustainable Development Goal 10	Reduced Inequalities	Reduce inequality within and among countries
Sustainable Development Goal 11	Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient and sustainable
Sustainable Development Goal 12	Responsible Consumption and Production	Ensure sustainable consumption and production patterns
Sustainable Development Goal 13	Climate Action	Take urgent action to combat climate change and its impacts*
Sustainable Development Goal 14	Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Sustainable Development Goal 15	Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

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Sustainable Development Goal 16	Peace Justice and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Sustainable Development Goal 17	Partnership for the Goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Table 3. List of the agreed-upon targets for the SDGs

Name	Description
SDG-1 Target 1.1	By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day
SDG-1 Target 1.2	By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions
SDG-1 Target 1.3	Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable
SDG-1 Target 1.4	By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance
SDG-1 Target 1.5	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters
SDG-1 Target 1.a	Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions
SDG-1 Target 1.b	Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions
SDG-2 Target 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
SDG-2 Target 2.2	By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons
SDG-2 Target 2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment
SDG-2 Target 2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality
SDG-2 Target 2.5	By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed
SDG-2 Target 2.a	Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries
SDG-2 Target 2.b	Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round

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SDG-2 Target 2.c	Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility
SDG-3 Target 3.1	By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births
SDG-3 Target 3.2	By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births
SDG-3 Target 3.3	By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases
SDG-3 Target 3.4	By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being
SDG-3 Target 3.5	Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol
SDG-3 Target 3.6	By 2020, halve the number of global deaths and injuries from road traffic accidents
SDG-3 Target 3.7	By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes
SDG-3 Target 3.8	Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all
SDG-3 Target 3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination
SDG-3 Target 3.a	Strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control in all countries, as appropriate
SDG-3 Target 3.b	Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade-Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all
SDG-3 Target 3.c	Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States
SDG-3 Target 3.d	Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks
SDG-4 Target 4.1	By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes
SDG-4 Target 4.2	By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education
SDG-4 Target 4.3	By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university
SDG-4 Target 4.4	By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship
SDG-4 Target 4.5	By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations
SDG-4 Target 4.6	By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy
SDG-4 Target 4.7	By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development

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SDG-4 Target 4.a	Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all
SDG-4 Target 4.b	By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries
SDG-4 Target 4.c	By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States
SDG-5 Target 5.1	End all forms of discrimination against all women and girls everywhere
SDG-5 Target 5.2	Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation
SDG-5 Target 5.3	Eliminate all harmful practices, such as child, early and forced marriage and female genital mutilation
SDG-5 Target 5.4	Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate
SDG-5 Target 5.5	Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life
SDG-5 Target 5.6	Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Programme of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences
SDG-5 Target 5.a	Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws
SDG-5 Target 5.b	Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women
SDG-5 Target 5.c	Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels
SDG-6 Target 6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all
SDG-6 Target 6.2	By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
SDG-6 Target 6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
SDG-6 Target 6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
SDG-6 Target 6.5	By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate
SDG-6 Target 6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
SDG-6 Target 6.a	By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
SDG-6 Target 6.b	Support and strengthen the participation of local communities in improving water and sanitation management
SDG-7 Target 7.1	By 2030, ensure universal access to affordable, reliable and modern energy services

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SDG-7 Target 7.2	By 2030, increase substantially the share of renewable energy in the global energy mix
SDG-7 Target 7.3	By 2030, double the global rate of improvement in energy efficiency
SDG-7 Target 7.a	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
SDG-7 Target 7.b	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support
SDG-8 Target 8.1	Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries
SDG-8 Target 8.2	Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors
SDG-8 Target 8.3	Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services
SDG-8 Target 8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead
SDG-8 Target 8.5	By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value
SDG-8 Target 8.6	By 2020, substantially reduce the proportion of youth not in employment, education or training
SDG-8 Target 8.7	Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms
SDG-8 Target 8.8	Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment
SDG-8 Target 8.9	By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products
SDG-8 Target 8.10	Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all
SDG-8 Target 8.a	Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries
SDG-8 Target 8.b	By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization
SDG-9 Target 9.1	Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
SDG-9 Target 9.2	Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries
SDG-9 Target 9.3	Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets
SDG-9 Target 9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

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SDG-9 Target 9.5	Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending
SDG-9 Target 9.a	Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States
SDG-9 Target 9.b	Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities
SDG-9 Target 9.c	Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020
SDG-10 Target 10.1	By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average
SDG-10 Target 10.2	By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status
SDG-10 Target 10.3	Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard
SDG-10 Target 10.4	Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality
SDG-10 Target 10.5	Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations
SDG-10 Target 10.6	Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions
SDG-10 Target 10.7	Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies
SDG-10 Target 10.a	Implement the principle of special and differential treatment for developing countries, in particular least developed countries, in accordance with World Trade Organization agreements
SDG-10 Target 10.b	Encourage official development assistance and financial flows, including foreign direct investment, to States where the need is greatest, in particular least developed countries, African countries, small island developing States and landlocked developing countries, in accordance with their national plans and programmes
SDG-10 Target 10.c	By 2030, reduce to less than 3 per cent the transaction costs of migrant remittances and eliminate remittance corridors with costs higher than 5 per cent
SDG-11 Target 11.1	By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums
SDG-11 Target 11.2	By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
SDG-11 Target 11.3	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
SDG-11 Target 11.4	Strengthen efforts to protect and safeguard the world's cultural and natural heritage
SDG-11 Target 11.5	By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
SDG-11 Target 11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
SDG-11 Target 11.7	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

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SDG-11 Target 11.a	Support positive economic, social and environmental links between urban, per-urban and rural areas by strengthening national and regional development planning
SDG-11 Target 11.b	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels
SDG-11 Target 11.c	Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials
SDG-12 Target 12.1	Implement the 10-year framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
SDG-12 Target 12.2	By 2030, achieve the sustainable management and efficient use of natural resources
SDG-12 Target 12.3	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses
SDG-12 Target 12.4	By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment
SDG-12 Target 12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
SDG-12 Target 12.6	Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle
SDG-12 Target 12.7	Promote public procurement practices that are sustainable, in accordance with national policies and priorities
SDG-12 Target 12.8	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature
SDG-12 Target 12.a	Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production
SDG-12 Target 12.b	Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products
SDG-12 Target 12.c	Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities
SDG-13 Target 13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
SDG-13 Target 13.2	Integrate climate change measures into national policies, strategies and planning
SDG-13 Target 13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
SDG-13 Target 13.a	Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible
SDG-13 Target 13.b	Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities
SDG-13 Target 13.c	* Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.
SDG-14 Target 14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

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SDG-14 Target 14.2	By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans
SDG-14 Target 14.3	Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels
SDG-14 Target 14.4	By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics
SDG-14 Target 14.5	By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information
SDG-14 Target 14.6	By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation
SDG-14 Target 14.7	By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism
SDG-14 Target 14.a	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries
SDG-14 Target 14.b	Provide access for small-scale artisanal fishers to marine resources and markets
SDG-14 Target 14.c	Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want
SDG-15 Target 15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements
SDG-15 Target 15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally
SDG-15 Target 15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world
SDG-15 Target 15.4	By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development
SDG-15 Target 15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species
SDG-15 Target 15.6	Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed
SDG-15 Target 15.7	Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products
SDG-15 Target 15.8	By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species
SDG-15 Target 15.9	By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts
SDG-15 Target 15.a	Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems

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SDG-15 Target 15.b	Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation
SDG-15 Target 15.c	Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities
SDG-16 Target 16.1	Significantly reduce all forms of violence and related death rates everywhere
SDG-16 Target 16.2	End abuse, exploitation, trafficking and all forms of violence against and torture of children
SDG-16 Target 16.3	Promote the rule of law at the national and international levels and ensure equal access to justice for all
SDG-16 Target 16.4	By 2030, significantly reduce illicit financial and arms flows, strengthen the recovery and return of stolen assets and combat all forms of organized crime
SDG-16 Target 16.5	Substantially reduce corruption and bribery in all their forms
SDG-16 Target 16.6	Develop effective, accountable and transparent institutions at all levels
SDG-16 Target 16.7	Ensure responsive, inclusive, participatory and representative decision-making at all levels
SDG-16 Target 16.8	Broaden and strengthen the participation of developing countries in the institutions of global governance
SDG-16 Target 16.9	By 2030, provide legal identity for all, including birth registration
SDG-16 Target 16.10	Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements
SDG-16 Target 16.a	Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and crime
SDG-16 Target 16.b	Promote and enforce non-discriminatory laws and policies for sustainable development
SDG-17 Target 17.1	Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection
SDG-17 Target 17.2	Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of ODA/GNI to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries
SDG-17 Target 17.3	Mobilize additional financial resources for developing countries from multiple sources
SDG-17 Target 17.4	Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress
SDG-17 Target 17.5	Adopt and implement investment promotion regimes for least developed countries Technology
SDG-17 Target 17.6	Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism
SDG-17 Target 17.7	Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed
SDG-17 Target 17.8	Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology
SDG-17 Target 17.9	Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals, including through North-South, South-South and triangular cooperation Trade
SDG-17 Target 17.10	Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through the conclusion of negotiations under its Doha Development Agenda

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SDG-17 Target 17.11	Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020
SDG-17 Target 17.12	Realize timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organization decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market access
SDG-17 Target 17.13	Enhance global macroeconomic stability, including through policy coordination and policy coherence
SDG-17 Target 17.14	Enhance policy coherence for sustainable development
SDG-17 Target 17.15	Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development
SDG-17 Target 17.16	Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries
SDG-17 Target 17.17	Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships
SDG-17 Target 17.18	By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts
SDG-17 Target 17.19	By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries

Table 4. List of the proposed indicators for the SDGs

Name	Description	Category
SDG Indicator 1.1.1	Proportion of the population below the international poverty line, disaggregated by sex, age group, employment status and geographical location (urban/rural)	Statistics
SDG Indicator 1.2.1	Proportion of the population living below the national poverty line, disaggregated by sex and age group	Statistics
SDG Indicator 1.2.2	Proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	Statistics
SDG Indicator 1.3.1	Percentage of the population covered by social protection floors/systems, dissaggregated by sex, and distinguishing children, the unemployed, old-age persons, persons with disabilities, pregnant women/newborns, work injury victims, the poor and the vulnerable	Statistics
SDG Indicator 1.4.1	Proportion of the population living in households with access to basic services	Statistics
SDG Indicator 1.5.1	Number of deaths, missing people, injured, relocated or evacuated due to disasters per 10,000 people	Statistics
SDG Indicator 1.a.1	Percentage of resources allocated by the government directly to poverty reduction programmes	Statistics
SDG Indicator 1.a.2	Spending on essential services (education, health and social protection) as a percentage of total government spending	Statistics
SDG Indicator 1.b.1	Number of national action plans related to multilateral environmental agreements that support accelerated investment in actions that eradicate poverty and sustainably use natural resources	Statistics
SDG Indicator 2.1.1	Prevalence of undernourishment	Statistics

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SDG Indicator 2.1.2	Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)	Statistics
SDG Indicator 2.2.1	Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age	Statistics
SDG Indicator 2.2.2	Prevalence of malnutrition (weight for height >+2 or <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5, disaggregated by type (wasting and overweight)	Statistics
SDG Indicator 2.3.1	Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size	Statistics/Geospatial
SDG Indicator 2.3.2	Total Factor Productivity	Statistics
SDG Indicator 2.4.1	Percentage of agricultural area under sustainable agricultural practices	Statistics/Geospatial
SDG Indicator 2.4.2	Percentage of agricultural households using irrigation systems compared to all agricultural households	Statistics
SDG Indicator 2.5.1	Ex situ crop collections enrichment index	Statistics
SDG Indicator 2.5.2	Percentage of local crops and breeds and their wild relatives, classified as being at risk, not-at-risk or at an unknown level of risk of extinction	Statistics
SDG Indicator 2.a.1	The agriculture orientation index for government expenditures	Statistics
SDG Indicator 2.b.1	Percentage change in import and export tariffs on agricultural products	Statistics
SDG Indicator 2.b.2	Agricultural export subsidies	?
SDG Indicator 2.c.1	Indicator of (food) price anomalies	index
SDG Indicator 3.1.1	Maternal deaths per 100,000 live births	Statistics
SDG Indicator 3.1.2	Proportion of births attended by skilled health personnel	Statistics
SDG Indicator 3.2.1	Under-5 mortality rate (deaths per 1,000 live births)	Statistics
SDG Indicator 3.2.2	Neonatal mortality rate (deaths per 1,000 live births)	Statistics
SDG Indicator 3.3.1	Number of new HIV infections per 1,000 uninfected population (by age group, sex and key populations)	Statistics
SDG Indicator 3.3.2	Tuberculosis incidence per 1,000 persons per year	Statistics
SDG Indicator 3.3.3	Malaria incident cases per 1,000 persons per year	Statistics
SDG Indicator 3.3.4	Number of new hepatitis B infections per 100,000 population in a given year	Statistics
SDG Indicator 3.3.5	Number of people requiring interventions against neglected tropical diseases	Statistics
SDG Indicator 3.4.1	Mortality of cardiovascular disease, cancer, diabetes or chronic respiratory disease	Statistics
SDG Indicator 3.4.2	Suicide mortality rate	Statistics
SDG Indicator 3.5.1	Coverage of treatment interventions (pharmacological, psychosocial and rehabilitation and aftercare services) for substance use disorders	Statistics
SDG Indicator 3.5.2	Harmful use of alcohol, defined according to the national context as alcohol per capita consumption (aged 15 years and older) within a calendar year in litres of pure alcohol	Statistics
SDG Indicator 3.6.1	Number of road traffic fatal injury deaths within 30 days, per 100,000 population (age- standardized)	Statistics
SDG Indicator 3.7.1	Percentage of women of reproductive age (aged 15-49) who have their need for family planning satisfied with modern methods	Statistics
SDG Indicator 3.7.2	Adolescent birth rate (aged 10-14; aged 15-19) per 1,000 women in that age group	Statistics

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SDG Indicator 3.8.1	Coverage of tracer interventions (e.g. child full immunization, antiretroviral therapy, tuberculosis treatment, hypertension treatment, skilled attendant at birth, etc.)	Statistics
SDG Indicator 3.8.2	Fraction of the population protected against catastrophic/impoverishing out-of-pocket health expenditure	Statistics
SDG Indicator 3.9.1	Mortality rate attributed to household and ambient air pollution	Statistic/Earth Observations
SDG Indicator 3.9.2	Mortality rate attributed to hazardous chemicals, water and soil pollution and contamination	Statistic/Earth Observations
SDG Indicator 3.a.1	Age-standardized prevalence of current tobacco use among persons aged 15 years and older	Statistics
SDG Indicator 3.b.1	Proportion of the population with access to affordable medicines and vaccines on a sustainable basis	Statistics
SDG Indicator 3.b.2	Total net official development assistance to the medical research and basic health sectors	Statistics
SDG Indicator 3.c.1	Health worker density and distribution	Statistics/Geospatial
SDG Indicator 3.d.1	Percentage of attributes of 13 core capacities that have been attained at a specific point in time	Statistics
SDG Indicator 4.1.1	Percentage of children/young people: (a) in grades 2/3; (b) at the end of primary; and (c) at the end of lower secondary achieving at least a minimum proficiency level in (i) reading and (ii) mathematics. Disaggregations: sex, location, wealth (and others where data are available)	Statistics
SDG Indicator 4.2.1	Percentage of children under 5 years of age who are developmentally on track in health, learning and psychosocial well-being. Disaggregations: sex, location, wealth (and others where data are available)	Statistics
SDG Indicator 4.2.2	Participation rate in organized learning (one year before the official primary entry age)	Statistics
SDG Indicator 4.3.1	Participation rate of youth and adults in formal and non-formal education and training in the last 12 months	Statistics
SDG Indicator 4.4.1	Percentage of youth/adults with information and communications technology (ICT) skills by type of skill	Statistics
SDG Indicator 4.5.1	Parity indices (female/male, rural/urban, bottom/top wealth quintile and others such as disability status, indigenous people and conflict- affected as data become available) for all indicators on this list that can be disaggregated	Statistics
SDG Indicator 4.6.1	Percentage of population in a given age group achieving at least a fixed level of proficiency in functional (a) literacy and (b) numeracy skills. Disaggregations: sex, location, wealth (and others where data are available)	Statistics
SDG Indicator 4.7.1	Percentage of 15-year-old students enrolled in secondary school demonstrating at least a fixed level of knowledge across a selection of topics in environmental science and geoscience. The exact choice/range of topics will depend on the survey or assessment in which the indicator is collected. Disaggregations: sex and location (and others where data are available)	Statistics
SDG Indicator 4.a.1	Percentage of schools with access to: (a) electricity; (b) the Internet for pedagogical purposes; (c) computers for pedagogical purposes; (d) adapted infrastructure and materials for students with disabilities; (e) single-sex basic sanitation facilities; and (f) basic handwashing facilities (as per the Water, Sanitation and Hygiene for All (WASH) indicator definitions)	Statistics
SDG Indicator 4.b.1	Volume of official development assistance flows for scholarships by sector and type of study	Statistics
SDG Indicator 5.1.1	Whether or not legal frameworks are in place to promote, enforce and monitor equality and non-discrimination on the basis of sex	?

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SDG Indicator 5.2.1	Proportion of ever-partnered women and girls aged 15 years and older subjected to physical, sexual or psychological violence by a current or former intimate partner, in the last 12 months, by form of violence and by age group	Statistics
SDG Indicator 5.2.2	Proportion of women and girls aged 15 years and older subjected to sexual violence by persons other than an intimate partner, in the last 12 months, by age group and place of occurrence	Statistics
SDG Indicator 5.3.1	Percentage of women aged 20-24 who were married or in a union before age 15 and before age 18	Statistics
SDG Indicator 5.3.2	Percentage of girls and women aged 15-49 who have undergone female genital mutilation/cutting, by age group	Statistics
SDG Indicator 5.4.1	Percentage of time spent on unpaid domestic and care work, by sex, age group and location	Statistics
SDG Indicator 5.5.1	Proportion of seats held by women in national parliaments and local governments	Statistics
SDG Indicator 5.5.2	Proportion of women in managerial positions	Statistics
SDG Indicator 5.6.1	Proportion of women aged 15-49 who make their own informed decisions regarding sexual relations, contraceptive use and reproductive health care	Statistics
SDG Indicator 5.6.2	Number of countries with laws and regulations that guarantee women aged 15-49 access to sexual and reproductive health care, information and education	Statistics
SDG Indicator 5.a.1	(a) Percentage of people with ownership or secure rights over agricultural land (out of total agricultural population), by sex; and (b) share of women among owners or rights-bearers of agricultural land, by type of tenure	Statistics
SDG Indicator 5.a.2	Percentage of countries where the legal framework (including customary law) guarantees women's equal rights to land ownership and/or control	Statistics
SDG Indicator 5.b.1	Proportion of individuals who own a mobile telephone, by sex	Statistics
SDG Indicator 5.c.1	Percentage of countries with systems to track and make public allocations for gender equality and women's empowerment	Statistics
SDG Indicator 6.1.1	Percentage of population using safely managed drinking water services	Statistics
SDG Indicator 6.2.1	Percentage of population using safely managed sanitation services, including a hand- washing facility with soap and water	Statistics
SDG Indicator 6.3.1	Percentage of wastewater safely treated	Statistics
SDG Indicator 6.3.2	Percentage of bodies of water with good ambient water quality	Statistics/Earth Observations
SDG Indicator 6.4.1	Percentage change in water use efficiency over time	Statistics/Earth Observations
SDG Indicator 6.4.2	Percentage of total available water resources used, taking environmental water requirements into account (level of water stress)	Statistics/Earth Observations
SDG Indicator 6.5.1	Degree of integrated water resources management implementation (0-100)	Statistics/Earth Observations
SDG Indicator 6.6.1	Percentage of change in the extent of water- related ecosystems over time	Statistics/Earth Observations
SDG Indicator 6.a.1	Amount of water- and sanitation-related official development assistance that is part of a government coordinated spending plan	Statistics/Earth Observations
SDG Indicator 6.b.1	Percentage of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	Statistics
SDG Indicator 7.1.1	Percentage of population with access to electricity	Statistics

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SDG Indicator 7.1.2	Percentage of population with primary reliance on clean fuels and technology	Statistics
SDG Indicator 7.2.1	Renewable energy share in the total final energy consumption	Statistics
SDG Indicator 7.3.1	Energy intensity measured in terms of primary energy and gross domestic product (GDP)	Statistics
SDG Indicator 7.a.1	Mobilized amount of United States dollars per year starting in 2020 accountable towards the $100 billion commitment	Statistics
SDG Indicator 7.b.1	Ratio of value added to net domestic energy use, by industry	Statistics
SDG Indicator 8.1.1	Annual growth rate of real GDP per capita	Statistics
SDG Indicator 8.2.1	Annual growth rate of real GDP per employed person	Statistics
SDG Indicator 8.3.1	Share of informal employment in non-agriculture employment, by sex	Statistics
SDG Indicator 8.4.1	Resource productivity	Statistics
SDG Indicator 8.5.1	Average hourly earnings of female and male employees, by occupation, age group and persons with disabilities	Statistics
SDG Indicator 8.5.2	Unemployment rate, by sex, age group and persons with disabilities	Statistics
SDG Indicator 8.6.1	Percentage of youth (aged 15-24) not in education, employment or training	Statistics
SDG Indicator 8.7.1	Percentage and number of children aged 5-17 engaged in child labour, by sex and age group	Statistics
SDG Indicator 8.8.1	Frequency rates of fatal and non-fatal occupational injuries, by sex and migrant status	Statistics
SDG Indicator 8.8.2	Number of International Labour Organization (ILO) Conventions ratified, by type of convention	Statistics
SDG Indicator 8.9.1	Tourism direct GDP (as a percentage of total GDP and in growth rate); and number of jobs in tourism industries (as a percentage of total jobs and growth rate of jobs, by sex)	Statistics
SDG Indicator 8.10.1	Number of commercial bank branches and automated teller machines (ATMs) per 100,000 adults	Statistics
SDG Indicator 8.10.2	Percentage of adults (15 years and older) with an account at a bank or other financial institution or with a mobile money service provider	Statistics
SDG Indicator 8.a.1	Aid for Trade commitments and disbursements	Statistics
SDG Indicator 8.b.1	Total government spending in social protection and employment programmes as a percentage of the national budgets and GDP	Statistics
SDG Indicator 9.1.1	Share of the rural population who live within 2 km of an all-season road	Statistics
SDG Indicator 9.1.2	Passenger and freight volumes, by mode of transport	Statistics
SDG Indicator 9.2.1	Manufacturing value added as a percentage of GDP and per capita	Statistics
SDG Indicator 9.2.2	Manufacturing employment as a percentage of total employment	Statistics
SDG Indicator 9.3.1	Percentage share of small-scale industries in total industry value added	Statistics
SDG Indicator 9.3.2	Percentage of small-scale industries with a loan or line of credit	Statistics
SDG Indicator 9.4.1	CO_2 emission per unit of value added	Statistics/Earth Observations
SDG Indicator 9.5.1	Research and development expenditure as a percentage of GDP	Statistics
SDG Indicator 9.5.2	Researchers (in full-time equivalent) per million inhabitants	Statistics/Geospatial

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SDG Indicator 9.a.1	Total official international support (official development assistance plus other official flows) to infrastructure	Statistics
SDG Indicator 9.b.1	Percentage of medium and high-tech industry value added in total value added	Statistics
SDG Indicator 9.c.1	Percentage of population covered by a mobile network, by technology	Statistics
SDG Indicator 10.1.1	Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population	Statistics
SDG Indicator 10.2.1	Proportion of people living below 50 per cent of median income, disaggregated by age group, sex and persons with disabilities	Statistics
SDG Indicator 10.3.1	Percentage of the population reporting having personally felt discriminated against or harassed within the last 12 months on the basis of a ground of discrimination prohibited under international human rights law	Statistics
SDG Indicator 10.4.1	Labour share of GDP, comprising wages and social protection transfers	Statistics
SDG Indicator 10.5.1	Adoption of a financial transaction tax (Tobin tax) at the global level	Statistics
SDG Indicator 10.6.1	Percentage of members and voting rights of developing countries in international organizations	Statistics
SDG Indicator 10.7.1	Recruitment cost borne by employee as a percentage of yearly income earned in country of destination	Statistics
SDG Indicator 10.7.2	International Migration Policy Index	Index
SDG Indicator 10.7.3	Number of detected and non-detected victims of human trafficking per 100,000 population, by sex, age group and form of exploitation	Statistics
SDG Indicator 10.a.1	Share of tariff lines applied to imports from least developed countries/developing countries with zero-tariff	Statistics
SDG Indicator 10.b.1	Total resource flows for development, disaggregated by recipient and donor countries and type of flow (e.g. official development assistance, foreign direct investment and other flows)	Statistics
SDG Indicator 10.b.1	Remittance costs as a percentage of the amount remitted	Statistics
SDG Indicator 11.1.1	Proportion of urban population living in slums, informal settlements or inadequate housing	Statistics/Geospatial
SDG Indicator 11.2.1	Proportion of the population that has convenient access to public transport, disaggregated by age group, sex and persons with disabilities	Statistics
SDG Indicator 11.3.1	Ratio of land consumption rate to population growth rate	Statistics/Geospatial
SDG Indicator 11.3.2	Percentage of cities with a direct participation structure of civil society in urban planning and management which operate regularly and democratically	Statistics
SDG Indicator 11.4.1	Share of national (or municipal) budget which is dedicated to the preservation, protection and conservation of national cultural natural heritage, including World Heritage sites	Statistics
SDG Indicator 11.5.1	Number of deaths, missing people, injured, relocated or evacuated due to disasters per 100,000 people	Statistics
SDG Indicator 11.6.1	Percentage of urban solid waste regularly collected and with adequate final discharge with regard to the total waste generated by the city	Statistics
SDG Indicator 11.6.2	Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)	Statistics/Earth Observations

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SDG Indicator 11.7.1	The average share of the built-up area of cities that is open space for public use for all, disaggregated by age group, sex and persons with disabilities	Statistics
SDG Indicator 11.7.2	Proportion of women subjected to physical or sexual harassment, by perpetrator and place of occurrence (last 12 months)	Statistics
SDG Indicator 11.a.1	Cities with more than 100,000 inhabitants that implement urban and regional development plans integrating population projections and resource needs	Statistics
SDG Indicator 11.b.1	Percentage of cities that are implementing risk reduction and resilience strategies aligned with accepted international frameworks (such as the successor to the Hyogo Framework for Action 2005- 2015 on disaster risk reduction) that include vulnerable and marginalized groups in their design, implementation and monitoring	Statistics
SDG Indicator 11.c.1	Percentage of financial support that is allocated to the construction and retrofitting of sustainable, resilient and resource-efficient buildings	Statistics
SDG Indicator 12.1.1	Number of countries with sustainable consumption and production (SCP) national action plans or SCP mainstreamed as a priority or target into national policies	Statistics
SDG Indicator 12.2.1	Material footprint and material footprint per capita	Statistics
SDG Indicator 12.3.1	Global food loss index	Index
SDG Indicator 12.4.1	Number of parties to international multilateral environmental agreements on hazardous and other chemicals and waste that meet their commitments and obligations in transmitting information as required by each relevant agreement	Statistics
SDG Indicator 12.4.2	Treatment of waste, generation of hazardous waste, hazardous waste management, by type of treatment	Earth Observations
SDG Indicator 12.5.1	National recycling rate, tons of material recycled	Statistics
SDG Indicator 12.6.1	Number of companies publishing sustainability reports	Statistics
SDG Indicator 12.7.1	Number of countries implementing sustainable public procurement policies and action plans	Statistics
SDG Indicator 12.8.1	Percentage of educational institutions with formal and informal education curricula on sustainable development and lifestyle topics	Statistics
SDG Indicator 12.8.a	Number of qualified green patent applications over total	Statistics
SDG Indicator 12.8.b	Residual flows generated as a result of tourism; direct GDP	Statistics
SDG Indicator 12.8.c	Amount of fossil-fuel subsidies per unit of GDP (production and consumption) and as a proportion of total national expenditure on fossil fuels	Statistics
SDG Indicator 13.1.1	Number of deaths, missing people, injured, relocated or evacuated due to disasters per 100,000 people	Statistics
SDG Indicator 13.2.1	Number of countries that have formally communicated the establishment of integrated low- carbon, climate-resilient, disaster risk reduction development strategies (e.g. a national adaptation plan process, national policies and measures to promote the transition to environmentally friendly substances and technologies)	Statistics
SDG Indicator 13.3.1	Number of countries that have integrated mitigation, adaptation, impact reduction and early warning into primary, secondary and tertiary curricula	Statistics
SDG Indicator 13.a.1	Mobilized amount of United States dollars per year starting in 2020 accountable towards the $100 billion commitment	Statistics

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SDG Indicator 13.b.1	Number of least developed countries and small island developing States that are receiving specialized support for mechanisms for raising capacities for effective climate change-related planning and management, including focusing on women, youth, local and marginalized communities	Statistics
SDG Indicator 14.1.1	Nitrogen use efficiency composite indicator	Earth Observation
SDG Indicator 14.2.1	Percentage of coastal and marine development with formulated or implemented integrated coastal management/maritime spatial planning plans (that are harmonized where applicable), based on an ecosystem approach, that builds resilient human communities and ecosystems and provides for equitable benefit sharing and decent work	Statistics
SDG Indicator 14.3.1	Average marine acidity (pH) measured at agreed suite of representative sampling stations	Statistics/Earth Observations
SDG Indicator 14.4.1	Proportion of fish stocks within biologically sustainable levels	Statistics
SDG Indicator 14.5.1	Coverage of protected areas in relation to marine areas	Earth Observations
SDG Indicator 14.6.1	Dollar value of negative fishery subsidies against 2015 baseline	Statistics
SDG Indicator 14.7.1	Fisheries as a percentage of GDP	Statistics
SDG Indicator 14.a.1	Budget allocation to research in the field of marine technology as a percentage of total budget for research	Statistics
SDG Indicator 14.b.1	Proportion of national fishery production by country that are catches by small-medium fishery businesses or Progress by countries in adopting and implementing a legal/regulatory/policy/institutional framework which recognizes and protects access rights for small-scale fisheries	Statistics
SDG Indicator 14.c.1	Number of countries implementing either legally or programmatically the provisions set out in regional seas protocols and ratification and implementation of the ILO maritime and fisheries conventions	Statistics
SDG Indicator 15.1.1	Forest area as a percentage of total land area	Statistics/Geospatial
SDG Indicator 15.2.1	Forest cover under sustainable forest management	Statistics/Geospatial
SDG Indicator 15.2.2	Net permanent forest loss	Statistics/Geospatial
SDG Indicator 15.3.1	Percentage of land that is degraded over total land area	Statistics/Geospatial
SDG Indicator 15.4.1	Coverage by protected areas of important sites for mountain biodiversity	Statistics/Geospatial
SDG Indicator 15.4.2	Mountain Green Cover Index	Index
SDG Indicator 15.5.1	Red List Index	Index
SDG Indicator 15.6.1	Number of permits or their equivalents made available to the Access and Benefit-sharing Clearing- House established under the Nagoya Protocol on Access and Benefit-sharing and number of standard material transfer agreements, as communicated to the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture	Statistics
SDG Indicator 15.7.1	Red List Index for species in trade	Index
SDG Indicator 15.7.2	Proportion of detected trade in wildlife and wildlife products that is illegal	Statistics
SDG Indicator 15.8.1	Adoption of national legislation relevant to the prevention or control of invasive alien species	Statistics/Policy
SDG Indicator 15.9.1	Number of national development plans and processes integrating biodiversity and ecosystem services values	Statistics/Earth Observations
SDG Indicator 15.a.1	Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems	Statistics/Policy

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SDG Indicator 15.b.1	Forestry official development assistance and forestry foreign direct investment	Statistics/Policy
SDG Indicator 15.c.1	Proportion of detected trade in wildlife and wildlife products that is illegal	Statistics
SDG Indicator 16.1.1	Number of victims of intentional homicide per 100,000 population, by age group and sex	Statistics
SDG Indicator 16.1.2	Conflict-related deaths per 100,000 population (disaggregated by age group, sex and cause)	Statistics
SDG Indicator 16.1.3	Percentage of the population subjected to physical, psychological or sexual violence in the previous 12 months	Statistics
SDG Indicator 16.1.4	Proportion of people that feel safe walking alone around the area they live	Statistics
SDG Indicator 16.2.1	Percentage of children aged 1-17 who experienced any physical punishment and/or psychological aggression by caregivers in the past month	Statistics
SDG Indicator 16.2.2	Number of victims of human trafficking per 100,000 population, by sex, age group and form of exploitation	Statistics
SDG Indicator 16.2.3	Percentage of young women and men aged 18-24 who experienced sexual violence by age 18	Statistics
SDG Indicator 16.3.1	Percentage of victims of violence in the previous 12 months who reported their victimization to competent authorities or other officially recognized conflict resolution mechanisms (also called crime reporting rate)	Statistics
SDG Indicator 16.3.2	Unsentenced detainees as a percentage of overall prison population	Statistics
SDG Indicator 16.4.1	Total value of inward and outward illicit financial flows (in current United States dollars)	Statistics
SDG Indicator 16.4.2	Percentage of seized small arms and light weapons that are recorded and traced, in accordance with international standards and legal instruments	Statistics
SDG Indicator 16.5.1	Percentage of persons who had at least one contact with a public official, who paid a bribe to a public official, or were asked for a bribe by these public officials, in the previous 12 months, disaggregated by age group, sex, region and population group	Statistics
SDG Indicator 16.6.1	Primary government expenditures as a percentage of original approved budget, disaggregated by sector (or by budget codes or similar)	Statistics
SDG Indicator 16.6.2	Proportion of the population satisfied with their last experience of public services	Statistics
SDG Indicator 16.7.1	Proportions of positions (by age group, sex, persons with disabilities and population groups) in public institutions (national and local legislatures, public service, and judiciary) compared to national distributions	Statistics
SDG Indicator 16.7.2	Proportion of countries that address young people's multisectoral needs within their national development plans and poverty reduction strategies	Statistics
SDG Indicator 16.8.1	Percentage of members and voting rights of developing countries in international organizations	Statistics
SDG Indicator 16.9.1	Percentage of children under 5 whose births have been registered with a civil authority, disaggregated by age	Statistics
SDG Indicator 16.10.1	Number of verified cases of killing, kidnapping, enforced disappearance, arbitrary detention and torture of journalists, associated media personnel, trade unionists and human rights advocates in the previous 12 months	Statistics

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SDG Indicator 16.a.1	Percentage of victims who report physical and/or sexual crime to law enforcement agencies in the previous 12 months, disaggregated by age group, sex, region and population group	Statistics
SDG Indicator 16.b.1	Percentage of the population reporting having personally felt discriminated against or harassed in the previous 12 months on the basis of a ground of discrimination prohibited under international human rights law, disaggregated by age group and sex	Statistics
SDG Indicator 17.1.1	Total government revenue (by source) as a percentage of GDP	Statistics
SDG Indicator 17.1.2	Proportion of domestic budget funded by domestic taxes	Statistics
SDG Indicator 17.2.1	Net official development assistance, total and to least developed countries, as a percentage of OECD/Development Assistance Committee donors' gross national income	Statistics
SDG Indicator 17.3.1	Foreign direct investments (FDI) as a percentage of total FDI and official development assistance	Statistics/Policy
SDG Indicator 17.3.2	Volume of remittances (in United States dollars) as a percentage of total GDP	Statistics
SDG Indicator 17.4.1	Debt service as a percentage of exports of goods and services	Statistics
SDG Indicator 17.5.1	Number of national and investment policy reforms adopted that incorporate sustainable development objectives or safeguards by country	Statistics/Policy
SDG Indicator 17.6.1	Access to patent information and use of the international intellectual property system	Policy
SDG Indicator 17.6.2	Fixed Internet broadband subscriptions, by speed	Statistics
SDG Indicator 17.7.1	Total amount of approved funding for developing countries to promote the development, transfer, dissemination and diffusion of environmentally sound technologies	Statistics
SDG Indicator 17.8.1	Proportion of individuals using the Internet	Statistics
SDG Indicator 17.9.1	The dollar value of financial and technical assistance, including through North-South, South- South and triangular cooperation, committed to developing countries' designing and implementing a holistic policy mix that aims at sustainable development in three dimensions (including elements such as reducing inequality within a country and governance)	Statistics
SDG Indicator 17.10.1	Worldwide weighted tariff-average	Statistics
SDG Indicator 17.11.1	Developing countries' and least developed countries' share of global exports	Statistics
SDG Indicator 17.12.1	Average tariffs faced by developing countries, least developed countries and small island developing States	Statistics
SDG Indicator 17.13.1	GDP	Statistics
SDG Indicator 17.14.1	Number of countries that have ratified and implemented relevant international instruments under the International Maritime Organization (safety, security, environmental protection, civil liability, and compensation and insurance) and the fundamental conventions and recommendations of ILO, and that have adopted carbon pricing mechanisms	Statistics
SDG Indicator 17.15.1	Numbers of constraints that are embodied in official development assistance or loan agreements, international investment agreements, regional trade agreements, etc.	Statistics

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SDG Indicator 17.16.1	Mutual accountability among development cooperation actors is strengthened through inclusive reviews	Statistics
SDG Indicator 17.17.1	Amount of United States dollars committed to public-private and civil society partnerships	Statistics
SDG Indicator 17.18.1	Proportion of sustainable development indicators produced at the national level with full disaggregation when relevant to the target, in accordance with the Fundamental Principles of Official Statistics	Statistics
SDG Indicator 17.18.2	Number of countries that have national statistical legislation that complies with the Fundamental Principles of Official Statistics	Statistics
SDG Indicator 17.19.1	Dollar value of all resources made available to strengthen statistical capacity in developing countries	Statistics
SDG Indicator 17.19.2	Inclusive Wealth Index	Index

The question is how many of this indicators can be measured using Geospatial information and which subset of them can be measured with Earth observation using the EV as in instrument.

To respond to the question of what SDG can be described using EO, we will cite again Marianne Fay (the chief economist for climate change at the World Bank) in the presentation to the Open Plenary of the Technical Committee of the OGC celebrated in Washington DC on March the 7th 2016. She listed the following SDGs and the corresponding Geospatial information that can be used in indicators (see Table 5).

Table 5. List of the seventeen SDG and how accurate and reliable geospatial information contribute to theSDGs

Name	Description	
SDG 1	End poverty in all its forms everywhere	Poverty maps Proposed indicator on losses of natural disasters
SDG 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Crop yield estimates, soil characteristics, crop water productivity, irrigation, vulnerability to flood risk Nutritional status maps.
SDG 3	Ensure healthy lives and promote well-being for all at all ages	Health facility locations Disease incidence and risk patterns
SDG 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	School facilities and access Literacy and educational achievement distribution
SDG 6	Ensure availability and sustainable management of water and sanitation for all	Access to improved water and sanitation sources Changing distributions of water resources
SDG 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Roads, Public transportation network Mobility maps and access to employment
SDG 11	Make cities and human settlements inclusive, safe, resilient and sustainable	Access to public green space Sub-standards housing and urban from classification
SDG 12	Ensure sustainable consumption and production patterns	Energy productivity Pollution sources
SDG 13	Take urgent action to combat climate change and its impacts*	CO2 emissions Exposure to extreme storms and droughts Disaster and risk mapping
SDG 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Coastal/Marine protected areas Harmful algal blooms Eutrophication

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SDG 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Land cover, land degradation, biodiversity Protected areas
SDG 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Social and armed conflict Crime and conflict mapping Refugee and IDP movement

Marianne Fay also enumerates that EO is currently used in the World Bank for water and forestry and agriculture (crop productivity) indicators. However, she complained that EO is not used at its full potential in the World Bank due to the lack of architecture to exploit it. Marianne ended this part of her speech with this significant remark: "Remote sensing and satellite imagery are going to be the key in the second data revolution."

As exposed before, the UN approved 17 SDGs that have recently been articulated in 169 targets and 240 indicators to measure progress towards these targets[1]. The UN has also release 17 documents (referred to as *metadata documents*; one for each SGD) that detail the reports of international agencies consulted by the UN on how the indicators will be measured in practice[2]. This was previously done with the past draft of the SDGs proposed by the Sustainable Development Solution Network.

After carefully examination of these 17 documents, we have concluded that 231 of the 240 indicators can be calculated with socio-economic data, only 30 can be extracted with the combination of socio-economic data and Earth observation (in-situ, airborne or remote sensing) and only 9 indicators by Earth observation alone. In one document, GEOSS is specifically mentioned for the Goal 6: *Ensure availability and sustainable management of water and sanitation for all*. This is considerably lower than in the previous version of the indicators for the old collection of the SDGs candidates released in February 14th, 2014 by the Sustainable Development Solution Network[3]. One of the reasons for this is the way Climate Change is considered in Goal 13: *Take urgent action to combat climate change and its impacts*. This goal has to take into account that the United Nations Framework Convention on Climate Change (UNFCCC) is the primary international, intergovernmental forum for negotiating the global response to climate change and also the overlap with the IPPC. The approach taken to Goal 13 is avoiding consideration of climate change monitoring and rather focusing on monitoring the impact of governmental decisions and policies for mitigation, adaptation, impact reduction and early warning for climate change. This moves Goal 13 and its targets and indicators away from the Earth observation domain. As discussed in Section 3, there is a need for a complementary set of indicators for sustainable development that links environmental changes to an overall sustainability metrics. For these indicators, EOs will be crucial.

In practice, ConnectinGEO considers that following the interpretation of the indicators exposed in the 17 *metadata documents* mentioned above and with the current status of the EV definition, EO can be used in the indicators for the following SDGs and targets listed below in Table 6.

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[1] http://unstats.un.org/unsd/statcom/47th-session/documents/2016-2-IAEG-SDGs-E-Revised.pdf

[2] http://unstats.un.org/sdgs/iaeg-sdgs/metadata-compilation/

[3] http://unsdsn.org/wp-content/uploads/2014/02/140214-SDSN-indicator-report-DRAFT-for-consultation.pdf

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Table 6. SDG measurable by EO linked to EV (as listed in Table 1)

- **Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture**
  - Target 2.3: By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources a
    - *Indicator 2.3.1: Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size.*
      - *Related proposed EV: Crop Area | Crop Yield (current and forecast) | Crop Management and agricultural practices*
- **Goal 3: Ensure healthy lives and promote well-being for all at all ages**
  - Target 3.3: By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases
    - *Indicator 3.3.3: Malaria incidence per 1,000 population.*
      - *Related proposed EV: Short term forecasting of communicable diseases | Precipitation | Temperature*
  - Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination against neglected tropical diseases
    - *Indicator 3.9.1: Mortality rate attributed to household and ambient air pollution*
      - *Related proposed EV: Carbon dioxide | Methane, and other long-lived greenhouse gases | Ozone and Aerosol, supported by their precursors | Water quality | Water us/demand (agriculture, hydrology, energy, urbanization) | Soil moisture | Soil carbon*
- **Goal 6: Ensure availability and sustainable management of water and sanitation for all**
  - Target 6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
    - *Indicator 6.3.2 Proportion of bodies of water with good ambient water quality*
      - *Related proposed EV: Water quality | Nutrients | Groundwater | Runoff/streamflow/river discharge | Water us/demand (agriculture, hydrology, energy, urbanization) | Lakes/reservoir levels and aquifer volumetric change*
  - Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
    - *Indicator 6.4.1 Change in water use efficiency over time*
      - *Related proposed EV: Water us/demand (agriculture, hydrology, energy, urbanization) | Lakes/reservoir levels*

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and aquifer volumetric change | Groundwater | Runoff/streamflow/river discharge

- ▪ *Indicator 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources*
  - - *Related proposed EV: Water us/demand (agriculture, hydrology, energy, urbanization) | Lakes/reservoir levels and aquifer volumetric change | Groundwater | Runoff/streamflow/river discharge | Glaciers/ice sheets | Snow cover | Evaporation and evapotranspiration*
- o Target 6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
  - ▪ *Indicator 6.6.1 Change in the extent of water-related ecosystems over time*
    - - *Related proposed EV: Lakes/reservoir levels and aquifer volumetric change | Groundwater | Runoff/streamflow/river discharge | Glaciers/ice sheets | Snow cover | Evaporation and evapotranspiration | Mangrove Area | Seagrass Area | Species populations (Species distribution, Population abundance, Population structure by age/size class) | Community composition (Taxonomic diversity, Species interactions) | Ecosystem structure (Habitat structure, Ecosys. extent and fragmentation, Ecosys. composition by functional type) | Land cover (including vegetation type) | FAPAR*

- **Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all**
  - o Target 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix
    - ▪ *Indicator 7.2.1 Renewable energy share in the total final energy consumption*
      - - *Related proposed EV: Ocean (fixed and floating offshore wind, wave, tidal, currents, OTEC)*
- **Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation**
  - o Target 9.4: By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in
    - ▪ *Indicator 9.4.1 CO2 emission per unit of value added*
      - - *Related proposed EV: Carbon dioxide | Methane, and other long-lived greenhouse gases*
  - o Target 9.c: Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020
    - ▪ *Indicator 9.c.1 Proportion of population covered by a mobile network, by technology*
      - - *Related proposed EV: not identified; need for new EVs*
- **Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable**

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o Target 11.3: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

  ▪ *Indicator 11.3.1 Ratio of land consumption rate to population growth rate*

    - *Related proposed EV: Land use, Land cover (including urbanization, hydrology, grid description)*

  ▪ *Indicator 11.3.2 Percentage of cities with a direct participation structure of civil society in urban planning and management which operate regularly and democratically*

    - *Related proposed EV: not identified; need for new EVs*

o Target 11.4: Strengthen efforts to protect and safeguard the world's cultural and natural heritage

  ▪ *Indicator 11.4.1 Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed, World Heritage Centre designation), level of government (national, regional, and local/municipal), type of expenditure (operating expenditure/investment) and type of private funding (donations in kind, private non-profit sector, sponsorship)*

    - *Related proposed EV: not identified; need for new EVs*

o Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

  ▪ *Indicator 11.5.1 Number of deaths, missing and persons affected by disaster per 100,000 people*

    - *Related proposed EV: not identified; need for new EVs*

  ▪ *Indicator 11.5.2 Direct disaster economic loss in relation to global GDP, including disaster damage to critical infrastructure and disruption of basic services*

    - *Related proposed EV: not identified; need for new EVs*

o Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

  ▪ *Indicator 11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)*

    - *Related proposed EV: Carbon dioxide | Methane, and other long-lived greenhouse gases | Ozone and Aerosol, supported by their precursors*

o Target 11.7: By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

  ▪ *Indicator 11.7.1 Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities*

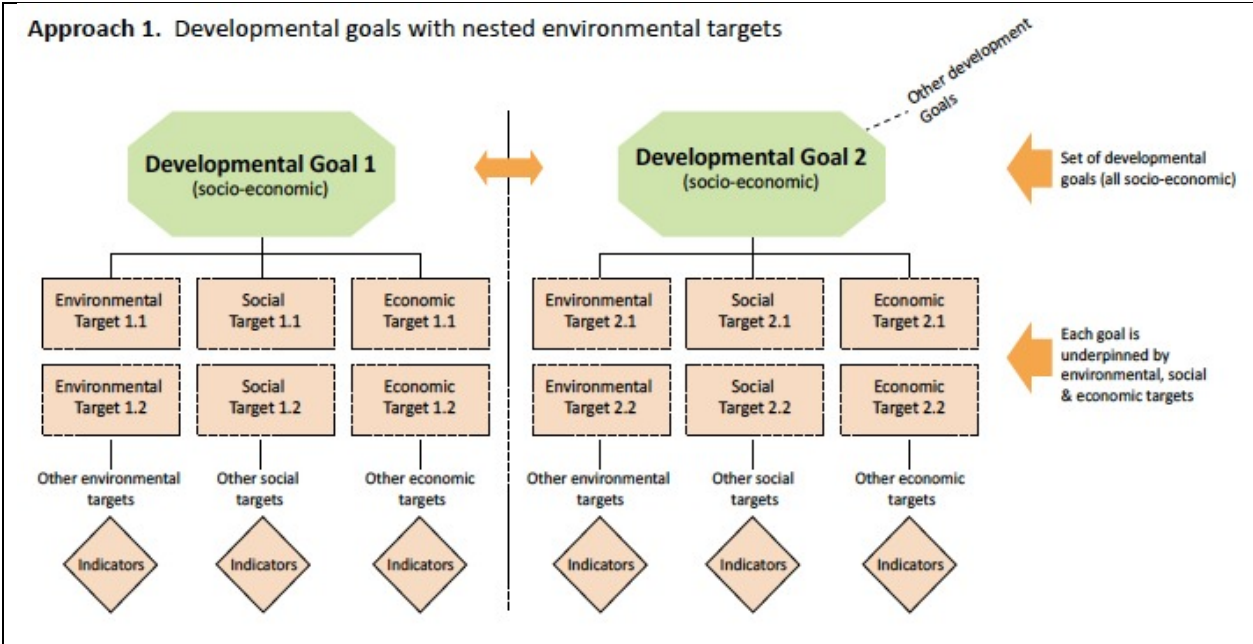   - *Related proposed EV: Land use, Land cover (including urbanization, hydrology, grid description)*

- **Goal 12: Ensure sustainable consumption and production patterns**

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- o Target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources
  - ▪ *Indicator 12.2.1 Material footprint (MF) and MF per capita, per GDP*
    - *Related proposed EV: Land use, Land cover (including urbanization, hydrology, grid description) | Crop Area | Crop Management and agricultural practices*
- o Target 12.3: By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including postharvest losses
  - ▪ *Indicator 12.3.1 Global food loss index*
    - *Related proposed EV: Famine early warning | Crop Type | Crop Management and agricultural practices*
- **Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development**
  - o Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from landbased activities, including marine debris and nutrient pollution
    - ▪ *Indicator 14.1.1 Index of Coastal Eutrophication (ICEP) and Floating Plastic debris Density*
      - *Related proposed EV: Ocean colour | Ocean acidity | Species populations (Species distribution, Population abundance, Population structure by age/size class) | Community composition (Taxonomic diversity, Species interactions) | Ecosystem structure (Habitat structure, Ecosys. extent and fragmentation, Ecosys. composition by functional type)*
  - o Target 14.3: Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels
    - ▪ *Indicator 14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations*
      - *Related proposed EV: Ocean acidity*
  - o Target 14.4: By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at l
    - ▪ *Indicator 14.4.1 Proportion of fish stocks within biologically sustainable levels*
      - *Related proposed EV: Species populations (Species distribution, Population abundance, Population structure by age/size class)*
- **Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss**
  - o Target 15.1: By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements
    - ▪ *Indicator 15.1.1 Forest area as a proportion of total land area*

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- *Related proposed EV: Community composition
  (Taxonomic diversity, Species interactions) | Ecosystem
  structure (Habitat structure, Ecosys. extent and
  fragmentation, Ecosys. composition by functional type) |
  Ecosystem function (Net primary productivity, Secondary
  productivity, Nutrient retention, Disturbance regime) |
  FAPAR | LAI | Above-ground biomass | Land cover
  (including vegetation type)*
- *Indicator 15.1.2 Proportion of important sites for terrestrial and
  freshwater biodiversity that are covered by protected areas, by
  ecosystem type*
  - *Related proposed EV: Land cover (including vegetation
    type) | Ecosystem structure (Habitat structure, Ecosys.
    extent and fragmentation, Ecosys. composition by
    functional type)*
- Target 15.2: By 2020, promote the implementation of sustainable
  management of all types of forests, halt deforestation, restore degraded
  forests and substantially increase afforestation and reforestation globally
  - *Indicator 15.2.1 Progress towards sustainable forest
    management*
    - *Related proposed EV: Land cover (including vegetation
      type) | Ecosystem structure (Habitat structure, Ecosys.
      extent and fragmentation, Ecosys. composition by
      functional type) | Ecosystem function (Net primary
      productivity, Secondary productivity, Nutrient retention,
      Disturbance regime) | FAPAR | LAI*
- Target 15.3: By 2030, combat desertification, restore degraded land and
  soil, including land affected by desertification, drought and floods, and
  strive to achieve a land degradation-neutral world
  - *Indicator 15.3.1 Proportion of land that is degraded over total land
    area*
    - *Related proposed EV: Land cover (including vegetation
      type) | Ecosystem structure (Habitat structure, Ecosys.
      extent and fragmentation, Ecosys. composition by
      functional type)*
- Target 15.4: By 2030, ensure the conservation of mountain ecosystems,
  including their biodiversity, in order to enhance their capacity to provide
  benefits that are essential for sustainable development
  - *Indicator 15.4.1 Coverage by protected areas of important sites
    for mountain biodiversity*
    - *Related proposed EV: Land use, Land cover (including
      urbanization, hydrology, grid description)*
  - *15.4.2 Mountain Green Cover Index*
    - *Related proposed EV: FAPAR, LAI*
- Target 15.5: Take urgent and significant action to reduce the
  degradation of natural habitats, halt the loss of biodiversity and, by 2020,
  protect and prevent the extinction of threatened species
  - *Indicator 15.5.1 Red List Index*
    - *Related proposed EV: Species populations (Species
      distribution, Population abundance, Population structure by*

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age/size class) | Species traits (Phenology, Body mass, Natal dispersion distance, Migratory behavior, Demographic traits, Physiological traits)

- o Target 15.9: By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts
    - *Indicator 15.9.1 Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020*
        - *Related proposed EV: Ecosystem function (Net primary productivity, Secondary productivity, Nutrient retention, Disturbance regime) | Ecosystem structure (Habitat structure, Ecosys. extent and fragmentation, Ecosys. composition by functional type) | Species populations (Species distribution, Population abundance, Population structure by age/size class) | Species traits (Phenology, Body mass, Natal dispersion distance, Migratory behavior, Demographic traits, Physiological traits) | Community composition (Taxonomic diversity, Species interactions)*
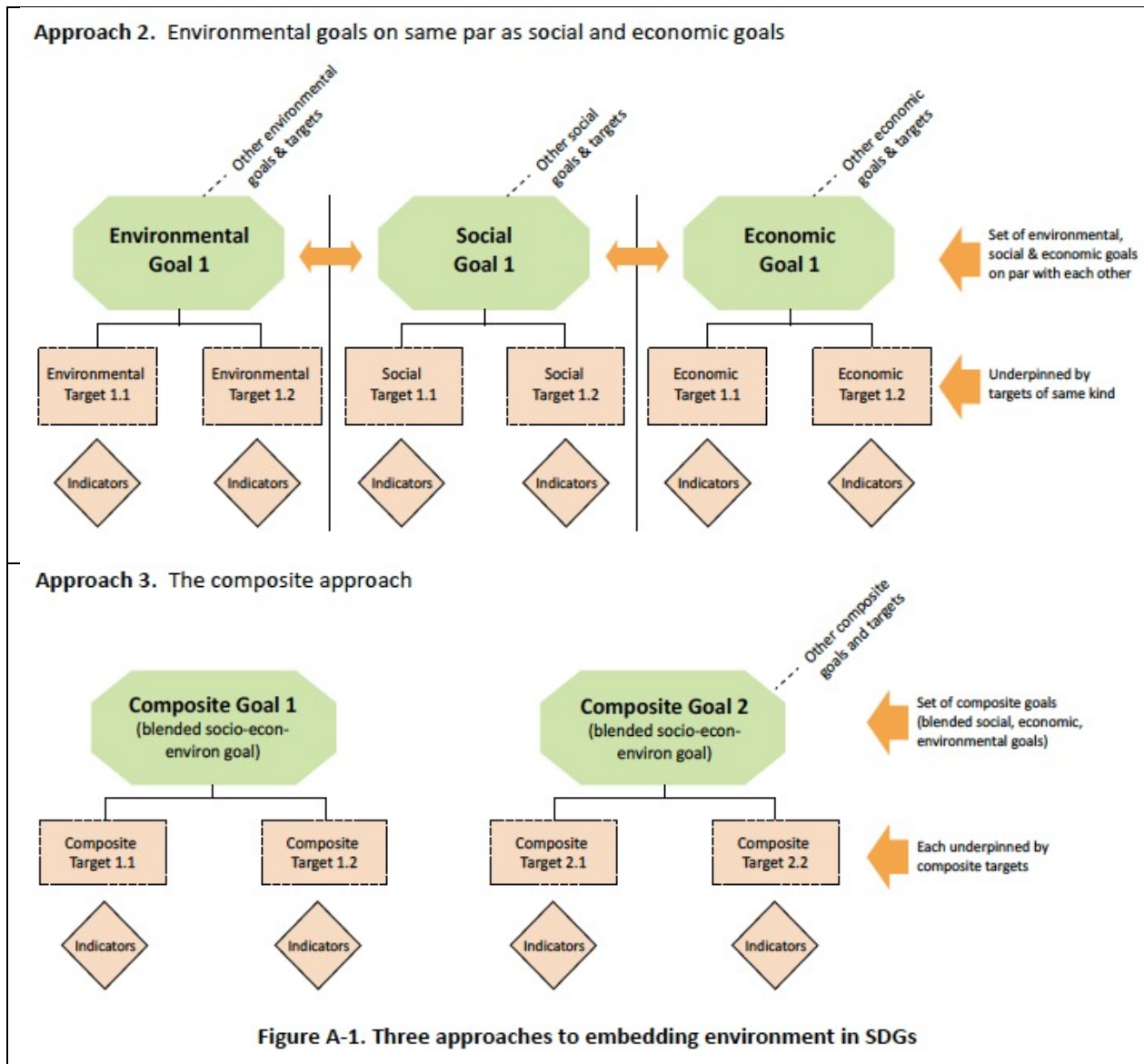
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Figure 4. Three approach to embedding environment into the SDGs. From UNEP (2013)

4. Connecting SDGs to the EVs and to actual EO measurements

4.1.   Introduction

As a prove of concept of the ConnectinGEO methodology and the goal-based approach to EVs, in this section we selected some examples of Essential Variables (EVs) that can be used as indicator for the achievement of a SDG, and we explain how they can be obtained by analysing EO data, as direct measurements or as a proxy. In-situ data are always needed for calibrating/validating the output products. In some cases, the integration of in-situ data is a component of the EV process evaluation. Such integration is mainly based on prior-expert knowledge.

The focus is on the Essential Biodiversity Variables (EBVs) that are also used in Ecosystems such as Species Distribution, Habitat Structure and Soil Moisture.

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4.2.   SDG 15 related EBV: Biodiversity: Species Distribution

The **EBV candidate: species distribution** can be linked to some targets and indicators of the SDG 15. These targets and indicators are:

Table 7. EBV candidate "species distribution" linked to SDG

Goals and targets (from the 2030 Agenda)	Indicators
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	
15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and dry lands, in line with obligations under international agreements	15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type
15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	15.5.1 Red List Index
15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	15.9.1 Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020

4.2.1. Species Population **class. EBV candidate:** *species distribution.*

Remote-sensing technologies can deliver data on habitat quantity (amount, configuration) and quality (e.g., structure, distribution of individual plant species, habitat types and/or communities, persistence across a range of spatial resolutions and temporal frequencies (Wulder et al., 2004). Species population is one class of Essential Biodiversity Variables [Pereira et al., 2013]. It includes species distribution, species abundance and population structure by age/size candidate EBVs. In times of increasing habitat loss, species distribution models (SDM) have become of main interest for conservation purposes. Such predictions can be obtained by using as input: species record from museum collections or in-field campaigns, combined with climate and/or land cover data. Land Cover (LC) data can be obtained at different scale from multiple Earth Observation sensors, depending on the required grain of the analysis. However, according to [Cord and Rodder, 2011], the assimilation of LC from satellite sensors into models seems still at the beginning since most of previous papers used a restricted number of categorical variables, due to both the loss of the inherent data variance during the conversion of spectral signature into categorical data and classification errors. At coarse resolution, Cord and Rodder, (2011) demonstrated that: *a)* when pure bioclimatic data alone are used for species distribution (and mainly for species in fragmented habitats) the predictions are less detailed, and *b)* the use of only LC data tends to over predict the species' range. Then, they obtained improved results by combining two continuous standard products, i.e. the Enhanced Vegetation Index (EVI) and the Land Surface Temperature (LST) from multi-seasonal MODIS-Terra imagery with bioclimatic data. In their analysis, the authors used the pairwise Paerson's correlation coefficients among all possible pairs of EO products and bioclimatic data and the Maxent-version 3.3.2 algorithm (Phillips et al. 2006) for estimating species probability distributions for 8 different taxa. As results, they proved that: *a)* differences in the *seasonality* of these products can improve species distribution

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modelling, and *b)* the application of *continuous remote-sensing variables* is superior to categorical land cover data. The authors affirm that, phenological characteristics based on satellite observations can easily be adapted to the specific ecology of the study species and fill also the gap related to the lack of updated and high-quality (with error measurements) land cover information worldwide. Consequently, recent Sentinel-2 mission can offer the opportunity to further improve the predictions of such models.

At Very High Resolution, WorldView2 were analysed in the framework of the FP7-Space BIO_SOS project (www.biosos.eu) for correlating in-field species distribution and habitat quality data from different taxa (e.g., plants, insects, birds) with EO continuous variables, such as the Normalised DifferenceVegetation Index and context-sensitive features (e.g., texture measurements from the Grey Co-occurrence Matrix). The results in   (Mairota et. al. 2015a; 2015b) demonstrate the potential of VHR-EO for habitat modelling and highlight the importance of identifying the appropriate scale of analysis for specific taxonomic groups of interest. Further, textural features are important in the modelling of functional group-specific indices which represent Biodiversity Surrogates in high conservation value habitat types.

Input from satellite EO data:
a) At coarse resolution, multi-seasonal Enhanced Vegetation Index (EVI) and Land Surface Temperature (LST) from Low resolution MODIS-Terra data.
b) At VHR, multi-seasonal WorldView2 images.
Input from in-situ data: bioclimatic data.

4.3.   SDG 6 and SDG 15 related EBV: Habitat structure

The **EBV candidate: habitat structure** can be linked to some targets and indicators of the SDG 6 and 15. These targets and indicators are:

Table 8. EBV candidate "habitat structure" linked to SDG

Goals and targets (from the 2030 Agenda)	Indicators
Goal 6. Ensure availability and sustainable management of water and sanitation for all	
6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	6.6.1 Percentage of change in the extent of water related ecosystems over time
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	
15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.1 Forest area as a percentage of total land area
15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	15.4.1 Coverage by protected areas of important sites for mountain biodiversity 15.4.2 Mountain Green Cover Index
15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	15.5.1 Red List Index

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4.3.1. Ecosystem structure class. EBV candidate: *habitat structure*

Habitat structure (Bell et al. 1990; Byrne, 2007) is defined as the amount, composition and three dimensional arrangement of physical matter (both abiotic and biotic) at a location. Previous research has shown that habitat structure is an important direct and/or indirect driver of many ecological patterns and processes. It can regulate community structure by providing resources (shelter, nutrients, nesting sites) and mediating interactions (predation, competition) for a diverse array of organisms in many ecosystem types.

Standardized long-term monitoring of habitats at local and Pan-European scale is an important issue especially after implementation of the Convention on Biological Diversity (CBD) which is an international legally-binding treaty pursuing three main goals: the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from genetic resources. The two most important legal instruments of the European Union (EU) for the implementation of biodiversity conservation are the 1979 Birds Directive (79/409/EEC), as changed in 2009 (2009/147/EC) and the 1992 Directive on the conservation of natural habitats and of wild fauna and flora, usually known as the Habitats Directive (92/43/EEC, HabDir).

The aim of the Habitats Directive is to contribute to ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora within the European Community as reiterated by the target 1 of the EU Biodiversity Strategy to 2020. Under Article 17 of the Habitats Directive (92/43/CEE), Member States must submit information on how the Directive is being implemented every six years. The stakeholders (e.g., national or regional authorities, depending on the Member States, require multiple-scale and mainly very high-resolution, comparable, up to date land cover/land use (LC/LU) maps and more importantly the coverage of Annex I habitat types.

Recently, automatic habitat mapping techniques from Very High Resolution (VHR) to High Resolution (HR) satellite data have been developed as output of two FP7 space projects, i.e. BIO_SOS (www.biosos.eu) and MS.Monina (http://www.ms-monina.eu), as documented in the joint white paper produced

(http://www.biosos.eu/publ/White_Paper_Biodiversity_Monitoring_BIOSOS_MSMONINA.pdf). Within the projects, complementary techniques, i.e. data driven and knowledge driven techniques, are provided in support to Natura 2000 site managers for their reporting commitments related to the Habitats Directive. The selection of the techniques depend on site characteristics and in-field data availability. If the site is not easily accessible (e.g. wetlands) or too large for collecting ground truth data, the *knowledge driven* system for habitat mapping developed in BIO_SOS can be applied. The system, named Earth Observation Data Habitat Mapping (EODHaM), can produce LC maps from multi-seasonal VHR satellite data (e.g., Worldview2/3) without any reference ground truth and subsequently translate LC classes into habitat categories by integrating each LC class patch with specific environmental attributes (e.g., landform, lithology, soil-surface aspect, soil subsurface aspect, climate, altitude, erosion, water quality). Such translation is carried out in the framework of the Food and Agricultural Land Cover Classification System (FAO-LCCS), as described in (Lucas et al. 2015; Adamo et al. 2014; Kosmidou et al. 2013: Adamo at al. 2015, Tomaselli et al. 2013). The integration of LC classes with environmental attributes is based on expert rules from botanists, ecologists and remote sensing experts.

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When ground truth data are available, supervised techniques can be applied according to the tools and recommendations developed in the MS.Monina project (Corbane et al. 2015, Strasser and Lang 2015).

The third dimension, i.e. plant height, can be extracted by considering LIDAR data from aerial campaigns. Such data are useful also for discriminating vegetation life forms. Applications can be found in (Mücher et al. 2015, Rapinel et al. 2015). When LIDAR data are not available, height categories for vegetated areas can be characterized through texture analysis of a single very high spatial resolution multispectral image (Petrou et al. 2015). A number of texture features are produced, including local variance, entropy, and binary patterns. These features are processed through a variety of machine learning algorithms, potentially including dimensionality reduction, and feature selection, multiple imputation of missing data, outlier removal, and data normalization. Following processing, each land patch is assigned to the respective height category through a number of different supervised classifiers.

Input from satellite EO data:
Multi-seasonal imagery (VHR to HR data) to produce LC maps. See Annex 1). Lidar data.
Input from in-situ data:
Environmental attributes (e.g., landform, lithology, soil-surface aspect, soil subsurface aspect, climate, altitude, erosion, water quality)
Prior expert knowledge:
Plant phenology, agricultural practices, water regime (e.g., for wetlands habitats).
Gaps:
a) Availability of in-situ environmental data (attributes). Lack of centralized data sets, which are scattered between local, national offices and research Institutes.
b) Availability of domain ontologies describing the expert rules from botanists and ecologists useful to automatize such LC to Habitats translation.
c) Regular tasking on Natura 2000 sites and LTER sites of multi-seasonal VHR EO data acquired according to specific plant phenology. According to the Copernicus

Consequently it is very difficult to systematically apply the LC to Habitat translation methodology for habitat mapping from VHR EO data, according to the commitments related to the Habitats Directive (92/43/CEE) and local/regional stakeholder's requirements.

4.4.   Soil Moisture

The **EBV candidate: Soil Moisture** can be linked to some targets and indicators of the SDG 6. These targets and indicators are:

Table 9. EBV candidate "Soil moisture" linked to SDG

Goals and targets (from the 2030 Agenda)	Indicators
Goal 6. Ensure availability and sustainable management of water and sanitation for all	
6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water use efficiency over time 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources

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4.4.1. EBV candidate: Soil Moisture

The superficial soil moisture content (m_v) is a critical variable of the land hydrologic cycle as its spatial and temporal distribution has a crucial impact on the exchange of heat fluxes at the soil-atmosphere interface. In operational hydrology, m_v plays a crucial role in several different tasks. For example, in water resource management m_v is one of the main state variables of the hydrological water balance, whereas in flood prediction, the so called "antecedent moisture condition" dramatically affects the rainfall-runoff transformation and, hence, the predicted streamflow and its peak (Balenzano et al. 2013). Additionally, it is an essential component of the carbon cycle (Kolassa et al. 2016). Soil moisture products at global scale are currently operationally derived from microwave radiometers at a coarse resolution (e.g. 15-25km). A recent review of operational ESA's soil moisture products is provided in (Mecklenburg et al. 2016). However, no operational product is yet available at higher resolution (e.g. below 1km) (Balenzano et al. 2013). This is partly because most past spaceborne Synthetic Aperture Radars (SARs), which are the most appropriate systems to retrieve m_v at a high or moderate spatial resolution (i.e. from 100m to 1000m), had a long revisit time (e.g. 35-46 days) not suited to monitor surface parameters characterized by a high time variability such as m_v.

The new space missions generation, such as COSMO-SkyMed constellation and TerraSAR, together with the new ESA Sentinel-1 (S-1), JAXA ALOS-2 and CONAE SAOCOM missions, all characterized by shorter revisit times (e.g. 1-14 days), aim at overpassing this limit and, then, approaching the user requirements for an effective employment of the m_v products (Wood, et al., 2011). In this context, a soil moisture retrieval algorithm, named Soil MOisture retrieval from multi-temporal SAR data (SMOSAR), has been developed within an ESA feasibility study (Mattia et al., 2011) with a view to the exploitation of the Sentinel-1 data (Balenzano et al., 2013, Satalino 2013). SMOSAR inverts the temporal change of the radar backscatter between subsequent and close acquisitions rather than each independent SAR acquisition to produce m_v maps. Multi-temporal acquisitions with a short repeat cycle can track the fast changes of m_v only, since the other surface parameters affecting the radar backscatter, e.g. surface roughness, canopy structure and vegetation biomass, change over a longer time scale and therefore can be considered as constant (excluding cultivation practice periods). The algorithm was developed and assessed using ASAR and RADARSAT-2 data collected over well-documented test sites and it has been adapted to process time series of L- and X-band SAR data acquired by the ALOS/PALSAR-1 and COSMO-SkyMed systems over agricultural sites in Southern Italy (Balenzano et al. 2013). The m_v maps produced by SMOSAR currently have a spatial resolution between 200 m and 1000 m and an estimated accuracy ranging between 5% and 7% m^3/m^3.

Other examples of studies aiming at developing m_v retrieval algorithms tailored to Sentinel-1 data stream can be found in (Pierdicca et al., 2012, Hornacek et al., 2012).
Recently, El Haji et al, (2016) used X-band SAR data for m_v retrieval over grasslands areas. Whereas the synergy of active AMSR-E scatterometer and passive ASCAT radiometer microwave data is the basis of daily m_v retrieval in (Kolassa et al. 2016). This is in preparation of the SMAP mission, with dedicated L-band sensors, to verify whether an active/passive synergy would be beneficial.

Operational soil moisture products: from SMOS, SMAP, MetOp missions and ESA Climate Change Initiative.

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Existing International soil moisture network: http://ismn.geo.tuwien.ac.at/ismn/ mostly dedicated to validated product at low spatial resolution.

Input from satellite EO data: for research soil moisture product at spatial resolution below 1km, time-series of: L-band ALOS/PALSAR-2, X-band COSMO-SkyMed,X-band Terra SAR X, C-band Sentinel-1..

Input from in-situ data: DEM; Soil texture maps; hydrological network of stations measuring volumetric near-surface soil moisture for cal/val activities of high resolution mv product.

Gaps: hydrological networks purposely designed to validate soil moisture products at HR. In addition, availability of updated HR LC and soil texture maps.

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ANNEX I

The following tables are based on tables from the FP7 BIO_SOS and MS.Monina projects' white paper (http://www.biosos.eu/publ/White_Paper_Biodiversity_Monitoring_BIOSOS_MSMONINA.pdf)

Table 1. *FP7 BIO_SOS* project. Input satellite images used for Natura 2000 sites: Peak of Biomass (PoB), Pre Peak of Biomass (PrePoB); Post Peak of Biomass (PostPoB); Dry Season (DS); Wet Season (WS); Greece (GR); Italy (IT).

Dominant habitats	*Site*	*Sensor(s)*	*Month of acquisition*	*Period*
Wetlands *in the Mediterranean*	Lago Salso (IT9110038) Le Cesine (IT9150014) Ekvoles Kalama (GR2120001) Elos Kalodiki (GR2120002)	WorldView2	Late June or early July	DS
			October	PostPoB
			February *	PrePoB
Grasslands; *sclerophyllous vegetation;* *broadleaved trees* *in the Mediterranean*	Murgia Alta (IT9120007); Valloni e steppe pedegarganiche (IT9110039); Stena Kalama (GR2120004). Rios Sabor e Maçãs (PTZPE0037 and PTCON0021)	WorldView2 and/or QuickBird (4 images better than three)	April or May	PoB
			Late June or July	DS
			October	PostPoB
			January	PrePoB
Wetlands in North-Western Europe. *Estuarine mire complex containing the largest uncut area of lowland raised bog.*	Cors Fochno/Borth Bog (UK0014791); Cors Caron/Tregaron Bog (UK0014790).	WorldView2	Late March or Early April	PrePoB
			Late June or July	PoB
			Late October or Early November*	PostPoB
Heathlands in North-Western Europe	Veluwe (NL3009017).	WorldView2	March	PrePoB
			July	PoB

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				Late September-October	PostPoB

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Table 2. *FP7 MS.MONINA* Detailed service requirements (site level)

Subservice (site-level)	Boundary conditions and satellite requirements
Habitat mapping (focus: riparian forest integrity and structural assessment)	- VHR1 satellite imagery (minimum 4 bands, 8 bands or more advantageous) - Time series analysis: Time step 5 – 10 years, minimum one summer scene (June – July) per time step, two scenes (summer, autumn: End October / November) advantageous. Optional additional windows begin of April – mid of May and end October / November (for enhancing tree species extraction, neophytes / undergrowth detection, phenology studies). - Reference data: georeferenced point data with high spatial accuracy (0.5 to 1 m), ground validated habitat field map for verification. Coregistrated reference data to tree crowns (optional). - Optional data: cadastre data, LiDAR DEM and DSM (> 10 pt/m2) - Habitat types: 91E0, 91F0, (9170), (9180), (other forest habitat types) - Biogeographical zone: Continental tested; Mediterranean, Alpine, Atlantic possible - Structural assessment requires software such as V-LATE (extension for ArcGIS) or similar tools for the analysis of polygonal data.
Habitat mapping (focus: Mediterranean habitats)	- VHR satellite imagery (desirable WorldView 2 type data; in case not available RapidEye data can be used) - Colour infrared aerial photos for image segmentation - Timing: At least two images acquired during early spring before leaf flush and an image in the post-spring period - Access to digital elevation model (at least 25 m grid cells) and if available to LIDAR DEM. - Habitat types: no constraints on habitat types. However the habitats must be contrasted (in terms of radiometry and structural characteristics) and not subject to frequent environmental changes (e.g. variability in the temporality of flooding levels, sensitivity to soil moisture, etc.). - The wider application of the method requires : (1) access to suitable reference data on existing habitats, ideally based on photointerpretation and ground-truthing by an experienced ecologist; (2) the availability of very high-resolution imagery with the NIR band as a primary source for segmenting the landscape into homogenous image objects that reflect the habitat patterns; and (3) the availability of ancillary data (e.g. DEM) that would lead to further enhancement of the classification of the habitats.

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Habitat mapping (focus: grassland structure monitoring)	▪ Availability of very high spatial resolution images during vegetation period (0.5-2m) ▪ Field knowledge and reference samples to calibrate indicator classification, ideally from identical vegetation period
Habitat mapping (focus: heathland mapping)	▪ [*hyperspectral*] Image requirements: hyperspectral, taken in vegetation growing season (May-Oct), spatial resolution approx. 2-5 m ▪ Reference data requirements: fair amount of field reference data needed, representing all classes to be mapped, coinciding as much as possible with image acquisition date ▪ Habitats: heathland habitats in Atlantic (and probably also Continental) biogeographical region ▪ [*fine-scale*] Image requirements: multispectral, very high spatial resolution satellite images (e.g. QuickBird, GeoEye, WorldView 2, Pleiades), at least 0.8 m spatial resolution of the panchromatic sensor needed ▪ Reference data requirements: at least 20 sites for every class needed for accuracy assessment and/or knowledge base adaptations ▪ Habitats: heathland habitats in Continental and Atlantic biogeographical region ▪ [*multi-temporal*] Image requirements: multispectral and multitemporal data with medium spatial resolution (e.g. RapidEye), at least 5 images throughout the phenological cycle needed ▪ Reference data requirements: a spectral field library with at least 5 measurements throughout the phenological cycle for every plant association ▪ Habitats: useful for all habitats with low human interaction and strong phenological aspects
Habitat mapping (focus: river delta habitats)	▪ WorldView-2 multispectral images of two dates: one before and one after the summer ▪ Field observations ▪ Existing reference data ▪ Results suggest that the KRC algorithm applied to dual date WV-2 satellite imagery covering seasonal flooding, can support monitoring of Mediterranean wetlands to an extend depending on the environment complexity. This doubles the cost of EO data necessary for this kind of mapping.
Habitat mapping (focus: Alpine habitats)	▪ Image requirements: multi-temporal RapidEye images (level 1B) acquired from May to October

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	- Reference data: For each habitat to be mapped, approximately 150 samples are required. Samples should ideally be collected during the time window in which the images are acquired. - Habitats: habitats in Alpine biogeographical regions
Vegetation species composition (ordination-based habitat monitoring)	- Image requirements: hyperspectral imagery, spatial resolution approx. 2-5 m, acquired during vegetation growing season between May and September - Reference data: field reference data collected during image acquisition period necessary - Habitat constraints: only applicable to open land habitat types, especially heathland and grassland types as well as bogs in Atlantic and Continental biogeographical regions
Habitat mapping (focus: wetland habitats)	- Image requirements: multispectral, very high-resolution data (1 – 4 meter ground resolution), collected within vegetation growing season (May – September) - Reference data requirements: suitable amount of reference field data representing vegetation classes is needed, collected close to image acquisition date - Method dedicated to wetland habitats located in the geographical zone with temperate climate
Land cover mapping	- Preferably multi-date (winter or spring and summer) VHR (< 5 m). - Management objects to provide a context for the analysis. - Close engagement with the end users prior to and during the production.