GEOESSENTIAL ERA-PLANET

Essential Variables workflows for resource efficiency and environmental management

Deliverable 8.1

Best practice white paper on use of EVs for UN programs

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1.1 Essential Variables and Complex systems

To address global sustainability challenges, timely and reliable access to environmental data and information is necessary. Data provide the foundation for reliable and accountable scientific understanding and knowledge to support informed decisions and evidence based policy advices (Giuliani, Nativi, et al. 2017). Consequently, achieving the objective of a sustainable development requires the integration of various data sets describing physical, chemical, biological and socio-economic conditions (Lehmann et al. 2017). All together, these different data allow characterizing a given location on Earth. When combined, environmental data allow monitoring and assessing the status of the environment at various scales (e.g., national, regional, global), understanding interactions between different systems (e.g., atmosphere, hydrosphere, biosphere), and model future changes (Costanza et al. 2016).

Earth Observations (EO) data, acquired remotely by satellite or in-situ by sensors, is a valid and globally consistent source of information for monitoring the state of the planet and increasing our understanding of Earth processes (Giuliani, Dao, et al. 2017). The Group on Earth Observations (GEO) has been established in 2005 in response to the need for coordinated, comprehensive, and sustained observations related to the state of the Earth (Anderson et al. 2017). GEO's global engagement priorities include supporting the UN 2030 Agenda for Sustainable Development , the Paris Agreement on Climate, and the Sendai Framework for Disaster Risk Reduction (CEOS 2018; GEO secretariat 2015).

To adequately describe the various sub-systems (e.g., atmosphere, biosphere, land, ocean) that constitute the Earth system and to ensure that observational data can be delivered to all potential users, the concept of Essential Variables has emerged in the recent years in various communities (Reyers et al. 2017). Essential Variables (EV) can be broadly defined as "*a minimal set of variables that determine the system's state and developments, are crucial for predicting system developments, and allow us to define metrics that measure the trajectory of the system*" (ConnectinGEO 2016a). In most GEO Societal Benefits Areas (SBA) and thematic areas, the development of a specific set of EV's is a community process leading to an agreement on an essential set of parameters to meet the objectives of a given community and to support national to global monitoring, reporting, research, and forecasting (Reyers et al. 2017).

The concept of Essential Variables emerged from the climate community through the effort of the Global Climate Observing System (GCOS) who defined a set of 50 Essential Climate Variables (ECV) as a response for more coordinated and consistent approach to climate observations (Ostensen, O'Brien, and Cooper 2008). Theses variables are required to support the work on the United Nations Framework Convention on Climate Change (UNFCC) and the Intergovernmental Panel on Climate Change (IPCC) (Bojinski et al. 2014). ECV's are selected based on their relevance for characterizing Earth's climate system as well as their technical and economic feasibility for systematic observations (Giuliani, Nativi, et al. 2017; Reyers et al. 2017). These parameters are now widely used in both science and policy domains and are regularly reviewed to adapt to the need of new priorities, knowledge and innovation.

Similar approaches have been followed in different scientific communities. The more mature development of EV's are in Climate, Ocean, and Biodiversity domains (Lindstrom et al. 2012; Pereira et al. 2013). Other communities are currently working on defining a common set of Essential Variables such as Water, Agriculture, Ecosystems (GEO 2014; ConnectinGEO 2016a). In particular, the Essential Biodiversity Variables further clarifies the role of EV's lying between primary observations and indicators (Geijzendorffer et al. 2015). Such definition allows accommodating both the diversity of data providers and the changing demand for indicators across regions and different policy needs (Reyers et al. 2017).

While the environmental dimension of sustainability is decently characterized by the EV approach, the social and economic dimensions are not yet adequately addressed. This currently impede effectively tracking progresses towards sustainable development targets (ConnectinGEO 2016b). Different approaches have been recently proposed for better understanding complex interactions between social and biophysical systems. Planetary boundaries, footprints, or socio-ecological metabolism approaches are aiming to explicitly link environmental, social and economic dimensions (Reyers et al. 2017; Rockstrom et al. 2009; Fang, Heijungs, and De Snoo 2015; Giampietro 2016). These approaches have the potential to pave the way to the definition of a set of Essential Socio-Economic Variables (ESEV).

All these efforts in systems and sustainability research allow advancing and identifying essential dimensions of social, economic and environmental systems change and evolution. The EV concept represents a significant opportunity to strengthen monitoring systems by providing more efficient observations and seize fundamental system dimensions. Finally, one EV can potentially contribute to multiple indicators, and a given observation can be linked to more than one EV. This can enable a potential reduction of the number of observations required to deliver indicators (Reyers et al. 2017).

1.2 Assigning EVs to SDGs

The UN approved 17 SDGs that have been articulated in 169 targets and 240 indicators to measure progress towards these targets. 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[1].

However, out of the all SDG 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. 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 International Council for Science, ICSU, showed that

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

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.

After carefully examination of these 17 documents, ConnectinGEO (2016) 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 from Earth observation alone.*

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 EO in complementing the current indicators with comprehensive data and products, including geospatial products directly relevant for the monitoring of the targets for these goals. Based on the notion that sustainable development requires the functioning Earth's life support system (Griggs et al., 2013), GeoEssential could propose to develop a set of complementary indicators that bring environmental aspects to the monitoring of SDG targets through the inclusion of some linkable EVs.

Within GeoEssential the linkage between SDGs indicators and EVs will be deepened and introduced into the dashboard.

1.3 Monitoring SDGs with EO

The 2030 Agenda for Sustainable Development provides a pathway to a sustainable future for the planet. The seventeen Sustainable Development Goals (SDGs) encompass a range of global challenges including poverty, hunger, disease, climate change and the environment, complemented by their associated targets and a global indicator framework.

Monitoring, data gathering, and evaluation processes are vital for the successful implementation of the SDGs (Lu et al., 2015). Hence, tracking progress towards the SDGs requires high-quality, timely and accessible data, often in areas or for sectors where very little data exists today (West and Pateman, 2017). Traditional means to gather such data (in particular for SDGs 1 and 2) has been the use of household surveys. However, the data required to track progress towards the SDG targets cannot come solely from governments or intergovernmental organizations or institutions (Hsu et al., 2014; Flueckiger and Seth, 2016). The requirements of the SDGs are now too large and complex, with ever increasing levels of detail required, translating into a growing burden on governments and agencies tasked with monitoring and implementation.

Hence, implementation of the SDGs will also require novel, scalable and cost-efficient approaches to ensure that the SDGs are met. New innovative approaches to data collection make use of various forms of Earth observation (EO) to address some of the data needs and increasing examples demonstrate this (e.g. tracking deforestation, early warning systems for natural disasters, global agricultural monitoring and more).

Efforts are underway on multiple fronts (e.g. GEO, CEOS, ESA and others) to outline a conceptual framework and demonstrate the important role that EO can play in tracking many of the indicators that will otherwise be extremely challenging to obtain via traditional methods only. The intent is to outline a framework on how an integrated and innovative approach can complement and strengthen data collection needs. Perhaps more importantly, EO in conjunction with Citizen Science could prove to be one of the most realistic options we have to implement the SDGs, as it has the potential to support societal transformation to sustainable development by creating empowerment among citizens.

What is needed is a roadmap to address the surmountable data challenges that the SDGs are facing, and offer a realistic solution for implementing the SDGs by involving all stakeholders, namely citizens together with satellite-based EO and traditional approaches in the entire SDG cycle, thus enhancing public awareness and action for SDG achievement.

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2 The current status of EVs – Indicators – SDGs

In the following pages, the current state of EVs and their connection to SDGs and their Indicators is presented briefly, exploiting the material found in the deliverables of the H2020 project ConnectinGEO: D2.2 "EVs current status in different communities and way to move forward", D2.3 "Proposal of EVs for selected themes", and of the H2020 project ECOPOTENTIAL D2.1 "Review of existing Essential Variables (EVs) relevant to PAs studies".

As the recent expand in the EV concept started from their definition and linkage to SDGs and Indicators by ConnectingGEO, the list of EVs is still growing and only few scientific communities have defined an adequate set of EVs. The community that has defined the highest number of EVs is currently the Climate one, covering – with its ECVs (Essential Climate Variables) – one third of the total number. The Ocean community, is also already working on a mature set of EVs. The Biodiversity, Water, and Energy communities, likewise, populated their lists to a considerable extent, while in the Agriculture community the EVs are still few in number and in a developing stage. In other areas, like 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.

Out of the 240 SDG indicators, only 30 with the combination of socio-economic and Earth observation data and only 9 indicators can be extracted by Earth observation alone. The Indicators which can be calculated from existing EVs will be mentioned herein, in connection to each EV category respectively, (ConnectinGEO 2016)

2.1 Climate – ECVs

The community that first defined the term of EVs, more than 10 years ago, was the Climate one (Bojinski et. al 2014), led by the Global Climate Observing System (GCOS)[2]. The Essential Climate Variables (ECVs) were proposed as a response to the need for a more coordinated approach to global climate observations and still hold the highest number of EVs until now (Reyers et. al 2017).

The SDGs and Indicators ECVs can contribute to, are:

<u>Goal 3: Ensure healthy lives and promote well-being for all at all ages</u>

- Indicator 3.3.3: Malaria incidence per 1,000 population.
- Indicator 3.9.1: Mortality rate attributed to household and ambient air pollution

[2] https://www.ncdc.noaa.gov/gosic/global-climate-observing-system-gcos

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

- Indicator 9.4.1 CO2 emission per unit of value added

Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

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

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

- Indicator 15.1.1 Forest area as a proportion of total land area
- Indicator 15.2.1 Progress towards sustainable forest management
- Indicator 15.4.2 Mountain Green Cover Index

EV	TYPE	EV-CODE	Similar EVs	EV-SHORT	CATEGORY	NAME
ECV	Climate	C_PRC	O_PRC, E_PRC	PRC	Atmosphere	Precipitation
ECV	Climate	C_PAS	O_PAS, E_PAS	PAS	Atmosphere	Pressure (surface)
ECV	Climate	C_SRB		SRB	Atmosphere	Surface Radiation Budget
ECV	Climate	C_WAS	E_WAS	WAS	Atmosphere	Surface Wind Speed and direction
ECV	Climate	C_TAS	E_TAS	TAS	Atmosphere	Temperature (surface)
ECV	Climate	C_WVAS		WVAS	Atmosphere	Water Vapour (surface)
ECV	Climate	C_ERB		ERB	Upper Atmosphere	Earth Radiation Budget
ECV	Climate	C_LIG		LIG	Upper Atmosphere	Lightning
ECV	Climate	C_TU		TU	Upper Atmosphere	Temperature (upper-air)
ECV	Climate	C_WVU		WVU	Upper Atmosphere	Water Vapour (upper air)
ECV	Climate	C_WNU		WNU	Upper Atmosphere	Wind speed and direction (upper-air)
ECV	Climate	C_AER		AER	Atmospheric Composition	Aerosols properties
ECV	Climate	C_CO2		CO2	Atmospheric Composition	Carbon Dioxide, Methane and other Greenhouse gases
ECV	Climate	C_CLD	E_CLD	CLD	Atmospheric Composition	Cloud Properties
ECV	Climate	C_O3A		O3A	Atmospheric Composition	Ozone
ECV	Climate	C_PRE		PRE	Atmospheric Composition	Precursors (supporting the Aerosol and Ozone ECVs)
ECV	Climate	C_AGB		AGB	Land	Above-ground biomass
ECV	Climate	C_ALB		ALB	Land	Albedo
ECV	Climate	C_GHG		GHG	Land	Anthropogenic Greenhouse Gas Fluxes
ECV	Climate	C_WTS	W_WTS	WTS	Land	Anthropogenic Water Use
ECV	Climate	C_FIRE		FIRE	Land	Fire

ECV	Climate	C_FAPR		FAPR	Land	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
ECV	Climate	C_GLA	W_GLA	GLA	Land	Glaciers
ECV	Climate	C_GWAT	W_GWAT	GWAT	Land	Groundwater
ECV	Climate	C_ICE	W_GLA	ICE	Land	Ice Sheets and ice shelves
ECV	Climate	C_LAK	W_LAK	LAK	Land	Lakes
ECV	Climate	C_LCV		LCV	Land	Land cover
ECV	Climate	C_LST		LST	Land	Land Surface Temperature
ECV	Climate	C_LSH		LSH	Land	Latent and Sensible Heat fluxes
ECV	Climate	C_LAI		LAI	Land	Leaf Area Index (LAI)
ECV	Climate	C_PFR		PFR	Land	Permafrost
ECV	Climate	C_RIV	W_RIV	RIV	Land	River Discharge
ECV	Climate	C_SNC	W_SNC	SNC	Land	Snow
ECV	Climate	C_SC		SC	Land	Soil Carbon
ECV	Climate	C_SM	W_SM	SM	Land	Soil Moisture
ECV	Climate	C_OSH		OSH	Ocean-Physical	Ocean Surface Heat Flux
ECV	Climate	C_SICE	O_SICE	SICE	Ocean-Physical	Sea Ice
ECV	Climate	C_SL	O_SL	SL	Ocean-Physical	Sea Level
ECV	Climate	C_SS	O_SS	SS	Ocean-Physical	Sea State
ECV	Climate	C_SSS	O_SSS	SSS	Ocean-Physical	Sea Surface Salinity
ECV	Climate	C_SST	O_SST	SST	Ocean-Physical	Sea Surface Temperature
ECV	Climate	C_SCUR	O_SCUR	SCUR	Ocean-Physical	Subsurface Curents
ECV	Climate	C_SALD	O_SALD	SALD	Ocean-Physical	Subsurface Salinity
ECV	Climate	C_COP	O_COP	COP	Ocean-Physical	Surface Carbon dioxide partial pressure
ECV	Climate	C_SCOP	O_SCOP	SCOP	Ocean-Physical	Subsurface Carbon dioxide partial pressure
ECV	Climate	C_TD	O_TD, E_TD	TD	Ocean-Physical	Subsurface Temperature
ECV	Climate	C_CUR	O_CUR, E_CUR	CUR	Ocean-Physical	Surface Currents
ECV	Climate	C_STR		STR	Ocean-Physical	Surface Stress
ECV	Climate	C_INC		INC	Ocean-Biogeochemical	Inorganic Carbon
ECV	Climate	C_NIO		NIO	Ocean-Biogeochemical	Nitrous Oxide
ECV	Climate	C_NUTD		NUTD	Ocean-Biogeochemical	Nutrients
ECV	Climate	C_COL	O_COL	COL	Ocean-Biogeochemical	Ocean Colour
ECV	Climate	C_OOD	O_OOD	OOD	Ocean-Biogeochemical	Oxygen
ECV	Climate	C_TRD		TRD	Ocean-Biogeochemical	Transient Tracers
ECV	Climate	C_HAB		HAB	Ocean-Biological	Marine Habitat Properties
ECV	Climate	C_PLK		PLK	Ocean-Biological	Plankton

2.2 Biodiversity – EBVs

The Essential Biodiversity Variables (EBVs) (Pereira et. al 2013), inspired by the ECVs, were clearly defined to "lie between primary observations and indicators" (Reyers et. al 2017), and were defined in a top-down approach based on the Aichi Targets for 2020. They are led by the Group on Earth Observations Biodiversity Observation Network (GEO_BON)[3].

The SDGs and Indicators EBVs can contribute to, are:

Goal 6: Ensure availability and sustainable management of water and sanitation for all

- Indicator 6.6.1 Change in the extent of water-related ecosystems over time

Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

- Indicator 14.1.1 Index of Coastal Eutrophication (ICEP) and Floating Plastic debris Density
- Indicator 14.4.1 Proportion of fish stocks within biologically sustainable levels

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

- Indicator 15.1.1 Forest area as a proportion of total land area
- Indicator 15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type
- Indicator 15.2.1 Progress towards sustainable forest management
- Indicator 15.3.1 Proportion of land that is degraded over total land Area
- Indicator 15.5.1 Red List Index
- Indicator 15.9.1 Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020

EV	TYPE	EV-CODE	Similar EVs	EV-SHORT	CATEGORY	NAME
EBV	Biodiversity	B_GCC		GCC	Genetic composition	Co-ancestry
EBV	Biodiversity	B_GCA		GCA	Genetic composition	Allelic diversity
EBV	Biodiversity	B_GCP		GCP	Genetic composition	Population genetic differentiation
EBV	Biodiversity	B_GCB		GCB	Genetic composition	Breed and variety diversity
EBV	Biodiversity	B_SPD		SPD	Species populations	Species distribution
EBV	Biodiversity	B_SPA		SPA	Species populations	Population abundance
EBV	Biodiversity	B_SPS		SPS	Species populations	Population structure by age/size class

[3] https://geobon.org/

EBV	Biodiversity	B_STPH		STPH	Species traits	Phenology
EBV	Biodiversity	B_STB		STB	Species traits	Body mass
EBV	Biodiversity	B_STN		STN	Species traits	Natal dispersion distance
EBV	Biodiversity	B_STM		STM	Species traits	Migratory behavior
EBV	Biodiversity	B_STD		STD	Species traits	Demographic traits
EBV	Biodiversity	B_STP		STP	Species traits	Physiological traits
EBV	Biodiversity	B_CCT		CCT	Community composition	Taxonomic diversity
EBV	Biodiversity	B_CCS		CCS	Community composition	Species interactions
EBV	Biodiversity	B_EFNP		EFNP	Ecosystem function	Net primary productivity
EBV	Biodiversity	B_EFSP		EFSP	Ecosystem function	Secondary productivity
EBV	Biodiversity	B_EFNR		EFNR	Ecosystem function	Nutrient retention
EBV	Biodiversity	B_EFDR		EFDR	Ecosystem function	Disturbance regime
EBV	Biodiversity	B_ESH		ESH	Ecosystem structure	Habitat structure
EBV	Biodiversity	B_ESE		ESE	Ecosystem structure	Ecosystem extent and fragmentation
EBV	Biodiversity	B_ESC		ESC	Ecosystem structure	Ecosystem composition by functional type

2.3 Water – EWVs

Led by the Integrated Global Water Cycle Observations Community of Practice (IGWCO), the water community, in the GEOSS Water Strategy Report, defined the concept of Essential Water Variables (EWVs). A number of EWVs are also ECVs (Lawford 2014).
Unlike several other communities, the methodology to identify EWVs starts at applications and identified user needs (ConnectinGEO 2015).

The SDGs and Indicators EWVs can contribute to, are:

<u>Goal 3: Ensure healthy lives and promote well-being for all at all ages</u>

- Indicator 3.9.1: Mortality rate attributed to household and ambient air pollution

<u>Goal 6: Ensure availability and sustainable management of water and sanitation for all</u>

- Indicator 6.3.2 Proportion of bodies of water with good ambient water quality
- Indicator 6.4.1 Change in water use efficiency over time
- Indicator 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
- Indicator 6.6.1 Change in the extent of water-related ecosystems over time

EV	TYPE	EV-CODE	Similar EVs	EV-SHORT	CATEGORY	NAME
EWV	Water	W_PRC	C_PRC, E_PRC	PRC	Primary	Precipitation
EWV	Water	W_EVA		EVA	Primary	Evaporation and evapotranspiration
EWV	Water	W_SNC	C_SNC	SNC	Primary	Snow cover (including snow water equivalent, depth, freeze thaw margins)

EWV	Water	W_SM	C_SM	SM	Primary	Soil moisture/temperature
EWV	Water	W_GWAT	C_GWAT	GWAT	Primary	Groundwater
EWV	Water	W_RIV	C_RIV	RIV	Primary	Runoff/streamflow/river discharge
EWV	Water	W_LAK	C_LAK	LAK	Primary	Lakes/reservoir levels and aquifer volumetric change
EWV	Water	W_GLA	C_GLA, C_ICE	GLA	Primary	Glaciers/ice sheets
EWV	Water	W_WQ		WQ	Primary	Water quality
EWV	Water	W_WTS	C_WTS	WTS	Primary	Water use/demand (agriculture, hydrology, energy, urbanization)
EWV	Water	WS_MET		WS_MET	Supplemental	Surface meteorology
EWV	Water	WS_RAD		WS_RAD	Supplemental	Surface and atmospheric radiation budgets
EWV	Water	WS_CLD		WS_CLD	Supplemental	Clouds
EWV	Water	WS_PERM		WS_PERM	Supplemental	Permafrost
EWV	Water	WS_LC		WS_LC	Supplemental	Land cover, vegetation, and land use
EWV	Water	WS_ELV		WS_ELV	Supplemental	Elevation/topography and geological stratification
EWV	Water	WS_ALTI		WS_ALTI	Supplemental	Surface altimetry
EWV	Water	WS_SRB		WS_SRB	Supplemental	Surface radiation budgets
EWV	Water	WS_AER		WS_AER	Supplemental	Aerosols
EWV	Water	WS_ARB		WS_ARB	Supplemental	Atmospheric radiation budgets

2.4 Ocean – EOVs

Regarding the Essential Ocean Variables (EOVs), the definition and identification process was coordinated by the Intergovernmental Oceanographic Commission (IOC)[4] led by the Global Ocean Observing System (GOOS)[5] in 2010, for three different ocean subthemes: ocean physics, marine biology and ecosystems, and marine biogeochemistry (ConnectinGEO 2015). The methodology to identify the EOVs is described in Lindstrom et al (2012). In general, it's a well-developed and reasonably completed methodology, through a simultaneous top-down and bottom-up approach, trying to address both scientific questions and tackle societal benefit areas.

The SDG and Indicators EOVs can contribute to, are:

<u>Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development</u>

- Indicator 14.1.1 Index of Coastal Eutrophication (ICEP) and Floating Plastic debris Density
- Indicator 14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations

[4] http://www.ioc-unesco.org/
[5] http://www.goosocean.org/

EV	TYPE	EV-CODE	Similar EVs	EV-SHORT	CATEGORY	NAME
EOV	Ocean	O_AIR		AIR	Physical surface	Upper-Air
EOV	Ocean	O_O		O	Physical surface	Oxygen
EOV	Ocean	O_TRD	C_TRD	TRD	Physical surface	Tracers
EOV	Ocean	O_ACI		ACI	Physical surface	Ocean acidity
EOV	Ocean	O_COL	C_COL	COL	Physical surface	Ocean Color
EOV	Ocean	O_COP	C_COP	COP	Physical surface	Carbon Dioxide Partial Pressure
EOV	Ocean	O_SICE	C_SICE	SICE	Physical surface	Sea Ice
EOV	Ocean	O_SL	C_SL	SL	Physical surface	Sea Level
EOV	Ocean	O_PAS	C_PAS, E_PAS	PAS	Physical surface	Sea Level Pressure
EOV	Ocean	O_SS	C_SS	SS	Physical surface	Sea State
EOV	Ocean	O_SSS	C_SSS	SSS	Physical surface	Sea Surface Salinity
EOV	Ocean	O_SST	C_SST	SST	Physical surface	Sea Surface Temperature
EOV	Ocean	O_CUR	C_CUR, E_CUR	CUR	Physical surface	Surface Current
EOV	Ocean	O_WND		WND	Physical surface	Surface Wind
EOV	Ocean	O_GHC		GHC	Physical sub-surface	Global Ocean Heat Content
EOV	Ocean	O_TD	C_TD, E_TD	TD	Physical sub-surface	Temperature
EOV	Ocean	O_SCOP	C_SCOP	SCOP	Physical sub-surface	Carbon Dioxide partial pressure
EOV	Ocean	O_SCUR	C_SCUR	SCUR	Physical sub-surface	Current
EOV	Ocean	O_SACI		SACI	Physical sub-surface	Ocean Acidity
EOV	Ocean	O_OOD	C_OOD	OOD	Physical sub-surface	Oxygen
EOV	Ocean	O_STRA		STRA	Physical sub-surface	Tracers
EOV	Ocean	O_SALD	C_SALD	SALD	Physical sub-surface	Salinity
EOV	Ocean	O_OBIO		OBIO	Biogeochemical	Oxygen
EOV	Ocean	O_NUT		NUT	Biogeochemical	Macro Nutrients: NO3, PO4, Si, NH4, NO2
EOV	Ocean	O_CAR		CAR	Biogeochemical	Carbonate System: DIC, Total Alkalinity, pCO2 and ph, at least 2 of 4
EOV	Ocean	O_TRTR		TRTR	Biogeochemical	Trascient Tracers: CFC-12, CFC-11, SF6, tritium, 3He, 14C, 39Ar
EOV	Ocean	O_SUSP		SUSP	Biogeochemical	Suspended particulates (POC, PON or POM) and PIC ++ laboratory, beam attenuation, backscatter, acidiflabile, beam attenuation
EOV	Ocean	O_PMAT		PMAT	Biogeochemical	Particulate Matter Export: POC export, CaCO3 export, BSi export
EOV	Ocean	O_NITO		NITO	Biogeochemical	Nitrous Oxide
EOV	Ocean	O_C13		C13	Biogeochemical	Carbon-13: 13C/12C of dissolved inorganic carbon
EOV	Ocean	O_DOM		DOM	Biogeochemical	DOM: Dissolved organic matter, DOC, DON, DOP
EOV	Ocean	O_CHL		CHL	Biology and Ecosystems	Chlorophyll

EOV	Ocean	O_CRL		CRL	Biology and Ecosystems	Coral Cover
EOV	Ocean	O_MGV		MGV	Biology and Ecosystems	Mangrove Area
EOV	Ocean	O_HAB		HAB	Biology and Ecosystems	Harmful Algal Blooms HABs
EOV	Ocean	O_ZPLK		ZPLK	Biology and Ecosystems	Zooplankton:biomass/abundance
EOV	Ocean	O_SMA		SMA	Biology and Ecosystems	Salt Marsh Area
EOV	Ocean	O_LMV		LMV	Biology and Ecosystems	Large marine vertebrates: abundance/distribution
EOV	Ocean	O_SGRA		SGRA	Biology and Ecosystems	Seagrass Area
EOV	Ocean	O_LMVT		LMVT	Biology and Ecosystems	Tags and Tracking of species of value/large marine vertebrates
EOV	Ocean	O_ZPKK		ZPKK	Biology and Ecosystems	Zooplankton, Krill

2.5 Agriculture – AGVs

The agriculture theme is defining and perusing EVs even if experts in field do not use the term yet. In GEOGLAM (the Group on Earth Observations Global Agricultural Monitoring Initiative)[6], EVs were defined based on monitoring needs to support policy and program development at the local, regional, national and global scales. AGVs are linked to EBVs and ECVs (ConnectinGEO 2015).

The SDGs and Indicators AGVs can contribute to, are:

Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

- Indicator 2.3.1 (Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size)

Goal 12: Ensure sustainable consumption and production patterns

- Indicator 12.2.1 Material footprint (MF) and MF per capita, per GDP
- Indicator 12.3.1 Global food loss index

EV	TYPE	EV-CODE	Similar EVs	EV-SHORT	CATEGORY	NAME
AGV	Agriculture	A_CA		CA	Crop	Crop Area
AGV	Agriculture	A_CT		CT	Crop	Crop Type
AGV	Agriculture	A_CC		CC	Crop	Crop Condition
AGV	Agriculture	A_CPH		CPH	Crop	Crop Phenology
AGV	Agriculture	A_CY		CY	Crop	Crop Yield (current and forecast)
AGV	Agriculture	A_CM		CM	Crop	Crop Management and agricultural practices

[6] http://www.geoglam.org

2.6 Renewable Energy – EREVs

The approach used for defining the Essential Renewable Energy Variables (EREVs) is a bottom-up, system-based approach. It starts from the stakeholders needs expressed since 2000 in collaborative projects. They were first defined in 2015, in the ConnectinGEO D2.2 "EVs current status in different communities and way to move forward". The international bodies fully or partly involved in the identification and collection of ER-EVs are GEO, IRENA (International Renewable Energy Agency)[7] and IEA (International Energy Agency)[8].

The SDGs and Indicators EREVs can contribute to, are:

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all

- Indicator 7.2.1 Renewable energy share in the total final energy Consumption

Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

- Indicator 11.3.1 Ratio of land consumption rate to population growth rate
- 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

Goal 12: Ensure sustainable consumption and production patterns

- Indicator 12.2.1 Material footprint (MF) and MF per capita, per GDP

EV	TYPE	EV-CODE	Similar EVs	EV-SHORT	CATEGORY	NAME
EREV	Renewable Energy	E_SSI		SSI	Solar	Solar Surface Irradiance and its components (global, direct, diffuse)
EREV	Renewable Energy	E_SUN		SUN	Solar	Sunshine duration (demand in energy)
EREV	Renewable Energy	E_LULC		LULC	Solar	Land use, Land cover, including urbanization, hydrology, grid description
EREV	Renewable Energy	E_ELEV		ELEV	Solar	Elevation, Orography
EREV	Renewable Energy	E_LST		LST	Solar	Land surface temperature
EREV	Renewable Energy	E_WAVE		WAVE	Ocean	Wave, height, direction, period
EREV	Renewable Energy	E_TDL		TDL	Ocean	Tidal (min, max, sea surface elevation)
EREV	Renewable Energy	E_CUR	O_CUR, C_CUR	CUR	Ocean	See current, speed, direction
EREV	Renewable Energy	E_BAT		BAT	Ocean	Ocean bathymetry
EREV	Renewable Energy	E_OFL		OFL	Ocean	Ocean floor type
EREV	Renewable Energy	E_TD	C_TD, O_TD	TD	Ocean	Temperature, sea-surface, sub-surface and deep-sea

[7] http://www.irena.org/
[8] https://www.iea.org/

EREV	Renewable Energy	E_OW		OW	Ocean	Ocean, fixed and floating offshore wind, wave, tidal, currents, OTEC
EREV	Renewable Energy	E_URB		URB	Terrestrial	Urbanization
EREV	Renewable Energy	E_WAS	C_WAS, O_WAS	WAS	Terrestrial	Wind speed and direction
EREV	Renewable Energy	E_CLD	C_CLD	CLD	Terrestrial	Cloud cover (demand in energy)
EREV	Renewable Energy	E_PRC	C_PRC, W_PRC	PRC	Terrestrial	Precipitation
EREV	Renewable Energy	E_TAS	C_TAS, O_TAS	TAS	Terrestrial	Surface air temperature
EREV	Renewable Energy	E_SH	C_WVAS	SH	Terrestrial	Surface humidity
EREV	Renewable Energy	E_PAS	C_PAS, O_PAS	PAS	Terrestrial	Surface athmospheric Pressure

2.7 Urban – UEVs

Urban Essential Variables are currently under development stage, mostly in the ERA-PLANET project SMURBS (SMart URBan Solutions for air quality, disasters and city growth)[9]. Recently, in the "National Methodological Framework for the mapping and biophysical valuation of the ecosystems in Bulgaria", Part D (Chipev et. al 2018), UEVs were defined among others, as indicator parameters (indicator inputs) for urban ecosystems. These parameters derived from a top-down approach based on the urban system's Drivers-Pressures-State-Impacts-Responses (DPSIR).

The SDGs and Indicators UEVs can contribute to, are:

<u>Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation</u>

- Indicator 9.4.1 CO2 emission per unit of value added

<u>Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable</u>

- 11.1.1 Proportion of urban population living in slums, informal settlements or inadequate housing.
- 11.2.1 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities.
- 11.3.1 Ratio of land consumption rate to population growth rate.
- 11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities.
- 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.

EV	TYPE	EV-CODE	Similar EVs	EV-SHORT	CATEGORY	NAME

[9] http://smurbs.eu/

UEV	Urban	-		-		Vegetation canopy cover
UEV	Urban	-		-		Soil sealing
UEV	Urban	-		-		Area of natural habitats
UEV	Urban	-		-		Reclaimed waste deposits areas
UEV	Urban	-		-		Air quality
UEV	Urban	-		-		Actual evapotranspiration
UEV	Urban	-	E_URB	-		Spatial structure of urban areas
UEV	Urban	-	C_CO2	-		Trend of total CO2 emissions
UEV	Urban	-	C_TAS, E_TAS, C_LST	-		Temperature sum totals (for the active growing period)
UEV	Urban	-	E_SSI	-		Solar-energy potential
UEV	Urban	-		-		Urban runoff coefficient
UEV	Urban	-	C_RIV, W_RIV			Natural ground water discharge
UEV	Urban	-		-		Risk to soil and atmospheric drought

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3 EO in support to SDGs: A portfolio of Best practices

3.1 Preamble

The Global Indicator Framework of the SDGs requires integrating multiple types of data. These data range from traditional national accounts, household surveys and routine administrative data, to new sources of data, like EO, geospatial information, citizen science, and Big Data. EO and geospatial information will play a significant role in meeting the SDGs in a global level as they are often continuous in their spatial and temporal resolutions, thus significantly expanding monitoring capabilities at local, national, regional and global levels, and across sectors[10]. EO has already been linked to multiple SDG Indicators by GEO in the framework of EO4SDG (Table 1).

In the following section, various actions originating from different worldwide or national organizations and institutes, are presented, to demonstrate the use of EO in support of the SDGs. These actions are introduced as examples by GEO, the United Nations Global Geospatial Information Management (UN-GGIM), the United Nations Office for Outer Space Affairs (UNOOSA), the Committee on Earth Observation Satellites (CEOS), the European Space Agency (ESA), the Global Partnership for Sustainable Development Data and the ConnectinGEO Project.

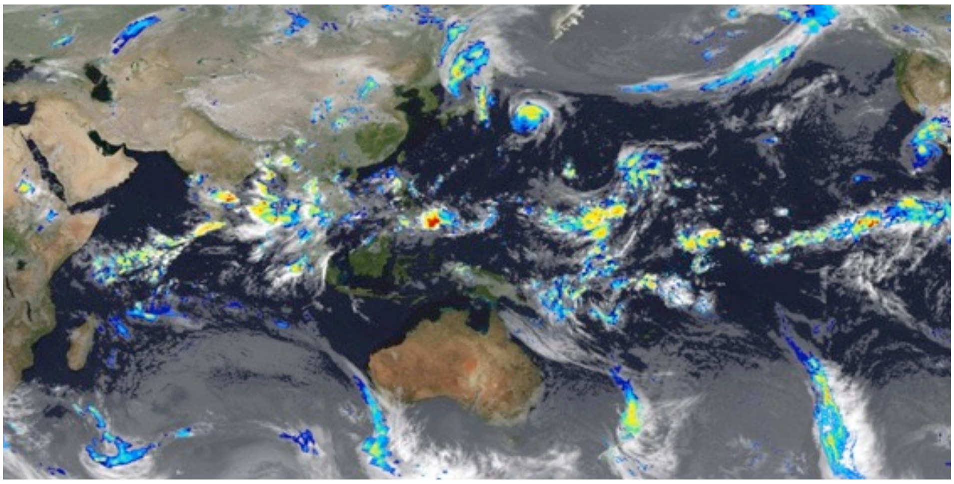
[10] https://www.earthobservations.org/documents/publications/201704_geo_unggim_4pager.pdf

Table 1: SDG Targets and Indicators that can be supported by Earth observations. Credit: EO4SDGs / CEOS.

Target Contribute to progress on the Target, not necessarily the Indicator									Goal	Indicator Direct measure or indirect support to the Indicator					
							1.4	1.5	1 No poverty	1.4.2					
						2.3	2.4	2.c	2 Zero hunger	2.4.1					
					3.3	3.4	3.9	3.d	3 Good health and well-being	3.9.1					
									4 Quality education						
								5.a	5 Gender equality	5.a.1					
		6.1	6.3	6.4	6.5	6.6	6.a	6.b	6 Clean water and sanitation	6.3.1	6.3.2	6.4.2	6.5.1	6.6.1	
					7.2	7.3	7.a	7.b	7 Affordable and clean energy	7.1.1					
								8.4	8 Decent work and economic growth						
					9.1	9.4	9.5	9.a	9 Industry, innovation and infrastructure	9.1.1	9.4.1				
						10.6	10.7	10.a	10 Reduced inequalities						
	11.1	11.3	11.4	11.5	11.6	11.7	11.b	11.c	11 Sustainable cities and communities	11.1.1	11.2.1	11.3.1	11.6.2	11.7.1	
				12.2	12.4	12.8	12.a	12.b	12 Responsible consumption and production	12.a.1					
					13.1	13.2	13.3	13.b	13 Climate action	13.1.1					
		14.1	14.2	14.3	14.4	14.6	14.7	14.a	14 Life below water	14.3.1	14.4.1	14.5.1			
	15.1	15.2	15.3	15.4	15.5	15.7	15.8	15.9	15 Life on land	15.1.1	15.2.1	15.3.1	15.4.1	15.4.2	
								16.8	16 Peace, justice and strong institutions						
17.2	17.3	17.6	17.7	17.8	17.9	17.16	17.17	17.18	17 Partnerships for the goals	17.6.1	17.18.1				

3.2 GEO examples

Title of action	GSMaP: Global Satellite Mapping of Precipitation
SDG Target: 6.5	By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate
SDG Indicator: 6.5.1	Degree of integrated water resources management implementation (0-100)
Essential Variables	Precipitation



The Global Satellite Mapping of Precipitation (GSMaP)[11] Project started in 2002 and is led by JAXA (the Japanese national aerospace and space agency). The aims of the GSMaP Project are the development of an advanced microwave radiometer algorithm and the production of precise high-resolution global precipitation maps, in order to obtain the basic information for the

[11] http://sharaku.eorc.jaxa.jp/GSMaP_crest/index.html

research of global precipitation variation and for the long term water resource management (Kubota et. al 2007; Ushio et. al 2003). GSMaP uses EO data from the Global Precipitation Measurement (GPM) satellite and provides hourly estimates of precipitation in a global level, offering the ability of transboundary cooperation, which is crucial in the event of floods caused by typhoons, or heavy rains. Furthermore, GSMaP contributes to flood prediction and early warnings broadcast that have already been implemented as pilots in Bangladesh, the Philippines, Vietnam and in Pakistan[12]. For all these reasons, it is clear that the GSMaP Project contributes to the SDG Indicator 6.5.1: Degree of integrated water resources management implementation (0-100), to meet Target 6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate. The EV that GSMaP Project is directly associated to is Precipitation.

References

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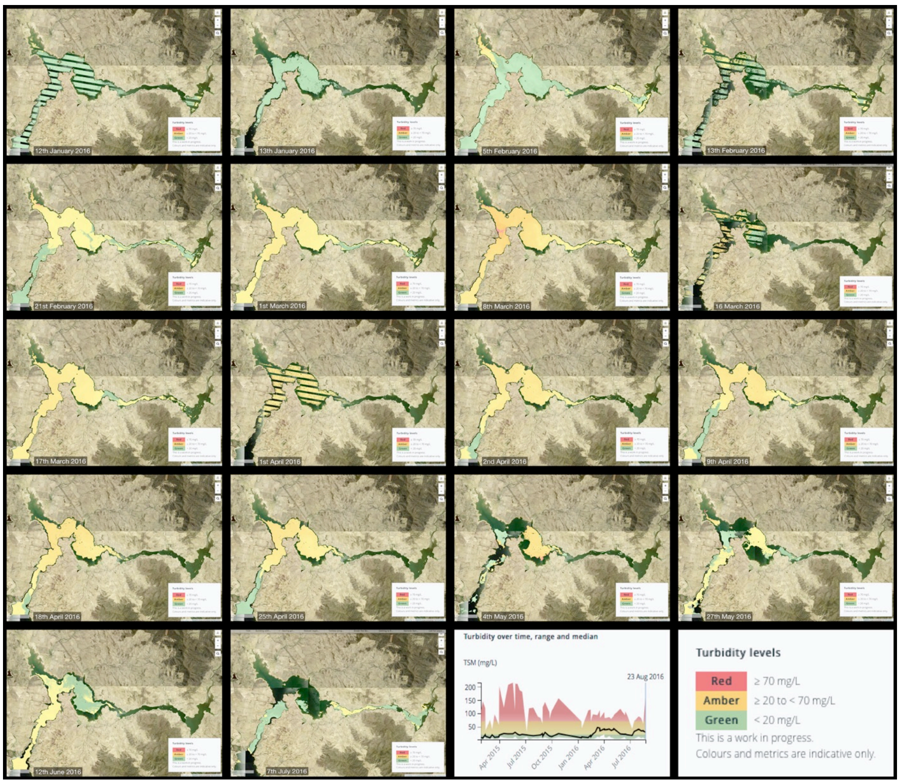
Title of action	Algal Early Warning System (AEWS)
SDG Target: 6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
SDG Indicator: 6.3.2	Proportion of bodies of water with good ambient water quality
Essential Variables	Chlorophyll, Harmful Algal Blooms HABs



One of the threats of inland waters that is of increasing concern is the rise of cyanobacterial (blue-green algal) blooms[13]. Causing extensive problems in lakes worldwide (including human and ecological health risks, anoxia and fish kills, and taste and odor problems), cyanobacterial blooms are a particular concern in both recreational waters and drinking water sources because of

[12] https://www.earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf
[13] https://www.earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf

their dense biomass and the risk of exposure to toxins, (Clark et. al 2017).
The Algal Early Warning System (AEWS) Project[14], is a collaboration between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the New South Wales (NSW) Department of Primary Industries - Office of Water, to develop a remote sensing approach to monitoring algal blooms in inland waters across large spatial scales, thus avoiding the limited spatial extent and time consumption of traditional field monitoring. The EO data that will be used within the project are Landsat and Sentinel data. The products of AEWS will have a direct input to SDG Indicator 6.3.2: Proportion of bodies of water with good ambient water quality, to meet 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.

References

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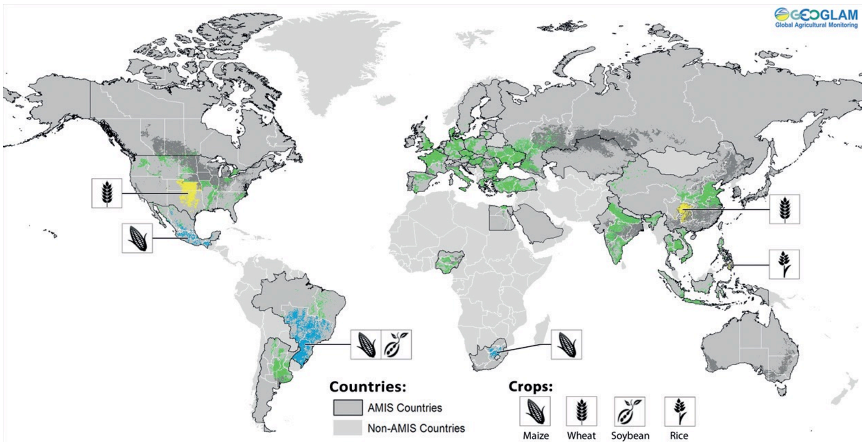
[14]http://www.water.nsw.gov.au/water-management/water-quality/algal-information/algal-early-warning-system

3.3 GEO-UN_GGIM examples

Title of action	GEOGLAM Crop Monitor for the AMIS
SDG 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 Indicator: 2.c.1	Indicator of food price anomalies
Essential Variables	Crop Area, Crop Type, Crop Management and agricultural practices, Soil moisture/temperature, Precipitation, Evaporation and evapotranspiration

Food price spikes can lead to significant increases in hunger and disruption, (Mitchell 2015). After the 2008 food price spike, the G20 established the Agricultural Market Information System (AMIS), in order to increase market information and transparency and to help prevent abnormal international market conditions. The Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM) Crop Monitor for the AMIS, is a monthly bulletin on current growing conditions for the four major crops (wheat, maize, soybean and rice) [15] in 51 countries, representing 80-90 percent of the global production of the four commodities[16]. It provides accurate consensus reporting on crop conditions based on reports by national, regional and international partners, with the aim to understand how food prices change. These actions seek to meet the SDG 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.
The data used within the framework are from a wide range of commercial and non-commercial satellites from which various EVs derive such as: Crop Management and agricultural practices, Soil moisture/temperature, Precipitation and Evaporation and evapotranspiration[17].



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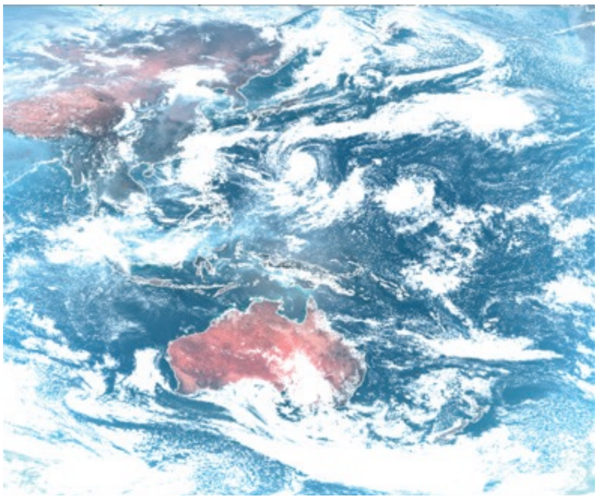
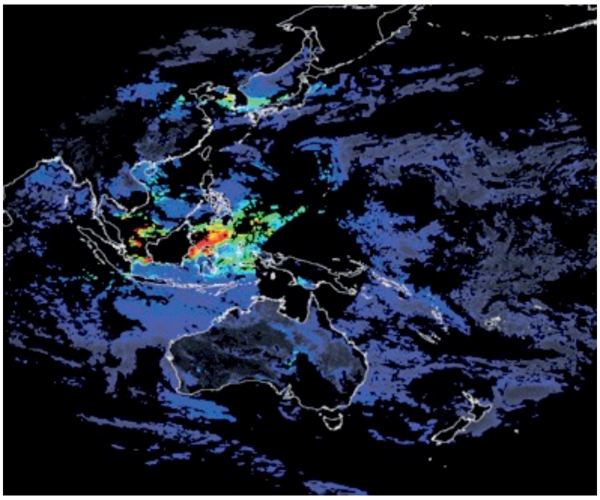
[15] http://www.geoglam.org
[16] https://www.earthobservations.org/documents/publications/201704_geo_unggim_4pager.pdf
[17] https://cropmonitor.org/index.php/data-and-tools/data/

Title of action	Air Polution Monitoring using Himawari-8
SDG 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 Indicator: 11.6.2	Annual mean levels of fine particulate matter (eg. PM2.5 and PM10) in cities (population weighted)
Essential Variables	Elevation/topography and geological stratification, Surface humidity, Aerosols properties

The world's largest environmental health risk, according to the World Health Organization (WHO), is air pollution, responsible for 3.2 million deaths in 2012[18]. As an effort to meet Target 11.6 of the SDGs: 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 must be monitored.





Himawari-8, a geostationary satellite by JAXA, delivers aerosol data every 10 minutes with 5km resolution. Hot spot detection and forest fire monitoring are conducted using other low Earth orbiting satellites, together contributing to estimates of particulate matter.

For Indicator 11.6.2 estimation, some of the EVs required are: Elevation/topography and geological stratification, Surface humidity and Aerosols properties, (Wang et. al 2017)

References

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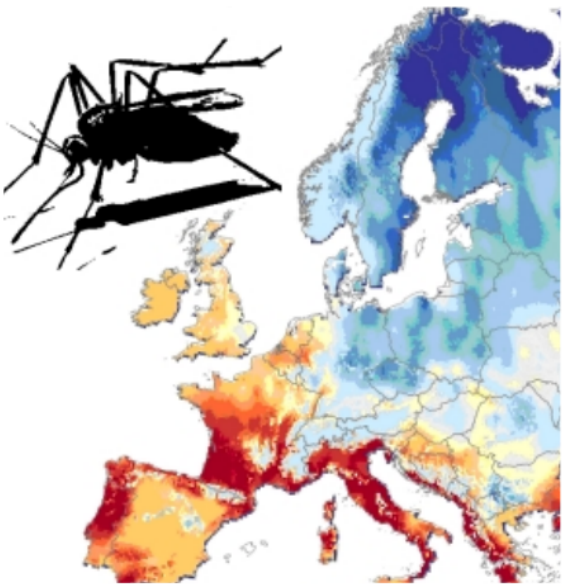
[18] https://www.earthobservations.org/documents/publications/201704_geo_unggim_4pager.pdf

3.4 UNOOSA examples

Title of action	Mapping habitats for vectors of infectious disease: VECMAP
SDG 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 Indicator: 3.3.3	Malaria incidence per 1,000 population
Essential Variables	Soil Moisture, Land Surface temperature, Land Cover, Land Use



Vector-borne diseases such as Malaria, Chikungunya, Dengue and West Nile are a persistent public health concern, (Kruijff et. al 2011). Prediction of vector distributions and associated risks is a challenge, but is of significant importance in order to achieve end of tropical disease epidemics and meet the SDG 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. EO provides data on the environmental factors that influence the emergence or the spread of the vectors or diseases (e.g. soil moisture, surface temperature, vegetation, land use) to be used in distribution models.
A consortium led by Avia-GIS developed a software called "VECMAP"[19], in the framework of the European Space Agency's Integrated Application Promotion program (IAP), which uses satellite imagery and GNSS for mapping vector diseases. VECMAP is able to automate and optimize complex tasks related to the mapping of disease vector presences and the tracking of their progress, making it possible to design strategies to contain them and manage the risks they pose[20]. The EVs that are required to make predictions in VECMAP (such as Soil moisture, Land Surface temperature, Land Cover, Land Use) consist of data that derive from EO.

References

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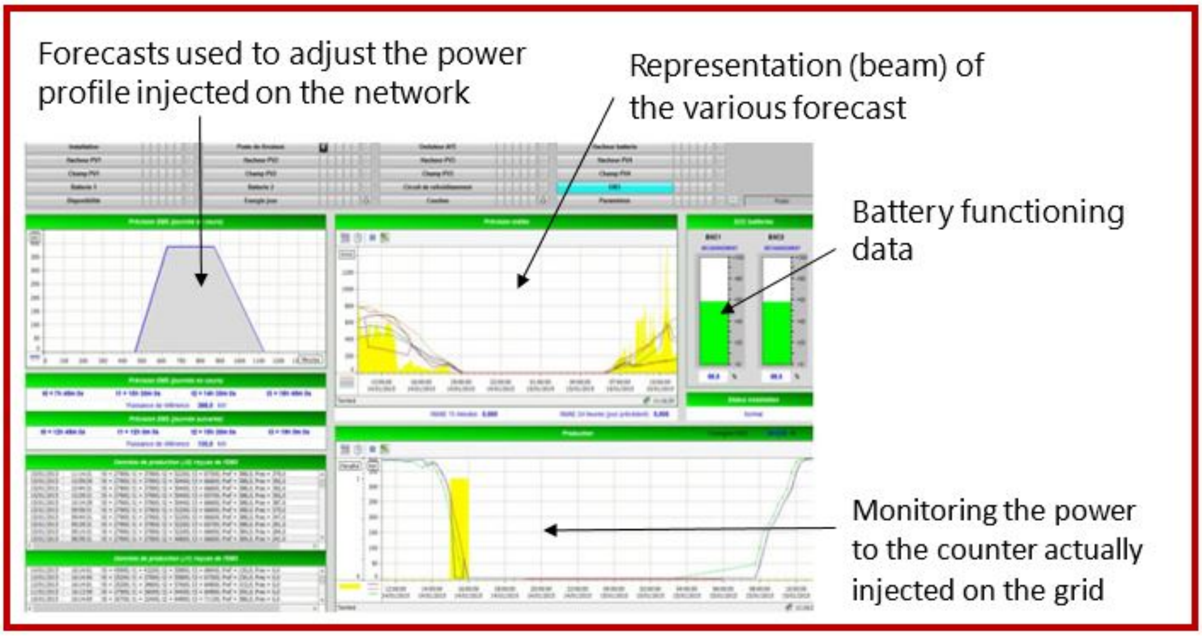
[20] http://www.unoosa.org/res/oosadoc/data/documents/2018/stspace/stspace71_0_html/st_space_71E.pdf

Title of action	Soleka: Solar energy forecasting tool
SDG Target: 7.2	By 2030, increase substantially the share of renewable energy in the global energy mix
SDG Indicator: 7.2.1	Renewable energy share in the total final energy consumption
Essential Variables	Solar Surface Irradiance and its components (global, direct, diffuse),

The Soleka Project[21] was co-financed by the European Union and supported by the European Regional Development Fund (ERDF) and the Reunion Region. Soleka is an innovative decision-making tool developed by Reuniwatt, a French company that uses EO data to monitor the productivity of solar panels. Reuniwatt affirms that, thanks to Copernicus, it is possible to improve the quality of forecasts by 30 per cent while reducing costs by up to 50 per cent for one-day forecasts and up to 15 per cent for six-hour and 30-min forecasts, thanks to time saved in data processing[22]. The innovation that the Soleka project provides will help overcome one of the major drawbacks that grid-connected solar farms have: intermittency of the produced energy, thus improving their efficiency and use to meet Target 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix.
EVs that are needed for the forecasting of Soleka include: Solar Surface Irradiance and its components (global, direct, and diffuse), Aerosols properties, and Albedo, (Cros et. al).



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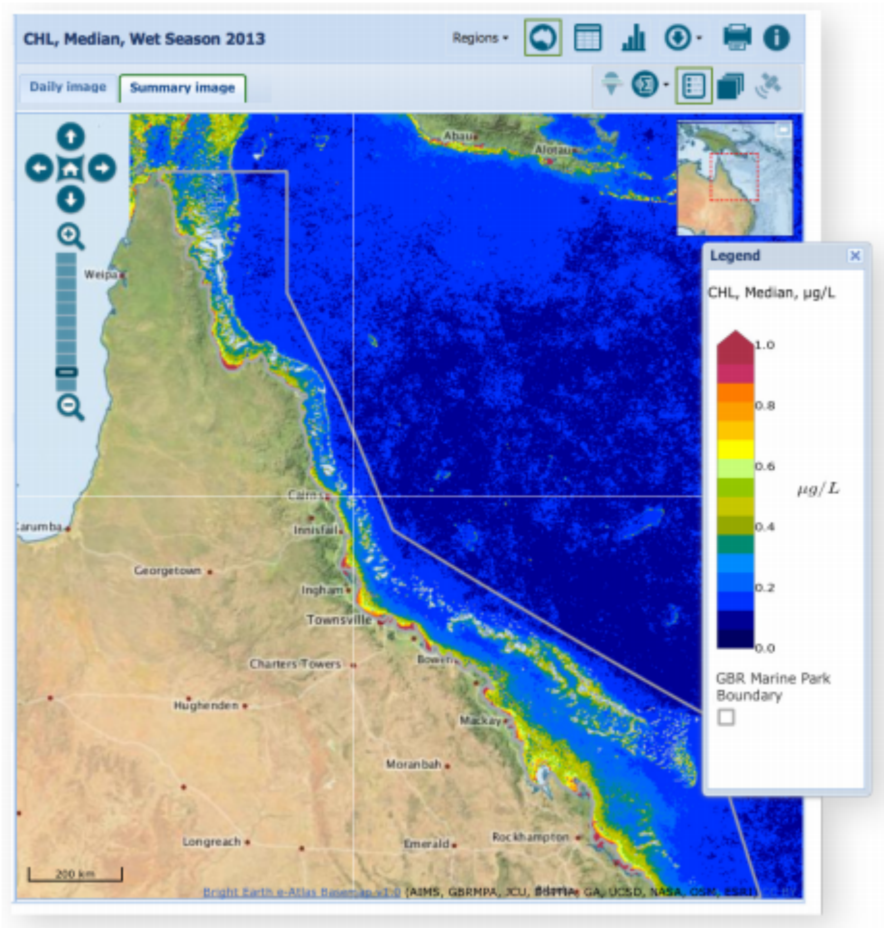
[22] http://www.unoosa.org/res/oosadoc/data/documents/2018/stspace/stspace71_0_html/st_space_71E.pdf

3.5 CEOS/ESA examples

Title of action	eReefs Marine Water Quality Dashboard
SDG 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
SDG Indicator: 14.1.1	Index of Coastal Eutrophication and Floating Plastic Debris Density
Essential Variables	Chlorophyll, Harmful Algal Blooms HABs



The eReefs Marine Water Quality Dashboard[23] is a tool to access and visualise a range of water quality Indicators for the Great Barrier Reef. It is a collaborative project between the Australian Institute of Marine Science, Bureau of Meteorology, CSIRO, Great Barrier Reef Foundation and the Queensland Government, (Marine Water Quality Dashboard). Apart from others, the information provided in the dashboard is chlorophyll-a levels[24]. Chlorophyll-a is the main indicator of algal blooms and its concentrations are used as indicators of the scale of excessive algal growth, known as eutrophication, (Bachir 2015). Chlorophyll, as an EV, contributes to the estimation of the SDG Indicator 14.1.1: Index of Coastal Eutrophication and Floating Plastic Debris Density, to meet 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.
The dashboard provides access to over ten years of water quality information and is updated daily with data from NASA's Aqua satellite.

References

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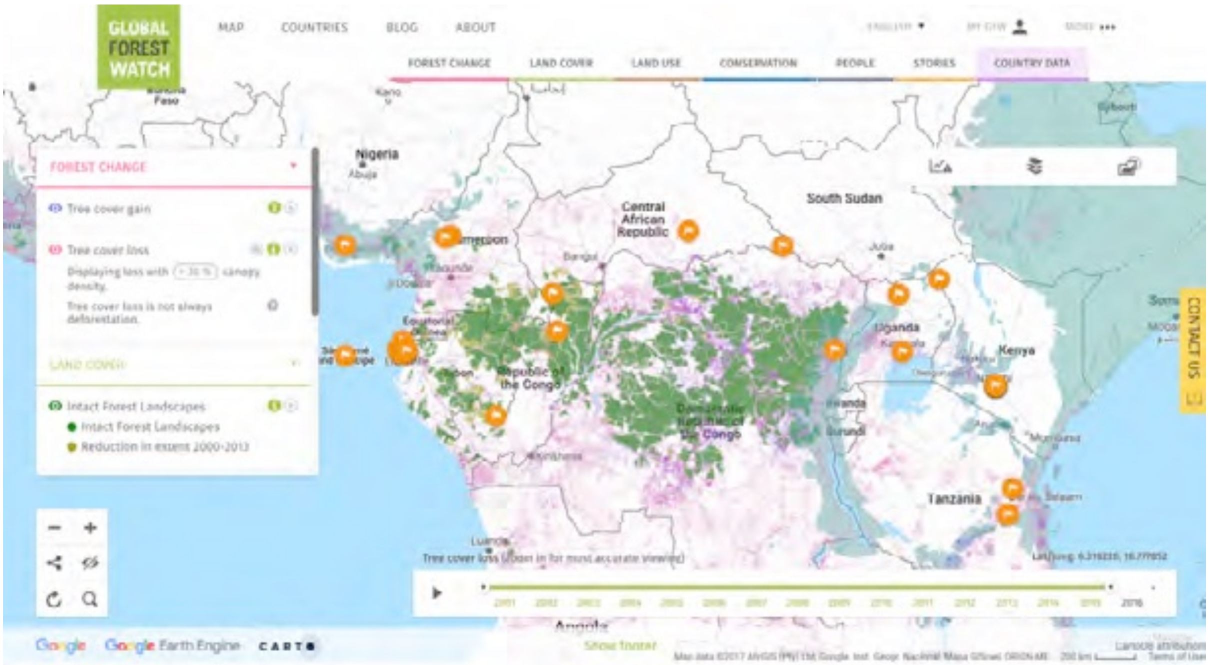
Title of action	Global Forest Watch (GFW)
SDG Target: 15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally
SDG Indicator: 15.2.1	Progress towards sustainable forest management
Essential Variables	Net primary productivity, Above-ground biomass, Land Use, Land Cover

The World Resources Institute's Global Forest Watch (GFW)[25] uses Landsat and MODIS data to provide spatially explicit information at a 30m resolution. Information is presented via a dynamic online forest monitoring and alert system empowering forest management stakeholders to create custom maps, analyze forest trends, subscribe to alerts or download data for their local area or the entire world[26]. The tropical zones of the platform's map are refreshed every 16 days, frequently enough to track deforestation in places like Indonesia and Brazil, (Strickland 2014).
Within the online platform, several EVs have been mapped globally such as Above-ground biomass, Land Use, Land Cover etc., contributing to the estimation of Indicator 15.2.1: Progress towards sustainable forest management and meeting 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.



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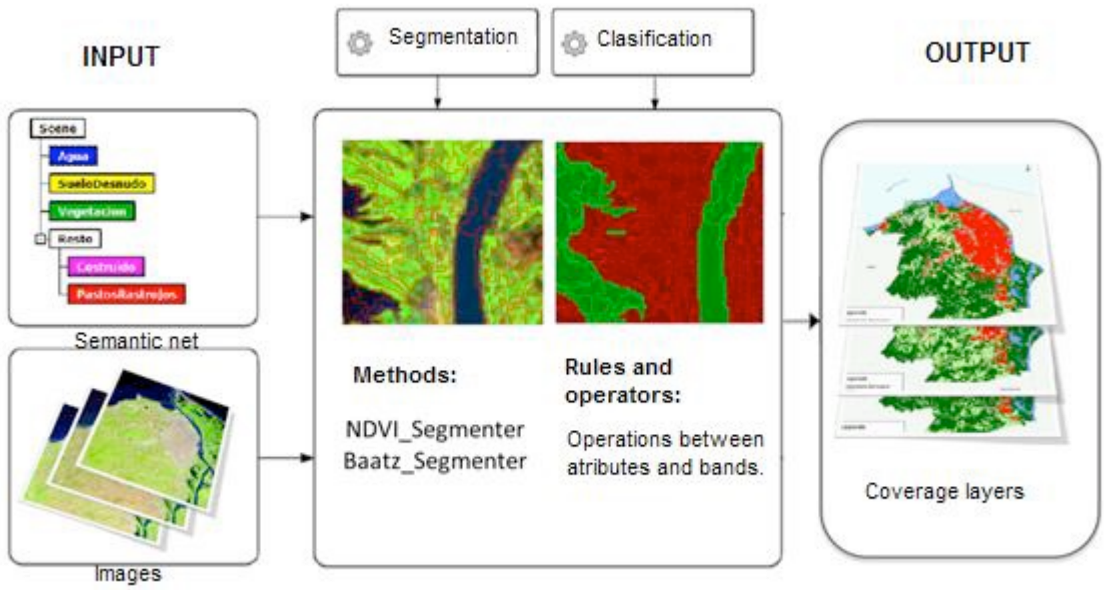
3.6 Global Partnership examples

Title of action	The Colombia Multi-Stakeholder Workshop on Data for the SDGs Roadmap
SDG 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 Indicator: 11.3.1	Ratio of land consumption rate and population growth rate
Essential Variables	Spatial structure of urban areas, Land Use, Land Cover

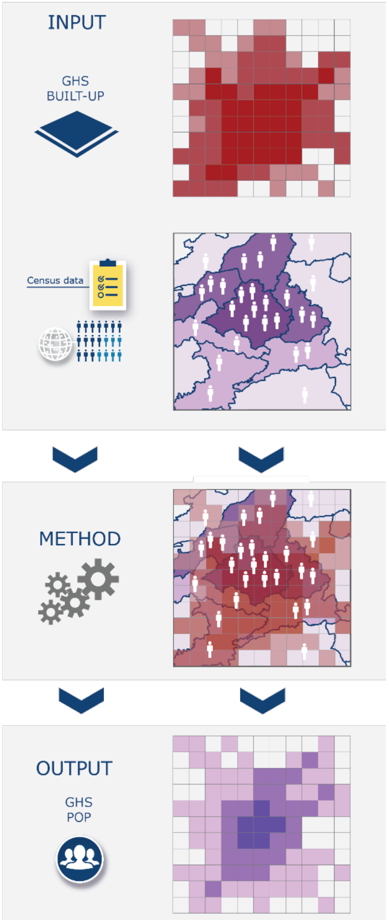
DANE (The Colombia National Statistics Office) conducted a pilot project in the Barranquilla metropolitan area, with contribution from the Global Partnership for Sustainable Development Data (GPSDD), to develop a method for calculating the SDG Indicator "Ratio of land consumption rate and population growth rate"[27]. The method uses Landsat data with a five-year time interval along with projected census population data, carrying out a Geographic Object-based Image Analysis (GEOBIA) and a semantic network classification scheme. The EVs which are mapped and are needed for the Indicator calculation are Spatial structure of urban areas, Land Use and Land Cover. GPSDD recommended the use of Google Earth Engine to scale the algorithms used in the pilot project to the whole country. The use of the Google Earth Engine platform automated the processing and classification resulting to the calculation of Indicator 11.3.1 for the six metropolitan areas of Colombia[28].



[27]http://www.data4sdgs.org/sites/default/files/services_files/CS1_Applying%20Earth%20Observation%20Data%20to%20Monitor%20SDGs%20in%20Colombia_Final2.pdf
[28] http://www.cepei.org/wp-content/uploads/2016/08/report-pilot-project-colombia-v3.pdf

3.7 ConnectinGEO examples

Title of action	The Global Human Settlement Layer (GHSL) framework
SDG 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 Indicator: 11.3.1	Ratio of land consumption rate to population growth rate
Essential Variables	Spatial structure of urban areas, Area of natural habitats, Land Use, Land Cover



The Global Human Settlement Layer (GHSL)[29] was developed and first released in 2014 in order to develop indicators and model (i) the access to services, market, industrial infrastructure, food, water, and land; (ii) the exposure to natural/human hazards, disasters, and pollution and (iii) the impact of the human footprint to land, water, and ecosystems, (Pesaresi et. al 2016).

The GHSL framework provides valuable information to various international organizations to support global policy processes, among others, to the SDGs, with particular focus on Goal 11: make cities and human settlements inclusive, safe, resilient, and sustainable. More specifically, the GHSL contributes directly to the SDGs Targets: 11.1: By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums; 11.3: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries and Indicators: 11.1.1: Proportion of urban population living in slums, informal settlements or inadequate housing; 11.3.1 Ratio of land consumption rate to population growth rate.

The GHSL is more than just build-up areas. It consists of built-up areas (EV: Spatial structure of urban areas), derived from the MODIS global urban extents (Schneider et. al 2010) and the Meris Globcover (Bontemps et. al 2011), along with the population density grid Landscan (Dobson et. al 2000). In addition, within the GHSL framework, by inverting built-up areas, open urban spaces can be calculated as well (EV: Area of natural habitats)[30].

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Pesaresi, M., Ehrlich, D., Ferri, S., Florczyk, A., Freire, S., Halkia, M., ... & Syrris, V. (2016). Operating procedure for the production of the Global Human Settlement Layer from Landsat data of the epochs 1975, 1990, 2000, and 2014. Luxembourg: Publications Office of the European Union.

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[30] http://www.gstss.org/2016_Laxenburg_Gaps/presentations/Ehrlich_Laxenburg_reduced_4.pptx

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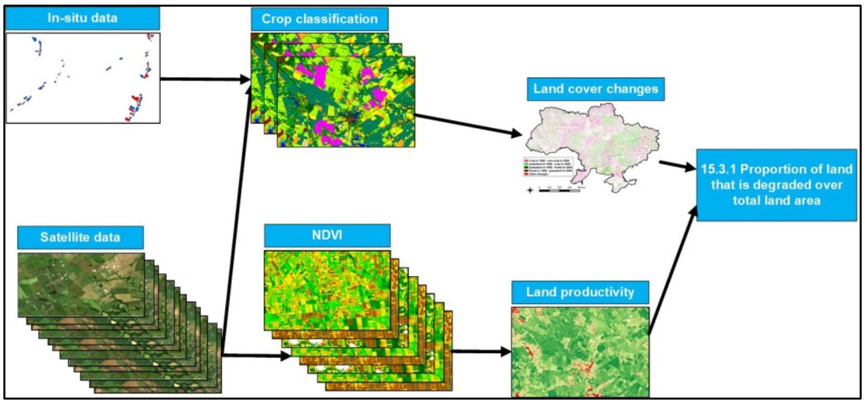
3.8 Misc examples

Title of action	United Nations Convention to Combat Desertification (UNCCD)
SDG 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 Indicator: 15.3.1	Proportion of land that is degraded over total land area
Essential Variables	Crop Area, Crop Type, Land Use, Land Cover



Within Global Support Programme and Land Degradation Neutrality (*LDN*) Target Setting Programme of *UNCCD* (UNCCD 2015) several proxies of assessing state of land according to Sustainable Development Goals (SDG) of Sendai Framework for Disaster Risk Reduction 2015–2030 are considered: (i) trends in land cover (vegetative land cover); (ii) trends in land productivity or functioning of the land (land productivity dynamics); (iii) carbon stock dynamics[31]. The LDN target setting processes are contributing to achieving the Sustainable Development Goal (SDG) 15, Life on Land, and in particular its target 15.3 and respectively Indicator 15.3.1.

To address analysis of land use changes as well as cropland productivity assessment land cover (Kussul et. al 2015) maps are essential as a proxy for understanding the processes in ecosystems and solving many applied problems of satellite monitoring, in particular Land Degradation Problem.

UNCCD secretariat provided to national authorities global datasets - in particular ESA CCI landcover for 2000-2015[32], land productivity map developed by JRC on 1999-2013 time series of NDVI (Ivits et. al 2016) for validation. Performed validation (Kussul et. al 2017) shows that global land cover maps overestimate cropland areas in Ukraine – thus use of national datasets is preferable. To address the problem at national level Ukraine proposed to use own developed datasets - in particular national land cover, 30 m for 1990, 2000 and 2010, 10 m for 2016 and 2017 (Lavreniuk et. al 2017; Waldner et. al 2016) could be used instead to global land cover. Total above-ground net primary production developed by JRC was used as inputs as well for preliminary results calculation.

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4 Lessons learnt – On-going process

In the previous pages, the current status of the EVs and their link to Indicators and Targets of the SDGs was presented, followed by examples of best practices of the use of EO data and EVs that derive from them, in support to the SDGs. Each example was linked to the SDG Indicator and Target it seeks to meet and a connection was also made to the EVs that are required and need to be calculated in each case.

EVs are defined by the H2020 Project ConnectinGEO in different thematics like Climate, Biodiversity, Water, Ocean, Agriculture and Renewable Energy but herein, Urban EVs are also presented in connection to the ERA-PLANET SMURBS Project.

Moreover, ConnectinGEO revealed that there are different levels of maturity and a considerable overlap between EVs identified by different communities. New dashboards that show the connection between EVs in these communities need to be created.

In all actions, this deliverable highlights that most EVs derived from EO data. EO data is becoming easily and freely available to all, in a global coverage and needs to be fully exploited. Access and usability of these data and their derived products however is often a limiting factor to utilization, particularly in low-income and lower-middle-income countries. Through GeoEssential, the necessary workflows to overcome these issues need to be demonstrated in order to show the way for EO use in meeting the Targets of the SDGs.

A careful examination of the presented actions reveals that a number of projects share the same need in EVs, though contributing to different indicators (i.e. “GEOGLAM Crop Monitor for the AMIS” and “United Nations Convention to Combat Desertification (UNCCD)”). In most actions though, EVs are estimated independently despite having the same scale and location, indicating that different areas of concerns of the environment are working in isolation. Therefore, there is a need for sharing large and complex data, standardizing them and improving the capacity to access them.

Despite the large number of actions sharing the same EVs, it was noted that these EVs where in many cases the same ones (i.e. Land Cover, Chlorophyll), leaving a large number of EVs unlinked to SDGs. Hence, there is a need to demonstrate the use of these EVs’ use in support to other SDGs.