Implementation Plan

2020-2022

Preface

The world is subjected to substantial changes, induced by human development in industry, economy, and society. People are more effective in harvesting resources, which is needed to sustain the growing world population, but at the same time recognition for the need to protect natural areas manifested itself. In this light, the concept of protected areas (PAs) to safeguard areas of natural importance like native flora and fauna as well as for humans and their well-being gained in popularity in many countries around the globe.

The International Union for Conservation of Nature (IUCN) defines a PA as “A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values”. PAs cover a diversity of environments including terrestrial landscape, such as forests, or seascapes, like freshwater lakes, or marine areas. Though a universal definition of PAs exists, the degree of protection and management strategies varies considerably between the types and location of such an area (UNEP-WCMC, 2014).

Successfully managing PAs is an inherently difficult challenge, particularly given the limited resources available and often multi-faceted management approaches required to effectively achieve desires changes within such areas. Managers and decision-makers are often forced to make decisions within restricted time frames, with limited data availability, restricted system knowledge, and limited financial as well as manpower resources for implementation efforts.

Initiated in 2016, the GEO Global Ecosystem Initiative (GEO ECO) aims to combine remote sensing and *in-situ* data to address the spatio-temporal scales of ecosystem processes, gather information and monitor long-term trends and produce knowledge about terrestrial and marine ecosystem status and the services they provide; enabling improved decision-making processes.

The following document provides the implementation plan for 2020-2024 for GEO ECO. GEO ECO has been put into implementation for only two years. Four challenges have been identified which will help to achieve three Sustainable Development Goals (SDGs): 13 Climate Action; 14 Life Below Water; and 15 Life on Land. Another seven tasks have been developed to address the challenges, with some of them tackling more than just one challenge.

Additionally, GEO ECO aims to effectively make use of Earth observations and Earth System modelling, enabling their use in a broader way to improve our understanding of ecosystem processes and of geosphere-biosphere interactions; inform decision and policy makers; promote data access; engage with potential end users; and, guide these in their decision for effective and sustainable management of their PA.

We welcome all your contributions and involvement in the services for the GEO community.

Warmly,

The GEO ECO Team

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Executive Summary

Terrestrial and marine ecosystems provide essential goods and services to human societies and are of crucial importance for the sustenance and development of our societies as well as achieving the Sustainable Development Goals (SDGs). In the last decades, however, anthropogenic pressures are causing serious threats to ecosystem integrity, functions, and processes, potentially leading to habitat degradation or loss for many species. The speed and the spatial extent of changes is exerting pressure on species populations, forcing them towards modified assemblages of species and disrupting biotic interactions. Natural processes of adaptation, migration, speciation and coevolution cannot respond adequately to current short-term and large-scale changes taking place. Biodiversity loss has many facets beyond local or global extinction of individual species. It is a proven fact that all aspects of biodiversity loss are linked to a decay in ecosystem functionality which results in emerging uncertainties and risks in face of a changing environment. Ecosystem degradation and loss of ecosystem services can seriously affect human wellbeing directly. In addition, the regulating contribution of ecosystems to climate services and carbon sequestration is increasingly under threat, potentially amplifying the negative effects of global change.

Knowledge-based conservation, management, and restoration policies are urgently needed in order to preserve biodiversity per se, but also to ensure delivery of ecosystem benefits in the face of increasing anthropogenic pressures. Fundamental to all these are effective monitoring, system understanding, and modelling of the state, trends, and evolutions in ecosystem functions and services. New monitoring methodologies have become available that combine approaches in geo- and bio-science, remote-sensing and *in-situ* monitoring with others of experimental nature investigating the potential of new methodologies in obtaining dynamic new and informative data sets providing additional information to support modelling efforts and supporting deeper understanding of system behaviours. Modern satellite missions, such as the European Sentinels, provide a large amount of high-quality data on the environment and ecosystem components. *In-situ* data is being made available in open access and data portals such as GBIF and organised through international activities such as the International Long-Term Ecological Research (ILTER) network and various open access and data portals. Access to such resources enhance the capacity of monitoring and modelling PAs, and provide a foundation for potential modified or enhanced data sets through statistical models or data fusion of both sources to inform on additional proxies and indicators of ecosystem functionality and health. Ecosystem models capable of incorporating the information from Earth Observations are being further developed to maximise the utility of said information databases, thereby enhancing their predictive capacities, and are made available in Virtual Research Environments such as in the European LifeWatch ERIC.

Based on these perspectives and building upon existing activities, the GEO ECO Initiative intends to utilise existing Earth Observation data, results, and information in order to generate tools, information, and decision support elements that facilitate the management and well-being of PAs and both staff and decision makers entrusted with their care. Such an ambition can be achieved through dialogs and co-development of tools and knowledge which is required to understand and communicate the complex interconnectivity of PAs with the natural and anthropogenic environments at multiple levels, including researchers, management, PA staff, and policy makers. This will support PAs of continental and global relevance, extending the analysis to vulnerable,

unprotected areas by adopting the view of ecosystems as "one physical system" with their environment. Furthermore, such efforts are enhanced by a strong consideration of geosphere-biosphere-anthroposphere interactions across multiple space and time scales. Both terrestrial and marine ecosystems are considered through this work, with a special focus on interactions and processes taking place in the layer at the surface of our planet (the Earth Living Skin) such as the Earth Critical Zone (ECZ). This extends to include the rocky matrix to the top of tree canopy for terrestrial ecosystems, and the dynamics in the euphotic layer and in coastal areas for marine ecosystems. The knowledge on ecosystems acquired through the activities of GEO ECO will be built together with the people in charge of the management of protected areas, ecosystems, and those with invested interest in the study thereof leading to the creation of an Ecosystem Community of Practice, encapsulating the users, researchers, decision-makers, and stewards of natural systems.

The primary contact for this initiative is Dr. Antonello Provenzale (CNR, Italy), Antonello.Provenzale@cnr.it.

Vision

Persistent and emerging environmental problems include all compartments of ecosystems and landscapes. Once such facet includes the understanding of interactions between biota and their abiotic environment , such as air, soil, bedrock and water, is crucial, when processes and mechanisms that are driving or controlling the environmental problems need to be identified. Finally, the role of humans needs particular consideration both in the perspective of cause and impact.

The increasingly growing extent and also the widened perception of environmental problems since the end of the 20th century, from local or regional scales to the global scale and from short-term solutions to long-term impacts beyond the individual lifetime of humans, do require a multitude of approaches. Technological progress, digital algorithms, and software tools are openly available and both customizable and applicable to a large variety of data sets and problems. Five categories of "instruments" can be identified: Big Data, in-situ and remote sensing Earth Observation, both field and laboratory Experiments, and Modelling. While these tools can be used singularly, the benefits and enhanced understanding through the implementation of all 5 to address ecological issues and investigate solutions. However, a clear understanding of the complexities, interactions, and interdependencies of environmental systems must be fully appreciated and the system knowledge defined prior to applying such tools lest oversight of interconnections lead to false assumptions and erroneous outputs of such approaches.

In recent years, tremendous amounts of spatial data have been made available in many fields related to ecology and the environment. Existing information has been digitized, data collections are organized, novel approaches such as citizen science are rapidly generating new data, open data repositories are made accessible and increase discoverability; these are all supported and encouraged beyond national or disciplinary scales by intergovernmental structures such as GEOSS or INSPIRE, but also need to be quality controlled through transparent and objective approaches. The need for accurate representation and documentation of both data and interpretations is further increased in such circumstances due to the ever growing volume of data sets and increase degrees of separation between collection, collation, dissemination, and utilization.

New views on the Earth, local ecosystems, regional landscapes, even global biomes and related aspects, such as biodiversity and carbon cycles, are enabled through aggregating and revised interpretations of data. Global analyses can be run based on spatial information when combining numerous thematic layers covering varying extents with either climatic or topographic information or even with the human and anthropogenic influences. This aids in the realization of a spatio-temporal patterns that can hardly be seen at smaller scales and through interpretation of singular or fracture data sets. Efficient and flexible open-source algorithms can be adapted to individual ecological research questions or societal challenges and applied to the wealth of open data available the modern paradigm of discoverable, interpretable and reusable data.

Most fascinating is the speed and power of developments in the field of remote sensing, from the first attempts dating just some decades ago. Here, too, free and ease of access to the generated data from an increasing variety of sensors is a key driver. The European Copernicus program and its Sentinel satellite programme are a champion in this regard and a role model for the free access and discoverability of such data sets. Business concepts are encouraged to benefit from such data and support the implementation of solutions for the threats related to the rapid change in the environment and likewise detection of rapid responses to remediation and management techniques. High spatial resolution (in the scale of meters) and frequent replication (in the scale of days) of the screening across a multitude of active and passive sensors is creating data amounts that could hardly be handled by processing and storage capacities just a few years ago. Now, utilizing the scalability of computing and processing resources, there is the a potential and indeed a need to benefit from these outstanding developments, supporting an environmental positive shift for stakeholders and entire societies, by reducing the negative impacts of pollution, climate change and biodiversity loss. Adaptation and mitigation strategies can be designed for cost-effective and nature-based solutions.

Earth Observation efforts are blending *in-situ* measurements (including big data approaches) with remote sensing over a wide variety of spatial and temporal scales made available through data resolutions, thereby supporting long-term monitoring of the environment at both large and small scales. Such an approach requires the developing relationships between the spectral patterns observed by sensors from space to ecosystem characteristics and proxies for functions. Additionally, characteristics that are not uniquely observable from space, such as soil types, can be linked with in situ monitoring data sets, resulting in blended remote and in-situ data complementing one another to increase the capacity of both, in terms of capabilities and resolution. Such systems enable, for specifically identified and relevant issues, in almost real-time, spatial analyses to be efficiently implemented globally. For instance, the immediate and continued ramifications of the Central European drought which occurred in the summer 2018 can be spatially analysed according to the impact on different ecosystem types, including forests, agricultural fields, grasslands, as well as larger aggregations of such types defined as PAs and Natura2000 sites for example.

Finally, powerful tools exist for the management and synthesis of these many data sources, originating from different sensors and sampling methodologies, at varying temporal and spatial scales, existing in various levels of processing as either raw measurements or adapted using algorithms and corrections. Synthesis tools, such as data fusion or application of Big Data concepts, allow for the combination of such different qualities of information and also the unique perspectives for future trends each data set provides. Ecological modelling approaches, both process-based and also correlative, deliver new insights and improve our knowledge about the environment. Linking spatial information with simulations about future conditions, e.g. climate scenarios and the related global circulation models, based on projected representative concentration pathways (translated to CO2 equivalents), allows realizing the probabilities for future ecosystem states and functioning. Through such efforts, the potential impacts and risks resulting from such changes can be detected, or at the very least indicate regions and ecosystem functions that will come under increasing pressures and are susceptible to shifts or collapse. Such interpretations can allow for the prioritization of mitigation, adaptation, or management strategies which allow for the lowest uncertainties and the highest probable benefit. Novel open source approaches allow for the adaptability of such systems to be applied to many areas across the globe and can generate both timely and user-oriented data products.

In all these aspects, it is key to identify and, whenever possible, quantify uncertainties and scale-related challenges. Ecosystems display a large complexity of traits, processes, mechanisms, and aspects in general. Some being quite unique to a specific system, others of general importance. It is the fluxes, storage, and regulation of compounds (matter, nutrients, water, air etc.), energy (chemical and physical), and information (i.e. gene pool, behaviour, biodiversity etc.) what makes up the quality of ecosystems.

TO PRESERVE AND PROTECT NATURE AND NATURAL SYSTEMS FOR POSTERITY AND THE BENEFIT OF HUMANKIND

PURPOSE

Generate and make available remote sensing products that provide relevant information on the past and present state of selected ecosystems while deriving metrics indicative of change. This will be achieved based on the work conducted in EU H2020 Projects (ECOPOTENTIAL, SWOS, and others), global ELU/EMU mapping initiatives from USGS and Esri, and visual platforms on RS-GPS and Web-GIS (Chinese Academy of Forestry). Remote sensing products will be made available through the dedicated portals of the projects/activities involved in GEO ECO, and through a link to the system of GEO portals, thereby increasing the discoverability, re-usability, visibility of products developed through research funds as well as the tools utilized to produce and interpret them.

Foster the availability and accessibility of *in-situ* data on selected ecosystems, especially in PAs, to allow estimates of the state and changes of the ecosystems and their environment. This will be achieved by the activities carried out in EU projects (e.g. ECOPOTENTIAL, SWOS, EU BON), European research infrastructures (e.g. eLTER RI, LifeWatch ERIC) and the International Long-Term Ecological Research Network (ILTER). The data will be made available through a set of dedicated portals, associated with the different projects supporting GEO ECO. Such portal will be aggregated, and links made available through the GEO ECO webpage that is currently under development and expected to come online in late 2019.

Create and make available a Virtual Laboratory Platform for the use of ecosystem and ecosystem service models for selected cases, including future projections and the estimate of the associated uncertainties. This will be achieved through the activities of the EU H2020 ECOPOTENTIAL project and in synergy with LifeWatch ERIC.

Contribute to the creation of data/product/knowledge repositories and portals, compliant with GEO requirements and supporting the GEOSS portals, on the "Earth Living Skin" (Earth Critical Zone and upper ocean layers) where most geosphere-biosphere interactions take place. A series of training schools and workshops on specific aspects of geosphere-biosphere interactions have been and will be organized, in cooperation with international initiatives such as Critical Zone Exploration Network (CZEN), eLTER RI, LifeWatch ERIC, and national programs such as the CZO network and NEON in the USA.
Contribute to the definition of Essential Variables for Ecosystems, based upon the developments in several projects and initiatives such as GEO BON, H2020 ECOPOTENTIAL, ConnectinGEO, ERA-PLANET, H2020 E-SHAPE, EuroGEOSS, and other European and international projects and activities.

Create an Ecosystem Community of Practice (CoP) to determine the applied needs of stakeholders and help to guide the definition of research needs and approaches.

Relationship with GEO

The main point is to benefit from the wide and interdisciplinary GEO community, sharing the data, methods, and knowledge in a broader context. Including the GEO ECO products into the GEO portals would allow prolonged survival and extended usability of the results obtained during the finite-time projects that support GEO ECO (for example, ECOPOTENTIAL). Public dissemination of GEO ECO activities in the framework of GEO has allowed a wider interest and contribution to the Initiative. The extension of the approach to the international network of PAs has yet to be fully implemented. One of the challenges is the difficulty of pinpointing specific targets, as well as a sometimes redundant reporting system. One serious challenge is the voluntary, non-supported nature of the contribution to GEO. GEO should insist for the funding, by part of international agencies, of GEO-related activities. EU is currently supporting GEO-related activities with project calls that explicitly indicate the need for contributing to GEO. Also, GEO should probably set up more specific and well-defined targets.

Initiative Overarching Goals

Based on Earth Observation, GEO ECO is addressing the spatio-temporal scales of ecosystem processes, gathering information and monitoring long-term trends and producing knowledge about terrestrial and marine ecosystem status and the services they provide; thus enabling improved decision-making processes. GEO ECO has defined three overarching goals and associated objectives to realise its vision, to be reached through action on the tasks and challenges defined in the next section.

Goal I	Collate, generate, and synthesise knowledge on status and trends across different terrestrial and marine ecosystems.
Goal II	Forecast climate and global change impacts on ecosystem status, functioning and services.

Goal III Enable improved decision-making at local, regional, national, continental, and global scales.

Goal I focuses on collating, generating and synthesising knowledge on the status and trends of different terrestrial and marine ecosystems. There are many monitoring initiatives and approaches on how to monitor and assess ecosystems; some of them are more successful than others, therefore coming up with one improved approach would be ideal. By doing so, existing knowledge-gaps can be identified. This leads to the four following objectives of the first goal.

Goal I focuses on the following objectives:

Objective 1 - Determining best suitable typology for monitoring ecosystems.

Objective 2 - Map existing monitoring initiative, with emphasis on critical zone observatories, Long-Term Ecosystem Research sites and other *in-situ* networks.

Objective 3 - Identify knowledge gaps and develop funding and research opportunities to fill them, including addressing novel conceptual developments and enhance understanding of fundamental ecosystem processes and geosphere-biosphere interactions.

Objective 4 - Improve remote sensed methods and products to monitor ecosystems state, functioning and services at a global scale

Goal II focuses on forecasting climate and global change impacts on ecosystem status, functioning and services. Climate and how it is affecting and changing the environment and inevitably human behaviour and consumption (most resources are delivered by ecosystems) have gained more and more attention among policy and decision-makers.

Goal II focuses on the following objectives:

Objective 5 – Gain a better understanding of the current state and functioning of ecosystems with particular focus on their contribution to the maintenance of biodiversity, carbon sequestration, and resilience towards extreme climatic events.

Objective 6 – Projecting future changes of ecosystems based on GCMs and RCPs under consideration of big data on functional diversity, dispersal capabilities, and life cycles linking correlative and process-based models.

Objective 7 – Identifying the role of climatic fluctuations and non-linear ecosystem dynamics for state changes and quantifying sources of uncertainty in order to develop solid application-oriented approaches such as vulnerability estimates and risk assessments.

Goal III focuses on enabling improved decision making at local, regional, national, continental, and global scales for PAs. Many tools and data are available these days, but often they are not used to its full potential due to lack of knowledge or inconvenient application. Therefore, three objectives could be identified in order to achieve this goal.

Goal III focuses on the following objectives:

Objective 8 - Develop a scientific basis and tools for better ecosystem management under deep uncertainties

Objective 9 – Establish a Community of Practice with managers, decision-makers and Earth Observation scientists

Objective 10 – Integrate data, products, models, and knowledge into Open Access hubs allowing dissemination and innovation powered by GEOSS

Objective 11 – Engage, communicate with, and train practitioners to use state-of-art science from ongoing monitoring and Remote Sensing

Implementation Plan

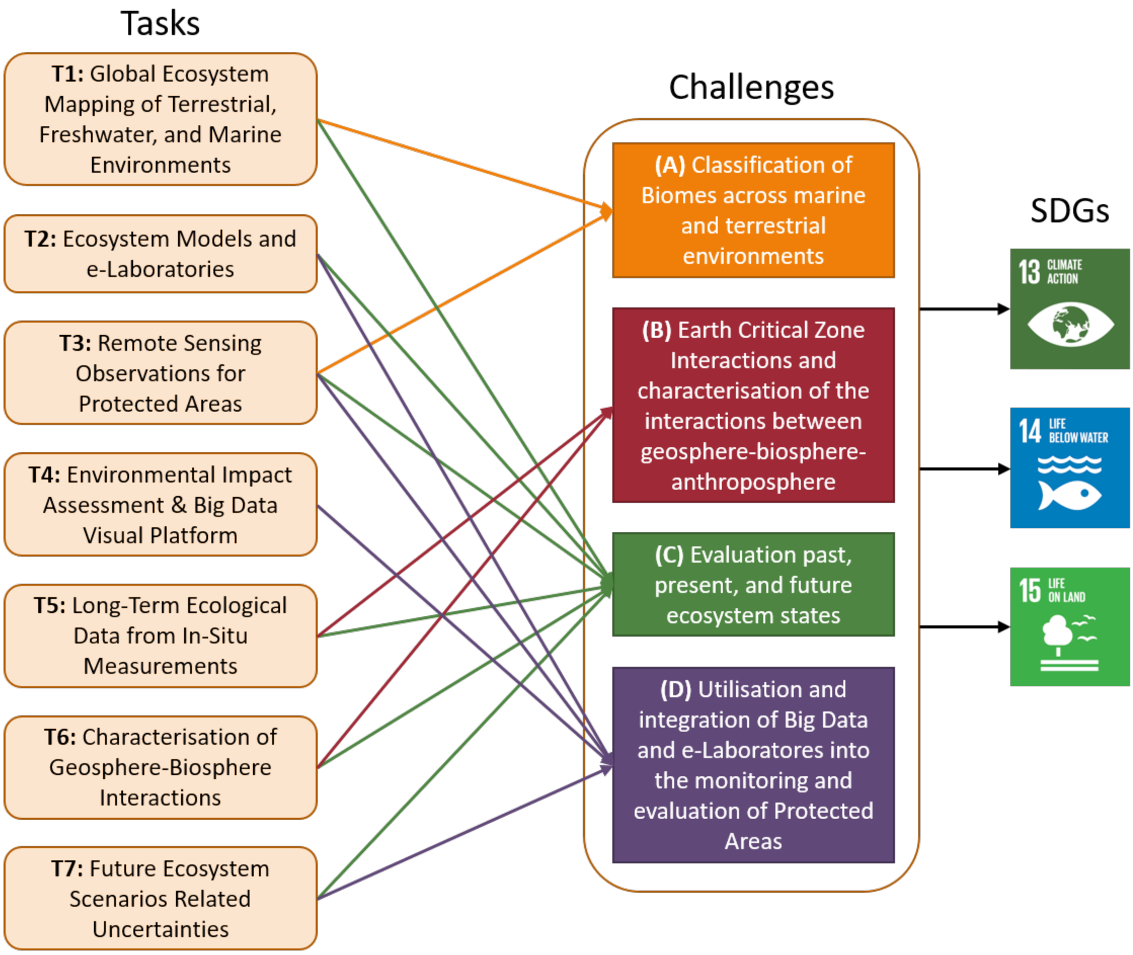
The following section deals with the primary implementation elements that address the objectives and goals of GEO ECO. Seven tasks were identified and formed seven working groups, respectively, for the coming period. These working groups are now devoted to address four main challenges, each from their perspective. Not all tasks address all four challenges but sometimes addressing only a specific challenge. These challenges will help to contribute to the different SDG goals.

Challenge A Identifying data-based terrestrial biomes as reference units at the global and continental scale which are not biased by a single criterion but cover the range of ecosystems and their processes, respectively.

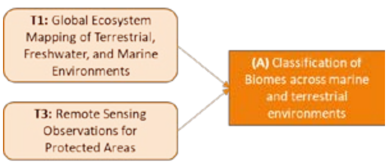
Challenge B Earth Critical Zone Interactions and the characterization of the fluxes of energy, matter and information between geosphere, biosphere and anthroposphere.

Challenge C Evaluation of past, present, and projected future ecosystem states, consequences for management actions.

Challenge D Utilisation and integration of Big Data and e-Laboratories into the monitoring and evaluation of PAs and Integration of uncertainty quantification across all elements to best support clear and accurate understanding of the ecosystem.

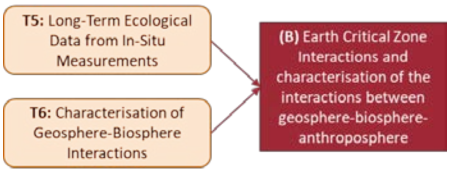


Challenge A



Biomes are large spatial units on the terrestrial earth surface. Semi-terrestrial ecosystems such as mangroves and limnic ecosystems such as rivers and lakes are part of the ecosystem composition of landscapes within biomes. Biomes exhibit a typical vegetation (formation) that is characterized by certain dominating plant functional types and the respective food webs, fauna, and microbiota that are adapted to the large-scale climatic conditions of biomes. Between biomes transition zones exist (ecotones) where aspects of neighbouring biomes are overlapping. Biomes are serving as reference areas for ecosystem development and biodiversity at the macro-scale. However, until today there is no generally accepted common ground as existing models are often biased by specific traits, either more ecosystem-oriented or more climatic-oriented. In GEO-ECO, we will develop a comprehensive approach that is based on big data on biotic and abiotic conditions. This approach will be compared with current patterns of land cover detected by earth observation in order to quantify deviation from expectation through direct human impact and large-scale trends in biome dynamics at the global scale. This reference will also serve as a basis for an efficient, flexible and sustainable network of protected areas independent from national bias.

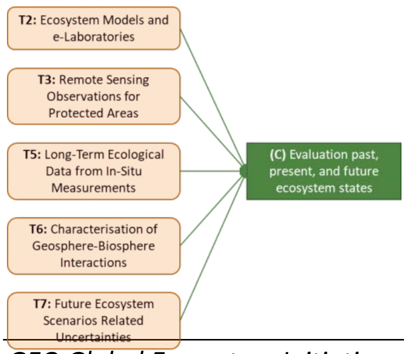
Challenge B



Ecosystems are characterized by the tight coupling of biotic and abiotic processes, with the physical, chemical and geological environment affecting the living components and, in turn, biotic processes influencing and sometimes controlling the environmental characteristics. Such two-way interaction between living and non-living components span all space and time scales, from the local action of "ecosystem engineers" such as beavers or desert shrubs to the processes of niche construction, to the global biogeochemical cycles. The same current composition of the atmosphere (notably, its oxygen content) is due to the action of the global ecosystem that about 2.5 billion years ago started to transform the surface environment from reducing to oxidizing. On top of these processes, in the last centuries, human activity has deeply altered most of the fluxes and balances operating in natural ecosystems, leading to what is now known as the "Anthropocene". The interactions between geosphere, biosphere, and anthroposphere are especially relevant when addressing conservation and management issues, which require a systemic approach and cannot cope with just one or a few species, a single characteristics of the ecosystem or a specific driver/threat. PAs are ideal places where to unravel some of these complex interactions, using both remote sensing information as well as the wealth of long-term *in-situ* data available in many PAs and/or ILTER sites.

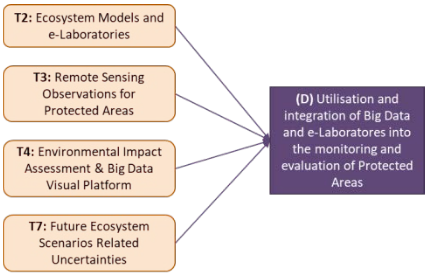
An especially interesting and important system where geosphere, biosphere, and anthroposphere interact almost inextricably is the Earth Critical Zone (ECZ). The ECZ is a heterogeneous environment at the Earth surface where chemical, physical, geological and biological processes interact with each other involving all environmental matrices such as rock, soils, water, air, and living organisms. The ECZ, also called the "living skin of the planet", is the transition zone between the atmosphere, vegetation, and the underground realm extending through the pedosphere into the unsaturated and saturate zone, and finally to the "undisturbed" bedrock. In the ECZ water, carbon, and energy cycles are tightly coupled with each other and determine exchanges of matter and energy throughout the terrestrial biosphere, providing essential ecosystem services such as water regulation and carbon sequestration. The study of ECZ is a multidisciplinary research arena where different scientific communities analyze a multiplicity of aspects (e.g., geochemistry, geology, hydrology, ecology) to unravel the workings of the support system of all terrestrial life and its response to human-induced disturbances. Such studies are based on field measurements, taken in a network of ECZ Observatories in the world (www.czen.org), remote sensing, and numerical modelling. In a sense, the ECZ is a prime example of the complex processes linking geosphere, biosphere, humans, and climate.

Challenge C



Several space programs, such as Landsat that was started in 1972, NOAA-AVHRR in 1981, and SPOT in 1986, have already been in orbit for more than 30 years. Several other programs are younger, e.g., SPOT-VEGETATION (1998) and MODIS (2000). In recent years, since 2014, the Sentinel space systems were launce and a variety of new images and products have been added to the Earth Observation arsenal. Characterized by many spectral regions, continuous and repeated acquisitions, the above-mentioned satellites are a source of valuable data that appears in a large variety of spatial scales (local, regional, national, continental, and global) and temporal scales (from minutes to days). Consequently, the data can be linked to ecosystem models at a range of spatial and temporal scales (Task 2). The temporal archives create a long time-series over the PA (Task 3) that might be applied to test, validate, or verify the predictions of ecological process models. Space images in conjunction with *in-situ* observations (Task 5) are used for characterizing geosphere-biosphere interactions (Task 6). Finally, the remotely sensed data can also be used for updating and/or adjusting the prediction of future ecological scenarios (Task 7).

Challenge D



In recent years, a vast amount of data from Earth Observations, such as satellite images, *in-situ* measurements, and model outputs, have become publicly available. Numerous providers and platforms offer different products; however, often this data is not understandable and usable for the end-user (i.e., PA managers, policy-makers). Monitoring and evaluating PAs is vital in order to determine the status of the ecosystem and to see if protective actions need to take place. Integrating the available data from numerous sources is a challenge; these are usually in different formats, and many programmes and software cannot handle big data.

Furthermore, it is important to accurately understand the ecosystem to make the right and most sustainable management decisions. As an ecosystem is a living system, uncertainty always plays a role. However, quantifying uncertainty is a challenge as there are many unknowns and different models have to be applied in order to come close to the real value. Tasks 2, 3, 4, and 7 have been identified to help address and solve this challenge.

Task 1: Global Ecosystem Mapping of Terrestrial, Freshwater, and Marine Environments

Task Leader: Roger Sayre, USGS

Standardised, robust, and practical mapping of global ecosystems for terrestrial, freshwater, and marine domains has been a core GEO ECO activity from the beginning. USGS, Esri, and a host of international experts have collaborated to produce first-of-their-kind, high-resolution maps of global ecological land units (ELUs), global ecological marine units (EMUs), and a new map of global islands. Mapping of global ecological coastal units (ECUs) and global ecological freshwater units (EFUs) is currently underway. Remote sensing is useful for mapping, verification, and monitoring of ecosystems at multiple scales, and enables updating of the distribution and condition of the ecosystems at different time intervals. High quality *in-situ* earth observation data is important for calibration and validation activities, thus need a coordination action on the designation of protocols for multiscale *in-situ* data collection.

Planned Events

- Participation in scientific conference and workshops

- Interfacing with national and global scale ecosystem initiatives

Current and Future Activities and Timeline

Regular task meetings take place to discuss the progress of the proposed activities. At the end of each year past activities are evaluated, new activities are developed and adjusted accordingly.

2020	2021	2022
Report on available earth observation missions suitable for mapping and the relevant scales along with the covered timespan	Focus on seagrass meadows ecosystem working on challenges and perspectives on how to achieve a global seagrass distribution map based on EO (Landsat/Sentinel)	

Task 2: Ecosystem Models and e-Laboratories

Task Leader: Ghada El Serafy, Deltares and Antonello Provenzale, CNR

Ecosystem models provide a context within which managerial actions and policy pathways can be tested and evaluated in terms of their impact on the ecological status and functioning of PAs and environments. Such models and e-laboratories utilise monitoring networks in order to enhance, calibrate, and/or validate the models themselves. The information provided by such efforts allows decision-makers and researchers to both glimpse at the potentialities of ecosystems while accounting for uncertainties.

Planned Events

- GEO Symposium
- Participate in GEO Plenary

Current and Future Activities and Timeline

Regular task meetings take place to discuss the progress of the proposed activities. At the end of each year, past activities are evaluated, new activities are developed and adjusted accordingly.

2020	2021	2022
Integration of VLAB with LifeWatch		
Updating and enhancement of existing modules in VLAB	→	→
Addition of new open source modules for remote sensing processing and ecological modelling	→	→

Task 3: Remote Sensing Observations for Protected Areas tools

Task Leader: Joan Maso, CREAF

Protected areas preserve natural ecosystems, and thus have a high intrinsic value for human societies. Remote sensing data acquired by Earth observation satellites (such as the European Sentinel fleet) is a game-changing technology that, for the first time, gives managers a comprehensive bird's-eye view of the geo-bio-physical variables that are regularly used to assess the status of their protected areas. The major advantage of this technology is that data acquisition can be performed continuously in space and time, allowing for a precise determination of the distribution of the trends in the whole region. GEO ECO builds up and offers the approach used in the European Horizon 2020 ECOPOTENTIAL project to other continents. Still the use of this data for the protected area managers need to be simplified and made more automatic. The GEO ECO Protected Areas from space portal and web service offers the possibility explore, combine and perform exploratory analysis on the data and study time series evolution. GEO ECO also explores the ingestion of the remote sensing data in a data cube easy to use for the protected areas.

Planned Events

- GEO Symposium
- Participate in GEO Plenary
- ESA Living planet presentations

Current and Future Activities and Timeline

Regular task meetings take place to discuss the progress of the proposed activities. At the end of each year past activities are evaluated, new activities are developed and adjusted accordingly.

2020	2021	2022
Identify analysis ready data remote sensing products and critical derived products that can be easy and automatically ingested in data cubes and map browsers	→	→
Support other continents in the preparation of RS data for protected areas	→	→
	Increase the number of tools for time series analysis in the map browser.	→

Task 4: Environmental Impact Assessment & Big Data Visual Platform

Task Leader: Mingyan Wang, CAF

As environmental monitoring systems expand, a need has been identified to harmonize, visualize, and share said information resources. Integration of monitoring equipment into a continuous online process while enhancing both existing and proposed equipment achieves governmental reporting and regulation standards and also benefits businesses striving towards reducing and remediating ecological impacts. Including an expanding pollutant list with heavy metals, volatile organic compounds, and others while expanding the upper and lower detection thresholds aims to provide a more robust and comprehensive reservoir of knowledge. Cloud computing services and analysis tools for monitoring and big data can help to improve the information database and support environmental protection and monitoring. EO data cubes are a promising solution to store, manage and analyse EO data and for users to interact with EO data.

Planned Events

Current and Future Activities and Timeline

Regular task meetings take place to discuss the progress of the proposed activities. At the end of each year, past activities are evaluated, new activities are developed and adjusted accordingly.

2020	2021	2022

Task 5: Long-Term Ecological Data from *In-Situ* Measurements

Task Leader: Johannes Peterseil, EAA

In-situ monitoring of drivers and effects of environmental change on ecosystems is important to understand processes and their long-term development. *In-situ* data are needed to develop models and calibrate them but also as an input to Earth Observation data flows. Efforts need to be taken to foster the implementation of the FAIR principles in order to facilitate open data provision. Providing sufficient metadata of the in-situ data, including information on provenance and data quality is a key aspect to these activities. The documentation of the observation sites provides important information on the observation context being of use for different user communities. The establishment of a common registry of long-term observation and experimentation sites as well as the linked datasets are the focus of future activities. This will enable the linkage of different observation networks. In the GEO context the site registry will be a major element of linking in-situ data observations to remote sensing data. Fostering the implementation of data services in the long run will enhance the interoperability and reusability of near-real-time in-situ data streams.

Planned Events

- Contribution to GEO Symposium
- Participation in GEO Plenary
- Interfacing with national and global scale long term observation programmes and networks
- Participation in scientific conferences and workshops

Current and Future Activities and Timeline

Regular task meetings take place to discuss the progress of the proposed activities. At the end of each year, past activities are evaluated, new activities are developed and adjusted accordingly.

2020	2021	2022
Interface with national, continental (e.g. ICP Forests, Natura2000) and global (e.g. ILTER) in-situ observation programmes and networks	→	→

Establish common catalogue of long term observation and experimentation facilities using DEIMS-SDR	→	→
	Identify Essential in-situ Observations for selected data workflows	
	Foster harmonisation and provision of metadata from large scale observation networks	
		Supporting interoperable access to selected in-situ data based on common requirements

Task 6: Characterization of Geosphere-Biosphere Interactions

Task Leader: Antonello Provenzale, CNR

GEO ECO adopts a complex system view where the Geosphere and Biosphere interact in a tightly coupled way across multiple space and time scales. Specific challenges addressed in GEO ECO concern the role of ecosystem engineers, the perturbations to biogeochemical cycles associated with global warming, and the spatial-temporal scales of ecosystem processes which control the fluxes of matter and energy in the ECZ. Global changes, including climate and land-use change, soil erosion and water/air pollution, affect the ECZ in many complex and potentially disrupting ways. Soil loss and degradation, modifications of water and carbon cycles, biodiversity loss and ecosystem disturbances are impacting the ECZ, potentially leading to a strong reduction in its ecosystem services provision. Specifically, in high-altitude mountain areas and polar regions, the ECZ is a thin but essential layer between ice, permafrost, rock and the atmosphere, and it is especially exposed to the dangers associated with environmental and climatic changes.

Planned Events

- GEO Symposium
- participate in GEO Plenary
- Organize summers schools on geosphere-biosphere interactions and ECZ dynamics

Current and Future Activities and Timeline

Regular task meetings take place to discuss the progress of the proposed activities. At the end of each year, past activities are evaluated, new activities are developed and adjusted accordingly.

2020	2021	2022
Link with other ECZ initiatives in the world, obtaining a global vision of current ECZ activities	→	→
Support the establishment of new ECZ observatories in	→	→

Protected Areas		
Support consideration of geosphere-biosphere interactions in virtual research environments such as LifeWatch ERIC	→	→
	Identify Essential Variables relevant to geosphere-biosphere interactions and ECZ dynamics	→
		Identify specific policy-relevant aspects of geosphere-biosphere interactions that need to be protected and properly managed to achieve SDGs

Task 7: Future Ecosystem Scenarios Related Uncertainties

Task Leader: Ghada El Serafy, Deltares

Within this initiative, it is critical to combine the various data sources on the current and potential future states of ecological systems. This includes the utilization of climate projections within process-based and statistical models as well as the development of policy pathway impact assessments so that stakeholders' and policymakers' can have a realistic idea of the impact resulting from their actions and decisions. This can be realized through implemented proposed and projected changes resultant of policy and planning with models in order to have ecological impact assessments available and representative of multiple pressures and influences placed on these systems.

Planned Events

- GEO Symposium
- GEO Plenary
- Workshop with AquaWatch

Current and Future Activities and Timeline

Regular task meetings take place to discuss the progress of the proposed activities. At the end of each year past activities are evaluated, new activities are developed and adjusted accordingly.

2020	2021	2022
Use the outcome and outputs of ECOP models and simulations to develop process-based and statistical models	→	→
	Development of policy pathway	→

	impact assessments	
Data assimilation and data fusion from different sources such as RS, *in-situ*, and model outputs	→	→

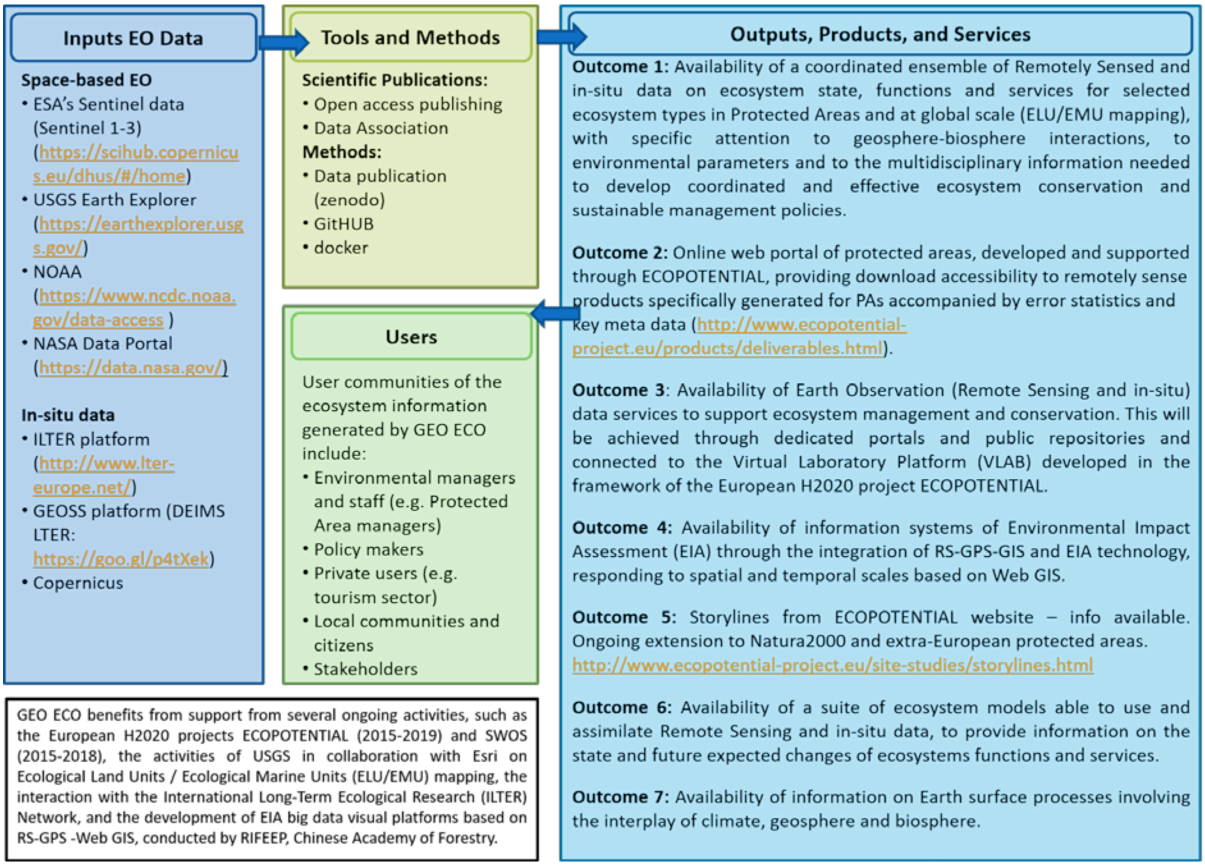
Data Policy and Data Flow

The initiative requires a wide range of remotely sensed data as well as *in-situ* monitoring data. The Sentinels including ILTER platform provision much of the RS data from both current and past satellite missions that can be beneficial to the GEO ECO Initiative. Some of this data have already been processed to higher level products through the initiative, which is relevant for application with the protected and vulnerable areas targeted through the initiative's work. Within the group, there is also an abundance of expertise on the processing and interpretation of remotely sensed data that allows for site-specific and enhanced processing of such data.

Furthermore, through close collaboration with the PA management and monitoring network staff, invaluable monitoring data can be accessed for many of the sites. The expansion of the CoP and inclusion of stakeholders on multiple levels, as described above, seeks to ensure that the relevant actors within protected and vulnerable areas collaborate and have a mutual outlook in respect to data, models, and needs, thereby mutually benefiting from the expertise across policy, management, remote sensing, modelling, and monitoring campaigns. As new areas are brought into the initiative, the inclusion of site-specific actors in the CoP and their databases will form the baseline of data accessible for new areas. Engagement with ongoing EU, national, and local projects and networks will bolster the amount of information and data which can be utilized. Furthermore, the ongoing activities of the Initiative, such as the land- and marine-use and classifications, amongst others, will continously iterate production to include new incoming, higher-resolution, and adapted data sets, maximizing the production potential.

The methods of data generation are well documented. When applicable, and not in direct conflict with existing IP rights, algorithms, methodologies and documents are freely shared to ensure reproducibility of the work as well as broad application of such data production methods to other sites, promoting transferability. In line with the aims of H2020 and EU funded projects, many of the data processing and analytic techniques used in affiliated projects such as ECOPOTENTIAL and SWOS are open-source and can be found in deliverables produced by these projects. Furthermore, the use of the Virtual Laboratory, as described above, takes these data processing techniques and makes them discoverable to a wider audience, while also decreasing the required technological skills required to utilize or engage with them. In this manner, a wider spectrum of end users will be able to make practical use of these data products, while those who can engage with and modify the algorithms are allowed to do so. It is envisioned that, by the burgeoning open data and open science mentality, algorithms, and data products, when possible, will be made public after quality assurances have been made. This may require addressing the limitation of liability for the data providers and product generators.

The GEO ECO initiative builds upon available Earth Observation data, results, and information, and use them on a global scale, identifying PAs of international relevance, extending the analysis to unprotected areas and adopting the view of **ecosystems as "one physical system" with their environment**, characterized by strong **geosphere-biosphere-anthroposphere interactions across multiple space and time scales**.



User and Protected Area Manager Engagement

User communities of the ecosystem information generated by GEO ECO include environmental (for example, Protected Area) managers, private users (for example, tourism companies), research communities, and citizens. In the proposed partnership, user communities are already involved. These include the Israel National Park Authority, the Gran Paradiso National Park in Italy, the Northern Limestone Park in Austria, amongst others. These partnerships have been strengthened during the ECOPOTENTIAL project. For this project, one of the aims was to contribute to the creation of an Ecosystem Community of Practice (CoP), composed by managers and staff of PAs, policy makers, local communities and other stakeholders, to determine the applied needs that should inform the research and data collection activities. This process started at the end of 2016, and a first implementation of the Ecosystem CoP was put in place before the end of 2017. Residential schools, workshops and web-based tutorials, including Webinars, have been and will be organised with the main aim of helping to practically use the data products and information made available by the GEO ECO Initiative. These connections are further developed and strengthened by this initiative.

Operating Environment

GEO ECO works on PAs, biodiversity, and ecosystem. Relevant international organizations include:

IUCN's Global Protected Area Programme and World Commission on Protected Areas (WCPA), the main global bodies which provide strategic guidance to national governments and others to plan PAs, investment in PAs and address challenging issues.

UNEP World Conservation Monitoring Centre (UNEP-WCMC) and IUCN-WCPA maintain the World Database on Protected Areas, the number of which reached 209,000 in 2014. The UNESCO World Nature Heritage and Ramsar Wetland sites are included in this list.

The **Convention on Biological Diversity** seeks to address all threats to biodiversity and ecosystem services through scientific assessments, the development of tools, incentives, and processes. Aichi Biodiversity Targets of CBD are the overarching framework on biodiversity for the UN System.

The **UN Statistical Commission** established the System of Environmental Economic Accounting (SEEA) that brings together economic and environmental information into a common framework and ecosystem is a major component of SEEA.

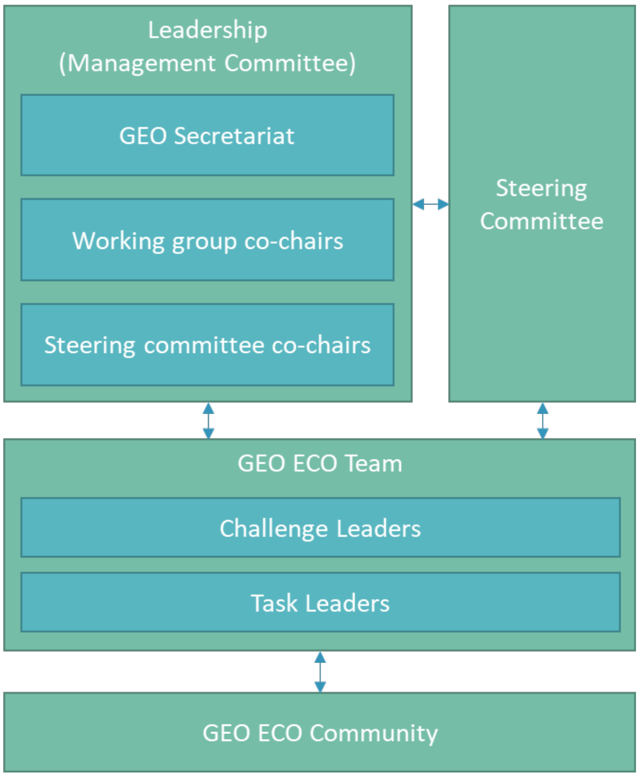
The use of Earth observation is being explored by these international organisations, as well as National Governments and Protected Area Management Authorities. The opportunity for GEO ECO is to generate and make available Earth observation products that provide relevant information on the past, present, and future state of selected ecosystems.

Governance

This section describes the overall management of GEO ECO that includes governance, internal communication, schedule, and evaluation. In this initiative, there are three active levels of involvement: Community, Team, and Leadership. The *Community* includes a broad range of people who are interested in the activities of GEO ECO, but who are not necessarily directly involved in the management of any of these activities. The *Team* includes the members who are directly involved in all GEO ECO activities. The *Leadership* is the core group of people who are leading and managing the GEO ECO initiative.

Till now, the overall direction of the initiative has been facilitated by CNR. This is supported through co-efforts mainly done by the Deltares team who co-leads the initiative, assists in the facilitation of virtual meetings, the composition of minutes, communication, generation of outreach materials, and dissemination of information both internally with the initiative members and with the public at large.

Regular virtual and face-to-face meetings are being organised, minutes distributed and actions divided.



Working Groups
The different working groups are part of the GEO ECO Team. As mentioned before, four challenges were identified which can constitute the working groups of the Initiative. These four working groups work closely together with the seven task leaders, who contribute to one or more of the working groups.

Steering Committee
The steering committee is currently being formed. The composition of such a steering committee would be of those who are outside of the current working group to facilitate a connection beyond those actively involved in the initiative and to ensure an unbiased fresh review of the activities and inner workings of the Initiative. To date, nominees for such a committee have been collected from the Initiative members. These nominees are in the process of being contacted to explain the prospective role ensure willingness to undertake such a position. It is expected that by the end of 2019, such a committee will be formally arranged.

Internal Communication
Regular core team teleconferences take place to review the current status and progress of all GEO ECO activities. Task leaders are required to attend these meetings. They will also provide routine status reports and identify new topics and opportunities.

A face-to-face meeting takes place annually for all members of the GEO ECO initiative. During this meeting, the initiative is reviewed in depth and spends some time on evaluating the initiative. This is meetings also serves as a platform to address resolve major issues requiring longer discussions than the regular teleconferences. If needed, GEO ECO and its standing bodies arrange in-person meetings in conjunction with major GEO events, such as the GEO Plenary and the GEO Symposium. If possible, these meetings are transmitted to members who are not present at the event.

Evaluation

The annual meeting and its preparation serve as the primary event for the Leadership, Team, and Community to reflect on the Initiative. Its progress, challenges, and direction are discussed and reviewed. All attendees review activities, assesses progress and performance, discuss successes, as well as items that did not go as planned.

During the event the formulation of the functional and performance requirements for GEO ECO are evaluated and whether they are in line with GEO objectives, and revise targets and schedule for the upcoming year. A key decision for each annual meeting is the status of the Initiative and whether to recommend changes to the GEO Programme Board. All bodies involved also conduct evaluations on their respective functions and report at periodic teleconferences as well as the annual meeting.

Resources

GEO ECO benefits from support by several ongoing activities, such as the European H2020 projects ECOPOTENTIAL (2015-2019) and SWOS (2015-2018), the activities of USGS in collaboration with Esri on Ecological Land Units / Ecological Marine Units (ELU/EMU) mapping, the interaction with the International Long-Term Ecological Research (ILTER) Network, and the development of EIA big data visual platforms based on RS-GPS -Web GIS, conducted by RIFEEP, Chinese Academy of Forestry.
At the moment, funding is secured by

- EU H2020 project E-Shape (about 15MEuro in the period 2019-2021)
- EU H2020 project ECOPOTENTIAL (about 16 MEuro in the period 2015-2019)
- EU H2020 project SWOS (about 5 MEuro in the period 2015-2018)
- The Italian Infrastructural project LifeWatch Plus (about 8 MEuro in the period 2019-2023)
- In-kind and cash contributions for ELU/EMU mapping at USGS and Esri
- In-kind and cash contributions for the activities on EIA big data visual platform based on RS-GPS -Web GIS by the Chinese Academy of Forestry
- In-kind contribution from Deltares

Past Activities

GEO ECO has made use of the knowledge and data gathered through the EU-funded projects ECOPOTENTIAL and SWOS.

SWOS - Satellite-based Wetland Observation Service

The objective of the project SWOS is to develop a monitoring and information service focussing on wetland ecosystems. Globally wetlands are the ecosystems with the highest rate of loss. This is alarming, considering their significance as biodiversity hotspots and ecosystems with a central role in the water cycle, including improving water quality and reducing water scarcity, in climate regulation and the economic benefit gained from using their services. A key limitation to their more effective conservation, sustainable management and restoration is the missing knowledge underpinning the consideration of wetlands in the implementation of key policy areas. Under the Biodiversity Strategy, the Member States in Europe have committed to the mapping and assessment of ecosystem services (MAES); this provides a key instrument for improved integration of wetlands in European policy.

SWOS is taking full advantage of the new and freely available data from the Sentinel satellites and integrating results from the ESA Globwetland and other projects. Production of maps and indicators, based on historical and current observations allow the assessment of biodiversity and monitoring of dynamic changes in an unmatched temporal and spatial resolution.

The SWOS Portal provides a unique entry point to locate, access and connect existing information. The SWOS Software toolbox GEOclassifier is an easy to use software toolbox to prepare maps and calculate indicators. With its Portal and toolbox SWOS contributes to establishing a Global Wetland Observing System (GWOS) (requested by Ramsar) by delivering the initial infrastructure.

User organisations working at all levels from local to global belong to the SWOS project team and build, together with external user organisations, the key user group of SWOS. User needs were captured through user requirements questionnaires and follow-up discussions and translated into technical requirements for the definition of SWOS products (maps and indicators). The services that SWOS provides facilitate local and EU monitoring tasks and support international reporting obligations. SWOS positions Europe in a leading role within GEO, in particular via the new GEO-Wetlands initiative. SWOS took a leading role from the beginning and is the main contributor. The Service Cases, developed in SWOS, put the SWOS into practice, test and validate the service and demonstrate how to use and benefit from it. The direct involvement of users ensures the usability and acceptance of the service, including harmonization with related activities, which provides a long-term impact.

ECOPOTENTIAL – Improving Future Ecosystem Benefits Through Earth Observation

Healthy ecosystems provide essential goods and services to human societies and are of central importance for meeting the Sustainable Development Goals (SDGs). However, anthropogenic pressures cause severe threats to ecosystem integrity, functions, and processes, potentially leading to the loss of ecosystem services - the benefits ecosystems provide to humankind. PAs, in particular, represent a crucial component of the natural capital and provide ecosystem services that are often unavailable in the surrounding regions.

Proper management and conservation actions require the quantitative knowledge of the state and changes taking place in ecosystems. Recent advances in Earth Observation (Remote Sensing and *in-situ* measurements) offer new opportunities to monitor ecosystem functions, processes and services, and the pressures they face. ECOPOTENTIAL focuses its activities and pilot actions on a targeted set of internationally recognized PAs, including mountain, arid and semiarid, and coastal and marine ecosystems.

The project aims to deliver products of Earth Observation data to understand and monitor ongoing changes in ecosystems and support effective management of PAs.

ECOPOTENTIAL also intends to quantitatively assess the future expected changes in ecosystems and ecosystem services. To achieve this goal, the project develops and implements climate and ecological models able to generate future ecosystem projections and with the ability to estimate the uncertainties on the projections. The project will consider changes in provisioning, regulating and cultural ecosystem services, while taking into consideration policy developments, including citizen science activities and implementing capacity building and outreach activities in close connection with the PAs personnel.

All data, model results, and acquired knowledge will be made available on common and open platforms that will be contributing to the Global Earth Observation System of Systems (GEOSS) and will be fully interoperable with the GEOSS Common Infrastructure (GCI). In this way, ECOPOTENTIAL will benefit different communities, scientists, Protected Area managers, and citizens.

GEO ECO is a relatively new initiative, and therefore only a couple of face-to-face meetings have taken place. Regular virtual meetings have been set up. In order to increase this initiative visibility, a detailed brochure and flyer have been created. These were distributed during the GEO Plenary in Kyoto, Japan in October 2018.