European long-term ecosystem, critical zone and socio-ecological systems research infrastructure PLUS

Discussion paper on eLTER Standard Observations (eLTER SOs)

Deliverable D3.1

5th March 2021

Editorial team:

Steffen Zacharias[1], Saku Anttila[2], Jaana Bäck[3], Kristin Böttcher[2], Ulf Mallast[1], Michael Mirtl[1], Marcus Schaub[4], Volodymyr Trotsiuk[4],

[1] *UFZ Helmholtz Centre for Environmental Research, Germany*

[2] *Finnish Environment Institute, Finland*

[3] *Department of Forest Sciences, University of Helsinki, Finland*

[4] *Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland*

Contributing authors:

Roland Baatz, Ilona Bärlund, Mario Brauns, Ricardo Díaz-Delgado, Jan Dick, Thomas Dirnböck, Martyn Futter, Peter Haase, Ingolf Kühn, Christin Müller, Nikolaos Nikolaidis, Daniel Orenstein, Alessandra Pugnetti, Karsten Rinke, Christian Siebert, Ute Skiba, Harry Vereecken, Joana Vicente

Prepared under contract from the European Commission

Grant agreement No. 871128

EU Horizon 2020 Research and Innovation action

Project acronym:	**eLTER PLUS**
Project full title:	**European Long-Term Ecosystem, critical zone and socio-ecological systems Research Infrastructure PLUS**
Start of the project:	Feb 2020
Duration:	60 months
Project coordinator:	Professor Jaana Bäck University of Helsinki, Finland https://www.lter-europe.net/projects/elter-plus

Deliverable title:	Discussion paper on eLTER Standard Observations (eLTER SOs)
Deliverable n°:	D3.1
Nature of the deliverable:	[Other]
Dissemination level:	[Public]

Citation:	Zacharias, S. et al. (2021). *Discussion paper on eLTER Standard Observations (eLTER SOs)*. Deliverable D3.1 EU Horizon 2020 eLTER PLUS Project, Grant agreement No. 871128.

Deliverable status:

Version	Status	Date	Author(s)
3.0	Final	5th Mar 2021	As listed in the authors list
3.1	Final, corrected	19th Apr 2021	As listed in the authors list

Table of contents

Preface

The manifold interactions of society with the environment, changes in the climate system and changes in land use generate diverse and long-term effects on ecosystems, which result in novel global environmental risks and, consequently, new scientific challenges. To enable science to provide adequate answers to these Grand Challenges, a comprehensive understanding of environmental processes and the interplay between the social drivers and the responses of the environmental system and associated feedback is needed. While today's research landscape is mostly fragmented according to scientific discipline and environmental domain boundaries, a holistic approach towards capturing environmental conditions and guiding integrative research by means of integrated observation is urgently needed to understand global issues, and find solutions to grand challenges based on ecosystem processes and biogeochemical cycles. The development and advancement of integrated observation systems is a crucial prerequisite to promote inter- and transdisciplinary research and is one of the today's Grand Challenges of Earth system sciences for global sustainability (Reid et al., 2010). It is also defined as one of the societal challenges of the European Commission for Europe 2020 - Development of comprehensive and sustainable global environmental observation and information systems (EC, 2017).

Understanding the multiple effects of global change on major European ecosystems, critical zone and socio-ecological systems requires an appropriately configured research infrastructure such as the eLTER RI, where scientists and research communities collaborate with policy makers and wider society across domains over the long-term at whole system research sites and platforms. The unifying approach for the elements and construction of the eLTER RI therefore rests on four conceptual pillars:

- Long-term: eLTER RI aims to collect, record, synthesize and make available information that documents the long-term development of ecosystems
- In-Situ: eLTER RI aims to collect and make available data on different spatial scales and for different ecosystem compartments of individual in-natura sites
- Process orientation: eLTER RI aims to identify and quantify interactions of ecosystem processes affected by external and internal drivers
- Whole System Approach: eLTER RI aims to provide a comprehensive description of the whole ecosystem including ecosystem processes, cycles, and human interactions.

The new challenges facing science today are accompanied by new and constantly growing demands on the design of environmental observations and environmental monitoring technologies (GCOS, 2010; Hari et al., 2016; Lawford, 2014; Mollenhauer et al., 2018; Reid et al., 2010; Shapiro et al., 2010; Zoback, 2001). The mission of eLTER is to enable outstanding, high impact research on the diverse and interacting effects of climate change, biodiversity loss, pollution, and unsustainable resource use across Europe`s terrestrial and freshwater ecosystems (incl. transitional waters). The central objectives of the eLTER RI Design are (i) to support excellent science by making comprehensive environmental data available and improving its accessibility and utility and (ii) to provide the most representative coverage possible of the major biogeographical and socio-ecological regions of Europe.

The number of LTER sites and LTSER platforms within each of the 26 national LTER networks in Europe vary significantly as a result of different approaches in developing the site networks. The entire LTER-Europe network consists of more than 450 formally accredited LTER Sites for ecosystem research and 35 LTSER Platforms for socio-ecological research (https://deims.org/). Several of these observatories are also designated Critical Zone (CZ) sites and are partners in various CZ projects or networks. Each of the sites and platforms represents different levels of infrastructural developments and the majority of their current research activities covers smaller spatial scales like plot or field scale or single research stations. Transforming these structures into a continental, harmonised, inter- and transdisciplinary research infrastructure is the central goal of the eLTER Preparatory Phase Project (eLTER PPP) and the eLTER PLUS project. To achieve the design goals, a hierarchical concept of site categories will be established, consisting of a set of observatories designed for the operational capacity and comprehensiveness (master sites) and a larger number of sites which are either less instrumented and/or focused on specific ecosystem compartments (satellite, regular and focal sites). The combination of intensively instrumented sites with research sites of more basic instrumentation will make it possible to significantly increase the density of sites in the eLTER RI, thereby increasing the spatial and temporal coverage and targeted geographical representativeness. The establishment of a standardised and harmonised design is the central prerequisite for the exchange of data between sites. This concerns both the geographical distribution of the study sites and, above all, the monitoring concept, i.e. the type and scope of environmental variables to be recorded and the methodology to be applied. Cross-site and cross-biome compliant standardized eLTER RI observations will enable the integration of measurements from plot to continental scales as required to address the eLTER Research Challenges.

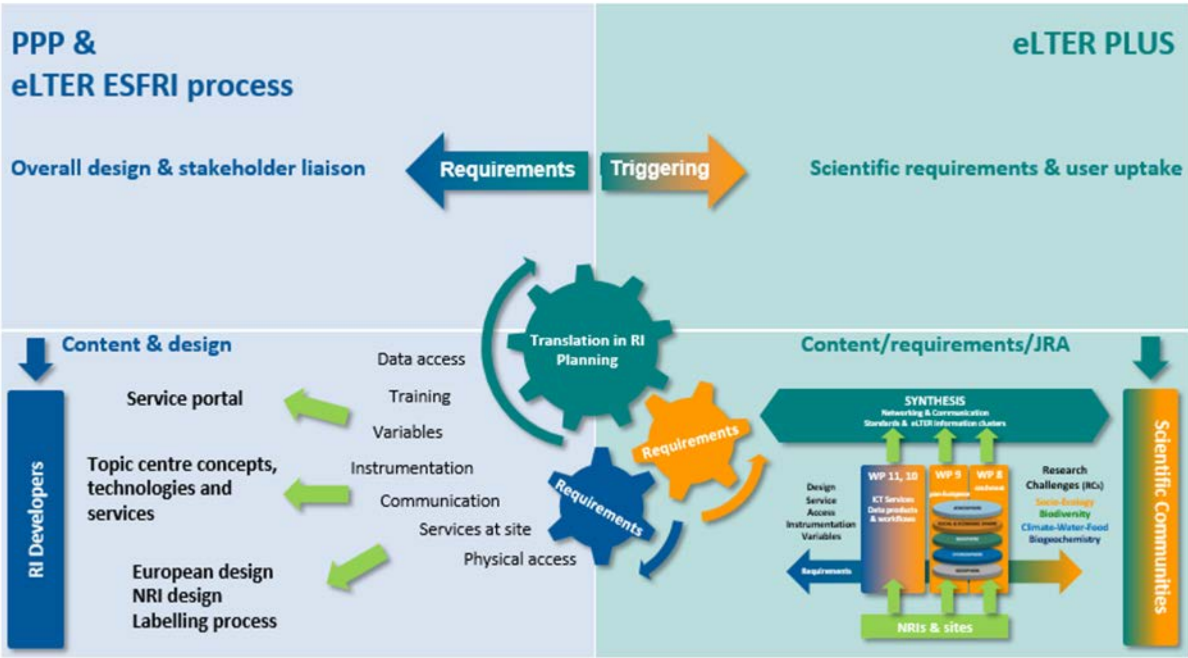

Figure 1: The links between the eLTER PPP and the eLTER PLUS project

The main objective of eLTER PPP is to prepare for the implementation and operation of the eLTER RI by coordinating all required planning and specification needed for the formal decision making. This includes the development of the operational framework and technical requirements as the cornerstones for quantifying the resources needed to construct and operate the eLTER RI. The resource demand is significantly influenced by the specifications regarding the mandatory monitoring programme and the measurement standards. A sustainable implementation of the network design and associated measurement protocols can only succeed if both are developed with close consideration of the user perspective. The eLTER PLUS project meets this challenge. As an Advanced Communities project, eLTER PLUS integrates the European ecosystem, critical zone and socio-ecological scientific user communities in order to allow for joint development of capacity building at eLTER RI sites and via the innovative services they offer. Within eLTER PLUS, WP3 focuses on the ‘interoperability of eLTER Standard Observation variables’. Central tasks of WP3 are the (i) development of recommendations of key variables, (ii) identification of in-situ design needs from the perspective of remote sensing applications, (iii) development of a concept for the harmonisation of methods and protocols, taking into account the concepts of other, already established RIs and networks. These objective are the essential justification for the formalising decisions to be taken in the eLTER PPP regarding network design at the European level and at the level of national research infrastructures (NRIs) (Figure 1).

This report provides a detailed overview of the current state of discussion on the "eLTER Framework of Standard Observations" within the eLTER PLUS project. It is one of the essential information bases for the development of an initial cost model for eLTER RI (see WP4 in eLTER PPP) and is an important reference for the national eLTER ESFRI processes towards the future National Research Infrastructures (NRIs) as major building blocks of eLTER RI. Therefore, national RI requirements will need to be duly considered in the iterative specification process.

1 eLTER and the process for defining Standard Observations

1.1 Standard Observations

Based on eLTER's whole system approach, the WAILS concept, the eLTER Standard Observations (SO) will include the minimum set of variables as well as the associated method protocols that can characterize adequately the state and future trends of the Earth systems. SOs should be able to determine the system's state and development and, furthermore, have a high impact, high feasibility, relatively low cost of implementation and sufficient spatiotemporal coverage (Masó et al., 2020; Reyers et al., 2017). We are, however, mindful of the comment by Werner Heisenberg "what we observe is not nature in itself but nature exposed to our method of questioning," (Gleiser, 2018) and thus recognise the need for trade-offs. The more specific requirements for the SOs are an ability to characterize an environmental system or process that can be generated and archived in an affordable way, relying on coordinated observation systems and proven current technology (Guerra et al., 2017). SOs can be seen also as a part of the harmonization process providing most critical information from the diverse primary observations in a standard format. In this sense, SOs have a number of commonalities with definitions of Essential Variables as developed in various scientific disciplines (see further exemplary references below). On the one hand, they take into account the academic-scientific perspective on the most comprehensive description of states and fluxes possible in the environmental system under consideration, as is also reflected in concepts of Essential Variables. On the other hand, however, the definition is aligned with the design of the eLTER RI by considering aspects of cost-effectiveness and operative feasibility, as preconditions in the consideration of methods and protocols (Figure 2).

To make best use of the SOs, a clearly defined standardisation and harmonization process must be developed. It is one of the important RI (like eLTER) roles to harmonize how data are collected and provide a unified model of interaction with those data. Standardization and harmonization concepts are both related to assessment and monitoring programs and aim to bring observational data together. Harmonization can be seen as a 'bottom up' methodological approach that aims to systematize the process of combining individual data that are collected in several observational networks at e.g. national level (Köhl et al., 2000). Combining data will increase sample size, but the quality of the harmonized result is only as high as the quality of the individual data sets and the comparability of the methods and protocols used. In contrast, standardization can be interpreted as a 'top-down approach', seeking to define common standards that can be later applied within different networks or RIs. Harmonization differs from standardization in that it does not impose a single methodology or norm, but rather seeks to find ways of integrating information gathered through disparate methodologies. The principal is to find pragmatic ways of making compatible and integrable datasets which have been collected for different purposes under different collection regimes, and using different standards and methodologies (GCOS, 2010). This means avoiding the need to convert all the data to a single standard, but rather finding ways to make it usable at some higher level of aggregation or generalization.

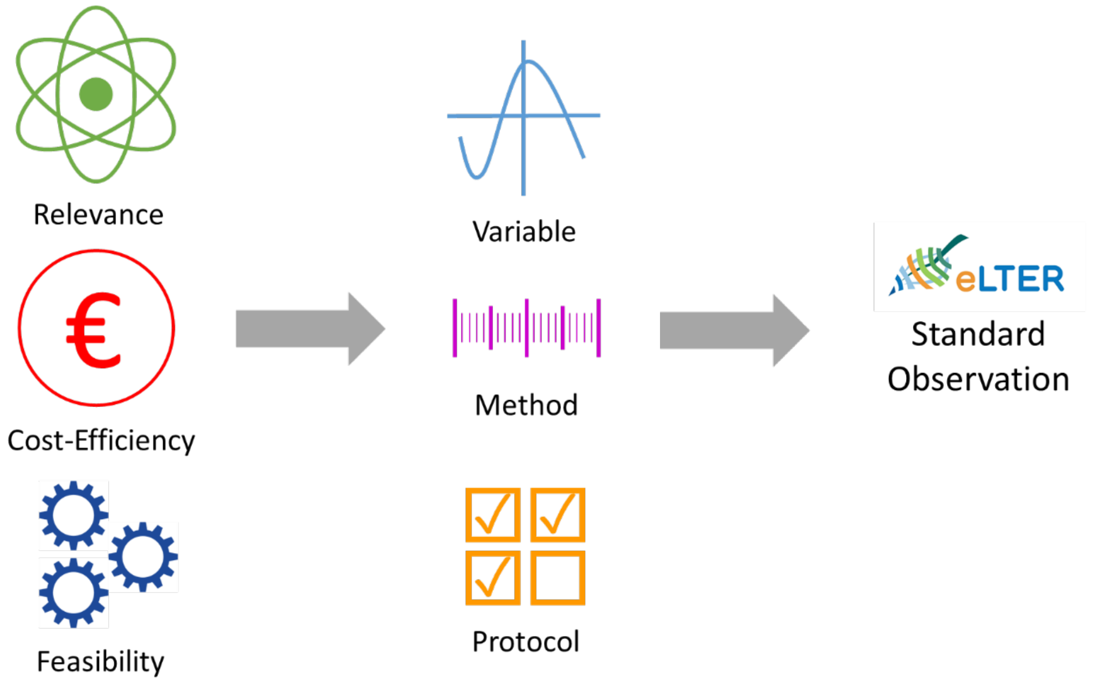

Figure 2: Definition of Standard Observations (variable + method + protocol) based on consideration of scientific relevance, cost and operative feasibility.

As part of the development of the eLTER SOs, an analysis was carried out to identify and compare research platforms and associated concepts that have already been realized and which have previously initiated the development of a minimum set of standard variables within their research domain. This information is crucial to identify conceptual interfaces with other networks and thus potentials for international and cross-network harmonisation. Pioneering work can be attributed to the development of definitions for Essential variables required for weather forecasting as early as 1850 (Masó et al., 2020). These definitions were to a larger extent later incorporated into Essential Climate variables (Bojinski et al., 2014). More recently, there was also progress in developing Essential Ocean variables (Miloslavich et al., 2018) and Essential Biodiversity variables. This list is not complete, and is continuously developing with the addition of new domains and networks (Patias et al., 2019).

1.2 Overall concept

Biodiversity loss, eutrophication, climate and land use change and related societal impacts are among the Grand Challenges addressed by eLTER RI. These processes influence the Earth system in an unprecedented way and a thorough understanding of the underlying interactions between physical, chemical and geological processes is an indispensable prerequisite for adequately addressing these Grand Challenges. Long-term forecasting of ecological developments is the order of the day. Understanding the multiple effects of global change on European major ecosystems and socio-ecological systems requires an appropriately configured research infrastructure such as the eLTER RI, where scientists and research communities collaborate across domains in the long term at whole system research sites and platforms. This requires sustained investment to improve our ability to observe the long-term evolution of the coupled biotic-abiotic and the coupled social-biophysical system.

The design of the eLTER RI is guided by two overarching scientific concepts, applicable from point to continental scales: the Press Pulse Dynamic Model (PPD) (Collins et al., 2011) as its horizontal component, and the spatially-nested hierarchical feedback paradigm of Macrosystems Ecology (MSE) (Heffernan et al., 2014) as its vertical component (Figure 3). While the PPD scheme identifies fundamental linkages between the social and the biophysical spheres at the "system level", the MSE scheme provides a unifying framework for the holistic study of ecosystems across different spatial and temporal scales. This cross-scale ambition is taken into account by the fifth conceptual pillar of the eLTER RI design - Wide-scale systematic coverage of major terrestrial and aquatic environments in Europe.

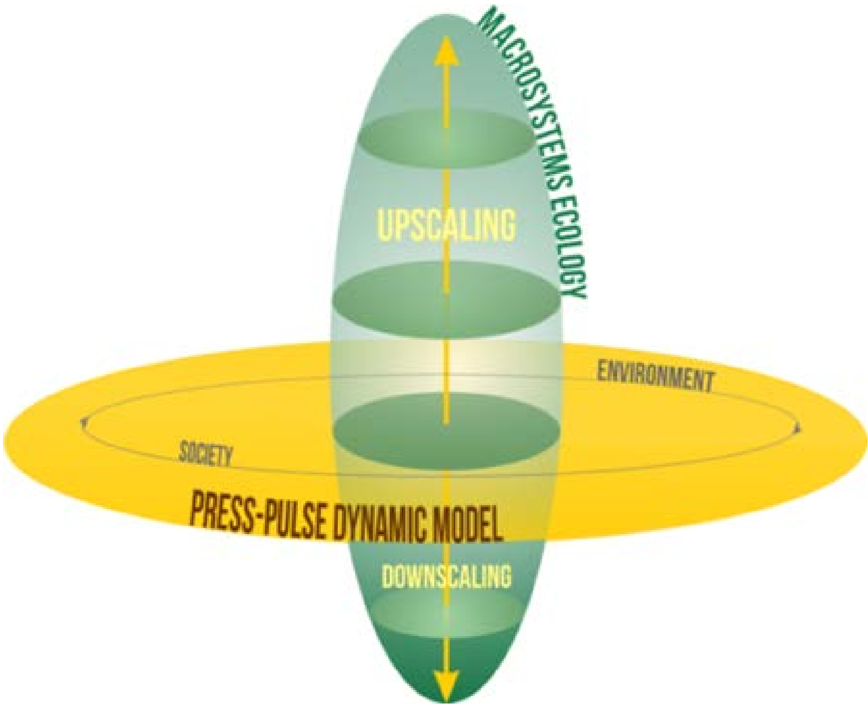

Figure 3: Schematic representation of eLTER's Whole-system Approach (WAILS, Mirtl et al., 2021 in preparation)

European LTER Sites, LTSER Platforms, critical zone observatories, and national networks are heterogeneous in terms of the investigated ecosystem type, scale of investigation, complexity and instrumentation. Individual sites measure a wide range of biotic and abiotic variables according to site-specific requirements (the site´s "ecological profile") and often follow site-specific standards for instrumentation and protocols. Standardization and harmonization, the definition of measurement programs consisting of a defined set of variables and associated methods and protocols - the eLTER Standard Observations - are the key to development of a high-performance, complementary, and interoperable ecosystem research infrastructure.

The development of the eLTER SOs demands translation of the scientific agenda of eLTER RI into a framework of requirements for the observatories and the actual design. A conceptual approach than can help to guide this translation process is the Ecosystem Integrity (EI) Concept (Haase et al., 2018; Müller et al., 2000). The idea of EI is to assess the complexity and ability for self-organisation of an ecosystem in order to safeguard sustainability in terms of functions, processes and related ecosystem services. The EI concept provides a holistic approach to ecosystem assessment biotic and abiotic fluxes and states. Following the EI concept, the ecosystem should be covered at the process level by describing energy, water, and matter budgets as well as the abiotic and biotic heterogeneity. With this approach, the EI concept fits very well into the WAILS scientific perspective and can be used to structure the process of selecting variables for the eLTER SOs. In detail, the SOs should fulfil the following criteria:

- Representation of key elements of the Ecosystem Integrity Concept
- Critical relevance for understanding the coupled human-nature system
- High sensitivity to environmental changes
- Critical relevance for environmental modelling

These four criteria determine and describe the impact of the SOs, while the eLTER RI science case is the foundation for the selection of the SOs. The four major research challenges of eLTER RI are intentionally linked with the selection of SOs in concrete, exemplary case studies in the eLTER PLUS work packages 8 and 9, which are, respectively, "eLTER Whole System Approach at site and catchment scale" and "Optimisation of the eLTER Network design at the pan-European scale". The research questions formulated there formed the basis for the first selection of SOs presented in this report.

A key challenge for the design of the eLTER RI, which must also be taken into account when selecting and defining the eLTER SOs, is to ensure a balance between academic flexibility (research) and service (e.g. routine measurements, data provision). eLTER RI will generate information that will be accessible to a wide range of stakeholders, including e.g., scientific users and environmental decision makers. This service is challenged by the fact that the operation of the observatories must be ensured by institutional research facilities and is embedded in the respective research agendas of these institutions and their funding bodies. The more complex the design and the more comprehensive the requirements for operating an observatory, the more challenging and difficult it becomes to ensure long-term operation.

Another criterion that must be taken into account, especially when defining methods and protocols for measuring variables, is coordination with other existing RIs and existing standards (e.g. ICOS, WMO, UNECE ICPs such as Forest, Waters, and Integrated Monitoring). Harmonisation of methods and protocols with other networks and initiatives is another essential key for improving synergies, increasing scientific impact, and catalyzing international scientific networking.

1.3 Process

The framework of eLTER SOs will include all variables, methods, and protocols that are defined as of priority in the sense of eLTER. The eLTER Standard Observations (eLTER SOs) are one of the central gears in the process of developing the eLTER RI. The selection of SOs are critical decisions for the design of the network and the services eLTER RI will provide. SOs drive costs in a decisive way and are therefore one of the critical key points for both the scientific decisions and the formal decision-making processes up to the Interim Council.

The process of developing the eLTER SOs has a long history. Its beginning lies in the eLTER H2020 and Advanced_eLTER projects and a first concretisation of the concept was part of the eLTER-application for the ESFRI-Roadmap. With the start of the eLTER Preparatory Phase Project (eLTER PPP) and the Advanced Community Project eLTER PLUS, we took on the task of continuing the process of standardisation and preparing the basis for formalised decisions regarding standardisation.

The main objective of the eLTER PPP in the context of the eLTER SOs is:

- to prepare for the implementation and operation of the eLTER RI by coordinating all required planning and specification needed for the formal decision making.
- to develop the operational framework and technical requirements as the cornerstones for quantifying the resources needed to construct and operate the eLTER RI.
- specify the resource demand, which is significantly influenced by the specifications regarding the mandatory monitoring program and the measurement standards.

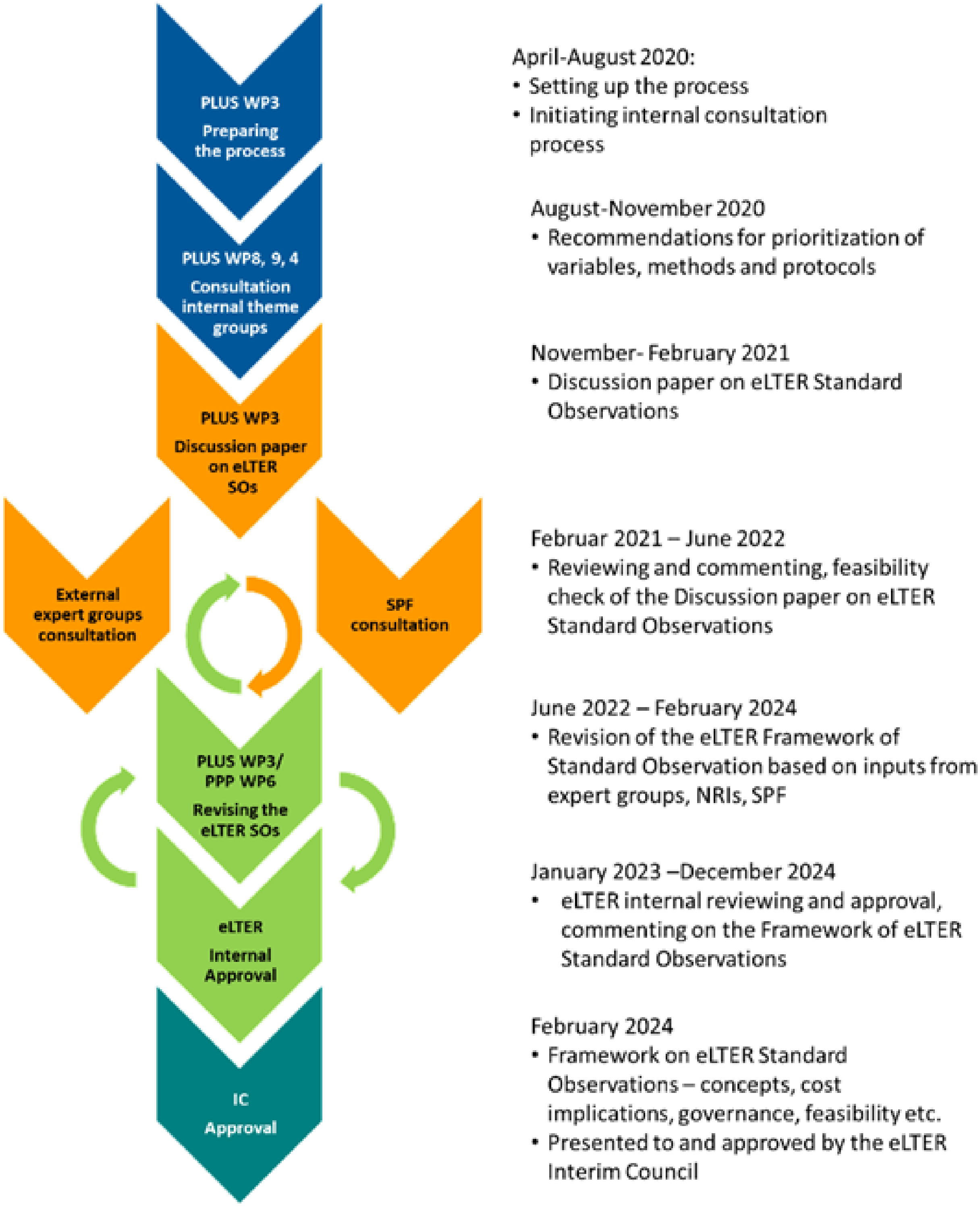

Figure 4: The process towards the eLTER Framework of Standard Observations

A sustainable implementation of the network design and associated measurement protocols can only succeed if both are developed with close consideration of the users' perspectives. The eLTER PLUS project meets this challenge as follows:

- It integrates the European ecosystem, critical zone and socio-ecological scientific user communities in order to allow the joint development of capacity building at the eLTER RI sites and platforms and through the development and provision of innovative services.
- eLTER PLUS WP3 focuses on the 'interoperability of eLTER Standard Observation variables'.
- It develops recommendations for key variables, methods and protocols.
- It identifies in-situ design needs from the perspective of remote sensing applications.
- It develops a concept for the harmonisation of methods and protocols, taking into account the concepts of other, already established RIs and networks.

These results from eLTER PLUS create the foundation for formalising decisions to be taken in the eLTER PPP regarding network design at the European level and at the level of NRIs.

A multi-stage procedure, culminating in a list agreed upon by all relevant stakeholders was developed. This procedure is composed of three main stages:

- Step 1: prioritization into two groups: "very high priority" and "high priority, but need for further discussion" - February 2021
- Step 2: collecting feedback from the scientific communities, from the National Research Infrastructures (NRIs) and the Sites-and-Platforms Forum (SPF), from the remote sensing data product providers - 2021/2022
- Step 3: providing a d efinition of the eLTER framework of standard observations (variables, methods, protocols) - 2023/2024

The **pivotal role of eLTER SOs makes it imperative that their development is carried out with the broad involvement of the eLTER community**. In the course of the conceptual development of SOs, there are various possibilities for direct participation in terms of content. Important part of the process of developing eLTER SOs are **iterative consultations at each stage of the procedure** as part of the development process. Direct participation and contribution of expertise is possible in various ways, which are briefly described below:

eLTER PLUS internal theme groups (related to the 4 eLTER Research Challenges)

- develop recommendations for prioritizing variables and measurement methods that are based on predefined criteria and reflect the different scientific expertise and perspectives in eLTER
- Who: Iterative discussions within the core team of research challenge leads, WP and task leads (vetted and adapted following consultations with other internal stakeholder groups; see below)
- How: coordinated by the eLTER PLUS theme leads; theme groups on biodiversity, climate-water-food nexus, GHG-climate and socio-ecology,
- When: October-December 2020
- Results are incorporated directly into the Discussion paper on eLTER Standard Observations (February 2021)

Site and Platform coordinators in the national context (NRI) and eLTER Sites and Platforms forum (SPF)

- What: provision of detailed feedback on the discussion paper on Standard observations reflecting scientific expertise, national specifics, current state of national infrastructural development
- Who: open for all members of the respective NRI and the members of the SPF
- How: organized and coordinated by the NRIs and the SPF
- When: February 2021 – June 2022

- Results are incorporated directly into the revised version of the eLTER SO framework (mid 2022)

External expert groups

- What: Reviewing the discussion paper on eLTER SOs and provide recommendations towards further development
- Who: open for larger scientific communities (external and eLTER-internal scientists) and peers in the field of environmental research
- How: Organized and coordinated by WP6 in eLTER PPP
- When: February-December 2021
- Results are incorporated directly into the revised version of the eLTER SO framework (beginning 2022)

The chronological sequence of the development of the eLTER Framework of Standard Observations is shown in Figure 4. In order to initiate the process, a request for cooperation and input has been sent to WPs 4, 8, 9 in June 2020. Based on a corresponding discussion process in these WPs, information has been provided to select and prioritize variables based on specific scientific perspectives against the background of eLTER's science agenda.

As described in chapter 2.1, there are basic criteria to be considered when selecting variables, with (i) relevance, (ii) feasibility, (iii) cost-efficiency being the most important. Consultation with data users and the scientific communities involved in eLTER PLUS in order to utilize their expertise, is indispensable. Within the scope of the query to WPs 4, 8, and 9, respondents were asked to give an assessment of the four criteria mentioned. This evaluation reflects the disciplinary expert knowledge and formed one of the essential bases for the prioritisation of the variables. A more detailed overview of the principles for the ranking of the categories is given in Table 1.

Table 1: Ranking principles for the criteria for the selection of variables (criteria following and adapted from (Costa et al., 2016; GEOBON, 2017)).

Criteria	Description	Ranking principles	Ranking
Relevance	The degree to which the variables represent key elements of the ecosystem integrity concept; Response to drivers of environmental change	Based on expert judgment from eLTER theme lead; the variable is highly relevant for many research themes/disciplines; variable responds highly sensitive for detecting/measuring current and potential future drivers of environmental change	High
		Relevant only for one or few research themes/ disciplines or not highly sensitive for detecting/measuring environmental change	Low
Cost efficiency	Describes required investment and operation costs	Measurement is already available at many locations; instrumentation can be implemented at low cost; fully automated measurements (low personnel costs) possible; low follow-up costs; high durability	High

Criteria	Description	Ranking principles	Ranking
		(withstand storms, extreme and low temperatures),	
		Very expensive instrumentation; High follow-up costs (laboratory, cooling costs etc.); labour-intensive; low durability	Low
Operative Feasibility	Describes potential for routine measurements at a large number of sites based on standardized methods	Well established standards available, part of routine measurements in international networks; easy to apply; high probability of being harmonised	High
		Extensive expertise needed for operation; logistically difficult, e.g. complex measurement campaigns needed; lack of widely accepted/applied protocol; low probability of being harmonised	Low

This document presents the selection of variables created in step 1 and provides additional information regarding methods, protocols, and relevance for remote sensing – the eLTER SO version 1. This list of SOs is an essential basis for the initial analyses of RI costs and to start the conceptual considerations on the design, the site hierarchies, and the selection of protocols and methods. Furthermore, this report also forms the basis for the subsequent further voting in the NRIs and the relevant scientific peer groups (also beyond eLTER).

2 eLTER Standard Observations

It is important to emphasize at this point that the list of Standard Observations (variables, methods, protocols) presented here represents only a starting point for an interactive discussion and decision making in the larger eLTER ESFRI process. More specifically, our prioritisation of variables, methods and protocols initiates the second phase of consultation involving the countries (NRIs), site and platform coordinators (SPF) and the scientific communities as described above (Figure 4). In that sense, this report forms the basis for the subsequent further ranking with inputs from within and beyond eLTER. In parallel, the prioritisation undertaken provides an important basis for the initial RI costs assessments, and to start the discussion about conceptual considerations on the design, the site categories, and the selection of protocols and methods. According to the nature of the eLTER ESFRI process towards concerted decisions across all participating countries these activities will be iteratively repeated as the eLTER Standard Observations evolve towards their final version that will be adopted by the eLTER Interim Council.

As a result of the consultations with WP4/8/9 in eLTER PLUS and with other experts, a total of 173 variables was identified that are considered relevant from the scientific perspective of the disciplines consulted. Of this variables, 76 were rated as highest priority variables. These variables were prioritised, with each variable being ranked based on the combined view of the three criteria: relevance, feasibility, and cost-efficiency. For the relevance criteria, we also considered the calibration and validation data requirements from the main remote sensing product providers (see chapter 4). The concrete assessment of the three main criteria was based on the information provided by the experts in WP4/8/9, but also the multitude of additional information received from conversations and discussions in eLTER (prior to and during eLTER PLUS) and the comparison with other RIs in the global context.

For the final prioritisation, the rankings in the three criteria were combined, with the criterion of scientific relevance being weighted higher. As a result, the ranking of the variables was generated. Variables with the highest scientific impact from the disciplinary point of view, with high cost efficiency and high feasibility at the same time were assigned “very high priority”. Variables whose relevance or scientific impact was assessed as somewhat lower because, for example, they are currently used less frequently in environmental modelling, or corresponding information can also be estimated from other variables, were assigned to the second group of variables and classified as variables with "high priority, but need further discussion". In a few cases, variables of very high relevance are also found in this group. This concerns variables whose measurement is very demanding either because of the necessary measurement technologies or the necessary expertise.

The classification of variables into the different categories of the Ecosystem Integrity concept is not always unambiguous, as a variable can be related to different components (e.g. variables describing ecosystem productivity) and a categorization partly also depends on the perspective of the respective scientific question. In order to avoid multiple entries, in these cases the relationship to other variables was also taken into account when assigning the component (e.g. variables on energy flows as one of the factors determining ecosystem productivity).

We want to explicitly stress that this document does not intend to suggest or favour a conceptual model of the environment. We choose the classification for pragmatic reasons. Some structure was needed and the Ecosystem Integrity concept is well published and frequently cited. In response to numerous feed-back on the classification rather than the content we consider to offer in the future views of the eLTER SOs according to other classifications by using semantic tools allowing for multiple assignments of instances in a polyhierarchy, - hoping that such flexible visualization will draw contributors attention to the actual purpose of selecting variables to form a mandatory element of eLTER Sites and eLTSER Platforms operation.

2.1 Abiotic site characteristics

The abiotic site characteristics represent the abiotic structure of an ecosystem. In general, this indicator describes essential elements of the "site conditions" that are largely responsible for the formation of observed patterns and gradients.

A total of 17 variables and surveys of very high priority has been proposed that can be assigned to this variable group. These are climate variables, soil-related variables and habitat structure surveys (Table 2).

Table 2: Proposed variables for the description of the abiotic site characteristics

Compartment Component	Variable	Relevance 1 = low 3 = medium 5 = high	Costs 1 = high 3 = medium 5 = low	Feasibility 1 = low 3 = medium 5 = high	Priority A = very high B = further discussion
Climate	Relative air humidity	5	3	5	A
Climate	Precipitation	5	3	5	A
Climate	Air temperature	5	3	5	A
Climate	Wind speed / Wind direction	5	3	5	A

Compartment Component	Variable	Relevance 1 = low 3 = medium 5 = high	Costs 1 = high 3 = medium 5 = low	Feasibility 1 = low 3 = medium 5 = high	Priority A = very high B = further discussion
Climate	Surface atmospheric pressure	5	3	5	A
Groundwater	water temperature	5	5	5	A
Lake	Vertical profiles of water temperature, pH, EC, turbidity	5	3	4	A
Soil	Soil inventory	5	3	3	A
Soil	Soil temperature	4	5	5	A
Soil	Soil organic C content (per horizon)	5	3	5	A
Soil	Soil total N content (per horizon)	5	3	5	A
Soil	Soil total P content (per horizon)	5	3	5	A
Soil	Soil pH (in H2O/KCl/CaCl2)	5	3	3	A
Soil	Soil cation exchange capacity	5	3	3	A
Soil	Soil base saturation	5	3	3	A
Streams/Rivers	Stream sinuosity	5	5	5	A
Streams/Rivers	pH, EC, water temperature	5	3	5	A
Groundwater	pH, O2, turbidity	3	3	4	B

Table 3: Information on methods and protocols for variables on abiotic site characteristics

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Relative air humidity	30 min	Field	Standard climate station	WMO, ICPF, ICOS,
Precipitation	30 min	Field	Standard climate station	WMO, ICPF, ICOS,
Air temperature	30 min	Field	Standard climate station	WMO, ICPF, ICOS,
Wind speed / Wind direction	30 min	Field	Standard climate station	WMO, ICPF, ICOS,
Surface atmospheric pressure	30 min	Field	Standard climate station	WMO, ICPF, ICOS,
Groundwater – water temperature	subdaily	Field	automatic sensor (NTC, PT1000)	ICP Waters

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Lake - Vertical profiles of water temperature, pH, EC, turbidity	Subdaily	Field	Multiparameter probe, thermistor chain	ICP
Soil inventory	Initial mapping	Field	Soil Inventory (Texture, Structure, Corg, …)	ICPF, INT
Soil temperature	30 min	Field	Beyond point scale, wireless sensor networks	INT
Soil organic C content (per horizon)	3-5 year interval	Field Laboratory	Need to specify depth/s	ICP
Soil total N content (per horizon)	3-5 year interval	Field Laboratory	Need to specify depth/s	ICP
Soil total P content (per horizon)	3-5 year interval	Field Laboratory	Need to specify depth/s	ICP
Soil pH (in H2O/KCl/CaCl2)	3-5 year interval	Field Laboratory	Need to specify depth/s	ICP
Soil cation exchange capacity	3-5 year interval	Field Laboratory	Need to specify depth/s	ICP
Soil base saturation	3-5 year interval	Field Laboratory	Need to specify depth/s	ICP
Stream sinuosity	Yearly	Field	GIS	INT
Rivers -pH, EC, water temperature	Subdaily	Field	Multiparameter probe	INT, ICP Waters
Groundwater - pH, O2, turbidity	Subdaily	Field	Multiparameter probe	INT

2.2 Socio-Ecology

The eLTER SO group Socio-Ecology comprises qualitative and quantitative descriptions of features characterizing the socio-ecological domain of the ecosystem. In general, it includes observations describing the demographic profile of [human] population, land use, resource use, and economic and governance structures. Some of the data can be collected via remote sensing or by analysing official national or European statistics. Other data, such as sense of place and degree of stakeholder engagement will depend on development of protocol and in depth inquiry into the platform population. A total of 46 variables (24 variables – priority A) has been proposed describing population, economic and political structure.

Table 4: Proposed variables/data for the description of socio-ecological features

Compartment Component	**Variable**	**Relevance 1 = low 3 = medium 5 = high**	**Costs 1 = high 3 = medium 5 = low**	**Feasibility 1 = low 3 = medium 5 = high**	**Priority A = very high B = further discussion**
Agriculture and Forestry	Area under tillage	5	3	4	A
Agriculture and Forestry	Land-based income	3	5	5	A
Agriculture and Forestry	Livestock feed management	4	3	4	A
Agriculture and Forestry	Agricultural products	5	4	4	A
Agriculture and Forestry	Harvest (cropland, grassland, forest) (t/ha)	5	3	3	A
Governance and stakeholders	Governance structure and character	5	3	5	A
Governance and stakeholders	Stakeholder engagement process indicators and profile of engaged stakeholders	4	2	3	A
Governance and stakeholders	Basic services provision: health & education	4	2	3	A
Land use and land cover change	Land use (historic)	5	2	3	A
Land use and land cover change	Land cover (CORINE)	5	3	5	A
Land use and land cover change	Land use change (CORINE)	5	2	5	A
Land use and land cover change	Land use (Statistics)	5	4	3	A
Land use and land cover change	Land cover (Orthophotos)	5	3	3	A
Platform characteristics	General information (DIEMS)	5	5	5	A
Platform characteristics	Ecosystem services profile	5	3	3	A

Compartment Component	Variable	Relevance 1 = low 3 = medium 5 = high	Costs 1 = high 3 = medium 5 = low	Feasibility 1 = low 3 = medium 5 = high	Priority A = very high B = further discussion
Platform characteristics	NUTS3 and Local Administrative Units (LAU) spatial databases	4	5	5	A
Platform characteristics	Per capita income / GDP per capita	5	4	4	A
Population	Population age profile	4	5	5	A
Population	Population status of employment	3	5	5	A
Population	Population education attainment	3	5	4	A
Population	Population residential profile/density	4	4	3	A
Resource use	Resource use (biomass, construction, iron/steel, fossil fuels), trade of resources	5	3	4	A
Resource Use	Subsidies programs / schemes	5	3	3	A
Resource use	Population consumption statistics	5	3	3	A
Agriculture and Forestry	Grazing timing, intensity	5	3	1	B
Agriculture and Forestry	Farm gate economic return	2,5	4	1	B
Agriculture and Forestry	livestock (livestock units)	5	3	3	B
Agriculture and Forestry	Irrigation management, timing, intensity	5	3	1	B
Agriculture and Forestry	Fertilizer input (N, P, K fertilisation, liming, pesticides)	5	3	2	B
Governance and stakeholders	Sense of Place / Nature connectedness	3	1	2	B
Governance and stakeholders	Relevant regional actors and initiatives (NGO's, civil society groups, etc.)	5	2	2	B
Governance and stakeholders	Wellbeing information of population	3	2	2	B

Compartment Component	**Variable**	**Relevance 1 = low 3 = medium 5 = high**	**Costs 1 = high 3 = medium 5 = low**	**Feasibility 1 = low 3 = medium 5 = high**	**Priority A = very high B = further discussion**
Governance and stakeholders	Property ownership/laws/institutions	4	3	3	B
Land use and land cover change	Land use (Archival cadastral)	5	2	2	B
Platform characteristics	Number of tourists/visitors to protected areas	4	3	4	B
Population	Population occupation	2	5	4	B
Population	Population place of birth	2	4	3	B
Population	Living conditions in dwellings: m2 per person; thermal quality; ….	3	2	2	B
Resource use	Infrastructure physically and in terms of services available	3	3	3	B
Resource Use	Records of important land users (e.g., forest enterprises)	5	2	2	B
Resource use	Resource use (energy carriers, electricity, biomass, construction, iron/steel, fossil fuels),	4	2	2	B
Transportation and Industry	mobility information: accessibility indicators, means of transport	3	2	3	B
Transportation and Industry	mobility: distances travelled (locals vs tourists)	2	2	2	B
Transportation and Industry	Physical infrastructure networks	3	3	3	B
Transportation and Industry	Buildings and other structures	3	3	4	B
Transportation and Industry	Roads, Railways, settlement areas	3	3	4	B

2.3 Biotic heterogeneity

Biotic heterogeneity is measured by variables that describe structural biodiversity and biotope quality. A total of 24 variables (8 variables – priority A) has been proposed that can be assigned to this variable group comprising terrestrial and aquatic observations (table 2). Biological data collection in particular often requires a very detailed expertise on the part of the researchers and is often difficult or impossible to automate. Particularly with regard to the best possible feasibility, the selection of the proposed variables focused on suggesting variables for which automated and harmonized collection and observation seems possible (e.g. sound recorders, photo traps, malaise traps, bulk samplers for eDNA analysis). The corresponding evaluation is also reflected in particular in the ranking of the feasibility. Still, these proposed observations can, so far, not replace existing in-situ non-automated measurements and need to be calibrated against them.

Table 5: Proposed observations for the description of the biotic heterogeneity

Compartment Component	Variable	Relevance 1 = low 3 = medium 5 = high	Costs 1 = high 3 = medium 5 = low	Feasibility 1 = low 3 = medium 5 = high	Priority A = very high B = further discussion
Terrestrial	Flying insects	5	5	5	A
Terrestrial	Habitat Structure, vegetation/plant phenology based on satellite remote sensing (European extent)	5	5	3	A
Terrestrial	Birds, bats, frogs, some insects (e.g., grasshoppers) using acoustic recording	5	5	3	A
Terrestrial	Pollen and spores from air	5	5	3	A
Terrestrial	Ground-dwelling animals	3	5	5	A
Terrestrial	Plant phenology	3	5	4	A
Terrestrial/ Aquatic	eDNA	5	3	3	A
Streams/Rivers	Instream habitat distribution (incl. sediment grain size distribution)	5	5	3	A
Groundwater	Total prokaryotic cell counts (TCC)	5	3	2	B
Groundwater	Microbial activity (e.g. ATP conc.)	5	3	2	B
Groundwater	Fecal indicators (E. coli & coliphages)	3	5	1	B
Groundwater	Groundwater microbial communities	3	4	1	B
Groundwater	Groundwater fauna	3	4	1	B
Lake	Algal community (quantitative)	5	3	2	B
Lake	Zooplankton (quantitative)	3	3	2	B

Compartment Component	Variable	Relevance 1 = low 3 = medium 5 = high	Costs 1 = high 3 = medium 5 = low	Feasibility 1 = low 3 = medium 5 = high	Priority A = very high B = further discussion
Lake	Fish community (quantitative)	1	3	2	B
Lake	Macrophyte community (quantitative)	1	3	2	B
Streams/Rivers	Fish community (quantitative)	5	1	3	B
Streams/Rivers	Algal community (quantitative)	5	1	2	B
Streams/Rivers	Macroinvertebrate community (quantitative)	5	1	2	B
Streams/Rivers	Riparian vegetation	5	5	3	B
Streams/Rivers	Macrophyte community (quantitative)	3	3	3	B
Terrestrial	Mammals	3	5	3	B
Terrestrial	Habitat structure, vascular plants, lichens, mosses/vegetation based on UAV remote sensing (local)	5	1	1	B

Table 6: Information on methods and protocols for variables on biotic heterogeneity

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Flying insects	Biweekly over vegetation period	Field Laboratory	Malaise traps	INT
Habitat structure, vegetation/plant phenology based on satellite remote sensing (European scale)	5-year interval	Field Model	Remote sensing: Sentinel imagery or equivalent 10-20m for habitat mapping, A combination of sensors and techniques can be suited to each site, with sentinel imagery supporting harmonized coverage across	INT, LUCAS
Birds, bats, frogs, some insects (e.g., grasshoppers) using voice recording	Weekly	Field	Voice recorders (voice recognition): e.g. transect of 500 m with 1 recorder per 100 m	INT

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Pollen and spores from air	Weekly	Field Laboratory	Cyclone sampler (DNA metabarcoding and/or image recognition via flow cytometry)	INT
Ground-dwelling animals	Four-week campaigns with weekly sampling, 3 repetition over the year	Field Laboratory	Pitfall traps (DNA metabarcoding)	INT
Plant phenology	Daily	Field	Automated cameras	INT
eDNA	Monthly	Field Laboratory	Soil and water samples (DNA metabarcoding; different markers covering invertebrates, plants, fungi)	INT
River – Instream habitat distribution (incl. sediment grain size distribution)	quarterly	Field	Visual inspection	ICP Waters
Total prokaryotic cell counts (TCC)	Monthly	Field Laboratory	flow cytometer	INT
Microbial activity (e.g. ATP conc.)	Monthly	Field Laboratory	bioluminometer	INT
Fecal indicators (E. coli & coliphages)	Monthly	Field Laboratory	plate counts, clean bench, incubator	INT
Groundwater microbial communities	Quarterly	Field Laboratory	water samples (DNA metabarcoding)	INT
Groundwater fauna	Quarterly	Field Laboratory	stereomicroscope, microscope, DNA metabarcoding	INT
Algal community (quantitative) - Lake	monthly	Field Laboratory	Sampler, storage & transport equipment	INT
Zooplankton (quantitative) - Lake	weekly	Field Laboratory	Sampler, storage & transport equipment	WFD, INT
Fish community (quantitative) - Lake	Yearly	Field Laboratory	Electro fishing, Sampler, storage & transport equipment	WFD, INT
Macrophyte community (quantitative) - Lake	Quarterly	Field Laboratory	Sampler, storage & transport equipment	WFD, INT
Fish community (quantitative) –River	Yearly	Field Laboratory	Electro fishing, Sampler, storage & transport equipment	WFD, INT

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Algal community (quantitative) - River	Quarterly	Field Laboratory	Sampler, storage & transport equipment	WFD, INT
Macroinvertebrate community (quantitative) - River	Quarterly	Field Laboratory	Sampler, storage & transport equipment	WFD, INT
River – Riparian vegetation	Yearly	Field	Visual inspection	ICP Waters
Macrophyte community (quantitative)- River	Quarterly	Field Laboratory	Sampler, storage & transport equipment	WFD, INT
Mammals	Weekly	Field Laboratory	Camera traps (image recognition)	INT
Habitat structure, vascular plants, lichen mosses/vegetation based on UAV remote sensing (local)	5 year interval	Field Model	LiDAR based sensing (.25 m resolution), UAV based, RGB cameras	INT

2.4 Energy budget

The incoming solar energy is the major source for the different energy fluxes that are essential for vegetation growth and ecosystem development. It drives key ecosystem processes like photosynthesis and evapotranspiration. The complexity of energy flows and the energy conversion in an ecosystem are essential indicators of the maturity and stability of an ecosystem. The ecosystem integrity component 'energy budget' contains variables that describe the process of energy turnover in the observed system.

A total of 17 variables (5 variables – priority A) has been proposed for this group of standard observations describing the energy input and the throughputs in relation to respiration and biomass growths. Many of the proposed observations involve considerable instrumentation and require a very high level of technical expertise for measurement (e.g. measurements using the eddy-covariance technique) which is expressed by the lower ranking of the criteria costs and feasibility. With ICOS RI, there is already an ESFRI RI which focuses its measurements on the collection of such data. In the sense of harmonising the European research landscape, close coordination between the RIs is necessary here, to coordinate possibilities for cooperation (e.g. co-location) and to ensure methodological alignments.

Table 7: Proposed observations for the description of the energy budget

Compartment Component	Variable	Relevance 1 = low 3 = medium 5 = high	Costs 1 = high 3 = medium 5 = low	Feasibility 1 = low 3 = medium 5 = high	Priority A = very high B = further discussion
Biomass	Aboveground biomass	5	3	5	A
Biomass	Leaf area Index (LAI)	4	3	5	A
Biomass	Net primary production (dendrometer)	5	1	5	A
Radiation Budget	PAR	4	3	5	A
Radiation Budget	Global solar radiation (direct shortwave incoming and diffuse radiation)	4	3	5	A
Biomass	Net primary production (EC-Station)	5	1	1	B
Biomass	Gross primary production	4	1	1	B
Biomass	Transpiration	4	3	3	B
Radiation Budget	Ground heat flux	3	1	1	B
Radiation Budget	Latent heat flux	3	1	1	B
Radiation Budget	Sensible heat flux	3	1	1	B
Radiation Budget	Direct incoming shortwave radiation (direct solar irradiance, direct solar radiation)	2	3	5	B
Radiation Budget	Reflected shortwave radiation	2	3	5	B
Radiation Budget	Diffused long-wave radiation from the sky	2	3	5	B
Radiation Budget	Diffused long-wave radiation from the surface	2	3	5	B
Net Ecosystem Exchange (NEE)	H2O concentration	3	1	1	B
Net Ecosystem Exchange (NEE)	H2O flux	3	1	1	B

Table 8: Information on methods and protocols for variables on energy budget

Variable	**Optimal frequency of measurement**	**Field Laboratory Model**	**Remarks on method**	**Available protocols (examples)**
Aboveground biomass	Annual	Field	Inventory	ICP Forests
Leaf area Index (LAI)	Daily, Monthly, Annual	Field	Forested sites only, hemispheric photos; automatic sensors	ICP Forests
Net primary production (dendrometer)	Daily, Monthly, Annual	Field	Forested sites only, dendrometer	ICP Forests
PAR	30 min	Field	PAR sensor	WMO
Global solar radiation (direct shortwave incoming and diffuse radiation)	30 min	Field	Pyranometer, net radiometer	WMO
Net primary production (EC-Station)	10 min - hourly	Field	EC-Station	ICOS, Fluxnet
Gross primary production	10 min - hourly	Field	EC-Station	ICOS, Fluxnet
Transpiration	Daily	Field	Forested sites only, sapflow	ICOS, Fluxnet
Ground heat flux	10 min - hourly	Field	EC-Station	ICOS, Fluxnet
Latent heat flux	10 min - hourly	Field	EC-Station	ICOS, Fluxnet
Sensible heat flux	10 min - hourly	Field	EC-Station	ICOS, Fluxnet
Direct incoming shortwave radiation (direct solar irradiance, direct solar radiation)	30 min	Field	Pyranometer, net radiometer	WMO
Reflected shortwave radiation	30 min	Field	Pyranometer, net radiometer	WMO
Diffused long-wave radiation from the sky	30 min	Field	Pyranometer, net radiometer	WMO
Diffused long-wave radiation from the surface	30 min	Field	Pyranometer, net radiometer	WMO
Net Ecosystem Exchange H2O concentration	10 min - hourly	Field	EC-Station	ICOS, Fluxnet

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Net Ecosystem Exchange H_2O flux	10 min - hourly	Field	EC-Station	ICOS, Fluxnet

2.5 Water balance

Hydrologic states and fluxes of the land surface drive and control all cycling processes in the ecosystem and decisively determine the matter fluxes and link the geosphere, atmosphere and biosphere. A robust description of the water balance, the hydrological description of the ecosystem from the point to the catchment scale, is an essential element of eLTER's whole-system approach. A total of 14 variables (12 variables – priority A) that are linked to the description of the terrestrial water bodies lakes, rivers, and groundwater has been proposed.

Table 9: Proposed observations for the description of the water balance

Compartment Component	Variable	Relevance 1 = low 3 = medium 5 = high	Costs 1 = high 3 = medium 5 = low	Feasibility 1 = low 3 = medium 5 = high	Priority A= very high B = further discussion
Groundwater	Groundwater level	5	5	5	A
Groundwater	Spring Discharge	5	3	5	A
Lake	Water level	5	5	5	A
Lake	Inflow/outflow	3	5	5	A
Lake	Ice cover	3	5	5	A
Soil	Soil water content	5	1	5	A
Streams/Rivers	Discharge	5	5	5	A
Streams/Rivers	Mean water depth	5	5	5	A
Streams/Rivers	Bed and water level slope	5	5	4	A
Streams/Rivers	Current velocity	5	3	5	A
Streams/Rivers	Streams wetted perimeter	5	5	1	A
Terrestrial	Snow cover	5	5	5	A
Terrestrial	Snow density	5	3	3	B
Streams/Rivers/ Lakes	Water and nitrate stable isotopes (18O, 2H, 15NO3)	5	3	1	B

Table 10: Information on methods and protocols for variables on water balance

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Groundwater – water level	Daily	Field	pressure sensor	ICP Waters
Groundwater – spring discharge	daily	Field	gauging weir with pressure sensor	ICP Waters
Lake - water level	daily	Field	(Surface and) bottom pressure sensors	ICP Waters
Lake – Inflow/outflow	daily	Field	Stream gauge	ICP Waters
Lake – Ice cover	daily	Field	Manual observation, remote sensing	ICP Waters
Soil water content	30 min	Field	Beyond point scale, wireless sensor networks, cosmic-ray neutron sensing	INT
River – Discharge	subdaily	Field	Stream gauge	ICP Waters
River – Mean water depth	quarterly	Field	Manual tape measurement	ICP Waters
River – Bed and water level slope	yearly	Field	Total station	ICP Waters
River – Current velocity	subdaily	Field	Acoustic/electronic	ICP Waters
River – Streams wetted perimeter	Quarterly	Field	Tracer addition	ICP Waters
Terrestrial – Snow cover	Daily	Field	Camera, measuring stick, remote sensing	ICP Waters
Terrestrial – snow density	Daily	Field	Snow pillow	ICP Waters
River - Water stable isotopes (18O, 2H, 15NO3)	Weekly - monthly	Field Laboratory	Sampler, storage & transport equipment, Picarro L2130-i Analyzer	ICP Waters

2.6 Matter budget

The transfer of nutrients and matter within the ecosystem, the dynamics of storages of nutrients as well as the abiotic carbon, turnover rates and efficiencies are important indicators of ecosystem state.

With a total of 54 variables and observations (7 variables – priority A) proposed by the eLTER community comprising measurements in all terrestrial and aquatic compartments the SO group Matter Budget is by far the most extensive. The vast majority of variables aim at describing the cycles of carbon and nitrogen and quantifying inorganic nutrients. While established automated measurement methods are already available for a large part of the aquatic measurements (e.g. multiparameter probes), many of the other variables require manual sampling in the field (e.g.

measurements in soil water) or require additional laboratory analyses. This is also reflected in the assessments of costs and feasibility.

Table 11: Proposed observations for the description of the matter budget

Compartment Component	Variable	Relevance 1 = low 3 = medium 5 = high	Costs 1 = high 3 = medium 5 = low	Feasibility 1 = low 3 = medium 5 = high	Priority A = very high B = further discussion
Groundwater	Electrical conductivity	5	3	5	A
Lake	Water transparency	5	5	5	A
Lake	Vertical profiles of chl a, pigments (proxy water quality)	5	3	4	A
Lake	Vertical profiles of dissolved oxygen	5	3	3	A
Lake	In-situ vertical profiles and inflow concentrations of TP, SRP, NO3, DOC, SAC 254	5	3	3	A
Streams/Rivers	Turbidity	5	5	5	A
Streams/Rivers	TP, SRP, NO3, DOC, SAC 254	5	3	3	A
Lake	In-situ vertical profiles and inflow concentrations TOC, POC, TN, NO2, NH4, SRSi, DIC	5	3	2	B
Streams/Rivers	TOC, POC, TDN, NO2, NH4, SRSi, DIC	5	3	2	B
Streams/Rivers	Cl, SO4, Na, K, Mg, Ca	5	3	2	B
Atmospheric deposition	Bulk NH4-N, NO3-N, Ntot, P, K deposition in precipitation	4	2	3	B
Atmospheric deposition	Bulk pH, anion, cation deposition in precipitation	4	2	3	B
Atmospheric deposition	Bulk NH4-N, NO3-N, Ntot, P, K deposition in canopy throughfall (forests)	2	2	2	B
Atmospheric deposition	Bulk pH, anion, cation deposition in canopy throughfall (forests)	2	2	2	B
Atmospheric deposition	Stemflow NH4-N, NO3-N, Ntot, P, K, pH, cation, anion deposition in stemflow (forests)	2	2	2	B
Atmospheric deposition	Dry deposition of N-components	2	2	2	B

Compartment Component	**Variable**	**Relevance 1 = low 3 = medium 5 = high**	**Costs 1 = high 3 = medium 5 = low**	**Feasibility 1 = low 3 = medium 5 = high**	**Priority A = very high B = further discussion**
Biomass	Aboveground litterfall (forests)	4	1	3	B
Biomass	Belowground biomass	4	2	1	B
Biomass	Belowground litterfall (fine roots)	2	4	1	B
Biomass	Leaf C, N, K, P, Ca, Mg, Mn content	3	3	3	B
Groundwater	Stable Isotopes (18O, 2H)	5	3	1	B
Groundwater	Greenhouse gases	5	3	1	B
Groundwater	Nutrient concentration: TP, SRP, TDN, NO3, NO2, NH4, DOC, DIC	3	3	3	B
Groundwater	Stable Isotopes (15NO3)	3	3	2	B
Groundwater	Major ion concentrations: Cl, SO4, Br, Na, K, Mg, Ca, B	3	3	1	B
Groundwater	DOM composition	3	3	1	B
Groundwater	Micropollutants: non-target screening [~1000 substances]	2,5	1	1	B
Groundwater	trace element concentration (Ba, Fe, REE)	1	1	1	B
Groundwater	Radioactive Isotopes (14C, T/3He, T)	1	1	1	B
Lake	Vertical profiles of major ion concentrations: Cl, SO4, Na, K, Mg, Ca	5	3	1	B
Net Ecosystem Exchange	CO2 flux	4	1	1	B
Net Ecosystem Exchange	CO2 concentration	3	1	1	B
Net Ecosystem Exchange	CH4 flux	3	1	1	B
Net Ecosystem Exchange	N2O flux	2	1	1	B
Net Ecosystem Exchange	CH4 concentration	1	1	1	B

Compartment Component	**Variable**	**Relevance 1 = low 3 = medium 5 = high**	**Costs 1 = high 3 = medium 5 = low**	**Feasibility 1 = low 3 = medium 5 = high**	**Priority A = very high B = further discussion**
Net Ecosystem Exchange	N2O concentration	1	1	1	B
Net Ecosystem Exchange	CO2 flux	2	1	1	B
Net Ecosystem Exchange	CH4 flux	2	1	1	B
Net Ecosystem Exchange (gas flux chamber)	N2O, NO, NOx flux	1	1	2	B
Soil water	pH value	4	1	3	B
Soil water	Conductivity	3	5	1	B
Soil water	Percolation	4	1	2	B
Soil water	NH4-N, NO3-N, DON concentration	4	1	2	B
Soil water	DOC concentration	4	1	2	B
Soil water	P concentration	4	1	2	B
Soil water	Cation concentrations	4	1	2	B
Soil water	Anion concentrations	4	1	1	B
Soil water	NH4-N, NO3-N, DON leaching	4	1	1	B
Soil water	DOC leaching	5	3	1	B
Streams/Rivers	Chl a (benthic, pelagic)	5	3	3	B
Streams/Rivers	Organic matter stable isotopes (13C, 15N)	5	3	1	B
Streams/Rivers	Dissolved oxygen	3	5	1	B
Streams/Rivers	Transient storage time of stream and hyporheic zone	3	1	1	B
Streams/Rivers	Micropollutants: non-target screening [~1000 substances]	3	1	1	B

Table 12: Information on methods and protocols for variables on matter budget

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Groundwater - electrical conductivity	Daily	Field	automatic sensor (4-electrodes cell)	ICP
Lake - Water transparency	Weekly	Field	Secchi disk, 2 spherical scalar PAR sensors (e.g. LICOR plus logger)	ICP
Lake - Vertical profiles of chl a, pigments	Subdaily	Field	Multi-channel fluorescence probe	INT
Lake - Vertical profiles of dissolved oxygen	Subdaily	Field	Multiparameter probe, or chain of optode loggers	ICP
Lake - In-situ vertical profiles and inflow concentrations of TP, SRP, NO3, DOC, SAC 254	Subdaily	Field	Multiparameter probe	ICP
Lake - In-situ vertical profiles and inflow concentrations TOC, POC, TN, NO2, NH4, SRSi, DIC	Biweekly	Field Laboratory	Laboratory	ICP
Rivers - Turbidity	Subdaily	Field	Multiparameter probe	INT
Rivers -TP, SRP, NO3, DOC, SAC 254	Subdaily	Field	Multiparameter probe	INT
Rivers -TOC, POC, TDN, NO2, NH4, SRSi, DIC	Biweekly	Field Laboratory	Laboratory	INT
Rivers -Cl, SO4, Na, K, Mg, Ca	Biweekly	Field Laboratory	Laboratory	INT
Atmospheric Deposition - Bulk NH4-N, NO3-N, Ntot, P, K deposition in precipitation	Monthly	Field Laboratory	Precipitation sampler, laboratory analysis	ICP
Atmospheric Deposition - Bulk pH, anion, cation deposition in precipitation	Monthly	Field Laboratory	Precipitation sampler, laboratory analysis	ICP
Atmospheric Deposition - Bulk NH4-N, NO3-N, Ntot, P, K deposition in canopy throughfall (forests)	Monthly	Field Laboratory	Forested sites only, litter traps, laboratory analysis	ICP
Atmospheric Deposition - Bulk pH, anion, cation deposition in canopy throughfall (forests)	Monthly	Field Laboratory	Forested sites only, litter traps, laboratory analysis	ICP

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Atmospheric Deposition - Stemflow NH4-N, NO3-N, Ntot, P, K, pH, cation, anion deposition in stemflow (forests)	Monthly	Field Laboratory	Forested sites only, stemflow sampling, laboratory analysis	ICP
Atmospheric Deposition - Dry deposition of N-components	Monthly	Field Laboratory	Passive samplers (e.g. Nitro Europe)	INT
Aboveground litterfall (forests)	Monthly, Annual	Field	Forested sites only, litter traps	ICP Forests
Belowground biomass	Annual	Field Model	Inventory and allometric equations	INT
Belowground litterfall (fine roots)	Monthly Annual	Field	Ingrowth cores, etc; can be obtained by allometric functions but very uncertain	INT
Leaf C, N, K, P, Ca, Mg, Mn content	Monthly, Annual	Field Laboratory	Litter traps, laboratory analysis	ICP Forests
Groundwater - Stable Isotopes (18O, 2H)	Monthly	Field Laboratory	Picarro or IRMS	INT
Groundwater - Greenhouse gases	Monthly	Field	Simple: Portable gas analyzer; Advanced: Picarro carbon gas analyzer including stable isotope signature analysis	INT
Groundwater - Nutrient concentration: TP, SRP, TDN, NO3, NO2, NH4, DOC, DIC	Monthly	Field Laboratory	Field sampling, Photometry, DOC/DIC analyzer, IC , Laboratory analysis	INT
Groundwater - Stable Isotopes (15NO3)	Monthly	Field Laboratory	Picarro or IRMS	INT
Groundwater - Major ion concentrations: Cl, SO4, Br, Na, K, Mg, Ca, B	Monthly	Field Laboratory	Field sampling, IC (anions), ICP-AES (cations), Laboratory analysis	INT
Groundwater - DOM composition	Monthly	Field Laboratory	Field sampling, spectrolyzer, spectrometer	INT
Groundwater - Micropollutants: non-target screening [~1000 substances]	Biweekly	Field Laboratory	Field sampling, LC-MS	INT

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Groundwater - trace element concentration (Ba, Fe, REE)	Yearly	Field Laboratory	Field sampling, ICP-MS	INT
Groundwater - Radioactive Isotopes (14C, T/3He, T)	Yearly	Field Laboratory	Field sampling, scintillation or AMS	INT
Lake - Vertical profiles of major ion concentrations: Cl, SO4, Na, K, Mg, Ca	Monthly	Field Laboratory	Sampler, storage & transport equipment, laboratory analysis	ICP
Net Ecosystem Exchange CO2 flux	10 min - hourly	Field	EC-Station	ICOS, Fluxnet
Net Ecosystem Exchange CO2 concentration	10 min - hourly	Field	EC-Station	ICOS, Fluxnet
Net Ecosystem Exchange CH4 flux	10 min - hourly	Field	Expensive (>100k€) because of the fast analysers	ICOS, Fluxnet
Net Ecosystem Exchange N2O flux	10 min - hourly	Field	Expensive (>100k€) because of the fast analysers	ICOS, Fluxnet
Net Ecosystem Exchange CH4 concentration	10 min - hourly	Field	Expensive (>100k€) because of the fast analysers	ICOS, Fluxnet
Net Ecosystem Exchange N2O concentration	Daily monthly annual	Field	Expensive (>100k€) because of the fast analysers	ICOS, Fluxnet
Net Ecosystem Exchange CO2 flux (Gas flux chamber)	Daily monthly annual	Field	LICOR (or other) autochambers	ICOS, Fluxnet
Net Ecosystem Exchange CH4 flux (Gas flux chamber)	Daily monthly annual	Field	Need online instrument, or autochamber collecting samples into vials, standard system (same is the case for N2O below	ICOS, Fluxnet
Net Ecosystem Exchange N2O, NO, NOx flux (Gas flux chamber)	Daily monthly annual	Field	Time consuming, need autochambers with online analysis for NO	ICOS, Fluxnet
Soil water - pH value	Monthly	Field Laboratory	pH-electrode	ICP
Soil water - Conductivity	Monthly	Field Laboratory	Conductivity meter	ICP
Soil water - Percolation	Monthly	Model	Modelling	ICP

Variable	Optimal frequency of measurement	Field Laboratory Model	Remarks on method	Available protocols (examples)
Soil water - NH4-N, NO3-N, DON concentration	Monthly	Field Laboratory	Dry combustion, modified Kjeldahl	ICP
Soil water - DOC concentration	Monthly	Field Laboratory	DOC/DIC analyzer	ICP
Soil water - P concentration	Monthly	Field Laboratory	Colorimetry	ICP
Soil water - Cation concentrations	Monthly	Field Laboratory	AAS	ICP
Soil water - Anion concentrations	Monthly	Field Laboratory	AAS	ICP
Soil water - NH4-N, NO3-N, DON leaching	Monthly	Modelling	Modelling	ICP
Soil water - DOC leaching	Monthly	Modelling	Modelling	ICP
Rivers - Chl a (benthic, pelagic)	Subdaily	Field	Multi-channel fluorescence probe	INT
Rivers - Organic matter stable isotopes (13C, 15N)	Monthly	Field Laboratory	Sampler, storage & transport equipment, laboratory analysis, EA-IRMS	INT
Rivers - Dissolved oxygen	Subdaily	Field	Optode	INT
Rivers - Transient storage time of stream and hyporheic zone	Quarterly	Field	Tracer addition	INT
Rivers - Micropollutants: non-target screening [~1000 substances]	Biweekly	Field Laboratory	Field sampling, LC-MS	INT

3 eLTER Standard Observations for Earth Observation calibration/validation activities

Apart from SOs as primary pillar supporting WAILS and allowing a European scale comparison across sites and biogeographical regions, a secondary pillar might be the support of Earth Observation (EO) calibration/validation (cal/val) activities. EO data and more specifically EO products rely on in-situ data at matching scales for the calibration of interpretation algorithms and for the validation of developed products. With the anticipated number of approx. 250 eLTER RI Sites and Platforms, eLTER RI can increase the number of available harmonized in-situ data for EO cal/val activities significantly. **Exactly this synergy between eLTER SOs and calibration/validation needs should be emphasized in the following lines.**

From an EO perspective, the role of timely, co-located, accessible, long term, fiducial quality and long-term in-situ data for cal/val purposes is crucial (Sterckx et al., 2020). Given that eLTER RI aims at meeting exactly these aspects, the potential in developing collaboration with the main EO data providers, including ESA and NASA, is at hand. Both of them have dedicated programs and working groups for coordinating the cal/val activities and respective data requirements. For the further definition and evaluation of eLTER SO's, there is a need to 1) identify eLTER SOs that possess a potential to facilitate cal/val activities, and 2) define monitoring strategies that fulfil cal/val needs and requirements as e.g. given in the Quality Assurance Framework for Earth Observation (QA4EO, qa4eo.org).

To identify requirements according to 1) eLTER SOs defined in chapter 2 were matched with EO products requirements from:

i. Copernicus services and NASA's working group on land product calibration and validation (including requirements for ancillary data)
ii. Operational EO products with global or pan-European coverage that already underwent actions of calibration/validation with limited number of in-situ data.

Thus, Table 13 contains SOs that could support EO calibration/validation activities and lists relevant EO products and instruments for each SO. There is a clear overlap between required variables for purposes of satellite land products by main data providers and the candidate list of SO (Annex, Table 2). Variables, such as the leaf area index, above ground biomass, vegetation structure, gross and net primary productivity, plant/ vegetation phenology, snow cover, soil moisture, among others, are already in the proposed eLTER SO list. Other variables, such as surface albedo and chlorophyll content/concentrations that are currently not identified as eLTER SO could potentially be monitorable with the eLTER RI.

The mutual added benefit for EO and eLTER RI are at hand. It is imperative to initiate a dialogue with EO data providers and reconcile activities, approaches and methods. Both tables in the Annex provide a discussion basis for this dialogue that will be started within eLTER among WP3 and WP4, but will be continued between eLTER and EO data providers to identify the most promising and feasible variable-based synergies and to suggest a concept for concrete cooperation and realization actions.

Important aspects to be discussed, among others, are adopted eLTER SO measurement strategies and methods to fulfil needs and requirements for calibration/validation as e.g. given in the Quality Assurance Framework for Earth Observation (QA4EO, qa4eo.org) (see above). Besides homogeneity factors these are especially EO relevant coverages, proper temporal coverages, and open data. Especially the temporal coverage can be assured with proper and automatized measuring devices. The EO relevant coverage must be considered and could either be tackled by a suitable monitoring sensor networks (e.g. as described in (Fersch et al., 2018)), or an upscaling approach through the provision of observations at various scales (plot, local, regional, continental) as given in (Lausch et al., 2013).

The result of these discussions will be summarized in a separate document (eLTER Plus project deliverable D3.2) and may serve as a basis for future eLTER SO adaptations.

Supporting EO activities also feeds back to eLTER needs when it comes to spatial upscaling of site-based information through the integrated use of space-borne, but also airborne EO data with eLTER SOs. It also bears the potential to complete time gaps and extend the temporal coverage of time series (Lehmann et al., 2020; Patias et al., 2019) and would thus enable detecting, quantifying and forecasting ecosystem processes, states and services down to certain spatial scales but on a large scale, standardized ad spatially continuous basis.

Several public agencies in Europe and globally provide Earth Observing Data and information services (Annex, Table 1). The technical development for the utilization of these strongly growing and, by definition, harmonized global data sets, advances rapidly at the moment. Similarly, there are significant efforts for the further uptake of EO data for various applications. For example, the Group on Earth Observations (GEO) as an intergovernmental partnership is advancing the use, harmonization and coordinated utilization of environment-related EO data, especially to support the 2030 Agenda for Sustainable Development, the Paris Agreement, and the Sendai Framework for Disaster Risk Reduction. One of GEO's fundamental tasks is specifically to promote coordinated and harmonized data sharing globally.

The aforementioned discussion with EO data providers will thus be extended internally with WP4 (and WP8/9/10) on which of the existing and future EO products are promising to complement eLTER SO spatially and temporally given the fact that most of the observed EO variables are not directly eLTER SOs but can be used as proxies.

Table 13: Overview of eLTER SOs relevant for EO calibration/validation activities

Component	Variable	Exemplary relevance for EO (either for Satellite Products or for in-situ components of EO provider)
Climate	Precipitation	TRMM, SM2RAIN-ASCAT, CMORPH, GSMAP, PERSIAN etc., ancillary information for soil moisture retrieval
Climate	Air temperature	Ancillary information for quality control and soil moisture retrieval
Climate	Wind speed / Wind direction	Ancillary information for soil moisture retrieval
Climate	Surface atmospheric pressure	Ancillary information for atmospheric correction
Soil	Soil temperature	Operational Land surface temperature (LST) products exists by Copernicus and NASA; ancillary information for calibration/validation of soil freeze and thaw state
Soil	Soil water content	SMOS, SMAP, ASCAT, S1A, Copernicus Global Land: Surface Soil Moisture
Soil	Soil organic C content (per horizon)	Top-soil organic carbon content for croplands (EO product under development)
Regional Habitat	Landscape heterogeneity and composition	Sentinel imagery or equivalent 10-20m for habitat mapping, A combination of sensors and techniques can be suited to each site, with sentinel imagery supporting harmonized coverage across Europe
Lake	Vertical profiles of chl-a, pigments	Copernicus Global Land Service has a trophic state product. National services for EO chl-a for lakes exists Operational algal bloom products exist especially for Sea and coastal areas. Development going on for lake areas
Lake	Algal community (quantitative)	Copernicus Global Land Service has a trophic state product. National services for EO chl-a for lakes exists Operational algal bloom products exist especially for Sea and coastal areas. Development going on for lake areas
Lake	Water Level	Copernicus Global Land Service: Water Levels
Lake	Ice Cover	Copernicus Global Land Service: Lake ice extent; Copernicus Pan-European: River and lake ice extent

Component	**Variable**	**Exemplary relevance for EO (either for Satellite Products or for in-situ components of EO provider)**
Groundwater	Level	GRACE, GRACE FO
Streams/Rivers	Instream habitat distribution (incl. sediment grain size distribution)	Copernicus Global Land Service
Streams/Rivers	Riparian vegetation	Copernicus Local component: Riparian zones
Terrestrial	Snow cover	Copernicus Global Service: Snow cover extent, snow water equivalent; Pan-European Service: High resolution snow and ice monitoring
Biomass	Aboveground biomass	Biomass, habitat mapping
Biomass	Aboveground vegetation growth	Biomass, habitat mapping
Biomass	Net primary production	MODIS, Copernicus Global Land Service, Copernicus Pan European High Resolution Vegetation Phenology and Productivity (under development)
Biomass	Gross primary production	MODIS, Copernicus Global Land Service, Copernicus Pan European High Resolution Vegetation Phenology and Productivity (under development)
Vegetation	Leaf area Index (LAI)	MODIS, Copernicus Global Land Service: Leaf Area Index
Vegetation	Leaf C, N, K, P, Ca, Mg, Mn content	
Climate	PAR	MODIS, Copernicus Global Land Service:FAPAR;
Eddy covariance	Net ecosystem C exchange	
Eddy covariance	Net primary production	MODIS, Copernicus Global Land Service: Vegetation Productivity Index; High resolution Vegetation Phenology and Productivity under development
Eddy covariance	Gross primary production	MODIS, Copernicus Global Land Service: Vegetation Productivity Index; High resolution Vegetation Phenology and Productivity under development
Eddy covariance	CH4 concentration	
Lake	Water transparency	Copernicus Global Land Service, and app: eoLytics WQ
Lake	In-situ vertical profiles and inflow concentrations of TP, SRP, NO3, DOC, SAC 254	Supportive information for Copernicus Global Land Service downstream products, and app: eoLytics WQ, national services
Lake	In-situ vertical profiles and inflow concentrations TOC, POC, TN, NO2, NH4, SRSi, DIC	Supportive information for Copernicus Global Land Service downstream products, and app: eoLytics WQ, national services
Streams/Rivers	Turbidity	Copernicus Global Land Service, and app: eoLytics WQ

Component	Variable	Exemplary relevance for EO (either for Satellite Products or for in-situ components of EO provider)
Land use	Grazing time, intensity	Land use in general (Copernicus pan-European component)
Land use	Crop, grassland harvesting	MODIS, Copernicus Global Land Service
Land use	Forest planting, thinning, clearcut	Land use in general (Copernicus pan-European component)
Land use	Irrigation timing, amount	Land use in general (Copernicus pan-European component)

Summary

A standardised and harmonised design is the central prerequisite for the exchange of data between sites and one of the decisive keys to achieving the two essential design objectives: (i) to support excellent science by making comprehensive environmental data available and improving its accessibility and utility and (ii) to provide the most representative coverage possible of the major biogeographical and socio-ecological regions of Europe.

The main objective of the eLTER preparatory phase is to prepare for the implementation and operation of the eLTER research infrastructure. This includes the development of the operational framework and technical requirements as the cornerstones for quantifying the resources needed to construct and operate the eLTER RI. The resource demand is significantly influenced by the specifications regarding the mandatory monitoring programme and the measurement. This concerns also the monitoring concept, i.e. the type and scope of environmental variables to be recorded and the methodology to be applied. Cross-site and cross-biome compliant standardized eLTER RI observations – the eLTER Standard Observation (eLTER SO's) – will enable the integration of measurements from plot to continental scales as required to address the eLTER Research Challenges.

The framework of eLTER SOs will include all variables, methods, and protocols that are defined as of priority in the sense of eLTER. The eLTER SOs are one of the central gears in the process of developing the eLTER RI. The selection of SOs are critical decisions for the design of the network and the services eLTER RI will provide. SOs drive costs in a decisive way and are critical for both the scientific decisions and the formal decision-making processes up to the Interim Council.

The process of developing the eLTER SOs has a long history. Its beginning lies in the eLTER H2020 and Advanced_eLTER projects and a first concretisation of the concept was part of the eLTER-application for the ESFRI-Roadmap. The two projects - the eLTER Preparatory Phase Project (eLTER PPP) and the Advanced Community Project eLTER PLUS - took on the task of continuing the process of standardisation and preparing the basis for formalised decisions regarding standardisation by setting up a multi-stage procedure, culminating in a list to be agreed upon by all relevant stakeholders. This procedure is composed of three main stages:

- Step 1: prioritization into two groups: “very high priority” and “high priority, but need for further discussion” - February 2021
- Step 2: collecting feedback from the scientific communities, from the National Research Infrastructures (NRIs) and the Sites-and-Platforms Forum (SPF), from the remote sensing data product providers - 2021/2022

- Step 3: providing a definition of the eLTER framework of standard observations (variables, methods, protocols) - 2023/2024

In order to initiate the process, a request for cooperation and input has been sent to the research themes and respective work packages in the eLTER PLUS project in June 2020. Based on a discussion process in these WPs, information has been provided to select and prioritize variables based on specific scientific perspectives against the background of eLTER's science agenda.

The variables are prioritized in the present document and classified into one of two categories: A = "very high priority" and B = "high priority, but need for further discussion". This ranking is the result of the overall view of all the information available so far. This includes the ratings for the categories (i) relevance, (ii) cost-effectiveness, and (iii) feasibility but also a multitude of additional information we have received from conversations and discussions in eLTER and the comparison with other RIs in the global context.

This document presents the results – the eLTER SO version 1. This list of SOs is an essential basis for the initial analyses of RI costs and to start the conceptual considerations on the design, the site hierarchies, and the selection of protocols and methods. Furthermore, this report also forms the basis for the subsequent further voting in the NRIs and the relevant scientific peer groups (also beyond eLTER).

It has to be emphasized that the document is a discussion paper. This means in particular: (i) none of the variables, methods or protocols mentioned is yet a formally confirmed part of eLTER SO and (ii) especially the variables of category B will go into the next process step in the upcoming months, the discussion with the Site-and-Platform-Forum and external expert groups. This document marks a start and not a finish line. But it is an important milestone on the road towards the eLTER RI and will help to guide the further discussion processes.

4 References

Bojinski, S., Verstraete, M., Peterson, T.C., Richter, C., Simmons, A., Zemp, M., 2014. The Concept of Essential Climate Variables in Support of Climate Research, Applications, and Policy. Bulletin of the American Meteorological Society 95(9), 1431-1443.

Collins, S.L., Carpenter, S.R., Swinton, S.M., Orenstein, D.E., Childers, D.L., Gragson, T.L., Grimm, N.B., Grove, M., Harlan, S.L., Kaye, J.P., Knapp, A.K., Kofinas, G.P., Magnuson, J.J., McDowell, W.H., Melack, J.M., Ogden, L.A., Robertson, G.P., Smith, M.D., Whitmer, A.C., 2011. An integrated conceptual framework for long-term social-ecological research. Front Ecol Environ 9(6), 351-357.

Costa, L., Hildén, M., Kropp, J., Böttcher, K., Fronzek, S., Swart, R., Otto, J., McCormick, N., Radojevic, M., Lückenkötter, J., 2016. Assessing climate impact indicators: Evaluation criteria and observed strengths and weaknesses. 9521146508.

EC, E.C., 2017. European Commission's Societal Challenges for EUROPE 2020.

Fersch, B., Jagdhuber, T., Schron, M., Volksch, I., Jager, M., 2018. Synergies for Soil Moisture Retrieval Across Scales From Airborne Polarimetric SAR, Cosmic Ray Neutron Roving, and an In Situ Sensor Network. Water Resources Research 54(11), 9364-9383.

GCOS, G.C.O.S., 2010. Implementation plan for the global observing system for climate in support of the UNFCCC (2010 Update).

GEOBON, G.o.E.O.-B.O.N., 2017. GEO BON Strategy for development of Essential Biodiversity Variables, Version 2.0.

Gleiser, M., 2018. How Much Can We Know? Nature 557(7706), S20-S20.

Guerra, C., Drakou, E., Pereira, H., Pendleton, L., Marques, A., Freyhof, J., Provenzale, A., Imperio, S., Proenca, V., Domingos, T., Ramoelo, A., El Serafy, G., Ziemba, A., Giamberini, M., Hummel, H., 2017. Review of existing Essential Variables (EVs) relevant to PAs studies. Deliverable 2.1, ECOPOTENTIAL project.

Haase, P., Tonkin, J.D., Stoll, S., Burkhard, B., Frenzel, M., Geijzendorffer, I.R., Häuser, C., Klotz, S., Kühn, I., McDowell, W.H., Mirtl, M., Müller, F., Musche, M., Penner, J., Zacharias, S., Schmeller, D., 2018. The next generation of site-based long-term ecological monitoring: Linking essential biodiversity variables and ecosystem integrity. The Science of the total environment 613-614, 1367-1384.

Hari, P., Petaja, T., Back, J., Kerminen, V.M., Lappalainen, H.K., Vihma, T., Laurila, T., Viisanen, Y., Vesala, T., Kulmala, M., 2016. Conceptual design of a measurement network of the global change. Atmos Chem Phys 16(2), 1017-1028.

Heffernan, J.B., Soranno, P.A., Angilletta, M.J., Buckley, L.B., Gruner, D.S., Keitt, T.H., Kellner, J.R., Kominoski, J.S., Rocha, A.V., Xiao, J.F., Harms, T.K., Goring, S.J., Koenig, L.E., McDowell, W.H., Powell, H., Richardson, A.D., Stow, C.A., Vargas, R., Weathers, K.C., 2014. Macrosystems ecology: understanding ecological patterns and processes at continental scales. Front Ecol Environ 12(1), 5-14.

Köhl, M., Traub, B., Paivinen, R., 2000. Harmonisation and standardisation in multi-national environmental statistics - Mission impossible? Environmental Monitoring and Assessment 63(2), 361-380.

Lausch, A., Zacharias, S., Dierke, C., Pause, M., Kuhn, I., Doktor, D., Dietrich, P., Werban, U., 2013. Analysis of Vegetation and Soil Patterns using Hyperspectral Remote Sensing, EMI, and Gamma-Ray Measurements. Vadose Zone Journal 12(4).

Lawford, R., ed., 2014. The GEOSS Water Strategy: From Observations to Decisions.

Lehmann, A., Nativi, S., Mazzetti, P., Maso, J., Serral, I., Spengler, D., Niamir, A., McCallum, I., Lacroix, P., Patias, P., Rodila, D., Ray, N., Giuliani, G., 2020. GEOEssential - mainstreaming workflows from data sources to environment policy indicators with essential variables. Int J Digit Earth 13(2), 322-338.

Masó, J., Serral, I., Domingo-Marimon, C., Zabala, A., 2020. Earth observations for sustainable development goals monitoring based on essential variables and driver-pressure-state-impact-response indicators. Int J Digit Earth 13(2), 217-235.

Miloslavich, P., Bax, N.J., Simmons, S.E., Klein, E., Appeltans, W., Aburto-Oropeza, O., Garcia, M.A., Batten, S.D., Benedetti-Cecchi, L., Checkley, D.M., Chiba, S., Duffy, J.E., Dunn, D.C., Fischer, A., Gunn, J., Kudela, R., Marsac, F., Muller-Karger, F.E., Obura, D., Shin, Y.J., 2018. Essential ocean variables for global sustained observations of biodiversity and ecosystem changes. Global Change Biology 24(6), 2416-2433.

Mollenhauer, H., Kasner, M., Haase, P., Peterseil, J., Wohner, C., Frenzel, M., Mirtl, M., Schima, R., Bumberger, J., Zacharias, S., 2018. Long-term environmental monitoring infrastructures in Europe: observations, measurements, scales, and socio-ecological representativeness. Science of The Total Environment 624, 968-978.

Müller, F., Hoffmann-Kroll, R., Wiggering, H., 2000. Indicating ecosystem integrity - theoretical concepts and environmental requirements. Ecological Modelling 130(1-3), 13-23.

Patias, P., Verde, N., Tassopoulou, M., Georgiadis, C., Kaimaris, D., 2019. Essential variables: describing the context, progress, and opportunities for the remote sensing community, Seventh International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2019), Paphos, Cyprus.

Reid, W.V., Chen, D., Goldfarb, L., Hackmann, H., Lee, Y.T., Mokhele, K., Ostrom, E., Raivio, K., Rockström, J., Schellnhuber, H.J., Whyte, A., 2010. Earth system science for global sustainibility: Grand Challenges. Science 330, 916-917.

Reyers, B., Stafford-Smith, M., Erb, K.H., Scholes, R.J., Selomane, O., 2017. Essential Variables help to focus Sustainable Development Goals monitoring. Curr Opin Env Sust 26-27, 97-105.
Shapiro, M., Shukla, J., Brunet, G., Nobre, C., Beland, M., Dole, R., Trenberth, K., Anthes, R., Asrar, G., Barrie, L., Bougeault, P., Brasseur, G., Burridge, D., Busalacchi, A., Caughey, J., Chen, D.L., Church, J., Enomoto, T., Hoskins, B., Hov, O., Laing, A., Le Treut, H., Marotzke, J., McBean, G., Meehl, G., Miller, M., Mills, B., Mitchell, J., Moncrieff, M., Nakazawa, T., Olafsson, H., Palmer, T., Parsons, D., Rogers, D., Simmons, A., Troccoli, A., Toth, Z., Uccellini, L., Velden, C., Wallace, J.M., 2010. An Earth-System Prediction Initiative for the Twenty-First Century. Bulletin of the American Meteorological Society 91(10), 1377-1388.
Sterckx, S., Brown, I., Kaab, A., Krol, M., Morrow, R., Veefkind, P., Boersma, K.F., De Maziere, M., Fox, N., Thorne, P., 2020. Towards a European Cal/Val service for earth observation. Int J Remote Sens 41(12), 4496-4511.
Zoback, M.L., 2001. Grand challenges in earth and environmental sciences: sciences, stewardship, and service for the twenty-first century. GSA Today 12, 41-47.

European long-term ecosystem, critical zone and socio-ecological systems research infrastructure PLUS

Discussion paper on eLTER Standard Observations (eLTER SOs)

Deliverable D3.1

Annex

24th February 2021

Steffen Zacharias[1], Saku Anttila[2], Jaana Bäck[3], Kristin Böttcher[2], Ulf Mallast[1], Michael Mirtl[1], Marcus Schaub[4], Volodymyr Trotsiuk[4], and the eLTER PLUS Research Themes

[1] *UFZ Helmholtz Centre for Environmental Research, Germany*

[2] *Finnish Environment Institute, Finland*

[3] *Department of Forest Sciences, University of Helsinki, Finland*

[4] *Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland*

Prepared under contract from the European Commission

Grant agreement No. 871128

EU Horizon 2020 Research and Innovation action

Project acronym:	**eLTER PLUS**
Project full title:	**European Long-Term Ecosystem, critical zone and socio-ecological systems Research Infrastructure PLUS**
Start of the project:	Feb 2020
Duration:	60 months
Project coordinator:	Professor Jaana Bäck University of Helsinki, Finland https://www.lter-europe.net/projects/elter-plus
Deliverable title:	Discussion paper on eLTER Standard Observations (eLTER SOs) - Annex
Deliverable n°:	D3.1
Nature of the deliverable:	[Other]
Dissemination level:	[Public]
Citation:	Zacharias, S. et al. (2021). *Discussion paper on eLTER Standard Observations (eLTER SOs) - Annex*. Deliverable D3.1 EU Horizon 2020 eLTER PLUS Project, Grant agreement No. 871128.

Deliverable status:

Version	Status	Date	Author(s)
3.0	Final	8th Mar 2021	As listed in the authors list

Inhalt

A1. The relevance assessment of SO's for the main Earth observation data providers

For the calibration and validation (cal/val) purposes of EO data products, the in situ data is essential and need to be timely, co-located, accessible, long term and of fiducial quality (Sterckx et al., 2020). The eLTER RI has thus great potential in developing collaboration with the main public EO data providers (Table 1) and contributing with certain in-situ data with above-mentioned properties (Table 2).

Table 1: The main public EO data and service providers as listed in the ESA's website

EO data provider	Provider website
ESA	https://earth.esa.int/web/guest/home
ESA-Sentinel	https://sentinel.esa.int/web/sentinel/
Sentinel Hub	https://www.sentinel-hub.com/
Eumetsat	http://www.eumetsat.int/website/home/index.html
USGS (Landsat)	http://earthexplorer.usgs.gov/
NOAA	http://www.ospo.noaa.gov/
NASA	https://earthdata.nasa.gov/earth-observation-data
Japan	http://www.eorc.jaxa.jp/en/about/distribution/index.html
China	http://www.cma.gov.cn/en
India	http://bhuvan.nrsc.gov.in/bhuvan_links.php

The requirements collected in Table 2 are based on documents from the Copernicus in situ component (Copernicus In situ Information System (2020), GBOV (2018)) and the Committee on Earth Observation Satellites (CEOS) Working Group on Land Validation and Calibration Land product validation (http://calvalportal.ceos.org/) and dedicated information exchange with the European Environmental Agency (EEA), coordinating the Copernicus In situ component. Additional requirements from other relevant sources (including the Group on Earth Observation) were also considered. Requirements for in situ data of the Copernicus services are collected in the Copernicus In situ Component Information System (CIS2) and synthesis reports of those are under preparation for each service at the EEA. Draft versions from the Copernicus In Situ Information System (2020) were utilized in this work. In the discussion with the EEA, the cal/val needs for the Copernicus High Resolution Vegetation Phenology and Productivity (HRVPP) pan-European product that is currently under development were highlighted.

Table 2: Variables for which in-situ data are already collected by global EO data providers as a service for cal/val activities, the description of state/flux is described, how each method is defined

Variable	**What state/flux does the variable describe or is it related to?**	**Current methods/recommendations/ further remarks (e.g. notes on the validity of currently used methods)**
Leaf area index [m^2 m^{-2}]	Photosynthesis, respiration carbon balance, interception of precipitation	Defined as one half the total green (i.e., photosynthetically active) leaf area per unit horizontal ground surface. Destructive (ecology), radiometric (LAI2000 or TRAC), **Digital Hemispherical Photographs (DHP)** (GBOV, 2018., Fernandes et al. 2014); sites mostly in the United States
Transmission through canopy	Photosynthesis, carbon balance, FAPAR	Amount of photosynthetically active radiation (400 nm – 700 nm, PAR) that is transmitted through the canopy, quantified as photosynthetic photon flux density (PPFD) in µmol (m-2.s-1). Radiation that is absorbed by photosynthetic pigments in plants for photosynthesis. Can be either derived from direct measurements or Digital Hemispherical Photographs (GBOV, 2018). Measurements currently mostly in the United States.
Fraction of Intercepted Photosynthetically Active Radiation (FAPAR)	Photosynthesis, carbon balance	Defined as the fraction of photosynthetically active radiation- Derived from incoming and upcoming PAR at top and bottom of the canopy through Digital Hemispherical Photographs (GBOV, 2018) , sites mostly in the United States
Above ground biomass [mass per unit area, typically Mg ha^{-1}]	Ecosystems; biodiversity; Photosynthesis; respiration, carbon, water and nutrient balance;	Defined as the above ground standing dry mass of live or dead matter from tree or shrub (woody plant) life forms, expressed as a mass or mass per unit area; Derived from terrestrial laser scanning, forest inventories; Airborne Lidar; Good practice guide currently in drafting phase; (Duncanson et al. 2019)
Vegetation structure		Terrestrial Laser scanning, forest inventories; Airborne Lidar (GBOV, 2018)
Gross and net primary productivity [g C m^{-2} yr^{-1}]	Carbon balance	Derived from Eddy covariance measurements

Variable	What state/flux does the variable describe or is it related to?	Current methods/recommendations/ further remarks (e.g. notes on the validity of currently used methods)
Vegetation phenology [day of year] and metrics	Carbon, water and nutrient balance	Plant phenological events can be derived from eddy covariance measurements, web-camera observations; distributed visual field observations of vegetation phenological stages
Terrestrial Chlorophyll	Photosynthesis; respiration, carbon, water and nutrient balance	Canopy reflectance spectra and chlorophyll content data. Note from Copernicus insitu component: Very limited set of in-situ data available. Currently sites from in UK and Spain
Land cover		Defined as the observed (bio)-physical cover on the Earth's terrestrial surface. Information and images on land cover and land cover change according to the EO classification systems (Copernicus global and pan European insitu requirements)
Habitats and biotopes / vegetation ground measurements	ecosystems; biodiversity; Photosynthesis; respiration, carbon, water and nutrient balance;	Various ground measures of vegetation type, cover and habitats. Requirement from Copernicus In Situ Information System; Report for Service Component: Global Land Component (GLC) ("The most shared Requirement is "Vegetation Ground Measurements", which is because this is an essential input to the global vegetation and broader Products.")
Soil moisture	Water balance	soil water content (mass or volume of water in the soil) or soil water potential (soil water energy status). Probes deployment at permanent sites (GBOV, 2018), measurement at 5 cm depth Good practice guide for satellite validation by Montzka et al. (2020)
Snow and Ice measurements Snow water equivalent	Water and energy balance, albedo	Defined as the unique area of snow covered surfaces projected on the local horizontal datum within a spatial mapping unit at a specified time. Fraction of snow on land, extent of snow and ice on rivers and lakes (Copernicus pan European insitu requirements); snow cover information is derived from snow depth observations, snow transects, webcam observations.

Variable	**What state/flux does the variable describe or is it related to?**	**Current methods/recommendations/ further remarks (e.g. notes on the validity of currently used methods)**
Soil freeze and thaw	Water balance	Derived from soil temperature and soil moisture measurements at different depths
Fire/ burned area	Disturbance	
Direct/ diffuse shortwave radiation (0.4 – 4 µm) [W m^{-2}]	Energy balance, top of canopy reflectance, surface albedo	Upward shortwave radiation (W.m-2) (Shortwave radiation emerging from the ground) Downward total shortwave irradiance (W.m-2) (Shortwave radiation incoming to the ground. This is the direct contribution i.e. incoming for the sun under a clear sky) Downward diffuse shortwave radiation flux (W.m-2) (Shortwave radiation incoming to the ground. This “diffuse” radiation has been scattered by particles in the atmosphere such as cloud droplets and aerosols.), measured with cosine-collector light meter; utilized for Top of canopy reflectance, surface albedo
Soil BRF	Energy balance, Top of canopy reflectance	Hyperspectral Bidirectional Reflectance Factor Schaepmann-Strub et al. (2006), Systematic airborne campaigns over stations every 3 years (GBOV, 2018). Measurements currently mostly in the United States.
Surface reflectance or Top of canopy reflectance	<several>	Ratio of the reflected to incident radiation; Utilized in the development, accuracy assessment and cal/val purposes of EO algorithms (Radiometric validation of optical signals. Validation of vegetation products and uncertainty assessment.)
Surface albedo	Energy balance	Defined as the ratio of the radiant flux reflected from a unit surface area into the whole hemisphere to the incident radiant flux of hemispherical angular extent (Schaepman-Strub et al., 2006). It can be defined for broad spectral regions or for spectral bands of finite width. Good practice guide in Wang et al. (2019).

Variable	What state/flux does the variable describe or is it related to?	Current methods/recommendations/ further remarks (e.g. notes on the validity of currently used methods)
Land surface emissivity	Energy balance, land surface temperature, Ancillary information	Ratio of the power emitted by an object to the power that would be emitted by a perfect black body having the same temperature as the object. Measured through field experiments, rarely on permanent ground stations (GBOV, 2018)
Direct/diffuse thermal radiation [W m^{-2}]	Energy balance, land surface temperature	Broadband and multispectral thermal infrared radiation in the upwelling and downwelling direction at the surface [4.0 – 25 µ], Upward thermal radiation (W.m-2) (Thermal radiation flux emerging from the ground.) Downward thermal radiation (W.m-2) (Thermal radiation flux incoming from the ground.) (GBOV, 2018), measured with cosine-collector light meter; utilized for land surface temperature products
Land surface temperature [K, °C]	Energy balance	Aggregated radiometric surface temperature based on a measure of radiance. Measured by radiometer or temperature sensors mounted on permanent stations (GBOV, 2018)
Meteo properties (Atmospheric pressure, precipitation, wind speed)	Meteorology; correction of atmospheric effects	Mostly for quality control of satellite products and soil moisture products
Atmospheric properties (Aerosol optical depth [], Angström exponent [])	Atmospheric conditions, correction of atmospheric effects	Ancillary information for satellite retrievals and atmospheric correction

Copernicus In Situ Information System (2020); Report for Service Component: Global Land Component (GLC), Framework Service Contract EEA/IIDM/15/026/LOT2 for Services supporting the EEA implementation of cross-cutting activities for coordination of the In Situ component of the Copernicus Programme Services, Issue 2.0.

Copernicus In Situ Information System (2020). Report for Service Component: Pan European Land (PLC), Framework Service Contract EEA/IIDM/15/026/LOT2 for Services supporting the EEA implementation of cross-cutting activities for coordination of the In Situ component of the Copernicus Programme Services, Issue 2.0.

Copernicus In Situ Information System (2020). Report for Service Component: Local Land (LLC), Framework Service Contract EEA/IIDM/15/026/LOT2 for Services supporting the EEA implementation of cross-cutting activities for coordination of the In Situ component of the Copernicus Programme Services, Issue 2.0.

In-situ data coordination with Copernicus Space Component – Progress Report

Copernicus Global Land Operations "Vegetation and Energy"- SCIENTIFIC QUALITY EVALUATION LAND SURFACE TEMPERATURE (2019), Version 1.2/Issue I1. "CGLOPS-1"https://land.copernicus.eu/global/sites/cgls.vito.be/files/products/CGLOPS1_SQE2019_LST-V1.2_I1.00.pdf

GBOV (2018) – Ground-based observations for validation (GBOV) of Copernicus Global Land Products, Product User Manual, GBOV-PUM-001-ACR, Version 1.1, Date: 8/11/2018;

Duncanson, L., Armston, J., Disney, M., Avitabile, V., Barbier, N., Calders, K., Carter, S., Chave, J., Herold, M., Crowther, T.W., Falkowski, M., Kellner, J.R., Labriére, N., Lucas, R., MacBean, N., McRoberts, R.E., Meyer, V., Næsset, E., Nickeson, J.E., Paul, K.I., Phillips, O.L., Réjou- Méchain, M., Román, M., Roxburgh, S., Saatchi, S., Schepaschenko, D., Scipal, K., Siqueira, P.R., Whitehurst, A., Williams, M. 2019. The importance of consistent global forest aboveground biomass product validation. *Surveys in Geophysics*. https://doi.org/10.1007/s10712-019-09538-8.

Fernandes, R., Plummer, S., Nightingale, J., Baret, F., Camacho, F., Fang, H., Garrigues, S., Gobron, N., Lang, M., Lacaze, R., LeBlanc, S., Meroni, M., Martinez, B., Nilson, T., Pinty, B., Pisek, J., Sonnentag, O., Verger, A., Welles, J., Weiss, M., & Widlowski, J.L. (2014). Global Leaf Area Index Product Validation Good Practices. Version 2.0. In G. Schaepman-Strub, M. Román, & J. Nickeson (Eds.), Best Practice for Satellite-Derived Land Product Validation (p. 76): Land Product Validation Subgroup (WGCV/CEOS), doi:10.5067/doc/ceoswgcv/lpv/lai.002.

Montzka, C., et al. (2020). Soil Moisture Product Validation Good Practices Protocol Version 1.0. In: C. Montzka, M. Cosh, J. Nickeson, F. Camacho (Eds.): Good Practices for Satellite Derived Land *Product Validation* (p. 123), Land Product

Validation Subgroup (WGCV/CEOS), DOI: 10.5067/doc/ceoswgcv/lpv/sm.001

G. Schaepman-Strub, M.E. Schaepman, T.H. Painter, S. Dangel, J.V. Martonchik, 2006. Reflectance quantities in optical remote sensing definitions and case studies. Remote Sensing of Environment 103 (2006) 27-42.

Wang, Z., Schaaf, C., Lattanzio, A., Carrer, D., Grant, I., Román, M., Camacho, F., Yu, Y., Sánchez-Zapero, J. & Nickeson, J. (2019). Global Surface Albedo Product Validation Best Practices Protocol. Version 1.0. In Z. Wang, J. Nickeson & M. Román (Eds.), *Best Practice for Satellite Derived Land Product Validation* (p. 45): Land Product Validation Subgroup (WGCV/CEOS), doi: 10.5067/DOC/CEOSWGCV/LPV/ALBEDO.001

A2. Glossary

AMS	Alpha Magnetic Spectrometer
CORINE	Coordination of Information on the Environment (EU-Project)
CZ	Critical Zone
DEIMS-SDR	Dynamic Ecological Information Management System - Site and dataset registry
DIC	Dissolved Inorganic Carbon
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
EA-IRMS	Elemental Analyzer - Isotope Ratio Mass Spectrometry
EC	European Commission
EC-Station	Eddy Covariance Station
eDNA	Environmental Desoxyribonucleic Acid
EI	Ecosystem Integrity
EU	European Union
eLTER	Integrated European long-term ecosystem, critical zone and socio-ecological systems research infrastructure
eLTER PLUS	Integrated European long-term ecosystem, critical zone and socio-ecological systems research infrastructure PLUS
eLTER PPP	Integrated European long-term ecosystem, critical zone and socio-ecological systems research infrastructure Preparatory Phase Project
eLTER RI	Integrated European long-term ecosystem, critical zone and socio-ecological system research infrastructure
EO	Earth Observation
ESA	European Space Agency
ESFRI	European Strategy Forum on Research Infrastructures
Fluxnet	Vast networks of meteorological sensors ring the globe measuring atmospheric state variables
GDP	Gross Domestic Product
GEO	Group on Earth Observations
GHG	Green House Gas
ICOS	Integrated Carbon Observation System
ICP	International Co-operative Programme
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP Forests	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
ICP Waters	International Cooperative Programme for assessment and monitoring of the effects of air pollution on rivers and lakes
INT	Alignment with existing standards in other international environmental observation networks

IRMS	Inductively Coupled Plasma – Mass Spectrometry
LAI	Leaf Area Index
LAU	Local Administrative Units
LC-MS	Liquid Chromatography
LST	Land Surface Temperature
LTER	Long Term Ecological Research
LTER-Europe	European Network of LTER sites
LTSER	Long Term Socio-Ecological Research
LUCAS	Land use and land cover survey
MSE	Macrosystems Ecology
NASA	National Aeronautics and Space Administration
NEE	Net Ecosystem Exchange
NGO	Non-Governmental Organisation
NRI	National Research Infrastructures
NUT	Nomenclature of territorial units for statistics
PAR	Photosynthetically Active Radiation
POC	Particulate Organic Matter
PPD	Press Pulse Dynamic Model
QA4EO	Quality Assurance Framework for Earth Observation
RGB	Red-Green-Blue portion of the electromagnetic spectrum
REE	Rare Earth Elements
RI	Research Infrastructure
SAC	Spectral Absorption Coefficient
SO	Standard Observations
SPF	Sites-and-Platforms Forum
SRP	Soluble Reactive Phosphate
SRSi	Soluble Reactive Silica
TCC	Total prokaryotic cell counts
TN	Total Nitrogen
TOC	Total Organic Content
TDN	Total Dissolved Nitrogen
UAV	Unmanned Aerial Vehicle
UNECE	United Nations Economic Commission for Europe
WAILS	Whole-system Approach for In-situ research on Life Supporting Systems
WFD	Water Framework Directive
WMO	World Meteorological Organization
WP	Working Package