# Full Proposal for the CEOS Biodiversity Virtual Constellation: Introduction

**Submitted for Endorsement at SIT-41 by the Biodiversity Study Team**
**14-16 April, 2026**
**Irvine, CA USA**

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**Version 1.0[2]**
**17 March 2026**

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**Preface**

The Full Proposal for the Biodiversity Virtual Constellation (B-VC) is composed of three parts—this Introduction, the Terms of Reference, and the Implementation Plan. This Introduction provides historical context, reviews the overall role of Earth observation for biodiversity monitoring and decision making, and summarizes the types of activities the B-VC has planned. The Terms of Reference follows the guidelines in the Virtual Constellation Process Paper by providing a mission statement and the supporting objectives, summarizing the types of activities that support those objectives, identifying the Agencies that will lead the VC, and explaining how it will be resourced. The Implementation Plan goes further and explains various aspects of how the activity categories will be executed, including the involvement of CEOS Working Groups and Virtual Constellations, and provides a high level schedule and other information.

**Introduction**

Biodiversity was recognized as a thematic gap in CEOS in 2012, resulting in the creation of the CEOS Biodiversity Activity. However, it only became fully active in 2022 with the creation of the CEOS Ecosystem Extent Task Team (EETT) at the 36th Plenary. The EETT was tasked with writing a white paper describing how existing and future EO missions can support Ecosystem Extent products and to develop demonstrators to show this.

The role of CEOS in biodiversity gained momentum when the Canadian Space Agency (CSA) became the 2024 CEOS Chair and selected biodiversity as one of its themes. This led to the formation of the CEOS Biodiversity Study Team (BST) which was tasked to conduct a stakeholder assessment, consult across the various CEOS Agencies and entities, assess options for sustainable support for biodiversity within CEOS, and recommend the best option for support. The BST's report, submitted for the 2025 CEOS Plenary, describes in detail the six options that were assessed, provides an evaluation of each of those, and explains its selection of a Virtual Constellation as the best option. At Plenary it was agreed that a Virtual Constellation was the best option and that the BST should proceed with development of the Full Proposal (Decision 39-08).

**Role of EO for Biodiversity Monitoring and Decision Making**

Space-based EO is essential for monitoring ecosystems and biodiversity. It provides near-global coverage on a regular basis and complements surface-based in situ observations that provide more detail but are relatively expensive and spotty in space and time. Although in situ data remains essential, EO is required to characterize ecosystems in several key ways to enable important products that facilitate decisions; these include maps of ecosystem distribution and the habitat characterization needed to make maps of where species live.

Although Earth observation has provided information on ecosystems and biodiversity for decades, recent and forthcoming missions will greatly expand its application and importance. These missions are complemented by simultaneous advances in science and technology that enable use of EO in ways that were not previously possible. For example, computing technology continues to rapidly accelerate, enabling products such as global time series that were previously not practical. Artificial intelligence capabilities are expanding even faster and are leading to new products and insights that have not been available before. And on the Earth surface, in situ observation capabilities are also expanding with new types of measurements to complement those from space and thus increase their value for biodiversity monitoring.

**Biodiversity's Societal Importance**
Biodiversity supports the health, stability, and resilience of ecological systems that sustain human well-being. Diverse ecosystems regulate carbon and water cycles, maintain soil health, and sustain fisheries, agriculture, and other natural resources that humans depend on, directly influencing human health, agricultural productivity, and economic security. Biodiversity also contributes to ecosystem resilience, enabling ecosystems to absorb disturbances in the face of environmental change. Integrating biodiversity considerations into policy, planning, and resource management is therefore essential for promoting sustainable development, climate resilience, and human well-being.

To highlight the connection between Agency missions and the ecosystem characteristics that need to be monitored, some specific examples are provided here.

- **Active sensors (SAR and lidar).** These sensors map and characterize three-dimensional ecosystem structure. On land, such characteristics include forest vertical profile, height, and biomass. The rapid expansion of spatial and temporal coverage that recent and planned missions provide, including NASA/ISRO's NISAR, ESA's ROSE-L (both augmenting JAXA's ALOS missions), ESA's BIOMASS, and JAXA's MOLI (which will augment NASA's GEDI mission), is enabling more accurate and routine monitoring of these and other parameters. In purely aquatic systems, ASI's LUCE multi-band lidar, now under development, will characterize the ocean's vertical community structure including phytoplankton and zooplankton distributions.
- **Multi- and hyperspectral missions.** A variety of multispectral missions remain essential for ecosystem monitoring in both terrestrial and aquatic systems. Imaging spectroscopy missions such as ASI's PRISMA, DLR's ENMAP, and NASA's EMIT are

enabling important insights into ecosystem composition, physiology, processes, and health, particularly for terrestrial ecosystems. In aquatic ecosystems, the increased spatial and spectral resolution of recent and forthcoming missions such as PACE are expanding monitoring capabilities and applications. More broadly, hyperspectral and multispectral observations will increase in coverage and frequency in the coming years with missions such as ESA's CHIME, NASA's SBG-VSWIR, and USGS/NASA's LandsatNext).

- **Thermal missions.** Missions such as Trishna, SBG-OTTER, and LSTM will help characterize ecosystems in several ways, including insights into functions. Each of these missions provides essential information on ecosystem condition and facilitates the ecosystem discrimination needed to map ecosystem extent.

Beyond the value of individual sensors for monitoring biodiversity, their complementary measurements enable EO data to be combined to describe ecosystems more completely than any single sensor can. For example, SAR and lidar sensors detect vertical and horizontal physical structure and multi- and hyperspectral data provide insights into ecosystem taxonomic composition and functional processes. EO is rapidly moving to an era where, for the first time, it will be possible to obtain routine global measurements of fundamental ecosystem characteristics: the value of this for biodiversity applications, and society more broadly, should not be underestimated.

**EO is moving to an era where it is possible to obtain routine global measurements of key ecosystem characteristics, from space, for the first time**

**User Needs, B-VC Activities, and Outcomes**

The Biodiversity Study Team did an extensive review of user needs in their stakeholder assessment and these are summarized in Appendix 1; they are the basis for all the B-VC's activities. In general, users highlighted the importance of monitoring ecosystem properties in support of decision making, including the distribution and condition of ecosystems and species of interest. The need for increasing user capacity and improving data usability was also highlighted. In response to these needs the B-VC plans to focus on six categories of activities designed to advance its three overarching objectives; details are available in the Implementation Plan.

- **Fill Data Product Gaps.** Users need information on a variety ecosystem properties but data products that provide that information are very often not available. For many users this lack of needed products is the biggest barrier to increased use of EO. Consequently, the B-VC will identify and facilitate filling gaps in priority biodiversity data products and related observations.
- **Enhance Analytical Tools.** Because users face challenges in accessing and using EO data, the B-VC will explore ways to improve the tools available to users to help

them access and utilize EO data. This approach complements the need for capacity building that addresses limitations in user technical capacity.

- **Build User Capacity.** User capacity is closely related to and complements the availability of appropriate tools. The B-VC will work with WGCapD to coordinate activities that enhance user capacity.
- **Increase User Engagement.** Because close engagement with users is essential to all of B-VC's activities, the B-VC will work to increase awareness, visibility, and uptake of EO capabilities using outreach and broader dissemination activities.
- **Develop Prototype Monitoring Systems.** The EETT developed three demonstration systems that not only showed the importance of EO for biodiversity applications but also provided a framework for developing and testing new products and tools, for educating and engaging users, and obtaining user feedback. Because these areas are also those that the B-VC will focus on, the B-VC plans to use a similar approach as a framework for developing its other activities. While the EETT demonstrators will continue, the B-VC will seek out new prototypes, in different ecosystems, including aquatic systems.
- **Global Biodiversity Observing System (GBiOS).** In the longer term the B-VC will coordinate with the GEO Biodiversity Observation Network to support the integration of EO products into GEO BON's GBiOS concept. This activity will focus on identifying the needs, gaps, and challenges where EO can add value, and on jointly guiding the development of GBiOS to maximize its use of space-based EO.

## Leadership

CSA, ESA, and NASA have each put forward co-leads and committed to their support:

- CSA: Lucie Viciano
- ESA: Marc Paganini
- NASA: Gary Geller

## Conclusions

The Biodiversity Virtual Constellation's mission, objectives, and activities have been carefully selected to increase the impact of Agency missions on biodiversity monitoring and decision making. Its activities, facilitated by prototype monitoring systems that provide a development and user engagement environment, are designed to directly respond to the user needs that the Biodiversity Study Team identified. Interactions with other CEOS Working Groups and Virtual Constellations will enable the B-VC to leverage their work and expertise and ensure a coordinated CEOS response.

## Appendix 1: Identified User Needs

This table summarizes the results of the Biodiversity Study Team's stakeholder assessment and also reflects consultations with Agencies, Working Groups and Virtual Constellations.

| General Need Category | Example Conservation Applications | Example Products or Tools Needed with Direct Relevance to EO |
|---|---|---|
| Species Distribution | ● Invasive species detection<br>● Endangered species management<br>● Extinction risk assessment | Environmental data |
| | | Mapping/visualization tools |
| | | Multi-sensor products (e.g., optical + SAR + lidar) that characterize ecosystem structure, composition, function |
| Ecosystem Extent | ● Managing ecosystems & protected areas<br>● Monitoring & assessing<br>● Planning ecosystem restoration | Ecosystem extent maps |
| | | EO-based tools for mapping ecosystem types |
| | | EO-based methods for monitoring changes |
| | | Time series & change maps |
| | | Distinguishing natural from plantation ecosystems |
| | | Multi-sensor products (e.g., optical + SAR + lidar) that characterize ecosystem structure, composition, function |
| Ecosystem Condition | ● Monitoring health & function of ecosystems<br>● Monitoring ecosystem degradation & restoration<br>● Identifying eutrophication | Ecosystem condition metrics |
| | | Time series & change maps |
| | | Trend maps & figures |
| | | Multi-sensor products (e.g., optical + SAR + lidar) that characterize ecosystem structure, composition, function |
| Increased user capacity, data access, & usability | All | Data access tools to simplify finding/accessing data |
| | | Data utilization tools to simplify analysis, particularly for SAR & hyperspectral data |
| | | Guidance on data to use for particular applications |

| | | |
|---|---|---|
| Ecosystem Services | ● Monitoring food, lumber, carbon sequestration, hydrological buffering, natural beauty, etc. | Data & products that characterize ecosystem functions & products that are useful to humans |
| Various | ● Ecosystem conservation (all aspects) | Vegetation indices, productivity, biomass |
| | | Change detection & mapping |
| | | Identification/mapping threats to biodiversity (e.g., climate change, LULCC, roads, invasive non-native species) |
| Ecosystem connectivity | ● Animal movement planning<br>● Ecosystem condition assessment | Ecosystem extent & condition maps |
| | | Combines Ecosystem Extent & Ecosystem Condition |
| Species extinction risk | ● Conservation planning | Identification of threats (e.g., climate change, LULCC, roads, shipping lanes, invasive non-native species, acidification) |
| | | Change in species distribution |
| Ecosystem degradation and restoration | ● Degradation & restoration assessment<br>● Restoration planning and reporting | Frequent plant productivity time series (10m or less, since 2000) |
| | | Land cover change (10m or less, annual) or marine area use change |
| | | Plant cover (or macroalgae), soil carbon, & soil moisture for dry, sparsely vegetated areas |
| | | EO standards for land degradation assessment |