CEOS WGCV Land Product Validation Work Plan 2026 – 2029

1. Introduction

This document presents the Land Product Validation (LPV) Work Plan for the period 2026–2029. The plan builds primarily on the outcomes of the LPV Plenary Meeting, held in Vienna on 26 June 2025, complemented by recent developments and priority areas emerging from the broader international framework. These include activities within the CEOS-WGCV, as well as cross-cutting CEOS initiatives and ongoing collaboration with other international frameworks, such as GCOS and GEOGLAM.

The document first recalls the LPV mission and objectives, then outlines the overall EO context, with particular emphasis on recent advances in satellite-based land remote sensing and the associated challenges expected in the near future. It then describes the strategy to be implemented over the next three-year period to address these challenges, along with the resulting actions, which are listed in Section 4, Table 1.

2. LPV Mission and Objectives

The mission of LPV, a subgroup of the CEOS-WGCV, is to coordinate the quantitative validation of satellite-derived land products. Its core focus is on the development of standardised approaches for intercomparison and validation across products generated by different satellites, algorithms, and agencies. LPV is organised into 12 Focus Areas (FAs), each led by two to three co-leads responsible for specific land surface variables, including Essential Climate and Biodiversity Variables (ECVs and EBVs).

The main objective of the LPV subgroup is to enhance the quality and reliability of global satellite land product through the development, and promotion of internationally agreed protocols. These documents address key aspects of the validation process, including field measurement techniques and sensors, sampling design, upscaling methods, accuracy assessment and reporting, as well as data and information exchange. In parallel, LPV works to improve the quality and representativeness of ground reference data used for product

validation. This includes supporting dedicated field campaigns and identifying and promoting "supersites" that can serve as long-term benchmarks for land product validation. Finally, LPV provides structured feedback to relevant international frameworks and coordination bodies, such as GCOS, contributing to the definition of requirements for product accuracy, and to the development and refinement of measurement standards for terrestrial ECVs.

3. Context and Strategy

The LPV strategy stems from the realisation of the current and upcoming challenges in satellite EO in the land domain and it is developed around the following pillars:

1. Develop and evolve validation practices and tools
2. Enhance representativeness and coverage of reference data
3. Expand and strengthen collaboration with user community
4. Reinforce focus on CEOS-FRM and CEOS-ARD
5. Enhance awareness and communication activities

The current status and challenges for each of these topics is further elaborated in the following paragraphs along with the resulting on-going and planned actions to be addressed by the LPV group.

3.1 Develop and evolve validation practices and tools

The landscape of satellite EO in the land domain is undergoing rapid transformation in the past years. New and upcoming satellite sensors, from both institutional and commercial providers, are delivering an unprecedented volume of data at ever increasing spatial, temporal, and spectral resolution, while advances in technology are enabling enhanced measurement capabilities. In parallel, ground-based and aerial systems are becoming increasingly automated, more affordable, and better suited to acquire potentially valuable reference validation data. Together, these developments create new opportunities but also introduce new challenges, as existing validation practices must evolve to reflect recent advances in sensors, platforms, and products.

The LPV subgroup has recognised this need, and initial efforts are underway to tackle these challenges. As an example, the shift toward higher spatial resolution products, now essential for regional-scale modelling and applications, notably in agriculture, has led to coordinated actions across multiple LPV teams. Within the Biophysical FA, a review paper is currently being elaborated to assess best practices for LAI and fAPAR validation at decametric resolution. This work will provide the scientific basis for revising the LAI protocol originally released in 2014, which focused on coarse resolution products (300 m – 500 m). Similar efforts are planned for other key variables, such as albedo, burned area, land surface temperature, and soil moisture. Beyond spatial resolution, validation protocols must also account for recent advances in satellite missions and reference systems, notably the expanding use of unoccupied aerial systems (UAS) and the rapid proliferation of automated sensors that are reshaping validation strategies.

Going forward, the range of variables addressed by LPV is expected to expand as new EO products emerge and prototype or R&D products, become systematically produced at global scale. Current and future hyperspectral missions (e.g. EnMAP, PRISMA, CHIME)

are enabling improved retrieval of leaf and canopy biochemical parameters, such as water and nitrogen content. Likewise, planned high-spatial-resolution thermal missions (TRISHNA, LSTM) will support enhanced retrieval of energy fluxes and evapotranspiration (ET) at field-scale resolution, which is essential for agricultural applications. Validation approaches for these variables are not yet mature, highlighting the need to work towards agreed, harmonised practices. Within the LPV group the new ET and NPP/GPP groups were formed two years ago to specifically address this need.

It is therefore essential that LPV remains closely aligned with the evolving EO landscape and continues to support the next generation of satellite missions and products. This requires the development and updating of relevant validation protocols, together with the associated tools needed to enable operational validation, ultimately achieving "Stage 4" within the LPV hierarchy. The detailed actions outlined in Section 4 (see *LPV26-AI-1*...*-10* in Table 1) have been defined in response to these needs.

3.2 Enhance quality and representativeness of reference data

The operational validation of satellite-based land products faces a fundamental and persistent challenge: the scarcity of long-term, reliable, and representative reference datasets. While established ecosystem monitoring networks, such as ICOS in Europe, NEON in the United States, and TERN in Australia, provide invaluable ground-based measurements for validating a range of terrestrial variables, e.g., fAPAR, LAI, AGB, and GPP, their geographical coverage is still limited, with vast regions of the Southern Hemisphere and unique biomes critically under sampled. Furthermore, the protocols used within these networks are not yet fully aligned with the needs of the satellite validation community. A notable example is the lack of understory measurements of biophysical variables, e.g., fAPAR and LAI, across some of those sites, which can lead to biases when comparing ground observations with satellite-derived estimates.

The remote sensing community has repeatedly called for complementing existing networks with additional sites and adapting their protocols to better align with satellite validation requirements[1]. Progress is being made in this respect. The EU's NUBICOS project[2] has equipped select ICOS sites with automated PAR sensors deployed according to a sampling design optimally tailored to satellite validation needs. Similarly, the GBOV project[3] has established new validation sites in previously under sampled regions, particularly in Africa and South America. Meanwhile, the LPV subgroup has undertaken a comprehensive review of LPV supersites, aiming for enhanced representativeness across biomes and eco-climatic conditions. Yet these advances represent only initial steps. To further sustain this effort and evolve in the coming years, the LPV chair, supported by FA leads, should establish and maintain close communication with the representatives of the relevant monitoring networks, and contribute to the evolution of the adopted protocols, enhancing their alignment with satellite validation needs (*LPV26-AI-11*). In parallel, the LPV Supersites list should be regularly updated to reflect recent advances, while improving their geographical coverage and thematic coverage (*LPV26-AI-12*).

[1] Niro, F., M. Cosh, and J. Nickeson (2024), Trustworthy satellite Earth observations for science and society, Eos, 105, https://doi.org/10.1029/2024EO240055. Published on 8 February 2024.
[2] NUBICOS project website: https://www.icos-cp.eu/projects/nubicos
[3] GBOV project website: https://gbov.land.copernicus.eu/

3.3 Expand and strengthen collaboration with user community

The land user community has progressively diversified in recent years owing to the increased availability and easier accessibility to satellite EO data. The climate community was the first to elaborate detailed space-based observation needs within the GCOS framework, leading to the definition of Essential Climate Variables (ECVs) and associated observation and uncertainty targets. These requirements[4] constitute the primary foundation of the LPV validation framework and have guided the development of LPV protocols. More recently, additional user communities have begun to coordinate their own observation needs. In the agricultural domain, the GEOGLAM initiative has established the list of Essential Agriculture Variables (EAVs[5]), with a growing focus on decametric resolution and daily revisit frequency to support operational monitoring and food security. In parallel, the biodiversity community, through GEO-BON, has made substantial progress in defining Essential Biodiversity Variables (EBVs[6]), although corresponding observation and uncertainty requirements for remote sensing products remain under development[7].

Historically, LPV validation framework and its associated protocols were largely driven by GCOS observation requirements defined by the climate modelling community, particularly with respect to the uncertainty targets. In practice, however, some of these requirements have proven challenging to meet in the field, owing to the uncertainties arising from the inherent spatio-temporal (and often spectral) mismatch between in situ and satellite observations at different scales. The ongoing revision and rationalisation of the ECV list[8], in which the LPV members were for the first time involved as reviewer, presents a significant opportunity to better align user expectations with validation capabilities. Continued engagement with GCOS, GEOGLAM and GEO BON will be essential to ensure that emerging observation and uncertainty requirements for climate, agricultural and biodiversity variables remain realistic, robust, and compatible with both current and evolving validation approaches (*LPV26-AI-13*).

3.4 Reinforce focus on CEOS-FRM and CEOS-ARD

The FRM are a suite of independent, fully characterised, including detailed uncertainty budget, and traceable (to a community agreed reference, ideally SI) measurements, tailored to address the Ca/Val needs of a class of satellite sensor. Building on this concept, CEOS-WGCV recognised the need to provide a clear pathway for data providers to demonstrate compliance with FRM principles. This led to the development of the CEOS-FRM maturity matrix[9], which offers a transparent overview of current strengths and gaps and identifies areas where further development is required.

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[4] GCOS requirements: https://library.wmo.int/records/item/58111-the-2022-gcos-ecvs-requirements
[5] GEOGLAM EAV table: https://agvariables.org/full-eav-table
[6] GEO BON EBVs: https://geobon.org/ebvs/what-are-ebvs/
[7] Skidmore, A.K., Coops, N.C., Neinavaz, E. et al. Priority list of biodiversity metrics to observe from space. Nat Ecol Evol 5, 896–906 (2021). https://doi.org/10.1038/s41559-021-01451-x
[8] GCOS ECV Rationalisation: https://gcos.wmo.int/site/global-climate-observing-system-gcos/essential-climate-variables/ecv-rationalization
[9] Goryl, P.; Fox, N.; Donlon, C.; Castracane, P. Fiducial Reference Measurements (FRMs): What Are They? Remote Sens. 2023, 15, 5017. https://doi.org/10.3390/rs15205017

Within LPV, the use of FRM has recently been included as one of the prerequisites for achieving "Stage 4" in the validation hierarchy. However, its adoption across existing validation practices and sites remains limited, and the applicability of FRM principles to certain terrestrial variables, notably for categorical variables such as land cover or burned area, remains challenging. The recent revision of LPV Supersites highlighted that most sites do not yet fully implement FRM guidelines, especially with respect to traceability and uncertainty budget estimation. Despite these limitations, progress is being made to embed key FRM principles into future LPV protocols, with notable progress underway for biophysical variables, soil moisture and fire-related products. Further strengthening alignment with the CEOS-FRM framework in the coming years will be essential to improve consistency and enhance the reliability of reference datasets (*LPV26-AI-14*).

In parallel, closer collaboration with the CEOS-LSI-VC group in shaping the future of CEOS-ARD would be beneficial. The CEOS-ARD concept, first elaborated in 2016, aimed to lower barriers to EO data uptake, enabling new users and applications, and improving interoperability. This effort led to the definition of several CEOS-ARD Product Family Specifications (PFS), primarily focused on Level 2 products, such as surface reflectance and land surface temperature. Since 2016, the landscape in EO has changed significantly, notably with the broadening of the EO user base, the evolving technology, including AI/ML, and the increasing demands for interoperability. To answer to this, a large user consultation survey was undertaken in 2025 to gather feedback on how the CEOS-ARD should evolve in the future. Among the feedback received, there was the request to enhance information about data quality and fitness for purpose, as well as the need to expand the domain of CEOS-ARD to higher level products. The LPV subgroup is well positioned to actively contribute to CEOS-ARD, notably by providing guidelines to ensure standardised quality assessment processes, supporting the definition of appropriate metadata and quality indicators (*LPV26-AI-15*), and by providing inputs to the 2026-2031 CEOS-ARD Strategy.

3.5 Enhance awareness and communication activities

The impact of LPV outcomes, notably the validation protocols, within the scientific community is well documented by their extensive citation in the literature. However, the validation community remains a relatively small niche within the broader EO landscape, and awareness of newly released LPV protocols is still limited. Strengthening visibility, both within the wider user community and among space agencies, is therefore essential to ensure that agreed practices are effectively adopted and that an active feedback loop is established, allowing future updates of the protocols to incorporate recent scientific and technological advances.

Several complementary actions can help raise awareness about LPV activities. One key opportunity is the organisation of a future edition of the LPVE Workshop (*LPV26-AI-16*), building on the successful series of ESA-hosted meetings held every three to four years, most recently in 2023[10]. In parallel, regular updates of the LPV website[11] are essential to ensure that key information remains visible, current, and easily accessible (*LPV26-AI-17*).

[10] LPVE Workshop 2023: https://nikal.eventsair.com/lpve-2023/
[11] LPV Website: https://lpvs.gsfc.nasa.gov/

Finally, LPV outcomes should be more systematically promoted at higher levels within CEOS. In this context, LPV will deliver new and updated protocols to key CEOS leadership meetings, i.e. the annual CEOS Strategic Implementation Team (SIT) Meetings, with the aim of achieving CEOS endorsement, following endorsement at a WGCV Plenary Meeting. This approach should be pursued for future LPV protocols to support broad uptake and consistent implementation across agencies (*LPV26-AI-18*).

4. Summary and Actions

The LPV strategy is driven by the recognition that satellite EO in the land domain is undergoing a profound transformation, characterised by rapidly evolving sensor technologies, expanding product portfolios, and a diversifying user community. In response to these changes, the strategy is structured around five pillars: the development and adaptation of validation protocols and tools; the enhancement of the quality and representativeness of reference data; strengthened engagement with user communities, in particular GCOS, GEOGLAM, and GEO-BON; reinforced alignment with CEOS-FRM and CEOS-ARD frameworks; and improved awareness and communication of LPV outcomes. The actions detailed below emerge from this strategy and reflect activities that are already recognised within the LPV group and are either ongoing or planned. Addressing these actions over the coming three years will be essential to ensure that the LPV group remains a trusted reference for land product validation in an increasingly complex and dynamic EO landscape.

Table 1 - LPV Work Plan actions.

Action ID	Action and deadline
LPV26-AI-01	*Biophysical team to work towards updating the LAI fAPAR and fCover protocol addressing the need for enhanced (decametric) resolution. The first step will be the elaboration of a review paper, which will the provide the foundation for the protocol* ***[Q1 2026 for the review paper, Q4 2028 for the protocol update].***
LPV26-AI-02	*Biophysical team to assess potential inclusion of new biophysical variables in their domain, such as leaf and canopy biochemical parameters* ***[Q4 2027].***
LPV26-AI-03	*Surface Radiation team to work towards reviewing albedo protocol in response to recent GCOS 2022 updates and availability of decametric resolution products* ***[Q1 2027 for first draft].***
LPV26-AI-04	*Surface Radiation team to finalise the downward radiation protocol* ***[Q2 2026].***
LPV26-AI-05	*Soil Moisture team to review the SM protocol to adapt to most recent updates in sensor technology, new and upcoming satellite mission with enhance spatial resolution and including outcomes from FRM4SM project* ***[Q4 2027].***
LPV26-AI-06	*Vegetation Index team to finalise and issue the VI protocol* ***[Q2 2026].***
LPV26-AI-07	*Fires team to review and consolidate the Burned Area protocol and elaborate first draft of AF and FRP protocol* ***[Q3 2026].***
LPV26-AI-08	*Phenology team to review and consolidate the LSP draft protocol* ***[Q2 2026].***
LPV26-AI-09	*Evapotranspiration team to prepare first draft of the ET protocol* ***[Q2 2026].***

LPV26-AI-10	*LPV chair to look for funding mechanism to support the systematic yearly update of the SALVAL tool and the development of the updated OLIVE tool* ***[Q4 2027].***
LPV26-AI-11	*LPV chair, supported by LPV group, to bring forward current gaps and limitations in ecosystem monitoring networks at scientific fora and communicate with key representatives to drive the evolution of protocols, enhancing their alignment with satellite Cal/Val needs* ***[Continuous].***
LPV26-AI-12	*LPV group to consolidate the list of Supersites V2 and keep this list updated in the future, including most recent initiatives and aiming at further extending their geographical and thematic representativeness* ***[Continuous]****.*
LPV26-AI-13	*The LPV Chair, supported by FA lead, should establish and maintain active collaboration with key user community groups, in particular GCOS, GEOGLAM, and GEO BON, to ensure that synergies are fully exploited, and that observational requirements and common validation practices are agreed upon and adopted across the communities* ***[Continuous]****.*
LPV26-AI-14	*The LPV group to work towards further embedding FRM principles as part of the validation framework and good practice documents, this is already on-going for biophysical, SM and FRP future protocols* ***[Q4 2028].***
LPV26-AI-15	*The LPV group, through the LPV chair and in coordination with WGCV and LSI-VC, to contribute to the evolution of future ARD concept* ***[Q4 2026].***
LPV26-AI-16	*LPV chair to organise next LPVE WS in the time frame 2026-2029* ***[Q4 2029]****.*
LPV26-AI-17	*LPV chair and secretariat to keep updated the LPV web site* ***[Continuous]****.*
LPV26-AI-18	*LPV chair to work towards endorsing the LC protocol at CEOS level* ***[Q2 2026]****.*