Use of Earth Observation for Ecosystem Accounting

Results from semi-structured practitioner survey

# Introduction

This survey is part of work in support of the EU KIP INCA project on integrated natural capital accounting to better understand the use of satellite observation data for ecosystem accounting. It is one of three outputs – next to a workshop on the potential use of Copernicus outputs for ecosystem accounting in Europe and a technical review of current Copernicus products.

Copernicus is the European Union programme for Earth Observation (EO)[[1]](#footnote-1) and monitoring. The Copernicus programme consists of the Sentinel satellites, downstream services to use the Sentinel data and derived products (collectively referred to as EO herein) as well as supporting in-situ data. Following the definition applied under Copernicus, In-situ data are all non-satellite based data sources. The Sentinel satellites cater for many EO needs and support an array of economic activities. The continuity and quality of observations is key for the future of the European Copernicus Space Component (CSC), but it is also recognised that the capabilities of the CSC could be broadened to address more and potentially new needs, including for ecosystem accounting.

In order to inform on the potential use of Copernicus data to support Ecosystem Accounting, the European Environment Agency (EEA), SYKE and UNEP-WCMC undertook a survey of user needs and experiences in the use of EO amongst ecosystem accounting and assessment experts. The survey was designed to assist answering the following broad set of questions:

* Which satellite earth observation services are most commonly used for ecosystem accounting and assessment?
* What are the particular strengths and weaknesses of satellite data for ecosystem accounting and assessment?
* Which other non-satellite data are needed to support satellite data for ecosystem accounting and assessment?
* Which different earth observation technologies are most useful for ecosystem accounting and assessment?
* How can satellite data and services be improved to support ecosystem accounting and assessment?

# Survey Design and Administration

The survey was administered via a semi-structured survey instrument. The survey instrument was tested in-person with ecosystem accounting and assessment experts at the EEA during a project team visit on 17th April 2018. The final survey instrument is presented in Appendix A and comprised of eight specific questions relating to the above, broader analytical questions.

The final survey instrument was administered to a set of sixteen experts between the 17th April and 1st June 2018. The surveys were administered via telephone, Skype or other web-based meeting platforms and, typically, took between 45 minutes and 1 hour. The set of experts who participated in the survey comprised five from the KIP-INCA partner organisations (specifically three from the EEA and two from JRC); five from academia; three from government agencies / research institutes; and, three from NGO and other research institutes. Ten of the respondents were based in Europe. In order to get a broader set of experiences, the survey was also administered to six respondents from the USA and Australia (combined). In total fifteen completed survey instruments were obtained by the project team. [[2]](#footnote-2)

# Survey Results

The survey results were reviewed with respect to the key questions set out in Section 1. The findings are set out below and cross-referenced to the appropriate survey questions in Appendix A. In addition to their responses to the semi-structured questions, interviewees also provided references to key publications they considered to be most relevant to the objectives of the survey. These are listed in Appendix B.

## Common use of satellite data (Survey Question 1)

Across the range of respondents various satellite data sources were used. This included Sentinel, as well as SPOT, Landsat and MODIS. Five respondents identified the project currently being progressed with NASA Ecological Forecasting Program on the use of Earth Observation for ecosystem assessment and services supply and use could also inform on the questions presented in the survey. One respondent considered that the work on the Red List of ecosystems provides a good summary of the current use of satellite data in assessment of ecosystem extent and condition and its limitations. This also provides a pathway to ecosystem services.

***Ecosystem Extent***

For ecosystem extent, satellite data on land cover was the most commonly mentioned satellite data derived product used by respondents. This had been used for developing land cover accounts, supporting ecosystem extent accounting but also as an input to various ecosystem condition and modelling approaches. Their use reflects a key role for satellite data in understanding the state and flows in land cover (including for forests). In this regard the importance of High Resolution Layers (HRL) to identify changes via the Copernicus Corine Land Cover (CLC) product was noted. Sentinel-2 data was identified specifically for use in crop and forest type extent mapping. A key observation was that the nomenclature for land cover classes is not sufficient to provide an ecologically meaningful representation of ecosystems. This limits its use for ecosystem extent accounting.

***Ecosystem Condition***

For ecosystem condition, direct observations by satellite have been used for assessing phenology (derived from vegetation indices); Nutrient levels (as a pressure indicator); Degradation from intensive use (via the ploughing indicator from Copernicus); and, Soil erosion. Several respondents noted that multiple data can be used in combination to provide more insight. For instance, combining HRL for forests with imperviousness layers, urban atlas and forest height to understand fragmentation issues. The potential to assess condition using the Burnt Areas layer was also noted, as was the use of dry matter cover used as a proxy for ecosystem condition in agricultural areas and as a potential explanatory variable for agricultural yields. For understanding ecosystem condition for biodiversity, satellite data was identified by several respondents for use in species distribution modelling (as well as for pollinators and pollination services supply). One respondent identified that composite condition indices could be derived from combining biodiversity and fragmentation data.

***Ecosystem Services***

For ecosystem services, CLC had been used by several respondents for modelling (generally via CLC Level 3 nomenclature). Approaches included expert judgement to associate with different services supply (including for recreation and habitat for pollinators). The integration of CLC with imperviousness and riparian zone layer had also been successful in understanding flood protection services. Leaf area index had also been used as a predictor for modelling supply of air regulation services and surface temperature layers for understanding urban cooling services by vegetation. Satellite data on evapotranspiration data has been used for estimating water provision, combined with digital elevation models and climate data for modelling this and other services. Satellite data on vegetation indices had been used to estimate biomass / carbon storage in vegetation, although it was acknowledged this approach did not allow for estimating soil carbon (an important component of the overall ecosystem storage of carbon). For some studies the urban atlas and human settlement layers had been used to provide information on ecosystem services use. However, several respondents identified the need for more specific information on ecosystem service demand.

## Strengths and weaknesses of satellite data (Questions 2 & 3)

The key strength of satellite data is its temporal resolution, repeatability and large scale / coverage of continuous observations. Often this data is also available at low cost to ecosystem accounting and assessment practitioners, making it readily accessible for analytical use. In particular its ability to measure biophysical parameters in a systematic, harmonised and robust way, globally. For the Copernicus programme a key advantage was the free open access to data. A key issue of concern was the commitment to continued provision of satellite data and products, for instance one respondent noted the U.S. are considering restricting access to Landsat 8 data and another having to pay for increased resolution in areas from SPOT data.

Two respondents observed the absence of a time series of data from Sentinel-2 is currently limiting its use for ecosystem accounting and assessment. For example, Landsat has continuous time series of data, whereas Sentinel-2 data means that ecosystem accounts would have to start in 2016. However, the higher repeat cycle of Sentinel-2 was identified as a specific advantage for ecosystem assessment, compared to Landsat and a time series will develop in due course.

***Ecosystem Extent***

Satellite data was identified as a key tool for delineating ecosystem assets in the landscape (albeit this hard delineation on the ground is an abstraction). Ecosystem with very obvious borders (e.g., forests), thus lend themselves better to observation from space. In this regard, the need to develop a pragmatic approach to classifying ecosystems is necessary and this should be flexible to adaptation in the future.

Generally, respondents indicated that the spatial resolution of CLC was sufficient for European level analysis, and (more generally) spatial resolution was not a key issue for ecosystem accounting. However, two respondents indicated that the spatial resolution of Sentinel 2 (10 – 20m in the visible and near infra-red) was not considered high enough for the assessment of linear features/green infrastructure (these are often key for biodiversity, condition and services assessment) and higher spatial resolution is likely to be necessary for urban environments. Furthermore, more thematic detail is required on forest and crop types. For Copernicus, it was noted that high resolution layers were limited for some ecosystem types, also they do not have a sufficient time series to support ecosystem accounting at this stage but this will develop in due course.

***Ecosystem Condition***

It was noted that until relatively recently there had been little interest in measuring ecosystem function over large scale. Most of the satellite data to date has related to primary productivity (e.g., eutrophication in waters, productivity in areas of agricultural land-use). However, one respondent noted that such measures were limited in their ability to inform on ecosystem condition and advances were being made in developing a better suite of satellite derived ecosystem condition indicators. A key weakness in satellite observation is it just captures biophysical properties, rather than information on biological functioning and processes.

Some proxy measures were proposed by respondents for assessing ecosystem condition for different purposes. One respondent noted that the MODIS Enhanced Vegetation Index had proven a good predictor of condition of ecosystems for Jaguars in Mexico. Also data on pressures (e.g., water / soil moisture, dry indices) can also provide useful information on ecosystem condition and can be obtained from satellite data.

It was noted by two respondents that EO data provided limited information on the existence of tippling points and thresholds in extent and condition. Overall, it was noted that there still needs to be consensus on what condition parameters to monitor (via satellite and generally), one respondent suggested the Red List of ecosystems could help steer this.

***Ecosystem Services***

For agricultural services, thematic fit was often poor due to limited information on crop types, including if they required pollination services. In addition, satellite data is best suited to capture ecosystem services or condition information on a broad scale, as such local ecosystem services or condition characteristics (e.g., suitable habitat for rare species) may be missed. Several respondents noted satellite data was key in understanding ecosystem services demand by identifying where people live and identifying artificial areas. However, there remain challenges in matching satellite data to economic sector and socio-economic data for understanding ecosystem services demand.

The importance of good temporal resolution and a sufficient time series was noted. In particular, the utility of 10 day composites of data (e.g., dry matter data for carbon sequestration services) was observed. The temporal resolution of different satellite derived products was identified as an issue when modelling ecosystem services with multiple datasets when reference years are not aligned (e.g., when integrating imperviousness and CLC layers for modelling flood regulation services). A related issue for ecosystem accounting is the need for consistent data over time. It was noted that comparisons between CLC 2000 and 2006 may not be robust (the existence of the CLC accounting layers was noted). Furthermore, in order to maintain an internal consistency, if CLC is used for extent accounts then this needs to be used for modelling ecosystem services and condition. This limits the ability to use other ecosystem specific datasets, for example Global Forest Watch or the JRC global surface water explorer. It also creates issues for how to incorporate new data and products as these are developed.

***Wider issues***

A key issue was how to get raw data from satellites transformed to thematic data suitable for ecosystem accounting. As satellites generate huge amounts of data that need bespoke technology and skills for processing. This may be a constraint for some countries.

Several respondents identified concerns over accuracy and need to better consolidate and validate data. One respondent was very concerned with the instability in land cover products at pixel level and large turnover in classifications observed. In addition all products from optical sensors are all grounded in the same observation (reflectance of chlorophyll). Also, for CLC, the change and status matches do not provide a consistent story (e.g., the 2006 state map plus 2006 to 2012 CC map do not provide the same result as the 2012 state map).[[3]](#footnote-3) A similar story was noted for MODIS, which states comparisons cannot be drawn between periods. As such, ensuring the spatial harmonisation and comparability between different time points will greatly increase the analytical possibilities for different land cover products. Moving to consistent time series will require versioning of different data to be thoroughly documented.

A general point of note was that whilst there are lots of research on remote sensing for ecosystem assessment, there is no legacy of production of relevant derived products. This includes for species, of vegetation indices and vegetation and habitat extent. There is a lot of data available to the research community but the community needs time to work out how to best use it and surety that its consistent production will continue.

## Use of non-satellite data (Question 4 and 5)

A number of respondents noted the need for ground based data to validate and train satellite based observations and associated machine learning algorithms. Several respondents noted the need to improve the availability of in-situ data for model calibrations and improving the insights from satellite data.

***Ecosystem Extent and Condition***

In Europe forest data on High Nature Value Forest (based on ground based measurements and naturalness); Forest monitoring level-II data and harvesting intensity (derived by the Humboldt institute) is also used to supplement satellite data for analysing forest themes. For local studies drones have also been used for land classification, ecosystem extent assessment and informing DEMs. Other data sources identified by respondents that they had used in their analysis included: digital elevation models (DEMs), terrain models, topographic maps and ortho-photos.

One respondent identified the use of vegetation maps to understand natural ecosystem extent changes due to satellite observed land cover change. For wider biodiversity assessment, Light Detection and Ranging (LiDAR) and field visits had been used in combination with satellite data to inform assessment of ecosystem condition for birds (i.e., with respect to habitat preferences). Satellite data had been used as a key input into modelling species occurrence, including pollinators (using CLC and other variables). One respondent had used species distribution and connectivity models with satellite data to identify habitat corridors, which will be of specific management concern. Other relevant biodiversity assessment approaches included extrapolating the inferences long-term ecological monitoring of flora and fauna, camera traps, rapid on-the-ground biodiversity field studies using satellite data.

***Ecosystem Services***

In order to asses soil erosion and prevention services, field based measurements of soil erosion have been extended using CLC and national cartographic systems in Germany for continuous monitoring of agricultural soil erosion. In Rwanda, ortho-photos had been used to identify changes in terracing practice for soil erosion modelling and prevention services. In separate work, the use of Leaf Area Index data in combination with in-situ air quality monitoring to model air quality regulation was noted. The role of forest inventories was noted as being important in supporting estimations of timber and biomass supply / storage and carbon storage. These have been compiled via field visits and using aerial photography.

For pollination services demand, LUCAS data had been experimented with by one respondent due to its richer thematic information on crop type. However, limited information on economic production was the fundamental constraint for calculating associated ecosystem services supply and use accounts.

For cultural ecosystem services use, one respondent had used geocached social media data and survey date (in combination with urban atlas data) to estimate supply and use of recreation ecosystem services. Several respondents noted the difficultly in understanding demand for ecosystem services using satellite based data only and this would often require integration of economic statistics, financial transaction, in-situ or survey type data that may not be available in a spatially disaggregated format. However, respondents provided examples for understanding ecosystem services demand more generally, these based on population (e.g., global human settlement layer) and census data and using this to identify population density and specific age groups.

***Key in-situ data-sets***

A number of respondents indicated that in-situ measurement of biodiversity, detailed taxonomic information on vegetation, soil parameters, chemical conditions and ecosystem condition generally would be the hardest to replace with satellite based observation. In addition some types of calibration data are likely to be more effectively collected in-situ (e.g., water flow, quality, sedimentation and nutrient concentrations).

For many ecosystem features, field data is required to validate assumptions based on satellite observations, especially where there are various surface layers to the ecosystem. Examples include: the need to validate the presence of coffee plantations beneath tree canopies, measurements for soil water content and nutrient balances. In addition the need for in-situ data on crop type was also identified, as this is generally not revealed by satellite data. It was also noted that for the Nature Directives and Water Framework Directive, most reporting is still based on in-situ observations.

Several respondents noted that it would be useful to develop in-situ monitoring programs in conjunction with satellite products that can best extrapolate the in-situ data for monitoring ecosystem features of interests. The potential to link long-term monitoring stations that provide continuous data (e.g., Gene Array Analysis of organisms in soils, Carbon flux towers) to satellite data was also noted to have the potential to inform on the capacity of ecosystems to provide services (particularly agro-ecosystems). This could help reduce the cost of effective in-situ monitoring programmes.

## Different earth observation technologies (Question 6)

The best earth observation technologies will depend on what is being measured. Optical sensors provide information on colour, which is useful in a range of applications. However, Radar is also very important. This is particularly the case in areas with high cloud cover and where 3-D structural information is needed. The use of airborne LiDAR was also noted as being very useful for improving thematic accuracy of satellite observations (e.g. for understanding the distribution of coffee plantations below canopies). One respondent noted better integration of LiDAR with satellite earth observation data would be useful way of validating and improving current land cover products. However, LiDAR was noted to be a, relatively, expensive source of earth observation data.

Several other specific satellite earth observation technologies were identified by respondents that could support ecosystem accounting and assessment, comprising:

* Ice Cloud and land Elevation Satellite (ICE Sat) and ICE Sat 2[[4]](#footnote-4) launched by NASA, which provide useful information on forest height (as well as supporting detailed cryosphere analysis).
* Microsatellites are an emerging technology that could be useful for improving the frequency at which satellite images can be obtained of areas on the earth.
* Two respondents identified that it would be good to explore the use of hyper spectral sensors, for example to monitor air pollution (e.g., for Nitrogen oxides) and forest tree species.
* The use of multi-temporal observations should also be explored further, for example the Rapid Eye constellation of five satellites[[5]](#footnote-5) had proved useful classification of tree types.
* Thermal remote sensing should also be explored as it seems to have been undervalued in the assessment of ecosystems (e.g., using surface temperature for inferring ecosystem condition).
* Combining different satellite data products to overcome issues such as cloud cover and poor resolution should also be explored (e.g., Google Earth analysis based on VHR Landsat with Sentinel data and MODIS and Landsat data combined via the Star/FM algorithm).

It was noted by a number of respondents that interpreting raw satellite imagery or other data is complex and most respondents were not familiar with the necessary procedures to undertake this type of data interpretation / processing. As such a large number of respondents noted that more derived products would be very useful for their work. One respondent indicated that high spatial resolution could be leading to misclassifications in derived products and it may be useful to move from 30m to 100m resolutions may be helpful to reduce the proportion of noise in the signals received by satellites. However, this reflects a trade-off, the relative benefits of which will be dependent on which ecosystem features are of interest for measurement in the landscapes being analysed (e.g., high resolution will be necessary for identifying small linear features in the landscape and the benefits they provide, which are typically of interest for European landscapes).

An important point for long term monitoring is that new technologies should not be at the expense of maintaining current data products and services. Every time technology is changed the ability to track change consistently over time is lost. This also illustrates the need to reach consensus on a long-term monitoring framework for a set of relevant ecosystem measurements using earth observations.

## Priorities for improving satellite data and products (Questions 7 and 8)

A key priority expressed by a number of respondents was the need to maintain continuity in products and access to these products. This requires systems to be in place to make this data available and commitment to make regularly repeated products. Two respondents identified that serving Copernicus products using web coverage services would be useful to encourage more widespread use. If data cubes could be generated to support countries in their own analysis it could dramatically reduce costs for processing and cleaning data. Clear guidance on which data to use for different accounting items would be a help to many practitioners, one respondent identified the need for this type of analysis using Copernicus products specifically. A key point was made by several respondents that it is not possible to observe all features of ecosystems from space.

***Ecosystem Extent***

Improving the thematic resolution and harmonisation of products on land cover and ecosystem extent was identified as a key priority. It was noted that there are constraints for combining high resolution Copernicus layers with CLC, the development of CLC+ will help address this. In addition moving to CLC Class 4 was noted as a possibility. Nonetheless, the ecosystem or geographic specificity of a number of derived layers makes harmonisation very challenging as borders of different ecosystems start to overlap and gaps emerge. This will open up the possibility for products with a better thematic fit for different ecosystems. However, better thematic data on ecosystem types is required (e.g., wetland (including seasonal), forest species and grassland type). In addition, the development of biomass satellite based products was identified as a key upcoming Copernicus service for contributing to ecosystem extent accounting. Addressing errors in current products was also noted as a priority, one respondent noted that areas of housing may get misclassified when there are trees in suburban gardens. Information on land-use was identified as a key product for development by several respondents.

***Ecosystem Condition***

The need to develop products for ecosystem condition was noted by several respondents. Ideas proposed include the use of NDVI to monitor vegetation recovery rates as an indicator of condition; and, deriving fragmentation / connectivity measures from satellite observations. One respondent identified that there needs to be a clear framework established on how to monitor condition, based on the use of ground and satellite based observations. At the moment there may be an issue with respect to putting the policy on ecosystem condition in place before the science is sufficiently developed to support it.

***Ecosystem Services***

Better quantification of the demand side of ecosystem services was also observed as a priority for ecosystem services assessment and accounting. For example, combining Census data and other surveys with satellite data more accurately to quantify ecosystem service beneficiaries. From the supply side, several respondents identified the need for better data on crop types (beyond Monfreda data for 2000 and USGS product quantifying staple crops and whether they are irrigated). In addition, a high resolution layer for semi-natural vegetation in cities and agricultural areas would be useful for modelling ecosystem services such as pollination and recreation. A product for net ecosystem production would also be useful for understanding biomass related services.

***Temporal Resolution***

Improving the repeatability of data observations was noted as a key priority by several respondents. For example there are only 1 – 2 images per year for some products (including local component of Copernicus). Ideally this would support direct annual analysis but seasonal data was also identified as desirable too. The absence of aligned temporal resolution of different Copernicus products was also identified as a constraint, particularly for modelling ecosystem services. A common reference year is necessary for the integration of multiple data for a common reference year to support various modelling approaches. Moving to three year updates of all Copernicus products would improve the potential for integration of multiple products.

A number of respondents indicated that more empirical work is needed to link satellite measurement data (particularly of condition) to data collected in-situ (e.g., water flow, quality, sedimentation and nutrient concentrations). This will allow understanding of these relationships to be built systematically across the Earth. This would support the use of more ground based data and integrating with probability based sampling to extend the measures of condition using satellite data. In this context a review of which satellite derived products could be developed in tandem with *in-situ* data (e.g., field data, citizen science, camera traps, envelope / species distribution modelling) would be useful. In addition, several respondents noted spatial data on economic statistics, agricultural production, Common Agricultural Policy payments or similar would be useful to allow integration with satellite data for analysing ecosystem services supply. One respondent observed this type of extended analysis should not be the responsibility of the Copernicus programme itself. However, a library of ground based or other relevant spatial data would support such endeavours.

***Wider Observations***

Ideally it would be good to establish a set of specific products that could be used for monitoring the key ecosystem features of interests (e.g., products on fragmentation, land-use, degradation, soils, a coherent and a consistent land cover map) and provide clearer information to practitioners to avoid the use of sub-optimal products. This should be supported with case studies of their use (e.g., for accounting or reporting on policy targets such as Aichi Targets) and flexible hierarchical classifications systems that are amenable to changes in the future. Respondents observed that there are a large number of potential opportunities to use satellite data for ecosystem assessment and accounting but the research community needs time to derive suitable products for these purposes. This will require investment in the research community, NASA has such a programme for MODIS teams within universities. Key support for this could include: Technical support for data management and analysis (including access to server space); access to open source code for processing satellite data; and, providing access to libraries of ground based data.

Two respondents suggested establishing a forum (or similar) that regularly reviewed new sensors and technologies as they emerged and how these could be harnessed and products derived to develop ecosystem assessment and accounting approaches. This should convene multiple disciplines, including remote sensing experts, ecologists, modellers, social scientists as well as ecosystem assessment and accounting practitioners.

# Key Messages

By design the survey instrument allowed a rich exploration of different insights across a number of practitioners using satellite based data observations in their ecosystem assessment and accounting work. The key messages from this exercise that are considered of most relevance to stimulate the uptake of Copernicus products and services for ecosystem assessment and accounting are summarised below:

* It is important to maintain continuity in the production of existing products to support time series analysis and for robust change detection.
* Appropriate data systems need to be maintained for accessing data and web based services or data cubes would likely increase use of Copernicus products.
* Improving the temporal resolution of products was identified as a key priority, ideally to support annual or seasonal analysis. Improving the possibilities for integrating multiple products using a common reference year was also identified as important for increasing the analytical possibilities for Copernicus products (e.g., for modelling condition and services).
* For ecosystem extent, improving the thematic resolution and harmonisation of products on land cover and ecosystem extent was identified as a key priority (e.g., moving to CLC Class 4). This could include better spatial integration of ecosystem specific products (e.g., between CLC and HRL Grassland layers) and data on forest species, crop type and seasonal wetlands. The upcoming Copernicus biomass product will provide richer thematic detail on ecosystems and their distribution.
* Developing a HRL for semi-natural vegetation and net ecosystem production would also be useful for better understanding ecosystem extent. These products would also provide key inputs into modelling services such as pollination, recreation and biomass storage and provision.
* More products for ecosystem condition, such as fragmentation are required, although the importance of In-situ data for measuring condition was generally acknowledged.
* Establishing an accessible library of wider earth observation (e.g., LiDAR, weather stations, flux towers) and in-situ ecosystem data (e.g., biodiversity monitoring, soil quality, water content, nutrient concentrations) will support efforts to expand the set of derived products available to practitioners.
* Overall, respondents indicated that more in-situ data was required. This reflected that not all ecosystem features can be observed from space. Furthermore, wider spatial statistics are required in order to understand ecosystem services supply and use (e.g., agricultural production, transactions, and populations).

Whilst not the responsibility of the Copernicus programme, the survey suggested that there still needs to be process to reach a consensus on which ecosystem features should be monitored and what are the best techniques (using EO and insitu-data) for achieving this in order to track the sustainability of development from an ecosystems perspective.

# Appendix A: Final survey instrument

**SEMI-STRUCTURES COPERNICUS / EARTH OBSERVATION SURVEY INSTRUMENT**

**Introduction**

Copernicus is the European Union programme for Earth Observation (EO) and monitoring. The programme consists of three core elements:

* The Sentinel satellites
* Downstream services
* In-situ data

The Sentinel satellites cater for many EO needs and support an array of economic activities. The continuity and quality of observations is key for the future of the European Copernicus Space Component (CSC), but it is also recognised that the capabilities of the CSC could be broadened to address more and potentially new needs - e.g. ecosystem accounting.

For this purpose and as part of the EU KIP INCA project, the European Environment Agency and UNEP-WCMC are gathering user needs and experiences in the use of EO amongst ecosystem accounting experts to shape the development of the CSC, looking toward the 2030 time horizon. Your voice and experience can help in specifying the services of the CSC which are most useful, which could potentially be improved, and to provide input to specifying the satellite systems of the future CSC.

We are attempting to articulate and capture your needs and views, with respect to ecosystem accounting and assessment, whatever these may be: general Earth Observation needs from space, application enhancements, instrument capabilities, experience in using Copernicus services or any other.

**Discussion topics**

1. Examples of the current use of satellite data in your ecosystem assessment or ecosystem accounting (please identify any that are derived from Copernicus).

*Probe on the following:*

* 1. *Land use and cover*
  2. *Ecosystem extent*
  3. *Ecosystem condition*
  4. *Ecosystem services supply & use*

1. What are the strengths of satellite data for assessing or accounting for ecosystem extent, condition and services?

*Probe on the following:*

* 1. Thematic / analytical fit of satellite data for assessing or accounting for ecosystem extent, condition and services
  2. their suitability for describing key changes in ecosystems extent, condition and services of interest
  3. data update frequency
  4. scale (geographic, resolution, temporal)

1. What are the weaknesses of satellite data for assessing or accounting for ecosystem extent, condition and services

*Probe on the following:*

* 1. Thematic / *analytical fit of satellite data for assessing or accounting for ecosystem extent, condition and services*
  2. *their suitability for describing key changes in ecosystem extent, condition and services of interest*
  3. *data update frequency*
  4. *scale (geographic, resolution, temporal)*

1. Can you describe any applications where you have used satellite data in conjunction with other EO or in-situ data for ecosystem accounting or assessment?
2. Can you reflect on the usefulness of different earth observation technologies?

*Probe on the following if not covered in 2 and 3):*

* 1. optical sensors vis-a-vis radar-based technologies
  2. important specifications that allow ecosystem features to be analysed via satellite-based techniques? *e.g. distinguishing optical signals in a more sophisticated manner (e.g., better spectral sampling of satellite sensors), spatial scale of observation unit, filtering signal from noise, seasonal, mid- and/or long term trends observation potential, etc.*
  3. *Development of derived products (e.g., more modelled data based on satellite observation)*

1. Do you expect there to be certain in-situ data monitoring exercises that are unlikely to be replaced by satellite based data collection? Which ones?
2. Can you name any particular data issues you are aware of for ecosystem extent, condition or services assessment or accounting?

*For example, data gaps in in-situ or other data on ecosystem condition. We are particularly interested in those you believe EO data could potentially fill.*

1. What are the most important steps that could be taken to improve the Copernicus Programme [or satellite data generally] and the products it provides to address data issues and facilitate a more rapid uptake for ecosystem accounting (or assessment)?

*Please distinguish between immediate pragmatics steps and medium term more ambitious steps.*

*Probe on the following:*

* 1. *Adaption of existing or completely new classes of observation? Can provide examples and the nature of necessary technical specifications? [Probe respondents re optical and radar-based sensors]*
  2. *Data collection/processing exercises*
  3. *Combination with other types of data*

# Appendix B: Recommended References

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1. The Group on Earth Observation (GEO) describe EO as gathering of information about planet Earth’s physical, chemical and biological systems. Commonly this refers to the use of remotes sensing or monitoring stations, for example satellites, ground-based, air-borne, and ship/buoy-based observations. This is the way Earth Observation is interpreted in this document. Whereas, data from field testing, surveying and sampling programmes is referee to s in-situ data in this document. However, it should be noted that the definition for Earth Observation employed under the Copernicus programme is restricted to satellite based observations only, with observations from other technologies and approaches collectively referred to as in-situ data. [↑](#footnote-ref-1)
2. Two respondents from the USA were interviewed simultaneously using the same survey instrument [↑](#footnote-ref-2)
3. It is likely that these differences emerge for the different minimum mapping units employed for the state (25 ha MMU) and change (5 ha MMU) products. [↑](#footnote-ref-3)
4. <https://www.nasa.gov/content/goddard/about-icesat-2> [↑](#footnote-ref-4)
5. https://www.planet.com/products/satellite-imagery/files/160625-RapidEye%20Image-Product-Specifications.pdf [↑](#footnote-ref-5)