Part 5 Questions & Answers

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Erika Podest (erika.podest@jpl.nasa.gov) or Sean McCartney (sean.mccartney@nasa.gov).

Question 1: For the radiometric indices calculation, when you say the reflectance in a band, for example, is it actually the average reflectance in that region?
Answer 1: The reflectance values used to compute the radiometric indices correspond to the reflectance recorded in different spectral bands of the used sensor. The value can be considered as the reflectance average over the spectral bandwidth, but, in fact, this is a simplification of the actual sensitivity of the sensor, which might vary according to the wavelength.

Question 2: Are agricultural crop classification techniques and principles applicable to natural vegetation too? If so, could you please indicate relevant publication(s) and/or other resources?
Answer 2: The algorithms and all associated concepts (features selection, pixel- vs. object-based approaches, etc.) are valid both for crop and land cover classification in general. Yet, the features that you should select for the classification such as the period (start and end dates of the input time series) and the classification parameters will be specific to the kind of land cover classes you wish to map. It is not easy to redirect you to specific papers, since there are as many papers as applications (general land cover mapping, forest mapping, crop mapping, etc.).

Question 3: What makes a spectral index successful in capturing specific vegetation/moisture? If we want to design a custom spectral index, what is needed for the successful creation of a spectral index?
Answer 3: Amongst success criteria for creating a successful spectral index, we can cite (i) the use of spectral bands that are sensitive to the phenomenon you want to observe (e.g., red, NIR, red-edge for vegetation; SWIR for water; red for bare soil; etc.) and (ii) the combination of these spectral bands in a way that facilitates the phenomenon discrimination (e.g., ratio, differences, normalization, etc.) by enhancing the spectral behavior difference.

Question 4: If we apply cloud removal algorithms, will it be okay or accurate to calculate the radiometric indices from the images?
Answer 4: Cloud removal is one of the very first steps of optical data processing. It needs to be applied before the radiometric indices are computed so that the indices are based only on cloud-free surface reflectance values.

Question 5: Can biophysical variables for soil brightness be used to quantify soil salinity?
Answer 5: If the salinity is changing the soil surface color, the soil brightness could indeed be related to the soil salinity assuming that all other influencing factors are constant (soil roughness, soil color, soil preparation, etc.). Not all soil salinity has an influence on the soil surface.

Question 6: During field measurements of LAI, will we not disturb the reflectance received by the satellite sensor?
Answer 6: The size of the pixel is usually much larger than the size of a person measuring LAI on the ground. Your concern would be justified when considering sub-meter image resolution (e.g., Worldview-3), but still, the field average won't be impacted.

Question 7: Which biophysical variable is best for monitoring time variations also of the non-photosynthetically active part of the vegetation (such as branches and tree trunks)?
Answer 7: It is often referred to as a fractional cover of non-photosynthetic vegetation (much studied for the Australian natural woodlands for instance, or the crop residues in the US). Some spectral indices based on shortwave infrared bands are often used for this purpose. Examples are the dead fuel index - DFI), the shortwave-infrared ratio (SWIR32), the normalized difference tillage index (NDTI), the modified soil-adjusted crop residue index (MSACRI), and the soil tillage index (STI).

Question 8: Is this GIFOV issue valid for ground water sampling (such as in-situ temperature measurement)? In such cases, how do you make sure that the satellite footprint measurement is correct?
Answer 8: This issue is valid for all remote sensing applications, and especially for those based on wide-swath sensors with wide angles. Yet, this issue is not the most well known and more effort could be done to take it into account as it may lead to mis-interpretation of the signal and of its correspondence with ground data. In thermal

bands, the surface temperature measured via satellite is also influenced by the surface-air exchange influenced by air turbulence, for instance.

Question 9: Is data acquired by drone or airplane LiDAR considered ground truth?
Answer 9: In agricultural applications, drone images are used more and more to acquire “ground data”. Drone or airplane LIDAR are a very good reference for height measurements, for instance.

Question 10: I have a question about the best way to compare crop phenology using remote sensing time series. Which approach has the best performance, classifying crops using phenometrics (like minimum or amplitude) or just measuring the time series distance using something like RMS or other?
Answer 10: This is a very good question, which has no unique answer. The best approach will depend on the application you have in mind. For instance, if you would like to do near-real time monitoring, the comparison of time series and anomaly detection will be the most appropriate approach. The mapping approach will be convenient if you are interested in grouping crops based on their phenological similarities, for instance (e.g., understanding seasonal dynamics, mapping the start of the season and identifying any gradients in your area of interest, distinguishing between different crop types, etc.).

Question 11: How do you obtain the lines for the NDVI time profiles in the time series analysis?
Answer 11: The NDVI profile should include only cloud-free, atmospherically-corrected observations. The line is then interpolated using one of various algorithms to smoothen the profile (typically the Savitzky-Golay method, splines, etc) .

Question 12: Is it possible to get support in setting up a Python environment for using SNAP in case we get stuck?
Answer 12: There is a SNAP support team that you can contact through the forum (https://forum.step.esa.int/). You can also benefit from similar questions already discussed by the SNAP user community.

Question 13: I couldn't understand how to derive a map from phenometric analysis. What will this map indicate?
Answer 13: A map of a phenometry could, for instance, show the date of the start of the season for each pixel on the image. Such a map displays in different colors the

different dates showing the spatial diversity of the start of the season. This is the same for each.

Question 14: Is this approach applicable to trees?
Answer 14: Like in Q2, the approach is not only valid for crops, but can be generalized for all vegetation types that show a seasonal behavior like trees. For instance, both the MODIS and Copernicus phenology products consider all types of vegetation (https://lpdaac.usgs.gov/products/mcd12q2v006/; https://land.copernicus.eu/pan-european/biophysical-parameters/high-resolution-vegetation-phenology-and-productivity).

Question 15: Can you please share how you achieve these field-level results?
Answer 15: The field-level results are obtained by considering the average value of the index or biophysical variable values of all the pixels belonging to the field of interest. These examples come from an application where the field boundaries are available as input (in Europe, the field delineation should be available for all countries for the needs of the Common Agricultural Policy).

Question 16: What are triangles in the mowing detection graph?
Answer 16: The yellow triangles in these graphs correspond to the period during which the mowing has been detected (the detection is not associated to a single date but to a period to allow a consolidation step for each detection).

Question 17: Can biophysical parameters such as biomass also be measured reliably for sub-aquatic plant species, such as seagrass?
Answer 17: We do not have any experience in sub-aquatic measurements by satellite. There is an ocean color community however that measures water chlorophyll content with satellite data.

Question 18: In the graphs of mowing detection, how do you attribute a single NDVI value to a parcel? Do you average the NDVI values of every pixel on the parcel, or do you calculate some other statistics? How do you deal with non-homogeneous parcels?
Answer 18: The NDVI signal is the average NDVI at the parcel-level. The boundary pixels (i.e., the pixels whose centroids are not located in the parcel) are not considered in the average computation. As explained in Q15, in Europe, all countries have their fields delineated and the validity of this delineation is checked every 3 years. In this

example, we made the assumption that all parcels were homogeneous. Yet, there are some methods that allow for assessing the parcel's homogeneity and that could be applied a priori.

Question 19: What do you mean by coherence with SAR data?
Answer 19: The coherence is a variable derived from a pair of SAR observations using the interferometric method (InSAR). The coherence is computed between two SAR images recorded by exactly the same instrument and following each other closely (at a 6-day interval for Sentinel-1, for instance). It expresses the similarity of the radar phase between acquisitions.

Question 20: In recent years, there is an increasing tendency to plant two or more crops in the same season (multicropping), and several varieties of cover crops to protect soil from erosion. Are these practices taken into account or is it assumed that only one crop at a time is grown and harvested in a certain field?
Answer 20: In the applications shown in the slides, it is assumed that there is only one crop at a time grown and harvested in a certain field. In the case of several crops, the proportion between these crops needs to be known to be able to adapt the approach.

Question 21: Is the NDVI enough to detect harvest or do we need other biophysical parameters?
Answer 21: In a non-cloudy environment (i.e., if we have a dense NDVI time series), the NDVI has proven to be enough to detect the harvest. Yet, in our approach, it was complemented by SAR backscatter and coherence because of the cloud cover. We found that the harvest detection based only on the Sentinel-1 signal was slightly less efficient (also because it was pre-processed at 20m resolution while Sentinel-2 is at 10m resolution), but it has a clear added-value because of its high density (each acquisition is a useful observation).

Question 22: Regarding the harvest time, is it best seen when the slope is starting to go down or the value of NDVI starts reducing, or when the NDVI value reduces to a minimum? Regarding the crop classification (winter crops and so on), is there a step-by-step manual we can access? As it was explained quickly and not fully understood.
Answer 22: The NDVI values start reducing during the maturity phase, long before the harvest time. This is the reason why the drop in NDVI is a prerequisite, but not

sufficient to detect the harvest time. The coherence increase is also necessary to make sure that the mature crop is harvested and to sharply identify the date.
Regarding the manual, the classification was not addressed in this session because it was covered in the previous session. The algorithm implemented in Sen4Cap is Random Forest. There are documents on the Sen4Cap website describing the algorithm and a user manual of the processor with step by step instructions.

Question 23: What is the reason that the EO technology for crop yield estimation is limited to coarse spatial resolution? Can't the same parameters/indicators be used for the estimation independent of whether it's based on coarse- or fine-resolution data?
Answer 23: Most operational crop yield applications are based on coarse spatial resolution simply because of the lack of availability of “free” HR sensors (only Landsat until the Copernicus Sentinel mission era). This is also because operational applications often take place at national (or even regional) scale, and working with HR data is much more demanding in terms of IT processing. This is evolving now and, as explained in the presentation, there are more and more successful demonstrations of yield estimates with HR data.

Question 24: How far is the development and application of AI/machine learning approaches for crop classification combining reflectance data with phenological development from time series (crop calendars)? If so, are there any lessons learned where this works and where it causes more challenges?
Answer 24: Machine learning, like random forest, is the current standard for crop classification, as learned in Part 3 of this training or with the Sen2Agri toolbox. Phenometrics can surely be used as inputs to machine learning algorithms. Deep learning (like CNNs) is a very active field of research leading to some successes and challenges (the need for a large calibration dataset and the limited transferability of AI models from one region to another and from one season to another).

Question 25: Can we use CubeSat data for yield estimation?
Answer 25: There is no reason why you could not use CubeSat data for yield estimation. Due to the fact that they are not free of charge, the AOI will certainly be limited and the application will probably be more R&D than operational; but from a technological point of view, this is possible.

Question 26: Sometimes ground truth data is difficult to collect (e.g., in remote areas with difficult accessibility). Are there any good examples collecting (surrogate) ground truth using planes or middle-long range drones?
Answer 26: This is totally true that in situ data collection might be very challenging in some areas. There are successful examples of ground data collection using light aircraft or drones. In South Africa, a national "ground" data collection campaign is carried out each year using light aircraft. You can find more information in the slides from the 5th Sen2-Agri webinar (last section of this presentation): http://www.esa-sen2agri.org/webinar-5/.
Another example is a field campaign in Tanzania (conducted with the Copernicus4Geoglam project) carried out this year using drones.

Question 27: Do the different dots in the graph that link yield and max LAI represent the different locations of a particular crop type?
Answer 27: Yes, each dot corresponds to an Elementary Sampling Unit (ESU) measured on the ground. Each graph is crop-specific.

Question 28: So basically, as of now, we cannot accurately estimate the yield using remote sensing?
Answer 28: More precisely, the yield estimation system based on satellite observations working operationally today has been calibrated for a given context (given region, given agricultural practices, etc). It is, however, common to use several sources of information (crop growth modeling, agrometeorological indicators, trend analysis, etc.) in addition to satellite remote sensing in order to provide yield estimation, or at least crop conditions, all over the world (see https://ec.europa.eu/jrc/en/mars/bulletins, https://fews.net/, https://cropmonitor.org/).

Question 29: What is the accuracy of SNAP in the retrieval of LAI for different vegetation types such as agriculture, forest, and grassland?
Answer 29: The LAI retrieval implemented in SNAP is the one based on the BV-Net approach introduced in this presentation. More information about this algorithm is available here: https://step.esa.int/docs/extra/ATBD_S2ToolBox_L2B_V1.1.pdf.
It includes some validation figures and nice references to papers focusing on the biophysical variable validation. Nevertheless, keep in mind that the validation should be considered in a specific context with specific crops.

Question 30: Does this system only work with Sentinel-2 or Landsat-8? Can we work with Sentinel-1?
Answer 30: The Sen2-Agri system is working with Sentinel-2 and Landsat 8 (no SAR data). Sentinel-1 is included in the Sen4CAP system (http://esa-sen4cap.org/), which works by object and will be included in the Sen4Stat system (not yet available but coming soon), allowing a per-pixel approach (https://www.esa-sen4stat.org/).

Question 31: Does Sen2Agri include forest cover types also?
Answer 31: Sen2-Agri includes a per-pixel classification processor based on the Random Forest algorithm. The system has been developed for crop mapping, but it can be used for other types of classifications, including forest cover types for example. In the Sen2-Agri user community, there are users who have successfully tested the system for general land cover mapping and for forest type classification.

Question 32: Can we extract Sen2Agri products from past years, assuming that I have the past years' training data?
Answer 32: Yes, the Sen2Agri can be run in near-real time or offline, allowing you to process the data from previous years, provided that you have the information for the crop classification.

Question 33: For crop growth monitoring in NRT system operation, can you provide more detailed validation and accuracy results using the Sen2Agri?
Answer 33: The crop growth monitoring processor is based on the BV-Net algorithm, which is fully documented here:
https://step.esa.int/docs/extra/ATBD_S2ToolBox_L2B_V1.1.pdf.
This ATBD already includes some validation figures and it refers to papers on this topic. Specific validation was done in Belgium over given fields, which confirm the good performance.

Question 34: How much training data should we have for Sen2Agri crop type to work?
Answer 34: This has to be designed according to the area of interest. The more diverse, the more training data will be needed. Typically, a few hundred samples of each crop type is needed to characterize the diversity when running a classification at the national scale. Samples can go up to 2,000. Some quantitative guidelines were given in a past Sen2-Agri webinar, for which slides are available here:

http://www.esa-sen2agri.org/wp-content/uploads/presentations/Webinar/Webinar5_20180719/Sen2-Agri_5thWebinar_19July2018_Summary_Challenges.pdf.

Question 35: Can Sen4CAP be used for areas other than the pilot areas (the Czech Republic, Italy, Lithuania, Netherlands, Romania and Spanish regions)? E.g., Can it be used for Ireland or the UK?
Answer 35: Yes, the system can be used anywhere. The only requirement is that the users need to have object boundaries.

Question 36: Can we download products from Sen4CAP using shapefiles? Do the products have global coverage?
Answer 36: Sen4CAP is a toolbox, not a set of products. You need to download the system and operate it by yourself to generate your own products.

Question 37: To use SAR biophysical parameters, do we also need to collect field data? Or are we just relying on the coherence data mentioned earlier?
Answer 37: It depends on the algorithm used to derive the biophysical parameters from Sentinel-2. To derive coherence data there is no need for field data. It is difficult to provide a generic answer. It depends on the parameter and methods used to derive it.

Question 38: Can we exclude agroforestry from cropland with Sentinel-2 or Sentinel-1 images through crop classification?
Answer 38: This will depend on your agroforestry patterns. If you have large trees, you can characterize them using high-resolution imagery. If there are linear features that are very narrow then it will be difficult to remove the agroforestry features from the cropland. This is much more a matter of spatial resolution rather than whether the information is from an optical or radar sensor.

Question 39: Can soil types be identified using indices? If so, which indices are preferable?
Answer 39: The soil type doesn't exactly refer to soil color but rather the soil profile (depth, drainage, etc). In some places soil type can be related to soil color. In such cases, we have coarse information about the soil type based on the surface color of the soil. In terms of indices, it depends on the area that you are looking at. It could also be a soil brightness index.

Question 40: Is the crop phenology region-specific or is it global? Can the phenology of a crop change with time or is it the same every year?
Answer 40: Phenology is completely variable, from one place to another, from one species to another, and from one season to another. There is no identical agricultural season. There is however, a crop calendar, which provides an idea of when a plant is sowed and harvested. This is not crop phenometrics, this is a crop calendar.
The difference between years is of great interest in order to monitor phenology and understand how crops behave, for example, this year compared to the previous year. Warning systems are monitoring the current crop conditions and comparing them with the previous years to detect anomalies.

Question 41: How do you get the biophysical parameters of the lower canopy in the case of intercropping?
Answer 41: If intercropping has the same phenology, then there is no way of separating the lower from the upper canopy. It will be combined in the biophysical variables and therefore LAI will be a combined LAI. If you have very high resolution, you can separate the upper and lower canopy.

Question 42: What indices does one use to identify the possibility of pest infestation or over-usage of water?
Answer 42: These are topics of research. Pest infestation is on the leaf-level on the internal structure of the leaf. This will be related to the red-edge or the NIR bands. In the presentation there is an illustration that shows the senescence of the leaf but pest symptoms would be very similar.
NDWI is a good indicator of water stress. Overuse of water will not be visible at the plant level, but may be related to soil moisture and might be detected using microwave data.

Question 43: Are there any indices that would help identify heavy metal stress using Sentinel data?
Answer 43: It is possible that hyperspectral data might be able to identify such stress.

Question 44: How do we quantify yield based on satellite imagery? Will you please share the steps? Thank you.
Answer 44: For the method discussed in the webinar, you collect ground data, and the success of the yield-estimation will be dependent on having a good yield proxy that

has good correlation with the ground data, which can then be generalized within your area of interest depending on the local conditions.

Question 45: What if we have two crop types on the parcel at the same time? In that case, how can I measure vegetation indices or biophysical variables?
Answer 45: The answer is similar as in intercropping. The vegetation indices and biophysical variables will provide a value combining both canopy covers, meaning the LAI combination of the vegetation of the two crops.

Question 46: Is the same crop mask applicable to all the crops or crops on different continents?
Answer 46: Not sure if we understand the question. There is a crop mask generated for the region you want to monitor, which is valid for all types of crops in that region. Once you generate the crop mask then you can do a crop type identification within that area.

Question 47: My question pertains to the capacity of a software package that can use/handle data processing for a big-coverage study area (country level). Some software has limitations of input data (number of training areas) and also needs high-capacity hardware to work with. So how about the Sen2Agri and package?
Answer 47: The limitation is not really the number of training areas from the user's perspective. The main limitation is that it only works in a Linux environment. In terms of the amount of data there is no limitation. The capacity is also limited if you are not in the cloud. If you were to download the dataset for a large area, this would be a major constraint.