



Questions & Answers Part 1

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 Amber McCullum (amberjean.mccullum@nasa.gov) or Britnay Beaudry (britnay.beaudry@nasa.gov).

Question 1: How do spectral indices help with atmospheric conditions, instrument noise, and sun angle?

Answer 1: Spectral indices are a simple band math calculation from two wavelength ranges. So you are obtaining a ratio between the two, and are not using the top of atmosphere or surface reflectance directly.

Question 2: Would NDVI be a good index for monitoring irrigation areas?

Answer 2: Yes, NDVI is one of the most widely used indices for monitoring vegetation. This can be done with Landsat and Sentinel-2 for example, but the same calculator could be done with commercial imagery or drone imagery if the near-infrared band is part of the sensor. Drones with a near-infrared band can be really useful since the spatial resolution is very high. Another metric often used is Evapotranspiration or ET, which can be derived from Landsat.

Question 3: NDVI shows healthy vegetation. Can we categorize or classify the forest based on its NDVI value? Say like primary forest, secondary forest in the tropics?

Answer 3: The NDVI is usually used to identify the relative health of vegetation, and it can be more difficult to use this index for identifying different types of vegetation. However, there has been some research on the general NDVI ranges for primary vs. secondary forest. I would recommend some ground-based information used in conjunction with NDVI when studying these ecosystems.

Question 4: How can the ranges of NDVI be divided into different classes to assess the health and density? At which value does the actual vegetation measurements start and how does these ranges differ in different satellites?

Answer 4: Negative values correspond to areas with water surfaces, man made structures, rocks, clouds, snow; bare soil usually falls within the 0.1- 0.2 range; and



plants will always have positive values between 0.2 and 1. Healthy, dense vegetation canopy should be above 0.5, and sparse vegetation will most likely fall within 0.2 to 0.5. However, it's only a rule of thumb and you should always take into account the season, type of plant, and regional peculiarities to know exactly what NDVI values mean. The ranges will be the same across different satellites, such as Landsat and Sentinel-2, because it is a ratio - you will always use bands from the same satellite in the calculation.

Question 5: Does a difference in resolution affect the accuracy when comparing different years? For example, if I compare data from 1987, will I have lower resolution than 2004 as a result of the advances in technology?

Answer 5: Yes somewhat. The difference in resolution will affect how much detail you can observe on the ground. For example, if you have a 250 m resolution you will only get one NDVI value for the entire 250 m area - which could include a more heterogeneous landscape compared to having one value for the entire 30 m area. It really depends on the scale of your study area and how you are using the data.

Question 6: Are Landsat 7 NDVI values comparable with Landsat 8 and 9 values, despite small differences in the red and NIR bands?

Answer 6: Please see slide 32 - The NIR bands have slightly different wavelength ranges for Landsat 7 and Landsats 8/9. The values will be very comparable.

Question 7: Is there a significant accuracy improvement when applying normalized difference indices to Level 2 images compared to Level 1 images?

Answer 7: I would use the Level 2 images when available. These are processed to a higher level and are generally considered more accurate and appropriate for spectral index calculations. Remember, this is a ratio.

Question 8: From which website will I find recent MODIS NDVI data?

Answer 8: Slide 40 will show the variety of places to go. Earthdata search is a great resource. AppEARS is also a very useful interface as well. All these are in Earth Engine too.

Question 9: Is it possible to share these scripts of NDVI extraction?

Answer 9: Yes, the code we used today is available (see slide 45). A GEE account is open and free.



Question 10: Does everyone use the same cloud masks?

Answer 10: How you mask out clouds depends on the satellite and sensor you're using. With Landsat 9, we use the 'QA_PIXEL' band to filter out cloud and cloud shadow. This cloud mask function starts on Line 44 in the script we used today. With Sentinel-2A, we use the 'QA60' band to mask out clouds, which you can see starting on line 105 in the script we used today.

Question 11: Can I use NDVI data and CDL data? I want to extract NDVI according to CDL. Is it possible?

Answer 11: If referring to the cropland data layer, we are not familiar with the analysis. That data layer is available for the US on a yearly basis. Extraction of the NDVI may not be possible. This is a USDA dataset.

<https://croplandcros.scinet.usda.gov/>

Question 12: In the GEE tutorial, since it's Level 2 data, are these bands atmospherically corrected? Do all spectral indices work with atmospherically corrected bands as opposed to TOA bands?

Answer 12: There are many levels of data. The ones we used today can be found here:

https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LC09_C02_T1_L2

https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S2_SR

You want to be sure the sensor you are using is necessary for your use. Match the spectral indices you are using with those bands. In parts 2 and 3 we will cover band values.

Question 13: Are the variable names case sensitive in GEE? minMax = minmax???

Answer 13: Variable names are case sensitive. minMax is a function, and is also case sensitive. I recommend looking at the "Docs" tab in the GEE interface on the upper left corner. There you can see all the different functions that GEE has to offer, and it's filtered by object type!

Question 14: I'd love to be able to fill in a form about code parameters in Earth Engine. I wish there was a non-code interface.

Answer 14: Check out GEE Map: <https://geemap.org/>. You still have to do some coding, but you can create small bits of code and then create point and click



functionality on the GEE interface. There are also other tools like Climate Engine that don't require coding.

Question 15: How can we evaluate which of two vegetation indices works better beyond visual interpretation?

Answer 15: Ground-based spectral measurements or even simple ground-based vegetation density estimates are always useful when using remotely sensed imagery. You could also estimate leaf area via ground-based estimates and remote sensing too.

Question 16: Any thoughts on why the Sentinel-2 Surface reflectance image collection GEE does not extend back before 2019? How can I encourage the GEE team to ingest the full record?

Answer 16: I'm not sure. I would check in with Google. You can search their data catalog here: <https://developers.google.com/earth-engine/datasets>

Question 17: Can NDVI be used for crop type classification based on this? If yes, can you tell me the accuracy that can be reached by this classification? If not, is there another index that can produce statistical results?

Answer 17: This is not my area of research, but I think you would need additional information in combination with NDVI for crop-type classification. Ground-based measurements for validation would be key. If you also have some knowledge of the phenology of the crop type you could compare the timing of green-up across different crop types with NDVI. Here is one example of the use of NDVI for crop classification and I am sure there are many others:

<https://www.sciencedirect.com/science/article/pii/S0303243414001615>

Question 18: How can you compare values of NDVI between times and locations? It seems it is not easy due to natural changes in vegetation over time, even from year to year.

Answer 18: The use of NDVI across time is one of the most beneficial applications - to better understand changes in vegetation health as it might relate to things like drought, degradation, deforestation, etc.

Question 19: If I use a drone to monitor the vegetation health in an agricultural field using an NDVI with a resolution of 1 m, I will get 100 values of the NDVI,



compared to Sentinel-2 with a resolution of 10 m for one pixel, which gives only 1 NDVI value. Is that correct?

Answer 19: Yes, You will get 1 NDVI value for each pixel. So if you are looking at the same area with Sentinel-2 (10m) you will get one value for every 10 square meters (so $10 \times 10 = 100\text{m}$ within that pixel).

Question 20: I worked with the Sentinel-2 Cloud Masking with s2cloudless that uses S2 1c and S2_HR. It stopped working as of images from February 2022. Do you know anything about this and why it happens?

Answer 20: I personally don't know why this happens, but I will provide a link to Google CoLab's tutorial on using s2cloudless:

<https://developers.google.com/earth-engine/tutorials/community/sentinel-2-s2cloudless>

Question 21: How can NDVI normalization be adjusted for climate-related factors, like rainfall?

Answer 21: You can compare changes in NDVI alongside changes in climate variables like temperature or rainfall, but the NDVI will always be the ratio between the Red and NIR bands. Here is an article that compares NDVI to climate related factors:

<https://www.mdpi.com/2071-1050/11/24/7243>

Question 22: In the GEE demo, the documentation for TerraMODIS shows min/max of -2000, 10000. The code uses a range of 0 and 8000. Can you explain the choice of min & max in the code?

Answer 22: The min/max values used for the TerraMODIS and VIIRS products were selected based off of the NDVI values the datasets initially have. You can read their documentation on how each product is created here:

VIIRS NDVI: <https://lpdaac.usgs.gov/products/vnp13a1v001/>

TerraMODIS NDVI: <https://lpdaac.usgs.gov/products/mod13q1v061/>

For this training, we simply visualized the products on the map, and didn't perform any scale factoring for proper analysis. Similar to how we applied scale factors to our Landsat and Sentinel-2A data, you can apply the correct scale factor to the VIIRS and TerraMODIS NDVI products. You can see the scale factor values necessary in the "Scale" row for each spectral band.



Question 23: How do you compute spectral indices (e.g., NDVI) for Hyperspectral images? In other words, how do I select adequate bands for a specific spectral index?

Answer 23: This depends on the type of vegetation you are interested in and the vegetation response in these very narrow wavelength bands of hyperspectral imagery. Machine learning correlation methods can be employed to identify which hyperspectral bands may be most useful for your study area. Here is a paper on these techniques:
<https://www.mdpi.com/2073-4433/14/7/1148>

Question 24: Can band ratios be applied with object-based image analysis, instead of by pixel? Are there any examples of this?

Answer 24: Object based image analysis is different from pixel based image analysis as it also includes features like shape, texture and spatial relationship with the surrounding pixels. You could compare pixel-based analyses (including NDVI) to object-based analysis for something like conducting a land cover classification to analyze which method works best for your area. Here are a couple resources:
<https://link.springer.com/article/10.1007/s11707-020-0848-7>
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5920549/>

Question 25: Does it matter which NIR band is used for NDVI? What if there are slight differences in the band center and/or bandwidth of the NDVI bands between different sensors?

Answer 25: See slides 32 and 33 for the most commonly used NIR bands from Landsat and Sentinel-2. If you have hyperspectral imagery you might do some type of correlation methods (via machine learning perhaps) to identify the best NIR bands for your study region. See question 23 as well.

Question 26: Can NDVI identify multispectral image resolution that is <10mm using a cloud cover detection model of dense canopy of vegetation over the RGB Sequence of Landsat?

Answer 26: I'm not sure I understand the question. Landsat has a partial resolution of 30 meters and Sentinel-2 has a resolution of 10 meters for the NDVI calculation. There are methods of cloud masking or creating image composites to deal with the effects of clouds in your region.



Question 27: Here we are masking clouds. Sometimes it gives us perforated images. Is it important to fill those gaps? If yes, how?

Answer 27: You can “fill in” missing areas from a cloud mask by extending the dates of imagery you’re using, like taking a monthly average rather than a bi-weekly average. But keep in mind that you’ll be using imagery from multiple days/overpasses and data validation will be much more difficult.

Question 28: Are there some benefits when we make a workflow with script rather than with a GIS software?

Answer 28: Using a coding language versus a GIS software usually comes down to an individual’s preference, but in some instances scripting can be utilized to perform tasks with more efficiency (like batch processing, for example).

Question 29: Bolivia has experienced a drought year. Could you give any additional applications for drought assessment using the NDVI index?

Answer 29: You could calculate NDVI anomalies across multiple years to see how severe this drought is. For example, you could generate a monthly average NDVI for say August in your study region from 1990-2010. Then you could subtract the 2023 August NDVI image from the long-term average to see if the NDVI values are higher or lower than average. Here is an example of a study that used NDVI anomalies for drought: <https://www.sciencedirect.com/science/article/abs/pii/S0140196318302659>
Here is another visualization from NASA on NDVI anomalies for drought: <https://svs.gsfc.nasa.gov/4916>

Question 30: Can you suggest a dream drone band wavelength combo?

Answer 30: This really depends on the application you have for the drone. If you are interested in using it for vegetation mapping it’s best to have R,G,B, NIR.



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Question 1: Can one differentiate farms from forests on the NDVI spectrum? I mean, which ranges are associated with farms and which with forests? Is it also possible to combine NDVI with other band combinations or even the thermal band to differentiate farms from forests?

Answer 1: Healthy, dense vegetation canopy should be above 0.5, and sparse vegetation will most likely fall within 0.2 to 0.5. However, it's only a rule of thumb and you should always take into account the season, type of plant, and regional peculiarities to know exactly what NDVI values mean. The NDVI range can really vary depending on the crop type (and crop phenology) and the density of the forest. Generally forests have slightly lower NDVI values than irrigated agriculture. But this is really dependent on your study region. In very dense forests, the Enhanced Vegetation Index or EVI can be beneficial - stay tuned for session 3.

Question 2: Can we use Python with the given Google Earth Engine code?

Answer 2: The code in the demo today was written in the Javascript version. If you want to use Google CoLab for GEE, you can check out these resources:
<https://developers.google.com/earth-engine/tutorials/community/intro-to-python-api>.

Question 3: Can we use spectral information to differentiate plant species?

Answer 3: Yes, but you generally need hyperspectral data for identifying vegetation at a species level. Check out a previous training on Hyperspectral data here:
<https://appliedsciences.nasa.gov/get-involved/training/english/aset-hyperspectral-data-land-and-coastal-systems>.

Question 4: What does NDVI <0 mean? What if NDVI is negative 0.5, when it is compared to -0.1? Does the difference mean anything in wetland context?



Answer 4: Negative values correspond to areas with water surfaces, manmade structures, rocks, clouds, snow; bare soil usually falls within the 0.1- 0.2 range; and plants will always have positive values between 0.2 and 1. Healthy, dense vegetation canopy should be above 0.5, and sparse vegetation will most likely fall within 0.2 to 0.5. However, it's only a rule of thumb and you should always take into account the season, type of plant, and regional peculiarities to know exactly what NDVI values mean. Here is a paper that used NDVI for wetlands with wide ranges in NDVI:
<https://www.mdpi.com/2072-4292/14/9/2107>.

Question 5: Can we use this index for the sea or inland water?

Answer 5: Yes, if you have chlorophyll or floating vegetation in water. However, there are other indices that may be more appropriate for your work. Stay tuned for next week's session on aquatic applications.

Question 6: Is it possible to compute a regression analysis between, LULC, NDBI, NDWI, NDVI for the impact of land use on wetland ecosystems?

Answer 6: Yes, you could compare land cover/land use, and other indices to assess changes in wetlands over time. Here is a paper that used NDVI and NDWI for wetland analysis as an example:
<https://www.sciencedirect.com/science/article/abs/pii/S2352938521000835>.

Question 7: What is meant by the value of Red or NIR? As in what quantity is this?

Answer 7: This is the spectral reflectance (or the amount of reflected radiation from an object) - the amount of energy reflected from an object in that wavelength range. The sensitivity of a sensor to this energy is the radiometric resolution, so the values of reflected energy will be within the range the sensor is able to detect. Radiometric resolution refers to dynamic range, or a number of various output numbers in every band of the data, and is identified by the number of bits into where the recorded radiation is partitioned. In the 8-bit data, the Digital Numbers range from 0 to 255 for every pixel. Please see the Fundamentals of Remote Sensing training for more information:

<https://appliedsciences.nasa.gov/get-involved/training/english/arset-fundamentals-remote-sensing>.



Question 8: Does the Normalized Difference Vegetation Index (NDVI) have a relationship with geological and geomorphological assessments? If so, could you explain this relationship?

Answer 8: NDVI is probably not the best index to use if you are interested in geological applications. The SWIR is likely more beneficial to use - as bare ground/soils/minerals tend to reflect more in the SWIR. Hyperspectral imagery may be useful for mineral mapping too. It's not my area of expertise, but there are many indices for those applications that we will not cover in this training. Here is a nice overview:

https://gcs-docs.s3.amazonaws.com/EVWHS/Miscellaneous/Whitepapers/White_Mine_ralSpace.htm.

Question 9: How was the formula for NDVI determined and ground-truthed?

Answer 9: Ground-truthing such as spectroradiometer measurements from the ground were compared extensively to the remotely sensed images. In the key paper from Compton Tucker in 1979, this is outlined: "*In situ* collected spectrometer data were used to evaluate and quantify the relationships between various linear combinations of red and photographic infrared radiances and experimental plot biomass, leaf water content, and chlorophyll content."

https://scholar.google.com/citations?view_op=view_citation&hl=en&user=IBvX950AAA_AJ&citation_for_view=IBvX950AAA_AJ:u5HHmVD_uO8C

Question 10: For the Southern African (SADC) region of Africa, how can we maximize on NDVI for the malaria control and eradication problem? A couple of papers have been published on integrating public health and remote sensing, however results have been somewhat inconclusive.

Answer 10: This is not my area of expertise, but I imagine it would also be beneficial to identify standing water bodies, so perhaps synthetic aperture radar or SAR data could also be used. I also imagine air temperature and humidity would be useful variables.

There are some NASA projects that study this:

<https://appliedsciences.nasa.gov/what-we-do/projects/myanmar-malaria-early-warning-system-mmews-multi-sensor-satellite-data-fusion>

<https://svs.gsfc.nasa.gov/30593/>.

Question 11: Given the 1 arc second product from MODIS, as well as the manually derived 30 m resolution product from Landsat 8/9, what is the potential from



MISR to provide more accurate recording of vegetation health or water stress in plants?

Answer 11: The Multi-angle Imaging SpectroRadiometer, or MISR, instrument is one of five instruments aboard NASA's Terra satellite - along with MODIS. The instrument views the Earth from nine different angles to get a better picture of various atmospheric particles, cloud forms and land surface covers. So there are many applications of MISR data and MISR has been used for above-ground biomass mapping. Here is an example: <https://www.sciencedirect.com/science/article/pii/S0034425722000785>.

Question 12: How do NDVI products differ from NDVI calculated from multispectral imagery?

Answer 12: NDVI products highlighted are using the same calculation over different regions. Depending on the product compared to the imagery you are using for your calculation, there may be differences in spatial resolution. Also, they might not be available for the time periods you are interested in, thus you might want to run the calculations yourself.

Question 13: Is there any way to actually download the multi-band data, as I would like to use ENVI's band math to calculate spectral indices. To use Google Earth Engine, one is forced to create an account.

Answer 13: You can access the datasets we used in the demo today on the LP DAAC:
<https://lpdaac.usgs.gov/products/hlss30v002/>
<https://lpdaac.usgs.gov/products/mod13q1v061/>
<https://lpdaac.usgs.gov/products/vnp13a1v001/>

Question 14: Can you explain again how you choose your own area of interest?

Answer 14: You can learn how to draw a geometry in GEE using this guide [here](#), and you can learn how to create a geometry programmatically using a list of coordinates [here](#).

Question 15: What language is used in NDVI?

Answer 15: The coding language we're using today is the Javascript version of Google Earth Engine.

Question 16: What was the purpose of applying the scale factor again?



Answer 16: To quote the USGS Landsat page directly: “Landsat Level-2 products are written as scaled integers to allow us to convert the data from floating point to integer for delivery. In most cases these are written to a 16-bit integer, which saves disk space and provides faster download times.

Each floating point pixel has an offset applied and then multiplied by a gain to bring the value into the 16-bit integer (or unsigned integer) range. These values are referred to as scaled integers. To allow the user to get the data back to its original floating point value, a scale factor and offset are provided for each band. The scale_factor should be applied to each pixel and then the offset added (i.e., Digital Number (DN) * scale_factor + offset).

You can apply a scale factor to the science products via a data script, through manual calculation, or within certain software programs.”

You can read more about the science behind scale factors [here](#) and you can read about how scale factors differ between Landsat products [here](#).

Question 17: Why did we select the QA band in the cloud masking function?

Answer 17: With Landsat 9, we use the 'QA_PIXEL' band to filter out cloud and cloud shadow. This cloud mask function starts on Line 44 in the script we used today. With Sentinel-2A, we use the 'QA60' band to mask out clouds, which you can see starting on line 105 in the script we used today. You can read about Landsat 8/9's QA bands [here](#), and more about it in the Landsat SR User Guide [here](#).

Question 18: How to add a specific file for our AOI?

Answer 18: You can upload files (shapefile, CSV, etc.) to GEE using the “Assets” tab in the upper left corner of the user interface. You can read more about how to do that here:

https://developers.google.com/earth-engine/guides/table_upload#uploading-table-assets.

Question 19: Is there any minimal size recommended of a polygon to have where doing an NDVI analysis is worth it, but below that size the NDVI is not useful because the spatial resolution is not good enough?

Answer 19: This really depends on your study area and the types of questions you are trying to answer using the imagery. This also depends on the heterogeneity of your landscape. For example you might want to consider “mixed-pixels” alongside a water



body where you might have influences from the water and the vegetation affecting the NDVI value. Just remember you get one value for each pixel.

Question 20: Do you know of any plans to add Harmonized Landsat/Sentinel-2 to the GEE data catalog?

Answer 20: Yes! Preliminary HLS data is currently available on GEE here. We will discuss more about HLS data and data products in the third session of this training.

Question 21: Why NIR and Red? Why not other colors?

Answer 21: Healthy vegetation absorbs in the Red and reflects very highly in the NIR - thus the ratio between those two bands will distinguish healthy vs. unhealthy vegetation. Please see the Fundamentals of Remote Sensing for more information.

<https://appliedsciences.nasa.gov/get-involved/training/english/aset-fundamentals-remote-sensing>.

Question 22: Are there instances where it is more computationally efficient to filter with filterBounds() before filtering with filterDate()?

Answer 22: I suppose that would depend upon the satellite/sensor's overpass frequency and the scale of a region of interest. To improve any computation efficiency, I would read GEE's Coding Best Practices guide:

https://developers.google.com/earth-engine/guides/best_practices

Question 23: Worldview 2 has 2 red bands (i.e., the red band, the red edge band). What's the difference between the 2 results and which would be best for environmental modeling and precision agriculture?

Answer 23: I think the red edge band has some advantages over the red band for identifying differences in vegetation health. Check out this resource for more information:

http://satimagingcorp.s3.amazonaws.com/site/pdf/WorldView-2_8-Band_Applications_Whitepaper.pdf.

Question 24: What are the pros and cons for Sentinel-2 NDVI and Landsat 9 NDVI?

Answer 24: The pros/cons are related to spatial resolution, temporal resolution, and length of record. Sentinel-2 has an improved spatial resolution of 10 meters, when compared to Landsat at 30 m. It also has a more frequent revisit time of 10 days with 5



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days with multiple systems in place, as opposed to the 16- or 8-day (based on one or two landsat satellites). The primary benefit is that Landsat data in some form has been available going back to the 1970s, as opposed to around 2015 for Sentinel, so if you are interested in looking back over time Landsat can provide that long time series.

Question 25: How do you export those calculations into a TIFF file?

Answer 25: GEE provides a guide here:

https://developers.google.com/earth-engine/guides/exporting_images

Question 26: Can the NDVI index be useful for bare soil extraction?

Answer 26: It can be used to identify bare soil, but there may be better indices for assessing geological attributes. Here is a nice overview:

https://gcs-docs.s3.amazonaws.com/EVWHS/Miscellaneous/Whitepapers/White_Mine_ralSpace.htm.

Question 27: Would you always recommend substituting min and max values in visualizations? That technically would be the same as stretching a histogram right?

Answer 27: Visualizing data is very case-specific, but all visualizations should be made to best represent the accuracy of the data and methods you're using.