

***Tutorial:*** ***Estimating the Soil Organic Carbon Index (SOCI) with QGIS***

Description of Indicator

The cropping cycle or agricultural cycle is the set of activities undertaken over time for the growth and harvesting of plants for human or animal consumption. Various activities for soil improvement might include tillage to improve the texture and water holding capacity, adding minerals and nutrients, and irrigation. Knowing which of these activities are needed and when they are needed requires knowledge of what happened on the field when it was last used, perhaps the measurements from last year. These measurements, often called agricultural indicators, can be used to keep track of soil health or quality to be able to compare production over time, and understand better how to improve production in the next season.

Soil quality has been defined as the capacity of a soil to promote the growth of plants. A combination of physical, chemical and biological properties that are common are texture, water-holding capacity, porosity, soil organic carbon (SOC), and depth. These soil properties can have direct and indirect impacts on soil quality. The soil acts first and foremost as a medium to support the growing plant. Next, the soil stores water and nutrients for plants, which plants draw on as needed. Rainfall, the source of much of the stored moisture, interacts with the landscape and either infiltrates and is held by the soil or runs off. The quality of the soil impacts that water-holding capacity. Degradation of the soil through erosion impacts attributes of quality such as the availability of nutrients and SOC. Tiny microorganisms decomposing the organic matter then indirectly impact the water-holding capacity, limiting amount available to plants.

Soil organic matter is considered a critical Tier 1 indicator of soil health (Soil Health Institute, 2018). Improving soil health boosts crop yield, enhances water quality, increases drought resilience, reduces greenhouse gas emissions, increases carbon sequestration, provides pollinator habitat, and builds disease suppression (Soil Health Institute, 2018). Increased organic matter boosts aggregation or soil clumpiness, improves permeability and infiltration.

On the other hand, soil organic matter is very difficult to measure, so laboratories often measure SOC as a proxy. However, measuring SOC has been a significant barrier to the assessment and adoption of soil health practices, as laboratories typically do this through taking soil samples, drying them and then weighing and measuring the carbon and nitrogen content. Recent remote sensing discoveries bypass this process using a calculated Soil Organic Carbon Index (SOCI) which has been compared with nearly 8,000 samples from the USDA Rapid Carbon Assessment (RaCA) database to verify that the SOCI can accurately predict SOC results (Thaler et al., 2019).

To calculate SOC today, very many visible multispectral satellite sensors will suffice. It is only necessary to have red, green, and blue channels (which are some of the most common imagery bands available). It is not necessary to have information about the specific crop planted, but it is important to know which crops are planted in the particular region and have some cropping calendars for those crops. Knowing the cropping calendars enables the analyst to be able to select a time of the year when the location is not severely impacted by rainfall and prior to planting, as SOCI should not be measured after germination. Knowing the cropping calendars and whether the farmers leave stubble on the ground after they grow those crops also helps with choosing a time of year long enough after harvest that stubble will have been eaten off.

This indicator calculates SOCI over a given area to qualitatively estimate the degree of organic matter in the field expected at a location or region during a period of time in a season. Ideally, the measure would be captured over several seasons (perhaps even as long as a decade) along with a program to increase soil organic matter.

Data Required

The data required for the calculation of the SOC Index are red, green, and blue channels of cloud-free satellite images. As cloud-free images often come at a premium, images that are not cloudy in parts of the satellite scenes well away from the area(s) needed are still sufficient for use. It is not necessary to calibrate the image values, unless the data are going to be compared over time or between satellite sensors. If the satellite image data need to be pre-processed (calibrated), then commonly used methods employ converting imagery to top of atmosphere (TOA) reflectance, re-projection to a common map projection, downsampling high resolution data (e.g Planetscope) (at 3.125m spatial resolution) to Landsat 8 (at 30m spatial resolution), if necessary (GDA Corp, 2017). Planet’s current constellation of Planetscope DOVE satellites, which number about 130 at this writing, have 4 bands of Red (R), Green (G), Blue (B), and Near-Infrared values (see the attached spreadsheet).

Though the spreadsheet tries to be comprehensive in the list of available data, the most likely sources for Mercy Corps will be Landsat, MODIS, Planetscope, and Sentinel data, which are listed above in this document. See the additional worksheet for the Access Points for acquiring the relevant satellite images to estimate the SOCI.

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| **Data Source** | **Spectral Resolution Needed (Satellite only)** | **Spatial Resolution** | **Frequency** | **Data Type** | **Comments** |
| Requires R, G, B visible satellite image bands. | Any visible satellite imaging sensor that has R, G, B bands can estimate SOCI. The resolution needed is dependent on the size of the farm, the number of desired samples, and budget. | There is no hard rule. If the farm is less than 2 acres, then high resolution imagery is recommended. | Seasonally, annually. SOC varies over space but not much over time (Davis, 2018) | SOCI is a satellite derived product | Validation of the SOCI estimation uses NIR and SWIR data. |

Protocols for calculation

There isn’t any particular need for preprocessing or time series data collection to estimate SOCI at one moment in time or over a long period. Efforts to validate the Index showed that it was not necessary to radiometrically correct the datasets prior to use (Thaler et al., 2019). The Index operates simply to show the percentage of organic carbon and therefore (through a conversion coefficient) the quantity of organic matter in the top 10 cm of the soil profile.

Annex 1 runs through the detailed calculation of this indicator using a specific example.

Protocols for collection of primary validation data

There is not a very simple/elegant solution for validating SOCI, and the inputs for calculating alternate data values to compare with SOCI are not widely available (which provided some of the impetus for developing SOCI in the first place). The two methods of calculating similar indices that show strong correlations with SOCI output include (a) the shortwave-infrared (SWIR) / near-infrared (NIR) index, and (b) the spectral index (SI)1001–679 nm (Thaler, 2019). US national carbon data across different land covers were used to validate the SOCI in the introductory article. The SOCI has been shown to work as well as or better than these existing indices for SOC (Thaler 2019).

Mercy Corps can also consider partnering with local agriculture institutions if desired to further test SOC in the laboratory and validate use of SOCI at Mercy Corps’ specific site locations. This can also help with determining whether the default soil coefficient (see Annex 1) or a different soil coefficient is appropriate locally. A local partnership can also build local buy-in. However, such a partnership is not scientifically necessary given the strong validation of SOCI already.

Estimated LOE

* 1 week of geospatial developer’s time to develop, document and train users on the script for subsequent use, depending on data availability
* 1 hour per run of an analyst’s time to set up script with desired imagery, run the script, and format output data for inclusion with MEL data.

**SOCI & SOIL ORGANIC MATTER REFERENCES**

Davis, M. R., Alves, B. J. R., Karlen, D. L., Kline, K. L., Galdos, M., & Abulebdeh, D. (2018). Review of Soil Organic Carbon Measurement Protocols: A US and Brazil Comparison and Recommendation. *Sustainability*, *10*(1), 53. <https://doi.org/10.3390/su10010053>

North American Project to Evaluate Soil Health Measurements. (n.d.). *Soil Health Institute*. Retrieved July 25, 2021, from <https://soilhealthinstitute.org/north-american-project-to-evaluate-soil-health-measurements/>

Thaler, E. A., Larsen, I. J., & Yu, Q. (2019). A New Index for Remote Sensing of Soil Organic Carbon Based Solely on Visible Wavelengths. *Soil Science Society of America Journal*, *83*(5), 1443–1450. <https://doi.org/10.2136/sssaj2018.09.0318>

**Tutorial for Estimation of the Soil Organic Carbon Index (SOCI)**

1. The first step is to identify the location of the work in the field. We are using an example of Burkina Faso and the village of Gorom-Gorom. In Google Earth Pro, locate Gorom-Gorom in Northern Burkina Faso on its borders with Niger and Mali. The Google Earth Pro imagery suggests some farming efforts to the East and North of the urban area and it is possible to see signs of tillage.
2. Next, use the [USGS Earth Explorer](https://earthexplorer.usgs.gov/) website to locate and download an appropriate Landsat 8 satellite image. If you do not have an account there, create one by clicking on Login, click Create New Account, and follow the prompts accordingly until it accepts your new account data and you are signed in on your new account.
3. The default location where Earth Explorer start is centered at Sioux Falls, South Dakota. Click and drag and zoom in/out to find the area of Northern Burkina Faso centered approximately on the site of Gorom-Gorom. When you’re zoomed and ready to start finding some satellite imagery, the site should look something like this:



1. If you click on the box in the upper left corner, you can change from the light gray map to the ESRI World Imagery with World Boundaries and Places to help with navigation. Zoom in 5 or 6 times and the screen might look like this:



1. If you explore the area Northeast, you´ll find a section of farming that looks like this:



1. On the left side, click on Polygon and then click on Use Map. It will automatically grab the four corner coordinates for the onscreen image. If you zoom back one click, you will see the four corner pins. You can also move these pins to more carefully choose the farming area to look like this:



This process seems to work better when you use only a few pins rather than more. The objective of the pins is to approximate the area of what we think is the farming activity.

1. Next, scroll down and select a date range for some imagery and a range of potentially acceptable cloud cover.
2. For this example, we will set the date range from December 15, 2019 to March 15, 2020. The reason we’re using these dates is because the rainy season in this region extends from May until September, and we don’t want the soil moisture from the rainy season to impact the estimation of soil organic carbon.
3. Click on the Cloud Cover and move the sliders to start about 0% and end about 20%. Ideally, we don’t want any cloud cover, especially in the area of our “farm”, but this setting will set a range from 0% to no more than 20% cloud cover. There is always some cloud cover, and very often if you select 0 percent cloud cover at both ends of the range, you will cut out a lot of potentially good images.
4. Click on Data Sets and zoom into the hierarchy of Landsat scenes to the level of Landsat Collection 2 Level 2 and click the small open box to the left of Landsat 8 OLI/TIRS C-2 Level 2. If you have zoomed back a little, your screen will look like this:



1. Next, click on Results. For this example, the search found 6 images ranging from December 24 to March 13. One of the images has a bit more cloud cover than you might like. You can see the images with the cloud cover if you select the small icon that is the 4th from the left side (Show Metadata and Browse). If you show the image with the cloud cover and then hover over the small icon 1st from the right side, you can “Exclude Scene from Results”. This is useful if you have a lot of results and you don’t want to go through them more than once to decide the useful ones and eliminate what isn’t necessary. If you’re going to select more than one image, you’ll need to select and add an image and more to the shopping cart for a Bulk Download. But in our case, we only need a single Landsat scene. We can left click the icon 5th from the left for Download Options, download the image from January 9, 2020, and then click the Download button to download the Level 1 GeoTiff image. This will take about 10 minutes, depending on your location.
2. Save the file in a place where you can find it again, and unzip it to that location. Then open QGIS. This example uses a recent version of the software (v. 3.16.9). <https://qgis.org/en/site/forusers/download.html>. (This is the long-term release which has been tested and debugged the most, not the most recent one with the newest features.)
3. Visible Landsat Bands 2, 3, and 4 are associated with Blue, Green, and Red light respectively. It may help to rename their long filenames to Band 2-Blue, Band 3-Green, and Band 4-Red.
4. The formula for the SOCI is simple and easily calculated in any number of raster GIS software, including QGIS. The formula is Band 2 / (Band 3 x Band 4), where input data are greater than or equal to 0.
5. For further information on how to use the results, see: <https://www.agric.wa.gov.au/measuring-and-assessing-soils/soil-organic-matter-influence-nutrient-availability>. The SOCI estimates the concentration of carbon in the soil using a standard conversion coefficient: the quantity of soil organic matter = SOCI \* 1.72 for the top 10 cm. The coefficient used can vary for the type of organic matter, soil type and soil depth, with conversion factors varying as high as 2.5 for subsoils. With these data, the tons of C per hectare can be calculated, as well as the amount of nutrients that are turned over, and we could calculate the amount of nitrogen, phosphorus, and sulphur available, and determine what and how much nutrient should be added to the soil. With the SOC available to greater depths, the degree of nutrients available within the rooting zone can be calculated. Not all of the nutrients will be available from soil organic matter breakdown to the plants; some will be leached and some will be used by soil microorganisms. The amount of soil organic matter and its makeup influences the capacity of exchange of nutrients (Cation Exchange Capacity).