Best Practices Guidelines for using Remote Sensing for Food Security

Developed in collaboration with European Space Agency

CONSERVATION INTERNATIONAL

VITAL SIGNS

Introduction

Datasets derived from satellite earth observation (EO) or remote sensing (RS) offer a cost-effective approach to data collection that supplements datasets from field collection.

This tutorial provides guidelines and best practices for accessing, verifying and validating remote sensing datasets for use by decision makers

In this Presentation we cover:

1. Definitions of Earth Observation and Remote sensing
2. Considerations before accessing and using Earth Observation
3. Verification of remote sensing products
4. Methods of verification
5. Validation of remote sensing products

Definitions

What is remote sensing?

- Remote sensing is the art & science of acquiring information about the Earth's surface without actually being in contact with it.
- It is a way of collecting and analyzing data to get information about an object without the instrument used to collect the data being in direct contact with the object

What is custom remote sensing?

Many remotely sensed datasets are freely available, but customized remote sensing products can be useful when free products are not available for the correct time period, region, or scale, or if information is needed that goes beyond what can be obtained from free datasets. Customized products can provide specific information at the relevant timing, interval, scale and extent for your project needs. However, custom products do require financial investment and/or available technical capacity to produce and analyze them.

Benefits

Major benefits of satellite earth observation are:

- Wide range of applications and potential users at multiple levels, from individual farmers to local/national/regional authorities and international organizations
- Integration with field data collection: satellite earth observation can improve sampling and support extrapolation or interpolation of field data points in space and time
- Robust (continuity) , consistent (independent of administrative boundaries), cost-efficient, and objective data collection
- Data is available in areas that are difficult to access

Considerations

2. Spatial resolution: How much detail do we need? Resolution of data products can vary, from sub-meter pixels to 10 x 10km pixels. The ideal resolution can be determined by the size of the area under review and level of detail required.

1. Spatial coverage: What is our area? - The spatial area of interest should be defined (See separate tutorial on creating a shapefile). Remote sensing has greatly increased the areas of the globe where we can gather information, expanding into remote areas that would be difficult to collect on the ground and allowing the sampling of large areas at once.

4. **Temporal coverage: For which period do we need data?** - Archived datasets allow us to see historical changes on earth, for example, in land cover or primary productivity using remote sensing. This can fill gaps in data that was not collected in the field in the past.

3. **Temporal resolution:**
How often do we need an update? - Temporal resolution is the number of times a product is collected (e.g. daily, every 16 days, monthly, annually).

5. Cost: What is our budget? Cost-effective – Satellite earth observation can be very cost-effective as compared to field data collection. There are numerous remote sensing derived products that are freely available (see Table 1).

Verification

Verification is the process of establishing the truth, accuracy, or validity of RS and RS-derived products. It helps to explain the socio-economic drivers of variations in vegetation cover. Due to the above considerations on spatial and temporal resolution and extent, these datasets can be validated on the ground to ensure accuracy when used in a specific location.

Example 1

The European Space Agency (ESA) offers annual land cover products with 37 classes at 300m resolution. While these data products have been validated, they may be too coarse if you are looking at small project areas where land cover is changing at a finer spatial scale. ESA also offers a 20m resolution land cover dataset, but this dataset is only available for 2015 and thus cannot be used to track change over time.

Example 2

Many climate datasets, including climate models, have a coarse spatial resolution (kilometers or more) but often a high temporal resolution (sometimes hourly or more). Changes in temperature are generally not drastic over space unless there are large elevational changes, but changes in temperature over time can be large. A finer spatial resolution dataset may not give more information in this case. To look at change of any kind, you will need at least two data products, collected or analyzed using the same methods, at different points in time for comparison.

Example 3

If you are looking for land cover changes over time, the ESA land cover data product may be suitable to show national or regional-level changes annually. If you wanted to look at seasonal changes, you would need a land cover product that shows changes more frequently, either semi-annually or monthly. When looking at vegetation trends, you may be interested in change from year to year, but also in changes during each year, e.g. changes during the different growing seasons.

Method

Many RS-derived products use modelling for analyses of RS datasets. Some of these models are based on physical principles, such as energy balance modeling to determine actual evapotranspiration. Others are more empirical and use ground truth data to train a model as used in supervised classification machine learning algorithms.

- **Example 1** - Datasets like the ISRIC soil datasets, are modeled using soil samples that have been analyzed using the same methodology at the same lab at ICRAF. This ensures a standard approach was followed to collect and analyze the nutrients in the soil. The results of these analyses were used to train a model so that soil properties can be inferred even in areas where no ground data was collected.

Approach

- To obtain information using remote sensing, you have several possibilities:

  - Do it yourself. This approach requires in-house expertise. This requires investments in hardware and software, although there are an increasing number of online options and tools such as Google Earth Engine and DIAS (https://www.copernicus.eu/en/access-data/dias processing) and Sen2Agri (http://www.esa-sen2agri.org/ land cover mapping tool).

  - Use free, existing products. The Sentinel fleet and the Landsat program have unlocked a large amount of free, high quality and high resolution satellite data. You can download the raw imagery, but very often further processed products such as surface reflectance and higher-level products such as land cover maps and biomass production
  - (https://wapor.apps.fao.org) are also available. These higher-level products require less expertise to utilize.

  - Use dedicated portals, such as the one developed for this project: https://foodsecurityiap.resilienceatlas.org/.
  - Work with partners. This eliminates the need for processing facilities, image interpretation and product development, but direct access to required information. This comes at a cost but could possibly be cheaper than setting it up from scratch.

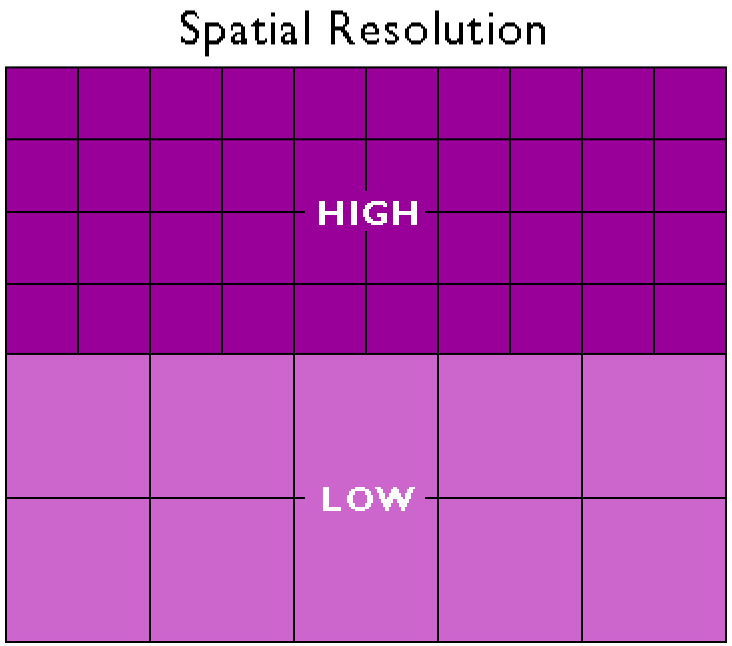
Validation

Validating datasets helps to identify different types of possible errors in the data. The scale, age, and formatting of data can degrade data quality. The level of accuracy and precision depends on the application of the dataset. There are tradeoffs associated with collecting data at very high levels of accuracy or precision. These tradeoffs include:

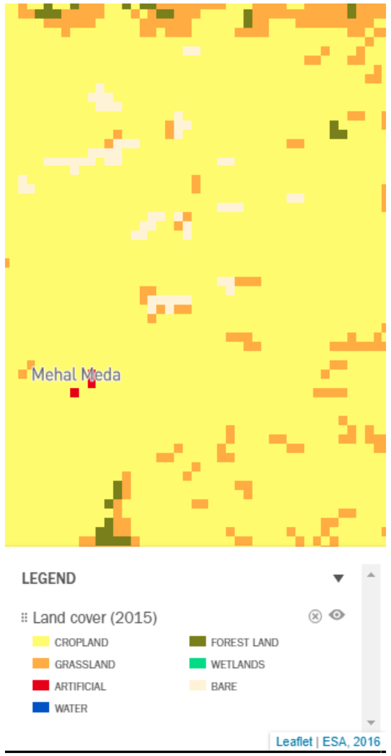
i. Cost: Validation will incur costs in both time and finances that must be incorporated into the available project budget. The investment in validation will ensure higher accuracy products.

ii. Scale
    - Pixel scale – compares the product with an independently observed data at the same time and location
    - Whole product – the process of validation an entire remotely sensed product by temporal or spatial pixel-by-pixel (or sampling) product validation where observation and validation occur continuously or are obtained within a heterogenous region
    - High resolution – these products are validated using Modulated Transferring Function (MTF), radiation quality, geometric quality and ground pixel resolution.

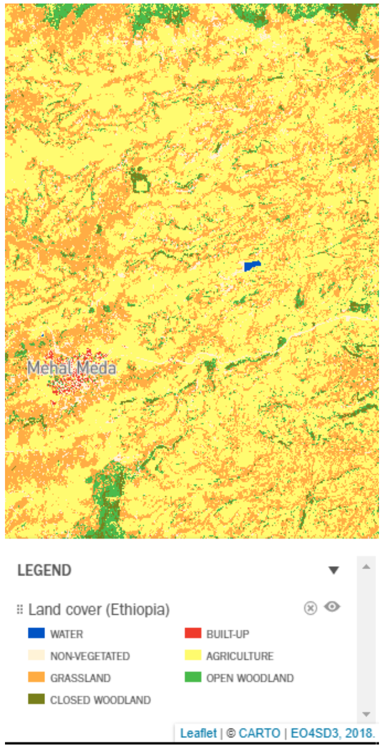
Validation: Images on spatial resolution



LOW



HIGH



Validation

Higher resolution datasets will create higher level of detail required for validation, as noted above.

1. Precision vs. Accuracy
    1. Trueness – estimate of systematic error (requires reference value)
    2. Precision – the level of measurement and exactness of description
    3. Accuracy/certainty – the degree to which information matches true or accepted values.

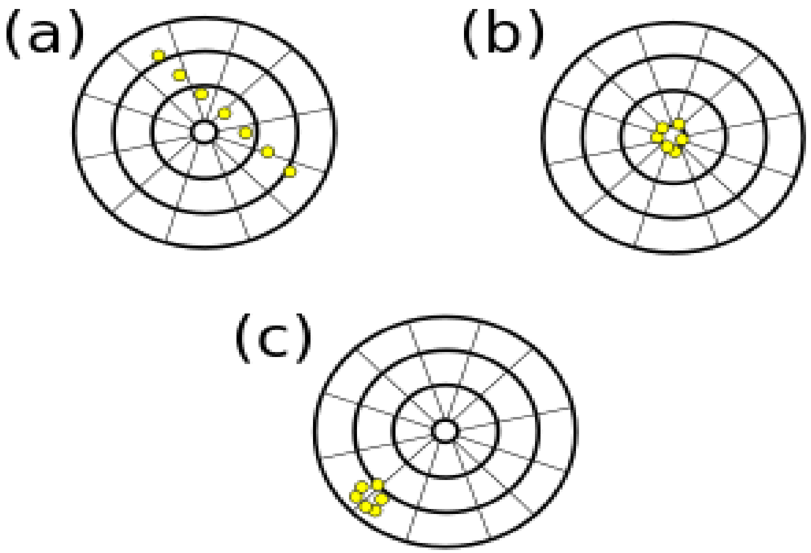


Figure 2. (a) Is neither precise nor accurate (b) is precision and accuracy (c) is precise but inaccurate.

Feedback

Once you have selected and validated a product there are three options:

1. Use the product – Assuming the product is accurate and has the appropriate temporal and spatial resolution to fit the needs of your work.
2. Use the product, after re-running analysis using ground-truth data collected from field or to produce a product for your area of interest from existing analyses
3. Do not use the product – if the product is inaccurate or does not reflect the conditions on the ground in your area of focus.

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