Geographic Information Systems 2023-2024

Exercise 9 - Calculation of NDVI indices

Introduction

> **GOALS OF THE EXERCISE**
>
> - NDVI analysis of 2 (close) pivot areas along the crop lifecycle

Spectral Remote Sensing

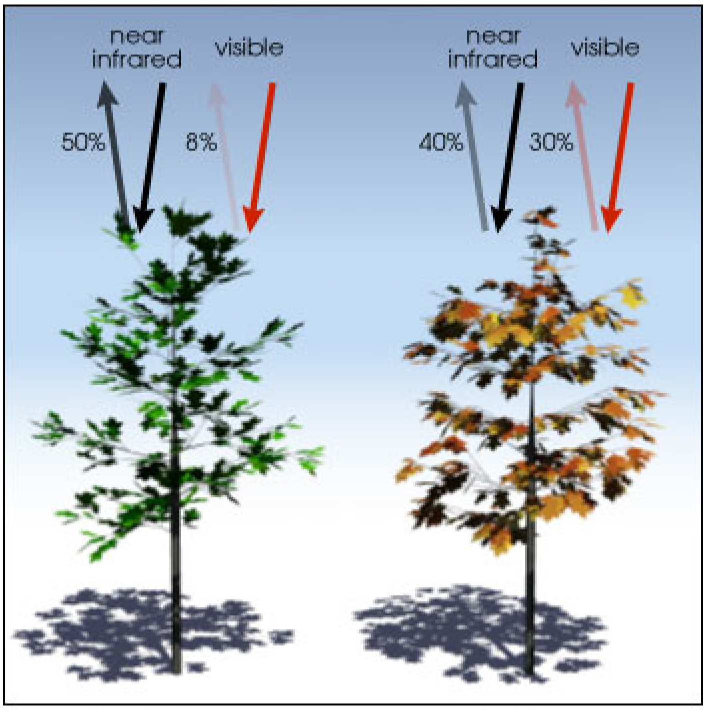
Satellite images are produced by the capture of the reflection of the Sun light by the Earth. Satellites contain multispectral sensors, which capture, for the same location on the surface, different parts - ranges of wavelenghts - of the spectrum of the visible and near visible light. These different ranges are called bands. Therefore, a multi-band-raster image is a raster image composed of a combination of different bands. For example, the Sentinel 2 satellite images contain 13 bands.

NDVI analysis

The **normalized difference vegetation index (NDVI)** is a simple indicator that can be used to analyze **remote sensing** measurements assessing whether or not the target being observed contains **live green vegetation**. It provides an indicator of the health or structure of the vegetation.

Actively photosynthetic vegetation is known to absorb visible light and reflect near-infrared light, while vegetation under drought stress, or lower chlorophyll content, will absorb less visible light.

See the following example (source: NASA):



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

Therefore, considering the following index expression:

```
NDVI = (NIR - Red)/(NIR + Red)
```

where NIR - near-infrared band Red - red band

you can analyse satellite images of the Sentinel 2 service to determine the NDVI index, where:

- Negative values of NDVI (values approaching -1) correspond to water.
- Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow.
- Low, positive values represent shrub and grassland (approximately 0.2 to 0.4)
- High values indicate a large presence of biomass (values approaching 1).

Within **precision agriculture** applications, NDVI data provides a measurement of crop health.

1. Set up your working environment:

Vector data

- The files for this exercise are in the course web page (FENIX). Download to your working area the file Ex09_pivots.zip
- The two polygons in the provided data represent the 2 pivot areas. Learn more about irrigation pivots.

Raster data

- Your raster layers will be satellite images from the Copernicus service (Sentinel 2 images).

You will access to the free Copernicus Data Space Ecosystem service to download:

- Source of input data: Sentinel 2 imagery

- Available via Copernicus Data Space Ecosystem (https://dataspace.copernicus.eu/), either through *Copernicus Browser* or *Data collections*
- or via SeNtinel Applications Platform (SNAP) (desktop application)
- Registration required on the Copernicus Data Space Ecosystem. Create your account to get a username and password at Copernicus Data Space Ecosystem

To download Sentinel 2 satellite imagery from the Copernicus Browser, you need to select the geographic area or interest for download and set additional selection criteria: - Sensing period: start and end dates - Select Sentinel-2 - Cloud cover: define a limit to up to 20% cover. You may try other values.

Check the video tutorials on how to download from the Copernicus Data Space Ecosystem.

2. Information about Sentinel 2 imagery (summary)

- Orthorectified images (products)
    - Tiles 100x100km projection UTM/WGS84
    - Level 1C - Top-of-atmosphere reflectances in cartographic geometry
    - Level 2A - Bottom-of-atmosphere reflectance in cartographic geometry - includes corrections to atmosphere
- Bands (13 available)
    - Spatial resolution 10 m:
        - Band 2 – Blue
        - Band 3 – Green
        - Band 4 – Red
        - Band 8 – infrared

3. Download images from Copernicus Data Space Ecosystem

1. Draw with your mouse the area of interest

    - you might prefer to use as basemap the satellite imagery, to better identify the pivots' area.

2. Define the following filter parameters

    - Define the sensing period between 2023-02-01 and 2023-04-01
    - Mission: `Sentinel-2`
    - Sattelite Platform: `S2A_*`
    - Product type: `S2MSI2A`
    - Could Cover %: `20%`

3. Download one product (images) for the beginning of February, and another for latest March, for your area. Make sure the image fully covers the pivots in the area of interest

Each product is downloaded in a zip file. The name of the file contains metadata. See the following example, for products for February 2020 products (pivot areas)

```
S2A_MSIL2A_20200219T112111_N0214_R037_T29SND_20200219T124126
S2A_MSIL2A_20200219T112111_N0214_R037_T29SNC_20200219T124126
S2A_MSIL1C_20200219T112111_N0209_R037_T29SND_20200219T120204
S2A_MSIL1C_20200219T112111_N0209_R037_T29SNC_20200219T120204
S2B_MSIL2A_20200224T112109_N0214_R037_T29SNC_20200224T133320
S2B_MSIL2A_20200224T112109_N0214_R037_T29SND_20200224T133320
S2B_MSIL1C_20200224T112109_N0209_R037_T29SNC_20200224T124010
S2B_MSIL1C_20200224T112109_N0209_R037_T29SND_20200224T124010
```

After unzipping it, images of 10 m resolution are in the folder: `<productName>.SAFE\GRANULE\<productName>\IMG_DATA\R10m`

4. Create a visualization of the image with visible bands

1. Add bands 2, 3, 4 and 8 to your GIS project

2. Create a composite bands image.

    - in ArcGIS, use the tool Composite Bands
    - in QGIS, use the menu Raster -> Miscellaneous -> Build Virtual Raster
        - make sure to check the option *Place each input file into a separate band*

3. Create a symbology. Make sure to select the correct band for each color. Also make sure to try the different options of contrast enhancement and min/max value settings, or stretch (depending if it is in QGIS or ArcGIS), and see the effect in the image rendering.

5. Calculate NDVI using the tool Raster Calculator

- Calculate the NDVI index in Raster Calculator for the begining of February, using the formula of above
- Do a **Clip raster by mask layer** (in QGIS) of **Extract by Mask** (ArcGIS), in order to clip, the areas of pivots 1 and 2.
- Calculate the histogram for each of the pivots, and compare them. Which of the pivots do you think has better crop vitality in that period
- repeat the index calculation for late March images, and compare the histogram with the beginning of February.

6. Additional exercise - Visualize SWIR

The Short Wave Infrared RGB Composite (SWIR) is a composite image that combines, for Sentinel 2, **bands B12, B8A and B04**. This composite can identify how much water is present in plants and soil. One use of this composite is to identify recently fire burnt land, as these areas reflect strongly in SWIR bands.

We can check an example based on the forest fire that occurred in the Natural Park of Serra da Estrela, center Portugal, in August 2022.

1. Download images from Copernicus Data Space Ecosystem

    - Find the locality Manteigas, which is between Castelo Branco and Guarda district capitals, in the center-east of Portugal

- draw a small area around the locality of Manteigas, to identify the area of interest.

2. Define the following filter parameters

    - Define the sensing period between 2022-08-01 and 2022-08-31
    - Mission: `Sentinel-2`
    - Sattelite Platform: `S2A_*`
    - Product type: `S2MSI2A`

3. Select the product `S2A_MSIL2A_20220827T112131_N0400_R037_T29TPE_20220827T185854` to download

4. Add bands 12, 8A and 04. Note that these bands only exist for resolution of 20 m or 60 m.

5. Create a Virtual Raster (in QGIS) or Composite Bands (in ArcGIS), as before.

6. Create a multiband color symbology. Make sure that the colors red, green and blue correspond to the bands 12, 8A and 04, in this order.

7. Observe the areas in red, which correspond to fire burnt areas.

7. More information

- About Copernicus Sentinel 2 - https://sentinel.esa.int/documents/247904/4180891/Sentinel-2-infographic.pdf
- Tutorials on accessing satellite data:
    - https://www.copernicus-user-uptake.eu/fileadmin/FPCUP/dateien/resources/2018-1-06/Guide_basics_satellite_data_english.pdf
    - https://appliedsciences.nasa.gov/sites/default/files/2021-10/Part2_Data-Download_EN.pdf
- https://www.youtube.com/watch?v=I58bUCW2UlU (&QGIS)
- https://www.youtube.com/watch?v=tu9kFbMhGV0 (Quick tutorial on Sentinel Hub)
- https://www.youtube.com/watch?v=9Jp8BBiZPsI (&QGIS)
- https://rus-training.eu (it is unnecessary to install the RUS virtual machine!)
- https://www.youtube.com/watch?v=jpPoZ6wv9dM (GEARS – RUS WEBINAR & OAH)
- https://www.youtube.com/watch?v=vtlN5MXYGaY (GEARS – RUS WEBINAR & SNAP)
- https://www.youtube.com/watch?v=xEwy8UMGu7M (GEARS – RUS WEBINAR)