I. The Earth Observation (EO) part in the EU Bee Health Project

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Preamble
Earth observation is the combination of remote sensing, GIS (Geographical Information System) and in situ data collections. The culmination of these data sets can be used within models to assess landscape structure and dynamics relevant for bee keeping, e.g. floral cycle maps and spatial information about the density and distribution of melliferous plants (Figure 1). Earth Observation can be defined as the combination of various data sets. Sometimes the data sets overlap and are redundant.

![Figure 1: Earth Observation components](image)

The following theory part will cover four parts: GIS, remote sensing, in situ observations and GPS. The practical, part II, is a step by step instruction on GPS and Smartphone mapping in QGIS and map making.

A. Theory Part

1. GIS
A Geographic Information System (GIS) is a computer-assisted system for the acquisition, storage, analysis and display of geographic data. Comprehensive GIS requires; (Figure 2):

   i. Data input - from maps, aerial photos, such as satellites, surveys, and other sources
   ii. Data storage - retrieval, and query
   iii. Data transformation, analysis, and modeling, including spatial statistics
   iv. Data reporting - such as maps, reports and plans
In GIS, there are various data structures that can be used. They include:

1. Data in a data plane have a specific "data structure" (NB by data structure, for example in a non-digital data, the structure can be written texts, maps, tables or photography)
2. A vector structure based on lines (digitised contours, rivers, roads, fall polygons grid, land use boundary, lithology or points - elevation, population, institutions
3. Raster structure based on matrix of points - grid points or pixels - multi-spectral imagery.

A combination of different data structures/models in a GIS gives a simulation of the real world (Figure 3).
There are numerous application areas where GIS analysis and map making is used. Key areas of application for GIS are:

- Agriculture planning (including honey production and pollination)
- Forestry & Wildlife Management
- Archaeology
- Geology
- Oil and gas exploration and production
- Municipal and regional planning

2. Remote Sensing

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation emitted from aircraft or satellites). The following plate 1 show a satellite taking an image of the earth from space.

Plate 1: A satellite orbiting the earth to take digital images. The images are used to make map of land cover features such as forests or changes
There are different types of satellites, classified by the spatial or spectral resolution. Essentially they are high resolution and low resolution satellites. They can also be classified by the source of energy they use to take an image. These include active satellites that use their own light to illuminate the object being captured or passive satellites which use incident light from the sun (Figure 4). These satellites measure reflected solar radiation from the earth.

Remote sensing has three information levels that are of interest in any field of application. These are the temporal, spatial and spectral information levels (Figure 5). Temporal resolution is based on time (temporal); a satellite that has three acquisition of an area in a year has low temporal resolution, while one with more than twenty acquisition has high temporal resolution. Spatial resolution has an aspect of space, in that an image that covers a big area on the ground has high spatial resolution and vice versa. Spectral resolution has an aspect of the number of bands across the electromagnetic spectra. An image with many bands has a high spectral resolution and vice versa. In this cluster we have multispectral and hyperspectral images, both of which are being used in the Bee Health Project. Lastly, images can be taken from space by satellites that are space borne, hence satellite images like Landsat, or from a sensor in an aircraft, hence aerial ones (Figure 6).

Figure 4: A satellite measures the solar illumination and surface reflectance of a feature to produce a map of various land cover types
Figure 5: A satellite observation system has various information levels that can be harnessed to produce a map

Figure 6: Aerial remote sensing using a digital camera onboard an aircraft

Benefits of Remote Sensing

i. Remote sensing makes it possible to collect data on dangerous (Gaza) or inaccessible areas (Okavango wetland).

ii. Remote sensing also replaces costly and slow data collection on the ground, ensuring in the process that areas or objects are not disturbed.

iii. Collects info that cannot be seen by a naked eye over larger areas in a consistent way

For the Bee Health Project, RS will be used to develop an earth observation monitoring system to capture the floral cycle in Africa. So far some work has been done and the results are promising as shown below (Figure 7)
Figure 7: Map derived from aircraft remote sensing showing the distribution of flowering plants and their flowering intensity

The green plants in the map are those that are non-flowering during the period the image was taken, while the red ones have a lot of flowers on them as shown in the key.

3. **In Situ Observation**

In earth observation, in situ data collection is a very key component. In situ/ground truthing refers to information collected on the ground. Ground truthing allows image data to be related to real features and materials on the ground. The collection of ground-truth data enables calibration and correction of remote-sensing data, and aids in the interpretation and analysis of the objects being sensed (Plate 2).
Ground truth data is important because it is used to calibrate and correct remote sensing data.

**Crowdsourcing Concept**
This is a new concept being exploited in the Bee Health Project. It is part of the in situ data collection in the larger earth observation. It is the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people, and especially from an online community (i.e. using Smartphones), rather than from traditional employees or suppliers. It combines the efforts of numerous self-identified volunteers or part-time workers, where each contributor on their own initiative adds a small portion to the greater result.

In the bee health project, crowdsourcing is used to gather information on the flowering status, abundance and flowering calendar of the project areas. Smart phones that are already synced with ICIPE are provided to farmers, who will go round taking snap shots of the plants at different times. This photos are geotagged to show the locations of the plant. They are then displayed and analysed in a GIS software (QGIS) (Figure 8).
Crowdsourcing is an important and new concept that, if used systematically, can render information cheaply, in real time and objectively. Moreover bee keepers can be involved effectively.

Global Positioning System (GPS)
The Global Positioning System (GPS), which is part of GIS, is a satellite-based navigation system. GPS provides continuous positioning and timing information, anywhere in the world under any weather conditions. GPS consists, nominally, of a constellation of 24 operational satellites (Figure 9).

Figure 8: Smartphone derived Geo-tagged photos can be uploaded and displayed in GIS and used for verification of the floral cycle

Figure 9: GPS satellite constellations
How does GPS work?

Receiver receives signal from 4 to 7 satellites - depending on time of day, visibility. The receiver calculates distance from signal speed.

A GPS needs at least 3 satellites to triangulate your position. However, the distance is measured based on the time the signal takes from the satellites to receiver. A fourth satellite is required to synchronize the receiver’s and satellites’ clocks (Figure 11).

![GPS Receiver](image)

**Figure 10: A GPS needs several satellites to derive an accurate**

**Sources of GPS error are;**

1. Ionospheric and atmospheric delays, especially for satellites on low elevation
2. Satellite and receiver clock errors
3. Multipath effect
4. Dilution of Precision

The Dilution of Precision (DOP) is a measure of the strength of satellite geometry

**B. Practical Part**

**Practical Exercise – “Collection of GPS data points and Geotagged photos”**

For the practical session, QGIS, which is an open source software will be used. Therefore, the training will start by installing this software as shown in Figure 11 below.
For the practical exercise, it is required that participants capture five ground features on the icipe campus using handheld GPS receiver and simultaneously take geotagged photos using smartphones of the same point features. GPS data and geotagged photos of the same point will be overlaid for comparison purposes. Therefore, participants will be split into five groups each with 1 GPS and 1 smartphone and writing materials. A demonstration on how to use the GPS to pick way points and smartphones to take geotagged photos will be done outside the training room for about 5 minutes.

**Downloading Data From GPS**

To download data from the GPS, we first install the Germin USB drivers, since we are using Germin GPS. This is done by navigating to Software folder provided and select the installer USBDrivers_23.exe to install Garmin USB drivers (Figure 12).
This is done by connecting the GPS using a cable to the computer, and using the QGIS software to download from the GPS tools in the vector tab (Figure 13 and 14).
Ensure the port is USB and feature type is Waypoints

Figure 14: Downloading data from a GPS

Then the GPS data downloaded will be displayed automatically on the canvas after the process is complete (Figure 15).

Figure 15: Displaying GPS data in QGIS

Downloading, Converting and Displaying Geotagged Photos
Geotagged photos are photos that have spatial info appended to them. This is done by activating the GPS in the smartphone and the Geotag tool in the camera of the smartphone. Since the phones are linked to the ICIPE computer, they are automatically uploaded to dropbox as soon as internet connection is established. Alternatively, they can be downloaded by connecting the phone to the computer using a usb cable. Once the photos are copied, they are stored in a known location, which can be accessed later on.

**Converting Photos to shape files**
Converting photos to shapefiles is done using QGIS. This is done using the photos to shape plugin which has to be activated from the plugin tab and then fetch python plugin (Figure 16). The photo to shape plugin is then activated.

![Figure 16: Installing the photo to shape plugin](image)

Once this plugin is installed, it can be found from the vector tab in QGIS as shown below (Figure 17).
When using the photo to shape plug in, one has to select the folder containing the geotagged photos, which will be the same folder where the created shape will be saved. Once done processing, a message will appear informing you of the progress and if some photos were not geotagged for whatever reason, a pop up window will appear with this information (Figure 18). The shape that is created will be displayed in the canvas.

To view photos associated with the shape, the eVis Event Browser is used (Figure 19). Therefore, it needs to be activated from the plug in window.
QGIS and eVis use the file path of the folder where the photos were stored to access them. Therefore, once you open the eVis Event Browser, go to the option tab and in the file path, select ‘filepath’ option and ‘remember this’ (Figure 20). Then click on save.
After that click on the ‘display’ tab to see the photos with their info. Click on next to view other photos (Figure 21).

To confirm that the data is accurate, we use high resolution satellite thanks to google earth. This is done by overlying the collected GPS and smart phone data with the google earth layer. To do
this, we have to activate the open layer plugin using the plugin window. Once it is installed, still use the plugin tab, where the open layer plugin can be found as shown below (Figure 22).

Figure 22: Using the open layer plugin

A satellite image will be displayed for the area data was collected (Figure 23).

Figure 23: Overlying GPS and smartphone data in the google satellite images