Co-funded by the
Erasmus+ Programme
of the European Union

DEVELOPMENT OF A TRAINING PROGRAM FOR ENHANCING THE USE OF ICT TOOLS IN THE IMPLEMENTATION OF PRECISION AGRICULTURE

2018-1-ES01-KA202-050709

Training package 2

Satellite imagery data sources

Student guidelines

Authors: UPC

Date: May 2020

Contents

1 INTRODUCTION

Satellite sensors designed for earth resource monitoring offer an important source of data for utilisation in prescription and precision farming[1]. The relative advantages of satellite imagery over aerial photography, airborne video, thermal and other forms of long wave energy sensing are presented by highlighting technical and data integrity problems of these alternative forms of data acquisition.

Satellite imagery is available at a range of different revisit frequencies, from a range of different providers, under a range of different conditions attaching to the use of this data, at a range of different spectral and spatial resolutions, at a range of prices that reflect the range of different product formats, accuracies and reliabilities. Selection of the appropriate imagery at a date of image acquisition that is appropriate to the task and stage of development of the crop under consideration are particularly important decisions affecting the utility and accuracy of the resulting analyses.

A tabular summary is provided of the orbital and imagery characteristics of the main forms of remotely sensed image data that are currently available (and soon to be available) on a commercial basis. This is followed by an introductory guide to critical issues that need to be considered in the selection of appropriate imagery.

Landsat ETM and SPOT satellite imagery has predominantly been used to date because of its ready availability, being acquired on a repetitive basis over the same location on earth within fixed acquisition cycles. The Australian Centre for Remote Sensing archives data from both sensors for most agricultural production areas in Australia. The Landsat satellite images an area of some 32400 km2 while a single sensor of the SPOT satellite images an area of some 3600 km2. The cost of satellite data per unit area is low – for Landsat the cost is $0.009/ha and for SPOT $0.024/ha. The spectral response and lower cost of Landsat mean that it is generally preferred for agricultural applications in general and prescription and precision agriculture specifically. However, the off-nadir viewing capability, higher resolution and guaranteed program continuity may mean that SPOT will become the preferred data source, despite its higher cost and fewer spectral bands compared with Landsat ETM.

The value of the data, particularly for prescription and precision farming, lies in the fact that the spatial resolution at which it is acquired (25m pixels for Landsat and 20m pixels for SPOT) is useful for detecting spatial variation in crop spectral response within the field sizes and at enterprise scales that are common in Australian agriculture.

---

[1] https://precisionagricultu.re/satellite-imagery-as-a-data-source-for-prescription-and-precision-farming-in-australia/

Satellite imagery provides a cost effective way to facilitate pre-harvest yield estimation and yield variability mapping without the need for high cost machine and GPS based yield monitoring equipment. Early season imagery enables emerging problems to be identified and appropriate intervention and crop management strategies to be invoked to minimize within field yield variance. The synoptic viewpoint combined with detailed pixelisation makes satellite imagery superior to existing field reconnaissance techniques, especially where ground based instrumentation at strategic locations and targeted field observations by consulting agronomists at more representative sites is used to calibrate the results of image analysis for greater accuracy and precision.

Spectral response detected within the area occupied by any single pixel represents the integration of all factors such as crop phenology, soil water status and nutrient status that determine plant vigour, biomass and ultimately, yield potential. Instead of attempting to measure individual discrete parameters, satellite imagery reads the response of the plant as a single integrated instrument. Instead of seeking to build physical models of complex atmospheric/plant/soil interactions on a computer based on extrapolation of experimental observations from a few local sites, an empirical approach based on satellite imagery enables agricultural users to start from an understanding of spatial variability and use diagnostic spatial patterning, form or image morphology to explain the cause of these variations that are likely to result in reduced yield potential. Digital processing and interpretation of satellite data translates changes in spectral response into products that identify areas of variability within an individual field. Resulting products can take the form of crop growth, plant vigour or yield potential variability maps and resulting yield estimates, and can be presented in digital, image, map, tabular or chart formats.

Localised variations in atmospheric conditions, non branching plant architecture, low biomass, poor vegetation cover or lack of canopy closure (LAI < 3) means that aerosols, soil type and condition exert a stronger influence on spectral response, compounding or complicating imagery analysis and interpretation. However, an empirical approach using satellite imagery enables management impacts to be detected and discriminated from environmental or physical factors using diagnostic visual queues.

Pixel specific spectral response measured from satellite imagery can be used to develop empirical models that can be used in turn to estimate parameters such as early season vigour and biomass, yield on offer well before harvest, even protein level of a grain crop to facilitate product segregation at harvest to capture premium commodity prices. The estimated yield maps help growers to view variability in terms of economic return and to identify regions in fields which require some form of remedial action or to plan froward selling of the crop. These maps may be incorporated into variable rate technology (VRT) systems with the proviso that the data is acquired at the correct time, processed and delivered rapidly for utilisation in such systems. Aspects such as cloud cover at the time of data acquisition and the fixed acquisition schedule limit the use of these products as the primary source of data for VRT applications.

The advent of IKONOS and other ultra high resolution imagery opens the door to the use of satellite imagery for prescription and precision farming for the highest value horticultural crops such as grapes and orchards.

2 AVAILABLE AND COMMON SATELLITES

2.1 PUBLIC

Landsat[2]

The Landsat program offers the longest continuous global record of the Earth's surface; it continues to deliver visually stunning and scientifically valuable images of our planet. This short video highlights Landsat's many benefits to society.

In 1975, NASA Administrator Dr. James Fletcher predicted that if one space age development would save the world, it would be Landsat and its successor satellites. Since the early 1970s, Landsat has continuously and consistently archived images of Earth; this unparalleled data archive gives scientist the ability to assess changes in Earth's landscape.

For over 40 years, the Landsat program has collected spectral information from Earth's surface, creating a historical archive unmatched in quality, detail, coverage, and length.

"It was the granddaddy of them all, as far as starting the trend of repetitive, calibrated observations of the Earth at a spatial resolution where one can detect man's interaction with the environment," Dr. Darrel Williams, the Landsat 7 Project Scientist, states about Landsat.

Landsat sensors have a moderate spatial-resolution. You cannot see individual houses on a Landsat image, but you can see large man-made objects such as highways. This is an important spatial resolution because it is coarse enough for global coverage, yet detailed enough to characterize human-scale processes such as urban growth

---

[2] https://landsat.gsfc.nasa.gov/about/

Sentinel 2[3]

The Copernicus Sentinel-2 mission comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. It aims at monitoring variability in land surface conditions, and its wide swath width (290 km) and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes) will support monitoring of Earth's surface changes. The coverage limits are from between latitudes 56° south and 84° north.

MODIS [4]

With its sweeping 2,330-km-wide viewing swath, MODIS sees every point on our world every 1-2 days in 36 discrete spectral bands. Consequently, MODIS tracks a wider array of the earth's vital signs than any other Terra sensor. For instance, the sensor measures the percent of the planet's surface that is covered by clouds almost every day. This wide spatial coverage enables MODIS, together with MISR and CERES, to help scientists determine the impact of clouds and aerosols on the Earth's energy budget.

In addition to recording the frequency and distribution of cloud cover, MODIS measures the properties of clouds such as the distribution and size of cloud droplets in both liquid water and ice clouds. MODIS also measures the properties of aerosols—tiny liquid or solid particles in the atmosphere. Aerosols enter the atmosphere from manmade sources like pollution and biomass burning and natural sources like dust storms, volcanic eruptions, and forest fires. MODIS helps scientists determine the amount of water vapor in a column of the atmosphere and the vertical distribution of temperature and water vapor—measurements crucial to understanding Earth's climate system.

MODIS is ideal for monitoring large-scale changes in the biosphere that are yielding new insights into the workings of the global carbon cycle. MODIS measures the photosynthetic activity of land and marine plants (phytoplankton) to yield better estimates of how much of the greenhouse gas is being absorbed and used in plant productivity. Coupled with the sensor's surface temperature measurements, MODIS' measurements of the biosphere are helping scientists track the sources and sinks of carbon dioxide in response to climate changes.

---

[3] https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2

[4] https://modis.gsfc.nasa.gov/about/

Meteosat[5]

Europe has its own weather satellites, called Meteosat. The first Meteosat was launched by ESA into geostationary orbit, 36 000 km above the Gulf of Guinea, on 23 November 1977.

Since then, eight more Meteosats have been launched. The latest of these (Meteosat-9) began full operation on 29 January 2004. Another two are planned in the next few years, followed by a Third Generation of satellites.

The most recent Meteosats (called 'Second Generation') have many design improvements over the earlier models. One advantage is that it can send back sharper pictures more frequently.

Meteosat-9 has one instrument that can study cloud, land, ocean, snow and ice during the day or night. Another instrument is dedicated to climate studies. The data collected helps weather forecasters to recognise and predict dangerous weather. This includes dense fog, thunderstorms and the sudden growth of intense storms with gale force winds and lashing rain. Long range forecasts are also improved.

2.2 PRIVATE

Wordlview 1 (DigitalGlobe company)[6]

WorldView-1, launched September 2007, is the first of our next-generation satellites—the most agile satellites ever flown commercially. The high-capacity, panchromatic imaging system features half-meter resolution imagery. Operating at an altitude of 496 km, WorldView-1 has an average revisit time of 1.7 days and is capable of collecting over one million sq km per day of half-meter imagery. The satellite is also equipped with state-of-the-art geolocation accuracy capabilities and exhibits stunning agility with rapid targeting and efficient in-track stereo collection. WorldView-1 resides in a descending node of 1:30pm

Geoeye 1 (DigitalGlobe company)[7]

The GeoEye-1 satellite is equipped with some of the most advanced technology ever used in a commercial remote sensing system. The satellite collects images at .46-meter panchromatic (black-and-white) and 1.84-meter multispectral resolution. The

---

[5] https://www.esa.int/kids/en/learn/Technology/Spacecraft/Meteosat

[6] LINK

[7]

satellite can collect up to 500,000 square kilometers of pan-sharpened multispectral imagery per day. This capability is ideal for large-scale mapping projects. GeoEye-1 can revisit any point on Earth once every three days or sooner.

3 CHARACTERIZE SATELLITES PERFORMANCE

Theory:

An equation which is useful in describing the motion of satellites is Newton's form of Kepler's third law. Since the logic behind the development of the equation has been presented elsewhere, only the equation will be presented here. The period of a satellite (T) and the mean distance from the central body (R) are related by the following equation:

$$\frac{T^2}{R^3} = \frac{4 * \pi^2}{G * M_{central}}$$

where T = the period of the satellite, R = the average radius of orbit for the satellite (distance from center of central planet), and G = 6.67 x 10-11 N m2/kg2.

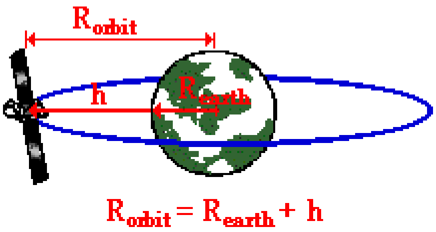
There is an important concept evident in all three of these equations - the period, speed and the acceleration of an orbiting satellite are not dependent upon the mass of the satellite.

$$v = \sqrt{\frac{G * M_{central}}{R}} \qquad a = \frac{G * M_{central}}{R^2} \qquad \frac{T^2}{R^3} = \frac{4 * \pi^2}{G * M_{central}}$$

None of these three equations has the variable Msatellite in them. The period, speed and acceleration of a satellite is only dependent upon the radius of orbit and the mass of the central body which the satellite is orbiting. Just in the case of the motion of projectiles on earth, the mass of the projectile has no effect upon the acceleration towards the earth and the speed at any instant. Whenever air resistance is negligible and all forces but gravity are nonexistent, the mass of the moving object becomes a non-factor. Such is the case of orbiting satellites.

Exercice 1:

A satellite wishes to orbit the earth at a height of 100 km (approximately 60 miles) above the surface of the earth. Determine the speed, acceleration and orbital period of the satellite. (Given: $M_{earth} = 5.98 \times 10^{24}$ kg, $R_{earth} = 6.37 \times 10^{6}$ m, $G = 6.67 \times 10^{-11}$ N m^2/kg^2)



Extra information:

https://thesai.org/Downloads/Volume5No6/Paper_2-The_Coverage_Analysis_for_Low_Earth_Orbiting_Satellites_at_Low_Elevation.pdf

4 SOURCES PUBLIC DATA

VIEWERS → https://eos.com/blog/7-top-free-satellite-imagery-sources-in-2019/

Landsat → https://landlook.usgs.gov/viewer.html

Sentinel2 → https://scihub.copernicus.eu/dhus/#/home

MODIS →https://earthdata.nasa.gov/earth-observation-data/near-real-time/rapid-response

Meteosat→https://www.eumetsat.int/website/home/Images/RealTimeImages/index.html

GENERAL, WorldView→ https://worldview.earthdata.nasa.gov/

5 EXTRACT IMAGES FROM SOURCES

Exercice 2: Download an image of your crop from the sentinel satellite:

https://www.sentinel-hub.com/