

Stage 5 Agricultural Technology – Satellite imagery in agriculture

Outcomes

- **AG5-2** explains the interactions within and between agricultural enterprises and systems
- **AG5-4** investigates and implements responsible production systems for plant and animal enterprises
- **AG5-6** explains and evaluates the impact of management decisions on plant production enterprises
- **AG5-12** collects and analyses agricultural data and communicates results using a range of technologies

Context

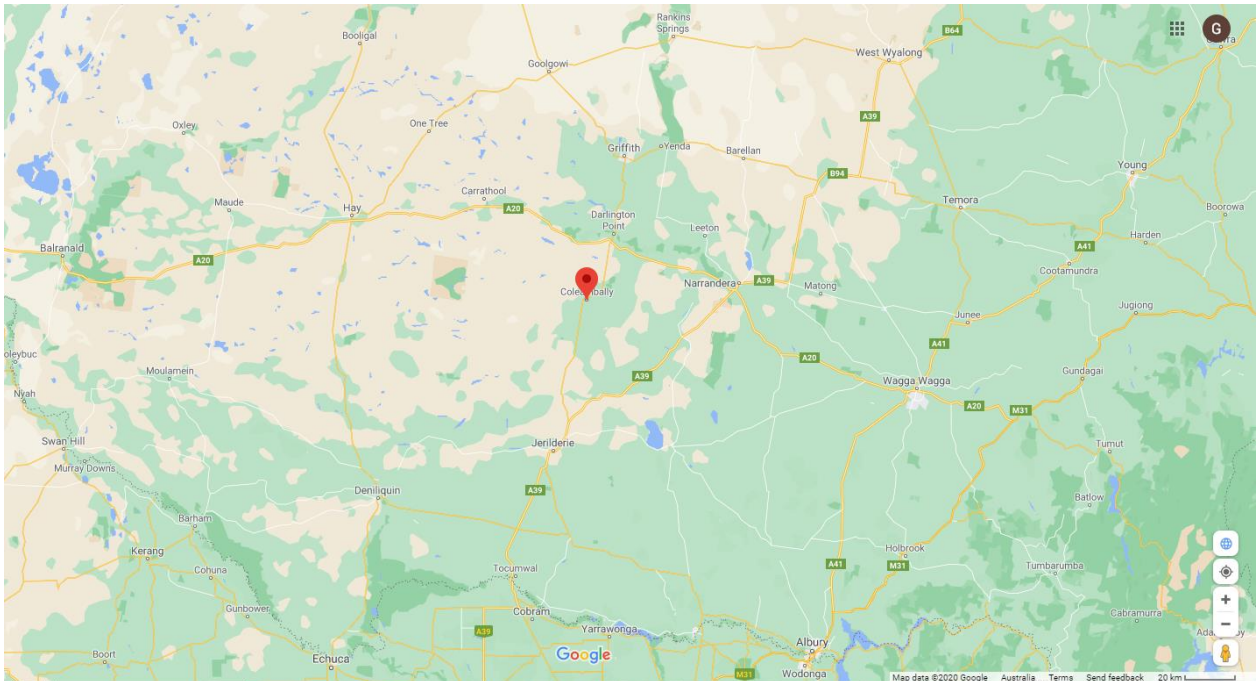
About the project

COALA is a European Union Horizon 2020 funded project. This project joins 11 partners across Australia and Europe. Their goal is to use satellites orbiting Earth to help farmers in Australia with their water usage and help monitor soil nutrient quality. Have you ever heard the saying ‘It’s hard to see the forest for the trees?’ Sometimes a little distance is what we need. We can learn a lot about Earth by observing it from a distance. Surprisingly, we can even learn a lot about what is going on, on the surface of Earth. Our eyes can only see visible light. Yet, light comes in many other “colours” - infrared, ultraviolet, and gamma-ray - that cannot be seen by the naked eye. So, satellites often ‘see’ Earth beyond visible light (blue, yellows, green, red, for example). COALA works with images from a constellation of satellites that orbit the Earth. The images that the satellites (called Sentinels) capture have a variety of uses. Take crops, for instance, these images can be used to distinguish different crop types and assess crop health. They can also monitor land-use change, track changes in seasonal water of wetlands and follow the dynamics of water bodies frequently, allowing us to see significant changes.

Where are the cultivated areas? What areas are under irrigation? These are questions that land managers and water authorities need to answer for planning purposes. So, these images are really helpful for practical purposes, as you will see in this exercise.

About the location

Coleambally, NSW is located in the Riverina area and is one of the youngest towns in the state, officially being opened in 1968. The town was built as a support area for the surrounding Coleambally Irrigation area. Currently the region grows a range of rice, cotton and corn/maize over the summer growing season, most of which is irrigated. During the winter, cropping changes to plants such as wheat and canola. Grazing livestock and fruit production are also found in the region.



Location of the Coleambally town in the Riverina of New South Wales, Australia; Murrumbidgee Council (red dot).

Land uses in Coleambally



Left image shows a maize Crop at Coleambally, 26.07.2007. Right image shows irrigation pipes at Coleambally. Image: Gregory Heath (CSIRO: <http://www.scienceimage.csiro.au/image/4691>)



Coleambally Main Canal (left) and Main street (right).

Detecting photosynthetic activity

Earth observation sensors or devices are designed to detect various types of energy from Earth. The energy detected by an Earth observation sensor is related to the properties of the Earth's features, physical, chemical or biological processes. Over 30 years ago, scientists began using satellite remote sensors in an effort to measure and map the density of green vegetation on Earth using a variety of satellites, the ones belonging to NASA — the [Landsat programme](#) with its multi-spectral scanner system (MSS) — were amongst the first. This tool carefully measures the wavelengths and intensity of visible and near-infrared light that is reflected by the surface of the Earth back into space. With the help of an algorithm called a “Vegetation index”, scientists can create maps of the Earth's green vegetation density that help identify where plants are growing well and where they are under stress. It is important to note however, in order to obtain an accurate image, there needs to be limited cloud cover as this can affect the reflection of light back to the satellites sensors.

When sunlight strikes an object, certain wavelengths of the visible and near-infrared spectrum are absorbed while others are reflected. Chlorophyll within the green leaf of a plant strongly absorbs visible light (from 0.4 to 0.7 μm) for its use in the process known as photosynthesis, while at the same time, strongly reflects near-infrared light (from 0.7 to 1.1 μm). The more leaves a plant has and therefore the more chlorophyll present, the more wavelengths of light that are absorbed and reflected.

The remote sensor on board the European Space Agency (ESA) satellite called [Sentinel-2](#) is called a Multi-Spectral Instrument (MSI) with channels that capture energy reflected from Earth surface objects in the range of the blue to the short-wave infrared; eight channels are sensitive to the wavelengths of light ranging from 0.49 to 0.865 μm . These sensors allow scientists to measure the amount of visible and near-infrared light reflecting off the Earth. This is then calculated into the ability of the plants in the area to photosynthesise, in a given pixel (a Sentinel-2 pixel covers 20mx20m of land surface). If there are more near-infrared wavelengths than visible light wavelengths reflected from an area, then the vegetation in that pixel is more likely to be forest or other high density vegetation. If there is very little difference between the intensity of the two types of wavelengths, then the pixel will most likely be less populated with vegetation and consist of grasslands, areas with very sparse vegetation or bare soils. Source: Onjira, P. (2014). Application of Remote sensing and rainfall-run-off inundation modelling to near-real time

flood monitoring in Kenya.

<https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.13140%2FRG.2.1.1283.3046>).

The Vegetation index uses a formula to quantify the density of plant growth: near-infrared radiation – visible (red) radiation divided by near-infrared radiation + visible (red) radiation. This formula results in what we know as Normalised Difference Vegetation Index (NDVI).

Formula: $NDVI = \frac{NIR - Red}{NIR + Red}$

Calculations for NDVI within a given pixel always result in a number between -1 and +1. A pixel with a zero calculation has no vegetation, while close to +1 indicates the maximum possible concentration of green leaves.

About the digital resource

The Earth observation imagery, or remote sensing¹ available in this resource for student use, covers data collected from September 2019 through to May 2020. The imagery was collected using the [Sentinel – 2 satellite from the Copernicus programme](#).

The image you see when adding base layer 'Bing Aerial', does not change across the time, it is a fixed image. To see changes you will need to look at false-colour composite, true-colour composite, NDVI and ETp daily data overlayed.

Read the article, [How to interpret a satellite image: five tips and strategies](#), to complete the following activities.

1. List the five pieces of information, according to the article, that are important for reading a satellite image successfully.
2. Create a KWL chart to show what you already know about using and/or reading satellite imagery and what you want to know but do not already. After reading the article, outline the interesting points you have learnt.

¹ Earth observation imagery, also known as remote sensing, is the practice of observing and examining the physical features of an area by calculating its reflected and emitted radiation at a distance, usually via satellite or aircraft. Specialised cameras collect remotely sensed images, allowing us to see much more than we can standing on the ground.

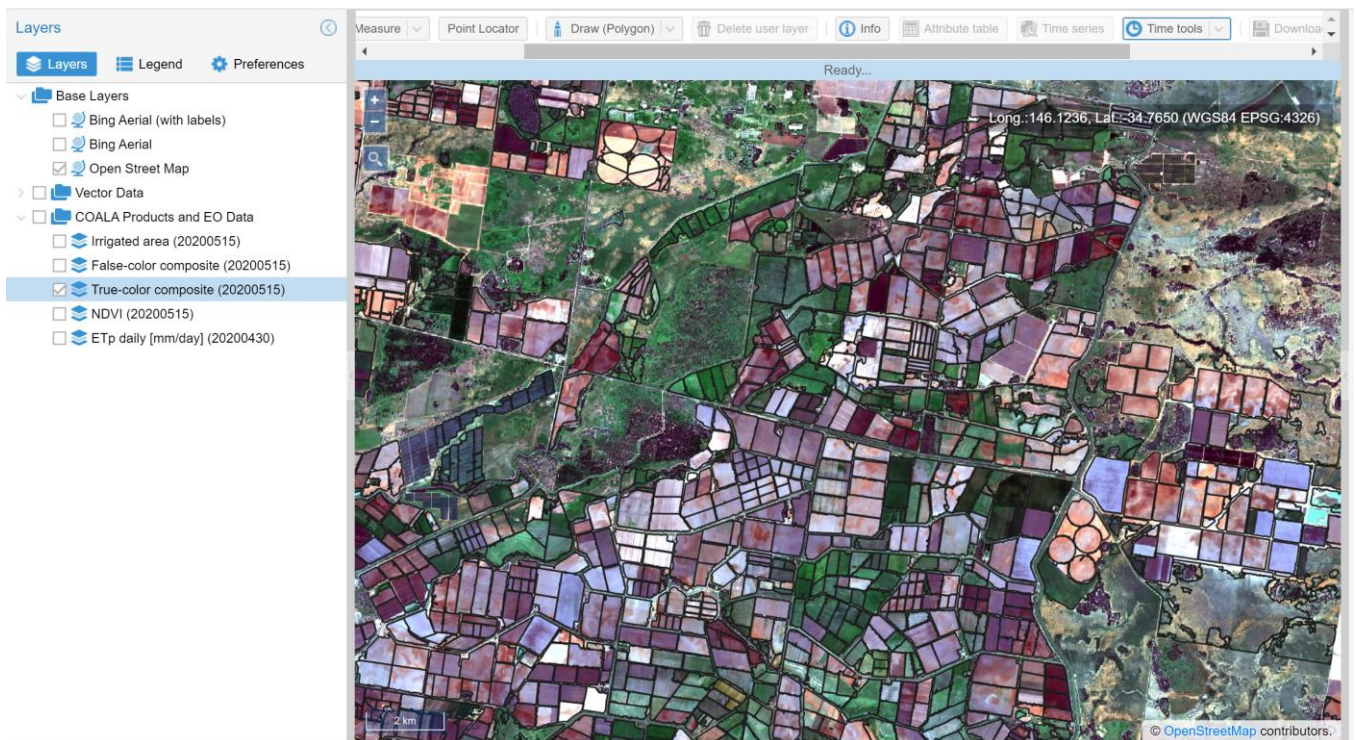
Explanation of terms used in program

Term (from 'Layers')	Explanation
Irrigated area	Land that is supplied water regularly by means other than natural rainfall.
False-colour composite	A representation of an image produced using bands of the satellite that collect energy that are not visible to the naked eye, for example near infrared and beyond. This highlights spectral differences to increase the interpretability of data. A healthy plant will have more chlorophyll, this cellular structure strongly reflects near-infrared light, displaying a strong false-colour composite.
True-colour composite	A representation of an image produced using wavelength bands that are visible to the naked eye, red, green and blues. The resulting image resembles what would be seen naturally by the human eye. While images can be interpreted into categories such as vegetation being green, and water shows as dark blue and bare ground usually depicted as light grey or brown, subtle differences are hard to recognise. Vegetation will appear green and differences between healthy and unhealthy vegetation may be difficult to distinguish.
NDVI	Normalised difference vegetation index (NDVI) is a calculation or number given to a pixel (1 square km of land surface) between -1 and +1. This calculation is based on the difference between the amount of visible and near-infrared light being reflected. Areas with a greater density of plants photosynthesising, will absorb more visible light wavelengths. Therefore, the difference between the reflection of visible and near-infrared will be greater, resulting in a number closer to +1. This directly correlates to 'healthier' vegetative areas.
ETp daily (mm/day)	Potential evapotranspiration. The amount of water that would be evaporated if sufficient water sources were available.

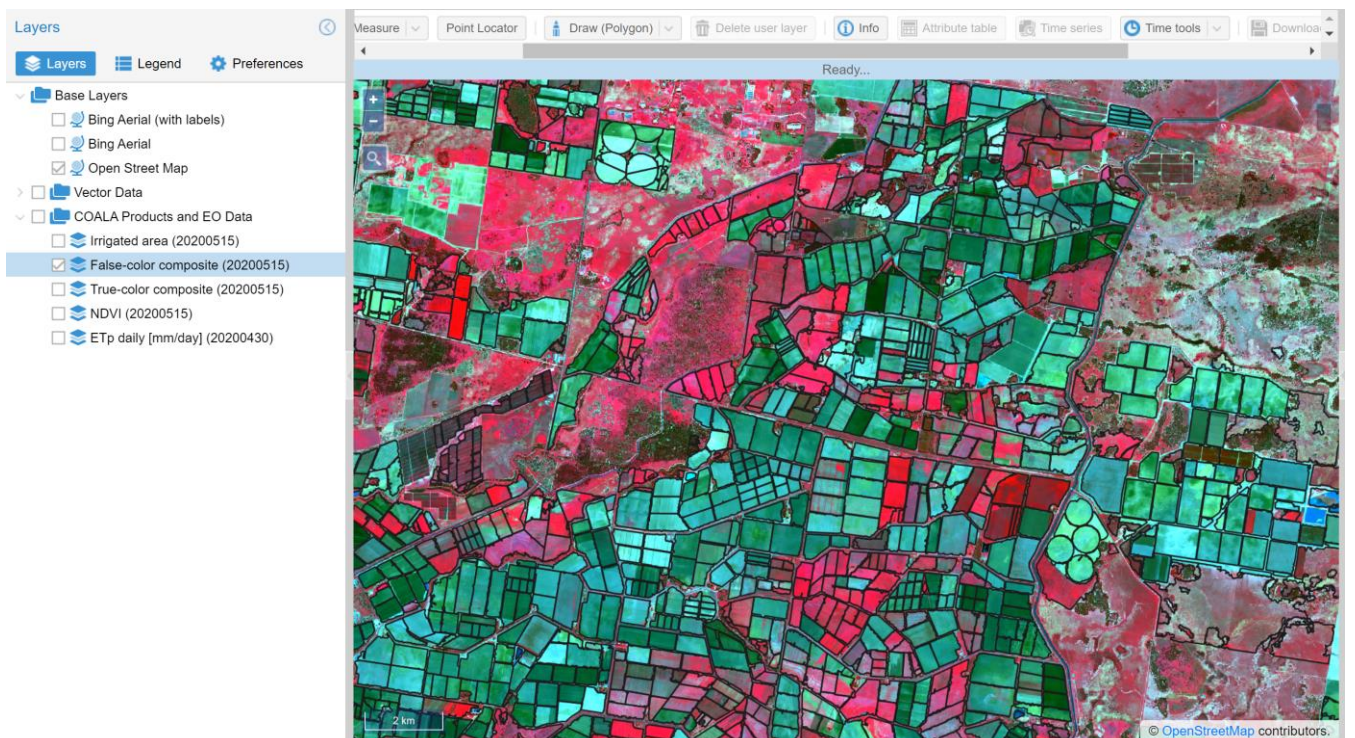
Understanding the difference between True-colour composite and false-colour composite

The colours in an Earth observation image will depend on what kind of light the satellite instrument has measured. True-colour images use visible light, so the colours are similar to what a person would see if they were looking down on the area. False-colour images include near-infrared light and can take on unexpected colours.

Below is an example of a true-colour composite image, using visible light. Notice the similarity in colours you would expect to see if you were looking down on this area from above. Greens represent areas where green light is being reflected from plants.



Below is an example of a false-colour composite image of the same area, using visible and near-infrared light sensors. You will notice extreme contrasts of reds and greens. In this image, the areas of red will range from dull to extremely bright. The brighter the red the greater the amount of near infrared being reflected, which directly relates to the amount of photosynthetic activity of the vegetation in the pixel. Areas showing brighter reds are therefore healthier vegetation areas, not the areas of green.



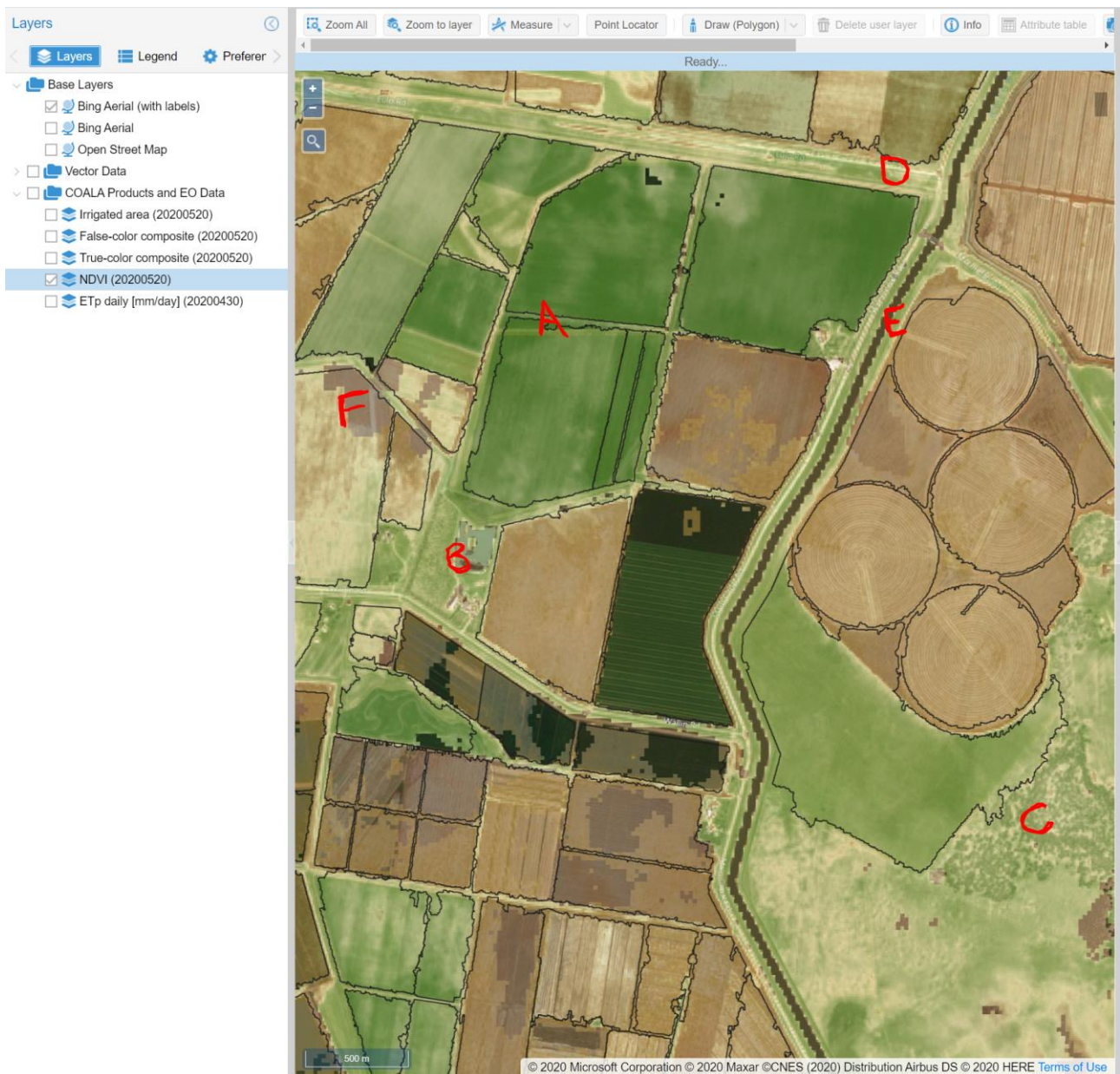
When comparing the two images, take note of the two circles areas, in the first image (true-colour composite) area one is very green, showing an area with vegetation, and area two is brown, showing an area without vegetation. When these are compared to the false-colour composite image, area one will display bright reds, also demonstrating this as an area with healthy vegetation (the greater intensity of near-infrared wavelengths reflected, the greater the photosynthetic rate, which equals healthier vegetation). Area two will now be transferred to green in colour, displaying less near infrared being reflected, and therefore less healthy, or absent vegetation.



Exploring the different layers

Use the following instructions to explore each of the layers explained in the table above. The questions in this section could be answered in written form, however using them to facilitate a class discussion would have more benefit for students.

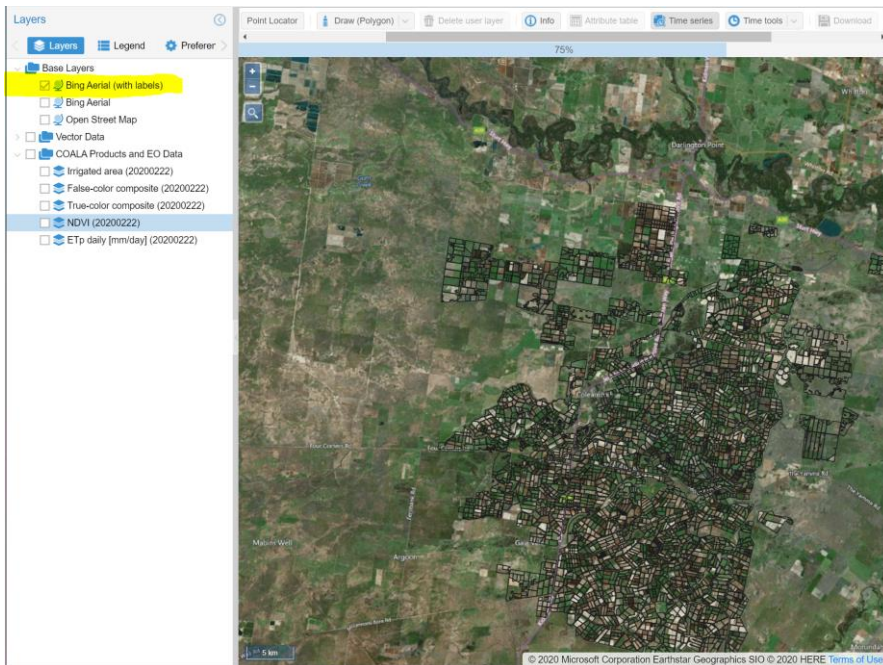
1. Zoom in on one area of the map until the scale in the bottom left corner changes to show a 500m distance. Please note, for class discussions, it may be useful to direct students to zoom in on the same area of the map.
2. Click on each of the following layers, one by one, de-select the previous before moving onto the next.
 - a Select 'irrigated area'. Access the legend tab to decipher what you are looking at in the image. Use the picture to describe what is occurring in the area you have selected.
 - b Select 'false-colour composite'. Describe what you can see in the image, refer to specific paddocks that stand out.
 - c Select 'true-colour composite'. Describe what you can see in the image. Describe any relationships you can see between the false-colour composite and 'true-colour composite images'?
 - d Select 'NDVI'. Access the legend tab to decipher what you are looking at in the image. Remember that areas with an NDVI closer to or at 0 has very little to no vegetation growth. Areas closer to 1.0 have healthy vegetation present. Using the information from the image, describe what you can see in this area of the map.
 - e Select ETp daily (mm/day). Access the legend tab to decipher what you are looking at in the image. Using the information from the image, describe what you can see.
 - f With consideration to the information you collected from 'false-colour' and 'true-colour' composite layers, NDVI and the ETp daily layer, identify areas of the map that have more, or healthier vegetation than others? Identify areas of the map that are water sources and roads. Explain how you can determine each of these features using the images.
3. Identify the following features of the map in the diagram below:
 - Road
 - Canal
 - Dam
 - Cloud
 - Trees
 - Paddock boundary



Observing changes in paddocks

Instructions

1. Click Bing Aerial (with labels) as the base layer for your map. See highlighted section of diagram. Your map should look like the one in the diagram below.

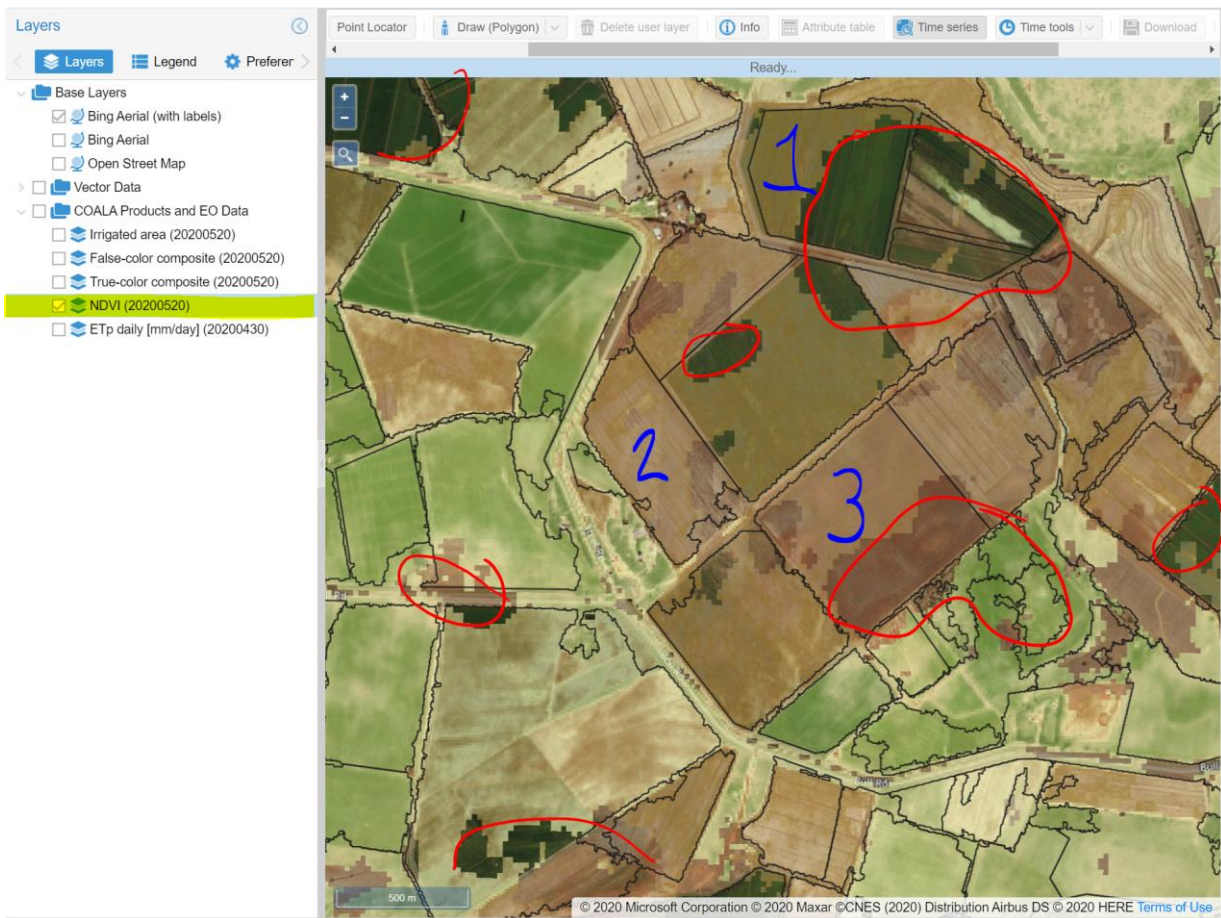


2. Zoom in on the middle left area of the map with the black outlines. Find where Bull Road meets Steele Road.

See yellow highlighted area with blue asterisk in the diagram below. (Longitude 145.8078; Latitude -34.8295)



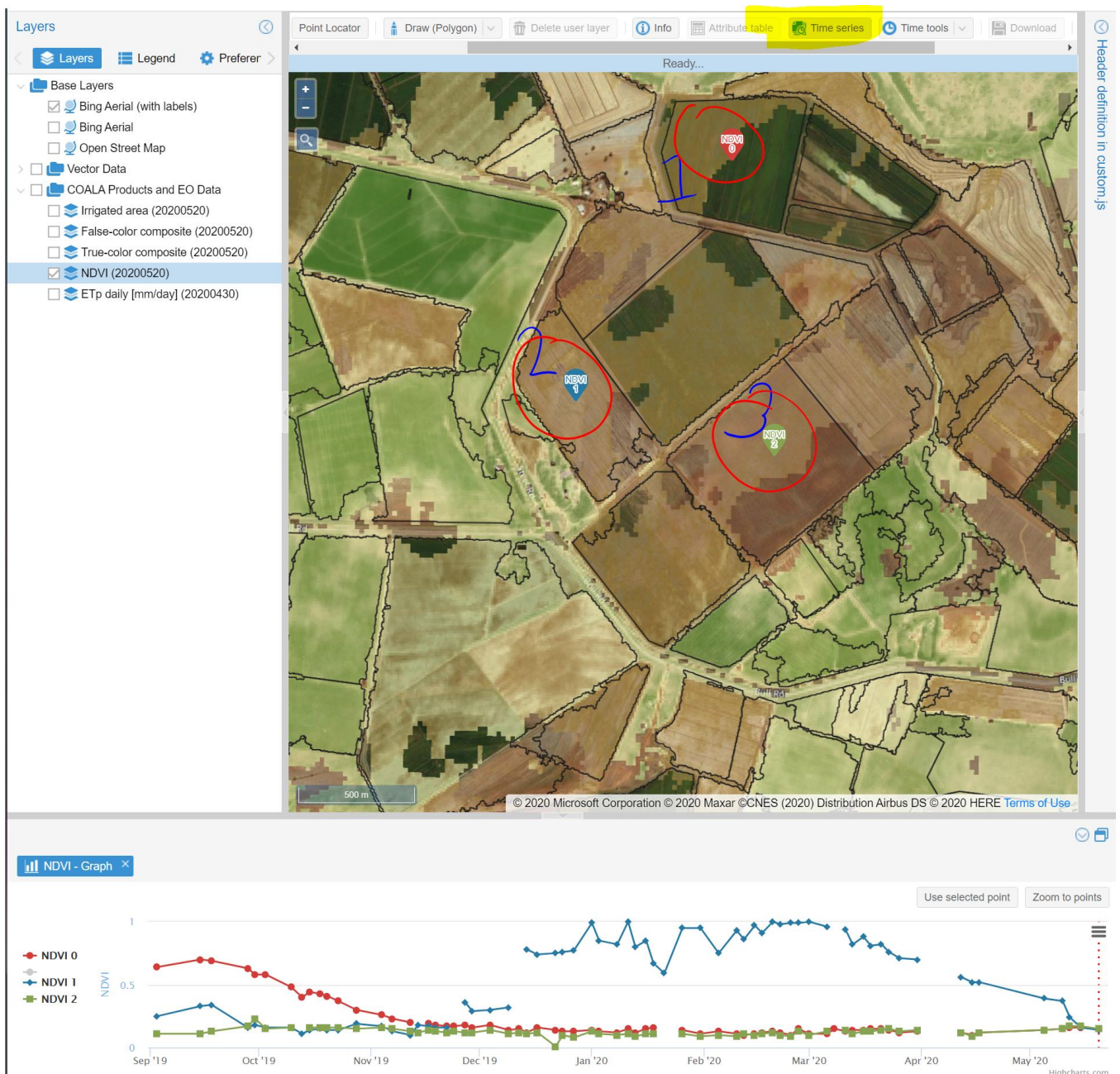
3. Identify the three paddocks in the diagram.
4. Check the NDVI box to overlay NDVI data to the image (it should look similar to the diagram below).



Please note: The image you have created will automatically be for the last set of satellite data collected by the system. On this diagram you can see there are discoloured patches as circled in red. These are caused by clouds interfering with the data. This image was taken on a cloudy day.

5. In the previous two images you will notice three paddocks numbered. For the purpose of this activity, we will be looking specifically at these three paddocks.
6. Click on the 'Time series' button as highlighted in the diagram, then click on the three paddocks in order from 1-3. You will notice three pins drop on these paddocks as seen in the diagram.

The three pin drops will create the line graph you see at the bottom of the diagram.



Questions

Using the data generated by the pin drops for paddocks 1, 2 and 3 and your knowledge of NDVI answer the following questions.

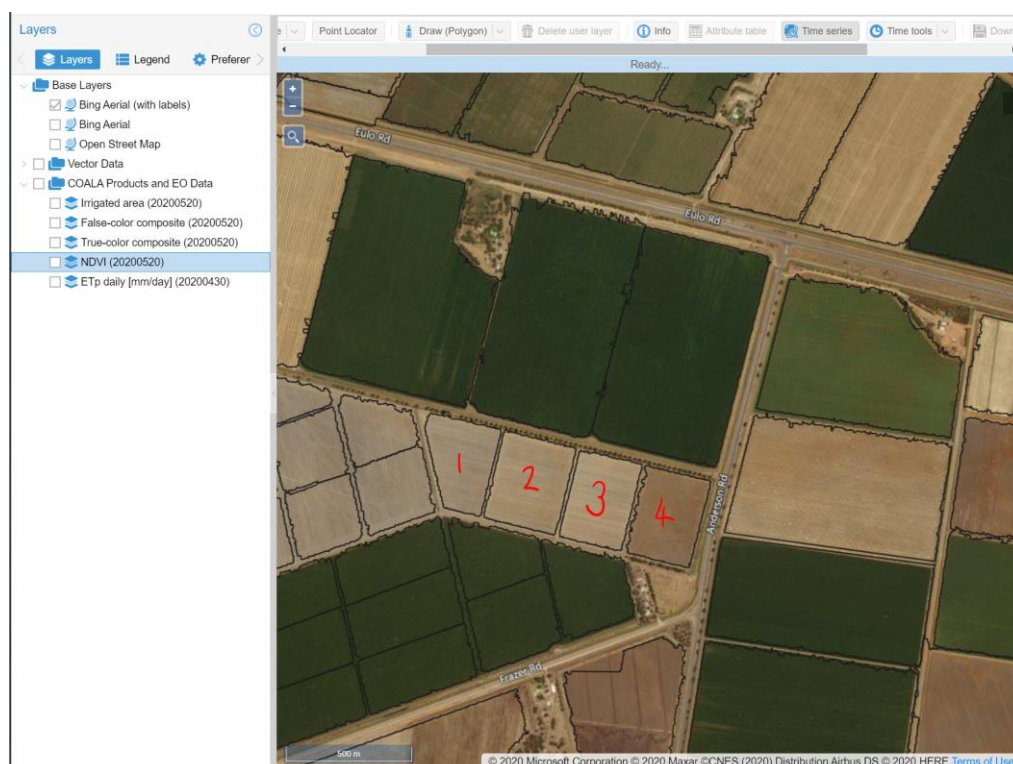
- Paddock one was growing a winter wheat crop. Estimate when the crop was harvested based on the data. Describe how you determined this.
- Is the crop grown in paddock 2 a winter or summer crop? How did you determine this?
- Estimate the time of year paddock 2 was planted and harvested.
- Describe what you think has occurred in paddock three over this time period.
- Paddock 2 has much higher readings of NDVI (closer to and at +1) during its growth period than paddock 1. Propose one reason for this and discuss as a class.

Using NDVI for management decisions

Using the 'Time series' function on the program can assist farmers in comparing NDVI data between a series of paddocks, or even different sections of the one paddock. In this activity, you will compare the NDVI graphs generated across four paddocks of the same farm to identify areas that perform better than others and make suggestions based on data.

Instructions

7. Locate the set of four paddocks at approximately longitude 146.0194; latitude -34.7665, numbered in the diagram below.



8. Select the NDVI layer and use the 'time series' function to begin generating graphs showing the changes in NDVI over the period of September 2019, to May 2020. Add and remove pins to different locations on each paddock to see the differences between and within paddocks.
9. Use the data collected through the time series function to identify higher and lower performing areas in terms of plant health from the NDVI data. Illustrate these on a hand drawn diagram of the paddocks.
10. Identify the two lowest performing areas of the paddocks on the farm.
11. Make three recommendations for this farmer on what further information needs to be collected to develop a clear picture of why these areas are underperforming in comparison to the rest of the paddocks.

Use of satellite imagery for sustainability

Earth observation imagery collected via satellites and other aerial devices can provide a range of data for farmers and environmental scientists that was once not available. The data collected can be used to:

- Map agricultural land, protected areas and ecosystems
- Monitor crop and pasture health, growth or feed availability
- Detect the presence of diseases or the effects of pests on crops and pastures
- Monitor effects of drought, floods and fires across regions
- Monitor changes in terrain or important environmental features such as sand dunes or identifying changes from erosion
- Develop management plans for farms or other significant sites
- Develop site specific crop yield management plans.

These are just some of the ways Earth observation imagery could be used. Many of the applications of this data can assist farmers and other people managing the environment to improve both short- and long-term sustainability of the land.

12. The research in this program focuses on the Coleambally region of NSW which is primarily an irrigated cropping area. Discuss as a class how each of the following stakeholders could use the data collected from Earth observation imagery to make decisions about improving the long-term sustainability for Coleambally. For each group, address the sustainability issues they would be focused on for the success of their business/career.
 - Irrigated cropping farmers
 - Livestock producers (extensive grazing systems)
 - Environmental groups
 - Town planners (local council)
13. Research one application of this technology used in either a plant or animal production enterprise. Create a poster/presentation explaining its use in the identified industry and evaluate its effect on sustainability (both short- and long-term sustainability).
14. Water security is viewed as a major agricultural issue in regional NSW. Propose how Earth observation imagery and its functions could be used to combat this problem. Consider its use with other information resources and technologies. Think outside the square. Develop a short presentation displaying your solution/s.