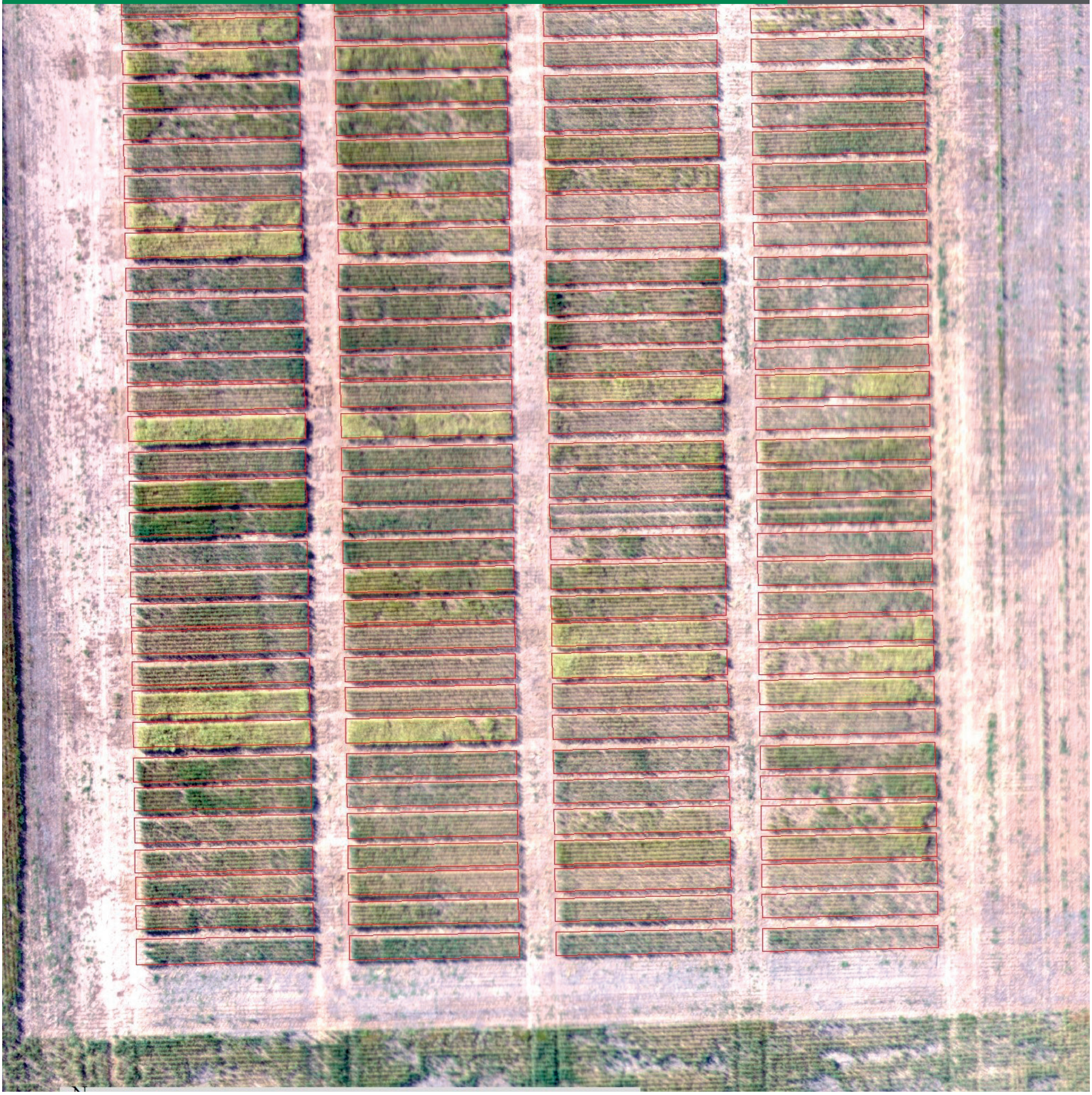
THE SMART TECHNOLOGY BEHIND SMART GRAIN

HOW EMERGING TECHNOLOGIES ARE ENHANCING THE CAPABILITIES OF AUSTRALIAN GRAIN GROWERS

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

A TEACHING UNIT FOR YEAR 10 AND 11 AGRICULTURAL STUDENTS



About the GRDC

The GRDC

The Grains Research and Development Corporation is a statutory authority established to plan and invest in research, development and extension (RD&E) for the Australian grains industry.

Its primary objective is to drive the discovery, development and delivery of world-class innovation to enhance the productivity, profitability and sustainability of Australian grain growers and benefit the industry and the wider community.

Its primary business activity is the allocation and management of investment in grains RD&E.

GRDC Vision

A profitable and sustainable Australian grains industry, valued by the wider community.

GRDC Mission

Create value by driving the discovery, development and delivery of world-class innovation in the Australian grains industry.

GRDC Values

- We are committed and passionate about the Australian grains industry.
- We value creativity and innovation.
- We build strong relationships and partnerships based on mutual trust and respect.
- We act ethically and with integrity.
- We are transparent and accountable to our stakeholders.

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Contents

1.0 Teaching the science of grains

The Grains Research and Development Corporation has invested in the development of a suite of user-friendly grain education resources and initiatives for students, teachers and families.

These resources have been developed with teacher and researcher input and have been designed following a comprehensive survey of more than 340 teachers throughout Australia.

In each of our curriculum-linked resources we have worked to incorporate a range of lesson plans which explore the latest science, technology, engineering, mathematics, nutrition, research and innovation in the Australian agricultural industry. You can use these resources as a unit or select components to complement your teaching plan.

Using an investigation and inquiry based approach students will touch, try, taste and even smell the science of the Australian grains industry. It provides an ideal and relevant teaching context to engage students in food production.

Specifically, resources are available to address the food and fibre curriculum descriptors in geography, science, home economics and agriculture.

We hope you have fun teaching with these resources. Please contact us for more information.

Kind regards
The GRDC Education Team

2.0 Learning outcomes and curriculum links

About the smart technology behind smart grains

Australians are living in an age of technology. We integrate it into all parts of our life – work, social, family, health and wellbeing, finance and even what we eat. Adopting new digital technologies has helped Australian farmers achieve improved yields and quality in cereal crops such as wheat and barley. Science and technology is becoming an increasingly important feature of farming. New technologies can improve everything from how you farm the land, to the plants you grow, to how you manage a workforce.

Overview

This resource uses an inquiry-based approach to explore current farming technologies. Students employ critical and creative thinking to answer questions and complete tasks. Students are asked to explore technologies through insights and activities around UAV/drones, GIS, online support and smart apps. By generating their own app, they employ numeracy and analysis skills to explore on-farm data and information.

Curriculum focus

Students should be able to

- Explain how the use of emerging technologies can increase the effectiveness and efficiency of growing grains.
- Identify the function of various data producing technologies used in agriculture, including geographical information systems.
- Examine data, assessing its reliability and potential use.
- Explore best practice methods explaining how technologies can enhance application.

Australian curriculum content descriptions

Design technologies

Design technologies

Knowledge and understanding

Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions (ACTDEK041).

Investigate and make judgments on how the characteristics and properties of materials, systems, components, tools and equipment can be combined to create designed solutions (ACTDEK046).

Science as a human endeavour

Use and influence of science

People use scientific knowledge to evaluate whether they accept that claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE160).

Science inquiry skills

Communicating

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS208).

Geography

Geography inquiry skills

Interpreting, analysing and concluding

Identify how geographical information systems (GIS) might be used to analyse geographical data and make predictions (ACHGS078).

3.0 Teaching unit content and overview

This resource contains a range of curriculum-linked lesson plans which teachers can cut, paste, and utilise as they see fit. Our team work to develop resources which are interactive, fun and fit into your busy teaching schedule. The below table summarises the wide modes of engagement strategies – activity supported insights, exploring critical and lateral thinking, investigation and inquiry. You can use some or all of these lesson plans. Whatever you do, we hope you have fun teaching your students about emerging technologies enhancing approaches to growing great grain.

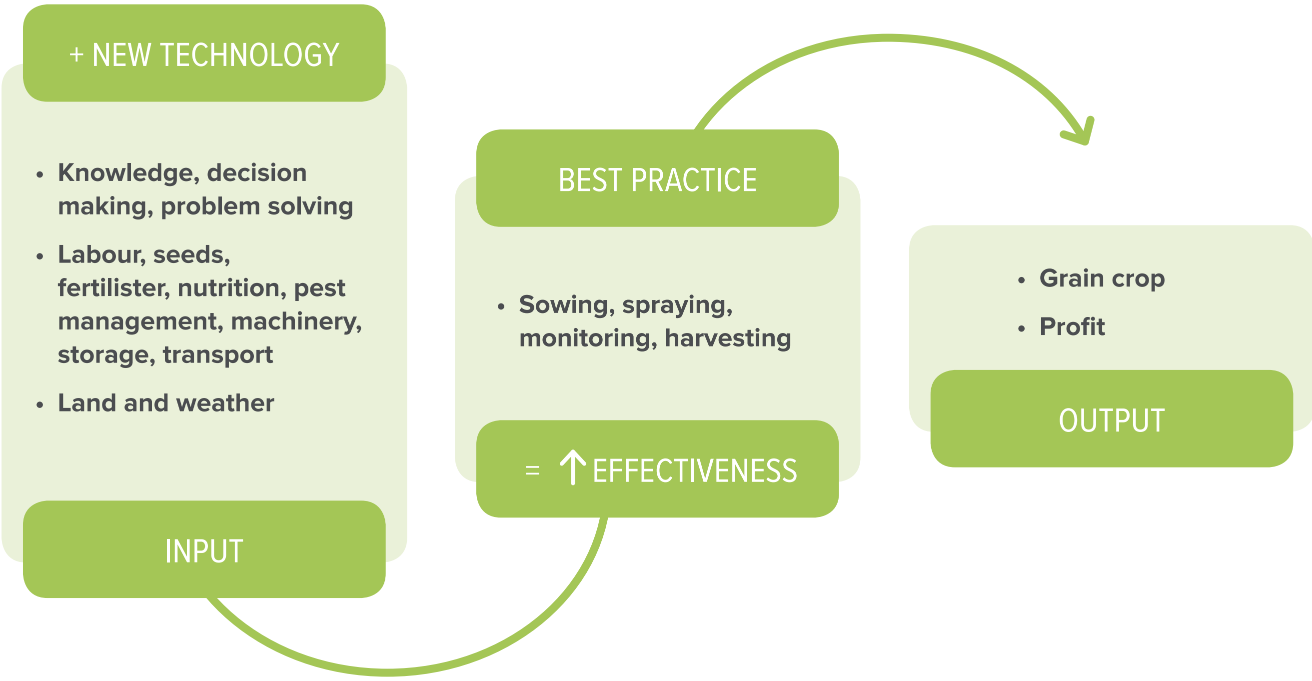
	Introduction	Get the class talking about agricultural innovation by creating a list of technologies used on farms. This may include machinery, hand held devices or systems which generate data.
	Watch	This short clip is a great introduction into technology use in farm management. Landline, *High Tech Farming*, Fiona Breen, August 2014 **http://www.abc.net.au/landline/content/2014/s4073139.htm** Alternatively, let students explore the opinions of farmers on where they think the industry will be in 70 years. 'On the farm in 70 Years – Farmer Predictions', 2015, ABC **http://www.abc.net.au/news/2015-05-12/on-the-farm-in-70-years-farmer-predictions-2085/6538152**
PAGE 9	**4.0 Activity** Technologies on farms	Students are to read through the insight 'Demand for food and future farms' individually or as a class. To break up the information, they are to note some of the statistics presented. From these notes, students are to create a simple infographic which explores the connection between the demand for food and the use of net-enabled technologies on farms. This could be done by hand or on the computer. Infographic: An infographic is a visual representation of information. It replaces the need for long paragraphs and instead highlights the facts on one page. Infographics should include short, to-the-point sentences and pictures which reshape information into a simpler form of presentation. Example of agricultural infographic *'Aussie farmers take a byte out of Big Data', CSIRO 2013,* **https://blog.csiro.au/aussie-farmers-take-a-byte-out-of-big-data/**
PAGE 11	**5.0 Activity** Emerging technologies	Engage students in thinking about future farms by asking them to think of ideas of how the new technologies listed could be used in growing grains to increase productivity. *Original article: Business Insider Australia '15 Emerging agriculture technologies that will change the world', Zappia, M, May 2014* **http://www.businessinsider.com.au/15-emerging-agriculture-technologies-2014-4**
PAGE 12	**6.0 Activity** GIS	To begin, ask students about their understanding of GIS and its applications across sectors, e.g. *before sowing:* soil nutrient and ground water variants in paddock, distribution of pests and weed. *Growing:* use the data to manage weeds, disease, pests. *Harvesting:* monitors yields, comparing to historical data. In partners, students are to explore real-world applications of GIS on farms by reading this article about Queensland peanut farmers and answering the questions which follow. 'Predictable technology signals farming revolution', Dr Andrew Robson, Tasmanian Times, April 2014, **http://tasmaniantimes.com/index.php?/pr-article/predictive-technology-signals-farming-revolution/**

PAGE 14	**7.0 Practical** Grain grid	To better understand GIS, have students create their own map. Students can use either their own yard or paddock, school paddock or school yard. On tablets or smartphones, download an app that will track the route and allow notes and photos to be linked to the map created (like My Track, Strava, MotionX GPS). Ensure the device's location services are switched on. Enable GPS iPhone > Settings > Privacy > Location Services > ON Android > Personal > Privacy and Safety > Location > ON This exercise can also be done without the use of smart devices. Use a regular camera and take notes of location with descriptions. Once these are collected identify the coordinates using the notes and an online map like Google Earth. Ask students to take photographs of relevant points of interest with their device. This may include areas of poor drainage, bare patches, areas which are weed heavy, fence lines etc. Use the app to tag each photo with GPS location and a short description. Additionally, ask the students to send the photos or map they have created through to a central file like Google Plus, Picasso or Box Folder. **http://www.gis.harvard.edu/services/blog/creating-interactive-story-map-contains-narrated-geotagged-photos-and-gps-track** Ask the students to elaborate on their understanding of global positioning technologies by writing a short report on what they found in creating their map. Were there areas with problems, notable geographical features, considerations that would be useful to note in managing a cropping area (e.g. knolls, weed patches, water flow, trees). Students should include photos with GPS coordinates in their report. An example of this task can be found in the appendix of this resource.
PAGE 15	**8.0 Insight** Using technologies to measure plant health	Begin by asking students what they know about UAVs or Drones, what areas of society they are currently being utilised and how. Students are to list how existing technologies are used in collaboration to create UAVs which are effective on farms. Students are to brainstorm other ways in which UAVs could be used in successfully growing grains.
	Watch	'Drones and the future of farming', National Geographic, 2015, **https://www.youtube.com/watch?v=v3YcZtlVrls** Overview of UAV use on farms. To explore how a UAV is useful in growing grains use the insight <u>How does a UAV collect data about health of a grain crop.</u> *'High Resolution NDVI', 4D Delta 2014,* **https://www.youtube.com/watch?v=UuldZ0vrb8U** - Example of images captured by a near Infra-red camera aboard a UAV in Western Australia's wheat-belt.
PAGE 19	**9.0 Activity** The big picture	Using a real example of UAV images and data, students are to put themselves in the shoes of a grain grower and analyse this information. Print the 'UAV trial plots image' as an A3 for ease. Students are to analyse these: what is the scale, what wave length is this map generated at, what size area does this UAV map cover. The activity has been divided up into a series of steps for which, depending on differentiation, teachers can assist with at varying degrees. For example '1. Plot size' will be the same for each student, so can be done as a class or individually. Step 2 onward can be done individually or in pairs. The final summary task enables students to elaborate on their understanding.

PAGE 25	**10.0 Activity** Smart grains	Grain growers are utilising their smart phones and devices increasingly to store farm data, check the weather, market prices, find information about equipment, research best practice methods and communicate, both socially and for business. Students are to explore this use of technology by researching and providing an explanation of apps which assist grain growers, before utilising the content of grains research and development fact sheets to plan their own app to assist growers. In pairs, students are to analyse three apps which could be used to assist grain growers. Students can search themselves or teachers can select from this resource. Grain Research and Development Corporation Apps: **http://www.grdc.com.au/Resources/Apps** AGEX Farming Apps Book (downloadable): **http://agex.org.au/project/apps-for-farmers-completed/**
PAGE 26	**11.0 Activity** Plan an app for the industry	Using the fact sheets suggested (found at **www.grdc.com.au**) or teacher selections, students are to plan an app for grain growers. The fact sheet will provide the content for the app. Discuss with students: Who would use this app (Audience: grain growers, agronomist). What features would be useful to deliver this information? (e.g. calendar reminder of crop application, weather alert for frost). What technologies which exist on a smart phone could be used to enhance the app? (e.g. GPS maps, camera to take photos of progression of crop growth, notes). Get students to engage with their peers by asking for feedback. **Have a specific area of grains which you would like students to focus on? Use this activity as a way to deliver student inquiry reports.*
PAGE 30	**12.0 Insight** Tracking the rain on grain	This provides an overview of the use and application of soil moisture probes. This has been kindly provided by Leighton Wilksch, Precision Ag expert.
PAGE 32	**13.0 Activity** Case Study: Karawatha Farm	Providing a context for technology use in farming grains, students are to explore and analyse real-world data from Karawatha Farm.
	Additional	To assist with engagement, integrate one of the following • Guest speaker who uses, develops or distributes crop monitoring equipment. • Focus on variable rate technology. Where is it used and what are its advantages? • Field trip to a farm or dealer to see technologies in context e.g. auto steer, nutrition maps, GPS.

4.0 ACTIVITY
Technologies on farms

There are many factors which affect the success of a grains farmer. Adopting new practices and technologies are important to ensuring food security and getting the most out of a crop. Farmers need to stay informed of new technologies available to help make their practices as efficient and effective as they can.



TASK:

You are to create an infographic using the following as your source of information.

1. **Read through the Insight on page 10, selecting some information to include in your graphic.** Make sure you include facts about:
   - Increasing demand for food, including grains.
   - Farms today.
   - Technology on farms.
   - Include 4 - 6 facts.
   - Three dot points of how you think use of technology on farms will help to grow more grains.
2. **Create an infographic:** An infographic is a visual representation of information. You can select pieces of information to highlight and present them as a fact, a short sentence or represent them as a picture. Infographics let you summarise information on one page in a creative, visual and to-the-point way.

INSIGHT: Demand for food and future farms

Did you know?

The National Food Plan states that demand for food across the world will increase by 75 per cent between 2007 and 2050. In Australia, we have an even bigger challenge. We need to increase our production value by 45 per cent by 2030 (CSIRO) to keep up with our growing export demands and to feed our own growing population.

Issue:

With the Australian and global populations increasing, there is added demand and expectations for Australian farmers to produce lots of high quality food. To achieve this, new technologies and innovation in farming must be developed. These technologies must ensure that food is produced to the highest standard while using sustainable farming practices.

Facts

Productivity trends in Australian agriculture

Within Australia, there are approximately 134,000 farm businesses with 99 per cent of these family owned and operated. Each Australian farmer produces enough food to feed 600 people, 150 at home and 450 overseas. Australian farmers produce almost 93 per cent of Australia's daily domestic food supply. (NFF, 2012)

Australian farmers are good at what they do. Agricultural outputs have more than doubled over the previous 40 years to 2003-04, and agricultural exports have almost tripled in value (Productivity Commission, 2005). This has been achieved through improved farming practices, the adoption of new technologies, innovative research and mechanisation.

Looking at the Australian grain industry, on average, 26.0 million hectares were sown to crops, excluding land used for pastures and grass. Western Australia cropped 8.6 million hectares while New South Wales and South Australia cropped 6.9 million hectares and 4.1 million hectares respectively (table 16.13). Wheat was Australia's biggest crop in terms of area used, with 13.9 million hectares planted or more than half the land area dedicated to cropping (table 16.14).

Furthermore, between 1980 and 2010 the number of grain enterprises in Australia dropped from 40,000 to 27,000 but farm sizes increased. In this time, grain productivity increased each year by an average of 1.9 per cent. To keep up with global demand over the coming decades Australian grain growers must increase grain production each year by a minimum of 2 per cent. (GRDC)

By adopting new practices and technologies, farmers are able to keep up with the demand, using their land in a more productive way.

Australian agriculture has a strong export focus. About 60 per cent of the gross value of farm production is typically exported (ABARES 2012).

Increasing need for net-enabled technologies

One of the factors that plays an ever increasing role in the use of new technologies on farms is access to the internet. This could increase productivity of farms, including growing grains, by 50 per cent over the next two decades. In 2007-08, the Australian Bureau of Statistics (ABS) reported that 65 per cent of sheep, beef cattle and grain growers were using the internet.

If we examine the use of internet by farmers and the use of internet by greater society, we can assume that adoption of this technology onto farms is increasing. In June 2008, the ABS found that only 34 per cent of the entire population were subscribed to the internet. By June 2015 this had increased to 55 per cent of the entire population. We can assume that this growth would be reflective in the grain growers' population, who are always looking for new ways to farm more effectively, efficiently and sustainably.

Solution:

What technology would you like to see in the future of agriculture?

One of the factors which will help grain growers keep up with the demand is investment in new technologies. That is, technologies which will enhance the practices of a farmer, not replace them.

In Australia, it has been suggested that the future of farming includes all machinery being driverless, drones being commonplace, computerised identification traps for pests like moths, enhanced imaging for quicker identification of disease, machines which recycle food waste on the farm and robots for just about everything. The overall management and decision making will however, remain the task of the grain grower and to be able to be effective operators, they must understand how the technology works and how to manage the data created.

5.0 ACTIVITY
Emerging technologies

In 2014, *Business Insider Australia* published an article on emerging agricultural technologies across the globe. The technologies mentioned highlighted the innovation of the agricultural industry at the time. By now even more advanced technologies are being developed.

Brainstorm

Listed below are some of the highlighted technologies, with Business Insider's prediction of when they would be financially available for farming. Can you think of how these technologies could be used on farm to increase the efficiency and effectiveness of growing great grains?

Air and soil sensors: Enabling real time feedback about the farm's air and soil qualities. FINANCIALLY AVAILABLE 2015.	
Equipment telematics: Lets machinery talk to each other across the farm. Also warns of any likely impending faults/failures. FINANCIALLY AVAILABLE 2017.	
Crop sensors: Including optical sensors and drones, these sensors inform of correct amounts of fertiliser needed before applications. FINANCIALLY AVAILABLE 2019.	
Variable rate swath control: Utilising geolocation technology, this technology can understand the productivity of different areas of a paddock. FINANCIALLY AVAILABLE 2016.	
Precision agriculture: Employing satellite imagery and advanced sensors to preserve resources. For example, soil moisture sensor deliver data which tells a farmer when and how much to water their crop. FINANCIALLY AVAILABLE 2024.	
Vertical farming: Growing food in multi-story buildings in cities using greenhouse techniques, energy efficient lighting and recycled water. FINANCIALLY AVAILABLE 2027.	

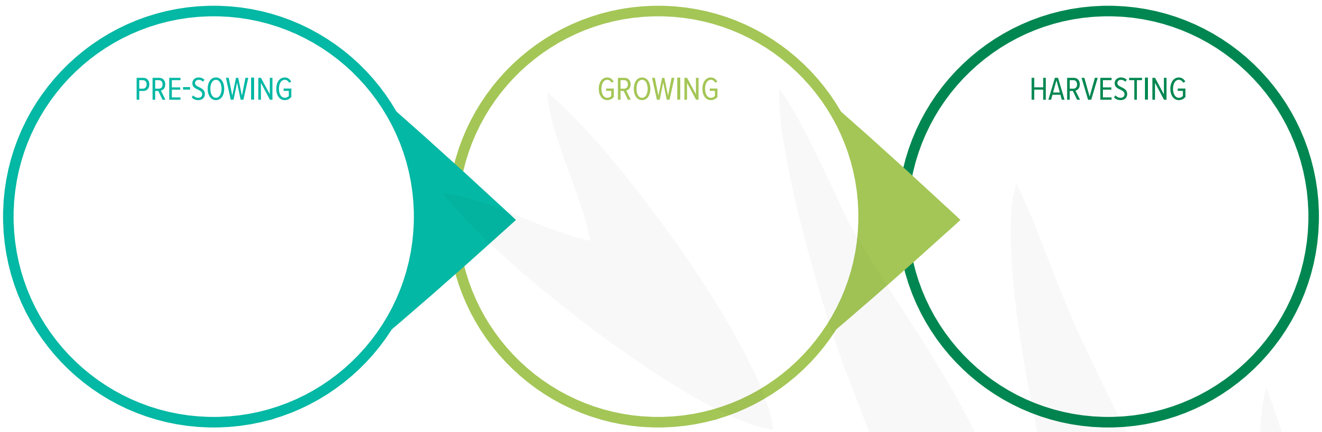
6.0 ACTIVITY
GIS

Farming grains in the 21st century has been greatly innovated by the introduction of GIS – Geographical Information Systems and GPS – Global Positioning System. These systems provide geographical data so growers know more about their land, their crop and can make applications site-specific. By integrating this data into their farming methods, farmers can potentially increase the time and cost efficiency of growing grains, use lower amounts of agro-chemicals and manage water usage better.

GEOGRAPHICAL INFORMATION SYSTEM: Displays and analysis geographical information.

GLOBAL POSITIONING SYSTEM: Uses satellites to provide geographical location.

List how GIS can assist grain growers at each step:



TASK:

Read the following article about how GIS technology is helping peanut farmers in Australia.
Answer the questions which follow.

'Predictable technology signals farming revolution', Dr Andrew Robson, Tasmanian Times, April 2014,
http://tasmaniantimes.com/index.php?/pr-article/predictive-technology-signals-farming-revolution/

What does the GIS technology enable peanut farms to forecast?

What does the data tell growers?

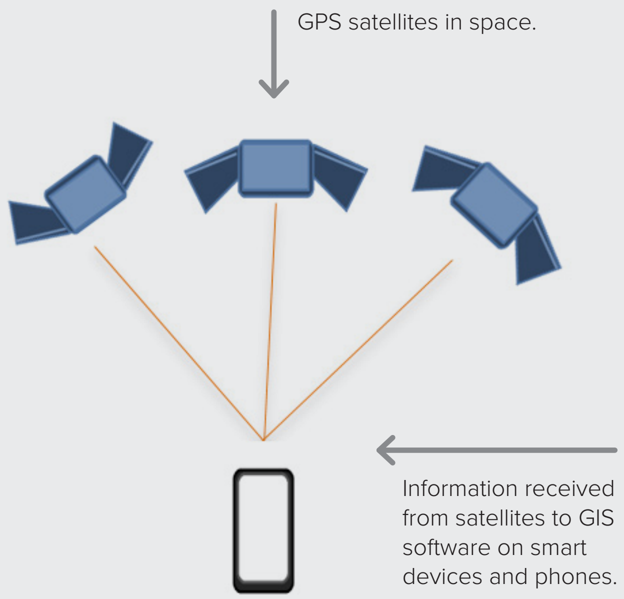
What do the GIS maps display?

7.0 PRACTICAL
Grain grid

There are 24 GPS satellites orbiting the earth and GIS technology on phones and smart devices will use three to four of these satellites to decipher an exact location and time (GPS Gov, USA).

On farms, GPS sensors have multiple uses. They can be attached to tractors, headers and other vehicles to help with navigation to increase precision and assist in poor visibility. GPS can be paired with other technologies to provide a more precise insight for grain growers into applications like fertilizer, pesticides, weed control and changes in irrigation.

Modern day phones commonly have GPS technologies which are used for directions from point A to point B, geotagging photos and notes, map journeys and within many apps.



TASK:

You are a grain farmer surveying your land planning where you will plant your next crop. You will use your smart device to do this, walking out the space and noting areas of interest. Use an app which will track your walking route.

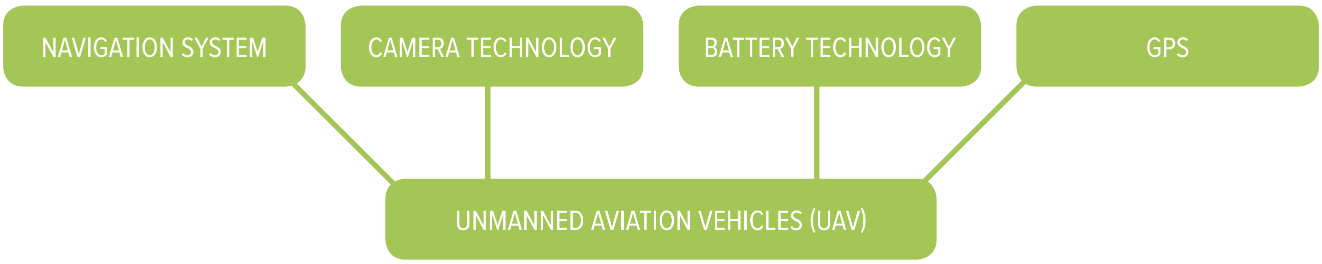
1. Choose an area and imagine this will be the area for your new crop. It may be a field, paddock or even your school oval.
2. On tablets or smartphones, download an app that will track the route and allow notes and photos to be linked to the map created (like My Track, Strava, MotionX GPS). Ensure the device's location services are switched on.
   Enable GPS
   iPhone > Settings > Privacy > Location Services > ON
   Android > Personal > Privacy and Safety > Location > ON
3. Walk the perimeter of the area, surveying across the area as you go. Take photos and notes on your device of areas of interest. This could include bare patches, drainage areas, weed patches, gates and fence lines. On your device go into the picture or note details or information and ensure a GPS location has been recorded.
4. **Report:** After completing your surveying you are to use the app to generate a map. Put this map and any photos and maps into a document. Explain what you found interesting, notable geographical features and things a grain farmer would need to consider when planning to plant a crop in this area.

8.0 INSIGHT
Using technologies to measure plant health

New technologies allow farmers to be more effective, more efficient and produce better results in growing food and fibre. We are always challenging the possibilities of the use of technology on farms.

For example, the use of Unmanned Aerial Vehicles (UAV) is becoming a more common practice in growing grains. UAV or drone technology has been improving at a rapid rate and is being developed through the utilisation of both new and existing technologies. Researchers look at what available technology exists across all industries and see if it can be adapted for use in agriculture.

Existing technology can be combined to create new technology.



How would each of these technologies be used as part of an Unmanned Aviation Vehicle on a farm?

NAVIGATION SYSTEMS / GPS (GLOBAL POSITIONING SYSTEMS)	
CAMERA TECHNOLOGY	
BATTERY TECHNOLOGY	
TINY CHEAP COMPUTER	

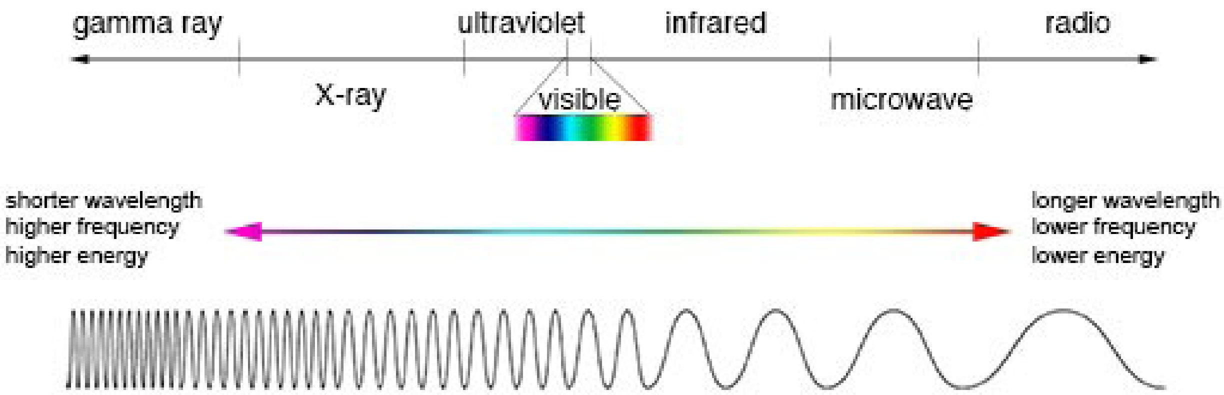
How does an UAV collect data about the health of a grain crop?

Unmanned Aerial Vehicles are used to collect data about the health of a grain crop using camera technologies, data collection and GPS.

Plants reflect sunlight at different wavelengths including visible light and infrared light.

When sunlight hits a grain crop, some of this light reflects off the plant at different wavelengths while some is absorbed. Some of this light is visible to the human eye as we see the colours of the rainbow. This is called visible light. Healthy plants absorb red and blue light to photosynthesise but reflect green light, hence their appearance.

Some of the light reflecting off the plant cannot be seen by the human eye, generating colours which we cannot see. This is called infrared and ultraviolet light.



(Source: http://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html)

INVISIBLE RAYS			VISIBLE RAYS	INVISIBLE RAYS		
GAMMA RAYS	X-RAYS	ULTRAVIOLET LIGHT	VISIBLE LIGHT	INFRARED LIGHT	MICROWAVE	RADIOWAVE

LIGHT WAVELENGTH	DESCRIPTION
VISIBLE RANGE	
INFRARED RANGE	

A grain grower can assess a plant's health by looking at its colour.

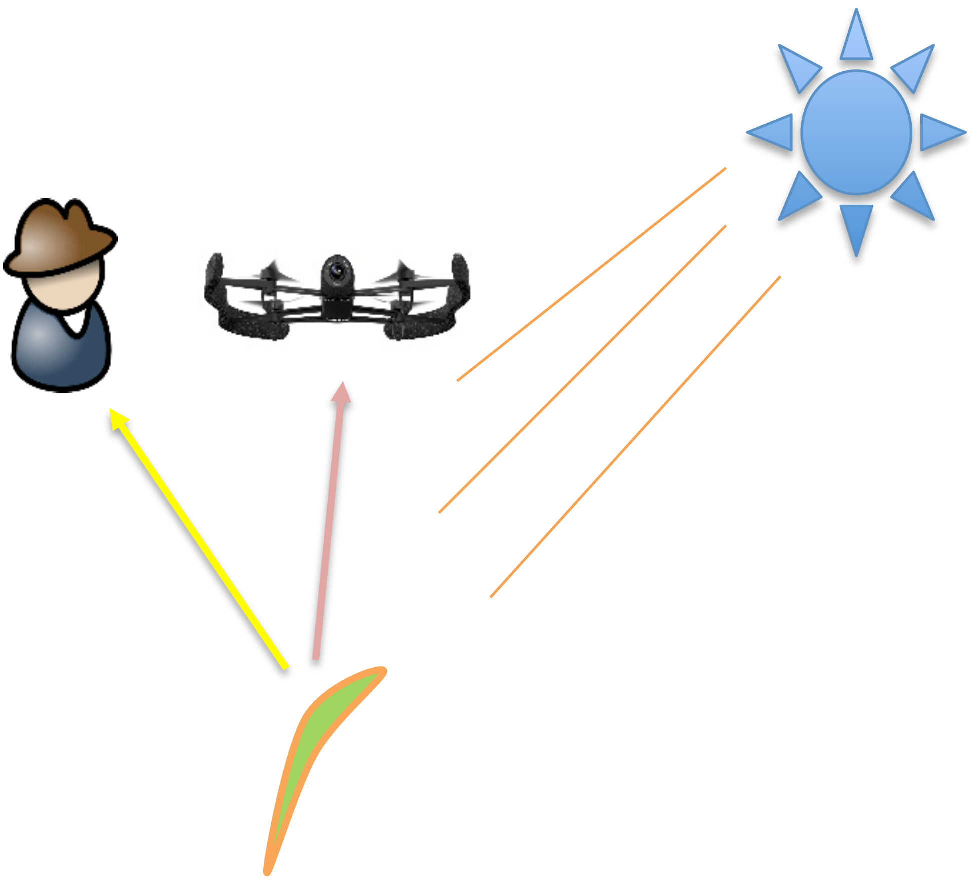
This is a good indication of plant health. We know that if a crop is very green it is most likely healthy.

However, the specialised cameras on a UAV/drone can capture the reflection of infrared light. This band provides a colour which is more indicative of the plant's actual health.

The data generated from infrared light capturing technology on UAVs can be used to assess plant health.

Through practice, grain growers can get an idea of how healthy their crop is by looking at its colour in visible wavelengths. Technologies like satellites and UAVs can provide an idea of plant biomass and health by capturing non-visible light reflecting off the crop, near-infrared wavelengths.

Camera technology on a UAV can capture both wavelengths and use an equation to calculate plant health. The data produced from this calculation is known as the Normalised Difference Vegetation Index (NDVI). *(Lilles and Thomas, Ralph W. Kiefer, and Jonathan Chipman. Remote sensing and image interpretation. John Wiley & Sons, 2014.)*



What is NDVI?

NDVI measures the difference between the plant's red reflectance (visible to humans) and near-infrared reflectance (not visible to humans).

NDVI = (rNIR - rRed) / (rNIR + rRed)

An UAV can generate data called the Normalised Difference Vegetation Index (NDVI). The index generates numbers between -1 and +1. Values between -1 and 0 are typical of snow and water. Bare soil and dead vegetation have low positive values. A healthy crop can generate values between +0.4 and +1, depending on its growth stage.

Values generated are between -1 and +1 with higher values being associated with greater density and greenness of the plant canopy (NASA)**.**

HIGHER VALUES	Healthy green plants
LOWER VALUES	Stressed or dead plants, plant disease
NEGATIVE VALUES	Bodies of water
ZERO VALUES	Bare patches of soil, snow and bodies of water

Satellites, UAVs and mapping plant health

Satellites and UAVs capture the various aspects of vegetation across the land and generate maps of NDVI which provide an understanding of the amount of live green vegetation. A wide array of data from satellites over Australia such as the Advanced Very High Resolution Radiometer (AVHRR), Landsat and SPOT are managed by many countries around the world, such as the US, France and India. Observations from these satellite are made very regularly (some satellites cover the earth twice a day). Maps and grids are available from the early 1970s until now (NASA). **http://earthexplorer.usgs.gov/** is an excellent resource that lets you explore much of this data, with a lot of free data that you can download—try the Landsat imagery!

9.0 ACTIVITY
The big picture

Grain farmers are always looking for more efficient and effective ways to manage their crop. Data has always been imperative to this and the amount of data we can now collect using new technologies is creating rapid change in crop management. For example, UAVs can collect pictures of crops using different cameras. This can then be paired with large data sets using mapping technologies.

Using data as a decision making tool   You are a grain farmer and trialling the use of UAVs on your farm. The data includes NDVI, thermal readings and pictures. You are to analyse both the data and pictures as part of your training for your new piece of technology.

1 **Plot size:** Measure the trial plot area, subtracting the pathways between each row so that you only calculate the area where the crop plots were sown. To complete the equation, follow the steps ('1' to 'Final')

Vertical measurement (Measure W to X)

1 = ______________mm
A

Measure vertical row spacing total (mm):

2 _________ X 3 rows = _________
B

Total vertical measurement

3 __________ - _________ = _________
A **B** **C**

Horizontal measurement (Measure W to Z)

4 = ______________mm
D

Approximate horizontal row spacing total

1mm X 36 rows = 36mm
E

Total vertical measurement

5 ________ - 36 = _________
D **E** **F**

6 Measure the scale on the UAV Trial Plot Image in millimetres = _________ mm
Scale

Vertical conversion

7 _______ ÷ _______ = ________
C **Scale** **V**

8 _________ X 20 = ________ metres
V

Horizontal conversion

9 _______ ÷ _______ = ________
F **Scale** **H**

10 _________ X 20 = ________ metres
H

Sown plot area
(vertical in metres x horizontal in metres)

_____________ X _____________

Final **Trial plot area total =** ____________________

2 **Select a plot**

You are to select three plots to focus on from the data table. The number on the Wilkawatt plot numbers table corresponds to the position of the plot on the UAV trial plots image. Record the plot ID in the table below.

3 **Analyse the NDVI data to understand the health of the crop**

Look at the NDVI for each plot. Note that there are two NDVI readings: D1NDVI and D2NDVI. These are readings of the same plot taken at two different periods. Record each and using a calculator, find the difference between them.

D2NDVI - D1NDVI = GROWTH RATE.

Calculate the average NDVI for each plot.

	PLOT NUMBER	D1NDVI	D2NDVI	AVERAGE NDVI
1	Example 420	0.6136	0.6477	0.6477 - 0.6136 = 0.341
2				
3				
4				

Values generated are between -1 and +1 with higher values being associated with greater density and greenness of the plant canopy (NASA).

HIGHER VALUES	Healthy green plants
LOWER VALUES	Stressed or dead plants, plant disease
NEGATIVE VALUES	Bodies of water
ZERO VALUES	Bare patches of soil, snow and bodies of water

Calculate

Calculate the average growth rate across the plots you have chosen and that of two peers (ensure you all have different plots). Discuss how the growth rate of your plots compare to the average. Fill in the equation below with the average growth rate values for your chosen plots and those of your two peers. Calculate the **overall average growth rate**. Discuss which plots had good growth rates and which had poor growth rates in comparison.

_______ + _______ + _______ +_______ + _______ + _______ +_______ + _______ + _______

= _______________

4 Data and visual

Comment on

1. How the data reflects the overall health of your plots.
2. Your own visual assessment of the plot: greenery, growth.

1	Example: Plot 420 sits on the far eastern side of the trial plots about half way down. The NDVI sits at 0.63065. As a higher value it seems that this plot has dense and healthy green foliage. When I look at the plot on the UAV Trial Plots Image, I can see that the density of foliage is even and thick and it is an evenly healthy green colour across the plot.
2	
3	
4	

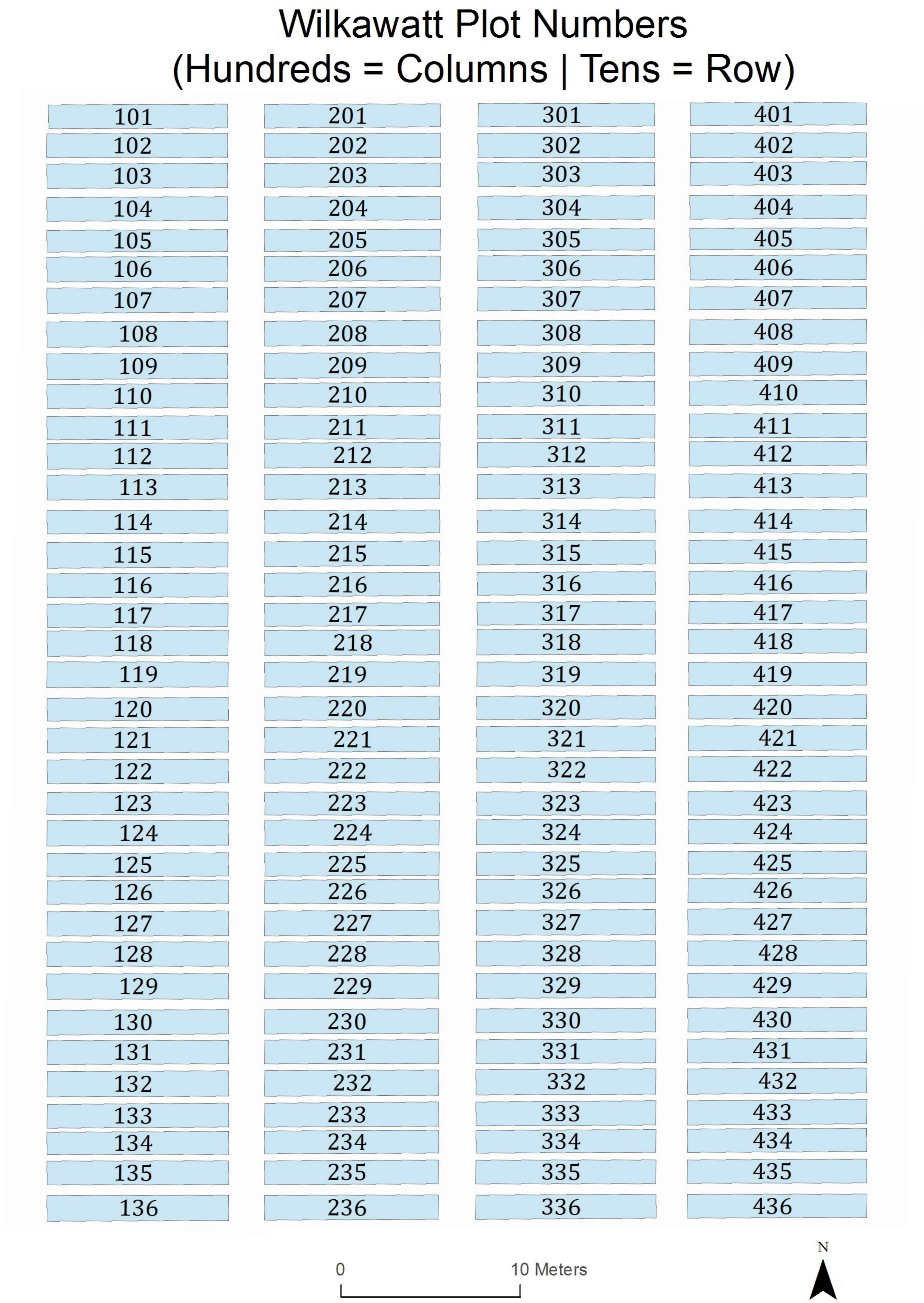
UAV Trial Plots Image: Trial plots of different types of wheat captured by UAV camera in visible wavelength (RGB)

Source: Courtesy of Dr Ramesh Raja Segaran

5 Select 4 plots. Highlight each.

ROW	COLUMN	PLOT_ID	D1NDVI	D2NDVI
1	D	401	0.4111	0.6159
1	C	301	0.3742	0.5754
1	B	201	0.4443	0.6407
1	A	101	0.4452	0.6612
2	D	402	0.6451	0.5946
2	C	302	0.5461	0.5632
2	B	202	0.6685	0.6408
2	A	102	0.6769	0.6709
3	D	403	0.5450	0.5581
3	C	303	0.5453	0.5397
3	B	203	0.6179	0.6167
3	A	103	0.6367	0.6702
4	D	404	0.4543	0.6058
4	C	304	0.3995	0.5533
4	B	204	0.4749	0.6464
4	A	104	0.5438	0.7138
19	D	419	0.5798	0.5618
19	C	319	0.6574	0.5615
19	B	219	0.7131	0.6078
19	A	119	0.8025	0.6705
20	D	420	0.6136	0.6477
20	C	320	0.6190	0.6286
20	B	220	0.7089	0.6656
20	A	120	0.6817	0.6808
21	D	421	0.6007	0.6374
21	C	321	0.6131	0.5983
21	B	221	0.6743	0.6440
21	A	121	0.7714	0.7450
22	D	422	0.4419	0.6588
22	C	322	0.3861	0.5545
22	B	222	0.5064	0.6656
22	A	122	0.4963	0.7595
30	D	430	0.4532	0.6785
30	C	330	0.4422	0.6151
30	B	230	0.4690	0.6288
30	A	130	0.4845	0.7250
31	D	431	0.4030	0.6114
31	C	331	0.4262	0.6071
31	B	231	0.4547	0.6021
31	A	131	0.5026	0.7296
32	D	432	0.5505	0.6010
32	C	332	0.5714	0.6031
32	B	232	0.6819	0.6170
32	A	132	0.6461	0.6445

Source: Courtesy of Dr Ramesh Raja Segaran



Source: Courtesy of Dr Ramesh Raja Segaran

10.0 ACTIVITY
Smart grains

Farmers can use the internet to search for best practice farming methods. However, with the large amount of information and data on the internet from all corners of the globe this can take a lot of time. Farmers and agronomists need technology to generate information and data that is specific to their area and their needs.

Smartphone apps are one of the modern ways this problem is being addressed. The app industry is worth $20 billion, with 400 million smartphone users worldwide generating this economy. With 157,000 farmers in Australia, we assume that most will have access to smartphone technology at hand, in the field.

Creating apps

Problems are identified and a solution is created by the creation of an app. This is as opposed to creating an app to later find out there was no problem which required such an app.

The following task asks you to investigate a problem that Australian grain farmers face and generate an app that could be part of the solution.

TASK:
Investigating apps

With a peer, assess any three apps that you use. Complete the following table.

SMARTPHONE/ DEVICE APP	PURPOSE	TARGET MARKET	ONE MAIN FUNCTION/ APPLICATION
1.			
2.			
3.			

11.0 ACTIVITY
Plan an app for the grains industry

A grains farmer has come to you wanting to increase their engagement with technology to better manage their farm. Select one of the following fact sheets about grain growing management and imagine this is the information that could be used to assist this farmer.

Use this resource to design an app that lets the farmer have this information at their fingertips. You can use all of the information supplied in the fact sheet or select a part to focus and expand on.

- GRDC Tips and Tactics Sunflower Disease Management
- GRDC Farm Business Management
- GRDC Soil Testing for Crop Nutrition
- GRDC Managing People
- GRDC Spray Water Quality
- GRDC Grain Storage

Creating your app

Purpose Creating an app is not about being a whizz bang computer programmer, making things look pretty or spending thousands of dollars on awesome marketing. It is about taking a problem and offering the solution. What is the problem? What does this app offer to solve that problem?

Audience

Who would find your app useful?

Content

Your app should provide information that is relevant and clear. It should be short, sharp and shiny.

Features

Could the app store photos and data? Provide alerts or notifications? Outline 'how-to'? Give directions? Share information and posts? Provide a directory? Connect a community?

Technology

Smartphones and devices already have a lot of technology built into them, ready to use. Include them if they enhance your features, exclude them if they serve little purpose. For example, camera, torch, speaker, microphone, GPS, clock, notepad, mail.

Feedback and marketing

It is important to get feedback on your idea from relevant people – this may be peers in your class or people working in the industry. Feedback is a valuable tool that will help you refine your app to make it better. This will also let you know the strengths of the app which you should focus on when marketing it.

Purpose

Solution to the problem

Audience

Who would this be used by?

Technology

Features of smartphone/device that will enhance the app

Content

Information on the app

Features

Photos, data, alerts, notification, how-to, directions, sharing, posting, directories, community….

Feedback and marketing

Improvements and where you would market your app

12.0 INSIGHT
Tracking the rain on grain

Soil Moisture Probe Technology –
WITH TECH GURU LEIGHTON WILKSCH

With growers concerned about the risks of farming with climate variability, many are now turning to technology to assist in their on-farm decision making.

Since rainfall is one of the greatest variabilities, and therefore risk factors on farm, growers need a sound understanding of how much, and when, rain is likely to fall… they then need to know if the rain is making it into the soil profile and filtering down to a region where plants roots can use it.

The timing and amount of rain affects decisions such as what variety to plant, what time of year to plant it, when to apply fertilisers, what diseases will be around and how to manage their crop. Knowing the exact amount of rainfall can also be used by a farmer to estimate what yields they can expect from a given crop in a given season.

Soil moisture probes are considered a ‘precision agriculture’ tool which can be used to track soil moisture through any given soil profile. Soil moisture probes (SMPs) quantify how much moisture is in the soil, what depth is at, where the plants roots are active and how much moisture is being used by the crop. The probes have extremely accurate sensors, in fact they can sense the amount of soil moisture every 10 centimetres down the profile.

Collecting multiple years of this moisture data can give a clear picture of how much soil moisture there was at any point in time compared to previous seasons. It also tells the growers where the moisture is in the soil profile and where (i.e. what depth) the plant roots are most actively drawing moisture from.

This technology is being rapidly utilised by farmers. Many are putting one probe on their farm and then linking up with their neighbours and others, creating a local network of SMPs (and weather stations). This provides incredibly valuable information on how the region is performing overall.

Data management is a key aspect of successfully using soil moisture probes. Growers must utilise specific software and manage the data carefully. Essentially, the data can be displayed as a graph which tracks soil moisture at a given depth over time. It is also possible to compare years and crop water use. From this information, growers can decide when and what to plant, when and how much nitrogen and fertiliser to apply, and how much yield the plant will produce.

Using Leighton Wilksch article and your own understanding, answer these questions

List 6 reasons growers need accurate rainfall information

Soil moisture probes are considered what type of tool? What do you think this means?

What are the benefits of using this technology on farm?

13.0 ACTIVITY
Case study: Karawatha Farm

Farming using technology

Research, technology and innovation is an important part of Andy Barr's 1150 hectare cropping farm near Owen in South Australia. The farms biggest challenge is the amount of rain received, as the farm does not have irrigation. Along with most other cereal cropping farms, the Barr family measure their success against the industry benchmark of 'how many kilograms of grain are produced per hectare per millimetre of rainfall'.

To monitor and track rainfall, the Barr family have a network of soil moisture probes and weather stations which they monitor closely. The information collected is used to guide the time of sowing, nitrogen fertiliser applications and variety choice. Knowing the amount of water in the soil profile can also help the farmer make a educated prediction of how much yield, or grain, a crop could produce.

TASK

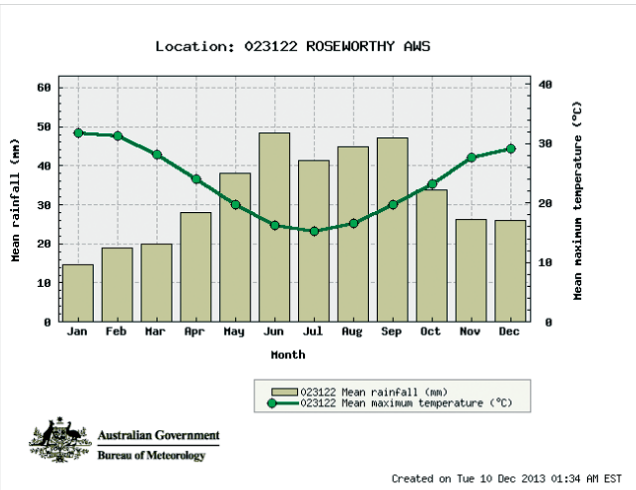
Review the newspaper article 'Technology wizards in Oz vital to success' story which features Belinda Cay (note: Belinda lives on the Barr family farm with her husband and two children, she is the daughter of farm owner and manager Andy Barr).

TASK

Dr Andy Barr has provided photos and data from his farm in South Australia's Mid-North. Analyse these examples and explain why each of these would be beneficial in growing grains.

1 Review and assess the information in the Australian Bureau of Meteorology (BOM) graph

Growers are able to freely access information from the BOM about the weather, climate and water in their region. The BOM provides specified data and maps to assist growers and graziers. The information is regionally relevant and is available in a range of formats, making it useful for decision making.



What month had the lowest rainfall?

According to the mean rainfall, when would be a good time to sow your crop?

When would be a good time to harvest your crop?

Stevenson Screen

Leet Wilksche worked with the Barr family to install an on-farm weather monitoring station, known as a Stevenson Screen. This contains a range of instruments....

Some of these instruments are listed below.

Find out what each of these instruments measures and explain.

Thermometer:

Barometer:

Thermograph:

Hygrometer:

Psychrometer:

Dewcell:

Precision sowing techniques

For many years now, Australia grain growers have been adopting precision agriculture technologies. Precision Agriculture (PA) (also known as Site-Specific Crop Management or Information Rich Agriculture) includes a suite of technologies which utilise global positioning systems (GPS) to provide a geo-referenced location for soil, farm or landscape data… So what exactly does this mean for farmers?

Well, satellite signals can be used to guide a tractor. In fact, GPS, or autosteer, means that farmers simply hook their tractor up to an autosteer and the tractor steers itself! It is so precise, the tractor will line up with 2 cm accuracy! The use of autosteer is important as it means farmers can plant their seeds in a specific location… You can even plant seeds in-between the stubble of last years crop. Inter-row sowing is an important sustainability measure on farms. Stubble retention means the soil is never bare, so there is less wind erosion. Vehicle guidance also reduces the overlap when applying fertilisers or pesticides, it means farmers can control soil compaction (where the wheels of the tractor go over the crop) and it is handy for yield monitoring or mapping.

Essentially, precision agriculture also allows farmers to collect different types of data from the same location. For example, farmers can map the topography, the yield and the soil type – then generate a map with overlies this information. A precision map is then handy to make informed agronomic decisions, specific to location on their property. Many farmers develop certain paddock management zones – each which is farmed slightly differently to suit is specific soil type or microclimate. This type of farming helps improve the productivity of each area.

Reference: CSIRO Publishing (2009) Preface: Use of Precision Agriculture by the Australian grains industry. Crop & Pasture Science, 2009, 60, 795–798. Viewed online at: http://www.publish.csiro.au/?act=view_file&file_id=CPv60n9_PR.pdf

Precision Agriculture in Action on the Barr farm

Sowing barley in the ‘V Paddock’. Here, James has set up the autosteer (a and b) to sow barley in lines which are perfectly straight. This not only looks good (!), but minimises overlap and allows inter-row sowing. Image c sows the results achieved – the new barley crop sown in between last years canola stubble.

The above image shows how precision agriculture is used to guide the tractor spreading fertiliser. Note the fertiliser placement within the row.

The above image shows a disc seeder in actions. Note the perfectly straight rows of beans.

TASK

Discuss the role of precision agriculture and then answer the following questions:

What other industries use precision agriculture?

List four benefits of farmers adoption precision agriculture considering economics, sustainability and human error...

1.
2.
3.
4.

What do you think would be the benefit of interrow sowing i.e. where the previous year's stubble is retained...

Soil benefit:

Economic benefit:

If the stubble remained and the technology did not offer such accuracy in sowing, what are some of the potential problems that may have arisen when sowing?

Soil Moisture Probes

Monitoring the weather above ground provides a great insight to how the farm should be managed. But for farmers, understanding the conditions below ground are just as important. Farmers can use soil moisture probes to track not only the surrounding weather but the soil temperature, humidity and moisture throughout the soil profile. This gives farmers a sound understanding of how effective their rainfall is i.e. how far it moves down the soil profile.



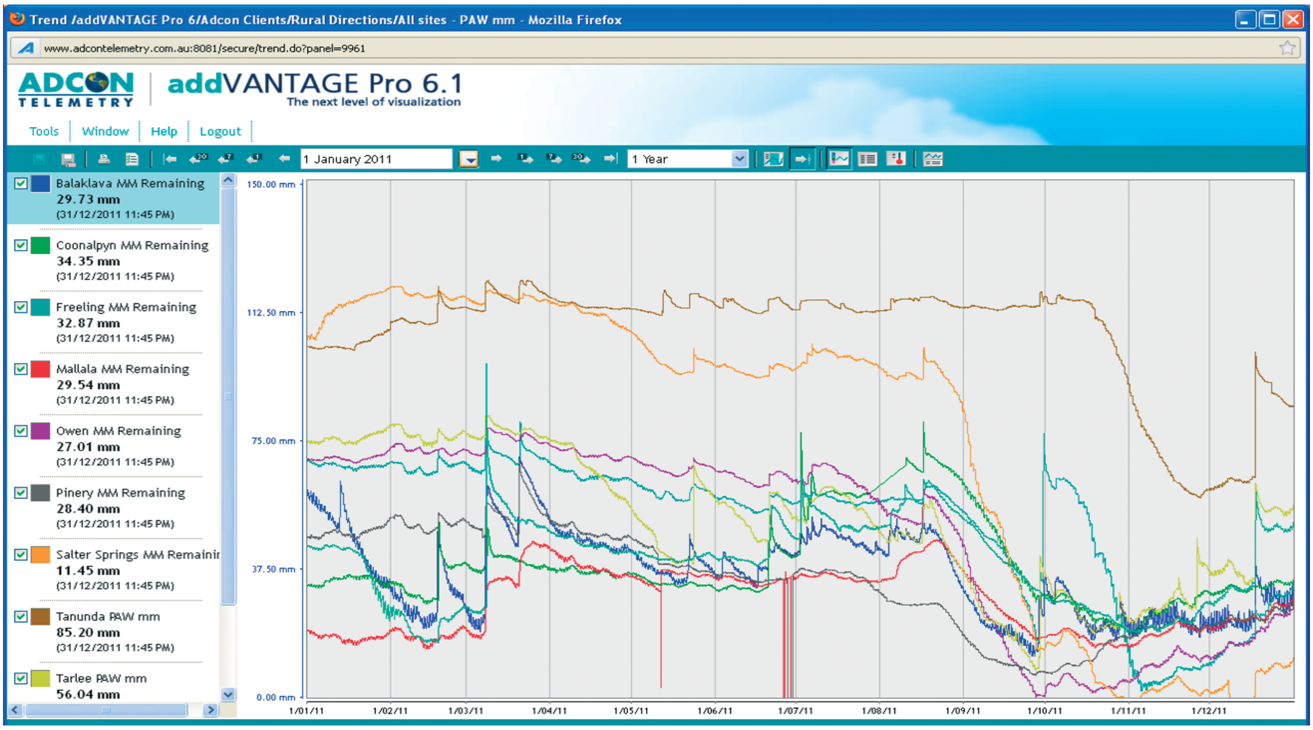
The above images show a range of soil moisture probes on farms throughout Australia. Note their position in the soil, which allows them to measure soil moisture at a range of depths, usually to around 1.5 meters.

Images provided by Sentek and Leighton Wilksche.

TASK

Review the data generated by the Barr's soil moisture probe and answer the following questions:

This graph shows real time, web based plant available water for 11 farms in Lower North of South Australia 2011. This data had been generated from Adcon moisture probes that have probes at 10 cm intervals to a metre.



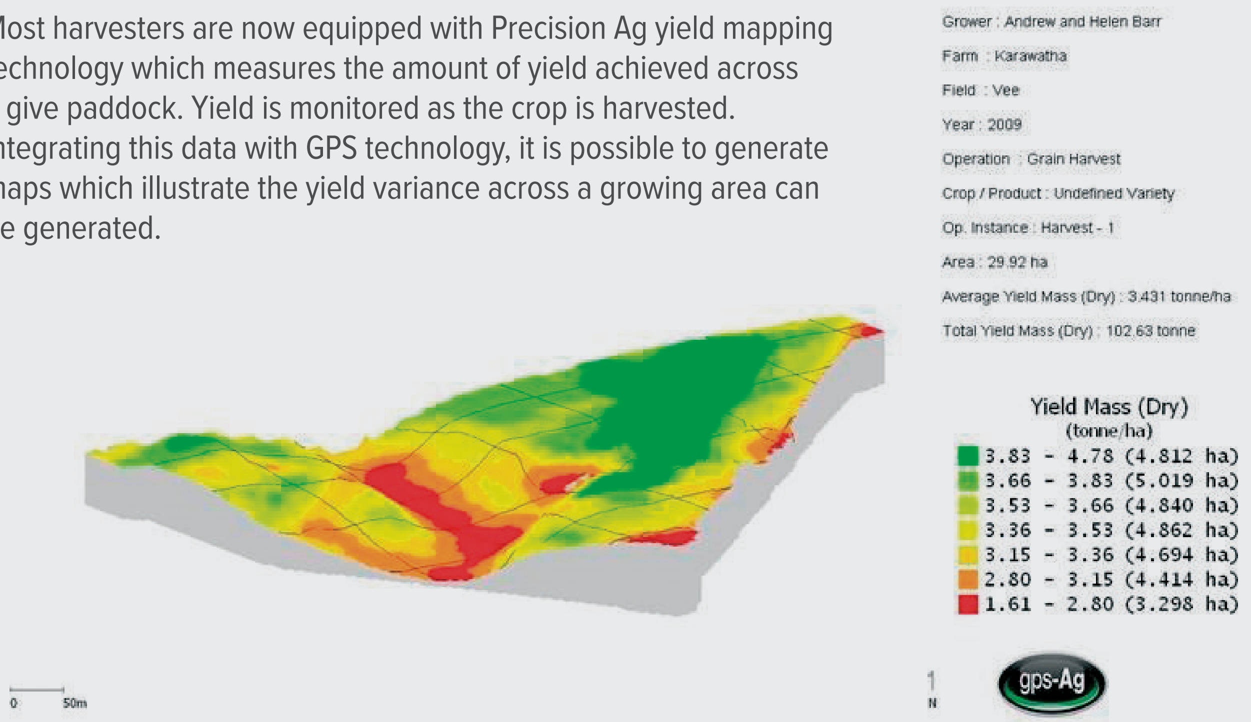
Comment on the yearly readings for Pinery.

What months brought significant changes in plant available water?

Approximately what was the lowest reading in Pinery for plant available water and when did this occur?

Precision Ag Yield Map

Most harvesters are now equipped with Precision Ag yield mapping technology which measures the amount of yield achieved across a give paddock. Yield is monitored as the crop is harvested. Integrating this data with GPS technology, it is possible to generate maps which illustrate the yield variance across a growing area can be generated.



Look at the topography of the yield map. Is there any relation to the topography of the paddock and the yield of the crop? Explain

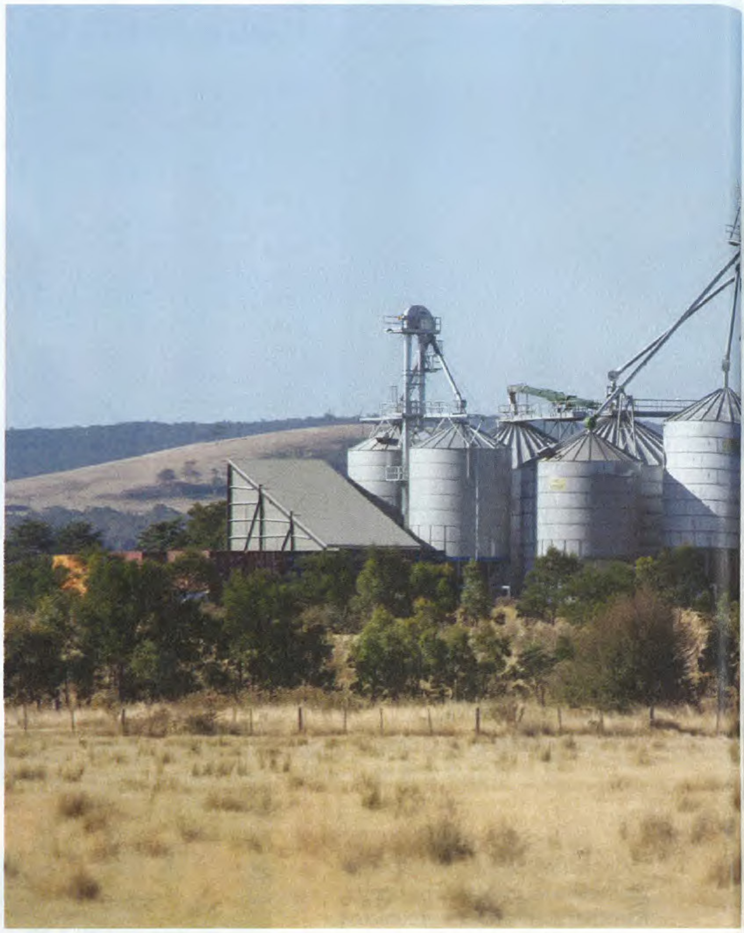
Discuss the variance in yield across the entire paddock. What are some potential reasons for these differences?

Using the total area and the average yield mass (dry), calculate how much yield in total would have been harvested.

How might you manage this land considering the variances in yield?

Technology wizards in Oz vital to success

While the UK debates how to spend levy money, the Australian approach to research is bringing big benefits to one farm, as Bayer's **Mike Abram** found out on a recent trip Down Under



Australian farmers pay a levy of 46p/t to fund research projects.

Levy-funded research is playing a key role in keeping one family farm in South Australia both profitable and sustainable, overcoming challenges such as resistant weeds.

Belinda Cay says the biggest priority on her 1,150ha family farm, near Owen, is cost of production. This is where research carried out by the Grains Research Development Council (GRDC) is helping her improve efficiency.

"Our farm does not receive any subsidies so we are really conscious of our labour and machinery costs. We've taken the approach that to be the best farm possible we have to adopt new technology to make sure we are really efficient."

The farm's biggest challenge is to use the available water as efficiently as possible. "We don't irrigate our cereals crops, which makes rainfall our limiting factor.

"Along with other farms in South Australia, our benchmark for success is how many kilogrammes of grain we produce per hectare per millimetre of rainfall."

SHARING WEATHER DATA

Wheat is planted around Anzac Day in late April through to mid-May, allowing the crop to take advantage of winter rainfall before harvesting in November. The varieties do not require vernalisation for flowering, as winter is mild so sowing dates and variety choice are carefully scrutinised and aligned with changes in day length.

Weather stations are strategically placed around the farm, and for the past five years these have been used to make detailed weather mapping plans to help guide sowing date decisions.

The farm is also part of a network of local growers, who share best practice, farming strategies and ideas.

"As an example of how we work together, we now have real-time, web-based plant available water monitoring systems, which are integral to the way we work.

"There are about 11 farms which have soil moisture probes; this gives us a great insight into our soil moisture levels, and allows us to estimate at any time in our season what our yields are going to be."

Ms Cay explains that the reason for doing this is that crop yields are limited by water. "We need to match our nitrogen application to drive the yield potential we believe is available for that season.

"In a good year we will put more nitrogen on, in a bad year, less – every millimetre of rainfall will affect how we manage our crop. If we put too much N on, we will bulk up our crop and put on too much biomass that won't be sustained to produce the yield at the end."

BREEDING

Innovations in plant breeding are also helping push production, Ms Cay says.

The farm's soils contain high levels of boron and transient salinity, so producing varieties that can cope with these stresses has been critical.

"The council, over the past 15 years, has funded the development of new varieties that have greatly increased yields. One of the advancements has been a resistance gene for boron toxicity, which has been important for us."

A previous breeding breakthrough introduced cereal cyst nematode resistance into varieties, which changed the face of our farming, she adds.

AUSTRALIAN GRAIN

Farming facts

* Australian farmers produce 93% of country's daily food supply
* Each farmer produces enough food to feed 600 people (150 domestically, 450 overseas)
* Three main grain growing regions in Australia
* Most Australian grain produced only using natural rainfall
* Half of Australian grain farms are mixed farms with livestock, 50% specialised arable farms
* In 2015, Australian farms forecast to produce 38.7m tonnes of grain

Cropping facts

22.9m ha of winter crops planted:

* Barley – 4m ha (8.2m tonnes)
* Canola (OSR) – 2.3m ha (3m tonnes)
* Wheat – 13.8m ha (23.6m tonnes)
* 1m ha of summer crops planted (3.8m tonnes) – mainly grain sorghum, rice and cotton
* 65% of Australian wheat exported (worth AUD23m to economy). About 10% of global export market

Key challenges for Australian grains industry

* Climate variability and water use
* Heat and frost
* No-till farming led to weeds, pest and disease challenges
* Low fertility soils
* Shifts in market demands (gluten intolerance, Asian demand for red meat)
* Grower profitability (input and labour costs high)

Belinda Cay is using technology to cut the cost of growing cereals.

JOHN EVESON/FLPA/REX SHUTTERSTOCK

CSIRO RESEARCH

* Researchers are developing automatic sensors that allow breeders to obtain key information about new varieties much more rapidly.

This will speed up the process of bringing new varieties to market.

The researchers, funded by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, have developed a golf buggy "Phenomobile."

The high-clearance buggy has laser scanning capabilities that can produce a 3D representation of the crops.

It is aimed at measuring characteristics that don't change very quickly, such as crop height, leaf angle, spike numbers and even biomass, explains CSIRO researcher Jose Jimenez-Berni, based near Canberra.

"Everything we know that can give us some useful information we have added to the machine's capabilities and it is all collected by a computer at the back."

But it is expensive and not very portable, so CSIRO developed a lite-version, with simple software for operation and which is much easier to take through crops, explains Mr Jimenez-Berni.

The system simplifies the capture of data – for example, automatically recording crop height or leaf angle rather than being done manually with a tape measure or protractor, he says.

"We can even measure spike numbers, which previously would have to be done in a laboratory," he adds.

More complicated measurements can be made, too. For example, comparing which varieties are photosynthesising for longer during the maturity phase, which could be an indicator of longer grain feeling that could provide better grain quality attributes.

Other equipment has been developed to take readings of variables that could change more rapidly, such as crop temperature.

"Cooler temperatures, for example, are an indicator for high transpiration rates, so could be used to help select for varieties with better water use efficiency," Mr Jimenez-Berni notes.

RESEARCH AND INNOVATION KEY TO FEEDING A GROWING GLOBAL POPULATION

* One hundred young people from around the world highlighted research and innovation to intensify or develop new production systems as a key driver for feeding a growing population.

The delegates at Bayer CropScience's Youth Ag-Summit in Canberra also highlighted the need for education about agriculture to the wider public, building skill levels of farmers and advisers, and tackling food waste and consumption.

These themes were built into the Canberra Youth Ag-Declaration, a global call for action to help solve the pressing issues facing agriculture and food security.

This declaration was presented in October to the UN's Committee on World Food Security in Rome.

The other area Ms Cay is conscious of is crop rotation.

"Continuous wheat is not possible because of soil-borne diseases," she says. "So we use a wheat, barley, lentils or chickpeas rotation on some fields, while on others it is a wheat, barley, oilseed rape rotation."

Oaten hay, which they export to Japan, has also been introduced to the rotation partly because it is an incredible weed and disease break.

"Again, through the work of the GRDC we have learned a lot about the science behind our rotations and how we can manage them to be more effective weed and disease managers."

WEEDS

Resistant weeds are a huge challenge in Australia, so another part of the farm's integrated weed management plan is to either burn the windrow dropped by the harvester or use a chaff-cart to capture all the chaff at harvest. This chaff is then either fed to livestock or burned in piles.

This can remove 80-90% of the weed seeds otherwise returned to the field in the header chaff and straw streams. Crops are direct-drilled, inter-row sowed into the previous crop's stubbles.

"It's really important to retain our stubble to help protect against the strong summer winds and during the crop establishment phase each year. If we didn't we would lose our topsoil, which is only 15cm deep."

SOIL MOISTURE

No-tillage systems also retain more water, so it allows less evaporation over the harsh summer months, where temperatures can reach more than 45C.

"Last summer we had five consecutive days of temperatures of over 46C, so it is a pretty harsh environment. Moisture is also crucial, and these stubble retention systems have helped push our average yields over 3t/ha using only rainfall-fed crops."

Improvements in the direct-drill system are also being researched by Ms Cay's brother, James Barr, as part of his GRDC-funded PhD to reduce the risk of soil erosion.

"James is working on a new bent-leg seeding tine, which instead of ripping a line in the soil, actually lifts the soil up and puts it down on to the seed, and minimises soil throw."

Every square metre of the farm is mapped using satellite systems to determine the topography, soil type and salinity and then yield maps are overlaid. That has helped match inputs to potential outputs.

GRAINS RESEARCH DEVELOPMENT COUNCIL

* Levy of 99c/t (46p/t) of grain matched by government funding for Grains Research Development Council research
* Budget of $195m/year (£90m)
* Funds about 1,100 projects

Projects include

* National Frost Initiative to help protect crops against late frosts
* Omega-3 oilseed rape breeding
* Ultra-low gluten barley
* Breeding for more water efficient crops
* Increasing nutrient efficiency in crops through better application
* Smartphone apps for decision support

"For example, we have found some areas that are susceptible to frosts in August when grains are flowering, and we can lose up to 15% of the yield. So we monitor those areas separately and, if necessary, will cut affected areas for hay.

"It is thanks to these types of technologies that our family farming business is successful," Ms Cay concludes.

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14.0 Good reads

GRDC, 'Unmanned aerial vehicles (UAVs) – how can they help agronomists?', Cladwell, L, February 2015 http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Unmanned-aerial-vehicles

CSIRO, 'Smart Farming: Leveraging the impact of broadband the digital economy', 2013, https://publications.csiro.au/rpr/download?pid=csiro:EP137659&dsid=DS2

Australian Government: Chief Scientist, 'Australian 2025: Smart Science – Agriculture', 2014, http://www.chiefscientist.gov.au/2014/07/australia-2025-smart-science-agriculture/

ABC Rural, 'Grower seeing the good in drones for precision agriculture', Coote, G, October 2013, http://www.abc.net.au/news/2013-10-11/grain-farmer-seeing-the-good-in-drones/5016072

IFL Science , 'Farmers of the future will utilise drones, robots and GPS', March 2015, Thomasson, A, http://www.iflscience.com/technology/farmers-future-will-utilize-drones-robots-and-gps

15.0 References

Australian Bureau of Statistics, 'Internet Activity, Australia June 2008', 2008, http://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/41BFD19AD2AA50EACA25758D0023D847?opendocument

Grains Research and Development Corporation, 'National R&D Strategy', 2011, https://www.grdc.com.au/uploads/documents/Grains_Industry_National_RDE_Strategy.pdf

Nuffield International, 'Potential of Unmanned Aerial Vehicles (UAVs) in the grains industry', Boughton, B, November 2014 http://www.nuffieldinternational.org/rep_pdf/1438074605BenBoughtonNuffieldReport_Final.pdf

Landline, High Tech Farming, Fiona Breen, August 2014 http://www.abc.net.au/landline/content/2014/s4073139.htm

ABC, 'On the farm in 70 Years – Farmer Predictions', 2015, http://www.abc.net.au/news/2015-05-12/on-the-farm-in-70-years-farmer-predictions-2085/6538152

CSIRO, 'Aussie farmers take a byte out of Big Data', 2013, https://blog.csiro.au/aussie-farmers-take-a-byte-out-of-big-data/

Business Insider Australia '15 Emerging Agriculture Technologies That Will Change the World', Zappia, M, May 2014 http://www.businessinsider.com.au/15-emerging-agriculture-technologies-2014-4

Bureau of Meteorology, 'Map Information – Normalised Differentiation Vegetation Index', http://www.bom.gov.au/climate/austmaps/about-ndvi-maps.shtml

Australian Year of the Farmer, ' Australian Year of the Farmer Productivity Video', 2011, https://www.youtube.com/watch?v=_pb2fCoPmjw

Edutopia, 'Inventing Infographics: Visual Literacy Meets Written Content', July 2014, http://www.edutopia.org/blog/infographics-visual-literacy-written-content-brett-vogelsinger

Precision Ag, 'Precision Ag with RTK Guidance Systems', Knight.Q, May 2014, http://precisionag.com.au/files/2014/05/Precision-Ag-with-RTK-Guidance-Systems.pdf