THE SCIENCE OF LIVING SOILS

INVESTIGATING SOIL CHARACTERISTICS AND HEALTH BY IDENTIFYING ITS MACRO AND MICRO INVERTEBRATE POPULATIONS

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

AN ACTIVITY FOR SECONDARY SCIENCE OR 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

Pests, such as diseases, are an ongoing battle for farmers who work to grow cereal crops throughout Australia.

There are a range of control mechanism which farmers can use, however, research suggests that paddock management can be one of the best lines of offence. Paddock management includes strategies such as crop rotation, application of protection products and using good bugs to eat pest insects (integrated pest management). In this resource, students are tasked with assessing the health of a range of soils using nematodes and bacterial populations as an indicator of biological health.

Learning Outcomes

Students will investigate soil structure and function. They will take soil samples and assess nematode populations. Students will learn how to identify soil micro-invertebrates and other free living organisms, learn how living soil biology can be used to monitor soil health and determine the role of soil in food production. Science investigation skills, particularly those relating to field work, and reporting are strengthened through this unit.

Curriculum focus

- Explore the lithosphere, with particular focus on how organisms within this system are imperative to plants within the biosphere.
- Engage in scientific investigation through field work and analysis.
- Makes observations and record data to showcase scientific understanding
- Communicate findings appropriately

Australian curriculum content descriptions

Earth and Space Sciences

Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere (ACSSU189)

Planning and conducting

Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS199)

Processing and analysing data and information

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS204)

Communicating

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

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 and inquiry. You can use some of these lesson plans or all. Whatever you do, we hope you have fun teaching your students about the role of soils and their management in growing great grains.

	Introduction	Soils are one of the most important factors in ensuring food security. In fact, it is estimated that 95 per cent of all food is produced directly or indirectly on the soils. Engage students in thinking about the importance of soils by setting the scene.
	The scene	*Issue:* To produce good food, farmers must carefully manage their soils, keeping them healthy and living. Further, farmers must manage pests in their paddocks. Soil microorganisms can be beneficial or detrimental to a plant's health. Knowing your soil health is essential to producing good quality grain for human consumption. *Solution:* Farmers and scientists have developed a number of successful strategies to keep their soils healthy and disease-free. These include: • Rotating crops so that no one disease or insect can build up; • Using plant protection products; • Good crop hygiene; • Integrated pest management – where good bugs are used to eat bad bugs; and • Breeding of disease resistant varieties. *The task:* Investigate the soil biodiversity and then investigate soil health by reviewing the nematodes populations living in different soils. Develop a management plan for improving soil health.
	Read	For further understanding read the 'National Soil Quality Monitoring Framework', 2015, Grains Research and Development Corporation. This article outlines one theme of research and development 'Monitoring soil quality for better decision making' and notes how farmers need access to monitoring tools to enhance the management and monitoring of their crops. **http://www.grdc.com.au/Research-and-Development/UWA00138** Grain growers can now access soil data specific to their local area, including biology, chemistry and physical characteristics. This information is available at www.soilquality.org.au and is used by farmers to benchmark their own data for the betterment of decision making.
	Watch	For more information Watch 'Introducing soilquality.org.au', **http://soilquality.org.au/videos**
PAGE 8	**Investigation overview** Living soils	Students are to explore the field tests used by grain growers, agronomists and soil scientists. This overview outlines four activities which students can do which emulate these field practices and understandings. All or individual tasks can be used in combinations to explore this topic. Initially, teachers will need to arrange an area where students can set up soil quadrants for sampling. • Start by discussing with your group what you know about soil. Collect a sample from the quadrant and assess its characteristics. • Define the soil texture. • Determine the pH. • Investigate the soil nematodes and make an assessment of the soil health.

PAGE 9	**4.0 Activity** What is soil...	In groups, students are to discuss what they know about soils and explore the soil characteristics of a healthy soil.
PAGE 11	**5.0 Activity** Soil texture assessment	Using the table 'Field Texture of Soils' and the 'Soil Texture Triangle', students are to examine and identify soil type of each sample.
PAGE 14	**Soil Texture Diagram**	Guide to Texture by Feel I NRCS Soils. Modified from S.J. Thien. 1979. A flow diagram for teaching texture by feel analysis. Journal of Agronomic Education. 8:54-55. **www.nrcs.usda.gov.** Viewed online at: h**ttp://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311**
PAGE 15	**6.0 Insight** Soil pH	Students are to read through this insight about pH and its characteristics in soil and discuss as a class.
PAGE 16	**Activity** Testing soil pH	Students will need access to the digital pH probe which is suitable for using on soil and can digitally generate data onto their computer. Alternatively chemical soil pH testing kits can be purchased readily from the hardware store with the same learning outcomes applied. See more at: **http://www.grdc.com.au/Media-Centre/Hot-Topics/Soil-Acidity-in-WA#sthash.ElRewpcO.dpuf** And **www.vernier.com**
PAGE 18	**7.0 Insight** Measuring soil health	Students are introduced to soils at a microscopic level focusing on macro and micro inverterbrates. Soil nematodes As the focus for the following activity, use this insight to introduce students to the role of nematodes in the soil.
PAGE 21	**8.0 Activity** Soil nematode check!	This activity will need some preplanning as extracting nematodes from a sample can take more than a week. Students will need to collect enough soil from the quadrant to fill a medium sized tray. They will need to be provided with spade, medium size tray with mesh bottom, slightly larger solid tray, a sieve with mesh X number of microns and a microscope.
	Extension	If your students already have an understanding of macro and macroinvertebrates they could investigate the living organisms in the soil quadrant, draw and label the invertebrate and macroinvertebrate soils. Ask students to review what soil diversity means and make a soil web in relation to growing grains.
	Science Investigation report	Ask students to compare soils types between groups and determine which soil types are best for food production. They are to write a summary about what they discovered about the soil sample from their quadrant and in their discussion, talk about how their sample compares to the samples evaluated by their peers.
PAGE 26	**9.0 Research** Paddock Planning Scenario	Students are to research the life cycle and attributes of a Root-lesion Nematodes. The Grains Research & Development Corperation has produce a fact sheet on this nematode **www.grdc.com.au**

Investigation Overview
Living Soils

Soils host a quarter of the world's biodiversity. They are important for food security and are essential to support many diverse ecosystems. In fact, the FAO (Food and Agriculture Organization of the United Nations) estimates that 95% of the world's food is directly and indirectly produced on soils. They also state that healthy soils are the basis for healthy food.

"Soil is the materials that makes up the outermost layer of our planet. It is a mixture of broken rocks and minerals, living organisms, and decaying organic matter called humus. Natural processes can take more than 500 years to form one inch of topsoil" (Poarch 2013).

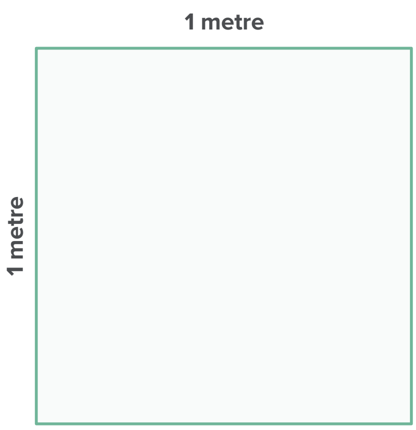
Soil health is essential to farming in Australia as soils and vegetation have an important relationship. Soils provide plants with essential nutrients, they hold water, provide an anchor point for the plant roots and provide a home for diverse array of vertebrates, invertebrates, fungi and bacteria. On the other hand, the vegetation helps prevent soil degradation, they stabilise the soil and maintain water and nutrient cycling (2015 International Year of the Soils).

The FAO, as part of the International Year of the Soil campaign released the following soil facts:

- Soils host a quarter of the planets biodiversity
- Soils is one of nature's most complex ecosystems
- Soil is one of the most diverse habitats on earth
- Over 1000 species of invertebrates can be found in a single meter squared of forest soils
- Nowhere in nature are species so densely packed as in soil communities
- A single gram of soil may contain millions of individuals and several thousand species of bacteria
- A healthy soil contains "tens of species" of nematodes.

ACTIVITY OVERVIEW
Living Soils

Divide into groups and find a range of different soil types throughout the school to investigate (i.e. the sand pit, veggie garden, school oval, under trees etc).



Map out a one meter by one meter quadrant. This is your study site. There are seven activities students can do with soil from this site:

1. What is soil – group discussion.
2. Investigate the living organisms in the soil quadrant, draw and label the invertebrate and macroinvertebrate soils.
3. Investigate the soil nematodes and make an assessment of the soil health.
4. Define the soil texture.
5. Determine the pH
6. Review what soil diversity means and make a soil web.
7. Compare soils types between groups and determine which soil types are best for food production.

4.0 ACTIVITY
What is soil...

Soil is the thin outer layer covering the land surface of the earth. It is made up of five main components:

- Mineral particles – such as sand, silt and clay
- Organic Matter - dead and decaying plants, animals and animal products
- Water
- Air – this fills the space (or pores) between the soil particles
- Organisms – living organisms such as micro invertebrates and macro invertebrates.

These five components constantly interact with one another (Carey and Harms 2006) and influence the overall soil composition.

Group Discussion

- Discuss what different soils students might have seen.

- Discuss what interactions might occur in the soil (what makes soils different colours?

- Why is soil important?

Characteristics of a Healthy Soil

According to the Soil Health Knowledge Bank there are six characteristics of a healthy soil. Below are some key words from each of these six measurable characteristics.

DISCUSS:

Discuss each of these points and talk about what each of these mean, and what would make it healthy vs unhealthy. If you were a farmer what would you do to maintain the health of your soil...

Healthy soils = healthy plants = healthy people!

5.0 ACTIVITY
Investigating Soil Texture

Soil is made of three core particle sizes – sand, silt, and clay. Soil textures depend on the amount (ratio) of each of these particles in the soil (Martin et al 1993).

Sand is the largest particle; these particles are 0.05-2 mm in diameter.

Silt is the particle in the middle; the diameter of these particles is 0.05 – 0.002 mm.

Clay is the smallest of the soil particles. The diameter of clay particles is less than 0.002 mm.

(Image source: Martin et al 1993, page 7)

Soils are put into texture classes by the way they feel and respond to handling (Poarch 2013).

- Sand feels gritty and the grains do not stick together when squeezed.
- Silt feels velvety or like flour when dry and forms a "ribbon" when wet.
- Dry clay feels smooth, clods are very hard and difficult to crush by hand. Wet clay feels sticky or smooth.

ACTIVITY OVERVIEW
Soil Investigation

Equipment

- Ice cream containers or kitty litter containers to collect and view soil
- White placemat (or clean white pieces of A4 paper)
- Spade
- Hand lenses or dissection microscope

Methodology

- Head out and collect THREE different samples of soil from around your school. Try under a tree, a bare patch and perhaps a school garden.
- Put a handful of on your sample mat (i.e. your white piece of paper).
- Spread the soil thin so that you can observe it closely.
- Use the hand lens to observe the sample of soil and record your observations.
- Now place a sample of soil under a dissection microscope then a microscope. Record what you see.
- Repeat with each soil sample.
- Complete the tables on the next page.

Hand lens	Hand lens	Hand lens

Microscope	Microscope	Microscope

HINT:

When you looking at your soil consider their different properties. '**Properties** are characteristics or attributes that describe matter' (Poach 2013). The properties you should consider are:

- **Texture:** This considers the composition of the soil i.e. is it made up of sand, a silt, clay or organic matter – or a mixture of all! The composition determines the look and feel of the soil.
- **Living organisms:** What can you see in the soil which might be living?
- **Colour:** What colour is it? (Fun Fact! Geologists officially recognize over 170 different soil colours (Poarch 2013). Usually (but not always) the darker a soil, the more nutrient rich it is. The darker colour indicates an increase in decomposed organic (humus).

SAMPLE 1: Notes

SAMPLE 2: Notes

SAMPLE 3: Notes

ACTIVITY: Soil Texture Assessment

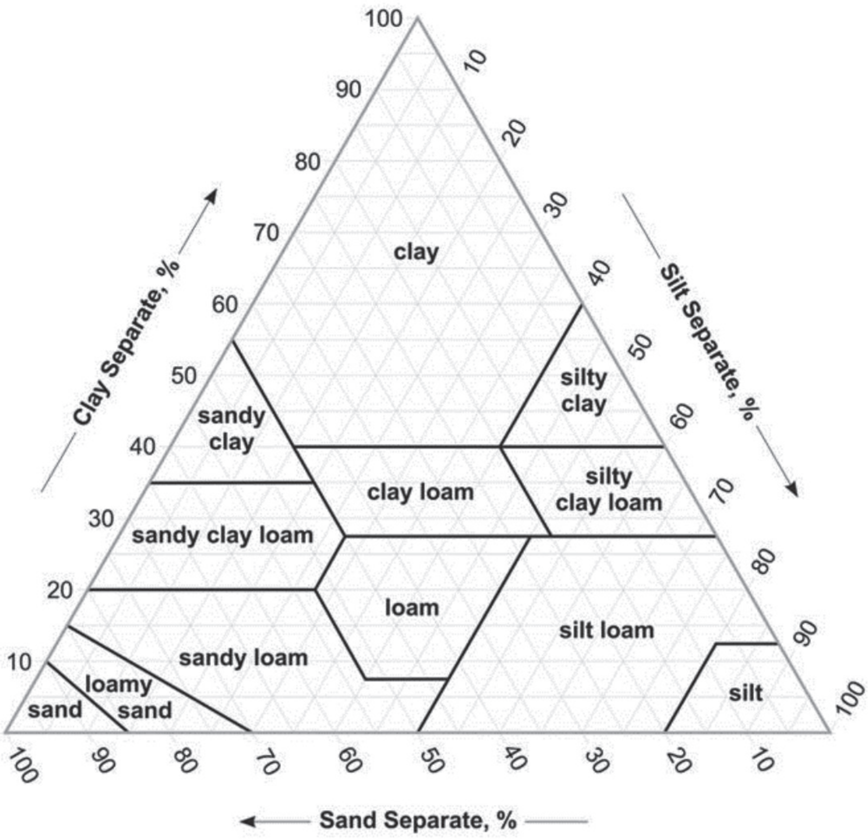
Now that you have taken an initial look at your soil, it's time to classify it. Use the below field texture of soils table and the soil texture triangle to classify the texture class of a soil. To do this, you need to take a handful of your soil and wet it (add the same amount as you would to make a scone dough). Then work through the steps outlined in the table.

Field Texture of Soils

STEP 1: Take a handful of soil and wet it (add as much water as you would when making a bread or scone dough).	**Length of Ribbon**	**Texture Grade**	**Approx. Clay Content**
STEP 2: Try rolling the soil into a ball… What happens now gives you a clue to the soil texture (i.e. what % of clay, silt, sand and organic matter)			
• Ball is smooth and feels like plastic. When handled feels like rigid plasticine and can be moulded into rod without cracking.	>75mm Firm resistance when made into ribbon	**Heavy Clay**	>50%
• Ball is smooth and feels like plastic. When handled feels like plasticine and can be moulded into rod without cracking.	>75 mm Moderate resistance when made into ribbon	**Medium Clay**	45 – 55%
• Ball feels like plastic. Smooth to touch	Approximately 75 mm Moderately hard to mould into ribbon	**Light medium clay**	40 – 45%
• Ball feels like plastic. Smooth to touch	50 – 75mm Can be a little hard to mould into ribbon.	**Light Clay**	
• Ball feels like plastic. Small to medium grains of sand can be seen and felt in clayey texture when made into a ribbon.	50 – 75mm	**Sandy clay**	35 – 40%
• Holds together well, feels smooth. When moulded into ribbon feels plastic and often silky to touch.	40 – 50mm	**Silty, Clay Loam**	
• Hold together well, feels plastic like. Medium size grains of sand can be seen	40 – 50 mm	**Clay Loam, Sandy**	30 – 35%
• Hold together well, feels plastic like. When made into ribbon feels smooth.	40-50 mm	**Clay Loam**	<30%
• Holds together strongly, sandy to touch, medium grains of sand	25 – 40 mm	**Sandy Clay Loam**	
• Holds together, when made into a ribbon feels smooth to silky	Approximately 25mm	**Silty Loam**	
• Holds together well and feels spongy. When made into ribbon feels smooth. Does not feel very sandy. Sometimes feels greasy if has a lot of organic matter (e.g. broken down leaves).	Approximately 25mm	**Loam**	25%
• Holds together but sandy, medium sized grains of sand and can be seen easily	Small ribbon of approximately 5 – 25mm	**Sandy Loam**	10 – 20%
• Holds together slightly, sticky when wet, lots of sand grains stick to fingers, clay stains hands	Small ribbon 5 – 15mm	**Clayey sand**	5 – 10%
• Holds together slightly	Small ribbon of approximately 5mm	**Loamy Sand**	
• Ball easily breaks down, cannot be moulded, singular grains of sand stick to fingers	Cannot be made into ribbon	**Sand**	< 5%

Source: SoilQuality.org.au & Dr Katharine Brow

Now, mark on the soil texture diagram (right) where you soil sits... This enables you to define your soil type.



Source: USDA http://www.nrcs.usda.gov/

SAMPLE 1: Texture

SAMPLE 2: Texture

SAMPLE 3: Texture

6.0 INSIGHT
Soil pH

Soil Chemistry is another important soil characteristic. Specifically, the pH of a soil can influence plant health by affecting its ability to absorb nutrients. If a soil is too acidic, the nutrients will be dissolved too quickly, and will leach away as the water drains. If a soil is too alkaline then nutrients will not dissolve quickly enough (Poarch 2013).

The pH of a soil can affect cereal crop growth and productivity – many areas throughout Australia's wheat belt face these conditions so knowing a soils pH is important so a management plan can be developed.

Some points about soil pH:

- The pH scale ranges from 0 to 14. Soils with pH above 7 are basic or alkaline. Soils with pH below 7 are acidic. A soil with a pH of 7 is neutral.
- Plants can be sensitive to soil ph – acidic or alkaline soils need to be carefully managed to ensure plant growth and development.
- Soil pH is a measure of the concentration of hydrogen ions (acid) dissolved in the soil water.
- Most good agricultural soils have a pH between 5 and 7 (Poarch 2013).
- Acidic soils are problematic due to their lack of nutrients.
- Alkaline soils may contain too much sodium for many plants. Further, some trace elements become more soluble at lower pH (for example aluminium (Al), which is toxic to plants, reducing shoot and root growth).
- The pH of soil is an important factor in determining which plants will grow because it controls which nutrients are available for the plant to use" (Vernier 2016).
- Lime can be added to acidic soils to help neutralise hydrogen ions.
- In South Australia there are over 2 million hectares of alkaline cropping soils (pH 8.0 plus); of which 1 million hectares are highly calcareous in the root zone (reference: Alkaline Soils Group).
- pH of soil controls which nutrients are available for the plants to use. As a general rule macronutrients are more available in soil with high pH and micronutrients are more available in soil with low pH (Vernier 2016).
- About 14.25 million hectares of WA wheatbelt soils are acidic or at risk of becoming acidic to the point of restricting crop yields.

See more at: http://www.grdc.com.au/Media-Centre/Hot-Topics/Soil-Acidity-in-WA#sthash.ElRewpcO.dpuf

And www.vernier.com

RESEARCH:

Plants require nutrients to grow, function and reproduce. Three of the primary plant nutrients are – nitrogen, phosphorus, and potassium. Because plants need them in large quantities, they are called *macronutrients.*

- Google common fertilisers and research their ingredients
- Make a table of plant macro and micro nutrients, researching what role each one plays in the plant.
- What symptoms would plants have if there was a nutrient deficiency or toxicity? Can you think of an experiment to test this?

ACTIVITY
Testing soil pH

It is possible to test the pH of a soil using a Soil pH Probe.

Follow the protocol to determine the soil pH of the three soils.

1. Gear up! Wear lab coats and safety glasses. Dust masks are available if needed.
2. Work in teams of two to collect three different soils from your local environment. Collect samples in a clean 500ml beaker. Ensure each beaker is labelled with the date and location of the sample. It is good practice to have a map and locate your sample collections on a map. You will also need a control, in this case it is ok to use distilled water which should be neutral.

MATERIALS

- computer
- distilled water
- Vernier computer interface
- 3 soil samples
- Logger Pro
- Two 250 mL beakers
- Vernier pH Sensor
- Wash bottle with distilled water
- 100 mL graduated cylinder
- 2 plastic spoons
- waste cup
- paper towels

NOTE THIS PROTOCOL WAS OBTAINED FROM VERNIER
Vernier (2016) Sample Labs Soil pH. Viewed online at: http://www2.vernier.com/sample_labs/ESV-06-COMP-soil_ph.pdf

PROCEDURE

1. **Prepare the water-soil mixture.**
   a. Label two beakers "A" and "B".
   b. Place 50 g of Soil A into Beaker A. To avoid cross-contamination of the soils, leave this spoon in the beaker.
   c. Using a new spoon, place 50 g of Soil B into Beaker B. Leave the spoon in the beaker.
   d. Add 100 mL of distilled water to each beaker.
   e. Stir both mixtures thoroughly.
   f. Stir once every three minutes for 15 minutes.
   g. After the final stirring, let the mixtures settle for about five minutes. This allows the soil to settle out, leaving a layer of water on top for you to take your pH measurement. Continue with Steps 2–5 while you are waiting.

2. **Connect the pH Sensor to the Vernier computer interface.** Important: For this experiment your teacher already has the pH Sensor in pH soaking solution in a beaker; be careful not to tip over the beaker when connecting the sensor to the interface.

3. **Prepare the computer for data collection by opening the file "08 Soil pH" from the *Agricultural Science with Vernier* folder.**

4. **Calibrate the pH Sensor.**
   - If your teacher directs you to use the stored calibration, proceed to Step 5.
   - If your instructor directs you to perform a new calibration for the pH Sensor, follow this procedure.

   First Calibration Point
   - Choose Calibrate } CH1: pH from the Experiment menu and then click.
   - Place the sensor tip into the pH-7 buffer. Type 7 (the pH value of the buffer) in the edit box. When the displayed voltage reading for Reading 1 stabilizes, click.

   Second Calibration Point
- Rinse the sensor with distilled water and place it in the pH-10 buffer solution.
- Type 10 (the pH value of the buffer) in the edit box.
- When the displayed voltage reading for Reading 2 stabilizes, click , then click.

5. **Measure the pH.**
- Carefully place the tip of the pH Sensor into the liquid part of Beaker A. If your sensor has a glass bulb at the tip, make sure it is covered by the water.
- Note the pH reading in the meter.
- If the reading is stable, simply record the pH value in the data table.

6. **If the reading is fluctuating, determine the mean (or average) value. To do this:**
- Click to begin a 10 second sampling run. Important: Leave the probe tip submerged for the 10 seconds that data is being collected.
- When the sampling run is complete, click on the Statistics button, to display the statistics box on the graph.
- Record the mean pH value in your data table.

7. **Rinse the pH Sensor with distilled water and repeat Steps 5 and 6 for the sample in Beaker B.**

8. **Rinse the pH Sensor with distilled water and return it to its storage container.**

9. **Your instructor will tell you whether you should keep the soil for further testing or clean up at this time.**

PROCESSING THE DATA

1. **Are the soils acidic, basic, or neutral?**
   a. SOIL 1:
   b. SOIL 2:
   c. SOIL 3:

2. **Looking at the below figure which indicates how pH affects a plants ability to absorb and utilise plant nutrients, look at your soils and suggest which nutrients might be in short supply for each of the soils?**
   a. SOIL 1:
   b. SOIL 2:
   c. SOIL 3:

EXTENSIONS

1. **Research how farmers adjust the pH of soils. Design and conduct an experiment to test the effectiveness of their methods.**

7.0 INSIGHT
Measuring Soil Health

Now that students understand more about the texture, profile and characteristics of their soils, it is possible to take an even closer look at what is actually in their soils – at a microscopic level.

In a nut shell, soils are amazing! Here's why...

(reference: FAO (2015) International Year of the Soils. Viewed online at http://www.fao.org/soils-2015/en/)

Soil is one of the most diverse habitats on earth.

Over 1000 species of invertebrates can be found in a single meter squared of forest soils.

A single gram of soil may contain millions of individuals and several thousand species of bacteria.

A healthy soil contains "tens of species" of nematodes.

Soil communities are amazing - nowhere else in nature are species so densely packed.

Essentially, the health of a soil can also be measured by looking at the populations of macro and micro invertebrates.

Macro and micro invertebrate populations can be affected by:

- The plant species and/or rooting systems. The more plants the better! If there are no or limited plant populations, then the soil organic matter content is reduced which in turn reduces the range of habitats and foods for soil organisms.
- Chemical inputs: Some fertilisers or sprays can affect soil biology – both positively and detrimentally.
- Farming practices such as cultivation and tillage.

Farmers recognise that the quality and health of soils largely determines production and sustainability. They also recognise that improving soil biodiversity is vital to ensure soil health and subsequent crop production. Most farmers now use a range of sustainable soil management systems such as no-till cropping, crop rotations to minimise disease build-up and other conservation practices.

RESEARCH:

Farming systems also use fertilisers and a range of pesticides – while these can have a range of benefits such as providing nutrients to support plant growth, misuse or overuse can impact soil.

Soil nematodes

Soil nematode populations are of particular interest to research scientists in the agricultural sector.

Nematodes are a type of 'non segmented' worm that live in the soil. They are one of the most abundant forms of life on the earth. Nematodes are only 50 microns in diameter and about 1mm long or less (Jenkins 2015). Nematodes live mainly in soil where they feed on fungi, bacteria and other soil organisms and in some cases plant roots (these are considered parasitic nematodes – these are the ones which damage crop plants) (Jenkins 2015).

Nematodes are found in the top few centimetres of the soil. They live in the thin films of water surrounding soil particles, as they require water to move. They are generally found in well-structured soils with large pore spaces, or coarser soils, where food is easily available (Jenkins 2015).

According to Jenkins 2015 there are three main types of nematodes, as follows:

(reference: Jenkins, A. (2005) Soil Biology Basics – Nematodes. Viewed online at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0015/41640/Nematodes.pdf)

1. **Predaceous nematodes:** These nematodes feed on other nematodes. They eat larger nematodes by attaching themselves to their cuticle and scraping away until the prey's internal body parts can be extracted. They also eat bacteria, fungi, and small single celled organisms (protozoa). The digested pests are then added to the soil organic matter reserves. Some have become specialised predators of insects, known as entomopathogenic nematodes
2. **Parasitic nematodes:** Parasitic nematodes cause problems in agricultural production because they feed on plant roots and slow plant growth. In some cases they also allow the entry of fungal rots that destroy the roots. Agricultural cultivation tends to encourage an increase in parasitic nematodes over other species.
3. **Saprophytic nematodes:** Saprophytic nematodes are also known as decomposers because they break down organic matter in the soil, release nutrients for plant use, and improve soil structure, water holding capacity and drainage. They are usually the most abundant type of nematode in the soil.

What do they do in the soil?

(reference: Jenkins, A. (2005) Soil Biology Basics – Nematodes. Viewed online at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0015/41640/Nematodes.pdf)

Nematodes have some incredible roles within the soil. For example, they play an instrumental role in nutrient cycling. Nutrients such as ammonium (NH4 +), stored in the bodies of bacteria and fungi, are released when nematodes eat them. The bacteria and fungi contain more nitrogen than the nematodes need so the excess is released into the soil in a more stable form where it can be used by plants or other soil organisms.

Nematodes also physically break down organic matter which increases its surface area, making it easier for other organisms to break it down further.

They assist in the dispersal of microbes... Bacteria and fungi cannot move around in the soil without 'hitching a ride' inside or on the back of nematodes. Nematodes are parasitised by some bacteria and fungi, which helps their dispersal through the soil.

They are also important for disease and pest control as beneficial nematodes attack and kill a range of pests such as borers, grubs, thrips and beetles with negligible effects on non-target species.

Why are nematodes good biological indicators?

When we want to measure the health of an environment or ecosystem, we can look for the presence of certain species that should exist if conditions are healthy.

There are a number of reasons why nematodes are commonly used as biological indicators:

- Nematodes occur in all soils. Even in relatively poor soils, there will be up to a million individuals in every square metre
- Nematodes are readily extracted from soil and their food sources can be determined by looking at their mouth parts under a microscope. Different mouth designs indicate what sort of food nematodes eat.
- Nematodes feed on plant roots and on all the organisms that live in soil (e.g., bacteria, fungi, algae, diatoms, protozoans, rotifers, tardigrades, arthropods, oligochaetes and other nematodes). Thus, the number and types of nematodes in soil is determined by the availability of these food sources
- Nematode numbers fluctuate in response to the population dynamics of the organisms they consume, and are also influenced by the soil physical and chemical environment.
- The ratios of different species indicates if the food web is disturbed, maturing, structured or degraded (NSW DPI)

What is nematode community analysis?

Nematode community analysis involves the following steps:

- A representative soil sample is collected from a field, usually in late summer, or 2-3 months before a winter crop is due to be planted
- Nematodes are extracted from the sample and all the nematodes are identified Information on the nematodes present, their feeding habits and their population densities is used to draw conclusions about the soil's biological status

If the soil tested is healthy, it will have the following characteristics:

- High numbers of free-living nematodes
- A low population of pest nematodes such *Pratylenchus*
- A nematode community that is dominated by free-living nematodes rather than plant parasites
- A diverse range of nematodes, and a good balance between bacterial and fungal feeders
- Relatively high populations of omnivores and predators

8.0 ACTIVITY
Soil Nematode

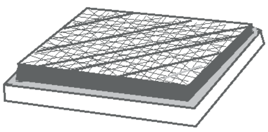
Your task is to test the samples of three different soils from around your school and assess their nematode and bacterial composition.

NOTE: Information for this experiment were kindly provided by Dr Katherine Linsell Senior Research Officer – Nematology, SARDI - Plant & Soil Health

STEP 1: SOIL COLLECTION

Dig up a shovel full of the soil (around 500g or half a bag) to be tested (numerous samples can be collected from throughout the target paddock). Try getting a range of samples:

- high v low in organic matter (OM)
- compacted v not compacted
- clay v silt



STEP 2: EXTRACTION

- Take the black mesh tray and line it with tissues.
  Fill this up to the top with your soil sample, include the leaf matter and soil.
- Place black tray into larger white tray
- Add water onto the soil until completely saturated
- Leave for 1 week if possible.

STEP 3: SIEVING

- The nematodes will float into the water in your sample tray.
  Carefully, tip water from white tray through the metal sieve.
  The nematodes will collect on the sieve plate.
- Gently squirt the sieve with water so the water rises the nematodes off of the sieve plate into your collection cup.

STEP 4: MICROSCOPY

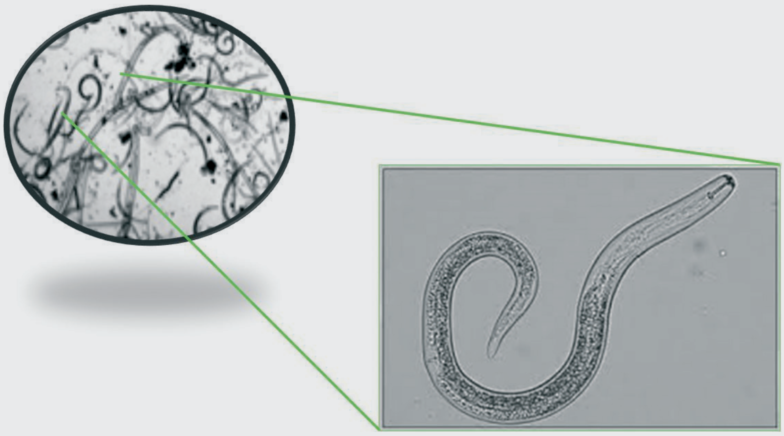
- Look at the diversity and abundance of microfauna under the microscope.
  Refer to the checklists and see if you can identify:
- Nematodes?
- Bacteria?
- Protozoa?

Know Your Nematodes

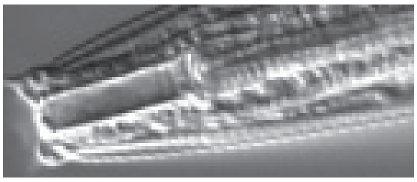
Refer to the images below to help identify your nematode species.

Look carefully at their mouthparts...

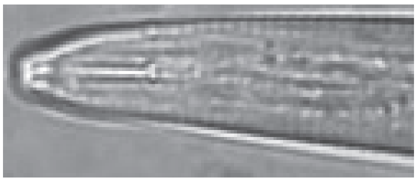
NOTE: This image was kindly provided by Dr Katherine Linsell Senior Research Officer – Nematology, SARDI - Plant & Soil Health



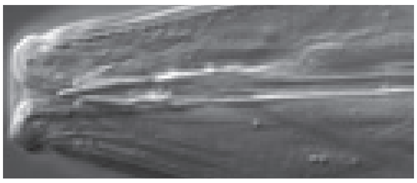
Nematodes



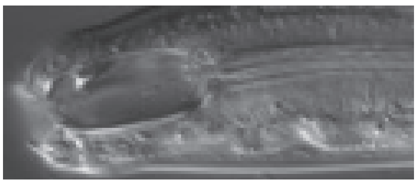
Bacterial-feeders



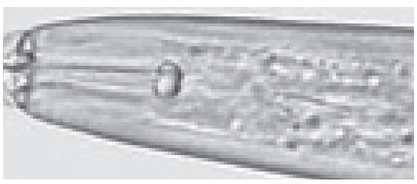
Fungal-feeders



Omnivores eat a variety of organisms



Predatory nematodes eat all types of nematodes and protozoa



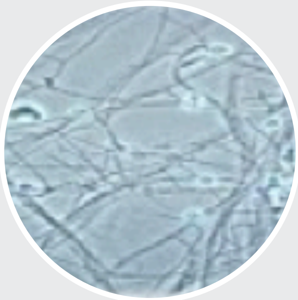
Root-feeders are plant parasites
- feed by puncturing the cell walls and sucking out the internal contents

Soil Biology:
Bacteria, Fungi, protozoa and arthropods

An incredible diversity of organisms make up the soil food web. They range in size from the tiniest one-celled bacteria, algae, fungi, and protozoa, to the more complex nematodes and micro-arthropods, to the visible earthworms, insects and plants.

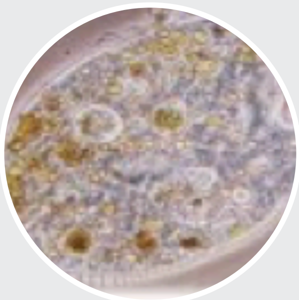
Bacteria

- tiny, one-celled organisms
- A teaspoon of soil contains between 100 million and 1 billion bacteria



Fungi

- multicellular organisms that usually grow as long threads of strands called hyphae
- push their way between soil particles, roots and rocks



Protozoa

- single-celled organisms that feed primarily on bacteria, but also eat other protozoa, soluble organic matter and sometimes fungi

Arthropods

- get their name from their jointed (arthros) legs (podos)
- Invertebrates, no backbone but an exoskeleton
- Spiders, mites, millipedes and centipedes

Images courtesty of Dr Katherine Linsall, SARDI.

Nematode Worksheet

1. Draw the nematodes you have found in your nematode wash.

2. Report your results:
Which organisms did you observe?
Use the following abbreviations to indicate how many you estimate were present in your sample.

VA – Very Abundant
A – Abundant
NVA – Not very abundant
NP – Not Present

SOIL TYPE	ORGANISM 1 NEMATODES	ORGANISM 2 BACTERIA	ORGANISM 3 FUNGI	ORGANISM 4 PROTOZOA	ORGANISM 5 ANTHROPODS
HIGH OM					
LOW OM					
NOT COMPACTED					
COMPACT					
CLAY					
SILT					

3. Do you believe your sample is a healthy or unhealthy soil? Explain why?

4. What could farmers do to improve the health of their soil?

5. Research the Cereal Cyst nematode – why are these a problem for Australian farmers and how are they managed?

9.0 ACTIVITY
Paddock Planning Scenario

1. Research the life cycle of the Root-Lesion Nematode. Draw this lifecycle.

2. How does the root lesion nematode affect plants?

3. How do farmers manage the root lesion nematode?

4. How is DNA used to measure the soil nematode populations?

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