# Regenerative Agriculture: Professional Learning for Educators

Edition 1


*Brought to you by the*
*Regenerative Agriculture Alliance*
*at Southern Cross University*

Southern Cross University

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Resilience through farming together

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*The delivery of this program is possible through the Australian Government's Agricultural Innovation Hubs Program.*

Australian Government
Department of Agriculture, Fisheries and Forestry

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SQNNSW Innovation Hub

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# Professional Standards, Curriculum and Syllabus Alignment

## Australian Professional Standards for Teachers

This professional learning aligns with the Australian Professional Standards for Teachers

| Graduate | Proficient | Highly Accomplished | Lead |
|---|---|---|---|
| **Domain: Professional Knowledge** | | | |
| Standard 2: Know the content and how to teach it | | | |
| Focus area 2.2: Content selection and organisation | | | |
| Organise content into an effective learning and teaching sequence. | Organise content into coherent, well-sequenced learning and teaching programs. | Exhibit innovative practice in the selection and organisation of content and delivery of learning and teaching programs. | Lead initiatives that utilise comprehensive content knowledge to improve the selection and sequencing of content into coherently organised learning and teaching programs. |
| **Domain: Professional Engagement** | | | |
| Standard 6: Engage in professional learning | | | |
| Focus area 6.2 Engage in professional learning and improve practice | | | |
| Understand the relevant and appropriate sources of professional learning for teachers. | Participate in learning to update knowledge and practice, targeted to professional needs and school and/or system priorities. | Plan for professional learning by accessing and critiquing relevant research, engage in high-quality targeted opportunities to improve practice and offer quality placements for pre-service teachers where applicable. | Initiate collaborative relationships to expand professional learning opportunities, engage in research, and provide quality opportunities and placements for pre-service teachers. |
| **Domain: Professional Engagement** | | | |
| Standard 6: Engage in professional learning | | | |
| Focus area 6.3 Engage with colleagues and improve practice | | | |
| Seek and apply constructive feedback from supervisors and teachers to improve teaching practices. | Contribute to collegial discussions and apply constructive feedback from colleagues to improve professional knowledge and practice. | Initiate and engage in professional discussions with colleagues in a range of forums to evaluate practice directed at improving professional knowledge and practice, and the educational outcomes of students. | Implement professional dialogue within the school or professional learning network(s) that is informed by feedback, analysis of current research and practice to improve the educational outcomes of students. |
| **Domain: Professional Engagement** | | | |
| Standard 7: Engage professionally with colleagues, parents/carers and the community | | | |
| Focus area 7.4 Engage with professional teaching networks and broader communities | | | |
| Understand the role of external professionals and community representatives in broadening teachers' professional knowledge and practice. | Participate in professional and community networks and forums to broaden knowledge and improve practice. | Contribute to professional networks and associations and build productive links with the wider community to improve teaching and learning. | Take a leadership role in professional and community networks and support the involvement of colleagues in external learning opportunities. |

## Australian Curriculum Syllabus

| Year Level | Design and Technologies | Science | Geography |
|---|---|---|---|
| 7 | **Knowledge and understanding**<br>Analyse how food and fibre are produced when designing managed environments and how these can become more sustainable (ACTDEK032) | **Biology**<br>Interactions between organisms, including the effects of human activities can be represented by food chains and food webs (ACSSU112)<br>**Earth and space**<br>Some of Earth's resources are renewable including water that cycles through the environment but others are non-renewable (ACSSU116) | **Water in the world**<br>The classification of environmental resources and the forms that water takes as a resource (ACHGK037)<br>The way that flows of water connect places as it moves through the environment and the way this affects places (ACHGK038)<br>The nature of water scarcity and ways of overcoming it, including studies drawn from Australia and West Asia and/or North Africa (ACHGK040)<br>Economic, cultural, spiritual and aesthetic value of water for people, including Aboriginal and Torres Strait Islander Peoples and peoples of the Asia region (ACHGK041) |
| 8 | **Knowledge and understanding**<br>Analyse how food and fibre are produced when designing managed environments and how these can become more sustainable (ACTDEK032) | **Biology**<br>Some of Earth's resources are renewable including water that cycles through the environment but others are non-renewable (ACSSU116) | **Landforms and landscapes**<br>Different types of landscapes and their distinctive landform features (ACHGK048)<br>Causes, impacts and responses to a geomorphological hazard (ACHGK053) |
| 9 | **Knowledge and understanding**<br>Investigate and make judgements on the ethical and sustainable production and marketing of food and fibre (ACTDEK044) | **Biology**<br>Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems (ACSSU176) | **Biomes and food security**<br>Distribution and characteristics of biomes as regions with distinctive climates, soils, vegetation and productivity (ACHGK060)<br>The human alteration of biomes to produce food, industrial materials and fibres, and the use of systems thinking to analyse the environmental effects of these alterations (ACHGK061)<br>Environmental, economic, and technological factors that influence crop yields in Australia and across the world (ACHGK062)<br>Challenges to food production, including land and water degradation, shortage of fresh water, competing land uses and climate change for Australia and other areas of the world (ACHGK063)<br>The capacity of the world's environments to sustainably feed the projected future global population (ACHGK064) |
| 10 | **Knowledge and understanding**<br>Investigate and make judgements on the ethical and sustainable production and marketing of food and fibre (ACTDEK044) | **Biology**<br>The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence (ACSSU185)<br>**Earth and space**<br>Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere (ACSSU189) | **Environmental change and management**<br>Human-induced environmental changes that challenge sustainability (ACHGK070)<br>The application of systems thinking to understanding the causes and likely consequences of the environmental change being investigated (ACHGK073) |

## Cross Curriculum Priorities

- Aboriginal and Torres Strait Islander histories and cultures
- Sustainability

## NSW Syllabus Curriculum

| Stage | Agriculture | Science | Geography |
|---|---|---|---|
| 4 | **AG4-1**<br>describes a range of plant species and animal breeds used in agricultural enterprises<br>**AG4-2**<br>outlines the interactions within and between agricultural enterprises and systems<br>**AG4-3**<br>identifies and explains interactions between the agricultural sector and Australia's economy, culture and society<br>**AG4-4**<br>implements responsible production of plant and animal products<br>**AG4-5**<br>identifies how agricultural products are used in industry and by consumers<br>**AG4-6**<br>identifies and uses skills to manage the interactions within plant production enterprises<br>**AG4-7**<br>identifies and uses skills to manage the interactions within animal production enterprises<br>**AG4-8**<br>examines the impact of past and current agricultural practices on agricultural sustainability<br>**AG4-9**<br>identifies aspects of profitability, technology, sustainability and ethics that affect management decisions<br>**AG4-10**<br>implements and appreciates the application of animal welfare guidelines to agricultural practices | **SC4-13ES**<br>explains how advances in scientific understanding of processes that occur within and on the Earth, influence the choices people make about resource use and management<br>**SC4-14LW**<br>relates the structure and function of living things to their classification, survival and reproduction<br>**SC4-15LW**<br>explains how new biological evidence changes people's understanding of the world | **GE4-1**<br>Locates and describes the diverse features and characteristics of a range of places and environments<br>**GE4-2**<br>describes processes and influences that form and transform places and environments<br>**GE4-3**<br>explains how interactions and connections between people, places and environments result in change<br>**GE4-4**<br>examines perspectives of people and organisations on a range of geographical issues<br>**GE4-5**<br>discusses management of places and environments for their sustainability<br>**GE4-6**<br>explains differences in human wellbeing |
| 5 | **AG5-1**<br>explains why identified plant species and animal breeds have been used in agricultural enterprises and developed for the Australian environment and/or markets<br>**AG5-2**<br>explains the interactions within and between agricultural enterprises and systems<br>**AG5-3**<br>explains the interactions within and between the agricultural sector and Australia's economy, culture and society<br>**AG5-4**<br>investigates and implements responsible production systems for plant and animal enterprises<br>**AG5-6**<br>explains and evaluates the impact of management decisions on plant production enterprises<br>**AG5-7**<br>explains and evaluates the impact of management decisions on animal production enterprises<br>**AG5-8**<br>evaluates the impact of past and current agricultural practices on agricultural sustainability<br>**AG5-9**<br>evaluates management practices in terms of profitability, technology, sustainability, social issues and ethics<br>**AG5-10**<br>implements and justifies the application of animal welfare guidelines to agricultural practices | **SC5-13ES**<br>explains how scientific knowledge about global patterns of geological activity and interactions involving global systems can be used to inform decisions related to contemporary issues<br>**SC5-14LW**<br>analyses interactions between components and processes within biological systems | **GE5-1**<br>explains the diverse features and characteristics of a range of places and environments<br>**GE5-2**<br>explains processes and influences that form and transform places and environments<br>**GE5-3**<br>analyses the effect of interactions and connections between people, places and environments<br>**GE5-4**<br>accounts for perspectives of people and organisations on a range of geographical issues<br>**GE5-5**<br>assesses management strategies for places and environments for their sustainability<br>**GE5-6**<br>analyses differences in human wellbeing and ways to improve human wellbeing |

## NSW Agriculture Stage 6 Syllabus

| Objectives | Preliminary course outcomes | HSC course outcomes |
|---|---|---|
| **Students will develop:**<br>1. knowledge and understanding of the physical, chemical, biological, social, historical and economic factors that interact in agricultural production systems | **A student:**<br>P1.1 describes the complex, dynamic and interactive nature of agricultural production systems<br>P1.2 describes the factors that influence agricultural systems | **A student:**<br>H1.1 explains the influence of physical, biological, social, historical and economic factors on sustainable agricultural production |
| 2. knowledge, understanding and skills required to manage agricultural production systems in a socially and environmentally responsible manner | P2.1 describes the biological and physical resources and applies the processes that cause changes in plant production systems<br>P2.2 describes the biological and physical resources and applies the processes that cause changes in animal production systems<br>P2.3 describes the farm as a basic unit of production | H2.1 describes the inputs, processes and interactions of plant production systems<br>H2.2 describes the inputs, processes and interactions of animal production systems |
| 3. knowledge of, and skills in, decision-making and the evaluation of technology and management techniques used in sustainable agricultural production and marketing | P3.1 explains the role of decision-making in the management and marketing of agricultural products in response to consumer and market requirements | H3.1 assesses the general business principles and decision-making processes involved in sustainable farm management and marketing of farm products<br>H3.2 critically assesses the marketing of a plant OR animal product<br>H3.3 critically examines the technologies and technological innovations employed in the production and marketing of agricultural products<br>H3.4 evaluates the management of the processes in agricultural systems |
| 5. knowledge and understanding of the impact of innovation, ethics and current issues on Australian agricultural systems | P5.1 investigates the role of associated technologies and technological innovation in producing and marketing agricultural products | H5.1 evaluates the impact of innovation, ethics and current issues on Australian agricultural systems |

Edition 1. The contents of this professional learning resource have been collated and developed by Lorraine Gordon, Simone Blom and Alison McGeary on behalf of the Regenerative Agriculture Alliance at Southern Cross University. With acknowledgement to Brian Wehlburg, Glen Chapman, Mathew Alexanderson, Kate Spry and Jacob Birch for their contributions. *Graphic design by Hiero Creative - hierocreative.com.*

# Introduction: Regenerative Agriculture: What will be covered?

Regenerative agriculture is complex, and it means a lot of different things to a lot of different people. One thing that is agreed upon however is that regenerative agriculture is an ongoing process of change that 'enables landscapes to renew themselves'.[1]

## Activity:

### Conventional or Regenerative?

Consider the following definitions:

*"Modern agriculture is underpinned by a colonial, industrial and productivist discourse.*

*Agricultural practices inspired by this discourse have fed billions but degraded socio-ecological systems. Regenerative agriculture (RA) is a prominent alternative seeking to transform food production and repair ecosystems".*[2]

*"Regenerative Agriculture integrates different farming approaches (Duncan 2015) to restore and realise the potential of damaged landscapes (Francis and Harwood 1985; Massy 2013, 2017; Wahl 2016)".*[3]

*"Regeneration is in part a self-organising quality inherent in nature, which many practices consciously or unconsciously encourage. This is a quality where every living system has inherit within it the possibility to move to new levels of order, differentiation and organisation. Whilst sustainable systems must maintain productivity, regenerative systems go a step further in restoring what has been lost and improving what is currently there".*[4]

➔ Discuss your thoughts on the following provocation, if we are not undertaking **regenerative agricultural practices**, are we using "conventional" agricultural methods?

## Activity:

### Defining Regenerative Agriculture

Consider the following passages from Gordon et al. (2023):

*"Modern agriculture operates on an industrial scale, relying on fossil fuel inputs, multinational companies and artificial fertilisers, pesticides and herbicides to grow output. It is inherently productivist, defined by Lowe et al. (1993) as committed 'to an intensive, industrially driven and expansionist agriculture with state support based primarily on output and increased productivity.'"*

*"As Gliessman (2007) points out, the dominant mode of agriculture is obsessed with the maximisation of profit and production. Its industrial character is extractive, signposted by large scale, capital-intensive and mechanised practices. These include synthetic fertiliser use, chemical control, genome manipulation, monocultural production, tillage and factory farming or intensive animal husbandry."*

*"The implementation and integration of these practices has, 'simplified agricultural systems in ways that are having alarming consequences on the health of people and landscapes'. Due to its mass uptake, industrial agriculture has become synonymous with the term 'conventional.' However, the use of chemicals and synthetic fertilisers is a post-war phenomenon. Ironically, relative to the period of time that humans have been practising agriculture, it's these conventional approaches that are still new on the agricultural scene."*

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[1] *Massy, C. (2020). Call of the reed warbler: A new agriculture–a new earth. Univ. of Queensland Press.*

[2] *Gordon, E., Davila, F., & Riedy, C. (2023). Regenerative agriculture: a potentially transformative storyline shared by nine discourses. Sustainability Science, 1-17.*

[3] *ibid.*

[4] *Gordon, L. (2021). Why we cannot certify regenerative agriculture. Farming Together. https://farmingtogether.com.au/why-we-cannot-certify-regenerative-agriculture/*

**Gordon et al. (2023)[5] point out that "the dominant mode of agriculture is obsessed with the maximisation of profit and production."**

- Refer to the  ABARES website, agricultural outlook page (https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook) and find some evidence that supports this statement.
- Discuss the idea that modern agriculture is often considered conventional agriculture, whilst regenerative agriculture is considered a somewhat new-age method.
- Is it possible that regenerative agriculture, with an agroecology mindset, could also deliver on productivity and profit?

[5] *Gordon, E., Davila, F., & Riedy, C. (2023). Regenerative agriculture: a potentially transformative storyline shared by nine discourses. Sustainability Science, 1-17.*

# Notes:

# Notes:

# MODULE 1: Regenerative Agriculture: Principles and Practices

## Consider the following words you might encounter during Module 1 of the Regenerative Agriculture course.

For each word, use a ✓ to indicate your understanding of the word:

RED = "I have no idea"

AMBER = "I have heard it and might know what it means"

GREEN = "I know exactly what this word means"- record your definition.

| WORD | RED | AMBER | GREEN | MEANING |
|---|---|---|---|---|
| Regenerative Agriculture | | | | |
| Biodiversity | | | | |
| Monoculture | | | | |
| Sustainability | | | | |
| Holistic grazing | | | | |
| Multi-species | | | | |
| Cropping | | | | |
| Carbon sequestration | | | | |

## Regenerative Agriculture: The Principles

**What's NOT regenerative agriculture? Often, it's easier to focus on what doesn't constitute Regenerative Agriculture in Australia, including;**

- ✗ Paddocks of bare soil/ lack of ground cover
- ✗ Monocrops/ lack of biodiversity
- ✗ Spraying out paddocks prior to sowing new pastures/ crops
- ✗ Set stocking
- ✗ Overuse of synthetic chemicals, fertilisers and pesticides
- ✗ Over-tillage/ disturbance of the soil

**Lorraine Gordon**
Regenerative Agriculture Alliance

FIGURE 1: Without cover, soil is susceptible to erosion[6]

FIGURE 2: A mixed cover crop[7]

Throughout the course you will come to understand what regenerative agriculture actually embodies; less reliance on external inputs (see figure 1) and more on embracing local ecological functions (see figure 2). In this introduction module, we provide you with a few key aspects of regenerative agriculture, including the key principles and practices.

[6] *Photo by Richard Bell on Unsplash: https://unsplash.com/photos/vpfEhvI5UE4*

[7] *Photo by Vera Kratochvil under a Creative Commons License in the Public Domain: https://www.publicdomainpictures.net/en/view-image.php?image=371878&picture=growing-grain-and-peas*

## Activity:

### The Seven Principles of Regenerative Agriculture[8]

**After considering each of the seven principles identified in column A, choose the best definition from column B to explain each principle.**

| | A- Principle | | B- Explanation |
|---|---|---|---|
| 1 | Be ecologically literate, think holistically and understand complex adaptive systems | A | Be active in reconciling the trauma of landscapes and displaced communities. |
| 2 | See your landscape as a community that you belong to and work in | B | There are many approaches to managing landscapes and be open to integrating them with your practice. |
| 3 | Acknowledge and consider diverse ways of working with landscapes | C | Appreciate how ecosystems behave in complex, adaptive and often unpredictable ways. Consider how the landscape is nested within, and interconnected with, smaller and larger ecological, social and economic systems. |
| 4 | Understand that human cultures are co-evolving with their environments | D | Focus on and monitor landscape functions such as biodiversity, soil health, carbon sequestration, ground cover, water cycles, mineral cycles and energy flow. |
| 5 | Engage with First Nations people | E | Your ecosystem is a community of species that you are part of. Do not try and control the members of this community but work alongside them. |
| 6 | Remain curious; seek transformative experiences and continuous learning | F | People and landscapes are relational. We are co-evolving with our environments on a biological and cultural level. |
| 7 | Engage in ecological renewal and make place-based decisions through monitoring | G | Be comfortable in the ambiguity that comes with not having all the answers, be open to the paradigm shifts and expanding your thinking. |

[8] Gordon, L. (2022). *A longitudinal study looking at the resilience of regenerative beef cattle grazing systems in Northern NSW. [Doctoral dissertation, University of New England]*

## Regenerative Agricultural Practices

Regenerative agriculture is a dynamic space that is evolving as we learn about our environment, our communities and ourselves. The changes that we make on land have the potential to impact our livelihoods, and the world. There are a range of practices and techniques that are used in regenerative agriculture. It is worth noting that while these practices may change, as they are influenced by our holistic context/vision, resources, locations, economics, technology and research, the principles essentially stay the same.

There are five key practices that underpin Regenerative Agriculture outlined here: inputs, grazing management, water, cropping and biodiversity. In this module we will elaborate on these practices.

## 1. Inputs

### a) Applying organic composts, fertilisers and bio amendments.

When considering compost, people often associate it with providing enzymes, hormones, and materials that facilitate plant growth. However, these substances have a short shelf-life and lose their effectiveness in both soil and compost[9]. The actual producers of these enzymes, hormones, and plant-growth-promoting materials are the various microorganisms that comprise the soil food web, including bacteria, fungi, protozoa, nematodes, and micro arthropods[10].

**Growers use compost for several reasons, including:**[11]

- Introducing organisms to the soil.
- Providing food to nourish existing bacteria, fungi, protozoa, nematodes, and micro arthropods.
- Improving soil structure. Compost varieties may contain physical components such as coir (coconut fibre), clay, fibre, and pieces of wood that can enhance soil structure.

[9] *Soil Foodweb Institue (Australia). (n.d). compost food web information. Soil Foodweb Institute. https://www.soilfoodweb.com.au/about-our-organisation/compost-food-web-information*

[10] *ibid.*

[11] *ibid.*

## Activity:

Consider the results illustrating the use of compost in horticulture

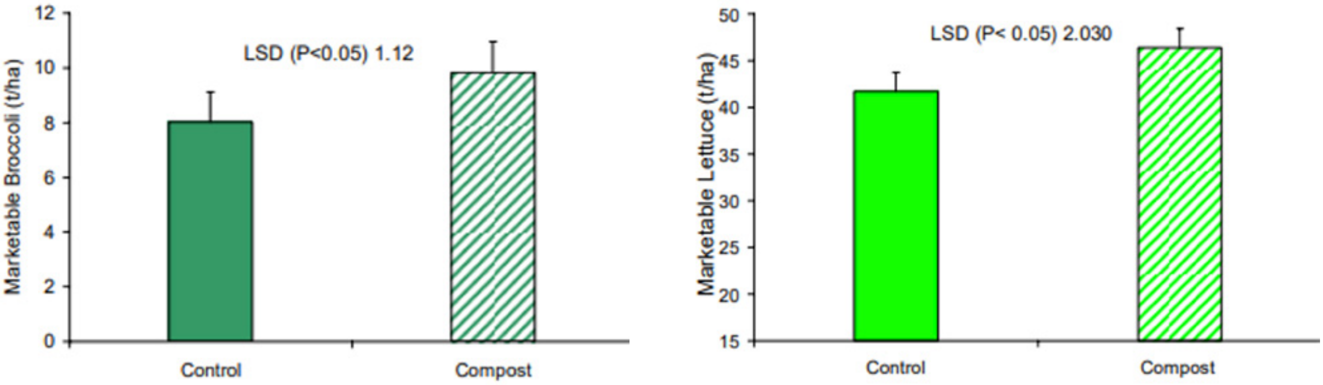


FIGURE 3: Effect of using compost in broccoli and lettuce production.[12]

➔ From the graphs in figure 3, outline the trend observed in the yield of vegetables based on application of compost.

The ideal situation is to create compost in situ; the microbial population exists already, introduction of foreign weeds or pathogens is less likely and the costs of transporting the compost are eliminated.

[12] *Paulin, R., & O'Malley, P. (2008). Compost production and use in horticulture. Department of Agriculture and Food Government of Western Australia. © State of Western Australia (Department of Primary Industries and Regional Development, WA) Used with permission.*

## Activity:

Benefits of Applying Composts

## Case Study: Richmond Capsicum Trial

Read the Case study: Growing crops with compost from the NSW EPA website: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/wastegrants/18p1128-case-study-growing-crops-with-compost-capsicum.pdf

**From the case study, describe the main benefits of applying composts to crops and the advantages of using compost as opposed to fertilisers.**

It is worth noting that some properties may not actually benefit from the addition of compost. If the soil microbiome is healthy and flourishing, introducing a multitude of new microorganisms can actually be detrimental. A situation may arise where the new microbes compete with the existing population. Jeremy Bradley, a well-known biological farmer, has witnessed this battle under the microscope!

Monitoring the health of the soil is an ongoing activity and farming decisions should be made with considerations for the soil as a priority. Many soil tests focus on the chemistry of the soil; the soil pH or the amount of potassium or nitrogen in the soil. It is imperative that soil tests also examine the biology of the soil – which is the biological health of the soil that compost aims to work with and regenerate. As Lorraine Gordon writes,

"RA involves a set of practices which are ever-adapting and evolving as part of a complex adaptive system. Farmers conduct their work within ecological systems that behave in complex, adaptive and often unpredictable and dynamic ways".

### b) Encouraging natural biological cycles and nutrient retention.

During composting, soil microorganisms carry out various essential processes. However, their significance extends beyond composting as these organisms also thrive and exist in the soil, on leaf surfaces, and around roots, leaves, stems, and blossoms. They can form a protective layer on the surfaces of plants, including leaves, stems, blossoms, fruit, and any other above or below-ground plant structures[13].

**Bacteria and fungi** are instrumental in preserving nutrients in compost, which eventually benefit your soil. They can also perform a similar role on your leaf surfaces if the compost is applied to them. One way to achieve this is by transforming the compost into compost tea[14].

**Protozoa and nematodes** play a crucial role in mineralizing the nutrients retained by bacteria and fungi. These mineralized nutrients in compost aid the growth of other organisms and facilitate the utilization of carbon sources present in the organic matter added to the compost pile[15].

Bacteria and fungi contribute to the formation of micro- and macro-structures within the compost, whereas protozoa and nematodes assist in creating larger pores. If the compost contains the appropriate biology, these organisms can construct air passageways and water infiltration channels within a week or so. As the biology thrives and forms structure, the need for turning the compost decreases[16].

[13] *Soil Foodweb Institue (Australia). (n.d). compost food web information. Soil Foodweb Institute. https://www.soilfoodweb.com.au/about-our-organisation/compost-food-web-information*

[14] *Soil Foodweb Institue (Australia). (n.d). compost food web information. Soil Foodweb Institute. https://www.soilfoodweb.com.au/about-our-organisation/compost-food-web-information*

[15, 16] *ibid.*

### c) Reducing or ceasing synthetic chemical inputs.

In an effort to increase agricultural production, our reliance on fertilisers has dramatically increased. In fact, the human use of **nitrogen** globally has increased remarkably over the last sixty years. See figure 4 to see how this compares to phosphorus and potassium use.

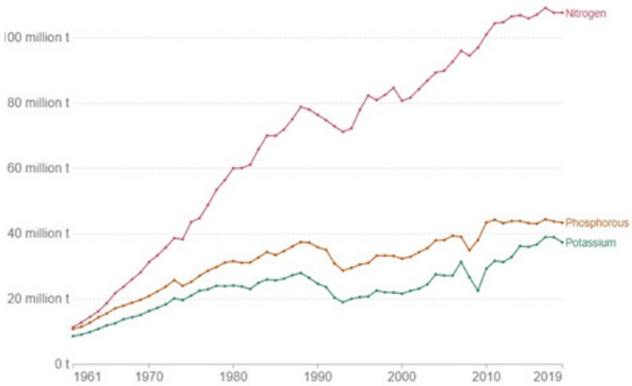


FIGURE 4: Global fertiliser use from 1961 to 2019[17]

According to the UN Environment Program,

“Nitrogen is essential for life on Earth but in excess, it is a dangerous pollutant and is poisoning water bodies, plants, animals and humans, while driving climate change through emissions of the potent greenhouse gas, nitrous oxide. Though little known to the general public, experts call the flood of excess nitrogen one of the most severe pollution threats facing humanity today.”[18]

Consider the implications on human health and health of the land of:

- Nutrient run-off from excess fertiliser application and ecosystem health.
- Ammonia emissions and respiratory health.
- Nitrogenous compounds and their role in climate change.

The main chemical constituent of fertiliser is phosphorus. Farmers often incur significant expenses for adding phosphorus to their crops, as it is a vital nutrient that is not always present in sufficient quantities in the soil. Despite being a relatively abundant element (constituting around 0.1% of the Earth's crust), only a small fraction of it can be readily absorbed by plants[19]. This is because phosphorus is released gradually from rocks during the process of soil formation, and it only becomes available to plants as the minerals in the soil continue to weather over time.

However, rather than adding excessive fertilisers, farmers can monitor the soil pH and maintain an appropriate pH level (see figure 5). In doing so, we activate the ability to unlock phosphate present in the soil.

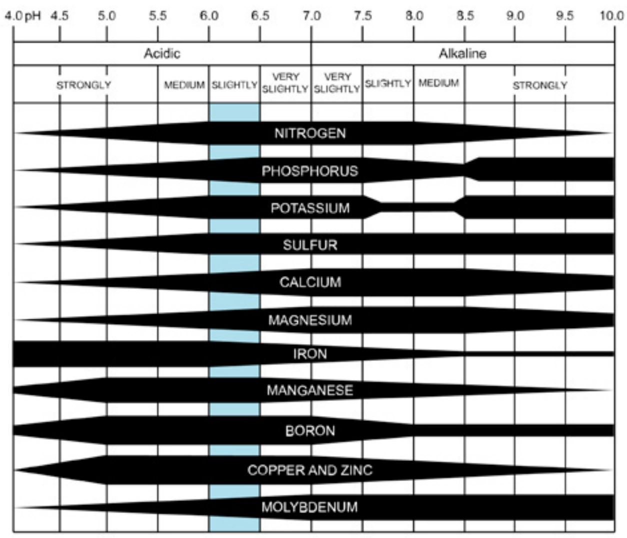


FIGURE 5: The link between pH and nutrient uptake[20]

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[17] *Ritchie, H., Roser, M., & Rosado, P., (2022) - "Fertilizers". Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/fertilizers. Used under a Creative Commons License*

[18] *Pradhan, M. (n.d). Fertilizers: challenges and solutions. UN environment programme. https://www.unep.org/news-and-stories/story/fertilizers-challenges-and-solutions*

[19] *Simpson, R. (2019). Phosphorus: a finite resource essential for life, critical for agriculture and food security. CSIRO. https://ecos.csiro.au/phosphorous/*

[20] *This file is licensed under the Creative Commons Attribution 4.0 International license.*

## Activity:

The impacts of Cover Crops on Soil Phosphorus

The information presented in Figure 6 depicts the effect of various cover crops on soil phosphorous levels to various depths.

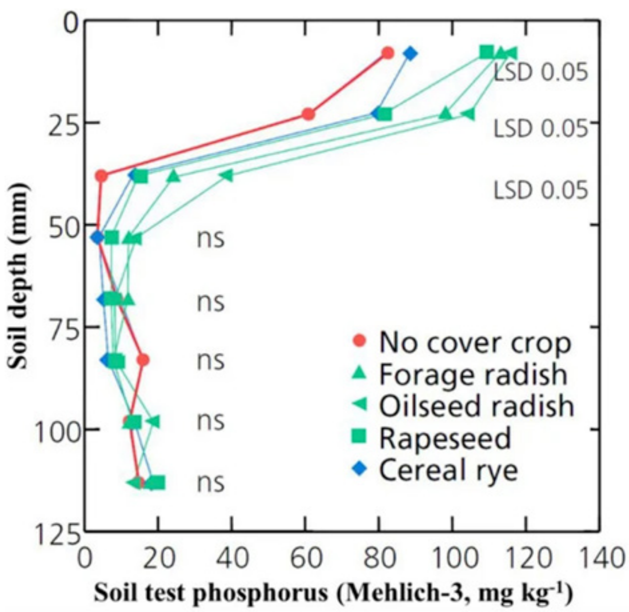



FIGURE 6: Managing phosphorus loss from agricultural cropping systems[21]

→ Outline the consequences of maintaining cover crops that would contribute to higher levels of phosphorous available to 30mm soil depth.

## Activity:

The problem of Applying Synthetic Fertilisers to Soil

Consider the quote from Jeremy Baynard, CEO of ACE Farming[22];

"They're like a drug. We use them again and again as short-term solutions because in a commodity-priced industry hugely impacted by weather shocks, we're always chasing margins. But in the long term, we're on a death roll, where we are destroying our greatest asset- our natural capital".

→ What do you think Jeremy is referring to when he says "they're like a drug"?

→ Would you agree or not? Explain your point of view.

## Activity:

Synthetic Fertilisers

Read the interview with Dr. Christine Jones about why humans rely so heavily on synthetic fertilisers on the regen. ag. farming news website: https://regenfarming.news/articles/917-sos-save-our-soils-dr-christine-jones

→ Explain why cultivating the soil and applying synthetic fertilisers to soil will ultimately reduce soil carbon content.

[21] Singh, G.; Kaur, G.; Williard, K.; Schoonover, J.; Nelson, K.A. Managing Phosphorus Loss from Agroecosystems of the Midwestern United States: A Review. Agronomy 2020, 10, 561.

[22] Neubauer, I. (2022). Farmers can cash in on natural capital. The Farmer. https://thefarmermagazine.com.au/establishing-a-link-between-natural-capital-and-farming-profitability/

## 2. Grazing management

Presently, 60% of Australia is under grazing lands. The decisions made with respect to grazing management will have an enormous impact on our future.

### a) Implementing regenerative grazing strategies: holistic grazing adaptive multi-paddock grazing/ time-controlled planned grazing.

#### i) Managing Pastures for Soil Health

Livestock grazing remains a prominent agricultural land use throughout Australia, with the way pastures are managed having a notable impact on soil condition. The direct relationship between grazing animals and the plants they feed on affects the root systems, which play a crucial role in determining the overall health and functioning of the surrounding soil (see figure 7).

FIGURE 7: Beneficial relationship between grazing animals and pasture plants

FIGURE 8: Controlling the grazing process allows management of animal intake and recovery[23]

FIGURE 9: Overgrazed plants with shallow root active systems have no capacity to enhance soil health of plants[24]

Plant grazing levels can have a significant impact on root growth. When plants are grazed too heavily, the above-ground portion of the plant is removed, and the roots are forced to use their stored energy reserves to regrow.

[23] *By Charlie Rahm / Photo courtesy of USDA Natural Resources Conservation Service., Public Domain, https://commons.wikimedia.org/w/index.php?curid=24834913. Used under a Creative Commons license.*

[24] *CSIRO, Creative Commons by 3.0 via Wikimedia Commons: https://upload.wikimedia.org/wikipedia/commons/3/32/CSIRO_ScienceImage_10444_Brahman_cattle_grazing_in_the_Burdekin_River_catchment_area.jpg. Used under a Creative Commons license.*

This can limit the growth of the root system, reducing its depth and extent, and thus affecting its ability to absorb water and nutrients from the soil. In contrast, when plants are grazed at moderate levels, the above-ground portion of the plant is not completely removed, and the root system is less affected. This allows the roots to continue to grow and expand, enabling them to access deeper soil layers and increasing the plant's overall ability to absorb water and nutrients. Proper grazing management can help maintain an appropriate balance between plant growth and animal forage needs, which is critical for promoting healthy root growth and overall plant health. The **frequency of defoliation** is a major consideration.

The impact of grazing is most notable in the root system. See the image on the effects of grazing on Paddock lovegrass from Local Land Services (https://www.lls.nsw.gov.au/__data/assets/pdf_file/0003/1270542/12-Managing-Pastures_FINAL.pdf). The roots of the Paddock lovegrass show the impact of different cutting intervals on their growth. The plant on the right was left uncut, while the other plants were cut to a height of 3cm every 2, 4, and 8 weeks for a duration of 12 months[25].

### ii) Stocking rate and stocking density

Stocking density refers to the number of animals that are grazing in a particular area of land, and must match the carrying capacity of the land. It is usually expressed as the number of animals per unit area of land, such as the number of cows per hectare or the number of sheep per acre. The appropriate stocking density depends on a variety of factors, including the type of animal, the quality and quantity of available forage, and the desired ecological and economic outcomes.

## Activity:

Conventional vs Subdivided Paddocks

To see the difference between a conventional paddock and a paddock subdivided into nine units, refer back to the Local Land Services factsheet (https://www.lls.nsw.gov.au/__data/assets/pdf_file/0003/1270542/12-Managing-Pastures_FINAL.pdf).

- ➔ What do you think the positives and negatives are of the two approaches?
- ➔ Do they outweigh each other to provide an overall better solution for grazing?

### iii) Holistic Grazing

In holistic grazing, livestock are managed in a way that mimics the natural grazing patterns of wild herbivores. The goal is to maintain a balance between plant growth and consumption by grazing animals, which helps to promote healthy plant growth, improve soil health, and enhance ecosystem function. The key principles of holistic grazing include managing livestock in large, concentrated herds for short periods of time, followed by long rest periods to allow for plant recovery. The use of electric fencing and other technologies can help to manage the movement of livestock and ensure proper grazing intensity and duration.

Holistic grazing also emphasizes the use of diverse, native plant species to promote ecological resilience and reduce the risk of invasive species. This approach can help to increase the nutritional quality of forage for livestock and reduce the need for costly inputs like fertilizers and supplements.

[25] *Earl, J. (2020). Managing Pastures for Soil Health. Local Land Services. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0003/1270542/12-Managing-Pastures_FINAL.pdf*

For more information about holistic grazing, you may like to explore the case studies from Soils for Life (http://www.soilsforlife.org.au/) and the Resources from Inside Outside Management with Brian Wehlburg (https://insideoutsidemgt.com.au/)

If we are to successfully address the issues arising from climate change, it is imperative we consider the sequestration of carbon from the atmosphere. It is obvious that holistic planned grazing offers a realistic option for this carbon sequestration by properly managing livestock to build soil life. Also, holistic grazing has the potential to restore agricultural productivity, enhance biodiversity and water resources, while also employing more people in rural communities.

## Activity:

Net-zero emissions.


Consider this statement: "The NSW Government has committed to an aspirational objective of achieving net-zero emissions by 2050. Net-zero emissions means emissions will be balanced by carbon storage".[26]

➔ Discuss the role of holistic grazing practices as a strategy to increase the rate of carbon sequestration, moving towards net-zero emissions and providing a response to Climate Change.

### b) Using grazing management and animal impact as farm and ecosystem development tools.

Grazing animals moving in tune with natural cycles and moving frequently across the landscape can regenerate land and improve soil health despite the contradictory belief that grazing animals only negatively impact the land. A property is not a simple matter. Each property has a complex structure which may hold several different land types, each with its own characteristic range of pasture species. Productive pastures have a balance of perennial and annual species. Perennials stabilise production and the soil surface but the annuals boost seasonal productivity[27].

Perennial grasses may dominate pasture composition and provide the 'backbone' of any grassland environment. Perennial grasses are well adapted to tolerate defoliation by grazing animals and they are exceptional in their capacity to enhance soil conditions. Understanding the response of perennial grasses to defoliation is key to effectively managing the grazing process to regenerate soil and improve plant and pasture productivity[28].

Grazing, slashing and burning all have the effect of defoliation (the removal of a proportion of the leaf area of the grass plant). The severity or intensity of defoliation, or the relative amount of leaf material removed, has significant consequences for the root system of the grass plant[29].

[26] *Office of Environment and Heritage, NSW https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Climate-change/achieving-net-zero-emissions-by-2050-fact-sheet-160604.pdf*

[27] *Earl, J. (2020). Managing Pasture for Soil Health: Factsheet 12. Local Land Services, NSW. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0003/1270542/12-Managing-Pastures_FINAL.pdf*

[28] *ibid.*

[29] *ibid.*

FIGURE 10: It is important to consider grazing patterns as they will impact on the quality of grass.[30]

It is imperative that sufficient green leaf is left on a grass plant after defoliation. This is to enable the plant to be able to produce energy for regrowth of the grass through the process of photosynthesis. There is relatively little or no impact on the size of the root system[31].

In the case that a grass plant is grazed severely, it is possible that the carbon stores in the root system may provide the energy for regrowth. For this to happen, after severe grazing assimilates, including carbon, move quickly from the roots to shoots and root death may occur within 20-30 minutes. It takes approximately 4 – 6 weeks after the leaf is regenerated for the root regrowth to occur[32].

[30] *Image sourced from shutterstock.*

[31] *Earl, J. (2020). Managing Pasture for Soil Health: Factsheet 12. Local Land Services, NSW. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0003/1270542/12-Managing-Pastures_FINAL.pdf*

[32] *Ibid.*

## c) Self-herding and stress-free stockmanship

The average person would not consider herding stock as stress-free. Images of unruly animals, noisy environments and a "battle of the wills" come to mind. Bruce Maynard worked to change this, developing Stress Free Stockmanship and Self Herding with Dr Dean Revell.

As an approach to manage stock in a more holistic manner, Self-herding involves allowing animals to move freely around the landscape and make their own grazing choices, without being actively herded or confined to specific areas. This approach can help to reduce stress on the animals and promote natural grazing behavior, which can lead to better animal health and productivity.

Stress-free stockmanship is a management approach that focuses on building positive relationships between livestock and their handlers, and reducing stress during handling and transport. This approach involves using low-stress handling techniques, such as moving animals slowly and calmly, avoiding loud noises or sudden movements, and providing comfortable transport conditions. The goal of stress-free stockmanship is to reduce animal stress, improve animal welfare, and increase productivity by promoting healthy behaviours and reducing negative impacts of stress.

The basics of self-herding rely on the use of **attractants** (small amounts of rewarding feeds or nutrients) and **signals** (sounds or objects which clearly indicate where and when a reward is available).

**There are seven factors that are important to self-herding:**

- People-animal interactions
- Internal feedback
- Animal experience
- Diet diversity
- Livestock adaptability
- Individuals and groups
- Broad consequences

## 3. Water

Water is one of the most important resources in agriculture, as it plays a critical role in plant growth and crop yield. It is essential for the maintenance of healthy soil, and for the transportation of nutrients throughout the plant. Adequate water supply is necessary for optimal crop production, and water stress can have a significant negative impact on crop yield. The availability of water is also a key factor in determining the types of crops that can be grown in a particular area, and can limit agricultural development in areas with water scarcity. Efficient water management practices are therefore essential to ensure sustainable agricultural production, and to meet the increasing demand for food production in a changing climate.

### Forms of Soil Water Storage

Water can be held in soil in several different ways, and not all of these forms of soil water are available to plants.

1. **Gravitational water:** This is water that drains quickly through the soil due to gravity. Plants cannot access this water because it moves too quickly through the soil.
2. **Hygroscopic water:** This is water that is held tightly to soil particles and is not available for plants to use. It is held so tightly that the plant roots cannot extract it.
3. **Bound water:** This is water that is chemically bound to soil minerals and is not available for plants to use. It can only be released through high temperatures or other extreme conditions.
4. **Capillary water:** This is water that is held in the small spaces between soil particles, and it is available to plants. However, the water may be held so tightly to the soil particles that the plant roots cannot extract it.

### Amount of available water for plants

The amount of soil water available to plants is governed by a complex interaction between several factors, including:

1. **Soil texture:** The texture of the soil, which refers to the relative proportions of sand, silt, and clay, affects the amount of water that the soil can hold and how easily water can move through it.
2. **Soil structure:** The arrangement of soil particles into aggregates, or clumps, can affect the amount of water that is available to plants. Well-structured soils with stable aggregates have more pore space for water to move through, making water more available to plant roots.
3. **Climate:** The amount and timing of rainfall, as well as temperature and humidity, affect the amount of water in the soil.
4. **Topography:** The slope and shape of the land can affect how water moves through the soil, and can also affect the amount of water that is available to plants.
5. **Vegetation:** Plants can affect the amount of water that is available to other plants by using water themselves, or by altering the soil structure and creating conditions that favour the growth of other plants.
6. **Human activities:** Land use practices, such as irrigation and tillage, can affect the amount of water in the soil and how it is distributed. Land use changes such as deforestation, can also have a significant impact on soil water availability.

These factors interact in complex ways, and understanding how they affect soil water availability is crucial for managing and maintaining healthy soils and supporting sustainable plant growth.

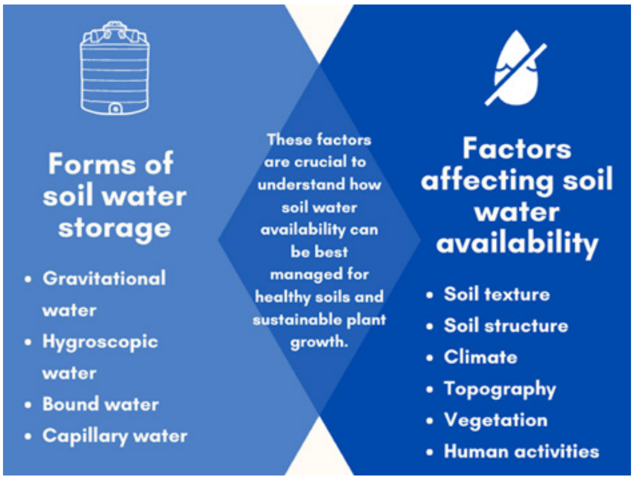



FIGURE 11: The complex factors which interact to determine soil water availability

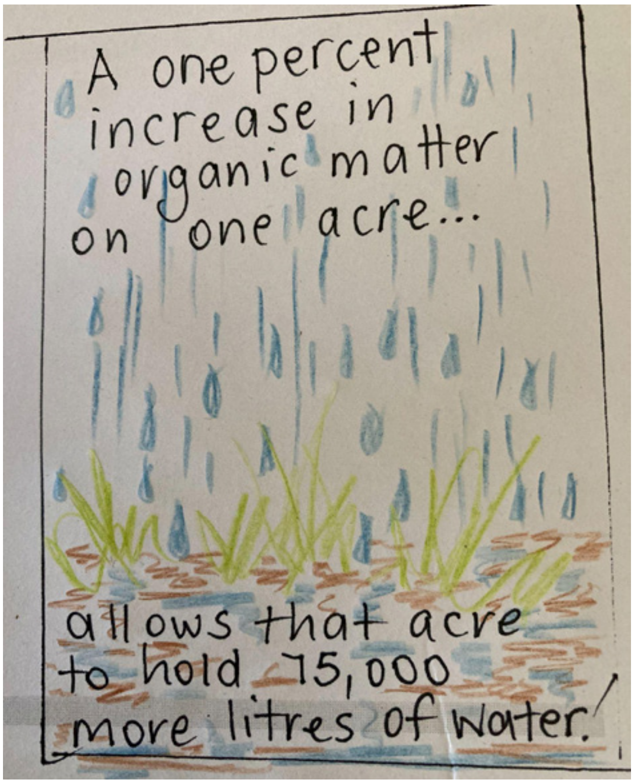



FIGURE 12: Student work sample on water.

## Activity:

Exploring the water-holding capacity of soils

**Consider the following statement:**

> *"increasing soil organic matter, particularly soil carbon, is directly related to increasing the water-holding capacity of soils".*

Using the information presented in this module so far, develop a list of management practices that would help increase soil organic matter. You may do extra research to support your response.

In what other ways could the students in your class display the information portrayed in this poster (see figure 12)?

## 4. Cropping

### Crops and pastures: what's the difference?

**Crops** refer to plants that are grown and harvested for human or animal consumption or for other uses, such as biofuels, fibres, or medicines. Examples of crops include grains (e.g., wheat, rice, maize), vegetables (e.g., tomatoes, carrots, lettuce), fruits (e.g., apples, oranges, grapes), and oilseeds (e.g., soybeans, sunflowers, canola).

**Pastures**, on the other hand, are areas of land where grasses and other forage plants are grown and used to feed livestock, such as cattle, sheep, and horses. Pastures can be natural (i.e., existing without human intervention) or created through seeding or other management practices. Grazing animals can also help to manage and maintain pastures by controlling the growth of certain plants and fertilizing the soil with their manure. Depending on location, there is some crossover between a crop and pasture. For example, some species that are annuals when grown on the coast are perennials when grown in the tablelands.

**Pasture cropping** is a sustainable agricultural practice that involves planting crops directly into perennial pastures. This approach allows farmers to simultaneously produce crops and maintain the health of their pasture ecosystems. In pasture cropping, farmers plant crops within their existing pastures, without the need to till or disturb the soil.

The C4 grasses, with their deep roots, provide ground cover and reduce soil erosion, while the C3 crops can be harvested for grain, hay or silage[33]. This approach also allows farmers to reduce the need for chemical inputs and fertilizer, as the perennial pastures provide a natural source of soil nutrients. Additionally, the grazing of livestock on the pasture-crop system can enhance soil health and improve carbon sequestration, contributing to the overall resilience of the system[34].

The cereal production (for grain and fodder) is integrated with an intensive, time-controlled grazing system. Ecological benefits of maintaining more perennial plants across agricultural landscapes are numerous, including increased soil carbon and increased soil biodiversity. In addition, the lower input costs and cycling of nutrients by the grazing animals can assist in adopting a strategy closer to natural systems.

## Case Study - Pasture Cropping

To find out more about pasture cropping, read the Case Study on Winona by Colin Seis through the Soils for Life website (https://soilsforlife.org.au/wp-content/uploads/2019/12/Chapter_2.pdf).

Colin Seis, a well known pasture-cropper, highlights the profitability of the system rather than high production levels. By using low rates of fertiliser and chemicals, he has dropped his costs substantially with only a small reduction in his output. He is able to lower his use of knockdown chemical inputs by utilising high impact grazing to reduce biomass[35].

FIGURE 13: Samples from a paired-site analysis showing the healthy and carbon-rich soils on Winona (left) achieved through Colin Seis' 'pasture cropping' technique, compared with a neighbouring paddock (right) which is farmed conventionally[36].

[33] *Millar, G., & Badgery, W. (2009). Pasture cropping: a new approach to integrate crop and livestock farming systems. Animal Production Science, 49(10), 777-787.*

[34] *Franzluebbers, A. J., Sawchik, J., & Taboada, M. A. (2014). Agronomic and environmental impacts of pasture–crop rotations in temperate North and South America. Agriculture, Ecosystems & Environment, 190, 18-26.*

[35] *Seis, C. (2012). Pasture Cropping. https://winona.net.au/pasture-cropping/*

[36] *Image taken at Winona by Colin Seis. Used with permission.*

## Multi-species cropping

Multi-species cropping involves sowing a variety of species together, each with a different role. Common combinations include: oats, peas, turnips, legumes, vetch, tillage radish and chicory.


FIGURE 14: The importance of multi-species cropping.

There are five main reasons that plant diversity is imperative to maintaining soil health (which flows on to animal and human health!):

1. **Ecosystem stability:** A diverse plant community provides a stable ecosystem by reducing the impact of environmental disturbances, such as droughts or pests, as different plant species have different tolerances to these stresses. This helps to maintain a healthy and productive ecosystem over time.
2. **Soil health:** Different plant species have different root structures and exude different chemicals that can improve soil health by increasing nutrient availability, improving soil structure, and reducing erosion.
3. **Increased productivity:** Plant diversity can increase productivity by ensuring that all resources, such as water, sunlight, and nutrients, are used efficiently. This can lead to higher crop yields, more forage for livestock, and more biomass for bioenergy.
4. **Pest control:** A diverse plant community can help to control pests and diseases by providing habitats for natural enemies of pests, such as predators and parasites.
5. **Cultural and aesthetic values:** Plant diversity provides cultural and aesthetic values by preserving plant species for medicinal, spiritual, and recreational purposes, and by enhancing the beauty of natural landscapes.

## Activity:

### The "No Till" Approach to Cropping

A "no-till" cropping approach involves destroying pasture with herbicides prior to planting the crops. This is then followed by actively re-establishing pasture after the cropping phase.

**Consider the graph in figure 15. With reference to the data displayed, outline how the need for this cycle of destroying and replanting pasture can be avoided.**

Growth rate of grasses over a 12-month period

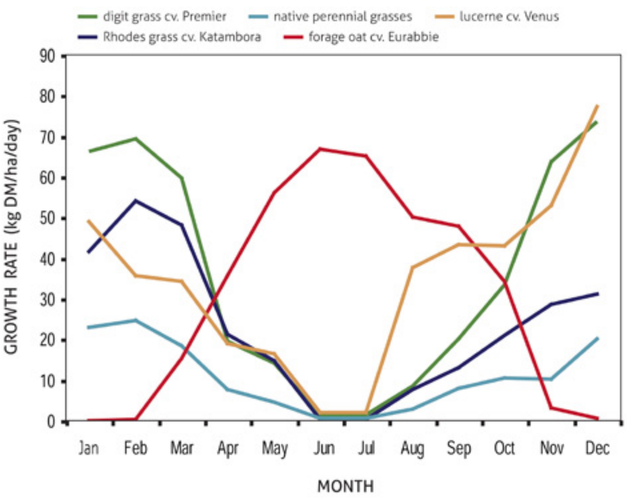



FIGURE 15: Growth rates (kg DM/ha/day) of digit grass, Rhodes grass, a native perennial grass pasture, lucerne and forage oat on a red Chromosol (duplex) soil on the north-west slopes of NSW[37].

One of the key benefits of pasture cropping is the increased soil carbon levels. This occurs due to maintaining greater biomass in the cropping system. Increasing soil carbon does not happen immediately; it is the result of years of implementing pasture cropping practices. The flow on effects of more soil carbon, are improved nutrient and moisture holding capacity[38].

## Activity:

### Other Options for Regenerative Cropping

**In groups of 3, and using the jigsaw method of researching and sharing information, look at the three other common methods of cropping used in regenerative agriculture:**

1. No Kill Cropping:
   https://research.csiro.au/mixedcovercrops/wp-content/uploads/sites/297/2020/03/Landscape-Function-Regenerative-Agriculture.pdf [39]

2. Cover Cropping:
   https://www.nswskn.com/cover-cropping/ [40]

3. Controlled Traffic Farming:
   https://www.vicnotill.com.au/regenerative-farming/no-till-farming-systems [41]

In your groups, after you have shared your findings, discuss the positives, negatives, similarities and differences of each approach.

---

*[37] Harris C.A., Boschma S.P., Murphy S.R., and McCormick L.H. (2014). Tropical Perennial Grasses for Northern Inland New South Wales—Second Edition. (Future Farm Industries Cooperative Research Centre: Perth). State of New South Wales (Department of Planning and Environment) https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/1345105/Tropical-Perennial-Grasses-for-Northern-Inland-NSW.pdf. Used with permission from the author.*

*[38] Leach, R. (2020). Pasture cropping: is it an option on your place? Local Land Services. https://www.lls.nsw.gov.au/regions/central-west/articles-and-publications/crop-production/pasture-croppin g-is-it-an-option-on-your-place*

*[39] Johnson, S. (2019). Boosting landscape function for profit and planet. Santfa: The Cutting Edge. p. 122 – 125. Commonwealth Government, Grains Research & Development Corporation and the South Australian Government. https://research.csiro.au/mixedcovercrops/wp-content/uploads/sites/297/2020/03/Landscape-Function-Regenerative-Agriculture.pdf*

*[40] Cover cropping. (n.d). NSW Soil Knowledge Network. NSW Government. https://www.nswskn.com/*

*[41] No-Till Regenerative Farming Systems Australia. (n.d.). VicNoTill. https://www.vicnotill.com.au/regenerative-farming/no-till-farming-systems*

## 5. Biodiversity

Our farming landscapes are complex adaptive systems, yet modern agriculture in its quest to increase yields has led to the creation of monocultures and simplified agricultural systems, which reduces biodiversity. Over 60% of the modern diet is now derived from three crops: wheat, rice and maize[10]. With over 10,000 varieties of edible plant worldwide and 150 currently used as human food, the risks to food security of producing most of our calories from just three plants is significant[42]. Greater plant diversity is important because it creates a greater diversity of root exudates and a greater variety of food substrates leads to a greater diversity of soil biota. On regenerative farms, biodiversity is increased through a number of practices. The absence of fungicides, weedicides and insecticides also promotes diversity. The increase in biodiversity, and decrease in agrochemicals, can also benefit our health.

There are similarities between the soil microbiome and the human microbiome, however, in our modern urban life, where we have less exposure to soil, increased exposure to modern agricultural chemicals, more processed foods, reduced diversity of foods, and less fibre intake, the human microbiome is less diverse[43].

Biodiversity includes managing agricultural landscapes for increased species diversity. It can involve integrating enterprises and implementing systemised changes that lead to a greater landscape function.

[42] *Galluzzi, G., Van Duijvendijk, C., Collette, L., Azzu, N., & Hodgkin, T. (2011). Biodiversity for Food and Agriculture. Contributing to food security and sustainability in a changing world. PAR platform, FAO, Rome.*

[43] *Blum, W. E., Zechmeister-Boltenstern, S., & Keiblinger, K. M. (2019). Does soil contribute to the human gut microbiome? Microorganisms, 7(9), 287.*

[44] *Cohen, W., Storhol, C., Martin, A., Castellanos, A., Arnott, C., Ostrander, C.R., Macmillan, C., Pershouse, D., Smith, D., Harris, E., Makepeace, F., Lowe, I., Handy, J., Rodriguez, K., Spry, K., Tucker, L., Rogers, L., Henry, L., Major, M. and Hawken, P. (2019). The Soil Story: The road to regenerative agriculture teaching curriculum, Australian Edition. Kiss The Ground and the Life Lab. https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf*

### Activity:

Other Options for Regenerative Cropping

Biodiversity is a very important part of Regenerative Agriculture, and it will be discussed in further detail in Module 4 of this workbook.

**So, for now, just consider:**

- ➔ What is the best way to increase biodiversity?
- ➔ Do you naturally consider the biodiversity of plants and animals, or do you immediately think "below the soil's surface"?

### Activity:

Where is carbon found on Earth?

Complete Lesson 1 from the *"Soil Story Curriculum: The road to regenerative agriculture teaching curriculum: rebuilding healthy soils for Carbon Cycle Balance"* from https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf

> *"Lesson 1 invites students to examine their existing understanding of carbon. From The Soil Story video, students learn that carbon is a natural element found in every living organism on Earth, as well as in many non-living objects such as rocks or coal. The Science and Engineering Practice of "developing and using models" enables learners to visualise where carbon is stored on Earth and how it cycles between the geosphere (rocks, minerals, fossils), hydrosphere (oceans, rivers, lakes), biosphere (plants, animals, microorganisms), atmosphere (air, water vapor, particles like dust, pollen, etc.) and pedosphere (soil, which contains elements from all the other spheres, including rocks, water, air, and life). The video asserts that the carbon cycle is out of balance and names some of the ways human activity has disrupted this naturally occurring cycle."* [44]

# Notes:

# Notes:

# MODULE 2:
# Resilience of a System

## Consider the following words you might encounter during Module 2 of the Regenerative Agriculture course.

For each word, use a ✓ to indicate your understanding of the word:

**RED** = "I have no idea"

**AMBER** = "I have heard it and might know what it means"

**GREEN** = "I know exactly what this word means"- record your definition.

| WORD | RED | AMBER | GREEN | MEANING |
|---|---|---|---|---|
| Resilience of a system | | | | |
| Environmental stresses | | | | |
| Biodiversity | | | | |
| Agroecology | | | | |
| Cropping | | | | |
| Connectivity | | | | |

## Resilience of a system

Resilience is a very different concept to resistance. Whilst **resistance** is *the ability to not be adversely affected by change*, **resilience** can be defined as *the ability to adapt to a new state of play after being disturbed*. Resilience explores how people and nature can use shocks and disturbances such as climate change to initiate renewal and innovative thinking. In fact, evolution demonstrates this. Some species will adapt and continue to survive, others will not. By enhancing the resilience of ecosystems, including agricultural systems, we are assisting these systems adjust to changes brought upon them, including those due to climate change.

### Activity:

Resistance and Resilience

Consider the following diagram depicting Resistance and Resilience.

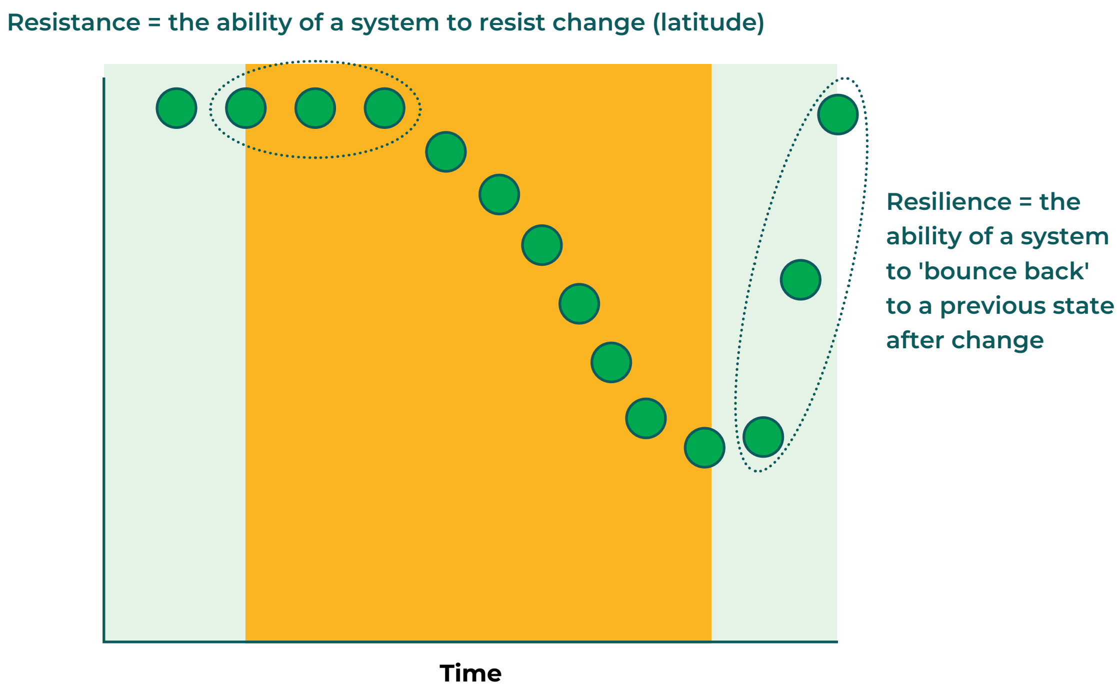



FIGURE 16: Representation of resistance and resilience[45].

→ How would you redraw this diagram to reflect the definition of resilience provided above: *the ability to adapt to a new state of play after being disturbed?*

[45] *Adapted from Australian Department of Climate Change, Energy, the Environment and Water, https://flow-mer.org.au/what-do-we-mean-by-ecological-resilience/*

## Activity:

Diversity and Resilience

In this activity, we examine the link between diversity and resilience in our food networks, from production to distribution.

First, let's consider another definition of resilience from MacFall et al. (2014, p. 614):

> *Resilience...is the capacity for a system to absorb disturbance and to reorganise, while retaining system function, structure, and self- organising processes...[this] can best be achieved within the food system by more food produced, distributed, and consumed within local geographies, while keeping the larger - even national - structures that fill gaps which cannot be filled locally or where those structures inform and support local efforts*[46].

- ➔ How is this definition different to the original definition supplied in this module?

Now, read:

## Case Study: The Southern corn leaf blight epidemic of 1970[47]

The case study starts at the end of page 609 - 610: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7099336/pdf/13412_2015_Article_321.pdf

- ➔ Discuss why the fungus had such a huge impact on the corn industry and a huge loss for farmers.
- ➔ What could be done to improve the resilience of this system so it is not so susceptible to disease?

Agriculture needs to be both resilient and sustainable. As shared by Bennett et al. (2014),

> *"Agriculture that causes long-term or widespread environmental crises is not resilient, no matter how economically successful or how much food is produced, making its profitability and productivity irrelevant."* [48]

This statement demonstrates the interconnectedness of the triple-bottom line thinking as applied to agriculture. It tells us how sustainable and regenerative practices are intrinsically integrated with environmental / ecological, financial and social (food production) outcomes.

**FIGURE 17:** How can corn crops be grown with greater resilience to Corn Leaf Blight?

[46] *MacFall, J., Lelekacs, J.M., LeVasseur, T., Moore, S. and Walker J. (2015). Toward resilient food systems through increased agricultural diversity and local sourcing in the Carolinas. J Environ Stud Sci. ;5(4):608-622. doi: 10.1007/s13412-015-0321-1.*

[47] *ibid.*

[48] *Bennett, E.M., S.R. Carpenter, L.J. Gordon, N. Ramankutty, P. Balvanera, B. Campbell, W. Cramer, J. Foley, C. Folke, L. Karlberg, J. Liu, H. Lotze-Campen, N.D. Mueller, G.D. Peterson, S. Polasky, J. Rockström, R.J. Scholes, and M. Spirenburg. (2014). Toward a more resilient agriculture. Solutions 5 (5):65-75.*

## Activity:

Analysing Changes to Import Prices

Figure 18 demonstrates some recent financial pressures facing agricultural production in Australia.

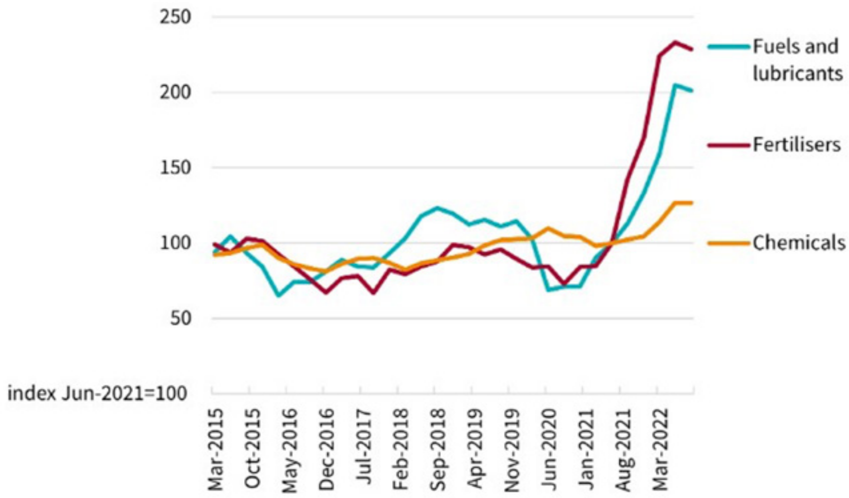



FIGURE 18: Import price index for fertilisers, chemicals, fuels and lubricants, March 2015 to September 2022.[49]

Consider the data presented in Figure 18.

- Identify the time when a systems shock occurred and account for possible causes of this shock.
- Explain how a diversity of agricultural enterprises on a farm might contribute to improved resilience of the farm.

[49] *ABARES, Australian Department of Agriculture, Fisheries and Forestry. https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/agriculture-overview#rising-inflation-hitting-consumer-spending-power-and-farming-inputs. Image used with permission.*

## The Seven Principles for Building Resilience

### Principle 1 Maintain Diversity & Redundancy

A diversity of crops and enterprises increases the resilience of a system. If one part of a system fails (becomes redundant) alternative parts can help cover the losses.

### Principle 2 Manage Connectivity

Connectivity across a farmscape can spread benefits across the land. This might include biological pest control from shelter belts or water management features like Natural Sequence Farming.

### Principle 3 Manage Slow Variables and Feedbacks

Not everything on the farm changes at the same pace, the short term impact of heavy fertiliser and pesticide use are very different to the long term impacts on soil fertility and water quality.

### Principle 4 Foster Complex Adaptive Systems Thinking

We are constantly learning more about the complex interactions, and flow on effects, of different actions on the farm. We need to step away from the reductionist paradigm and look to better understand these dynamics and interactions.

### Principle 5 Encourage Learning.

Continues learning allows us to understand what's going on in our landscapes and gives us the ability to be proactive instead of reactive to change. Continual learning allows us to build resilience.

### Principle 6 Broader Participation

Social-ecological resilience comes from the development of trust, legitimacy and knowledge around our enterprises, approaches and practices. Each of these inform our decision making process and our ability to manage change.

### Principle 7 Promote Polycentric Governance

Polycentricity further develops the other six principles listed above. Having multiple governing bodies allows of the sharing of knowledge across institutions. Simply put, if you want to go fast go alone, if you want to go far go together.

FIGURE 19: The seven principles for building resilience[50]

[50] *Adapted from: https://www.stockholmresilience.org/research/research-news/2015-02-19-applying-resilience-thinking.html*

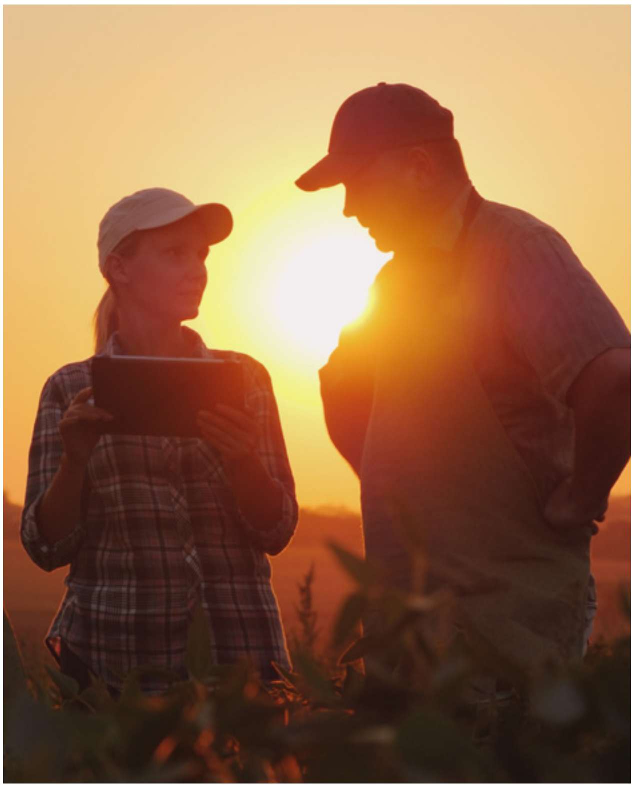
## Activity:

Putting the principles of resilience into practice

Consider the seven principles of resilience as identified by the Stockholm Resilience Centre (see figure 19).

- Create a table to align various on-farm practices with each of these principles.
- Read the article “Doing more with less is the new path for ag: Henry Crooke[51]” from VicNoTill’s “The Ground Up” publication in Australia: https://www.vicnotill.com.au/2021/09/doing-more-with-less-is-the-new-path-for-ag-henry-crooke.

  Identify which of the seven resilience principles are referred to within it.



[51] *Pouliot, M. (2021). Doing more with less is the new path for ag: Henry Crooke. VicNoTill. https://www.vicnotill.com.au/2021/09/doing-more-with-less-is-the-new-path-for-ag-henry-crooke*

# Notes:

# Notes:

# Notes:

# MODULE 3: Ecosystem Services: Biodiversity

## Consider the following words you might encounter during module 3 of the Regenerative Agriculture course.

For each word, use a ✓ to indicate your understanding of the word:

RED = "I have no idea"

AMBER = "I have heard it and might know what it means"

GREEN = "I know exactly what this word means"- record your definition.

| WORD | RED | AMBER | GREEN | MEANING |
|---|---|---|---|---|
| Root exudates | | | | |
| Hyphae | | | | |
| Mycelium | | | | |
| Microbiome | | | | |
| Microrhizal fungi | | | | |
| Homogeneity | | | | |
| Vermiculture | | | | |

**“Biodiversity is the greatest treasure we have... It’s diminishment is to be prevented at all costs”**

Thomas Eisner,
Ecologist and entomologist

## Ecosystem Services - Biodiversity

The ancient Greeks used the term bios, meaning *life*. Therefore, biodiversity is the term used to describe a diversity in living systems. In pursuit of higher yields, modern agriculture has resulted in the development of monocultures and simplified farming systems, causing a decline in biodiversity. However, regenerative farming practices aim to counter this by promoting biodiversity through various approaches at different levels, including genetic, species, and ecosystems.

Regenerative farming is focused on building farming enterprises that are resilient and are not single point sensitive like monoculture crops. This means that farming that lacks biodiversity is more vulnerable to collapse if their point of weakness fails (for instance, one pest or one adverse weather event in a monoculture can wipe out the entire crop). Biodiversity of plant species avoids vulnerability to collapse by creating farm ecosystems that can adapt to varying weather conditions and changing climates. For crop production, biodiversity provides better pest-predator relationships, and for livestock it provides a highly varied diet.

In modules 1, 2 and 3, we have discussed the importance of soil structure and *soil chemistry* on soil microbial diversity. It is important to also understand the vital role of the plant species in promoting microbial diversity. Soil ecological communities are impacted by land use intensity, where more intense land use types lead to reduced diversity and biomass. Research has shown that microbial biomass and enzyme activities are greater in pasture systems compared to crop systems, and the microbial compositions differ between the two[70]. Additionally, soil fungal community composition is influenced by the composition of the plant community in pasture systems.

## Activity:

Bacteria and Fungi

Consider the information presented in figure 22.

Soil chemical properties explained the largest amount of variation across both bacterial and fungal communities

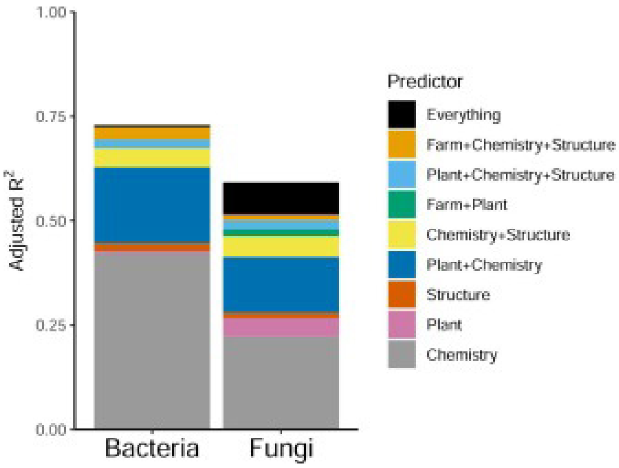



FIGURE 22: Proportion of variation in bacterial and fungal scores explained by the different components.[71]

➔ Based on this information, answer TRUE or FALSE to each statement.

a) According to this data, soil chemistry has a greater effect on bacteria than fungi.

b) The soil structure is not important in promoting diversity of soil microbes.

c) The soil fungi are not affected by plant species.

d) A combination of factors (eg soil chemistry and structure) affects soil microbes.

e) Fungi are the most sensitive to a combination of all factors (everything).

[70] *Seaton, F. M., Griffiths, R. I., Goodall, T., Lebron, I., & Norton, L. R. (2022). Pasture age impacts soil fungal composition while bacteria respond to soil chemistry. Agriculture, Ecosystems & Environment, 330, 107900.*

[71] *Seaton, F. M., Griffiths, R. I., Goodall, T., Lebron, I., & Norton, L. R. (2022). Pasture age impacts soil fungal composition while bacteria respond to soil chemistry. Agriculture, Ecosystems & Environment, 330, 107900. https://doi.org/10.1016/j.agee.2022.107900. Used under a Creative Commons License.*

## Activity:

Healthy Soil: what role do soil microbes play in the carbon cycle?

Complete Lesson 3 from the *"Soil Story Curriculum: The road to regenerative agriculture teaching curriculum: rebuilding healthy soils for Carbon Cycle Balance"* from https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf

> *"By Lesson 3 students are primed to look more closely at the molecular exchange that happens under the ground. Most students have a cursory understanding that plants get essential nutrients from the soil, but they do not necessarily understand how these nutrients are made available to plants. One of the primary mechanisms by which this happens is a "Great Exchange" between plants and soil biota. Students explore the concept of interdependence in which the plants provide carbohydrates to fungus, bacteria, and invertebrates in the soil and those soil dwellers, in turn, provide the plants with decayed nutrient matter. To reinforce this concept, students gather evidence for soil life by observing the presence of biotic matter in rich soil and comparing it to the relatively inert qualities of dirt. As they examine another interaction between the pedosphere and biosphere, students deepen their understanding of how carbon cycles on Earth."* [72]

## Focus on Fungi

Fungi are one of the most amazing organisms on the planet. They are incredibly diverse, with scientists estimating there could be as many as 5 million fungal species in existence[73]. Fungi play a vital role in the environment, and their importance to all life on earth cannot be overstated. Just like we rely on the World Wide Web for our connection to others in our world, fungi have created their own web, connecting each organism to the others around it!

**Here are some reasons why fungi are amazing:**

1. Fungi are essential for the survival of plants

When the first plants made the transition from sea to land approximately 450 million years ago, they did so without roots and relied entirely on fungi to provide nutrients and water for their growth[74]. Today, fungi continue to play a crucial role in the growth and survival of plants. Fungi form symbiotic relationships with plant roots, providing them with essential nutrients in exchange for carbohydrates produced by the plants through photosynthesis.

2. Fungi are incredible decomposers

Fungi are excellent decomposers, breaking down dead plant and animal matter and returning essential nutrients to the soil. Without fungi, the environment would be littered with dead matter, and nutrients would become scarce. Fungi are also responsible for breaking down many human-made materials, including plastics, pesticides, and other toxic chemicals[75][76].

[72] *Cohen, W., Storhol, C., Martin, A., Castellanos, A., Arnott, C., Ostrander, C.R., Macmillan, C., Pershouse, D., Smith, D., Harris, E., Makepeace, F., Lowe, I., Handy, J., Rodriguez, K., Spry, K., Tucker, L., Rogers, L., Henry, L., Major, M. and Hawken, P. (2019). The Soil Story: The road to regenerative agriculture teaching curriculum, Australian Edition. Kiss The Ground and the Life Lab. https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf*

[73] *Blackwell, M. (2011). The Fungi: 1, 2, 3… 5.1 million species? American journal of botany, 98(3), 426-438.*

[74] *Smith, S. E., Smith, F. A., & Jakobsen, I. (2003). Mycorrhizal fungi can dominate phosphate supply to plants irrespective of growth responses. Plant physiology, 133(1), 16-20.*

[75] *Zeghal, E., Vaksmaa, A., Vielfaure, H., Boekhout, T., & Niemann, H. (2021). The potential role of marine fungi in plastic degradation–A review. Frontiers in Marine Science, 8, 738877.*

[76] *Pinto, A., Serrano, C., Pires, T., Mestrinho, E., Dias, L., Teixeira, D. M., & Caldeira, A. (2012). Degradation of terbuthylazine, difenoconazole and pendimethalin pesticides by selected fungi cultures. Science of the Total Environment, 435, 402-410.*

3. Fungi are a source of medicine

Many of the medicines we use today are derived from fungi. Penicillin, one of the most famous antibiotics, was discovered in a fungus. Fungi produce a wide range of secondary metabolites[77], including compounds with antimicrobial, antiviral, and anticancer properties.

4. Fungi are excellent bioindicators

Fungi are excellent bioindicators of environmental health. Changes in the fungal community can indicate changes in the soil, water, and air quality. Some fungi are sensitive to environmental pollutants, making them valuable indicators of pollution levels.

5. Fungi are incredibly adaptable

Fungi are incredibly adaptable and can survive in extreme environments, including high temperatures, low oxygen levels, and high radiation levels. Some fungi can even survive in outer space, making them fascinating subjects for space research.

6. Fungi are a source of food

Fungi are an essential source of food for humans and other animals. Mushrooms are the most well-known edible fungi, but many other fungi are also edible, including truffles, morels, and chanterelles.

7. Fungi are essential for the production of fermented foods

Many of our favourite foods are made using fungi, including bread, beer, wine, and cheese. Fungi are essential for the fermentation process, breaking down sugars and producing flavourful compounds that give these foods their unique taste and aroma.

Fungi are truly amazing organisms with a wide range of benefits to both the environment and human society. They are essential for the growth and survival of plants, play a crucial role in nutrient cycling and environmental health, and are a source of food and medicine. Without fungi, life on earth would not be possible.

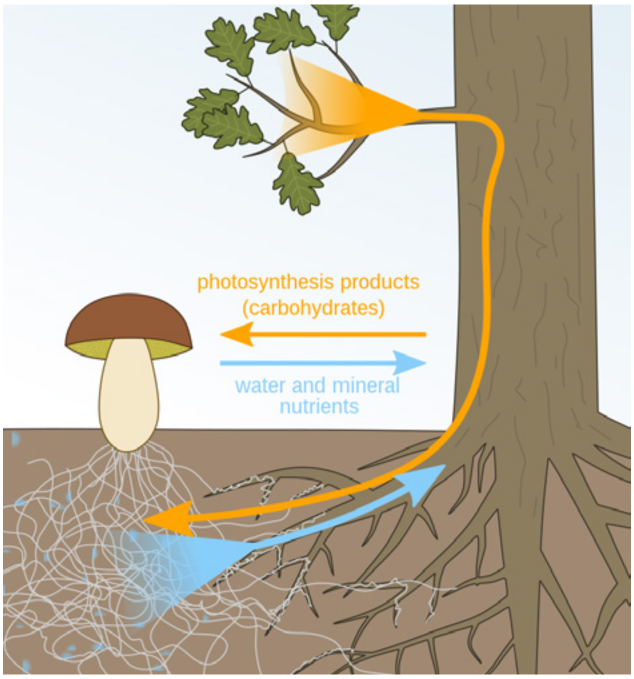



FIGURE 23: Mycorrhizal fungi produce a network of mycelial hyphae greatly enhancing a plant's capacity to access nutrients, particularly phosphorous and soil moisture. Used under a Creative Commons License.

## Activity:

Fungi in Trouble

**Consider the possibility of diminishing the diversity of fungi populations in the soil. Write down three possible outcomes.**

1. ______________________

______________________

2. ______________________

______________________

3. ______________________

______________________

[77] *Brakhage, A. A. (2013). Regulation of fungal secondary metabolism. Nature Reviews Microbiology, 11(1), 21-32.*

## Ecological Succession

Ecological succession is the process by which an ecosystem undergoes a series of changes over time, resulting in a gradual shift in the types of species that inhabit the area. These changes occur as a result of both biotic (living) and abiotic (non-living) factors, and can take place over years, decades, or even centuries.

Ecological succession typically begins with the colonisation of a new or disturbed habitat by pioneer species, which are usually fast-growing, adaptable organisms such as lichens, mosses, and ferns. As these early colonisers take hold and begin to alter the physical and chemical properties of the environment, they make it more suitable for other, more complex organisms such as shrubs and trees.

Over time, these new species will outcompete the earlier ones, and the ecosystem will continue to change until it reaches a stable state known as a climax community. This final stage of succession is characterized by a relatively stable community of species that is well-adapted to the prevailing environmental conditions.

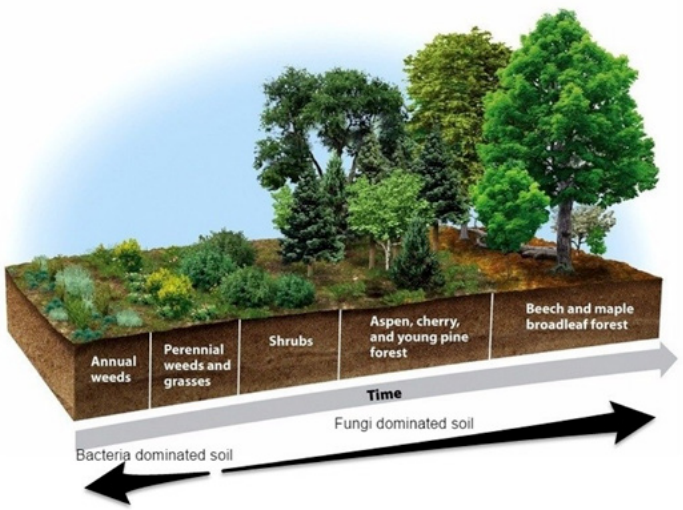



FIGURE 24: Ecological succession is a model that can be used to improve the quality of the soil.[78]

Generally, fungi respond to surface decomposition, whereas bacteria prefer soil disturbance.

### Activity:

Fungi and Ploughing

Re-read this last sentence.

→ Complete the passage;

Fungi respond to ______________________ ,

whereas, bacteria prefer ________________ .

→ Explain the implications on soil microbial diversity of the practice of ploughing paddocks.

FIGURE 25: Soil disturbance due to ploughing.[79]

[78] *Horvath, W. (2023). Soil Building – How to Make Deep Rich Soils by Imitating Nature. Permaculture Apprentice. https://permacultureapprentice.com/building-soil/. Used with permission.*

[79] *Image by Eugene1978 at FreePik. https://www.freepik.com/premium-photo/red-farm-tractor-cloud-dust-cultivates-soil-field-with-cultivator-after-harvest-summer-sunny-day-fertile-land-modern-agricultural-machinery-copy-space-high-quality-photo_19018163.htm. Used under a Creative Commons license.*

# Notes:

# Notes:

# Notes:

# MODULE 4: Landscape Function and Soil Health

## Consider the following words you might encounter during module 4 of the Regenerative Agriculture course.

For each word, use a ✓ to indicate your understanding of the word:

RED = "I have no idea"

AMBER = "I have heard it and might know what it means"

GREEN = "I know exactly what this word means"- record your definition.

| WORD | RED | AMBER | GREEN | MEANING |
|---|---|---|---|---|
| Synergy | | | | |
| Solar energy flow | | | | |
| Mycelium | | | | |
| Infiltration rate | | | | |
| Compaction | | | | |
| Rhizosphere | | | | |
| Root-mucilage | | | | |

## Landscape Function

Landscapes are complex, adaptive systems, where every element has an impact on the environment. It's crucial to approach landscape management with an understanding of this complexity, as our decisions can have cascading effects on various systems within and beyond the area. Maintaining healthy soil is particularly essential as it plays a significant role in the ecosystem's overall wellbeing. The main ecosystem processes to consider are the mineral cycle, the water cycle, solar energy flow and community dynamics.

A change in biodiversity can influence the supply of these ecosystem services.

The Food and Agriculture Organization (FAO) offer an overview of the positive and negative impacts on ecosystem services[80].

| Positive impact on ecosystem services | Negative impact on ecosystem services |
|---|---|
| Agriculture provides habitats to wild species and creates aesthetic landscapes. | Pesticides, as well as landscape homogenisation, can decrease natural pollination. |
| Forests help maintain healthy aquatic ecosystems and provide reliable sources of clean water. | Deforestation or poor management can increase flooding and landslides during cyclones. |
| Animal excreta can be an important source of nutrients, seed dispersal and can maintain soil fertility in grazed grasslands. | Excess of animal excreta and poor management can lead to water pollution and threaten aquatic biodiversity. |
| Sustainable and integrated aquaculture can enhance the mangrove functionality of flood protection. | Overfishing has a devastating impact on ocean communities as it destabilises the food chain and destroys the natural habitats of many aquatic species. |

[80] *HFAO. (2023). Ecosystem Services & Biodiversity (ESB). Food and Agriculture Organization of the United Nations. https://www.fao.org/ecosystem-services-biodiversity/en/*

## Activity:

Food and Farming: what role do farmers play in carbon cycle?

Complete Lesson 4 from the *"Soil Story Curriculum: The road to regenerative agriculture teaching curriculum: rebuilding healthy soils for Carbon Cycle Balance"* from https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf

*"After students have been introduced to the role soil microbes play in the carbon cycle, Lesson 4 asks students connect to healthy soil with agriculture, the system by which humans grow the foods and fibres that enable our survival. Students learn that the human gut is similar to the soil, in that both are rich biomes filled with microorganisms working together. In many regards, microbes in the soil and microbes in human gut work in similar ways. New technologies are helping us understand the human microbiome and how healthy soil contributes to healthy people. Students engage all of their senses as they mindfully taste fresh produce, which sets the stage for a critical discussion of different types of agricultural practices. Using "agricultural practice" cards, students engage in argument from evidence about what farmers can do to increase soil biodiversity (i.e., nurture bacteria, fungus, and invertebrates) and decrease carbon release into the atmosphere."* [81]

### The biosphere

The biosphere refers to the part of the Earth's surface, atmosphere, hydrosphere, and lithosphere where living organisms exist. It includes all living things, from the smallest microorganisms to the largest mammals, and all their interactions with each other and with their environment.

The biosphere works through complex ecological processes that involve the exchange of matter and energy between living organisms and their environment. These processes include photosynthesis, respiration, nutrient cycling, and the food chain.

Photosynthesis, as we've discussed, is the process by which green plants and other photosynthetic organisms use sunlight to convert carbon dioxide and water into organic compounds, such as glucose and oxygen. Respiration is the opposite process, in which organisms use oxygen to break down organic compounds and release energy.

Nutrient cycling involves the movement of essential elements, such as carbon, nitrogen, and phosphorus, between living organisms and their environment. For example, plants absorb nutrients from the soil, which are then consumed by animals, and eventually returned to the soil through decomposition.

The food chain describes the transfer of energy and nutrients from one organism to another. In a typical food chain, plants are consumed by herbivores, which are then eaten by carnivores, and so on. Each level of the food chain depends on the level below it for energy and nutrients.

As shared by Lorraine Gordon, "Technology is not the answer. It is merely a tool that, when applied correctly, can contribute to a solution."

[81] *Cohen, W., Storhol, C., Martin, A., Castellanos, A., Arnott, C., Ostrander, C.R., Macmillan, C., Pershouse, D., Smith, D., Harris, E., Makepeace, F., Lowe, I., Handy, J., Rodriguez, K., Spry, K., Tucker, L., Rogers, L., Henry, L., Major, M. and Hawken, P. (2019). The Soil Story: The road to regenerative agriculture teaching curriculum, Australian Edition. Kiss The Ground and the Life Lab. https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf*

## Activity:

Biosphere Processes

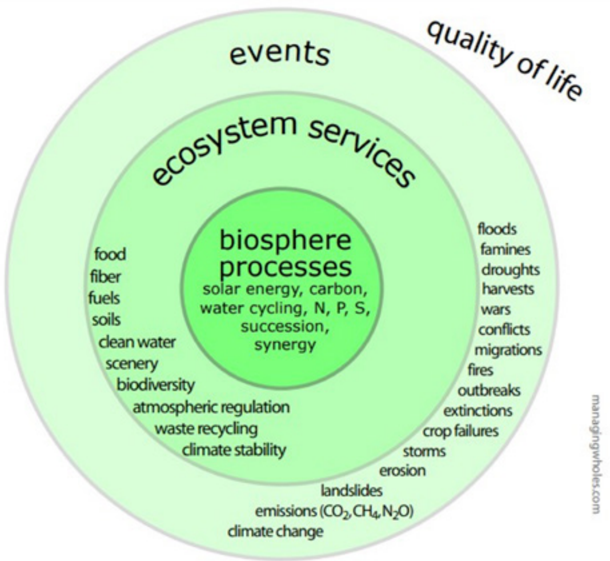



FIGURE 26: The importance of monitoring and the impact of our decisions and management strategies.[82]

Consider the diagram in figure 26.

- On which level do we, as humans, typically focus our efforts?
- If we want to transform the situation, where is the centre of gravity? Where can self-reinforcing or positive feedback create fundamental shifts?

## Soil Health

> **A country that destroys its soil destroys itself.**
>
> Franklin D Roosevelt,
> 2nd President of the US

## Activity:

Spotting the difference between soil and dirt

- What do you think when you hear the term soil, from Latin solum "soil, ground"?
- Investigate / research a common definition of the term soil. Did your thinking match that of your research?

We say “**soiled**” as in “soiled nappies”. This comes from Old French *soillier* "to splatter with mud, to foul or make dirty”.

- What influence do you think the term soiled has on how people perceive soil?
- Could the word dirt be used to describe soil?

**Dirt** is the metathesis of Middle English *drit*, drytt "excrement, dung, feces, any foul or filthy substance”, or from Old Norse drit, cognate with Old English dritan "to void excrement".

- What are the connotations of this term? That is, what does the word dirt make you think of when you learn about the origins of the word?

**Earth** from the Old English *eorþe* "ground, soil, dirt, dry land; country, district".

- Does the term Earth have the same connotations as soil or dirt?

[82] *Donovan, P. (2013). Measuring Soil Carbon Change: a flexible, practical, local method. Soil Carbon Coalition. https://soilcarboncoalition.org/files/MeasuringSoilCarbonChange.pdf Used under a Creative Commons License.*

## Activity:

Exploring our perceptions

Think of the words that encompass these terms, such as ‘earthenware’ or ‘dirty’. For each word, consider the connotations of the word and how you think this affects our perceptions of soil.

| Term | Connotations and perceptions |
|---|---|
| dirty | |
| night-soil | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

### The soil food web

The soil food web refers to the intricate and complex interactions among various living organisms that inhabit soil, including bacteria, fungi, protozoa, nematodes, arthropods, earthworms, and more. These organisms play vital roles in decomposing organic matter, cycling nutrients, and maintaining the overall health and fertility of the soil.

The soil food web can be broadly divided into two categories: the decomposer food web and the predator food web. The decomposer food web consists of organisms that break down dead organic matter, such as plant and animal debris, into simpler compounds. This includes bacteria, fungi, and detritivores like earthworms, millipedes, and woodlice. These organisms play a crucial role in releasing nutrients from organic matter and making them available to plants.

The predator food web consists of organisms that consume other organisms in the soil, ranging from small predators like mites and springtails to larger ones like centipedes and beetles. These predators help to regulate the populations of other soil organisms, prevent overgrazing, and maintain balance in the soil ecosystem.

The soil food web is an incredibly complex and interconnected system, and disruptions to any part of it can have far-reaching effects on soil health and fertility. For example, the use of pesticides can harm beneficial organisms and disrupt the balance of the soil food web, leading to reduced soil fertility and decreased plant growth. On the other hand, promoting healthy soil through practices like composting and crop rotation can help to support a diverse and thriving soil food web.

Soil organisms' range in size from microscopic single celled bacteria to larger complex organisms like arthropods and then to the more visible organisms such as earthworms. Each have their own roles to play within the soil food web.

| Organism | Typical numbers |
|---|---|
| Bacteria | 100 million - 1 billion/gram |
| Fungi | Several metres/gram |
| Protozoa | Several thousand flagellates & amoebae and >100 ciliates/gram |
| Nematodes | 10-20 bacterial feeders/gram |
| Arthropods | Up to 900/$m^2$ |
| Earthworms | 50 or more/$m^2$ |

FIGURE 29: Typical numbers of different organisms in a healthy agricultural soil.[83]

→ **Question:** Based on what you know about soil microbes, how important are "biological" contributions to soil formation? Outline the reasons for your response.

## Soil formation: the importance of time

The formation of soil is a slow and gradual process that can take hundreds or even thousands of years. The exact time it takes for soil to form depends on various factors such as climate, topography, vegetation, parent material, and the presence of organisms.

In general, the formation of soil begins with the weathering and breakdown of rocks and minerals by physical, chemical, and biological processes. Over time, these weathered materials mix with organic matter from dead plants and animals, and gradually become more complex and fertile.

In some cases, soil formation can be accelerated through human activities like composting, adding organic matter, and applying fertilizers. However, these practices may also have negative impacts on soil health if done improperly or excessively.

It's important to note that soil formation is a continuous process, and soils can continue to develop and change over time. Therefore, it's important to take measures to protect and maintain healthy soil for future generations.

Unfortunately, we don't always take care of our soils, as Ng and Chen (2017)[84] state –

> *"About two thirds of agricultural land in Australia is suffering from acidification, contamination, depletion of nutrients and organic matter and/or salinisation. And in case anyone forgets, soil is every bit as non-renewable as oil because soil formation is a very slow process."*

[83] *Earl, J. (2020). Soil Biology. Understanding Our Soils: increasing adoption and innovation in soil management. Local Land Services. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0006/1270527/7-Soil-Biology_FINAL.pdf*

[84] *Ng, E., L, & Chen, D. (2017). Save our soils: why dirt matters. The University of Melbourne. https://pursuit.unimelb.edu.au/articles/save-our-soils-why-dirt-matters*

But there is hope, as Dr Christine Jones from Amazing Carbon shares,[85]

> *"People have confused the weathering of rock, which is a very, very slow process, with the building of topsoil, which is altogether different. Most of the ingredients for new topsoil come from the atmosphere — carbon, hydrogen, oxygen and nitrogen".*

Carbon fixation in soil is a cyclical process that involves carbon in three different phases: gas, liquid, and solid. Unfortunately, a significant amount of the carbon that used to be in a solid phase in the soil has now become gas, which poses a potential threat to human beings. This situation is not only a concern for climate change, but it also has significant implications for food security, nutrient density of food, and soil's ability to retain water. Therefore, it is crucial to maintain carbon in a solid phase in the soil for various reasons.

## Activity:

Types of Carbon

→ Outline what you believe constitutes;

A. Solid carbon

B. Liquid carbon

C. Gaseous carbon

The phase likely to be least understood is "liquid carbon". Liquid carbon is basically dissolved sugar. Sugars are formed in plant chloroplasts during photosynthesis. Some of the sugars are used for growth and some are exuded into soil by plant roots to support the microbes involved in nutrient acquisition.

### Leaky roots

Plant roots leaking nutrients is known as root exudation. Root exudates are compounds that are released from the roots of plants and can have a variety of functions[86], such as attracting beneficial microorganisms, deterring plant pathogens, and facilitating nutrient uptake.

Some examples of compounds that can be released in root exudates include sugars, amino acids, organic acids, enzymes, and secondary metabolites[87]. These compounds can have a significant impact on the soil microbiome and nutrient cycling in the ecosystem.

Root exudation can be influenced by a variety of factors, including plant species, environmental conditions, and soil nutrient availability. Understanding the complex interactions between plants and their surrounding soil communities is an active area of research in the field of plant ecology.

### The plant-microbial bridge

The plant-microbial bridge refers to the intricate and mutually beneficial relationship between plants and microorganisms in the soil. Plants and microbes have coevolved over millions of years, resulting in a complex web of interactions that are essential for the health and productivity of ecosystems.

In this relationship, plants provide nutrients and energy to microbes through the release of root exudates and decaying plant material. In return, microbes help to break down and mineralize organic matter in the soil, making nutrients more available to plants. Microbes also play a key role in disease suppression, helping to protect plants from harmful pathogens.[88]

[85] *Jones, C. (2015). Dr. Christine Jones explains the life-giving link between carbon and healthy topsoil [Interview]. regenfarming.news. https://regenfarming.news/articles/917-sos-save-our-soils-dr-christine-jones*

[86] *Dakora, F. D., & Phillips, D. A. (2002). Root exudates as mediators of mineral acquisition in low-nutrient environments. Food security in nutrient-stressed environments: exploiting plants' genetic capabilities, 201-213.*

[87] *Carvalhais, L. C., Dennis, P. G., Fedoseyenko, D., Hajirezaei, M. R., Borriss, R., & von Wirén, N. (2011). Root exudation of sugars, amino acids, and organic acids by maize as affected by nitrogen, phosphorus, potassium, and iron deficiency. Journal of Plant Nutrition and Soil Science, 174(1), 3-11.*

[88] *Mazzola, M. (2004). Assessment and management of soil microbial community structure for disease suppression. Annu. Rev. Phytopathol., 42, 35-59.*

## Activity:

Rhizodeposition

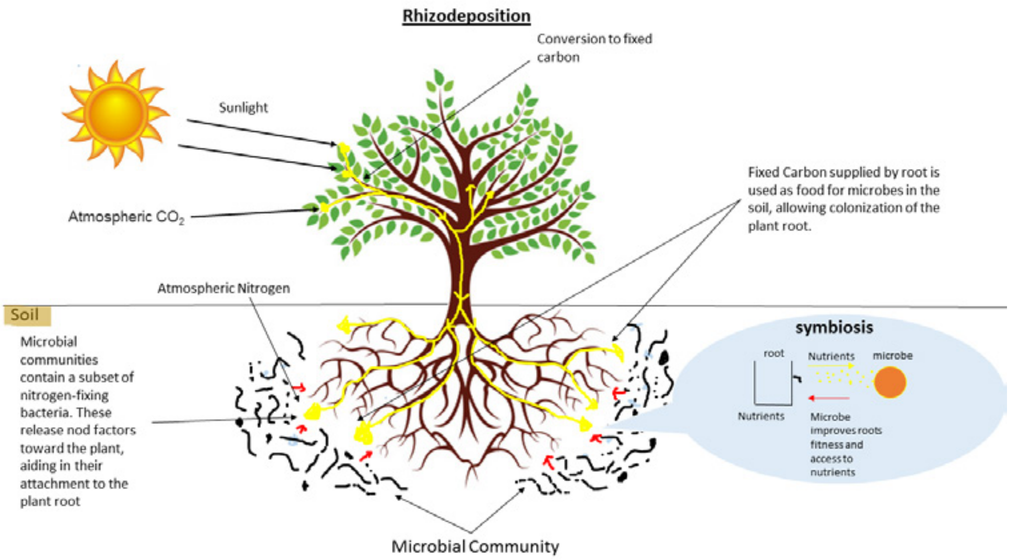



FIGURE 27: A dynamic microbial community in symbiotic relationship with plant roots in the rhizosphere.[89]

➔ Complete the cloze passage using the terms provided.

**TERMS:**

symbiotic | growth-promoting hormones | benefits
photosynthetic | products | root hair | exuded hyphae

**PASSAGE:**

Roots are colonised by a dynamic community of microbiota, including fungi, bacteria and archaea. In this ________________ relationship, the microbial communities associated with plant roots subsist off ________________ (carbon rich compounds) __________ from the plant host. Because fungi are multicellular, they can extend ____________ from nutrient exchange organs within host cells into the surrounding rhizosphere and soil.

The __________ to the plant include improved access to soil nutrients, due in part to stimulation of the growth of ________________. Additional benefits include the influence by __________________________, improved environmental stress tolerance and activated defences against pathogens.

[89] *Rhizodeposition: https://commons.wikimedia.org/wiki/File:Rhizodeposition.png Used under a Creative Commons License.*

## The role of soil organisms[90]

| Soil organism | Function |
|---|---|
| Algae | Soil algae are photosynthetic microorganisms that play a role in soil ecosystems, contributing to nutrient cycling and soil structure through their interactions with other microorganisms. They also have the potential to produce organic compounds that can be used as food for other soil organisms. Additionally, they can act as indicators of soil health and fertility. |
| Archaea | Archaea are important microorganisms that play roles in various ecosystems, including those with extreme conditions such as high temperatures and acidity. They also contribute to the cycling of nutrients, such as nitrogen and carbon, and can have a symbiotic relationship with other organisms, such as methanogenic archaea in the gut of some animals. |
| Bacteria | Soil bacteria are essential for maintaining healthy and fertile soil. They perform functions such as nutrient cycling, decomposition, soil structure formation, and plant-microbe interactions. Their roles support plant growth and productivity, which is crucial for healthy and sustainable agricultural practices. |
| Cellulolytic microbes | Cellulolytic microbes are a type of soil bacteria that break down cellulose, a complex carbohydrate found in plant material, into simpler sugars that can be used by other soil microbes and plants. They play a crucial role in the decomposition of plant material and nutrient cycling in soil ecosystems. |
| Earthworms | Earthworms improve soil structure and nutrient cycling through their burrowing activity and consumption of organic matter. They also facilitate the movement of water and air into the soil, and their castings contribute to soil fertility. Additionally, they can be indicators of soil health and are often used in soil management practices. |
| Fungi | Soil fungi play an important role in decomposing organic matter, which releases nutrients back into the soil for plant uptake. They also contribute to soil structure and nutrient cycling.<br>Mycorrhizal fungi form mutualistic relationships with plant roots, where they exchange nutrients and water for carbohydrates produced by the plant. They support plant growth and nutrient uptake, particularly in nutrient-limited environments, and contribute to soil structure and ecosystem health. |
| Nematodes | Soil nematodes are important in soil food webs, playing roles as predators, herbivores, and decomposers. They also contribute to soil structure and nutrient cycling through the breakdown of organic matter. Additionally, they can be indicators of soil health and are often used as bioindicators for assessing soil quality. |
| Protozoa | Protozoa play an important role in soil ecosystems by consuming bacteria, fungi, and other microorganisms, which helps regulate microbial populations and nutrient cycling. They also contribute to soil structure and help to maintain soil fertility. |

[90] *Information adapted from: Earl, J. (2020). Soil Biology. Understanding Our Soils: increasing adoption and innovation in soil management. Local Land Services. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0006/1270527/7-Soil-Biology_FINAL.pdf*

### The soil is alive

The soil food web is "the community of organisms living all or part of their lives in the soil".[91] This complex living system is a food web, and the greater the diversity it contains, the more resilient the soil. Surrounding the plant roots is a space not much wider than 3 – 5 mm called the rhizosphere. The rhizosphere is home to the highest activity of bacteria and fungi and is where an actively growing plant sources its nutrients.[92]

### Practices promoting a healthy soil food web

The diversity and magnitude of the soil food web depends on the number of plants and roots. As shared by Earl (2020), the fundamental needs for beneficial soil organisms to grow and thrive are:

1. A food source in the form of organic plant or soil organism matter.
2. Well aerated soil (most beneficial organisms are aerobic!).
3. Soil moisture. Soil moisture directly influences the soil biology. Essentially, greater water holding capacity of soil equals greater biological activity.[93]

## Activity:

The relationship between plant and soil diversity

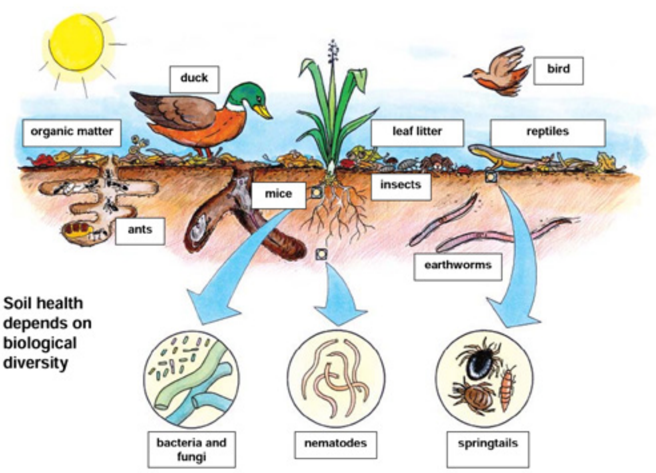



FIGURE 28: The role of biodiversity on soil health.[94]

→ Outline how a decrease in the biodiversity of plant species will impact the biodiversity of the soil.

### Humus: not a product of the breakdown of organic matter

> **"Humus cannot be "extracted" from soil any more than wood can be "extracted" from a tree."**
>
> Dr. Christine Jones, 2015.[95]

Humus is commonly perceived to be a product of broken-down matter. However, it is actually an anabolic process, that is, a process of building up organic matter. Instead of sugar being the final product, sugar is the start point. Soil microbes use sugars to create complex, stable forms of carbon, including humus, which is constituted of approximately 60% carbon along with other soil minerals.[96]

[91] *Your Soil is Alive: Understanding the soil food web on your land. (2023). United States Department of Agriculture. https://www.growingresiliencesd.com/_files/ugd/f128aa_cc97c729dcb14ba18abcf61efe55e539.pdf*

[92] *ibid.*

[93] *Earl, J. (2020). Soil Biology. Understanding Our Soils: increasing adoption and innovation in soil management. Local Land Services. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0006/1270527/7-Soil-Biology_FINAL.pdf*

[94] *Lines-Kelly, R., McLeod, M., Slavich, P., Tinning, G., Iskandar, T., Moore, N., Rachman, A., Jenkins, A. and Cox, J. (2009). Working with our friends in the soil: A farmer's guide to life in the soil. State of NSW Depatment of Primary Industries. https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/285871/NSW-DPI-Soil-biology-booklet.pdf Used with permission.*

[95] *Jones, C. (2015). Dr. Christine Jones explains the life-giving link between carbon and healthy topsoil [Interview]. regenfarming.news. https://regenfarming.news/articles/917-sos-save-our-soils-dr-christine-jones*

[96] *ibid.*

## Activity:

### Humus Under the Microscope

Consider the following passage from the Department of Primary Industries:[97]

*"On farms the main sources of organic matter are plant litter (plant roots, stubble, leaves, mulch) and animal manures. Earthworms and microorganisms decompose these materials. The process of decomposition releases nutrients which can be taken up by plant roots. The end product of decomposition is humus, a black crumbly material resistant to further decomposition. A complex chemical substance, humus stores plant nutrients, holds moisture and improves soil structure."*

Many sources present information on soil as if this vital living ecosystem can be easily separated into four components; minerals, water, air and organic matter. You might find reference to the organic matter as "decayed animals, plants and microbes" and would likely find reference to humus as the product of the decomposition of organic matter.

- Outline how you would explain the formation of "humus" as an anabolic process, the role of microbes in its formation and the benefit of humus in storing carbon in the soil.

[97] *Soil organic matter. Department of Primary Industries. https://www.dpi.nsw.gov.au/agriculture/soils/more-information/structure/organic-matter*

## The ongoing benefits of healthy soil

# Activity:

Analysing Soil Health

Soil organic matter and soil health comparisons[98]

| Location (Crop) | SOM (R) | Haney (R) | SOM (C) | Haney (C) | SOM Ratio (R/C) | Haney ratio (R/C) |
|---|---|---|---|---|---|---|
| Lebanon, CT (-) | 11.1 | 23.9 | 3.3 | 3.3 | 3.4 | 7.3 |
| Lewisburg, PA (corn) | 3.3 | 23.3 | 3.3 | 5.8 | 1.0 | 4.0 |
| Hickory, NC (corn) | 7.0 | 18.2 | 5.2 | 3.4 | 1.3 | 5.4 |
| Manchester, TN (soy) | 6.3 | 23.5 | 3.2 | 6.2 | 2.0 | 3.8 |
| Shenandoah, IA (corn) | 5.7 | 12.8 | 4.6 | 7.2 | 1.2 | 1.8 |
| Waverly, KS (soy) | 5.4 | 14.5 | 3.7 | 13.3 | 1.5 | 1.1 |
| Holton, KS (sorghum) | 4.6 | 17.7 | 4.4 | 14.3 | 1.1 | 1.2 |
| Bismarck, ND (peas) | 5.0 | 20.8 | 3.0 | 8.8 | 1.7 | 2.4 |
| Ekalaka, MT (peas) | 3.3 | 11.4 | 1.8 | 6.3 | 1.8 | 1.8 |
| Sebastopol, CA (cabbage) | 11.6 | 30.1 | 2.1 | 8.1 | 5.5 | 3.7 |

FIGURE 30: Comparison of regenerative and conventional farming practices on soil health.[99]

Figure note: Soil Health metrics for paired regenerative (R) and conventional (C) farms. SOM = % soil organic matter. Haney = Haney soil test soil health score.

Consider the data collected from ten locations across the USA. The Haney Soil Health Test (HSHT) is a recent approach used by scientists to quantify soil health by focusing mostly on soil biology.

➔ Describe the relationship displayed between the level of soil organic matter (%SOM) and the health of the soil (Haney score).

*Montgomery et al. (2020) note that, "Cabbage from the regenerative farm had 20%, 41%, and 70% more vitamins C, K, and E, respectively, as well as more than twice the phenolics and phytosterols, and 48% more carotenoids than cabbage from the conventional field. Corn, soy, and sorghum grown under regenerative practices respectively had 17%, 22%, and 23% more zinc".*[100]

➔ Based on this data, explain the apparent effect of regenerative farming on soil health and crop nutrient density.

[98] *Montgomery, D. R., Biklé, A., Archuleta, R., Brown, P. and Jordan, J. (2022). Soil health and nutrient density: preliminary comparison of regenerative and conventional farming. PeerJ. National Library of Medicine: national centre of Biotechnology Information. doi: 10.7717/peerj.12848. Used under a Creative Commons License.*

[99] *ibid.*

[100] *ibid*

## Activity:

Symbolism of Soil

FIGURE 31: Prime Minister Gough Whitlam pours soil into the hands of Vincent Lingari, symbolising giving the rights to a small piece of land back to the Gurindji people (16 August 1975).[101]

The powerful photograph of Whitlam pouring soil into the hand of Vincent Lingiari (see Figure 31) is an image that reminds us of the connection between people, places and soils; the connection between social and environmental justice; and the connection between the present and the past that resides in the land.

→ Explain why this photo (figure 31) was such a powerful image to portray a monumental event.

It goes without saying but there is also plenty of research that proves: **healthier soil, means healthier plants and animals that depend on this soil.**[102] We humans are these animals. We rely on the plants, and the soil the plants live in, for our very existence.

[101] *Wave Hill walk-off: Facts for Kids. (2023). Kiddle Encyclopedia. https://kids.kiddle.co/Wave_Hill_walk-off. Used under a Creative Commons License.*

[102] *Leifert, C. (2022). Organic Farming Provides a Blueprint to Improve Food Quality, Safety and Security. Agronomy, 12(3), 631. https://doi.org/10.3390/agronomy12030631*

# Notes:

# Notes:

# MODULE 5:
# Holistic Decision Making

## Consider the following words you might encounter during module 5 of the Regenerative Agriculture course.

For each word, use a ✓ to indicate your understanding of the word:

RED = "I have no idea"

AMBER = "I have heard it and might know what it means"

GREEN = "I know exactly what this word means"- record your definition.

| WORD | RED | AMBER | GREEN | MEANING |
|---|---|---|---|---|
| Holistic | | | | |
| Paradigm | | | | |
| Doughnut Economics | | | | |
| Planetary Boundaries | | | | |
| Tipping Points | | | | |

## Holistic Thinking

**The roots of regenerative agriculture stem from holistic thinking. This is because farmers conduct their work within nested, living systems. These cannot be understood without a holistic approach.**

Lorraine Gordon,
Regenerative Agriculture Alliance.

The concept of regenerative agriculture encompasses a holistic approach. It is a paradigm that has many facets and complexities. Ensuring management decisions are based around a holistic approach ensures a continuous cycle of improvement occurs. As Lorraine Gordon (2022) shares,

*"All living systems are made of smaller systems nested within larger systems… all of these levels of systems are whole and distinct from one another, and at the same time they are dynamically interdependent and inseparable… this is the concept of holism".*[103]

Holistic management provides a framework for decision-making for complex systems. Considerations of economic, environmental and social parameters enable use of resources to better manage stresses, challenges and changes and create an improved agricultural ecosystem.

Management functions and biophysical functions cannot be separated, but are integrated in holistic management.

Planning procedures include:

- Land planning
- Financial planning
- Ecological monitoring

[103] *Gordon, L. (2020). Gippsland Climate Change, Regenerative Agriculture and Community Resilience Forum.*

## Activity:

Management in Regenerative Agriculture

**Create a flowchart to indicate your understanding of holistic management in regenerative agriculture.**

You might include labels such as: monitoring current situations, ideas and strategies for improvement, discussions with others with experience, engaging outside specialists, community collaboration, feedback, use of available indigenous knowledge and practices, implementation of chosen options, monitoring resources, sharing measures of progress, implementation of additional strategies...

## Managing Holistically[104]

| | |
|---|---|
| **1. Nature functions in wholes** | The complexity in which we manage means you cannot change or control something in one area without it impacting on something else in another area. |
| **2. Observe and understand the environment that you manage** | Taking an action in one environment may yield a totally different outcome if you took the same action in a different environment. |
| **3. Define what you are managing** | Holistic management requires you to think about what you are managing. Initially, that is done by considering the people, equipment and money that are available as resources. Secondly, you will need to create your Holistic Context, that is *why* you want to manage holistically. This is considered through:<br>1. Quality of life: a description of how you want your life to be.<br>2. Your future resource base: a description of how your resource base must look for you to continuously meet a level of production that will allow you to live the quality of life you stated. |
| **4. What we are managing, and a covered ground is a key management aim** | You need to know about the four ecosystem processes on your land – the mineral cycle, water cycle, solar energy flow and community dynamics |
| **5. Play with a full deck – consider All the Tools** | You need to consider all the tools that may be available to you. They are technology, fire, rest, grazing animal impact and behaviour, and living organisms. |
| **6. Livestock can be a tool to improve the health of land** | Animals are critical to the health of the land, and we mimic that predator prey relationship by using grazing planning. |
| **7. Check your decisions** | Undertake a decision-making process using a relevant tool or framework to step you through the important factors that you need to consider. The decision process allows us to ensure we have considered the Social, Environmental and Economic outcomes and impacts of our decisions. This is ALWAYS with reference to our Context (our '*why*') to make sure we are progressing to where we want to be |

[104] *Summarised by Glen Chapman www.southernblue.com.au from the work of the Savory Institute (https://savory.global/)*

## Holistic Decision Making

We are constantly making decisions, and these decisions have an impact on every aspect of life, often far removed from the site of the decision. The choices we, our neighbours, and governments are making, and have made in the past, changes the way we live in often incomprehensible ways, and has led us to where we stand today... economic unpredictability, social instability and environmental degradation (virtually every inch of land on the planet today is managed – the result of human decisions). We need to challenge the way in which we make decisions and be cognisant of the continual greater understanding of how emotions and prior experience (including in utero) shape decision making capacities of people

Our current decision making tends to focus on a single aim, hoping for a simple solution. We often don't consider the broader vision we have for our lives or think about the decision against the values we hold. Likewise, the impact of our actions in an environmental, social and economic sense are rarely considered. We seldom assess our daily decisions to make sure they match the quality of life we seek. We are often focused on the symptoms instead of the causes for concern in our life, and are guided simply by our likes and dislikes. We resist change, comfortable in the safety of doing the same old thing, rarely looking at the broader implications of our decisions and actions.

However, holistic decisions making is one way to provide a decision-making framework, and was predated by agroecology, biodynamics, Keyline etc that have their own themes and approaches. Each approach is worth investigating as you discover what works for you.

## Activity:

We're running out of time

Almost ten years ago Allan Savory stood before a global audience and delivered a TED talk that received a standing ovation. It was called, "We're running out of time".

> **We're running out of time...**
>
> Allan Savory - March 2014

Watch the 50 minute video that documents Allan Savory's thinking: https://www.youtube.com/watch?v=q7pI7IYaJLI.

Consider the following questions:

- What did Allan Savory mean that we are 'running out of time'? Do you agree or disagree with this statement?
- What have we done in the past decade? Are we doing enough?
- How do we work to make positive changes without feeling overwhelmed or disheartened about our future?

## Activity:

Taking Action: what role do you play in the carbon cycle?

Complete Lesson 5 from the "Soil Story Curriculum: The road to regenerative agriculture teaching curriculum: rebuilding healthy soils for Carbon Cycle Balance" from https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf

"In Lesson 5 students take on the role of soil activists. Inspired by the Kiss the Ground origin story, students examine their newfound understanding of the carbon cycle and the importance of the pedosphere to evaluate the environment around their school campus or community. They revisit their carbon cycle model and identify one interaction they can impact with collective action. Then they plan and implement a community project to increase soil biodiversity and share what they've learned with others. Students can also build a compost pile in the school garden or plant a tree in their community."[105]

### Living holistically and with Country

**Be comfortable in ambiguity and embrace transformation and transformative learning.**

Lorraine Gordon[106]

➔ Is the holistic way of being such a new concept?

Incorporating this concept as a core principle of regenerative agriculture may lead some to believe it is a new-age, "out-there" approach. Nothing could be further from the truth.

**Consider this:** From the Indigenous Peoples' Statement for Planetary Health and Sustainable Development, which resulted from a 2019 global conference on health promotion held in Aotearoa, New Zealand:

*"Core features of Indigenous worldviews are the interactive relationship between spiritual and material realms, intergenerational and collective orientations, that Mother Earth is a living being – a 'person' with whom we have special relationships that are a foundation for identity, and the interconnectedness and interdependence between all that exists, which locates humanity as part of Mother Earth's ecosystems alongside our relations in the natural world."* [107]

Indigenous peoples have been custodians of Country for thousands of years when they cared for their land and seascapes as an extension of their own bodies. For generations, they honoured this care and custodianship using traditional knowledge and practices. This traditional knowledge and these traditional practices demonstrate an instrinsically holistic approach to caring for land, for Country. However, due to the influence of Western / minority world practices, the Earth is now facing an ecological crisis. As shared by Dr. Meg Parsons and Dr. Lara Taylor (2021),

*"To reverse the decline and avoid reaching tipping points, we must adopt more holistic and integrated governance and management approaches. These governance and management systems are based on Indigenous knowledge that connects places and cultures and emphasises holistic approaches. The acknowledgement of inter-relationships between human and nonhuman beings (plants, animals, forests, rivers, oceans etc.) is a common thread. So is an emphasis on reciprocity and respect towards all beings."* [108]

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[105] *Cohen, W., Storhol, C., Martin, A., Castellanos, A., Arnott, C., Ostrander, C.R., Macmillan, C., Pershouse, D., Smith, D., Harris, E., Makepeace, F., Lowe, I., Handy, J., Rodriguez, K., Spry, K., Tucker, L., Rogers, L., Henry, L., Major, M. and Hawken, P. (2019). The Soil Story: The road to regenerative agriculture teaching curriculum, Australian Edition. Kiss The Ground and the Life Lab. https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf*

[106] *Gordon, L. (2020). Gippsland Climate Change, Regenerative Agriculture and Community Resilience Forum.*

[107] *Langbecker, K. (n.d.). We are the soil that walks. UNESCO Mahatma Gandhi Institute of Education for Peace and Sustainable Development. https://mgiep.unesco.org/article/we-are-the-soil-that-walks*

[108] *Parsons, M. and Taylor, L. (2021). Why Indigenous knowledge should be an essential part of how we govern the world's oceans. The Conversation. https://theconversation.com/why-indigenous-knowledge-should-be-an-essential-part-of-how-we-govern-the-worlds-oceans-161649*

➔ What can Western agricultural science learn from this approach and this way of thinking about land?

In a piece written for The Conversation, Andrew Peters, a lecturer in Indigenous Studies at Swinburne University of Technology writes how Indigenous knowledge and technology have existed and been linked since the beginning of time. When thinking about the role of technology and how it can be beneficial rather than destructive, he notes that Indigenous concepts such as relationality and connection, reciprocity, reflexivity, and country are the foundation upon which we can collectively use technology for the good of all. He cites specific examples such as fire management, Native agriculture and aquaculture, astronomy and geology, health and well-being, as well as Native foods and medicines. While his piece is focused on Aboriginal innovation in Australia, this knowledge lives with Indigenous knowledge holders around the world. Further, these concepts are about working with the living world, and how technology can be embraced in doing this, rather than fighting against or dominance over it.[109]

[109] *Peters, A. (2021). Indigneous technology is often misunderstood. Here's how it can be part of everyday life. The Conversation. https://theconversation.com/indigenous-technology-is-often-misunderstood-heres-how-it-can-be-part-of-everyday-life-167191*

## Activity:

Lake of Scars

Watch the 95 minute documentary Lake of Scars: https://www.lakeofscarsfilm.com/


➔ What are the opportunities for working together and reconciliation that exist for Western agriculture with Aboriginal Australian thinking and practice?

To conclude this module, and this workbook, we'd like to share some First Nations Perspectives on Regenerative Agriculture – in particular, holistic decision making – from scientist and Gamilaraay man, Jacob Birch.

> *Regenerative agriculture is not prescriptive; rather, it is a mindset of conceptualising, investigating, developing, and applying context specific and holistic practices to regenerate the environment, economy, community and develop a culture committed to equity, collaboration, and diversity.*
>
> *The holistic system is greater than the sum of its parts. This is perhaps why Western science struggles to quantify regenerative agriculture. Conversely, First Nations culture is entirely comfortable in dealing with diverse, complex, and holistic systems.*

*There are several learnings we can take from First Nations in decision making. First Nations people will make decisions that benefit all First Nations people. Decisions are also made for happiness and well-being; and decisions that align with First Nations values and ethics. For example, water is protected first and foremost because it is not only vital for life, but it is vital for spiritual wellbeing, mental wellbeing, and recreation.*

*Another learning can be taken from First Nations people's deep understanding of ecology. First Nations people don't just have deep reverence for large totemic species like kangaroo, emu and crocodile, but smaller totemic species like insects. Ants, wasps, and the native honeybee are particularly important species. Totemic species are linked to certain habitats and other species, which they have important relationships with. So, in protecting one, you must invariably protect all species related to that totem. This impacts decision making. For example, a sand goanna person will understand, protect, and maintain the habitats that are important for ensuring the ongoing sustainability of the sand goanna population. This is a very basic description because deeper knowledge is not appropriate to share. The main point is, understanding your local ecology, and the relationships between soils, vegetation, and all animals, is vitally important for appropriate decision making.*

# Notes:

You never change things by fighting the existing reality.
To change something, build a new model that makes the existing model obsolete.

Buckminster Fuller

# Notes:

"Students must learn how to discard old ideas, how and when to replace them...how to learn, unlearn, and relearn."

Alvin Toffler

# MODULE 6: Carbon Farming, Sequestration and Markets

## Consider the following words you might encounter during Module 6 of the Regenerative Agriculture course.

For each word, use a ✓ to indicate your understanding of the word:

RED = "I have no idea"

AMBER = "I have heard it and might know what it means"

GREEN = "I know exactly what this word means"- record your definition.

| WORD | RED | AMBER | GREEN | MEANING |
|---|---|---|---|---|
| Carbon sequestration | | | | |
| Carbon trading | | | | |
| Carbon-neutral produce | | | | |
| Australia's NDC | | | | |
| ACCU's | | | | |
| ERF | | | | |

## Carbon Farming, Sequestration and Markets

Soil is a natural reservoir for carbon, and it plays a vital role in regulating the Earth's carbon cycle. Carbon is stored in soil through the process of photosynthesis, where plants take in carbon dioxide from the atmosphere and use it to create organic matter through the process of photosynthesis. This organic matter is then decomposed by soil microorganisms, releasing carbon dioxide back into the atmosphere, or it can be stabilized in the soil for extended periods, contributing to soil carbon storage.

Soil carbon is an essential component of soil organic matter, which is critical for soil health and productivity. It helps to improve soil structure, water holding capacity, nutrient cycling, and microbial activity. Furthermore, soil carbon plays a significant role in climate change mitigation by acting as a carbon sink[52]. When carbon is stored in the soil, it is not released into the atmosphere as carbon dioxide, where it can contribute to global warming and climate change.

However, human activities such as deforestation, land use changes, and intensive agricultural practices can cause significant losses of soil carbon, releasing it back into the atmosphere and contributing to climate change[53]. This makes the management of soil carbon crucial for sustainable land use and climate change mitigation. Strategies such as reducing tillage, planting cover crops, and promoting agroforestry can help to increase soil carbon levels and contribute to a more sustainable future[54].

[52] *Lal, R., & Kimble, J. (1997). Conservation tillage for carbon sequestration. Nutrient Cycling in Agroecosystems, 49, 243-253.*

[53] *Sedjo, R., & Sohngen, B. (2012). Carbon sequestration in forests and soils. Annu. Rev. Resour. Econ., 4(1), 127-144.*

[54] *Newton, P., Civita, N., Frankel-Goldwater, L., Bartel, K., & Johns, C. (2020). What is regenerative agriculture? A review of scholar and practitioner definitions based on processes and outcomes. Frontiers in Sustainable Food Systems, 4, 194.*

## Activity:

### The Carbon Cycle

**Use the labels provided to create a diagram illustrating the cyclic nature of carbon in a healthy agricultural setting.**

| | |
|---|---|
| Livestock increase the availability of major nutrients in the soil | Plants absorb carbon dioxide |
| Plants produce oxygen | Carbon enters the soil |
| Long-term carbon storage in the soil | Carbon-rich soils hold more water |

Diagram:

## Activity:

### Representing Photosynthesis

In the space provided, create a sketch to demonstrate how students would outline the process of photosynthesis.

Diagram:

## Activity:

Analysing Photosynthesis

Consider the image in figure 20. It is likely that many people would probably illustrate photosynthesis with an image similar to that in figure 20.

- Outline the production of carbohydrates by the plant in this sketch.

  It is a misconception that most of the sugars formed in the process of photosynthesis end up as leaves and stems.

- Consider and discuss what happens below the surface.

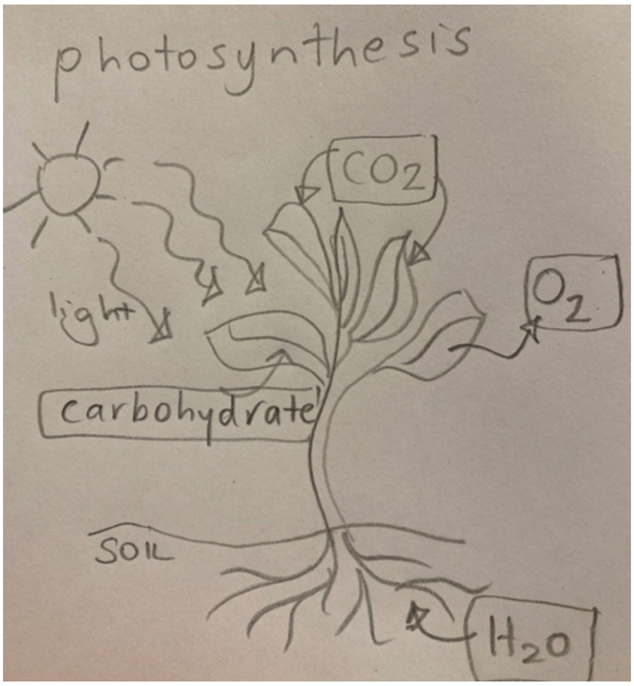


FIGURE 20: Student sketch of photosynthesis.

## Activity:

Photosynthesis: what role do plants play in the carbon cycle?

Complete Lesson 2 from the *"Soil Story Curriculum: The road to regenerative agriculture teaching curriculum: rebuilding healthy soils for Carbon Cycle Balance"* from https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf

> *"In Lesson 2, students collect evidence that plants absorb carbon (in the form of CO2) from the atmosphere during the process of photosynthesis. By observing evidence of the chemical reaction that takes place inside of plants, algae, phytoplankton, and other microorganisms, students begin to develop an understanding of the molecular interactions in the carbon cycle. Essentially, they discover that carbon dioxide molecules in the atmosphere are broken down and rearranged to form carbohydrate molecules in plant matter in the biosphere."*[55]

## Soil carbon: types and properties

Within the soil, there are two types of carbon. Soil organic carbon is relatively available and comes from the decomposition of living organisms and through the exchange discussed above. Soil inorganic carbon is derived from the mineral forms of carbon, often through weathering. Carbon is lost through fire and poor soil management. Tillage exposes soil organic matter to oxygen which causes oxidation and the loss of carbon from the soil, leading a to decrease soil health and function.

However, both roots and shoots contribute to carbon entering the soil.

[55] *Cohen, W., Storhol, C., Martin, A., Castellanos, A., Arnott, C., Ostrander, C.R., Macmillan, C., Pershouse, D., Smith, D., Harris, E., Makepeace, F., Lowe, I., Handy, J., Rodriguez, K., Spry, K., Tucker, L., Rogers, L., Henry, L., Major, M. and Hawken, P. (2019). The Soil Story: The road to regenerative agriculture teaching curriculum, Australian Edition. Kiss The Ground and the Life Lab. https://kisstheground.com/wp-content/uploads/2021/12/Soil-Story-Curriculum__Aus_190311-1.pdf*

Generally, above ground plant matter contributes minimally to soil carbon. On average, leaf matter is made up of about 42% carbon, root material about 58% carbon and only upon partial decomposition is plant matter considered to be contributing to the soil carbon bank.[56]


FIGURE 21: Sources of soil carbon.[57]

Microbial biomass is potentially a significant contributor to soil carbon. Under conventional management, up to 5% of total soil organic carbon originates from microbial biomass.

➔ How do you think a regenerative agriculture management system would compare?

As discussed previously, there are two main types of soil carbon: organic and inorganic. In this section we explore the sub-types of organic soil carbon. Each of these sub-types has different biological, physical and chemical properties. These, in turn, have different roles in soil function, health, fertility and productivity[58].

**There are 3 main soil organic carbon sub-types:**[59]

1. **Particulate Organic Carbon (POC).** This the least stable and shortest lived. It usually only lasts weeks or months before the carbon is decomposed further and either released as $CO_2$ or becomes part of the soil. Particle size is 0.05 to 2mm.
2. **Humus Organic Carbon (HOC).** Relatively stable. Lasts for years or decades. Usually decomposed material found as large organic molecules attached to soil particles (size <0.05mm).
3. **Resistant Organic Carbon (ROC).** Very stable and may last for hundreds of years. Contains inert material, mostly charcoal, and levels change very little over time.

**Consider: “Collectively, the amount of carbon associated with soil organic carbon is some 3.3 and 4.5 times more than that contained in atmospheric $CO_2$ and living biomass, respectively.”**[60]

[56] *Earl, J. (2020). Soil Carbon & Organic Matter. Local Land Services, New South Wales. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0005/1270526/6-Soil-Carbon-and-Organic-Matter_FINAL.pdf*

[57] *Image adapted from the Local Land Services: https://www.lls.nsw.gov.au/__data/assets/pdf_file/0005/1270526/6-Soil-Carbon-and-Organic-Matter_FINAL.pdf*

[58] *Hamilton, L. and Anderson, G. (2015). Soil Carbon Snapshot. FertCare, Agriculture Victoria. https://agriculture.vic.gov.au/__data/assets/pdf_file/0006/857607/Soil-Carbon-Snapshot-updated-May-2022.pdf*

[59] *ibid.*

[60] *Richardson, A., Coonan, E., Kirkby, C. and Orgill, S. (2020). Soil Organic Matter and Carbon Sequestration. In Australian Agriculture in 2020: From Conservation to Automation. Jim Pratley and John Kirkegaard (Eds.). Australian Society of Agronomy. http://www.agronomyaustraliaproceedings.org/images/sampledata/specialpublications/Australian%20Agriculture%20in%202020.pdf*

## The Soil Carbon Sponge

The "soil carbon sponge" refers to the ability of soil to absorb and store carbon from the atmosphere, much like a sponge absorbs and stores water. This process, known as carbon sequestration, occurs when plants absorb carbon dioxide (CO2) from the atmosphere during photosynthesis and store it in their tissues[61]. When plants die and decompose, some of the stored carbon is released back into the atmosphere as CO2. However, a significant portion of the carbon can be stored in the soil, where it can remain for hundreds or even thousands of years.

Soil acts as a carbon sink, absorbing and storing carbon from the atmosphere through several mechanisms. These include:

1. **Plant roots:** When plants grow, they release sugars and other compounds into the soil through their roots. These compounds can be used by soil microorganisms, which in turn release CO2 back into the atmosphere. However, some of the carbon is stored in the soil as organic matter.
2. **Soil microorganisms:** Soil microorganisms, such as bacteria and fungi, play a crucial role in breaking down organic matter in the soil[11]. During this process, they release CO2 back into the atmosphere. However, as with plant roots, some of the carbon is stored in the soil as stable organic matter.
3. **Physical protection:** Soil particles can physically protect organic matter from decomposition by burying it deep in the soil, making it less accessible to soil microorganisms.

Increasing soil carbon levels has numerous benefits, including improving soil fertility and water-holding capacity, reducing erosion, and mitigating climate change by removing carbon from the atmosphere. To enhance the soil carbon sponge, land management practices such as reducing tillage, planting cover crops, and using compost and manure can be employed to increase the amount of organic matter in the soil, leading to increased carbon sequestration[62].

## Becoming a carbon farmer

**According to Carbon Farmer, Lorraine Gordon, there are 9-steps to Carbon Farming:**[63]

1. Carbon ready: conduct an initial farm assessment and appraisal.
2. Complete a Carbon Management Plan to increase soil carbon.
3. Register the farm as a project with the Federal Government. It is a lengthy process - so be prepared!
4. Consider entering the project into competitive ERF auction process for a carbon contract to sell ACCU's to the Federal Government within 10 years.
5. Complete baseline documentation to establish history of previous practice.
6. Baseline soil testing and audit (government requires 3 testing regimes spaced apart in total) includes: mapping, recording, analysis and record keeping
7. Review Management Plan annually.
8. External independent audits undertaken with the 3 testing regimes.
9. Payment to farmer within 3 to 5 years from sale of ACCU's to either Government, Corporates or both!

**Practices that do not contribute to carbon farming**

- Paddocks of bare soil/lack of ground cover
- Monocrops/lack of biodiversity
- Spraying out paddocks prior to sowing new pastures or crops
- Set stocking
- Reliance synthetic chemicals, fertilisers and pesticides
- Over tillage/disturbance of soil

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*[61] Masters, N. (2019). For the love of soil: strategies to regenerate our food production systems. Integrity Soils Limited.*
*[62] Sala, O. E., & Paruelo, J. M. (1997). Ecosystem services in grasslands. Nature's services: Societal dependence on natural ecosystems, 237-251.*
*[63] Read more about Lorraine's Carbon Farming journey here: https://farmingtogether.com.au/wp-content/uploads/2021/06/Moffat-Falls-Case-Study-v2.pdf*

### Examples of Other Types of Carbon Farming

While the most popular method of carbon farming is storing carbon in the soil such as carbon sequestration, cropping, pasture, horticulture, and mixed enterprises where soil carbon must be measured to directly calculate rather than modelled; there are other less common options available. Some of these are:[64]

- Planting native trees and shrubs (Native Forest)

  This method requires planting trees to capture and store carbon dioxide from the air. It involves a commitment to establishing a permanent plantation of forests of native tree species on cleared land[65].

- Managing stock to allow native forest to regrow

  This method involves managing or removing external factors that prevent vegetation regrowth from occurring. It is mainly suitable for larger areas – from about 5000 hectares – where native vegetation is allowed to regenerate[66].

- Beef Herd Improvement – reducing methane

  In the Beef Herd Improvement method, farmers are provided financial incentives for minimising the methane from cattle. It is suited to larger herds, where the action used to reduce methane is not prescribed. However, the Beef Herd Calculator must be used for calculations[67].

- Reducing nitrous oxide emissions from irrigated cotton

  This method is available for irrigated cotton producers only. Nitrogen fertiliser releases a potent 'greenhouse gas' when applied (nitrous oxide) and reducing this release can earn carbon credits[68].

### Incentives to increase the carbon content in soils:

**ACCU's:**

Australian Carbon Credit Units: ACCU represents one tonne of carbon dioxide equivalent net abatement (through either emissions reductions or carbon sequestration).

**ERF:**

The Emissions Reduction Fund- a voluntary scheme that incentivises organisations and individuals to adopt new practices and technologies to reduce their emissions or store carbon. The Emissions Reduction Fund provides ongoing opportunities for farmers and land managers to:

- participate in emissions reduction, and
- capture and store carbon (carbon sequestration).

Under the scheme, landowners and farmers who adopt approved ERF methods can earn Australian Carbon Credit Units (ACCUs). These units can be sold to the government or on the secondary private market to generate additional income streams, while benefiting the environment.

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[64] *"What can I do on farm to earn a carbon credit?" (n.d.). Carbon Farmers of Australia. https://carbonfarmersofaustralia.com.au/carbon-farming/available-methods/*

[65] *ibid.*

[66] *ibid.*

[65] *ibid.*

[67] *ibid.*

[68] *ibid.*

## Activity:

### Opportunities for Landholders

Consider the possible options available to landholders outlined below.[69]

**Opportunities for the land sector**

| Agricultural | Vegetation |
|---|---|
| Animal effluent management | Avoided clearing of native regrowth |
| Beef cattle herd management | Avoided deforestation |
| Estimation of SOC sequestration | Human-induced regeneration of a permanent native forest |
| Reducing GHG emissions by feeding dietary additives to dairy cows | Measurement-based methods for new farm forestry plantations |
| Reducing GHG emissions by feeding nitrates to beef cattle | Native forest from managed regrowth |
| Reducing GHG emissions from fertiliser in irrigated cotton | Plantation forestry |
| | Reforestation and afforestation |
| | Tidal restoration of blue-carbon ecosystems method |
| | Verified carbon standard project |

- Which of these do you think would have the greatest impact on reducing Australia's emissions? Explain your reasoning.
- Based on your location, which of these might be of interest to you? Are there more that might appeal?
- What particular legislations govern the use of these strategies?
- Are there particular skills/ qualifications required for adopting the approved ERF practices?

[69] *"Emissions Reduction Fund methods". (2023). Australian Government Clean Energy Regulator. https://www.cleanenergyregulator.gov.au/ERF/Pages/Method-development.aspx*

# Notes:

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*The delivery of this program is possible through the Australian Government's Agricultural Innovation Hubs Program.*