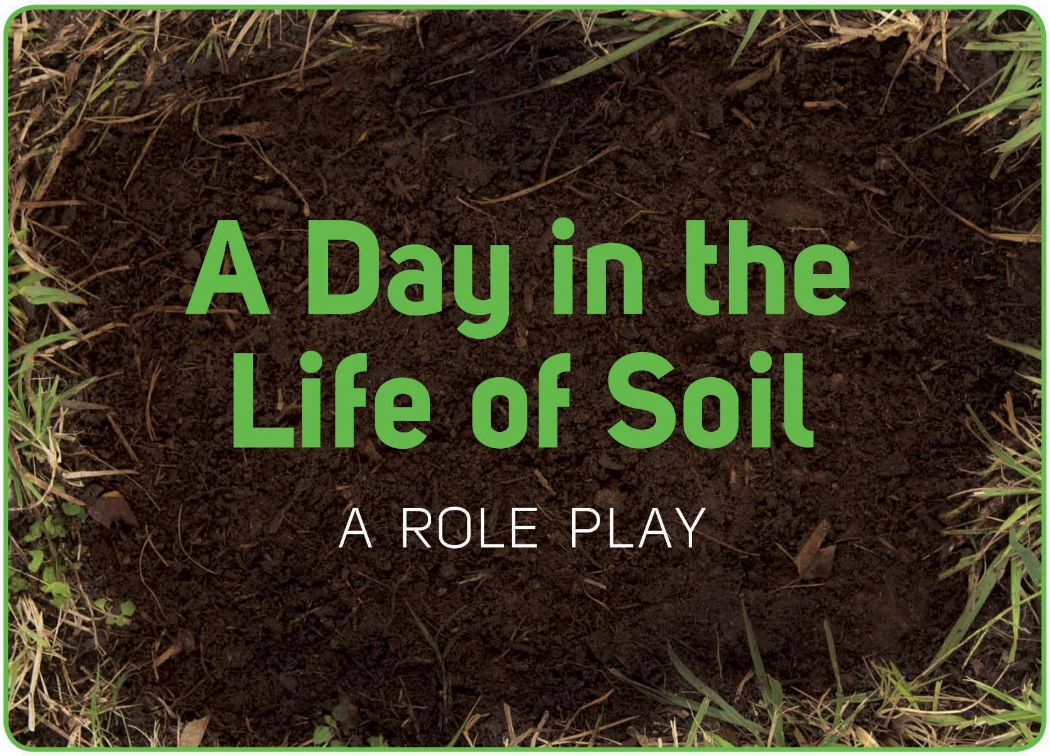

Version as at 23 September, 2022

A Day in the Life of Soil *was first developed by David Hardwick, a consultant with Soil Land Food. It was released under a Creative Commons 3.0 licence in 2012. This version has seen some modification by Simon Hamlet (Department of Agriculture, Fisheries and Forestry Queensland).*

Endorsements

This is an entertaining, ingenious and original way to convey the importance of soil creaturers and the soil food web.

James Nardi, Author of “Life in the Soil”.

I can heartily endorse the Day in the Life of Soil presentation. The role play was a very clever and enjoyable means of introducing students of all ages to this very busy ecosystem; they now have a good awareness of everything that is going on in the soil, that we can't see.

Most of our students have a rural background and you could almost see the lights go on as they related what they were learning through the role play to their own farming knowledge and experience.

Thanks again for simplifying the Science to a level that the students could clearly understand, through an experience that they could all participate in and still have fun doing it.

Jenny Lane
Primary Science Teacher

What is in the kit

18 role play cards
These instructions

What you will need to provide

15 Black Unifix blocks (‘Carbon’) … or a bag of minties
15 Green Unifix blocks (‘Nitrogen’) … or a bag of fantails
15 Blue Unifix blocks (‘Phosphorus’) … or a bag of milky chews

A box to hold each of the above

Set up

Slide Show: Decoding the Cards

Hand out the eighteen cards to participants. Not all the cards are needed for the exercise; the essential group is cards 1-8. I also require volunteers to play the roles of the atmospheric carbon pool, the atmospheric nitrogen pool and the rock bound phosphorous pool.

Have participants examine their cards and ask them to stand in groups according to their organism's characteristics, grouping one feature at a time; eg. kingdom, size, diggers, etc. Facilitate a conversation about diversity in the soil system, and the way in which many of the important components in the soil are not visible to the naked eye.

Image for decoding the cards is available on the slide show.

Point out that only 18 cards are represented in the role play. Can participants think of other organisms which could be on the cards? James Nardi's book *Life in the Soil* is an excellent resource to help with this.

Inform participants that at the end of the role play they will be using the cards to construct a soil food web.

Pulled from thin air

Slide Show: Proportional Composition of Dry Air

This is an optional opening procedure, which focuses on the significance of air to the plant.

1. Have students blow on their hands ... the reason we can feel the breeze is because air has weight.
2. Refer to the air density calculator. This will allow you to customise the air weight for the days presentation. For this exercise I will work through an example which assumes an elevation of 10m and a temperature of 24 °C, at which air has a density of 1.183 kg/m^3.
    a. Note that the density of air is influenced by elevation above sea level and temperature and presence of water vapour. The higher the elevation the lower the density and the higher the temperature the lower the density.
    b. For the purpose of this exercise we will consider dry air. The addition of water vapour to air actually decreases the density of air.
3. Introduce the makeup of Air. The composition is most often conceptualised as proportion by volume. Mostly, N (78%), O (21%), Ar, and CO_2. Show on a pie chart, the fraction of CO_2 is so small it appears as a line, scientists report this as ppmv (parts per million by volume). Due to the difference in the molecular weights of the components which make up air, the proportions by weight are somewhat different (see http://www.engineeringtoolbox.com/air-composition-d_212.html).
4. Weight of CO_2 in a cubic meter of air = 1,183 * 0.00046 = 0.54 grams of CO_2.
5. We are interested in Carbon Cycling, 27.3% of the weight of CO_2 is C, so amount of carbon in a cubic metre of air = 0.54 * 0.27 = 0.147 grams of C per cubic metre of air.
6. Look out the window. 97% of all the weight in all the plants you can see comes from this tiny fraction of CO_2 in air.
7. Hold up a piece of wood of known weight. For this exercise I will use a block of pine wood weighing 500 grams. A piece of dried pine wood is approximately 50% C.
8. We may think that we could take a piece of wood like this 500g piece of pine. Divide that by 50% to get 250g. Then Divide 250g by 0.147g to get approx 1,700 m^3.
9. But plants also respire! That amount of air needed is much greater.
10. When introducing the rhizobia and other nitrogen fixing organisms refer back to point 3 above.

Building the soil

Call out Card 1, 'the plant'. The plant is the key focus for the agricultural soil system; this is the crop. It is also the only primary source of carbon (C). Plants bring C into the soil via photosynthesis; water plus carbon dioxide in the presence of light (and chlorophyll) produces oxygen plus carbohydrates (which contain C). C is represented by black Unifix blocks. Give a handful of these blocks to the 'plant'. Stress that this C comes from the air. The vast majority of plant biomass is derived from air.

Slide Show: List of macronutrients.

While the majority of the weight of a plant may be C, H & O all derived from carbon dioxide and water. A number of other elements are essential. These are identified as macronutrients and are obtained by the plant, mostly from the soil. We will consider the movement of two of these: Nitrogen (N) and Phosphorous (P). But others are worth consideration, for example Magnesium (Mg) is an essential component of Chlorophyll

Symbionts

Slide Show: What are Symbionts

There are two symbiont cards in the deck: rhizobia (bacteria) and mycorrhiza (fungi). A symbiont is a member of a symbiotic relationship, in this case with a plant. Symbiosis is the process by which organisms live together for mutual benefit, in this case the mycorrhiza invades the plant cell and the rhizobia live in nodules specially produced by the plant for them to live in.

Crash Course Ecology #9 Nitrogen and Phosphorus Cycles (9:21)

https://www.youtube.com/watch?v=leHy-Y_8nRs&index=9&list=PL8dPuuaLjXtNdTKZkV_GiIYXpV9w4WxbX

Rhizobia.

Slide Show: Importance of Nitrogen (N)

Nitrogen (N) is an essential and common element. Every amino acid contains some N, and 78% of the earth's atmosphere is N. However atmospheric N is in a form called dinitrogen (N_2) which is not accessible to plants. Rhizobia contain enzymes which convert this N_2 into plant usable forms of N. N is represented by green Unifix blocks. Give a handful of these to the ‘rhizobia’. Like the C captured by photosynthesis the N in plants also comes from the air.

> Producing 2.5kg of ammonia fertiliser takes an amount of energy equivalent to burning 1000kg of coal. Even for bacteria that do it naturally, nitrogen fixation requires a great deal of energy.
>
> Spencely et al (2004), p. 208.

Mycorrhiza

Slide Show: Importance of Phosphorus (P)

Phosphorus (P) is also an essential element. Most of the cellular processes in all living things are powered by an enzyme called adenosine tri-phosphate, which as its name implies contains P. Each nucleic acid, the molecular chain that carries genetic information, is held together by a backbone of phosphate groups. Cell membranes are made of phospholipid bilayers. The P in rocks is not in a form usable by plants, so plants require the services of other organisms to solubilise the P in the environment. Mycorrhiza do this by excreting acid. 80-90% of plant species have some form of mycorrhizal relationship that assists the plant in many ways, but for the purposes of the role play we are focusing on their ability to solubilise P. P is represented by blue Unifix blocks. Give a handful of these to the ‘mycorrhiza’. You may like to store the blue Unifix blocks in a container with some rocks to show that the P comes from rocks rather than from the air.

Both rhizobia and mycorrhiza live inside the plant roots. The plant exchanges C captured via photosynthesis for the N and the P converted by the symbionts. Encourage the plants and the symbionts to negotiate the value of the N and the P and engage in an exchange. Show that the symbiont makes a direct exchange with the plant ie. injecting into the plant root, not into the soil.

In this game the uptake of N is via rhizobia in a symbiotic relationship with the plant, ie. the plant is a legume. What if the plant was not a legume? How would the plant get its N? It would be reliant on organic matter in the soil, or free-living nitrogen-fixing organisms, eg. Card 15, azotobacter. The plant ‘leaks’ C into the soil to attract organisms which may benefit the plant, a process called exudation. Up to 20% of the carbohydrates produced via photosynthesis are released into the soil as exudates. David Hardwick likens this to the discarded by-catch from a fishing trawler that attracts many creatures from the ocean; likewise many creatures are attracted to plant exudates. This process is less efficient than a direct exchange between symbionts, as losses can occur due to other processes in the soil.

The next two cards both solubilise phosphorus: the fungi (penicillium, card 4) and the bacteria (azotobacter, card 5). Note that the soil system has multiple pathways to perform the one function that is the solubilising of phosphorus.

Progressively call up other organisms that eat the organisms already called up. Eg. Ask “who eats plants?” and ‘Root-feeding Nematode’ should come forward. Ask “who eats root-feeding nematodes?” and ‘Carnivorous Fungi’ should come forward. Be aware that some organisms are consumed by multiple organisms, eg. protozoa are eaten by predatory nematodes, mites and springtails.

Participants enact ‘eating’ by taking Unifix blocks from other organisms. After eating, participants should ‘excrete’, by dropping some blocks on the floor. This process is called mineralization. The blocks that fall on the floor are elements in a form that other organisms, including plants, can uptake; this cycles the N and the P in the top soil. The Unifix blocks on the floor represent organic matter, so organisms who eat organic matter can come and ‘eat’ this material on the floor.

Some organisms have a digger icon on their card and should be encouraged to ‘excrete’ on a different part of the floor to the one they were standing on when they ‘ate’. This will demonstrate that digger organisms have an important role in moving essential elements within the soil profile, both vertically and horizontally.

Play until only the ‘farmer’ card remains unplayed. Note that this is a model of soil in its natural state and a good opportunity to stop and record the soil food web.

The Farmer (Card 9)

The farmer has no role indicators at the bottom of the card. This is because the role he or she plays in the system is very much determined by the management practices they choose to use. For example, if a plant is given an application of soluble fertiliser, what impact will this have on the system?

Start at the plant. The plant no longer needs the symbiotic relationships to provide P and N, so it will reduce the amount of C it exchanges with them, instead applying it to vegetative growth. It will reduce its root-based search for nutrients. It will reduce its root exudation rate, as the services of some of the other organisms are no longer needed.
What impact does this have on the system? Role play the reduced contribution of carbon by the plant into the system.
This is just one scenario. Other scenarios are in the stage 2 list (overleaf). The modelling of other scenarios would be a valuable extension activity.

The short version

I played this game a number of times to student groups of about 20 who were rotating through various stations at the Moo Baa Munch, a program put on by AgForce to encourage interest in agriculture. I only had 30 minutes, so I developed a short version with 12 cards. I will outline the talk with dot points.

- Use the air introduction above.
- Call out the PLANT and explain photosynthesis … enact
- Call out the RHIZOBIA and explain nitrogen fixation … enact
- Call out MYCORRHIZA and explain phosphorus solubilization … enact
- Explain the concept of a symbiont
- Call out AZOTOBACTER, PENCILLIUM and PSEUDOMONAS show that non-symbionts have similar roles, how do they get their energy? … explain root exudates.
- So far we have not modelled any predation in the soil food web.
- Call out PROTOZOA, then SPRINGTAIL, then PREDATORY NEMATODE.
- So far everything, due to its small size eats and poos in the same place.
- Call out EARTHWORM, explain the important role of the DIGGER

Game extensions (optional)

Building on the basic model, this role play can be extended in the following three topic areas:

Nutrients: forms, cycles and pools: parent materials, primary and secondary minerals, storage, fixation, loss, turnover, solubilisation, mobilisation, mineralisation, assimilation, translocation. Available, exchangeable and total soil nutrient pools. 2 types of nutrients - Inorganic and organic forms. 4 pathways of cycling, 2 ways of uptake. Use the N and P cycles to illustrate these processes.

Carbon and organic matter: photosynthesis, living biomass, root exudation, organic matter (categories), organic biochemicals, active and stable carbon, oxidation and respiration, the rhizosphere, the O and A horizons, humus categories, humification.

Soil emergent properties: Humus and humus forms, soil structure, aeration and water holding capacity, Clay-Humus exchange complex, CEC. Balanced nutrient cycling to plants, production of growth co-factors, Plant disease resistance via optimal nutrition, soil disease suppression through functional diversity and biological fertility.

Begin by looking at an undisturbed ecosystem and how the above processes occur in a natural ecosystem. After looking at how 'natural soil' functions, introduce various farming practices and show how disturbance influences the different processes. Grazing, tillage and equipment, fertilisers (slow and soluble forms) and agricultural chemicals can all alter the system.

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In the spirit of a Creative Commons Licence these instructions are a work in progress. The opportunity is present for farmers, scientists and participants to engage in an ongoing collaboration to refine this tool for a number of uses. If you find a way to improve this document, or you develop new cards we would appreciate hearing from you

References:

Bisby F., Roskov Y., Culham A., Orrell T., Nicolson D., Paglinawan L., Bailly N., Appeltans W., Kirk P., Bourgoin T., Baillargeon G., Ouvrard D., eds (2012). Species 2000 & ITIS Catalogue of Life, 2012 Annual Checklist. Digital resource at www.catalogueoflife.org/col/. Species 2000: Reading, UK.

Colorado State University (2011). The Living Soil. Retrieved July 16, 2013 from http://www.ext.colostate.edu/mg/gardennotes/212.htm

Nardi, J. B. (2007). Life in the Soil: a guide for naturalists and gardeners. University of Chicago Press.

Spenceley, M., Weller, B., Mason, M., Fullerton, K., Tsilemanis, C., Evans, B., Ladiges, P. McKenzie, J., Batterham, P., Sanders, Y. (2004) Heinemann Queensland Science Project Biology - A Contextual Approach. Melbourne: Pearson.

Taiz, L. & Zeiger, E. (2006). Plant Physiology, 4th edition. Sinauer & Associates: Massachusetts.
Munns, R., Schmidt, S. & Beveridge, C. (eds) (2010). Plants in Action 2nd Edition. http://plantsinaction.science.uq.edu.au/

Other helpful links

Fortuna, A. (2012) The Soil Biota. Nature Education Knowledge 3(10):1 http://www.nature.com/scitable/knowledge/library/the-soil-biota-84078125
Jansa Jan, Bukovská Petra, Gryndler Milan (2013) Mycorrhizal hyphae as ecological niche for highly specialized hypersymbionts – or just soil free-riders? Frontiers in Plant Science 4 http://www.frontiersin.org/Journal/10.3389/fpls.2013.00134/full
Northern River Soil Health Card. Accessed March 4, 2014 at http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/168703/northern-rivers-soil-health-card.pdf