Green Foundation Ireland

Educational Module for Transition Year Students

Soils and Soil Stewardship

Teacher's Resource

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INTRODUCTION

This is the resource document accompanying the Green Foundation Ireland's Transition Year Module on Soils. In this document are definitions, explanations, discussion points, facts and experimental set-up instructions to assist a teacher in delivering the aforementioned module.

Please note that the videos and links present within this document are not owned by Green Foundation Ireland, and are merely suggestions of audio-visual aids which can be shown in class to reinforce learning, can be suggested to students, or can be viewed by teachers to familiarise themselves with, or learn more about, the topics explored in this module.

Photographs of the topics discussed in this module are not provided here, for copyright reasons. However, teachers are encouraged to source photographs from the internet to demonstrate to classes, as a visual aid to reinforce learning.

SESSION 1: Soil composition, formation

Time allowing, a teacher may wish to show the following video, produced by Teagasc, to a class within the first session, to give students an overview of the issues facing soils, as well as the value of soils: https://youtu.be/2qcqPifl_bk.

Mineral matter is the fine, broken down particles of the underlying bedrock.

Water and air within the soil are contained within pores. Air within the soil is not static, and air diffuses between the soil and the surrounding air. Air, like water in the soil, is absorbed and used by plant roots and microorganisms for their metabolism.

Organisms within the soil are extremely diverse, including a wide range of vertebrates and invertebrates, as well as plants, fungi, and many other types of organism.

- Small amounts of soil contain incredible biodiversity. One estimate states that in just 1 gram of soil are billions of bacterial cells, including tens of thousands of different species, as well as fungi and many species of animals.

Humus is decaying organic matter. It is dark in colour, and formed from plant matter, such as leaf litter, as well as decaying animals and fungi. Organisms such as worms contribute to humus generation by digesting plant matter. Humus-rich soil is fertile, reducing the need for use of fertiliser and other human interventions.

Soils form when physical and chemical processes lead to the breakdown of bedrock. These miniscule rock particles are then infiltrated by microbes, including algae and lichens. Over time, the life, death, and decay of these organisms creates a build-up of organic matter. This process is discussed in this video: https://youtu.be/vbgM54TXdnk.

- Soils form very slowly, less than 1 millimetre per year. Therefore, degrading or erosion of soil takes a long amount of time to replenish!

How do flora and fauna in an area impact human activity? They influence a region in a number of ways. Culture, folklore, art and history are all influenced by the flora and fauna of a region. Recreational activities are also influenced, such a birdwatching, gardening, camping, and many other hobbies.

Impact on economy: The soils of a region impact what kind of foods can be grown there, and what kind of foods are imported. As an example, compare the agricultural practices of two different regions in Ireland. In the east of Ireland, land tends to be more flat, and soils more fertile. In the west, there are more mountains and bogs. Along with the weather, this impacts the type of agriculture that can take place there, and thus, the economy.

Impact on food culture: The variety of plants that can historically grow in a region shape the way cuisine develops there. Naturally soils are not the only factor that impacts the food culture of a region. A wide range of factors are also important, such as climate, immigration, and other factors also influence food culture.

Soil identification experiment: The experiment is based on the different weights of different soil constituents, with sand, silt and clay being progressively heavier, and therefore settling at different levels when suspended in water. This video demonstrates the set-up of the experiment: https://www.youtube.com/watch?v=UoD-cUMkRZY.

SESSION 2: Value of soils and ecosystem services

YouTube link to a video demonstrating use of a soil texture triangle to identify soil types: https://youtu.be/SXp8Lg0SFPQ.

Provision of food: Almost all food that we eat is dependent on soil health, and the fertility of soil, either directly or indirectly. Growth of crops relies on soil health, and feeding of livestock relies on the health of soils.

Recent global events, such as COVID-19, the blocking of the Suez Canal, or the recent invasion of Ukraine by Russia, make clear to us the fragility of the **global supply chain**. Additionally, importing of food produce from other regions involves increasing the **carbon footprint** of our food, contributing to climate change. In order to have access to food that is both reliable and sustainable, soil health is essential.

Biomass is solid biological matter, usually plant matter, which is used to generate energy. While biomass fuels are considered a more sustainable energy source than fossil fuels, there is some debate as to whether it is truly sustainable. Felling of trees for use as biomass removes their function to remove carbon dioxide from the air. Additionally, grass, food waste and other waste products can be turned into biogas for energy by way of an anaerobic digestor. Naturally, the production of these biomass solids are dependent on soil health.

The cultural value of soils are varied. **Gardening** is a key example. Especially for older people, gardening promotes exercise, cognitive ability, and other health benefits.

Ecosystem services are benefits gained by humanity via the normal functioning of ecosystems, and the activities of organisms within those ecosystems. Examples of this include:

- Trees creating oxygen.
- Pollination of plants by insects.
- Purification of water.

(It can be pointed out that all of the above ecosystem services are also dependant on soil health.)

There are four types of **ecosystem services:**

- Regulating services – Functions of ecosystems that make a region more habitable, such as air and water purification, climate regulation, and biological control of pests.
- Provisioning services – Things produced by ecosystems of value to humans, such as wood, food, medicinal resources.
- Cultural services – The value of nature as an inspiration for art, use in recreation, value for religion or heritage.
- Supporting services – Services that do not directly impact humans, but that support the function of other ecosystem services.

The functions of organisms within soil **break down organic matter**. Organisms in the soil digest and break down dead and decaying matter, both animal and plant matter. This means that the nutrients that make up the decaying matter are available to nourish plants and other organisms.

Soil **stores carbon**, preventing release into the atmosphere. A later session will go into more detail on carbon storage.

Healthy soils **protect against flooding**, as well aerated, biodiverse soils can capture and hold more water than compacted soils, soils with no vegetation cover, etc. Soils that do not absorb water can lead to pooling of water, causing flooding. With the potential for sea level rise and more extreme weather events with **climate change**, the ability of soils to prevent flooding will be essential in mitigating the effects of climate change.

Role of soil in water filtration: Soil filters water in 3 different ways: Water moving through soil particles causes physical filtration. Chemically, negatively charged soil particles cause certain positive ion particles, such as calcium, to be removed from the water, and remain in the soil. Biologically, bacteria and fungi can digest and break down contaminants within water.

SESSION 3: Soil biodiversity

Soil biodiversity: The diversity of organisms within the soil, including bacteria, animals, fungi, plants, and other organisms. In order to promote healthy soils, mindset is important; we must consider soils to be a complex ecosystem, rather than an inert resource.

- It has been estimated that soil biodiversity contributes to ecosystem services that are worth between 1.5 and 13 trillion US dollars annually.
- Soil is home to up to one quarter of the Earth's biodiversity.

Within the soil, fungi form a **mutualistic relationship** with plants. Fungi called mycorrhizae surround the roots of plants, and capture minerals from the soil that the plants could not normally access. In exchange, plants actually exude sugars, made *via* photosynthesis, to feed and maintain populations of bacteria and fungi near their roots. The presence of these fungi allows plants to more efficiently absorb nutrients by hugely increasing its surface area. This is not true for every plant species, but the majority of them.

Bioturbation: Mixing of soils caused by organisms moving throughout the soil. Causes mixing of soils, and is vital in moving organic matter down into the soil, increasing the humus content, and allowing aeration. Aeration leads to a better **soil structure**, allowing soil to hold more water. Video demonstrating the activity of soil organisms that contributes to bioturbation: https://youtu.be/Mxp1nnrUG0Q. As can be seen in the video, the activity of soil organisms breaks down organic matter, returning it so the soil as humus, as well as mixing the soil, creating well-mixed, aerated, fertile soils.

Nutrient cycling: As discussed in the last class, organisms in the soil, including earthworms, bacteria, insects, fungi and others, work to decompose organic matter, releasing nutrients to the soil.

Rhizobia: Nitrogen is an essential resource for plants. However, atmospheric nitrogen, in the air, cannot be processed by plants. The activity of bacteria can take nitrogen from the air and "fix" it, converting it into nitrites and nitrates, forms of nitrogen that can be absorbed by plants.

Video demonstration of soil biodiversity experiment: https://youtu.be/joKBXCMupKo.

SESSION 4: Threats to soils

With an understanding of the many ways in which soils are important to us, it is next important to know the current threats to soils. According to the Food and Agriculture Organisation of the United Nations, approximately 25% of the global land surface is already degraded.

Monoculture: Lack of diversity. Growing one species of plant or crop in an area causes several problems. As the same species of plant removes the same nutrients from the soil repeatedly, those nutrients can be depleted. In terms of crop sustainability, it is also problematic, as it makes the crop susceptible to pests and disease, and as such, often requires significant use of pesticides and fertilisers, which have their own negative impact on soils.

- The crop of the most frequently eaten banana variety of the 1950s, grown as a monoculture on a massive scale, was destroyed by a fungal pathogen, as discussed in this TED Talk: https://youtu.be/hqEA1kHlAuo.

Soil compaction: Compaction of the soil caused by heavy machinery or livestock, especially when on soil that is wet. Compacted soil removes air pockets from soil. It causes loss of biodiversity, as plant roots, earthworms and other fauna cannot easily penetrate compacted soils. It also reduces permeability, leading to pooling of water. According to Teagasc, Ireland's soils are particularly vulnerable to compaction due to the high levels of rain meaning soil is frequently wet. Machinery is considered a higher risk for soil compaction than livestock.

Vegetation removal: Removal of vegetation, and particularly roots, from the soil removes the binding agent, and exposes the underlying soil to erosion, allowing moving wind and water to strip the fertile layer of topsoil and deposit it elsewhere. It also exposes the soil to direct sunlight, meaning that soil can become dried out, reducing fertility and making it more susceptible to erosion.

Sealing: the covering of soil with impermeable surfaces. Caused largely by urbanisation, and covering of soils with concrete, asphalt, etc. when building pavements or roads. Reduces arable land, reduces biodiversity, and reduces permeability to water, increasing risk of flooding. Sealing also has the negative impact of dividing unsealed soil areas from each other, potentially stopping soil organisms from moving between them.

- Thankfully, Ireland has relatively low soil sealing levels compared to other European countries, with between 1 and 2% of soil surface sealed. Germany has approximately 4 times this amount.

Fertiliser use and pesticide use: Pesticides impact soil microorganisms in a number of ways, including directly killing them, reducing reproduction, and reducing their growth. This naturally has a knock-on effect on soil biodiversity and communities, and the normal processes of soil. They can affect the symbiotic fungi and bacteria in the soil, interrupting the ability of plants to access nutrients. Pesticide and fertiliser use will be discussed in more detail in session 6.

Tilling: Tilling breaks up aggregates that bind soil particles together. Because soil particles are now in smaller structures, they are lighter, and thus more susceptible to being blown away by wind or washed away by rain. Additionally, tilling stops plants reaching the root paths of other, dead plants. Access to these root paths is beneficial to plants, as it allows them to grow their root system with less mechanical resistance from the soil. Because of the impacts of tilling on soil, the movement of no-till farming has been growing in recent years.

Deforestation, land-use and farming practices leading to deforestation: Deforestation and vegetation clearing can be caused by a wide range of farming practices. Often, rearing of livestock requires large amounts of space, leading to clearing of previously fallow land. When land is cleared, soil becomes exposed to erosion.

Overgrazing: Overgrazing by livestock strips vegetation down to the soil level, leading to the issues of both vegetation removal and soil compaction. Overgrazing can be caused both by leaving livestock in one area for too long, or by placing animals in one area too frequently.

Removal of topsoil for construction, etc: During construction projects, topsoil may be removed and transported elsewhere. On slopes, in particular, there is a risk to soils nearby, as once topsoil is removed, rain can cause movement down the slope.

Soil erosion causes **infertility** by removing fertile topsoil, exposing the lower subsoil layers. These lower layers lack the humus content of topsoil, making them less fertile. Similarly, they may be limited in their ability to hold water. Therefore, plants may struggle to grow once topsoil is eroded.

Carbon emission is caused by soil erosion because, as the topsoil layers store carbon, soil erosion can cause breakdown of the carbon content within topsoil. Some of this breakdown produces carbon dioxide, a greenhouse gas.

Eutrophication: Caused by run-off of eroded soils entering water bodies, nutrients rise can cause rapid blooms of algae, which leads to bacteria reducing oxygen in the water, in turn leading to death of fish and other fauna. The effect of eutrophication can be worsened when fertilisers are applied to soil, and the fertilisers run-off into water bodies. This video demonstrates how eutrophication is caused: https://youtu.be/92TFJTtuq6k.

- Eutrophication is a problem in Ireland: approximately 19% of our coastal waters are affected. This is caused primarily by use of nitrogen and phosphorous fertilisers.

Video of soil erosion experiment: https://www.youtube.com/watch?v=5Xv6GRcZwgw.

SESSION 5: Soil stewardship

Soil stewardship is the careful and responsible management of the soil. It can also encompass activities that restore and promote soil health.

- A key factor toward improving soil health is increasing the soil organic matter content.

Planting native grass species in lawns can make lawns hardier, reducing the need for use of water, pesticides and fertilisers, as well as encouraging native biodiversity.

Reduced cutting of grass increases biodiversity. Additionally, increased management of grass increases the incidence of pest species. Grass that is cut less frequently, and left longer when cut, also develop bigger root systems, meaning that more carbon dioxide can be captured from the air in the form of plant roots.

Replacing fences with hedges provide soils with structure, as well as providing habitats for birds and other animals.

Green roofs, or roof gardens, are a sustainable living measure wherein house roofs are seeded. The benefits of green roofs are numerous: they improve air quality, they slow water run-off from roofs, meaning that water pooling is less likely to occur, and they insulate the roof of a house, reducing heating bills. They can also buffer against noise pollution.

Legumes are known as nitrogen-fixing plants. Legumes themselves do not fix nitrogen, but have nodes in their root systems that house nitrogen-fixing bacteria. Planting peas, and beans, therefore, boosts nitrogen levels in the soil, increasing fertility. Video on legumes and nitrogen fixing: https://youtu.be/A8qTRBc8Bws.

Eco-Eye featurette on **climate-friendly gardening**, and organic solutions to pest problems in gardens: https://youtu.be/QIlLDfHAun4.

A Benjes hedge (or dead hedge) is a structure composed of dead branches, wood, twigs and other materials, stacked, typically up to 1.5 metres high. A Benjes hedge has many benefits for a garden. Firstly, it functions as a habitat for animals. Also, by functioning as a windbreak, a Benjes hedge can aid the growth of small plants, reducing their exposure to strong winds. Similarly, they can stop soil being eroded by the wind.

Growing **Jerusalem Artichokes** is a very effective way to sequester carbon from the atmosphere. They are a healthy probiotic vegetable, and grow very quickly. Since they grow very fast, they absorb a lot of CO_2 from the air.

- Jerusalem artichokes can sequester up to 3.5 times as much CO_2 from the air as a forest, per unit area.

Worm composters are multi-tier composting structures which house worms and are used to degrade kitchen waste to make compost. It creates compost ready to use in the garden, as well as creating a liquid fertiliser that can be used on houseplants. Video demonstrating worm composter set-up and function: https://youtu.be/zLTcNnyoHBs.

Hügel beds (or Hügelkultur) is a mainland European practice which involves creating a raised bed by burying carbon matter, particularly wood or grass sods. Hügelkultur requires less irrigation than other gardening practices. Importantly, hügelkultur sequesters carbon, burying wood material and removing it from the atmosphere, rather than burning it. https://youtu.be/Th0-nMd5kKE.

SESSION 6: Carbon sequestration, pesticides and fertilisers

Carbon sequestration: Is the removal of carbon from the atmosphere. Particularly, it refers to removing carbon dioxide, a greenhouse gas, from the atmosphere. In the case of soils and vegetation, it involves capturing carbon dioxide as part of the growth of plants, as they take carbon dioxide from the air for their metabolism, and "trapping" as solid vegetation. Therefore, carbon sequestration can be achieved via essentially "burying" carbon matter, such as food waste or plant matter. Gardening methods such as the hügel beds discussed last week are an example of this.

The emphasis in the case of how plants and soil sequester carbon is that plants primarily source their carbon from the atmosphere, rather than the soil, and so growing plants essentially "move" carbon from the atmosphere to the soil, in the form of shoots, roots, and decaying plant matter, as explored in the below TED talk.

The following video summarises the capacity of soils to store carbon, and ability to fight climate change: https://youtu.be/wgmssrVInP0.

Pesticides can kill **insects and other animals** that allow soil to function normally, that degrade leaf litter, and that add humus to soil.

Pesticides can kill non-target soil microorganisms such as the beneficial mycorrhizae, reduce their growth, or limit their reproduction. By impacting the **microbial community** in soil, pesticides can interrupt the symbiotic relationship between plants, soil fungi, and bacteria.

- According to the Food and Agriculture Organisation of the United Nations, pesticide use has been identified as the most significant driver of soil biodiversity loss in the last decade.

In a process called **bioaccumulation**, pesticides absorbed by smaller organisms can impact larger animals that consume them, For example, eating insects that contain pesticides can lead to the build-up of pesticide residues in birds.

- The insecticide DDT, used to control insect populations, can cause eggshell thinning in birds. This eggshell thinning causes egg breakage, which impacts bird populations. Peregrine falcons in the UK suffered population decline as a result of its use.

Health issues can arise from pesticide use to humans and pets. Skin irritation, gastrointestinal illness, and nausea are just some of the effects. Severe cases can lead to death. There can also be chronic, long-term health effects.

Companion planting is a practice of using plants that serve as a natural repellent to pests, planting them close to species you wish to protect. Therefore, the necessity for pesticide use is reduced. As an example, carrot plants can be protected by planting mint nearby, as it repels carrot root fly.

Biological control is a method of controlling pest species using natural predators of that species. An example of this is that aphids, which feed on garden plants, are the natural prey of ladybirds. Therefore, planting dill or chives in a garden, plants which attract ladybirds, will mean a reduction of aphid density in your garden.

When soils containing fertilisers enter water, it causes a risk of **eutrophication**.

Use of fertilisers can **alter the pH** and acidify the soil, changing the make-up of microbes in the soil. Acidic soils favour fungi over bacteria, and reduce earthworm density. Increased nitrogen concentration promotes bacterial growth. Any of these changes can imbalance the natural functioning of the soil ecosystem.

Chemical scorch is caused by overuse of chemical fertilisers, which contain soluble salts. These salts can draw moisture out of plant tissues, causing a wilting of leaves, and damaging plant tissues.

Planting native species means plants are more adapted to our climate, and thus will need less support from fertilisers.

About Green Foundation Ireland

Green Foundation Ireland aims, through education, to inspire the public to work towards a sustainable society for Ireland.

Green Foundation Ireland (GFI) is an independent registered charity which promotes education for sustainability in Ireland. It is affiliated to the Green European Foundation (GEF).

GFI aims, through education, to create public support for a sustainable society and economy in Ireland and elsewhere. We aim to engage with both the arts and sciences to create a new environmental narrative that promotes action to conserve and protect life on earth.

For more information about what Green Foundation Ireland does, or if you would like to contribute to our work in any way, please contact us at:

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