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SOIL ORGANISMS HAVE FAVORITE FORAGE PLANTS

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YOUNG REVIEWERS:

JACK
AGE: 13

SOPHIA
AGE: 15

Cows and sheep eat plants known as forages. Forage plants can include grass, chicory, and clover. Forage plants vary in nutrients and tastiness. These plants can also change the ecosystem belowground for soil animals. Soil animals may move to eat or live beneath different forages. Earthworms mix up the soil and food, improving the soil habitat. Fungi break down dead plants, and organisms that eat fungi speed up this breakdown process, which creates more food for other plants and soil animals. We tested which forage plants soil animals preferred. Large numbers of earthworms were found under white clover. Tiny fungal-feeding worms and springtails (insect-like creatures) were found in greater numbers under clover and chicory. Plant-eating soil animals compete with cows and sheep for food. These plant-eaters were found in larger numbers below ryegrass. Growing plants that increase the numbers of helpful soil animals can lead to healthier soils.

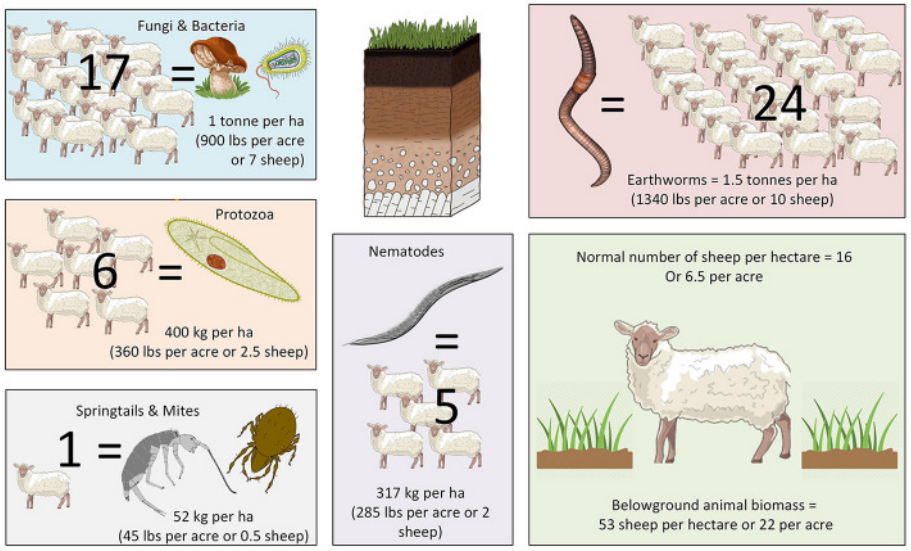

Figure 1

Figure 1

Weight of soil animals per hectare (ha), measured in sheep. Adult sheep weigh around 60 kg [1]. The soil organisms in one hectare weigh around 53 sheep [2]. The standard for farming is around 16 sheep per hectare so, added up, the weight of soil organisms is more than the weight of sheep above ground, per hectare.

FORAGE/FORAGE PLANTS

Plant material eaten by grazing animals, like cows and sheep.

ECOSYSTEM SERVICES

The important things environments do for people and animals. In soil ecosystems, examples include recycling nutrients, retaining and draining water, and mixing dead plant material into the soil.

TAP ROOT

A large, wide, main root, tapering in shape and growing directly downwards (similar to a carrot).

SOIL ORGANISMS

All the organisms that live below ground, including tiny microorganisms like bacteria, fungi, protozoa and nematodes, medium-sized organisms like springtails and mites, and large organisms like earthworms.

SO MANY SOIL ANIMALS!

Cows and sheep eat a wide-ranging diet that depends on the types of plants growing within a field, which are called **forage plants** or simply **forages**. The most common forage plant is grass (ryegrass), but others include clover and chicory. These plants vary in their tastiness and nutrient content, which gives cows and sheep a choice of food and provides a healthy, varied diet. In addition, forage plants provide **ecosystem services**. For example, clover creates its own nitrogen fertilizer to help itself (and other plants) to grow. Chicory has a deep **tap root** that helps increase the airflow within the soil.

Taken together, the soil animals that live below ground weigh more than the sheep and cows above them (Figure 1)! These soil animals eat lots of different foods, and they choose to live in different places because of the plants growing there. Imagine living in a city: in some areas there are lots of people living close together, while in other areas there are fewer people. Some people like to be close to resources like schools, work, and shops. However, some may prefer to live in less crowded areas. The same is true for soil animals. When resources are limited or poor, soil animals may move to find more or better ones. Soil animals also provide important ecosystem services within the soil. For example, they break down dead plant material, recycle nutrients, and improve soil structure.

Forage plants provide a stable habitat for **soil organisms**. After they are planted, forages grow and are grazed for many years, without disturbing the soil. There is a large diversity of soil animals that all have different roles within the soil. Earthworms are the superheroes of the soil, or "ecosystem engineers." They change the whole soil habitat, mixing soil, and moving air and food within it. Springtails and mites

help to break down dead plant material, making the soil stick together properly, and disperse fungi. Nematodes (tiny worms) eat fungi and bacteria, speeding up **nutrient cycling**. The number of organisms that live within the soil can be an indicator of soil health. Increasing the number of soil organism can lead to better soil health and can help plants grow.

NUTRIENT CYCLING

Movement and exchange of various nutrients between the living and non-living parts of an ecosystem. Nutrient cycling helps plants grow.

DO SOIL ORGANISMS HAVE FAVORITE FORAGE PLANTS?

Since there have not been many studies looking at the effects of forage plant species on soil organisms, we decided to do an experiment. We grew forages of ryegrass, chicory, red clover, and white clover in separate plots. These plots were next to each other in the same field. There were four plots for each forage. The plants grew for 3 years, during which the forages were cut regularly, to simulate grazing by sheep and cows. After 3 years, soil animals (earthworms, springtails, mites, insects, and nematodes) were measured within each plot, to see which forage plants they preferred.

Different sampling methods were used to count the soil animals. For earthworms, we dug up a square cube of soil and sorted through it, picking out all the earthworms we could find. Earthworms were then sorted into groups, based on their size and color. To collect springtails, mites, and other small insects, we took small soil samples and placed them on **Tullgren funnels**. You can make your own Tullgren funnel at home by following instructions in Barreto and Lindo [3]. We had to identify these soil animals with a microscope because they are so small. Nematodes were collected by placing soil within tissue paper and resting it in a tray of water. The nematodes swam out of the soil into the water, where we collected them and identified them under a microscope.

TULLGREN FUNNEL

Device in which the soil is warmed up and the small soil animals move away from the heat and light, falling into a collection pot under the funnel.

WHITE CLOVER INCREASES THE NUMBER OF SOIL ANIMALS

Our results are summarized in Figure 2. The most earthworms were found in the white clover plots, and the fewest in the ryegrass plots. Earthworm numbers in the soil below the chicory and red clover forage plots were in-between. The deep-burrowing (**anecic**) earthworms showed the most plant preferences compared to other kinds of earthworms. Dividing the nematodes into feeding groups, showed some had favorite forages. Larger numbers of fungal-feeding nematodes were found below the clovers compared to the ryegrass. Plant-eating nematodes were found in larger numbers below the ryegrass compared to the clovers or chicory. Thousands of springtails and mites were found per square meter of soil. Two groups of springtails were found in different numbers in the soil below the

ANECIC

Group of large earthworms that create deep vertical burrows that go up and down through the soil, moving dead plant material around to eat later.

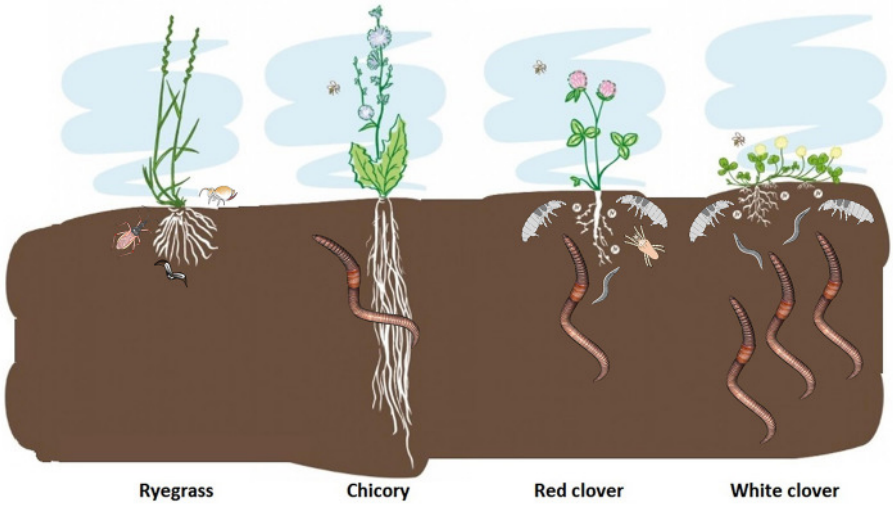

Figure 2

Figure 2

Differences in soil animal numbers below ryegrass, chicory, red clover, and white clover forage plants. Ryegrass had the most plant-eating soil animals (true bugs, thrips, and plant-feeding nematodes). White clover had the most earthworms, fungal-feeding nematodes, and Poduromorpha springtails. Red clover had in-between numbers of earthworms, fungal-feeding nematodes, and Poduromorpha springtails. Red clover had a larger number of predatory mites than the other forages. Chicory had in-between numbers of earthworms but fewer of the other organisms than the clovers (Plant pictures adapted from Cotswold Seeds).

forage plants. A group of springtails called **Poduromorpha**, which eat fungi, bacteria, and dead plant material, were found in larger numbers below the clovers. Plant-eating springtails (Symphypleona) were found in larger numbers below the ryegrass. Greater numbers of predatory mites were also found below the red clover plants. "Other" invertebrates were found to differ in numbers in the soil below the forages. The ryegrass plants had many more "other" invertebrates in the soil than either red clover or chicory. There were large numbers of bugs and thrips (tiny plant eating insects) below the ryegrass plots compared to the other forages.

We calculated the *total* soil animal biodiversity for each forage and found that the lowest animal diversity was found in the ryegrass soil and the highest was in the soils of the two clovers. The diversity of soil animals below chicory was in-between.

PODUROMORPHA

Group of springtails that look fat and have a small springing tail, mostly eat fungi, bacteria, and dead plant material.

HEALTHY SOIL ORGANISMS = HEALTHY AGRICULTURE

Large and diverse populations of soil organisms are thought to improve soil health, which could lead to increased crop growth. It is important to monitor soil animal numbers to see if they are affected by the types of forages grown by farmers. This will tell us whether changes in the types of plants farmers choose to grow might affect the health of the soil. Our findings show that soil animal numbers change depending on the type of forage plants grown. This means that changes in plant species can influence the biodiversity of the soil animals living under those plants.

All plants were located next to each other within the same field, so the soil animals could move to live below whichever forage plants they preferred. Three years of plant growth led to changes in the

soil habitats, because the four forages had different root structures and changed the nutrient availability in the soil. The moving speeds of soil animals vary. For example, earthworms can move more than 1 m per day, but some species of mites only move 1–8 m per year [4, 5]. The earthworms found below white clover had time to move there during the three-year experiment. However, some of the other animals may not have had enough time to reach their favorite forage crop to live below it. Earthworm numbers reflect how much food is available. The larger numbers found under white clover suggest there is more food there. Since earthworms can improve soil structure, larger numbers of earthworms could improve soil health [6]. Plants can use the deep burrows of anecic earthworms as ready-made channels for their roots to grow into. Forage plants that draw large numbers of anecic earthworms could therefore improve other plants growth.

Maintaining a high diversity of soil animals is important. If soils experience a loss in soil animal biodiversity due to poor soil management, this could reduce the ability of the soil to grow plants, store water and cycle nutrients. Our research showed that changing the type of forage plants being grown could help to maintain soil animal biodiversity and therefore help to keep soils healthy. Healthy soils are important because they support the growth of crop plants. This means that choosing the right forage plants could ultimately help farmers grow enough food to feed the growing human population!

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CONFLICT OF INTEREST: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

JACK, AGE: 13
My name is Jack. I am interested in coding, programming, and cybersecurity. I participate in science and math competitions like Science Olympiad and Math League. I am an avid basketball player. I love to travel and have visited 4 of the 7 continents so far.

SOPHIA, AGE: 15

My name is Sophia. I am on the pre-med pathway in high school. I compete in Science Olympiad, Quiz Bowl, and the Science Fair. I have a love for spelling. I won my school spelling bee multiple years and competed in the Scripps national spelling bee. For relaxation, I enjoy doing art projects and baking culinary treats for my friends and family. I also love to travel. One of my favorite places is Tokyo.

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Dr. Felicity Crotty is a senior lecturer in soil science and ecology at the Royal Agricultural University. She has been researching soil biology and soil health for the last 14 years, focusing on understanding the linkage between sustainable agriculture and soil health, within both the animal and crop sectors. *felicity.crotty@rau.ac.uk