Soil science

Pack 1

Types and properties of soil

Pack Code: SS1

This pack you will help you to understand:

- The main soil types
- How soil is formed
- The components of soil
- The properties of soils.

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National Consortium
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About this pack

Objectives

When you have completed this pack you should be able to identify the main soil types.

This pack will help you to understand:

- the main soil types
- how soil is formed
- the components of soil
- the main physical and chemical properties of soils.

This pack is relevant to the level 3 unit **Understand the principles of soil science,** and in particular to the following outcome:

- Outcome 1: Be able to investigate soil characteristics
- Outcome 2: Understand how soil characteristics affect plant growth and development
- Outcome 3: Understand how soil characteristics affect plant selection

It may also provide useful background for the level 3 unit **Understand Agricultural Organic Production**, Outcome 2.

Links to other packs

This is one of a series of learning packs, each tackling an aspect of soil science. They are:

- Pack 1: Types and properties of soil
- Pack 2: Soil structure and organic matter
- Pack 3: Plant nutrients
- Pack 4: Soil treatments and fertilisers
- Pack 5: Plants and soil

Each pack contains several activities which ask you to think the topic through or to apply it to an organisation you know of. In some cases you may be able to work on these activities with other people in your group.

Introduction

A knowledge of soil chemistry is important to anyone who grows plants or manages animals which graze on plants. If you look at which plants grow on particular soils you can get a good idea of the character and condition of the soil.

This soil/plant inter-relationship is important because soils determine which plants can grow in a place and, in turn, plants can modify the soil.

Soils determine which plants grow on them by:

- availability of nutrients
- acidity of the soil
- soil drainage
- soil depth.

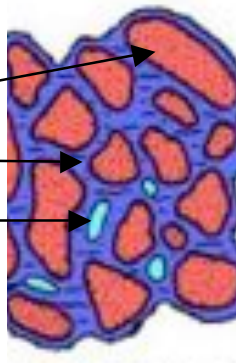
Plants modify the soil by:

- removing nutrients
- adding organic matter
- changing the structure of the soil by root activity.

The components of soil

The main components of soil are:

- mineral matter (sand, silt and clay)
- water
- air
- organic matter
- nutrients (either dissolved in water, or held on the mineral and organic matter).



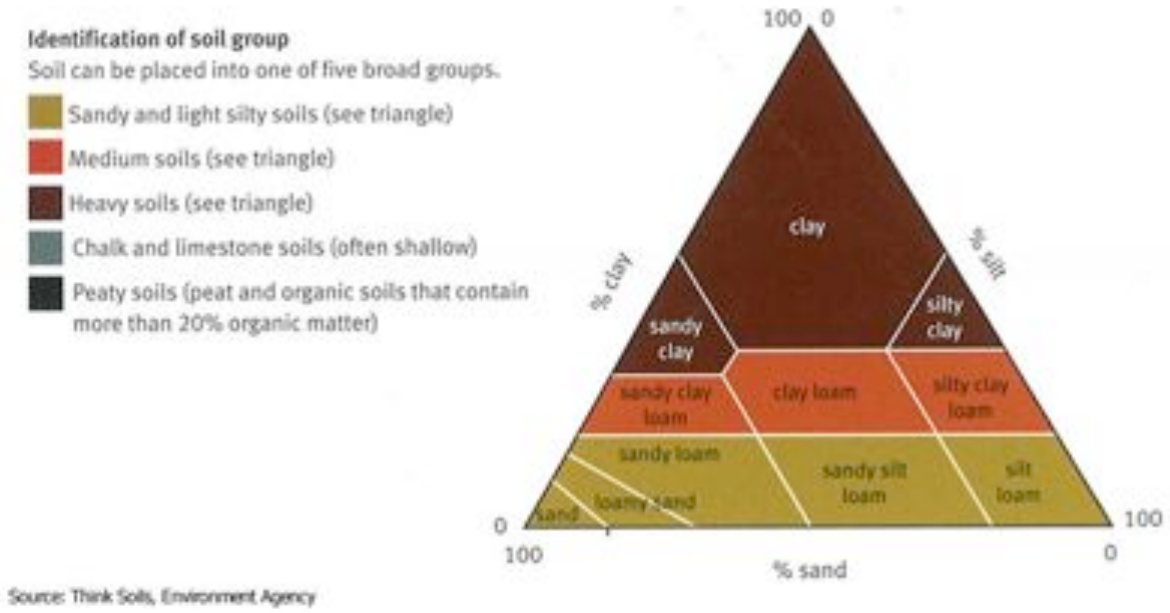
There is generally approximately **50% solid matter** – principally rock and organic matter – and **50% water and air**. The proportion of air and water varies, depending on rainfall, drainage and plant uptake of water.

Types of soil

Soils can be predominantly made up of sand, silt, clay or organic matter. Mixtures of these types of particles make up soils with different textures. There are advantages and disadvantages to each type of soil.

	Soil	Advantages	Disadvantages
	**Clay** soils feel sticky and you can roll them into a ball	Hold water well and tend to be rich in nutrients	Heavy to work, warm up slowly, prone to waterlogging
	**Sandy** soils feel gritty between your fingers	Easy to work, light and free draining, warm up quickly	Do not hold nutrients or water
	**Silty** soils feel smooth or silky when you roll them between your fingers	Quite fertile, hold some water, warm up quite quickly	Dense and easily compacted and can lose nutrients
	**Loams** have a balance of clay, sand, silt and organic matter	Fertile, easy to work, warm up quite quickly	Very few.
	**Organic** soils have a high organic content and feel moist and spongy	Fertile, easy to work, hold water	Usually acidic and can become waterlogged

The most useful soils are likely to have a balance of clay, sand, silt and organic matter. These are known as the loams. **Loams** which have a higher proportion of clay are usually the most productive. The triangle below shows the different types of soils you are likely to find. In SS2 there is an exercise to identify different soil types by feel.



Source: Think Soils, Environment Agency

How soil is formed

The earth's crust is made up of rocks formed over a long period of time.

The landscape results from movements, erosion and deposition which have created mountains, valleys, lakes, canyons and many other features. An example of a movement would be an earthquake, while erosion or deposition could be caused by the action of rivers or glaciers.

Soil forms when rocks are broken into small fragments. How this happens and the type of soil which forms as a result depends on:

- the type of rock being weathered (known as the **parent rock**)
- the breakdown of the parent rock by physical or chemical means (known as the **weathering process)**.

Here's how the process works:

When rock matter has been broken down enough to support plant life it becomes soil.

↓

Rocks and soils contain **minerals**.

↓

Minerals are the source of **nutrients** from which plants get their food.

The weathering process

Rocks are broken down to form soil by the action of weathering agents. This can happen in three ways:

- **mechanical or physical** agents: split the rock into pieces by physical forces such as heating and cooling, freezing and thawing, wetting and drying and abrasion.
- **chemical** agents: which cause permanent chemical changes in the original rock minerals.
- **biological** agents: such as plant, animal or human activities.

Rock weathering produces the basic soil forming ingredients of:

- rock fragments
- iron oxides
- soluble materials
- newly formed secondary minerals such as clay.

Properties of soil

Farmers and growers need to understand and manage soil properties as they affect its productivity. The properties of soils include:

- soil particles and pores
- water capacity
- aeration
- organic matter
- nutrient holding capacity
- stability.

Soil particles and pores

The spaces between the particles of solid matter in the soil are known as **soil pores.** Water and air is held in the soil pores.

The size of pores depends on the size of the particles. For example, sand grains are quite large compared to clay particles and because of this they have large spaces between them.

The water retention capacity of a soil will depend on the soil's total pore space and pore size. For example, sandy soil allows water to drain quickly, but it might drain too quickly so that nutrients are leached out. Clay particles are very fine and clay soil tends to hold too much water. This can stop gases moving in and out of the soil.

The right balance of water and air is crucial to the productivity of soils. This allows plants to take up nutrients through their root systems.

Activity

Match each statement in column A to the right one in column B.

Column A	Column B
1 Sand helps make soils	a) take up nutrients through their root systems.
2 The right balance of water and air in the soil allows plants to	b take up nutrients before the water moves from their roots.
3 Too much silt can lead to	c) stop gases moving in and out of the soil.
4 Soils that drain too quickly do not give plants enough time to	d) light and free-draining.
5 Soils that hold too much water	e) dense, easily compressed soils which are low in nutrients.

Check your answers with those at the end of the pack.

Water capacity

Water is retained in soil pores as a film around soil particles. However, not all water in the soil is available to plants as shown in the table below.

Type of water in soil	How is the water held?	Is it available to plants?
Hydroscopic water	Like a skin around each particle of soil	No
Capillary water	In **micropores** (small pores) which let the water move slowly through the soil from wetter to drier areas by an action called capillary pull.	Yes
Gravitational water	In **macropores** (large pores) which fill quickly with rainfall, but empty quickly as a result of gravitational pull.	Yes, but for a very short period of time

The amount of water that can be held in a particular type of soil is called the **Available water holding capacity.** This is determined by

- the amount of water added by rainfall
- the amount of water lost by evaporation, plant transpiration and drainage
- the pore size between soil particles.

Water retention in soils has a great effect on growing conditions. It affects:

- Soil temperature – wet soils are slow to warm up in spring and so have a shortened growing season
- Ease of cultivation – heavy and wet soils are difficult to work and have restricted cultivation times compared to lighter, sandy soils
- Plant growth – high soil water content can reduce oxygen availability and reduce plant growth.

Optimum water retention is when the water does not pass through the soil too quickly and is not held in the soil for too long. This happens when soil particles of different sizes, with different pore sizes, are mixed. The maximum amount of water that a soil can hold against free drainage is known as **field capacity.**

Soil water can be managed by:

- controlling drainage and irrigation
- providing a good soil structure
- adding organic matter
- avoiding compacting the soil.

Aeration

When pores between soil particles are not filled with water they will be filled with air.

The chemical composition of air in the soil is different from air in the atmosphere as there are higher levels of carbon dioxide in the soil. Carbon dioxide needs to be able to escape from the soil. It is replaced by oxygen which is used by plants when taking up nutrients.

Activity

Why do you think factors concerning air are important to the health of soil and plants?

Check your answers with those at the end of the pack

Nutrient holding capacity

Nutrients are chemical elements which are found in the soil. Nutrients provide plants with food. You can get indications of nutrients by looking at the soil and its situation. Clues are:

- the type of parent rock and its mineral properties
- the colour, depth and texture of the soil
- the types of plants growing on the soil and their condition
- the climate of the area.

See Pack 3 for more on nutrients.

Electrical charges

Clay and humus particles carry electrical charges (**ions**) on their surfaces.

- Clay charges are mainly negative
- Humus charges are negative and positive

Most soils therefore have a potential net negative charge.

If the negative charges of individual particles are not neutralised the particles repel each other and will not aggregate properly **(flocculate)** when the soil dries. A deflocculated soil will be very poorly structured

Application of fertilisers and lime which have positive ions helps to neutralise the soil's negative charges and particles will flocculate into crumbs.

Soil stability

The stability of soil is also important. An important aspect of a soil's stability is its strength to withstand outside pressures. If a soil is too weak, then it will not anchor a plant effectively. If it is too strong, then roots will not penetrate the soil. Stability will partly depend on other characteristics, such as the soil's water retention capability, and how readily it can be compacted.

Glossary

Available water holding capacity	The amount of water that can be held in a particular soil
Field capacity	The maximum amount of water that a soil can hold against free drainage
Flocculate	Where individual soil particles aggregate well
Humus	The stable end product of organic matter decay
Ions	Electrical charges
Soil pores	The spaces between the particles of solid matter in the soil
Weathering	The breakdown of parent rock by physical or chemical means

Further reading

You will find a number of publications dealing with soil types in the college library. You may find the following helpful:

- Ashman, M and Puri, G (2008) Essential Soil Science Blackwell
- Brady, N and Weil, R (2007) The nature and properties of soil, Pearson Prentice Hall
- Foth, H D (1991) Fundamentals of Soil Science, 8th Edition, Wiley
- White, R (2005) Principles and practice of Soil Science, Blackwell
- Environment Agency (2007) Think Soils Manual. Available at: http://adlib.everysite.co.uk/adlib/defra/content.aspx?doc=263232&id=263233

You can download a number of useful publications from www.soil-net.com/downloads including:

- Nortcliffe, S (1984) Down to earth: An introduction to soils; Leicestershire Museums, Art Galleries and Records Service
- Jarman, M (1984) Groundwork - Practical ways of learning about soils; Leicestershire Museums, Art Galleries and Records Service

Answers to activities

Activity on page 6

The statements in the activity on page 6 match up as below.

1 & d, 2 & a, 3 & e, 4 & b, 5 & c.

The table would then look like this.

Column A	Column B
1 Sand helps make soils	d) light and free-draining.
2 The right balance of water and air in the soil allows plants to	a) take up nutrients through their root systems.
3 Too much silt can lead to	e) dense, easily compressed soils which are low in nutrients.
4 Soils that drain too quickly do not give plants enough time to	b) take up nutrients before the water moves from their roots.
5 Soils that hold too much water	c) stop gases moving in and out of the soil.

Activity on page 8

As with water retention, pore size and air movement are important to the health of the soil and plants. The soil must have a loose enough structure to allow the carbon dioxide to escape and to allow oxygen to enter.

This cannot happen if the soil has compacted because of small particles and small pores, or as a result of being pushed down by heavy machinery or human weight.

Knowledge quiz

1 Approximately what proportion of soils is solid matter?

2 Give three components of soils.

a)

b)

c)

3 Give two examples of types of solid mineral matter to be found in soils.

a)

b)

4 Where are water and air held in soils?

5 Which drains quickest, sandy or clay soils?

6 Which type of soil water is available to plants?

7 Name two gases moving in and out of the soil.

a)

b)

Acknowledgements

This learning pack has been produced by the Land Based Colleges National Consortium Ltd.

The LBCNC is a consortium of colleges working in the land-based sector which co-operate in the development and production of quality flexible learning materials which encourage independent learning.

We would like to acknowledge the contributions made by the following individuals and colleges in the development of this learning pack.

Initial source material and guidance

This pack was developed from source material provided by:

John Bates and Derek Fancett, Cannington College

Critical review of earlier editions

Andy Daw, Joanna Kerr: Kingston Maurwood College

Nigel Foskit: Rodbaston College

Eileen Swan: Broomfield College

Tony Jenner, Hartpury College

Feedback on the revised edition

James Trounce, Easton College

Joe Hanlon, TEAGASC

Cover photograph: Steve Watson, Riseholme College

Developed and produced for LBCNC by Learners First

Revised in October 2013

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