THE PERMACULTURE ASSOCIATION

Permaculture Research: Soil Advice Handbook

Chris Warburton-Brown
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This booklet should be used with the accompanying *Soil Tests Handbook* and *Soil Record Sheet,* downloadable for free: https://www.permaculture.org.uk/research/soil-yield-and-biodiversity-tests-project

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The Permaculture Research: Soil Advice Handbook.
First published in 2015 by the Permaculture Association.
Hollybush Conservation Centre, Broad Lane, Kirkstall, Leeds, LS5 3BP.
Website: https://www.permaculture.org.uk/
Telephone/Fax: + 44 (0)845 458 1805 (calls charged at local rate)
E-mail: research@permaculture.org.uk
E-mail: research@permaculture.org.uk

The Permaculture Association's vision is an abundant world in which we care for the earth, each-other and future generations, whilst living within nature's limits. Our mission is to empower people to design thriving communities across Britain, and contribute to permaculture worldwide.

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Content

What is good soil?

Good soil is central to food production, and therefore to human life. It is necessary for strong, healthy plants that can feed us well. Modern industrial agriculture makes huge demands on soil and there is widespread evidence of soil erosion and a slow decline in soil fertility. Improving you growing soil will not only improve the crops you grow, it is a crucial contribution to healing the planet.

Good growing soil has three characteristics; rich biological life, good structure, and readily available nutrients. The Association's soil tests (see *Permaculture Association Soil Test Handbook*) focus on the first two of these characteristics; biological life and structure. We use the term 'bio-structural' to describe this approach. Soil nutrients are difficult to measure without using a lab, so you may want to submit a sample to a lab to find out the balance of nutrients in your soil. However, if you feed your soil properly, look after its biological life, and ensure it has a good structure, it will generally feed your plants well unless it is lacking in a specific mineral.

Good soil has rich biological life ranging from billions of things you can't see like bacteria and fungi to big things like worms and beetles. In our tests we use one measure, earthworms, which are easy to catch and to count. They act as a proxy for all the other biological life in the soil. The biological life in your soil creates the soil through its digestive activities and binds the soil together. Whatever kind of soil you have, improving the biological life will improve it; in sandy soil, biological life will bind it together, improve the amount of water it can hold, and keep nutrients in the soil. In clay soil, biological life will break up the lumps in your soil and free up trapped nutrients for plants to use.

Good soil has a number of structural features; it lets water through when weather is wet and holds water when weather is dry; it consists of a number of small, loosely packed balls (crumbs) which allow plant roots to pass between them while anchoring them securely, it is deep enough to allow plant roots to grow extensively, and it is not easily eroded by water or wind. The Permaculture Association soil tests measure all of these aspects of your soil. In this booklet, we explain why each characteristic is important, and suggest some ideas for improving your soil once you have established its characteristics through testing.

Preliminary tests

Smell

Why is soil smell important?

•Soil smell can identify a soil that lacks oxygen (anaerobic conditions).
•If the soil has a sour, putrid chemical smell this indicates unhealthy anaerobic conditions in which de-nitrifying bacteria create these smells.
•If the soil smells sweet, earthy and fresh this indicates a humus-rich, healthy microbe community living in aerobic conditions (plenty of oxygen).

Moisture

Why is soil moisture important?

•Waterlogged soil will drown worms and roots, and become anaerobic.
•Permanently dry soil will kill the soil ecosystem and no plants will grow.
•Good soil holds roughly the same amount of moisture all year round and never becomes waterlogged or completely dry.

How to Improve Soil Smell and Moisture

Permanently waterlogged soil requires major work. Here are some possibilities;
•Identify the source of the water; there may be broken or blocked drains or ditches which can be fixed, or directed elsewhere.
•Create a channel to take water into a nearby stream or pond.
•Divert water away by digging a sloping trench and filling it with rubble.
•Build a ditch and bank across the slope above the waterlogged area.
•Create a soak-away at the lowest point (a deep hole filled with rubble).
•Build raised beds over the waterlogged ground.
•Turn part of the waterlogged area into a pond or stream.
•Plant trees in the waterlogged area which like wet roots, such as willow.
•Install field drains; a major job requiring specialist knowledge.

Permanently dry soil also requires a lot of work. Ideas to fix it include:
•Irrigate with water from another part of your site or from a storage tank.
•Dig in lots of organic matter to improve water holding capacity.
•Redirect streams or drains on the site to bring water into the area.
•Remove rocks and stones from the area.
•Build a bank across the slope just below the dry area.
•Plant trees or grasses in the dry area that thrive in drought conditions.
•Create shade for the soil through planting trees or broad leaved plants.
•Mulch the soil so evaporation is reduced.
•Water by hose or bucket during dry periods.

1) Drainage

Why is soil drainage important?

•Soil drainage affects the level of moisture in the soil all year round.
•Poor drainage will reduce oxygen availability for plants and the soil ecosystem.
•Excessive drainage (run-off) can cause soil and nutrient loss through erosion.
•Plants need permanent access to moisture in the soil.
•Achieving the optimum balance between drainage and water retention is critical for good, reliable crop yields.
•Quick draining soil is also likely to be short of plant nutrients.

How to Improve soil drainage

•*Increasing the amount of organic matter in the soil* will improve drainage regardless of soil texture type, so add a 5cm deep layer of good compost or well-rotted manure to the soil every year
•*Mulch regularly* if possible using natural mulch such as grass clippings; man-made mulch, such as sheets of cardboard; or living mulch like clover under fruit trees. Mulch is best applied in spring when the soil is damp.
•*Water the soil regularly* in dry weather with a hose or bucket.
•Improve your soil by double digging.
•*Consider raised beds.* These will allow you greater control over the type of soil in the beds and are ideal for improving drainage *but* on a dry, windy site they will dry out very quickly.
•*See also the tips for waterlogged or permanently dry soil on p.2.*

2) Earth worms

Please note that the earthworm test may not be suitable for all parts of the world. In some places, for example, termites may have a key role in building soil. Please get in touch if you would like to help us develop a test for such places.

Why are earthworms important?

•Their burrowing aerates the soil and improves soil structure.
•Their Faeces promote fine crumb soil structure.
•They breakdown organic matter for micro-organisms which in turn promotes humus production.
•They mix organic matter into soils.
•They turn and mix the soil as they pass through it
•They promote the presence of positive bacteria and fungi in soils.

How to improve the population of earthworms in your soil:

•*Do not use any chemicals* on your soil as these are likely to have adverse effect on any earthworms there. Pesticides can kill worms or their food, while fertilisers will not provide nourishment to the worm population.
•*Use plenty of organic matter* in your soil as this will promote optimum moisture and temperature for earthworms to thrive and give them a good source of food. This organic matter can be in the form of compost, mulch or manure.
•*Maintain a soil pH of 5 to 7*.
•*Avoid walking on your soil* as this will cause compaction which in turn makes it harder for earthworms to move around. Use wooden boards or create permanent paths.
•*Do not to over-water or water-log the soil* as this results in earthworms rising to the soil surface due to burrows and tunnels being flooded. One way to prevent this is to utilize drip irrigation.

3) Top soil depth

Why is top soil depth important?

•Increased soil depth means increased soil volume, which in turn means increased soil water storage capacity.

•Increased soil volume mean increased availability of nutrients for plant growth.

•Plant roots can go much deeper if the soil is deeper; many plants will naturally extend roots down to three feet or more if the soil is deep enough.

•Plants on deep soil can be spaced closer together than plants on shallow soil without losing root space.

• If soil is very shallow many plants will not grow as they will not have adequate space to put down their roots.

•Plants growing on shallow soils can fall over in strong winds.

•Shallow soils can easily be washed away.

How to increase soil depth

•*Add a thick layer of rotted manure, mulch or compost* to the soil surface. Even a 5cm layer added each year will soon significantly increase your soil depth.

•*Consider bringing in additional top soil* from another site or from another part of your site.

•*Create raised beds*; these can be up to 60 cms deep.

•*Grow crops in containers or tubs.*

•*Prevent erosion on shallow soils,* especially by providing protection against flooding and run-off.

4) Soil Texture

Why is soil texture important?

•Soil texture is largely responsible for the retention of water and nutrients.
•Understanding your soil texture will enable you to improve and manage it.

Understanding soil texture

•*Sandy soil* contains large particles (termed grains). Plant roots can penetrate it easily but it dies not hold water or nutrients for long.
•*Silty soil* contains medium sized particles. It holds water, nutrients and plant roots well. However it can easily be washed away or become compacted.
•*Clay soil* contains small particles (termed platelets). It holds water and nutrients well. But it can bake hard when dry and become heavily compacted when wet; plant roots and even digging tools can struggle to penetrate it.
•*Loamy soil* is a mix of sand, silt and clay, making the best garden soil: "Good garden soil contains 30 to 50% sand, 30 to 50% silt, and 20 to 30% clay, with 5 to 10% organic matter." - *Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web,* Lowenfels & Lewis 2010

How to improve your soil texture

Improving clay soil: Deeply dig in as much organic matter (compost, manure) as possible to loosen the particles and improve structure; if the soil is too hard to work spread several centimetres on the surface. Do this in autumn when the soil is dry but still workable. Planting cover crops during fallow periods has similar benefits. Never walk on clay soil when wet as this will cause compaction; you can use boards to distribute your weight, or make paths. Another solution is raised beds which also improve drainage.

Improving silty soil: Dig in organic matter annually to improve/preserve structure. Several centimetres of organic matter should be forked in or spread over the soil surface in spring or autumn. Use wooden boards or permanent paths to avoid compacting the soil. Try to prevent erosion of the soil through flooding or run-off.

Improving sandy soil: Sandy soils are hungry and thirsty. They need lots of organic matter to bind the particles together and prevent loss of water and nutrients. It is best to work in the organic matter in spring or autumn. Apply mulch in early spring whilst the soil is wet from winter to keep the soil moist. Sandy soils lose nutrients quickly so crops can become hungry; use liquid foliar feed like compost tea to give plants a boost.

5) Soil structure

Why is soil structure important?

•Good structure means good air and water flow for soil ecosystem and plant roots.

•Good structure will hold water in dry weather, but will not become waterlogged in wet weather.

•Provides space for roots, seeds and soil fauna.

•Good soil structure allows roots to explore a larger volume of soil, giving plants access to more nutrients and water.

•Help with ease of cultivation.

•Bad structure means loss of nutrients from run-off, erosion and drainage.

How to improve soil structure

•*Add organic matter.* This can be in the form of compost of well-rotted manure. By adding organic matter the micro-organisms in the soil will thrive and breakdown the matter to form humus. On clay soils humus will force tightly packed soil aggregates apart, this improves soil drainage and makes it easier for plant roots to penetrate. On sandy soils humus will bind lose particles together. It will also act like a sponge and will slow drainage. In summary: increased nutrients → increased micro-organisms → increased humus → better soil structure.

•*Dealing with a pan.* If you have a pan (a hard, compacted layer running horizontally through your soil) it will prevent roots, nutrients and moisture reaching the deeper parts of your soil. If the pan is shallow (less than 25cm) a crop of deeply planted potatoes will probably break it up. If it is deep (greater than 50 cm) you could leave it, but you will need to change your soil depth test result accordingly. Otherwise you will need to double dig the soil, which will remove all pans down to about 50 cm. If you look after your soil properly, pans will not recur once dealt with.

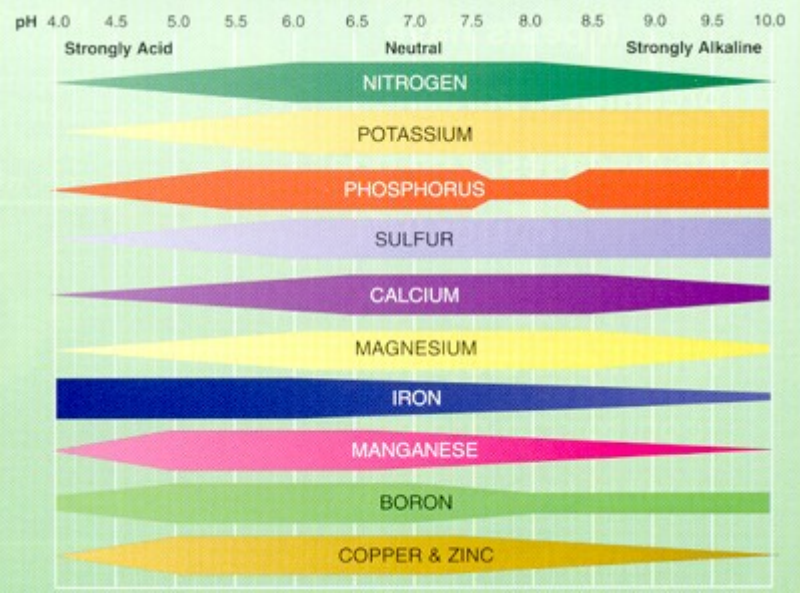
6) Soil PH

Why is soil pH important?

•It affects the types of micro-organisms that live in the soil.
•It determines the availability of varied nutrients for uptake by plants.
•All plants have a preferred pH range, most between 5.5 and 7 but blueberries like pH4 and lilacs pH 8.
•Maintaining a pH of 5 to 7 encourages earthworm populations.

Understanding soil pH.

pH is a measure of acidity or alkalinity. PH of 1 means very acidic, pH of 7 means neutral (neither acid nor alkali) and pH of 14 means very alkali. Soil pH can range from about 4 to about 9. Soil pH differs from one place to another for various reasons. Limestone, for example, creates alkaline soils. Past use, like mining or forestry, may have changed soil pH. Soil bacteria produce acid as part of their digestive process, so well-manured soil becomes more acidic over time; agricultural lime is often used to restore alkalinity. PH of 6 to 7 is ideal for most plants. This range also allows plants best access to nutrients:



How to deal with soil pH

pH can be raised (made more alakali) by adding calcium or lime in the form of agricultural lime, oyster shells or wood ash.
pH can be lowered (made more acid) by adding sulphur in the form of aluminium sulphate, urea, pine needles or pine sawdust, or organic matter.
If you have a pH around 5, grow blueberries, potatoes and oats.
If you have a pH around 6, grow brassicas, peas, beans, carrots and squash.
If you have a pH around 7.5, grow beets, spinach, parsnip, onion and lettuce.

7) Soil compaction

Why is soil compaction important?

•For most plants to grow well the soil needs to be soft and crumbly for ease of root and shoot movement.
•Low levels of compaction encourage earthworm populations.
•Heavily compacted soil can become waterlogged and even have puddles on the surface.
•Compacted soil is hard to cultivate.

How to deal with overly compacted soil

Unfortunately it is not possible to alleviate soil compaction without significant physical exertion.
•*Forking in organic matter*: cover the soil with 3 inches of light compost and fork it in. When the soil is extremely compact this is very hard work.
•*Double digging:* this may be necessary if the soil is very compacted. This is very hard work and should be done only in small doses! Double digging will break up the soil and remove all compaction. It only needs to be done once if the soil is then maintained well and properly fed.
•*Punch core aerator:* this requires more specialist equipment and a degree of brute strength. By punching holes in the soil the area becomes more aerated and is therefore easier to fork over with compost.
•*Reduce compaction in the first place:* avoid walking or driving on the soil. This is particularly important when the soil is wet or clay-based. Use wooden boards or permanent paths to reduce compaction.