SOIL

AGRICULTURE'S MOST VALUABLE ASSET

WHEN FARMING MEANS BUSINESS

Realising the full potential of farming is about growing and developing your business, not only your crop or livestock, but also your profit. Improve productivity and profitability by focusing on the positives and minimising disadvantageous aspects, through strong, dedicated management.

Success springs from determination and clear targets, from laying down the appropriate strategy and allocating correct investments for the future. Quality results require the right ideas and equipment. When there is work to be done, you need the optimal setup and smart solutions that support you towards an easier, more profitable way of working. You need solutions that make tough and demanding conditions less complicated.

Soil has always been the main factor in providing farmers with the necessary requirements for crop establishment and production.

The demand within the industry for increased knowledge on the composition of varying soil types and their structure has increased dramatically along with the need of understanding of how we can effect and improve the soil by modern farming practices.

This brochure aims to provide a basic understanding of the soil structure make-up and the positive and negative effects of our current farm systems.

DEAR READER,
SOILS ARE A SCARCE GOOD

Soils provide biodiversity, food, feed, clothes, shelter and energy. They store and filter water, recycle nutrients, retain carbon and host 25 % of our biodiversity. Soil health is crucial to fulfil all these functions. Living soils benefit from sufficient organic matter via both residuals and cover crops. Soil management that increases the humus content can support the formation of clay-humus-complexes and increase biotic engineering by providing a good environment for soil organisms. Diverse and rich soil life is therefore the key to sustainable healthy soil which can meet the demands of highly productive agriculture.

Almost all of the agronomic problems we face, weeds, diseases, insects, fertility, etc., can be traced to problems with ecosystem processes. We must recognize destructive impacts of tillage on soil and water and lack of diversity. Soils should be sink, not source for CO_2. We consider a dramatic increase of CO_2 loss over the last decades as a result of oxidizing processes due to land use. Rotations that are not consistent in terms of either interval or sequence provide the best protection against species shifts and biotype resistance. Perennial sequences are an excellent way to "jump start" the system. An increase in diversity and intensity needs to be balanced with profitability and will start with improved soil health.

Farmers use all efforts to achieve a crumbly structure, continuity of pores into deeper layers, balanced pH-Value due to soil texture and optimize soil organic matter. We create climate resilient systems by increasing adoption of Conservation Agriculture through innovation, knowledge sharing and faster implementation.

Prof. Dr. Thomas Weyer, Fachhochschule Süd-Westfalen, Soest (Germany)




WHY DO WE NEED A GOOD SOIL STRUCTURE?
THE POTENTIAL TO MAXIMISE RETURNS

Good Plant & Root Development
Yield can be directly linked to good or poor soil structure. Crops with sensitive root systems such as the Brassica family are extremely susceptible to compaction and drought whilst cereals are greatly effected by inconsistency in the residue mix within the soil profile.

Benefit to the Soil Eco-System
Good soil structure contains an increased percentage of organic matter in conjunction with a higher volume of micro and large organisms which provide valuable plant nutrients.

Impact on the Environment - Compaction & Erosion
Compaction restricts root growth and limits infiltration of water and air into the soil. It can also enhance soil run off leading to erosion of topsoil and leakage of nutrients and pesticides into the surface waters.

Ability to Manage Risk
With extreme weather patterns and legislation controls the need for flexibility in crop varieties, rotations and establishment becomes greater. Good soil structure increases the options available without sacrificing output.

Optimum plant growth depends on the complex structure of physical, chemical and biological soil properties.

SOIL TYPES
REFER TO THE DIFFERENT SIZES OF MINERAL PARTICLES

Sandy Soil –
(Light Soils)

- More acidic and low in nutrients.
- Light in mass with high proportion of sand and less clay.
- Good water drainage, quick to warm up and dry out.
- Easier to work in spring than clay soils but tend to dry out in summer.
- Susceptible to erosion if left loose and open.
- Added organic matter can help boost nutrients by improving the nutrient and water holding capacity of the soil.

Clay Soil –
(Heavy Soils)

- Benefit from being higher in nutrients.
- Highest in nutrients, pH through liming is crucial.
- Can remain wet and cold in winter and dry out in summer.
- Heavier in mass, over 25% clay with high water retention particles.
- Slower draining and take longer to warm up especially in spring.
- Attention to efficient drainage and traffic management essential.
- Susceptible to cracking in summer and waterlogging in winter they can be one of the most challenging and weather dependant soils.

Silt Soil –
(Light to medium with high fertility rating)

- Medium sized particles well drained and moisture retaining.
- Fine particles which can easily be compacted.
- Susceptible to water erosion.
- By adding organic matter, the silt particles can be bound into more stable sections.
- Dry conditions after rainfall can cause surface capping.
- Low wearing effect on metal.
- Most effective in water supply to plants in all water tension levels.

Chalk Soil –
(Light or heavy)

- High alkaline levels from calcium carbonate or lime within structure.
- Shallow soils usually less than 30cm deep.
- High calcareous content based on underlying limestone or chalk rock.
- Usually low in organic matter and nutrients.
- Free draining with lower moisture retention.
- High wearing effect on metal.

Loam Soil –
(High fertility mixture of sand, silt and clay)

- Ideal mix of 40% sand, 40% silt, 20% clay.
- Good drainage ability and moisture retention.
- Depending on sand to silt mix can be labelled sandy or clay loam.
- Balance of soil particles considered the ideal growing environment.
- High in organic matter and nutrients.
- Can be both easily workable and condensed particles.

Peat Soil –
(High fertility especially in the top soil)

- Organic matter content can exceed 20%.
- High content of decomposed plant material.
- Prone to wind erosion in drier regions.
- Not easily workable.
- Naturally saturated high water retention capability.

Increased soil variety means different demands.

SOIL COMPOSITION
WHAT IS THIS MAJOR ASSET MADE OF?

Basic soil composition consists of minerals, water, organic matter, gases and microorganisms making up approximately 50%. The rest is pore space with 40-60%.

A healthy soil consists of 50% solid matter and 50% pore volume, of which 50% to 75% of pore space should be filled with water.

Source: Kahnt

Minerals
The key elements of soil texture and organic matter contribute towards soil type. Soil texture is determined by the relative mass of the main minerals Clay, Silt & Sand.

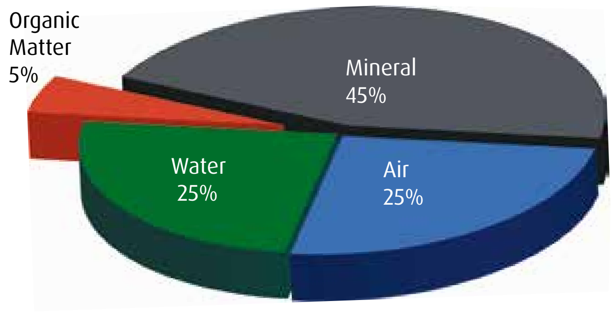
Moisture/Water
Water is a vital component within soil for distribution of nutrients and assisting with the breakdown of organic material.

Organic Matter
Consisting of decomposed residues from plants and animals supplying nutrients, organic matter also has a very high water retaining capacity.

Air
The air held within the soil profile contains natural gases such as nitrogen, carbon dioxide and oxygen the latter of which provides respiration for plants and organisms within the soil to breath.

The right composition is key.

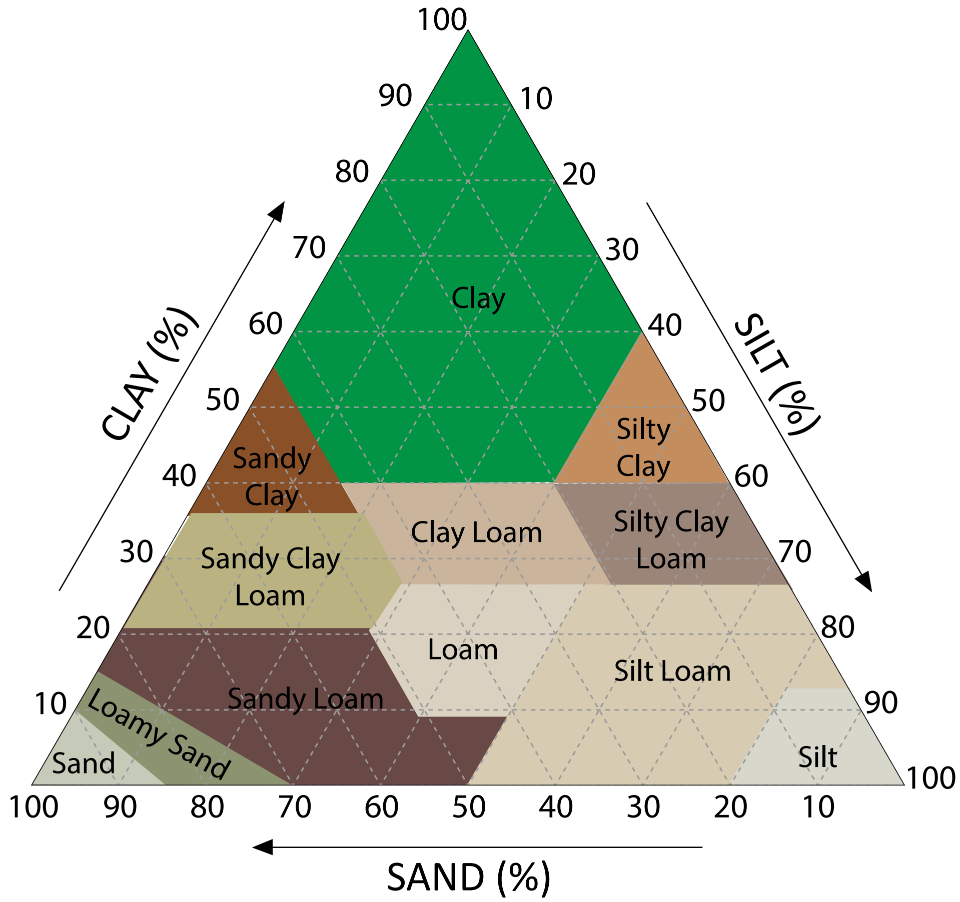
Microorganisms
Soil can contain very high numbers of microorganisms ranging in size from earthworms to fungi but equate to no more than 1% of the soil volume. They consume and recycle organic matter thus providing available plant nutrients and soil condition improvement.



Ideal Soil Composition

Texture	Nutrient Capacity	Water Infiltration	Water Holding	Aeration	Work-ability
Clay	Good	Poor	Good	Poor	Poor
Silt	Medium	Medium	Medium	Medium	Medium
Sand	Poor	Good	Poor	Good	Good
Loam	Medium	Medium	Medium	Medium	Medium

Source: USDA



The soil texture chart helps determine which of the 12 soil types within the soil triangle a particular sample represents. In this case a sample containing 13% silt, 21% clay and 66% sand would indicate a Sandy Clay Loam soil texture.

ORGANIC MATTER
SERVES AS A RESERVOIR OF NUTRIENTS AND WATER

Of all the components of soil, organic matter is probably the most important and most misunderstood. Organic matter serves as a reservoir of nutrients and water in the soil, aids in reducing compaction and surface crusting, and increases water infiltration into the soil. Yet it's often ignored and neglected. Let's examine the contributions of soil organic matter and talk about how to maintain or increase it.

What is Organic Matter?

Many times we think of organic matter as the plant and animal residues we incorporate into the soil. We see a pile of leaves, manure, or plant parts and think, "Wow! I'm adding a lot of organic matter to the soil." This is actually organic material, not organic matter.

What's the difference between organic material and organic matter? Organic material is anything that was alive and is now in or on the soil. For it to become organic matter, it must be decomposed into humus. Humus is organic material that has been converted by microorganisms to a resistant state of decomposition. Organic material is unstable in the soil, changing form and mass readily as it decomposes. As much as 90 % of it disappears quickly because of decomposition.

It is stable in the soil.

Organic matter is stable in the soil. It has been decomposed until it is resistant to further decomposition. Usually, only about 5 % of it mineralises yearly. That rate increases if temperature, oxygen, and moisture conditions become favourable for decomposition, which often occurs with excessive tillage. It is the stable organic matter that is analysed in the soil test.

What are the Benefits of Organic Matter?

1. **Nutrient Supply**
2. **Water-Holding Capacity**
3. **Soil Structure Aggregation**
4. **Erosion Prevention**
5. **Faster increase in soil temperature**
6. **Livelihood of soil biota**

What are the functions of Microorganisms?

1. Break down organic matter
2. Recycle nutrients
3. Create humus
4. Create soil structure
5. Fix nitrogen
6. Promote plant growth
7. Control pests and diseases

MICROORGANISM
SOIL IS ALIVE

Living organisms large and small, contained within the soil such as earthworms, nematodes, bacteria, and fungi have a vital role in providing good soil health.

The billions of organisms contained within the soil help mineralise the organic matter and nutrients available making them easily absorbed by and more beneficial to the plant roots.

It is estimated that 70 to 80% of the soils organisms are held within the top 4 to 6cm of the soil profile. As well as maintaining the soil health the soil temperature is able to rise faster which is especially beneficial in spring during establishment and the growing period.

70 to 80% are active in the topsoil.

Farming practices focused on improving soil structure, organic matter content and reducing erosion can help increase the level of organisms within the soil and its fertility leading in general to higher yields.

The soil should be considered and treated as one living organism and its health maintained which in turn will create healthy plants.

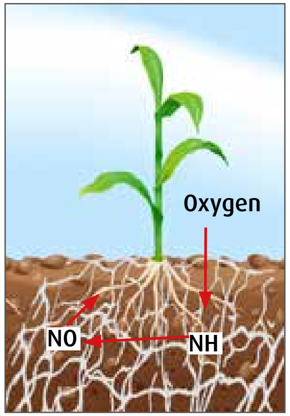
AIR SITUATION IN THE SOIL
AEROBIC AND ANAEROBIC SOILS

Most soils are aerobic. This is important because plant roots consume oxygen and carbohydrates while releasing carbon dioxide and there must be sufficient air —especially oxygen—in the soil to support most forms of soil life.

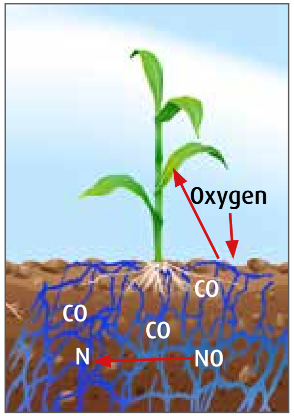
Anaerobic Soils
Anaerobic conditions are mostly created by overly wet soil or by the presence of root-rotting organisms, and are not caused by soil depth alone. When water does not have the ability to drain from the soil, fresh oxygen cannot be pulled in. This results in the soil's biological functions, decomposing organic matter, and tree roots using up all the available oxygen. (This is different from low oxygen soils, where water leaves the soil, but too slowly). Therefore, anaerobic conditions can occur at any soil depth. Roots generally need about 10% oxygen in order to grow. Creating a planting area using healthy, lightly compacted soil with adequate drainage should make the risk for anaerobic conditions extremely low, regardless of the depth. Result from a restriction of oxygen in the soil. This can occur in a number of ways including but not limited to poorly drained soils, over cultivation, heavy textured soils, compaction and heavy rainfall coupled with poor drainage.

Good water infiltration ensures aerobic condition.

Anaerobic conditions in soil affect plant productivity as well as organic matter and nutrient dynamics. It will also severely impact plant roots and restrict the growth of plants which aren't adapted to this type of environment. The effects on plants include a slowing of leaf and shoot extension, a yellowing of the older leaves, wilting and disease leading to reduced production levels. Anaerobic soils have high populations of putrefactive microbes which are reductive and produce toxins. These soils have higher levels of soil borne diseases and result in low production.



Well-aerated soil
Nitrification



Waterlogged soil
Denitrification

Sand

Clay

Silt

SOIL PROFILES
AND THEIR CHARACTARISTICS

Well structured soil allows unobstructed movement of air, water and nutrients through fissures between the structural units. Good soil structure is essential in the management of risk for example with moisture retention in dry periods and trafficking.

The various processes involved in soil formation lead to the fact that the soils are not structured uniformly in their entire depth, but are subdivided into more or less surface parallel horizons.

Each soil type has its own special characteristics.

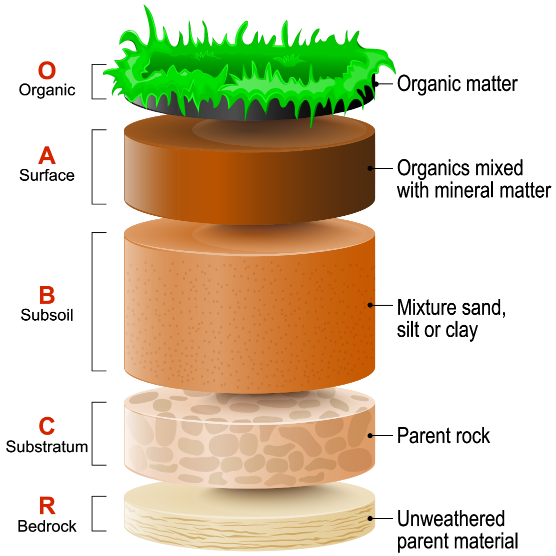
Topsoil O and A-Horizon:
The topsoil is usually the darkest soil layer containing the major percentage of organic material and therefore the highest level of biological and microorganism activity.

Subsoil B-Horizon:
This layer holds more minerals and water than the topsoil and less organic material.

Parent or Bedrock C and R-Horizon:
Further down, the soil profile usually diffuses into the unweathered parent or bedrock. Their physical properties, e.g. mineral content and grain size, and their chemical properties, such as weathering stability, influence soil formation.

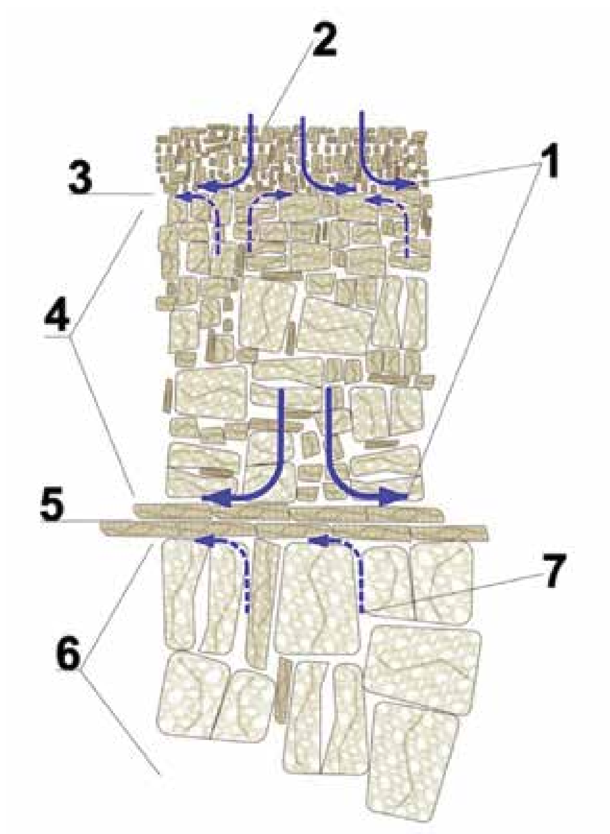
The soil horizons that develop in the course of soil development together form a characteristic soil profile. Soils with largely identical profile characteristics are combined to form one soil type.

SOIL LAYERS



Moisture remains in the soil after the use of the Kverneland Flatliner subsoiler with double DD rear roller.

MOVEMENT OF WATER AND NUTRIENTS
LIGHT AND HEAVY SOILS

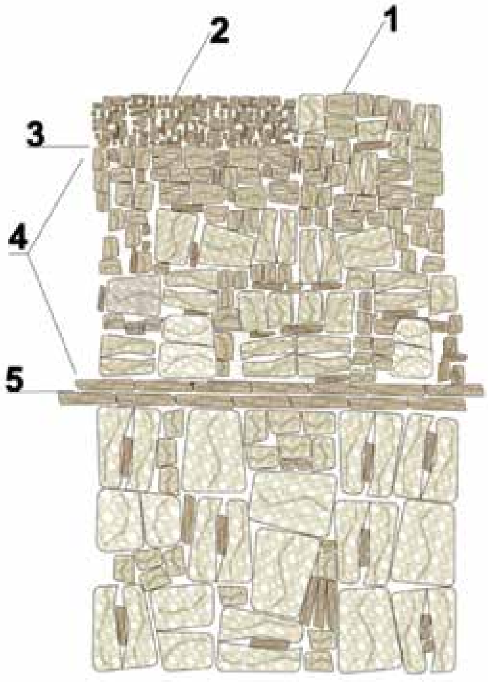


Barriers to water, air and nutrient movement are created by compacted layers (pans) and by layers between soil aggregates having different pore sizes.

- Water movement (1) through changes in bulk density or aggregate size by capillary action is severely restricted, unless the soil is saturated, where gravity can then take over.
- Aggregates (2) with smaller or larger pore size are often influenced by cultivation. The layers 1 to 4 represent traditionally ploughed and power harrowed profile on many soil types.
- Water movement (3) from small to large pores is slow in an unsaturated state (Eagleman, 1962), as the capillary pressure holding the water is higher in aggregates with small pores.
- Zones (4) below layers (3) can have restricted water (a perched water table is one example).
- Compacted layers (5) of high bulk density also restrict water, air and nutrient movement.
- Zones (6) below compacted layers are not readily available to roots. In dry summers pod or grain filling can be restricted leading to early maturing, loss of crop potential and yield.
- Upward water or air movement (7) is also restricted by pans or changes in aggregate size. This can have a significant effect in dry seasons where upward water movement by capillary action can benefit establishing crops with shallow root systems. All cultivations should therefore reflect the need to create the correct soil structure, and avoid sharp changes in aggregate size.

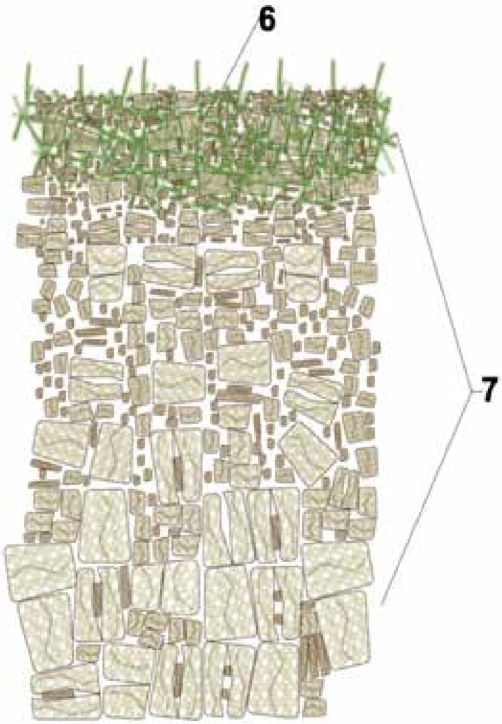
SOIL STRUCTURE
LIGHT AND HEAVY SOILS

The most important tool to assist maintaining good soil structure is a spade or penetrometer. Without digging soil profiles it is not possible to determine the structure and how to correct problems. Furthermore, unless cultivations are carried out when the soil is in an appropriate state, any actions decided upon are unlikely to be entirely successful.



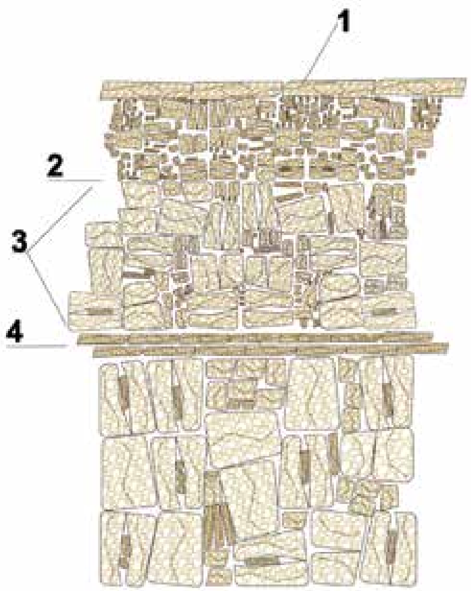
HEAVY SOIL POOR STRUCTURE:

- Surface (1) is rough and cloddy with poor seed to soil contact.
- Surface (2) is too fine, prone to moisture loss and erosion.
- Area (3) shows clear distinction between zones creating barriers to moisture movement.
- Layers (4) below the surface are dense and blocky, cracks and fissures are generally horizontal.
- Cultivation pans (5) can form barriers to roots, water, air and nutrients. Where trash is inverted above such layers, this becomes anaerobic, creating additional barriers to root growth.
- When digging these structures it may not be possible to easily break apart the mass of soil by hand, or dropping onto a firm surface from 1000mm height, when it is in a friable state, near to the lower plastic limit (see page 24).



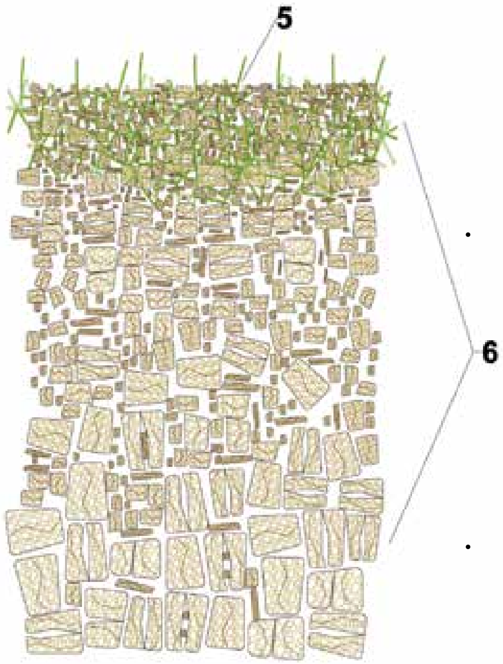
HEAVY SOIL GOOD STRUCTURE:

- Surface horizons (6) are a combination of stable aggregate sizes and organic matter, consolidated for good seed to soil contact, moisture retention and weatherproofing.
- Zone (7) shows a gradual transition to larger, structured aggregates at depth, the structure having open pores of varying size to hold water, air and nutrients, and allow roots to access these through the profile without any restricting layers.
- Cracks and fissures are generally vertical, indicating that water, air and roots can then pass readily through the profile to depth. Such fissures are generally supplemented by worm channels.
- When digging such structures, it is possible to break open the larger aggregates easily by hand or by dropping the soil (again, in a friable state) from 1000mm height onto a firm surface.



LIGHT SOIL POOR STRUCTURE:

- Surface (1) can be capped and structureless, forming a barrier to emerging plants, encouraging erosion and run-off preventing drying of the upper layers after rain (or in the Spring). This can delay seeding, or require additional passes to loosen the surface. Extra passes can risk compaction by tractor wheels with the soil in such a condition
- A clear distinction (2) can exist between zones with layers creating barriers to moisture movement.
- Layers (3) below the surface can be dense and blocky, resulting in poor root growth and water/nutrient access. Cracks and fissures are often horizontal, as opposed to vertical
- Cultivation pans (4) are frequently present, forming barriers to roots, water, air and nutrients. Where trash is incorporated, this is often anaerobic, creating additional barriers to root growth.



LIGHT SOIL GOOD STRUCTURE:

- Surface horizons (5) combine stable aggregate sizes and organic matter, consolidated for good seed to soil contact. In capping prone soils, OM provides stability, and methods of consolidating the soil are available to minimise surface caps and restrictions to seedling emergence.
- Zone 6 shows gradual transition to larger, open granular aggregates at depth, the structure having open pores of varying size to hold water, air and nutrients, and allow roots to access these through the profile. No distinct layers exists with beneficial roots and worm channels present to depth. Cracks and fissures are generally vertical.
- The same principles regarding breaking open the structures apply as per heavy soil section.

SOIL DIAGNOSTIC
WHEN IS THE RIGHT TIME TO CULTIVATE?

A simple, “field” method of identifying the soil condition relative to the lower plastic limit is by rolling out a small ball of soil worked in the hand.

If a long thread rolls easily, soil is wetter than the plastic limit and compaction will result from traffic by many vehicles, even if exerting pressures as low as 6 to 12psi (40 to 80kPa). Clay based soils will be most prone to damage if cultivated in this state. If it is not possible to roll a thread, but the soil smears easily, it is much wetter than the plastic limit and trafficking and cultivations will generally be detrimental in all situations. If the soil can just be rolled without crumbling, but is “on the edge” of crumbling, it is about at the plastic limit. Soil in this condition can be called “friable”.

Soil plastic limits: When to cultivate.

Cultivation will normally be effective, however ground pressures of above 15psi (100kPa) can compact the soil to some extent. If the soil cannot be rolled, but crumbles and breaks into hard crumbs, it is below the plastic limit and compaction by normal farm traffic is unlikely to occur. Care should be taken in severely dry situations to ensure that cultivation (for example seedbed making) is cost effective, as clods can be formed which will not break until soil moisture increases. Additionally, if the soil is light and forms powder, conditions are too dry to be effective and pulverisation of the ground will be harmful and potentially will risk erosion by wind or water.

Check Out Your Soil

1. Surface structure
2. Root penetration of the soil
3. Macropores and biopores
4. Soil structure and compaction
5. Organic residues
6. Colour and smell

RISK MANAGEMENT
TO PRESERVE A GOOD SOIL STRUCTURE

Good soil structure increases ability to manage extremes such as weather, trafficking and the soils ability to absorb moisture.

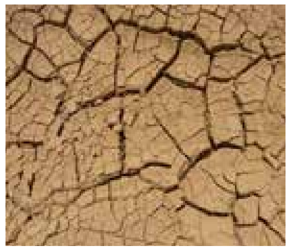
1. **Dry conditions:**
    - Roots need water to grow
    - Moisture conservation via good structure, cultivations
    - Nutrient transport becomes limited
    - Organic matter and aggregation help

2. **Wet conditions:**
    - Anaerobic issues – denitrification
    - Imbalance of air/water – toxicity, slow gas transport & accumulation of CO_2
    - Leaching of some nutrients detached from minerals or lost by erosion

Stable Soil Structure provides:

- **Weatherproofing**
- **Buffering against extremes**
- **Flexibility of establishment to manage risk**
- **Crop rotation possibilities**

The right balance is the key.



How to affect the soil structure?

- Drainage
- Crop Rotation
- Residue Management
- Estabishment practice and settings

HOW CAN WE CHANGE SOIL STRUCTURE?
MANAGING PARAMETERS TO EXERT INFLUENCE

Measures for the conservation and promotion of soil fertility are always to be considered in the long term. It is important that the entire management system of soil, plant, and machinery is always considered. Only in this way can the desired effects be achieved in terms of sustainability.

Drainage

Good drainage remains vital in avoiding anaerobic conditions following rainfall and maintaining the soils water and air balance. By reducing the potential damage to soil structure from saturation, field operations and nutrient usage are more efficient.

Crop Rotations

Choice of crop rotations and time of establishment can be both beneficial and harming to the soil's structure. Managing timeliness of operations, cover crop introduction and agronomy practice are some of the key factors.

Residue Management

The balance between crop residue removed, retained on the surface or incorporated within the soil profile greatly effects soil structure with potential for compaction from increased passes, restricting layers or type of establishment practice required.

Establishment practice & settings

Choice of establishment system, timeliness management, machinery specification and settings can be either beneficial or detrimental in maintaining, improving or damaging the soil. Attention to detail is a main priority.

YOUR KVERNELAND
INTELLIGENT FARMING SOLUTIONS

Choose the best farming solution for you and your land. Combine the highest possible yields with sustainability. This will start with the correct tillage. The choices you make depend on various factors and should match your specific circumstances, like soil structure, crop rotation, residue management, economic and ecological viabilities.

The choice is yours!

You must consider environmental and legal issues. From conventional methods to conservation tillage: the balance of operations at the right time has to be found to achieve high yields with the best soil condition (air, moisture, biological activity, etc.) with a minimum amount of energy, time and investment. For this, Kverneland offers a full range of intelligent farming solutions.

CONVENTIONAL TILLAGE

Conventional Tillage
- Intensive method of cultivation
- Complete soil inversion e.g. by a plough
- Less than 15-30% crop residues left on soil surface
- Seedbed preparation done by an active tool or special seedbed harrow
- High phytosanitary effect by reduced pressure of weed and fungi diseases - fewer herbicides and fungicides needed
- Better dry-off and faster increase of soil temperature for better nutrients absorbation

CONSERVATION TILLAGE

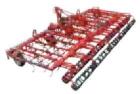
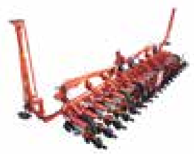
Mulch Tillage
- Reduced intensity in terms of depth and frequency
- More than 30% of residues are left on soil surface
- Extended repose period of the soil
- Cultivator and/or discs incorporate the crop residues within the top 10cm of soil for stable bearing soil
- Full-width tillage - seedbed preparation and seeding in one pass
- Protection against soil erosion; reduce soil loss by run-off and improve water storage capacity.
- Improvement of soil moisture retention

Strip Tillage
- Zonal strip loosening before or during seeding of up to 1/3 of the row width (Loibl, 2006). Up to 70% of the soil surface remains untouched
- Strip-till combines the soil drying and warming benefits of conventional tillage with the soil-protecting advantages of no-till by disturbing only the area of the soil where the seeds are placed
- Exact fertilising deposit
- Soil protection against erosion and drought

Vertical Tillage / No-Till
- Extensive method
- Working soil vertically avoids additional horizontal layers or density changes
- Increasing water infiltration, root development and nutrient take-up
- Plants' roots dictate the overall health of the plant, as they deliver nutrients and water throughout the season, contributing to a higher yield
- A strong set of roots make plants more resistant to wind and drought.
- Lower energy input required

CROP ESTABLISHMENT SYSTEMS

KVERNELAND'S INTELLIGENT FARMING SOLUTION

		Soil coverage after Seeding	Method		Deep Tillage (not a must)	Basic Tillage	Seedbed Preparation	Seeding	Spreading	Spraying
CONVENTIONAL	intensive	up to 15%	**Conventional**	with soil inversion		 				
CONVENTIONAL		15 - 30%	**Reduced Till**	without soil inversion						
CONSERVATION		> 30%	**Mulch Seeding**	without soil inversion						
CONSERVATION		> 30%	**Strip Tillage**	stripewise loosening						
CONSERVATION	extensive	> 30%	**Vertical Tillage**	shallow tillage						

CLASSIFICATION OF TILLAGE METHODS KVERNELAND (Source: adpated from KTBL)

WHEN FARMING MEANS BUSINESS

kverneland.com