Soil Structure:
Compaction: how to assess and manage problems

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Leading the way in Agriculture and Rural Research, Education and Consulting

Soil Structure

Structure is the how the particles bind together to form aggregates that allows:

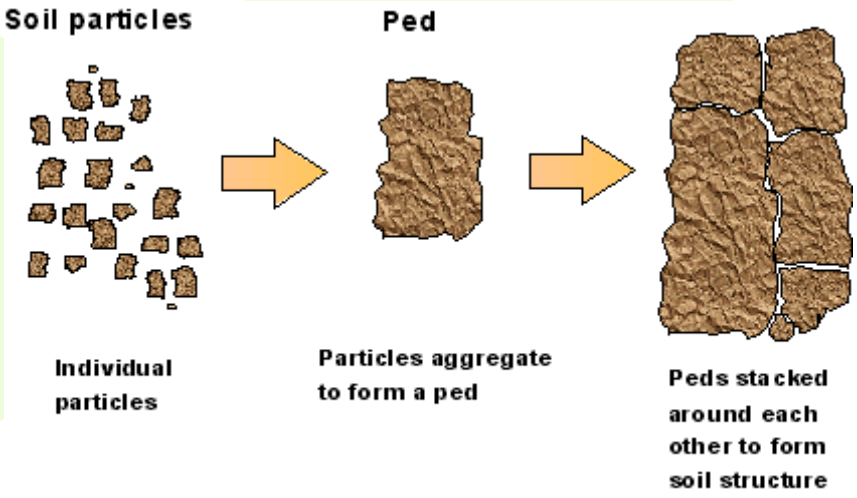
- roots to anchor the plant
- water to drain through pores and cracks
- water retention
- air to roots for favourable gas exchange
- mineralisation of nutrients and release to crop roots
- biodiversity of microbes

Structure formation

- Cycles of freezing and thawing
- Cycles of wetting and drying
- Binding action of roots and hyphal strands
- Addition of plant and faunal residues and their decomposition in the soil

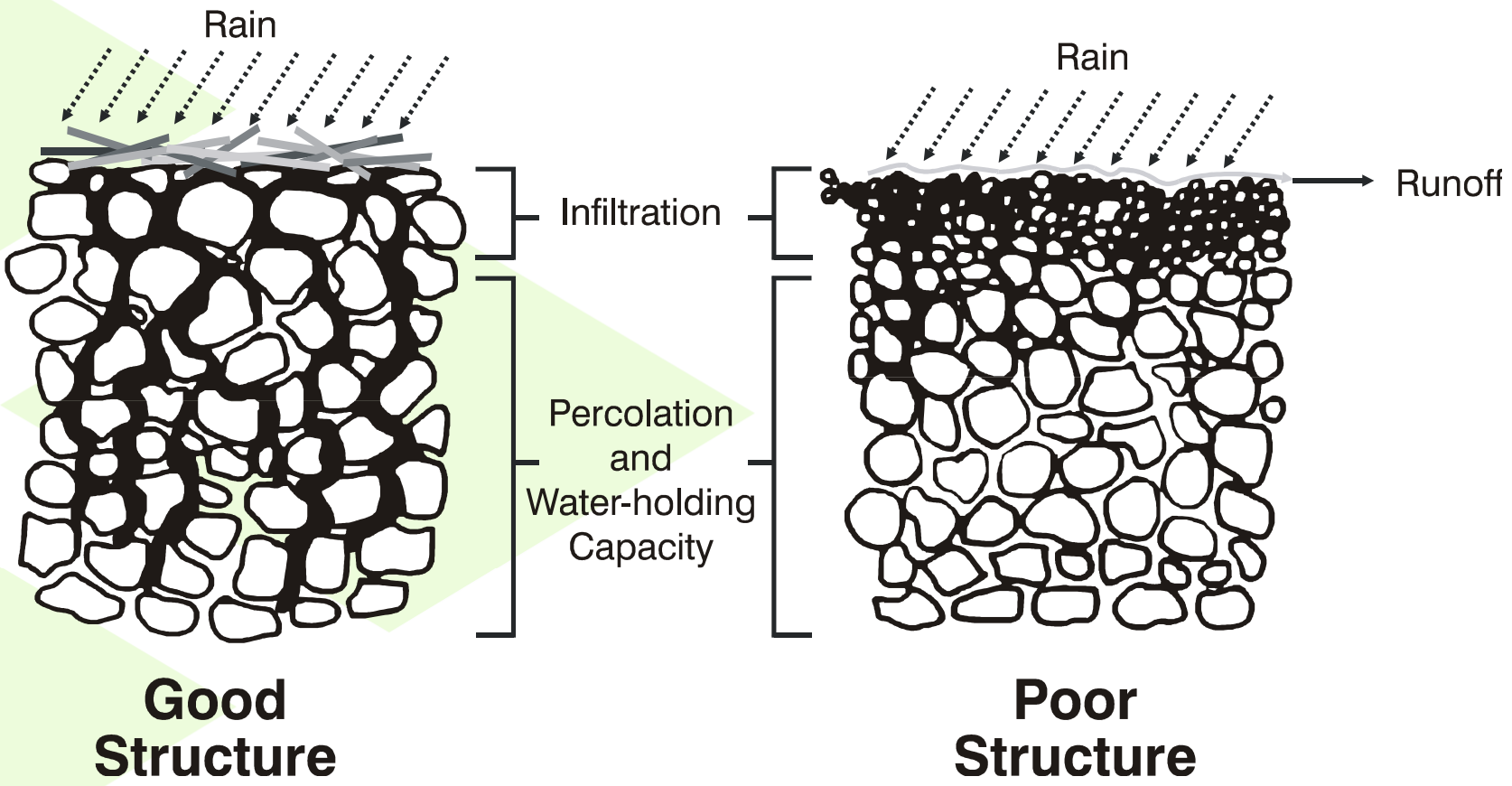
Aggregation

- A grouping of particles joined together or a grouping of aggregates (from pinhead to hand size)
- Joining is by ‘glues’ of clay and organic matter and binding by roots and fungal hyphae

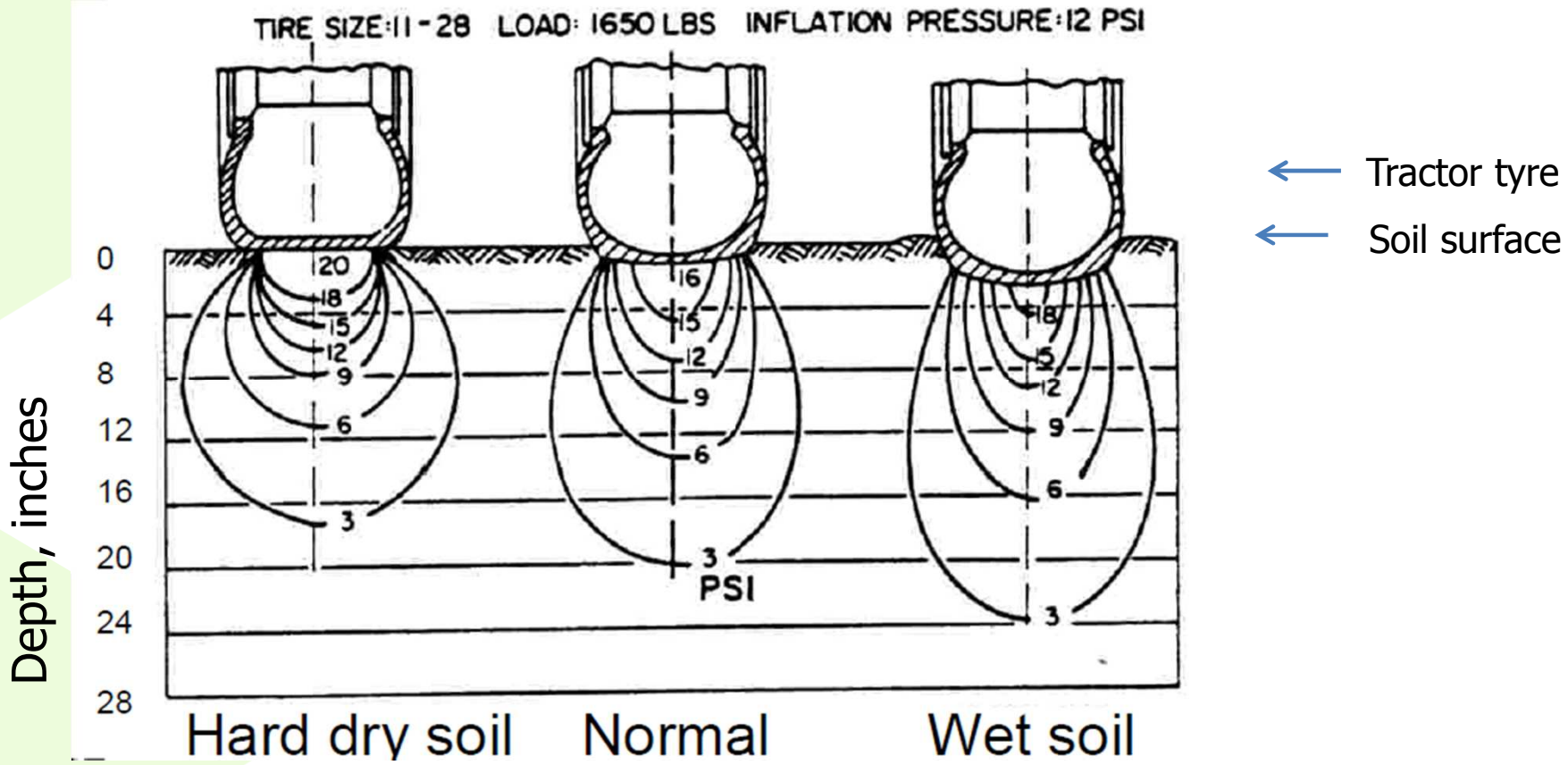


Aggregate Sizes

Structure affected by compaction



Compaction and soil moisture



As soil moisture increases - amount and depth of compaction increases

http://www.engr.uconn.edu/~lanbo/CE240LectW041fieldcompaction.pdf

Assessment of Soil Structure

- Methods of structure assessment
- Visual Evaluation of Soil Structure (VESS)
- Giving Values to Structure
- Compaction
- Providing solutions

Visual Evaluation of Soil Structure (VESS)

What is needed?

- A Spade!
- Show if aeration or sub-soiling is needed and how successful it has been
- Monitor soil health – take photographs
- Areas of field with suspected compaction
- Topsoil assessed with spade
- Subsoil and topsoil assessed by digging pits

Visual Evaluation of Soil Structure

Soil structure affects root penetration, water availability to plants and soil aeration. This simple, quick test assesses soil structure based on the appearance and feel of a block of soil dug out with a spade.
The scale of the test ranges from Sq1, good structure, to Sq5, poor structure.

Equipment:
Garden spade approx. 20 cm wide, 22-25 cm long.
Optional: light-coloured plastic sheet, sack or tray ~50 x 80 cm, small knife, digital camera.

When to sample:
Any time of year, but preferably when the soil is moist. If the soil is too dry or too wet it is difficult to obtain a representative sample.
Roots are best seen in an established crop or for some months after harvest.

Where to sample:
Select an area of uniform crop or soil colour or an area where you suspect there may be a problem. Within this area, plan a grid to look
at the soil at 10, preferably more, spots. On small experimental plots, it may be necessary to restrict the number to 3 or 5 per plot.

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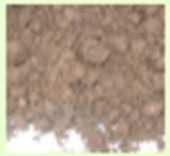
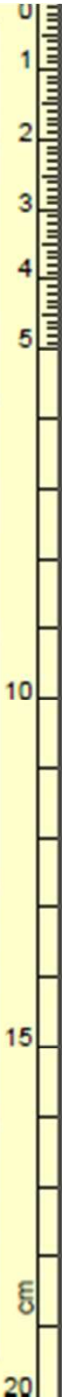
Method of assessment:

Step	Option	Procedure
Block extraction and examination		
1. Extract soil block	Loose soil	Remove a block of soil ~15 cm thick directly to the full depth of the spade and place spade plus soil onto the sheet, tray or the ground
	Firm soil	Dig out a hole slightly wider and deeper than the spade leaving one side of the hole undisturbed. On the undisturbed side, cut down each side of the block with the spade and remove the block as above.
2. Examine soil block	Uniform structure	Remove any compacted soil or debris from around the block
	Two or more horizontal layers of differing structure	Estimate the depth of each layer and prepare to assign scores to each separately.
Block break-up		
3. Break up block (take a photograph - optional)		Measure block length and look for layers. Gently manipulate the block using both hands to reveal any cohesive layers or clumps of aggregates. If possible separate the soil into natural aggregates and man-made clods. Clods are large, hard, cohesive and rounded aggregates.
4. Break up of major aggregates to confirm score		Break larger pieces apart and fragment it until a piece of aggregate of 1.5 - 2.0 cm. Look to their shape, porosity, roots and easily of break up. Clods can be broken into non-porous aggregates with angular corners and are indicative of poor structure and higher score.
Soil scoring		
5. Assign score		Match the soil to the pictures category by category to determine which fits best.
6. Confirm score from:		Factors increasing score:
	Block extraction	Difficulty in extracting the soil block
	Aggregate shape and size	Larger, more angular, less porous, presence of large worm holes
	Roots	Clustering, thickening and deflections
	Anaerobism	Pockets or layers of grey soil, smelling of sulphur and presence of ferrous ions
	Aggregate fragmentaion	Break up larger aggregates ~ 1.5 – 2.0 cm of diameter fragments to reveal their type
7.Calculate block scores for two or more layers of differing structure		Multiply the score of each layer by its thickness and divide the product by the overall depth, e.g. for a 25 cm block with 10 cm depth of loose soil (Sq1) over a more compact (Sq3) layer at 10-25 cm depth, the block score is (1 x 10)/25 + (3 x 15)/25 = Sq 2.2.

Scoring: Scores may fit between Sq categories if they have the properties of both.
Scores of 1-3 are usually acceptable whereas scores of 4 or 5 require a change of management.

15 Oct 2012

Structure quality	Size and appearance of aggregates	Visible porosity and Roots	Appearance after break-up: various soils	Appearance after break-up: same soil different tillage	Distinguishing feature	Appearance and description of natural or reduced fragment of ~ 1.5 cm diameter
Sq1 Friable Aggregates readily crumble with fingers	Mostly < 6 mm after crumbling	Highly porous Roots throughout the soil			 Fine aggregates	 The action of breaking the block is enough to reveal them. Large aggregates are composed of smaller ones, held by roots.
Sq2 Intact Aggregates easy to break with one hand	A mixture of porous, rounded aggregates from 2mm - 7 cm. No clods present	Most aggregates are porous Roots throughout the soil			 High aggregate porosity	 Aggregates when obtained are rounded, very fragile, crumble very easily and are highly porous.
Sq3 Firm Most aggregates break with one hand	A mixture of porous aggregates from 2mm -10 cm; less than 30% are <1 cm. Some angular, non-porous aggregates (clods) may be present	Macropores and cracks present. Porosity and roots both within aggregates.			 Low aggregate porosity	 Aggregate fragments are fairly easy to obtain. They have few visible pores and are rounded. Roots usually grow through the aggregates.
Sq4 Compact Requires considerable effort to break aggregates with one hand	Mostly large > 10 cm and sub-angular non-porous; horizontal/platy also possible; less than 30% are <7 cm	Few macropores and cracks All roots are clustered in macropores and around aggregates			 Distinct macropores	 Aggregate fragments are easy to obtain when soil is wet, in cube shapes which are very sharp-edged and show cracks internally.
Sq5 Very compact Difficult to break up	Mostly large > 10 cm, very few < 7 cm, angular and non-porous	Very low porosity. Macropores may be present. May contain anaerobic zones. Few roots, if any, and restricted to cracks			 Grey-blue colour	 Aggregate fragments are easy to obtain when soil is wet, although considerable force may be needed. No pores or cracks are visible usually.



Assessing Soil

- Smell
- Colour
- Ease of break up of the soil
- Larger soil aggregates
- Sharper points to soil aggregates

Good Soil Structure (Sq1)

Good but larger aggregates (Sq2)

Signs of compaction (Sq3)

Compaction Issues (Sq4)

Very compacted (Sq5)

Management from VESS Scores

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Threshold Sq values for sustained agricultural productivity

Sq score	Soil structural quality	Management needs
1-2	Good	No changes needed
3	Fair	Long-term improvements
4-5	Poor	Short-term improvements

Types of Compaction

Animal trampling effect the upper layer of the soil (0-10cm).

Mechanical compaction – much heavier and effects of compaction are further down the soil profile (0-20cm).

Compaction Treatment - Surface

Soil After Compaction Treatments

Bulk Density (g cm^3)
(soil depth 0-10cm)

	October 2011	October 2014
SRUC	1.02	1.15
SRUC	1.02	1.23
SRUC	1.02	0.94

Dry Matter Yield Reductions (t/ha)

SRUC

	SRUC					Harper Adams			
	Yield Reduction (t/ha)		Percent reduction (%)			Yield Reduction (t/ha)		Percent reduction (%)	
	Trampled	Tractor	Trampled	Tractor		Trampled	Tractor	Trampled	Tractor
2012	0.6	0.3	6.5	1.0		0.6	0.1	6.2	1.8
2013	0.4	1.0	5.6	11.5		0.2	0.6	1.9	-5.1
2014	1.6	2.0	11.0	14.3		2.0	2.3	12.2	14.3
All Years	2.6	3.3				2.8	3.0		

Compaction and Nitrogen Use

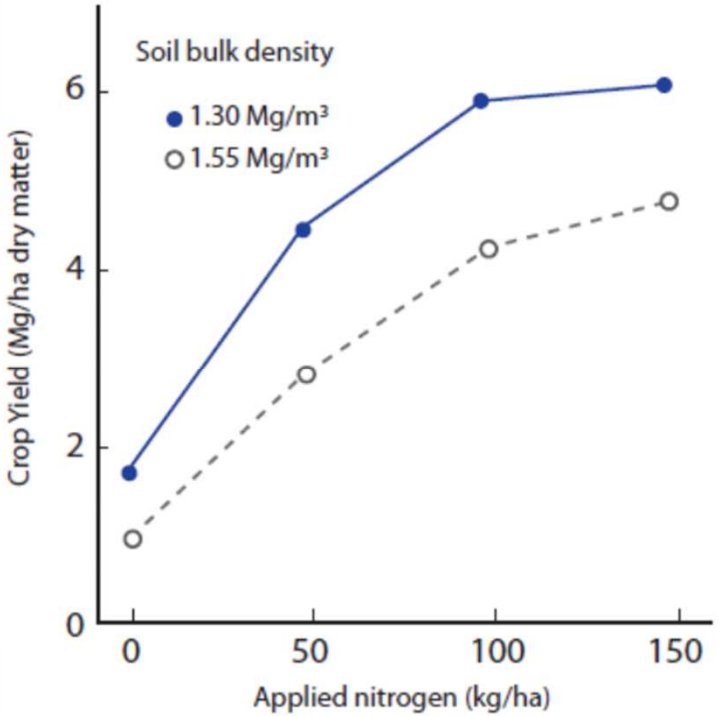


Figure 8.3: The relationship between the amount of nitrogen applied and crop yield under different compaction regimes. A compacted soil (bulk density of 1.55 Mg/m³) may require more nitrogen to obtain a similar yield to a non-compacted soil (bulk density of 1.30 Mg/m³). From Soane and Vanouwerkerk (1995)

Waterlogging – long-term

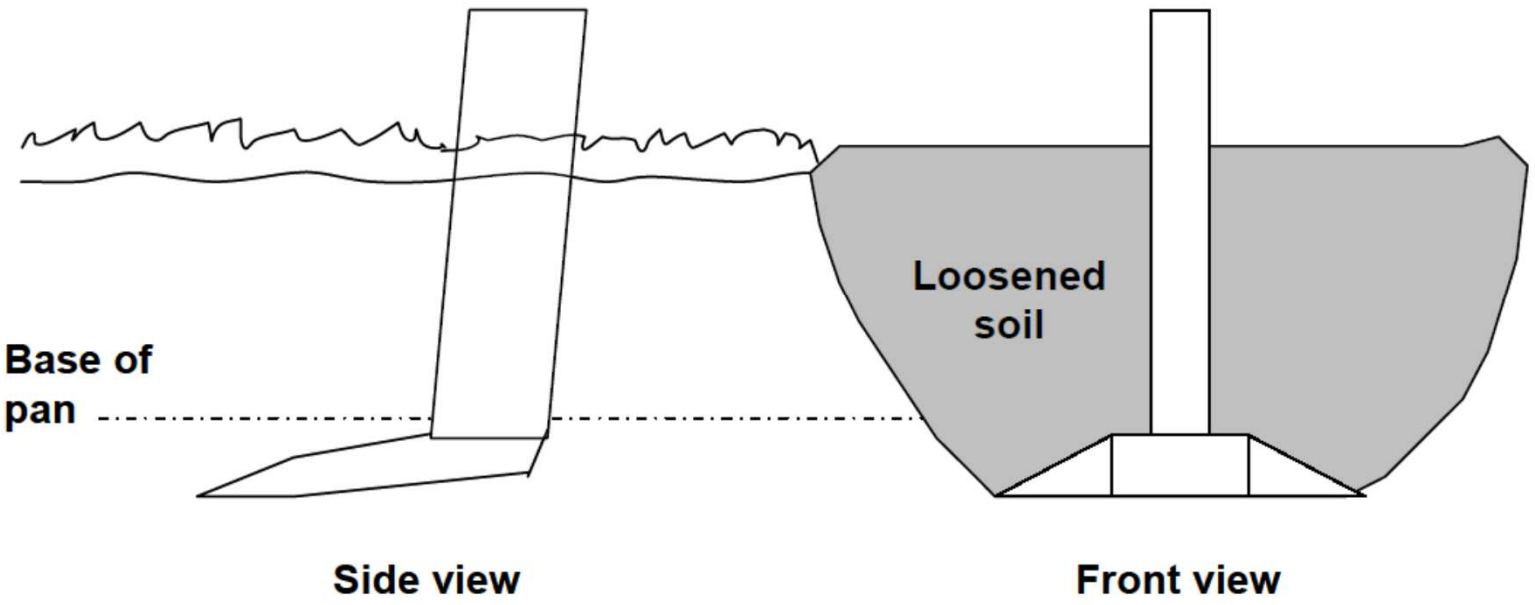
Waterlogging prevents oxygen from reaching soil organisms and roots causing them to suffocate. Available nutrients are lost. Sulphate, manganese and iron are reduced producing dull grey/blue colours.

Remediation and Working Depths

Type	Typical working depth (cm)
Aerators i.e. spiking or slitting	0 – 15cm
Sward Lifters	15 -35cm
Sub-soilers	35 – 50cm

Sward lifters

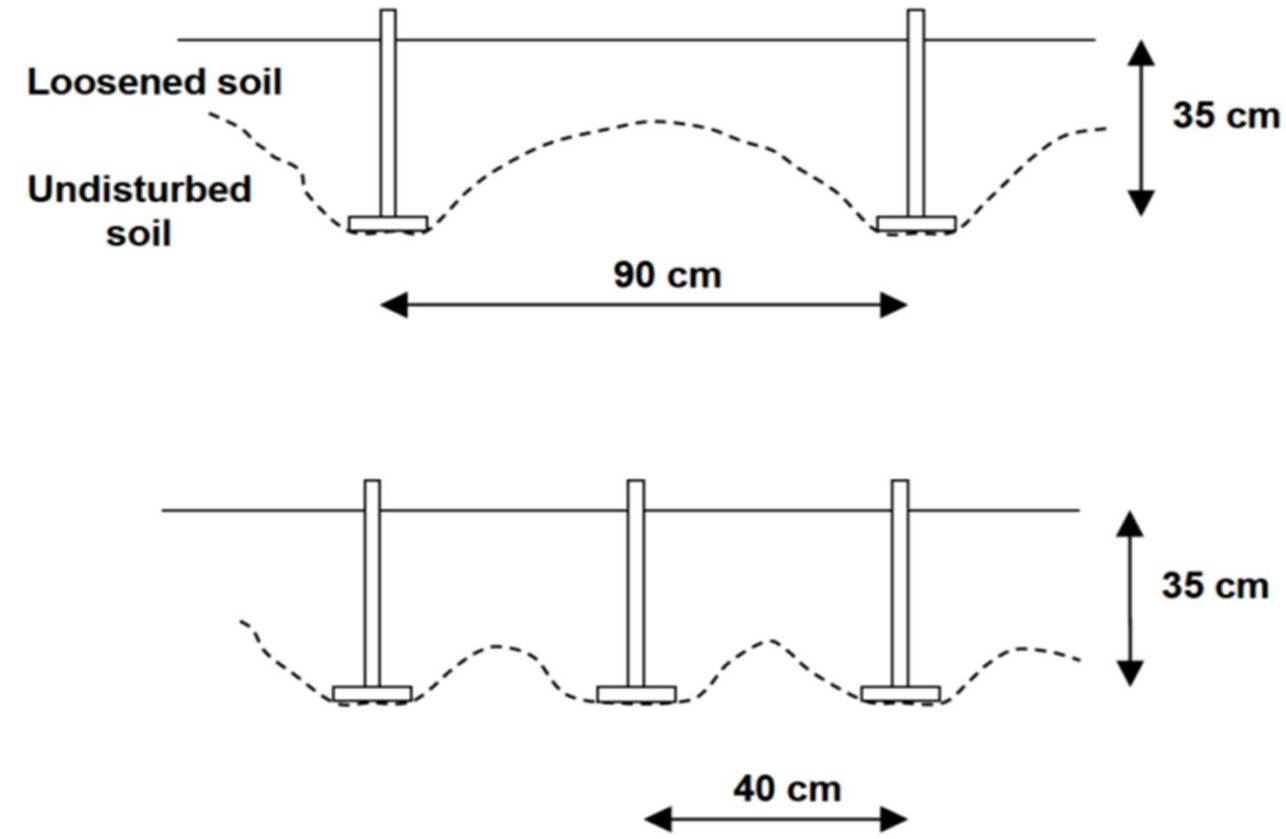
Loosening a compaction pan with a sward lifter (adapted from NSRI, 2002).



Note: the working depth has to be just below the zone that needs to be broken up.

Sward lifters

Soil disturbance profiles for a winged tine at different tine spacings.



Remediation of severe wheel rutting

- Make fissures across the ruts
- Allows water to drain into the adjacent uncompacted soil

www.mascus.com

Minimising Compaction

Mechanical

- Reduce weight – remove ballast, lighter machines
- Reduce ground pressure – wide tyre, low inflation pressure

Animal

- Cow tracks
- On/off and strip grazing
- Good network of tracks and gateways
- Grasses with dense tillering

General

- Check drains and ditches
- Improve drainage

Thank You

SRUC receives funding from Scottish Government
Work funded by AHDB Dairy

Problems with compacted soil

- Surface capping - break down of the soil surface structure, decreasing emergence
- Erosion - loss of surface soil in run-off
- Compaction – poor root penetration
- Reduced water infiltration
- Anaerobic layers - caused by poor drainage and compaction
- Reduced nutrient efficiency