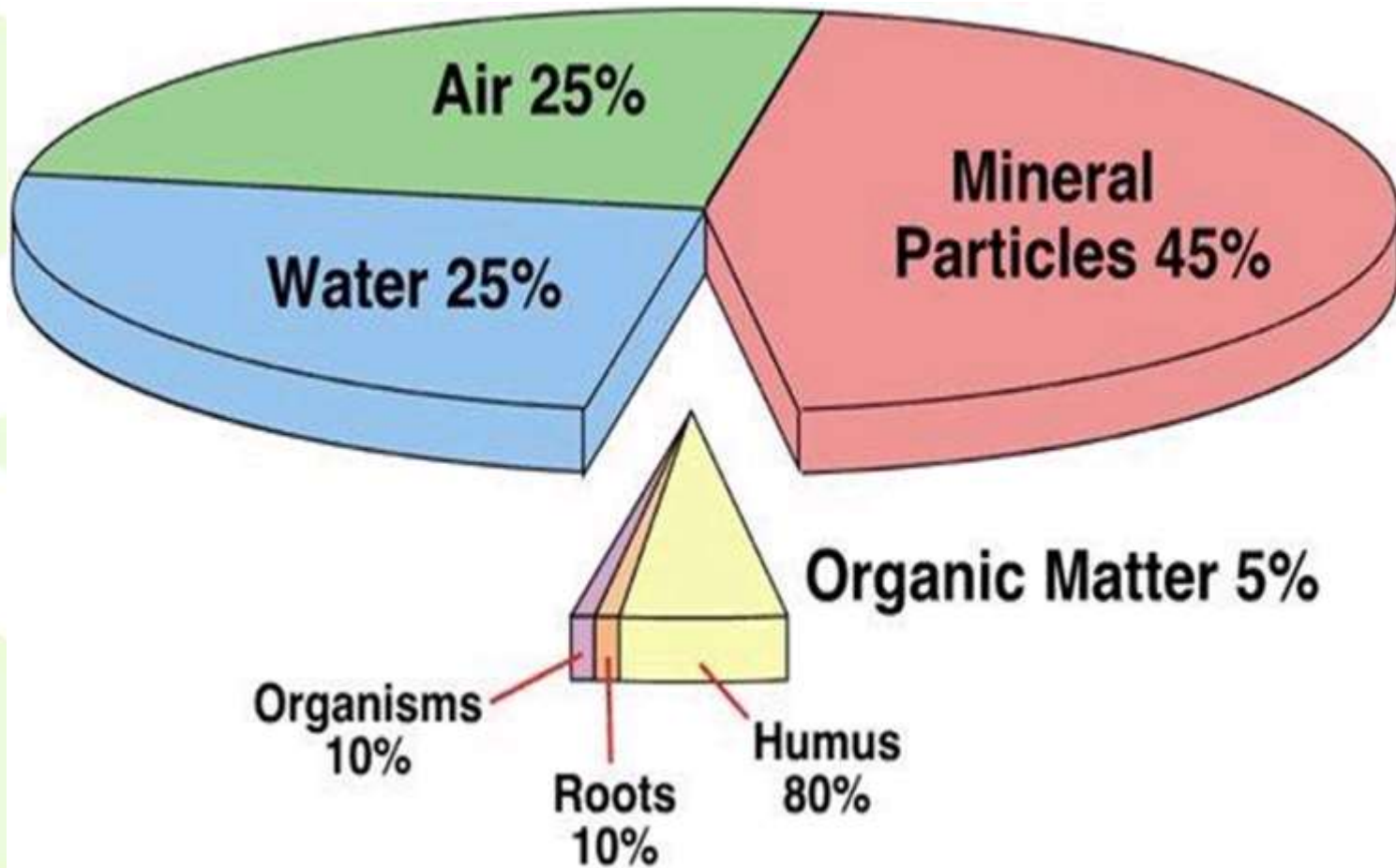


# Soils and Integrated Crop Management

Dr. Paul Hargreaves, SRUC



# What is Soil?





# Good soil management

- It can take 500 years to replace 25 mm of top soil
- In the UK it is estimated that 2.9 million tonnes of soil are eroded each year
- Soil quality is diminished by poor practices.
- A good drainage system relies on good soil structure
- Soils with poor structures are likely to be a source of direct surface run-off to watercourses of nutrients
- In addition to waterlogging and erosion.



VESS Score Sq1

A good soil structure has rounded aggregates that readily crumble in the fingers when moist, with many pores that allow easy root growth and passage of water throughout



VESS Score Sq5

A poor soil structure is almost always very compact with mostly large (> 10 cm) hard and sharp blocks. Porosity is very low and fissures tend to be horizontal and contain any roots. The soil can be grey or blue in colour with a sulphur smell (rotten eggs) indicating a lack of oxygen



# What is a healthy soil?

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Looks good  
Feels good  
Smells good

Easy to work  
Supports lot of life



# Know Your Soil



## Biological

Feed the soil regularly through plants and OM inputs

Move soil only when you have to

Diversify plants in space and time

**KNOW YOUR SOILS; principles to improve soil health**

## Chemical

Maintain optimum pH

Provide plant nutrients – right amounts in the right place at the right time

## Physical

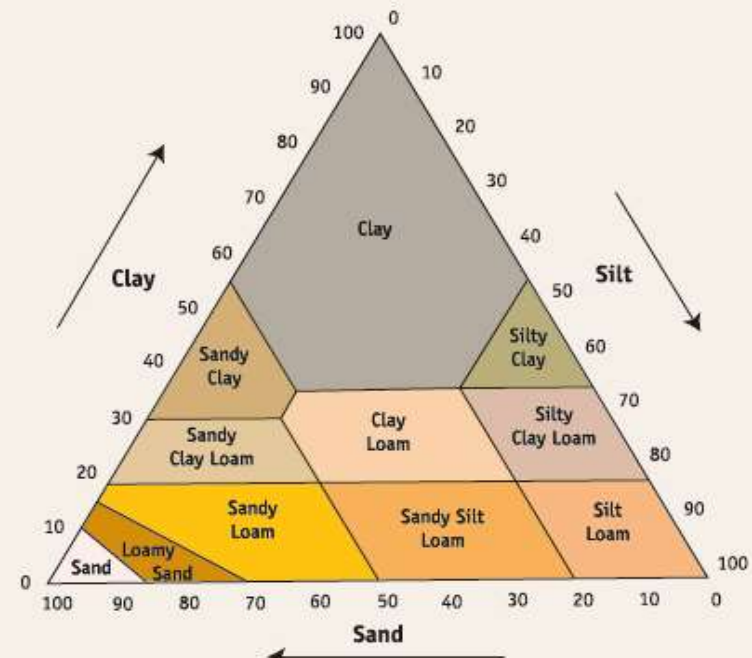
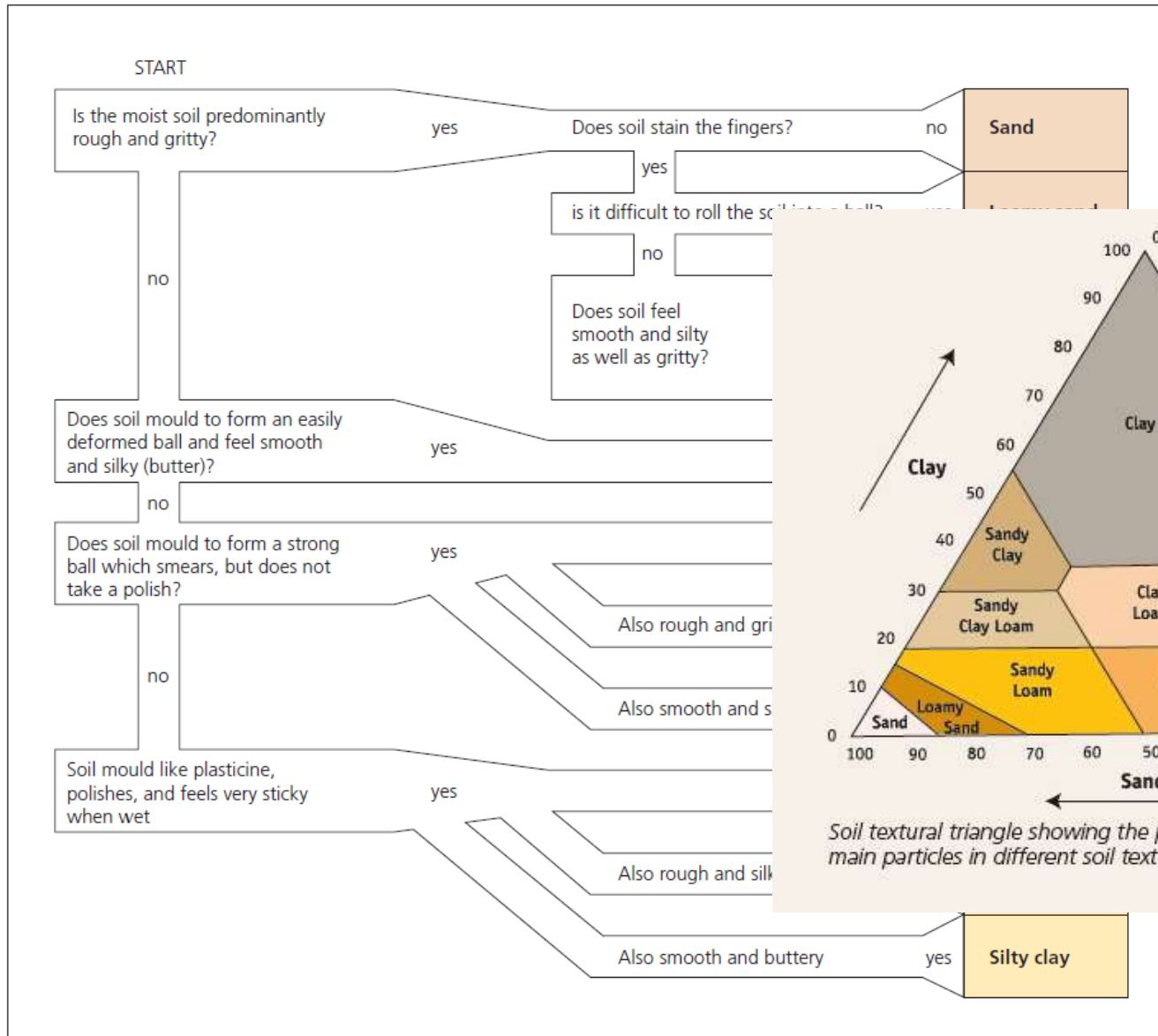
Texture and limits to workability, trafficability

Optimise water balance through drainage

Soil structure



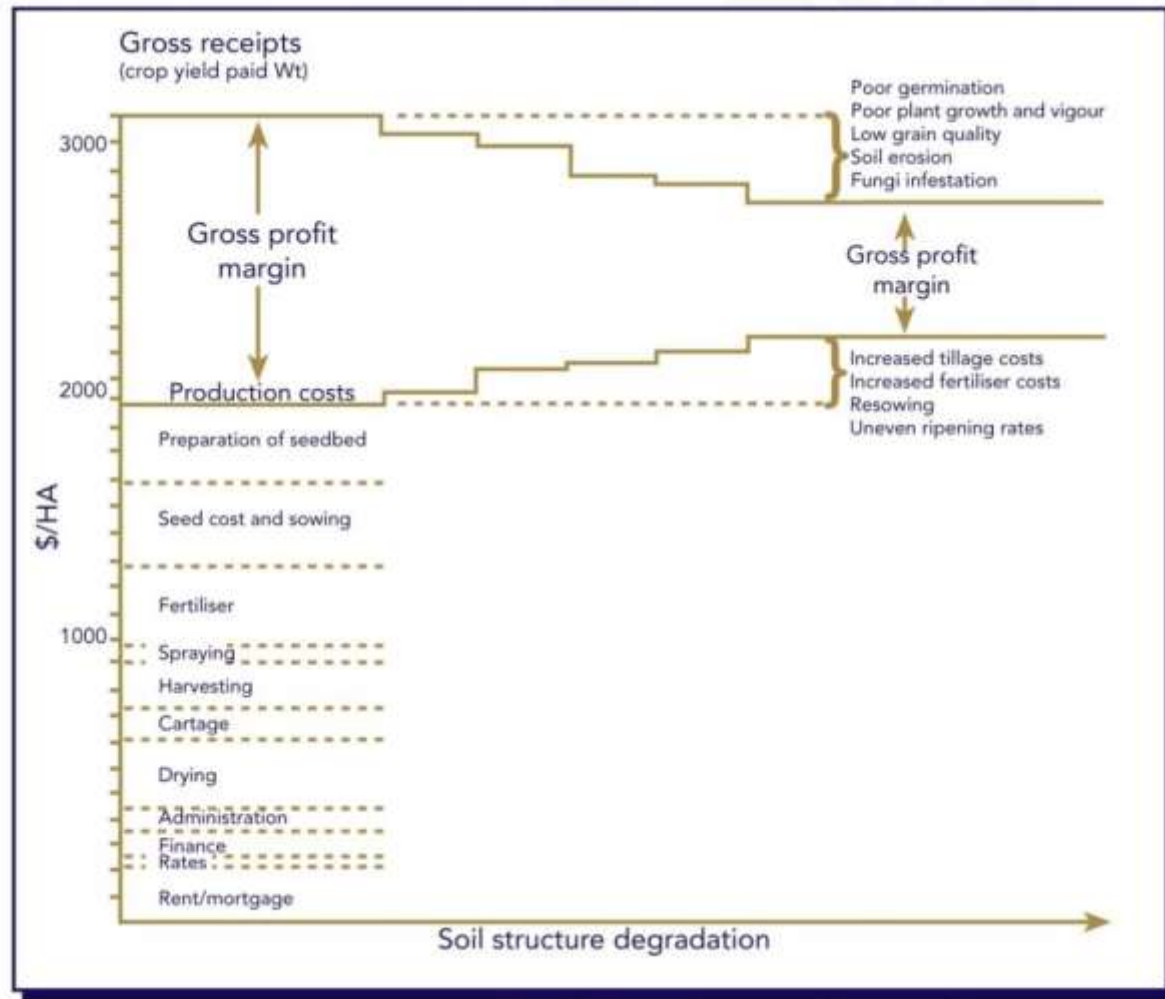
# Field assessments of soil texture



Soil textural triangle showing the proportions of the three main particles in different soil textures



# Reductions to Margins



Production costs (\$/ha) and narrowing profit margin associated with increasing soil structure degradation.

(G. Shepherd, Bioagrinomics, New Zealand)



# Soil Compaction

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## Soil Compaction Problem

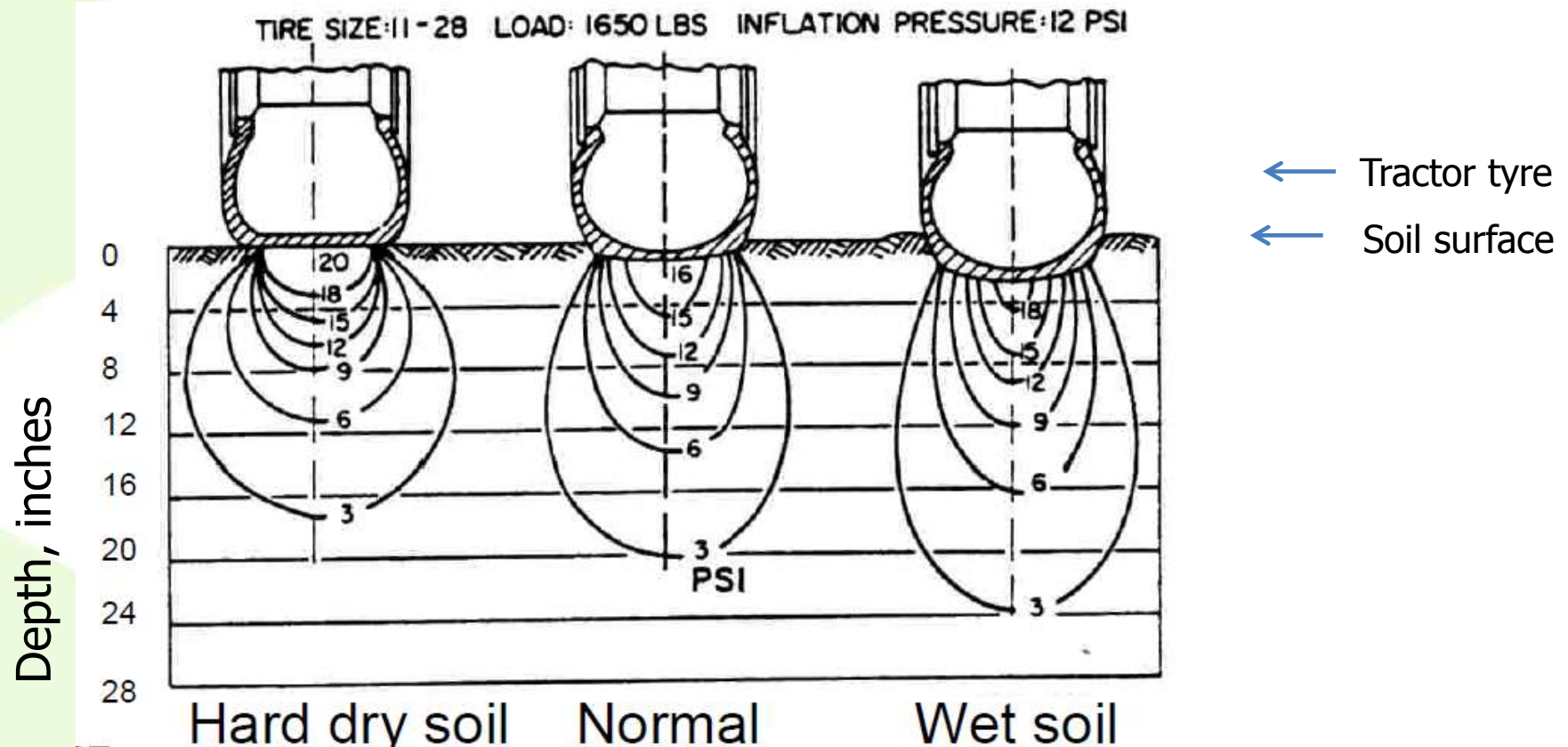
- Severe or poor soil condition in 8 - 12% of grasslands\*
- If moderate fields included then over 70%\*
- Reduced pore space/increased water filled pore space
- Reduced oxygen diffusion
- Microbial activity decreases



\* Newell-Price et al., (2013). Soil & Tillage Research, 127



# Compaction and Soil Moisture



As soil moisture increases - amount and depth of compaction increases



# Causes of compaction

Identifying likely causes of compaction. The depth of the compaction zone gives an indication of possible causes.

- 
- Surface level capping** Capping on new reseeds
  - 0-5 cm deep** Sheep trampling at high stocking densities
  - 5-10 cm deep** Cattle pressure e.g. grazing in very wet conditions
  - 10-15 cm deep** Heavy machinery trafficking e.g. silage, muckspreading  
*Remember: 70% of the damage occurs on the first wheelings*
  - > 15 cm deep** Plough pan due to repeated cultivation





# AHDB Dairy Compaction Experiment



The compaction experiment – 2011 to 2014.

Three main treatments:

- **Trampling**
- **Mechanical load**
- **No compaction**



Sub-treatments

- **Surface aeration**
- **Sward lifting (~25cm)**



SRUC Crichton (Scotland)  
and Harper Adams University (England)



# Soil After Compaction Treatments



Bulk Density ( $\text{g cm}^3$ ) (soil depth 0-10cm)		
	October 2011	October 2014
SRUC	1.02	1.15
HAU	1.17	1.21



SRUC	1.02	1.23
HAU	1.17	1.19



SRUC	1.02	0.94
HAU	1.17	1.14



# Visual Evaluation of Soil Structure (VESS)

## 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.



Source: from: <http://www.sructure.com/veess/>  
Further resources: University of Huddersfield: <http://www.huddersfield.ac.uk/~geography/veess/>  
Tom Davies, Independent Consultant: <http://www.tomdavis.co.uk/veess/>  
Lars Rasmussen, University of Aarhus: <http://www.sructure.com/veess/>

### Method of assessment:

Step	Action	Procedure
<b>Block extraction and examination</b>		
1. Select soil block	Lucas test	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.
	Pen test	Dig out a more tightly water and denser 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 shown.
2. Examine soil block	Uniform structure	Remove any consolidated soil or debris from around the block.
	Two or more separate types of differing structure	Estimate the depth of each layer and prepare to assign scores to each separately.
<b>Block break-up</b>		
3. Break up block	Take a photograph (optional)	Measure block length and cut for roots. 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 maintain close. Clods are single, hard, cohesive and rounded aggregates.
4. Break up of major aggregates to confirm score		Break larger clods apart and fragment to a piece of aggregate of 1.0 - 2.0 cm. Look to their shape, porosity, roots and signs of break up. Clods can be broken into non-cohesive aggregates with angular corners and are indicative of poor structure and higher scores.
<b>Soil scoring</b>		
5. Assign score		Match the soil to the pictures (category 1) category to determine which the best.
6. Confirm score then:		
Block extraction	Factor in increasing score	Difficulty in extracting the soil block
Aggregate shape and size	Larger, more angular, less porous, presence of large worm holes	
Roots	Clustering, increasing any reflecting	
Aerobium	Pockets of layers of grey soil, smearing of sulphur and presence of ferrous ions	
Aggregate fragmentation	Break up larger aggregates > 1.0 x 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 20 cm block with 10 cm depth of loose soil (Sq1) over a more compact (Sq2) layer of 10 cm depth, the block score is $(1 \times 10) + (2 \times 10) = 30$ 3.0.

**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.

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	cm
Highly porous roots throughout soil			Fine aggregates	1 cm The action of breaking the block is enough to reveal them. Large aggregates are composed of smaller ones, held by roots.	0
Most aggregates are porous roots throughout soil			High aggregate porosity	1 cm Aggregates when obtained are rounded, very fragile, crumble very easily and are highly porous.	5
Macropores and roots present porosity and roots throughout within aggregates.			Low aggregate porosity	1 cm Aggregate fragments are fairly easy to obtain. They have few visible pores and are rounded. Roots usually grow through the aggregates.	10
Sq4 Compact			Distinct macropores	1 cm Aggregate fragments are easy to obtain when soil is wet, in cube shapes which are very sharp-edged and show cracks internally.	15
Sq5 Very compact			Grey-blue colour	1 cm Aggregate fragments are easy to obtain when soil is wet, although considerable force may be needed. No pores or cracks are visible usually.	20



# Dry Matter Yield Reductions (t/ha)



	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		



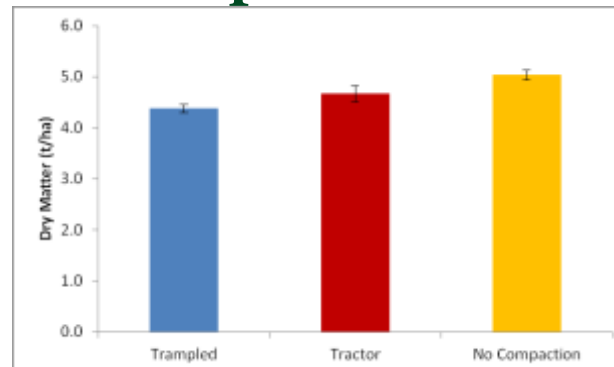
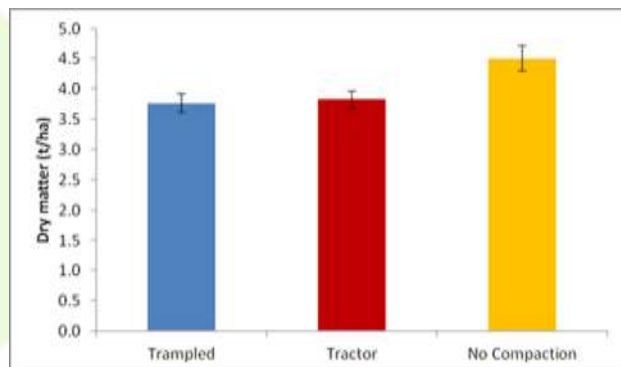
# 1<sup>st</sup> Cut Dry Matter Yield (t/ha)



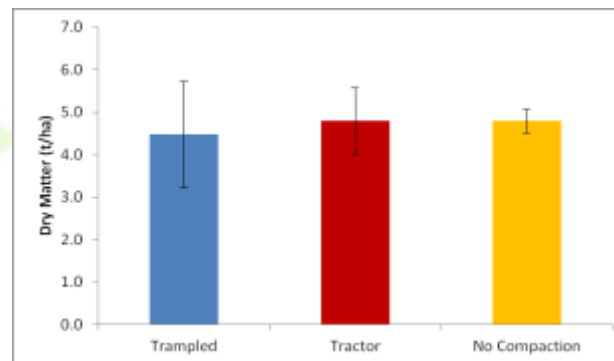
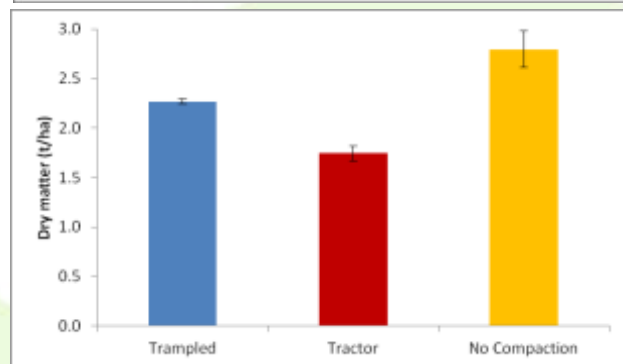
## SRUC

## Harper Adams

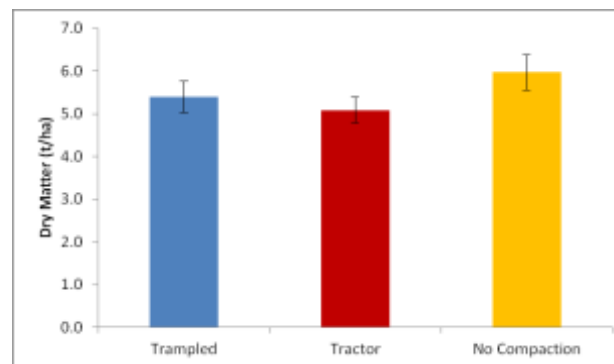
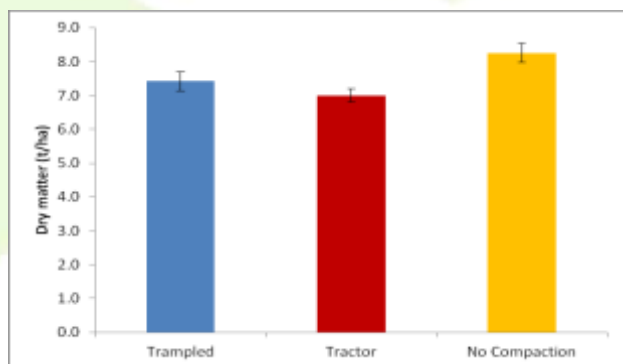
2012



2013



2014





# Natural Recovery



Measurement	Treatment	SRUC		Harper Adams	
		Compaction	Recovery	Compaction	Recovery
<b>Soil Bulk Density (g cm<sup>3</sup>)</b>					
	Trampled	1.15 <sup>a</sup>	0.94 <sup>b</sup>	1.21	1.22
	Tractor	1.23 <sup>a</sup>	1.05 <sup>b</sup>	1.06	1.08
<b>DM Yield (t/ha)</b>					
Total of all cuts	Trampled	11.35	11.36	11.69	12.96
	Tractor	10.93	11.53	11.42	12.10



# Remediation and Working Depths

Type	Typical working depth (cm)
Aerators i.e. spikers or slitters	0 – 15 cm
Sward lifters	15 – 35 cm
Sub-soilers	35 – 50 cm





# Grass DM Yield (t ha<sup>-1</sup>) - Years 2013 and 2014

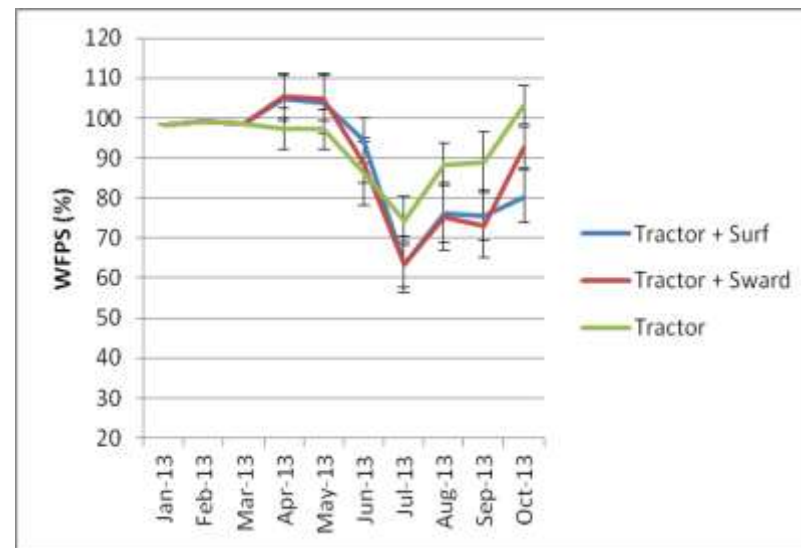
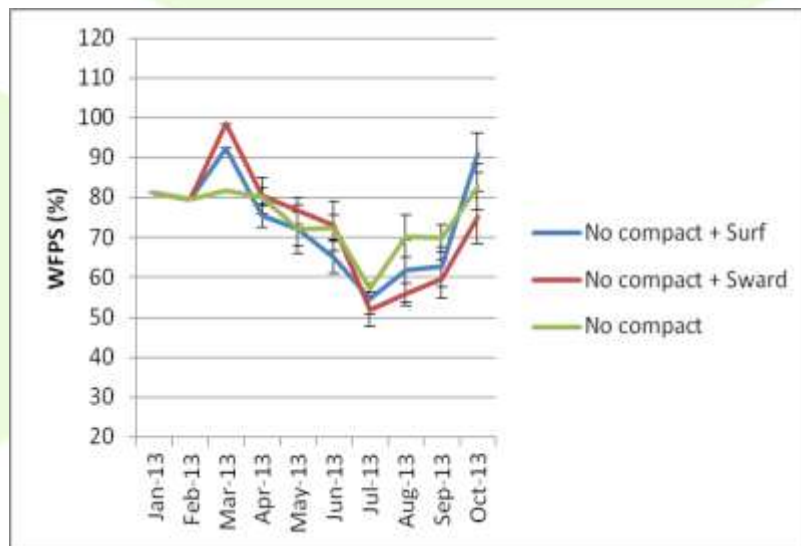
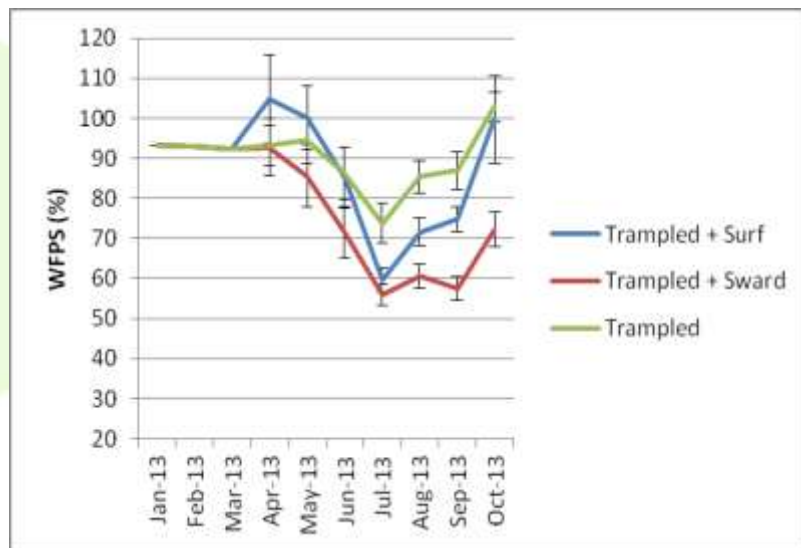


SRUC	1 <sup>st</sup> Cut			2 <sup>nd</sup> Cut			3 <sup>rd</sup> Cut		
	No Comp.	Tramp.	Tractor	No Comp.	Tramp.	Tractor	No Comp.	Tramp.	Tractor
<b>2013</b>									
No Alleviation	2.7	2.2 <sup>a</sup>	1.9	2.6	3.1	3.1	2.4 <sup>a</sup>	2.4	2.5
Sward Lifting	2.3	1.7 <sup>b</sup>	1.7	2.8	3.0	3.5	2.2 <sup>b</sup>	2.4	2.5
Surface Aeration	2.8	2.0 <sup>a</sup>	1.7	3.1	2.8	3.7	2.5 <sup>a</sup>	2.4	2.4
<b>2014</b>									
No Alleviation	8.0 <sup>a</sup>	7.4	7.0 <sup>a</sup>	1.7	1.4	1.4	2.5	2.5	2.5
Sward Lifting	5.2 <sup>b</sup>	5.6	5.3 <sup>b</sup>	1.8	1.7	1.6	2.4	2.5	2.5
Surface Aeration	5.7 <sup>c</sup>	5.7	6.0 <sup>a</sup>	1.9	1.4	1.4	2.4	2.5	2.4

All values as t ha<sup>-1</sup>



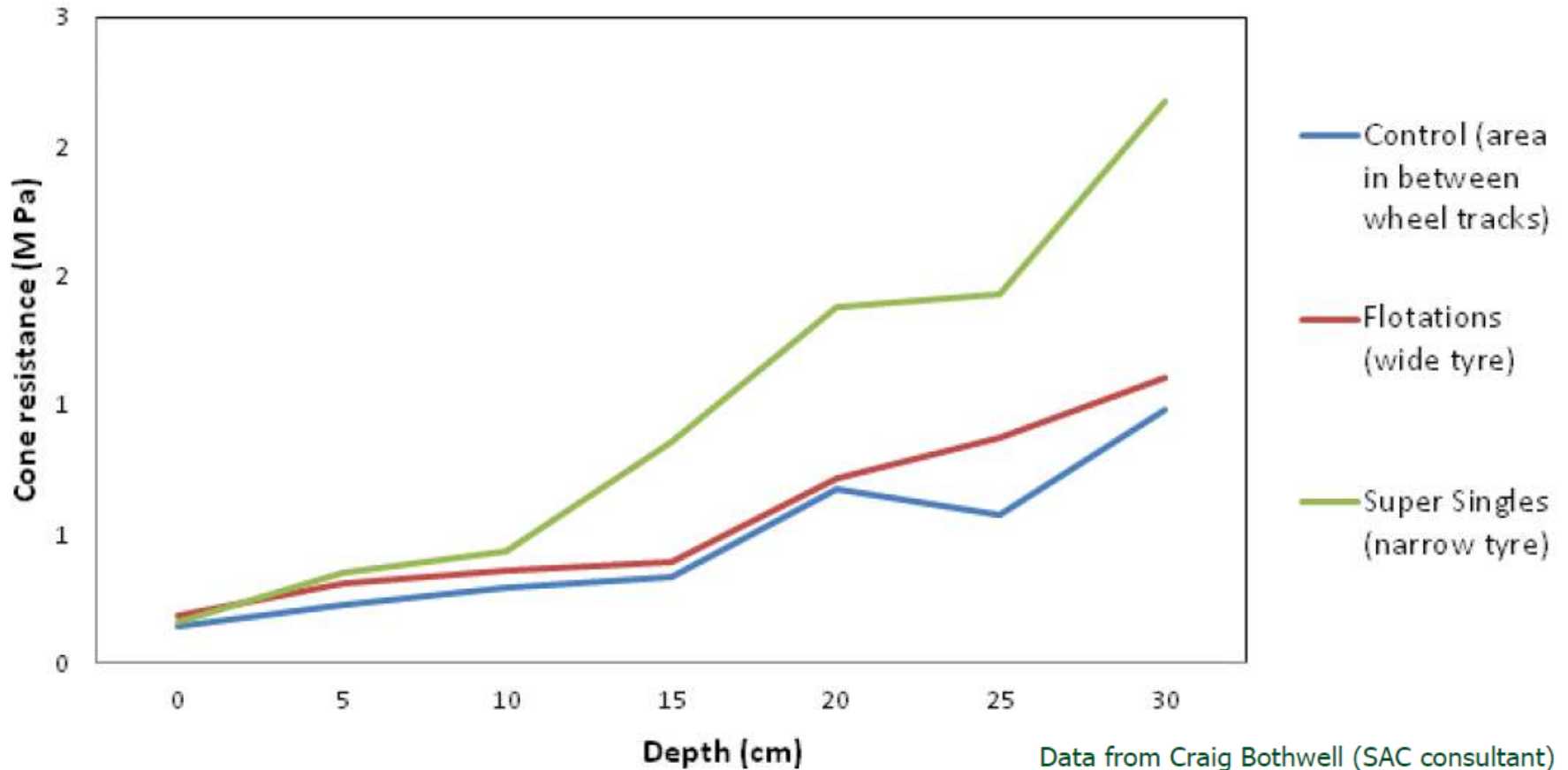
# Water Filled Pore Space (%) 2013





# Practical steps for avoiding compaction

Soil strength: comparison after different tyre choice





# Checking soil drainage status

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## Drainage 10 point check list

1. Investigate wet/waterlogged areas of field to assess soil structure
2. Remove soil compaction to help drainage
3. Check farm plans to see if a field drainage system exists
4. Check outflows and drains are clear, jet if necessary
5. Keep drainage ditches clear of silt and the water level at least 15 cm below the level of the outflow
6. Only use mole drains if soils > 30% clay and not too stoney
7. Make sure any new drainage system is suited to soil type and conditions
8. Lateral drains should always run across the slope
9. Backfilling drains with a permeable material helps maintain their use and allows connection to mole drains
10. Ensure the correct drainage pipe diameter/material is used



# The effect of soil compaction on grass yield



- Yield decrease due to soil compaction is in the range 5 – 74%
- Long-term yield decrease for UK conditions is in the range of 5 – 20% with a mean of 13%
- Largest yield decrease generally takes place during the first cut caused by traffic either in the previous autumn or spring





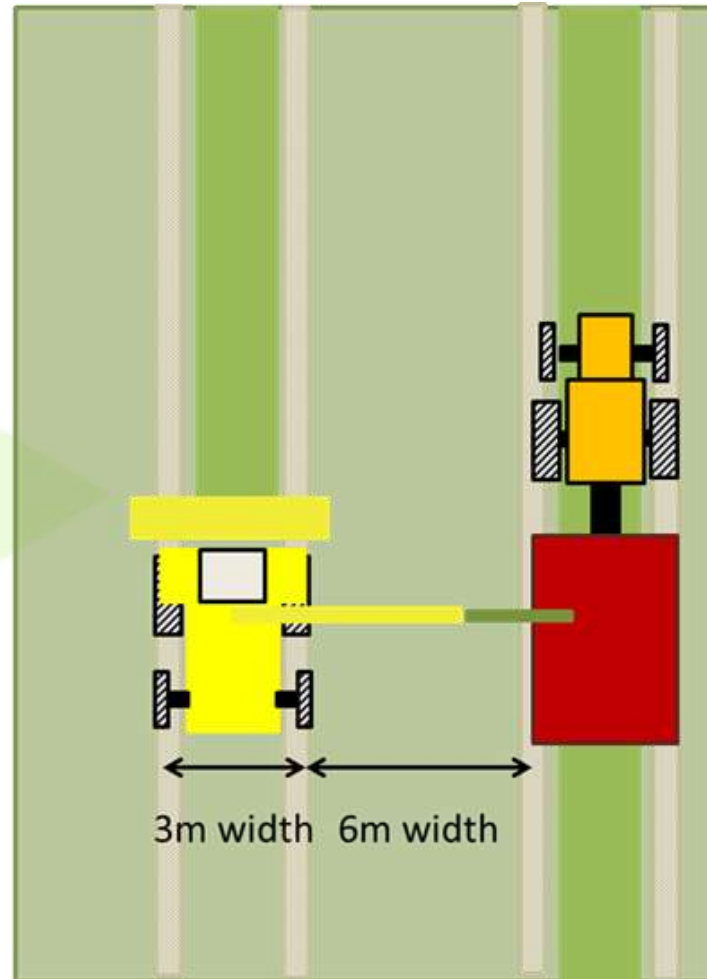
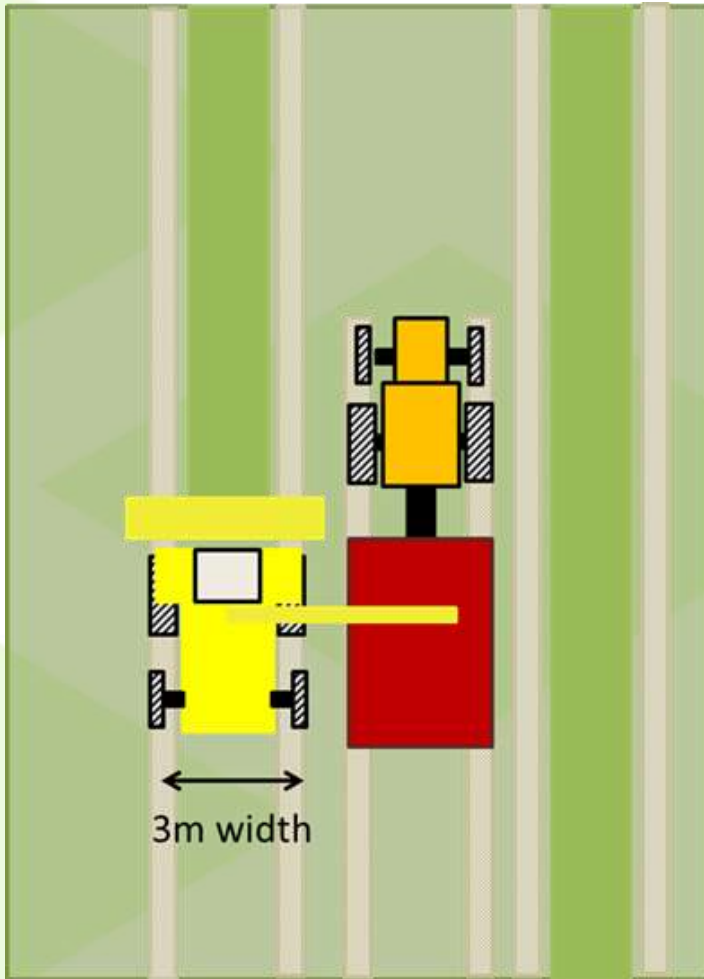
# Experimental Work



- An 8 ha perennial ryegrass field at SW Scotland split into two
- Two traffic management treatments: normal (N) and CTF
- 3-cut silage system
- 9 m triple gang mower (9 m working width)



# Controlled Traffic Farming – Working widths





# Results of Experimental Work



Measurement	Normal Traffic	Controlled Traffic
Bulk Density (g cm <sup>3</sup> )	1.02	0.99
VESS	1.93	1.84
pH	6.5	6.4
P (Index)	2	2
K (index)	2-	2-

Silage Cut	Normal Traffic	Controlled Traffic	Difference (t DM ha <sup>-1</sup> )	P-value
1 <sup>st</sup> Cut (t DM ha <sup>-1</sup> )	5.28	5.43	0.15	0.27
2 <sup>nd</sup> Cut (t DM ha <sup>-1</sup> )	3.58	3.88	0.30	0.72
3 <sup>rd</sup> Cut (t DM ha <sup>-1</sup> )	2.34	2.84	0.50	<0.01
2 <sup>nd</sup> + 3 <sup>rd</sup> Cut	5.92	6.72	0.80	<0.05
Total silage	11.29	12.15	0.96	



# Soil health: organic matter



- Soil organic matter increases soil stability, drainage (reduces run-off), fertility and encourages biodiversity
- Organic matter is lost from a field as a result of continued cultivation when stubbles are not ploughed back into the soil or when organic manures are not returned
- Intensive tillage during potato cultivation increases the susceptibility of soils to organic matter loss and compaction
- Scottish agricultural soils have typical organic matter contents of 5 to 10%





# Soil health: earthworms

Earthworms burrow through soil and feed on organic matter, improving the movement of air, water and nutrients through the soil



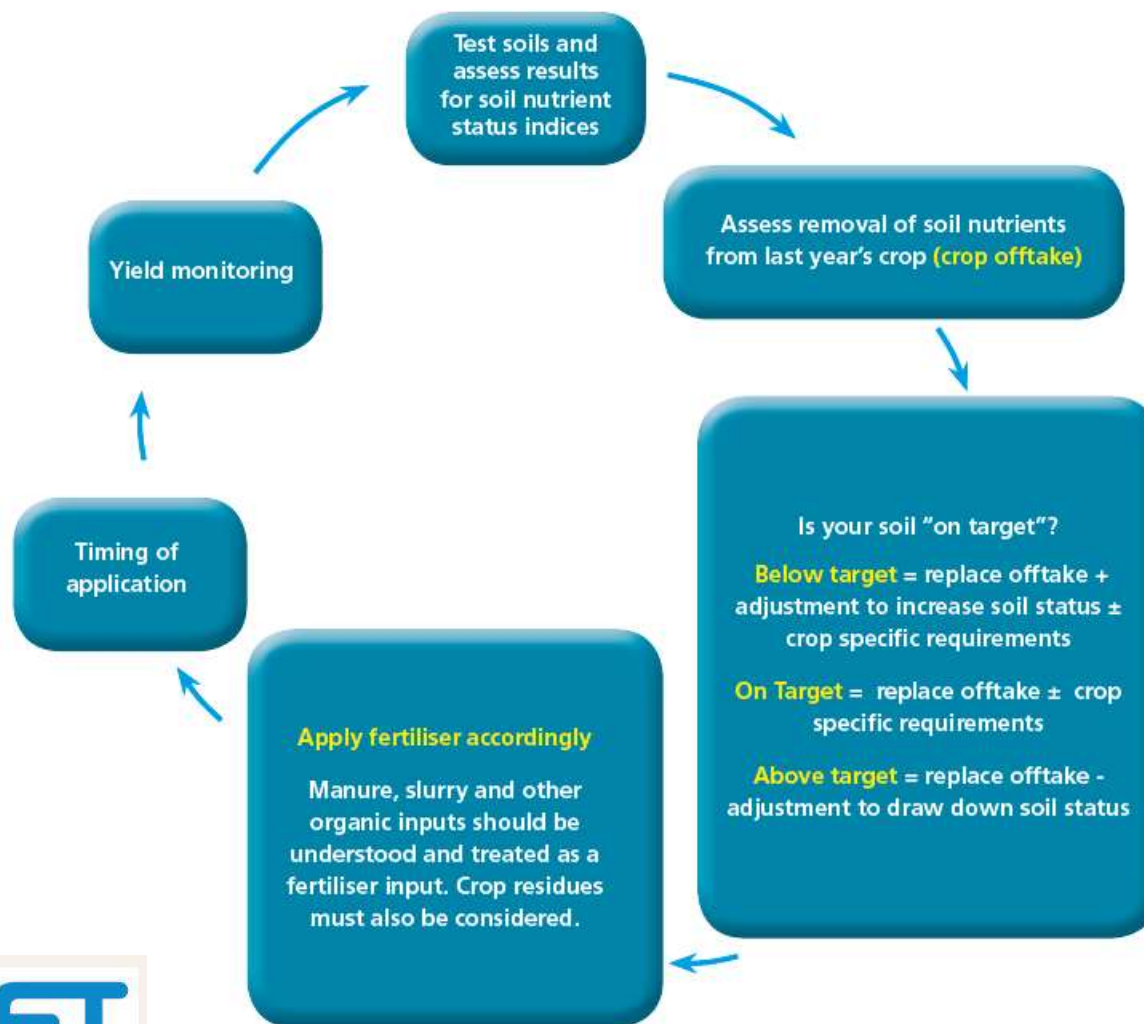
A healthy soil would normally have 5-10 earthworms in a 10 cm thick slice of soil to spade depth

Feeding the 'underground livestock' is essential for productive land with healthy soil. The soil food web is part of energy, nutrient and water cycles



# Nutrient Budgets

Key steps in an effective nutrient budget

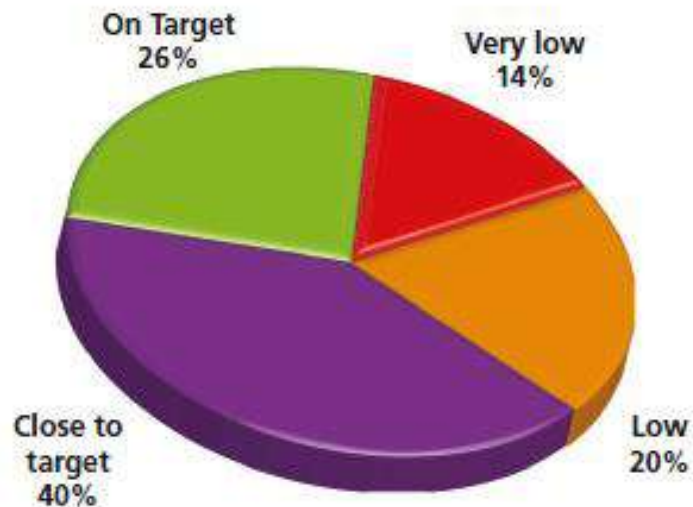




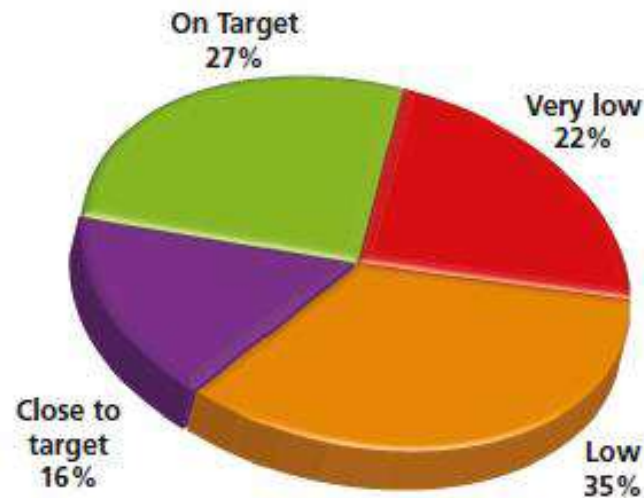
# Assessments of Scottish agricultural soil pH



Arable soil pH



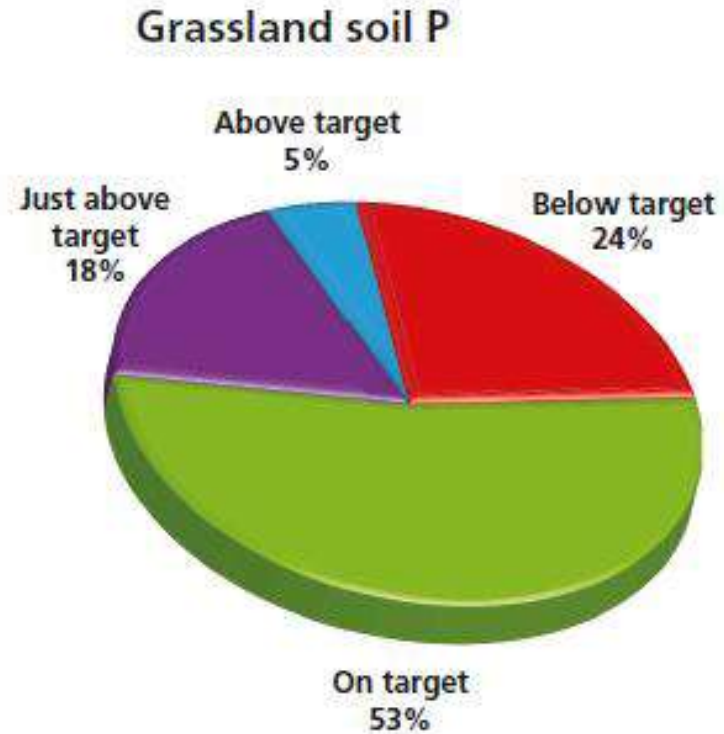
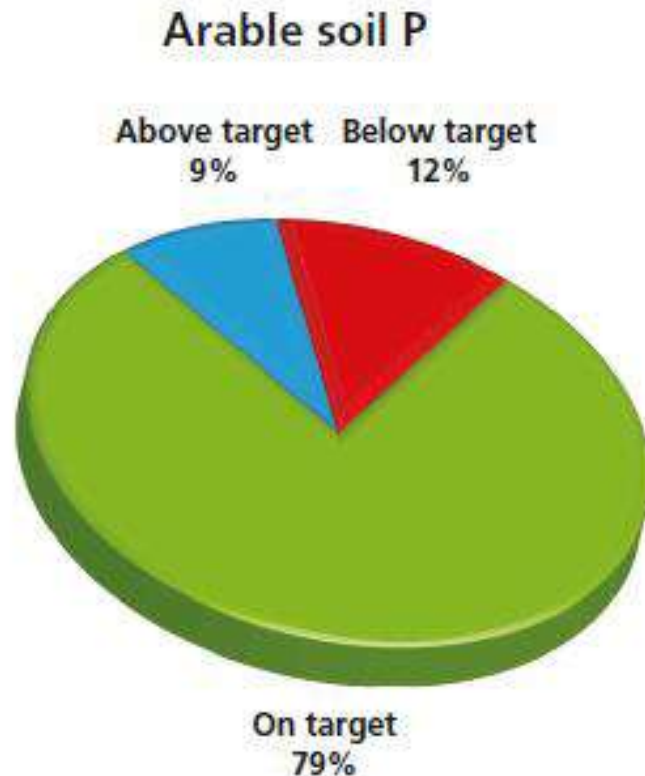
Grassland soil pH



- Consequence – the majority of soils are being managed below optimal pH status.
- Applied fertilisers are being used less efficiently causing reduced crop production and a potential risk to the environment.



# Assessments of Scottish Arable Soil P



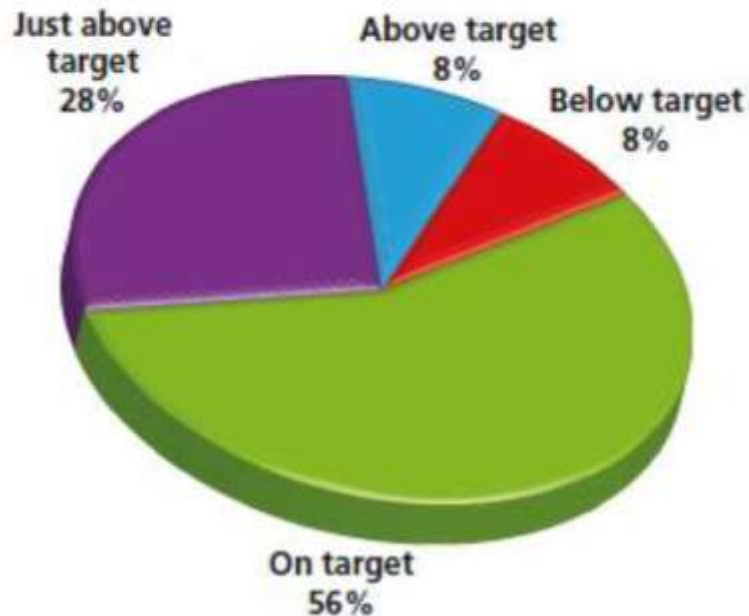
Arable soil P levels required maintenance rather than any increase or decrease, to maintain economic and environmentally sustainable status, so future P inputs are balanced to annual crop off-take

Consequence – at or above target could save around £12/ha by making better use of soil P reserves

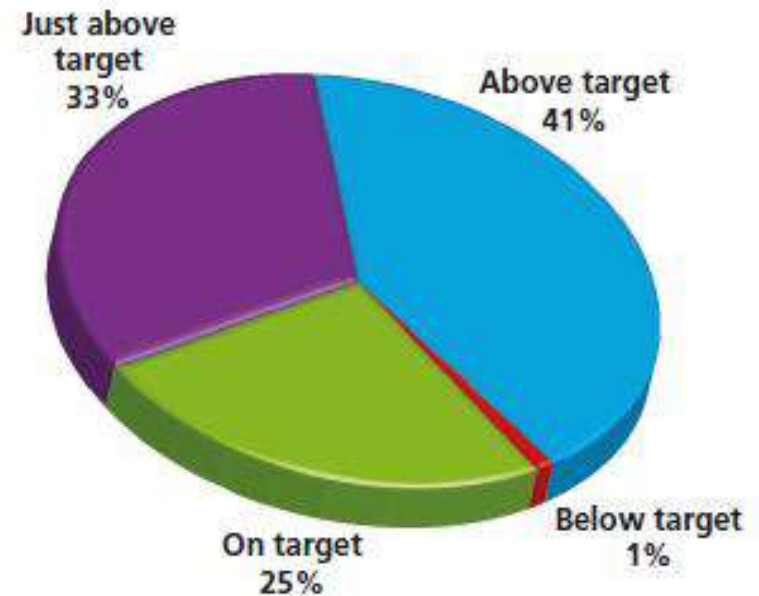


# Assessments of Scottish Arable Soil K

Arable soil K



Grassland soil K

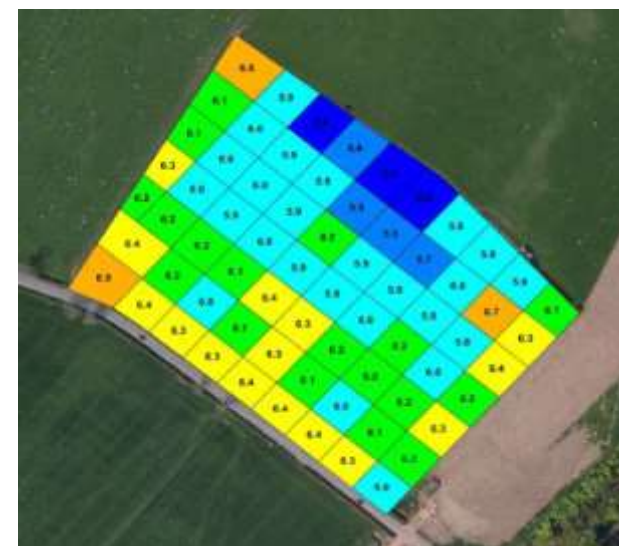
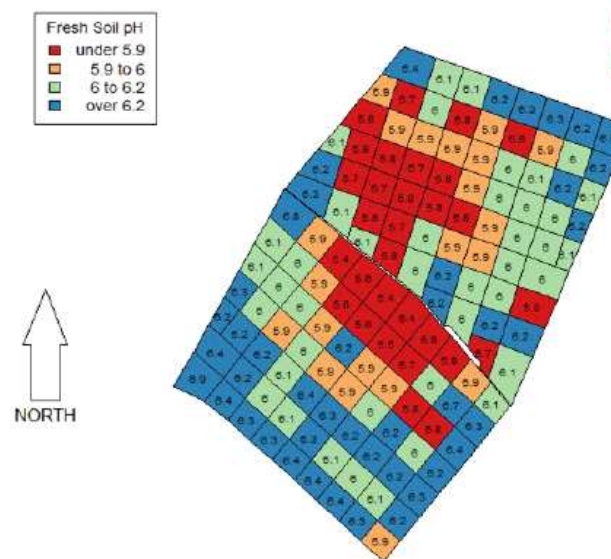


Consequence – farmers that are at or above target could save around £43/ha by making better use of soil K reserves



# Soil testing - nutrient management

- Soils must be maintained at a suitable pH with adequate soil nutrients to provide fertility for growing crops
- Soil testing is an essential nutrient management tool that allows you to assess fertiliser requirements for optimal crop growth
- Where fertilisers supplement the natural fertility of the soil, it requires testing every 4-5 years (pH and extractable P, K, Mg) to be effective and efficient
- GPS sampling for soil pH and variable lime application can be an effective cost and carbon footprint reducing option





# Conclusions

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- Know your soil
- Compaction caused a loss of yield
- Visual Assessment helps with management
- Controlled traffic maintained yield in grassland
- Soil alleviation did increase yield
- WFPS effected by soil alleviation
- Natural recovery gave an indication of improvement
- Soil quality is important
- Maintain and manage nutrients



# Thank you



**Scottish Government**  
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