Soil Health/Soil quality – what is it and how do we measure it?

Bryan Griffiths

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1

What is a healthy soil?

Looks good
Feels good
Smells good

Easy to work
Supports lot of life

What is soil?

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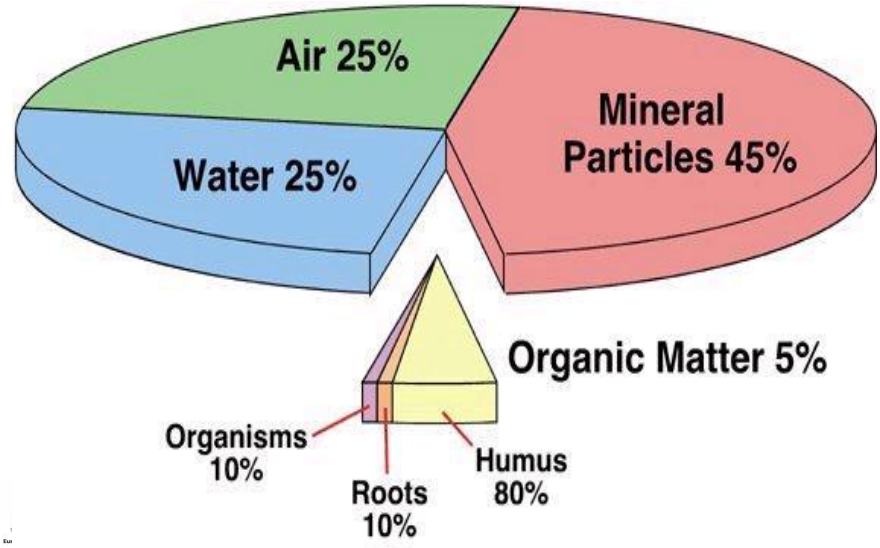


Living soils

- Huge quantity of organisms
  - Fauna: 1-5 T/ha
  - Fungi: 3.5 T/ha
  - Bacteria: 1.5 T/ha


F. Ippolito

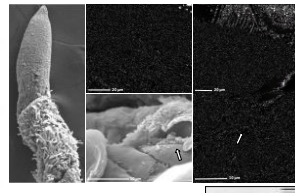
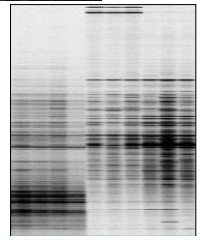
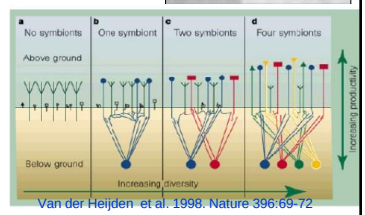


Photo : L. Avoscan & A. Viollet

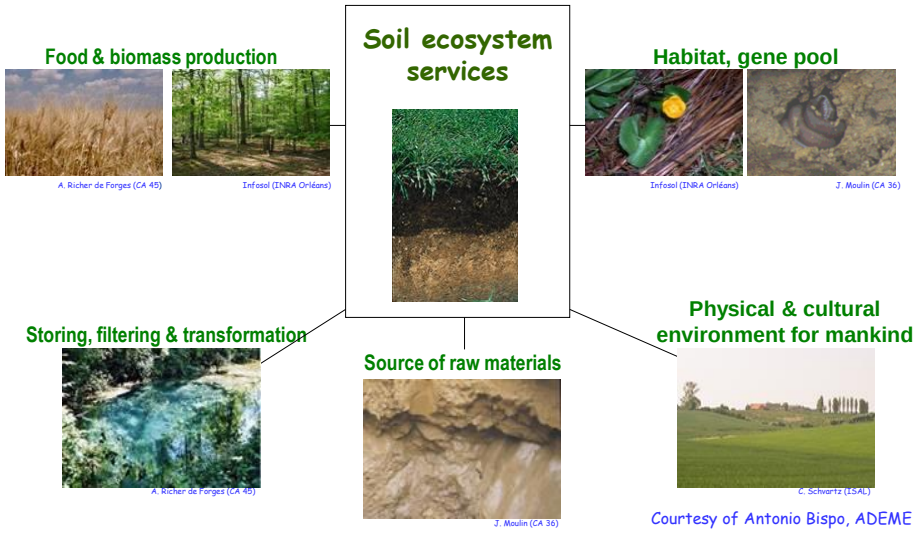


- Fantastic diversity
  - Until recently: only access to culturable microorganisms
  - Methodological progresses
    - ⇨possibility to extract DNA from soils
      - ↳ 10^4 – 10^6 bacterial genotypes / g sol
- A lot to be explored on the relations between below & aboveground diversity



Van der Heijden et al. 1998. Nature 396:69-72

Soils deliver many ecosystem services



Courtesy of Antonio Bispo, ADEME

Ecosystem services

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- Supporting — Nutrient recycling, primary production and soil formation, make it possible for the ecosystems to provide other services
- Provisioning — Food, crops, raw materials (including timber, fodder, and fertilizer), genetic resources (including crop improvement genes), water
- Regulation — Carbon sequestration and climate regulation, waste decomposition, purification of water, pest and disease control
- Cultural — Spiritual, historical, recreational

Europe investing in rural areas

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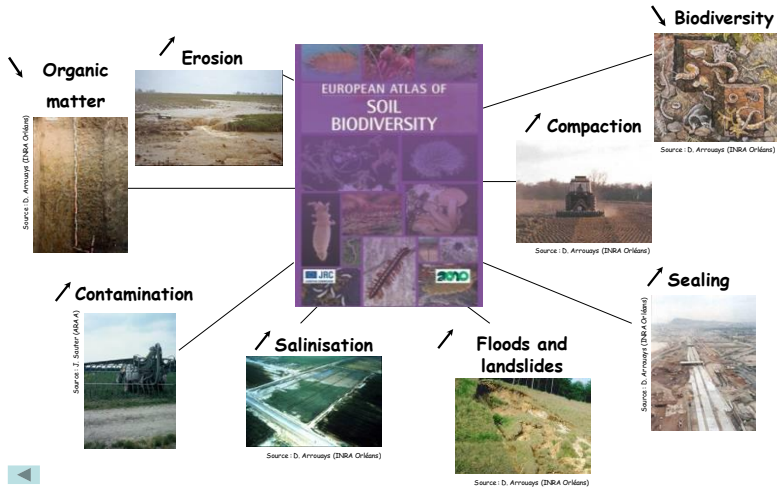
Soils and biodiversity are submitted to major threats



- **Erosion:** 115 million hectares subject to water erosion, 42 million hectares to wind erosion.
- **Contamination**: 3.5 million sites could be contaminated
- **Decrease of organic matter:** About 45% of European soils have low organic matter content
- **Soil sealing:** 1990-2000: 1,000 km² of soil/year , 2000-2006, the average loss increased by 3%

http://ec.europa.eu/environment/soil/

So why is this important

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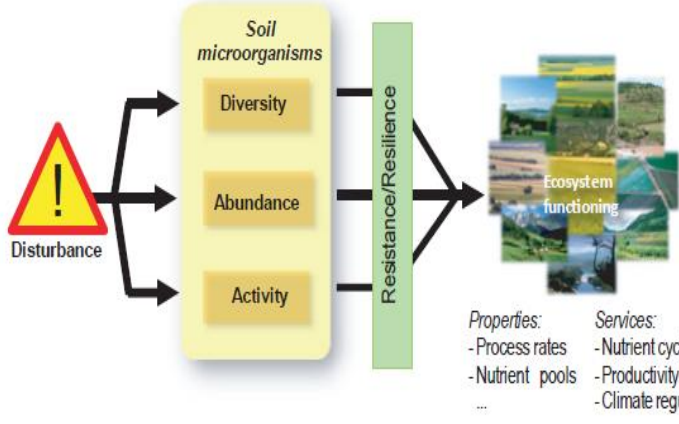

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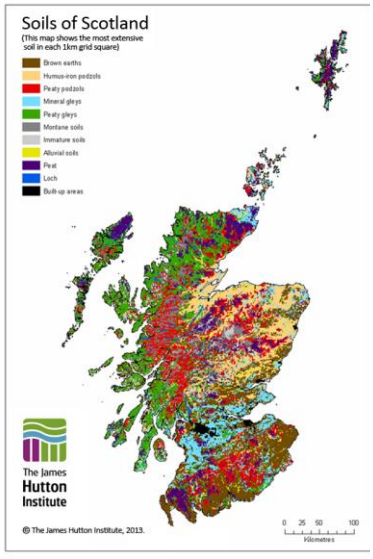
Why measure soil quality?

- Think of it in terms of:
- An MOT for your soil Or A check up at the doctors

Scottish soils – information available



http://www.soils-scotland.gov.uk/

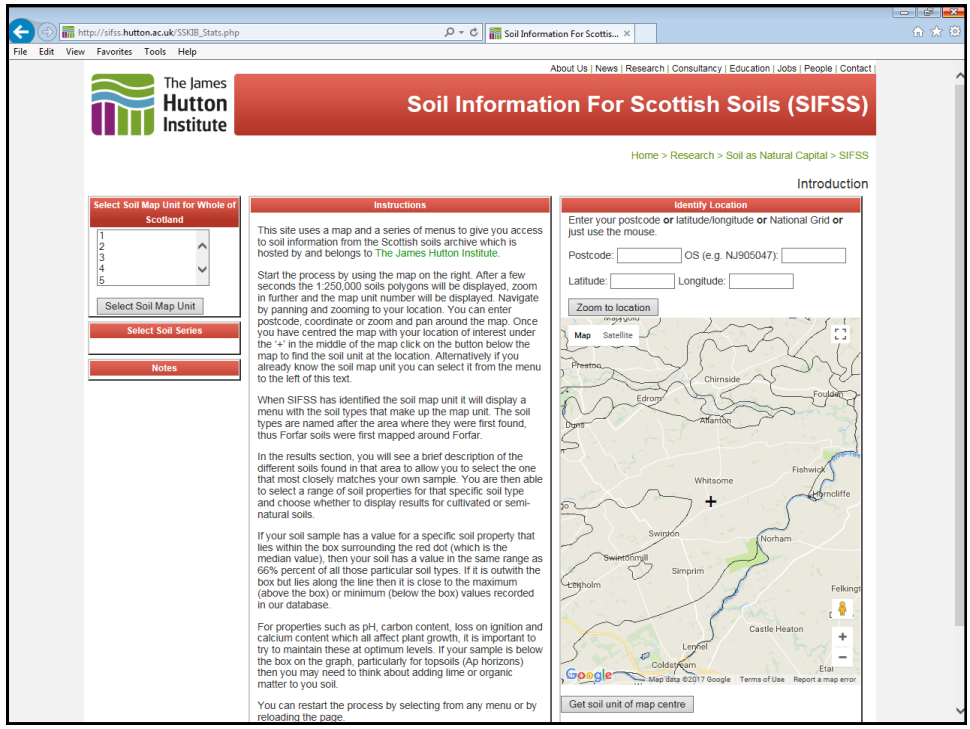
https://horticulture.ahdb.org.uk/greatsoils-resourcesmaterials

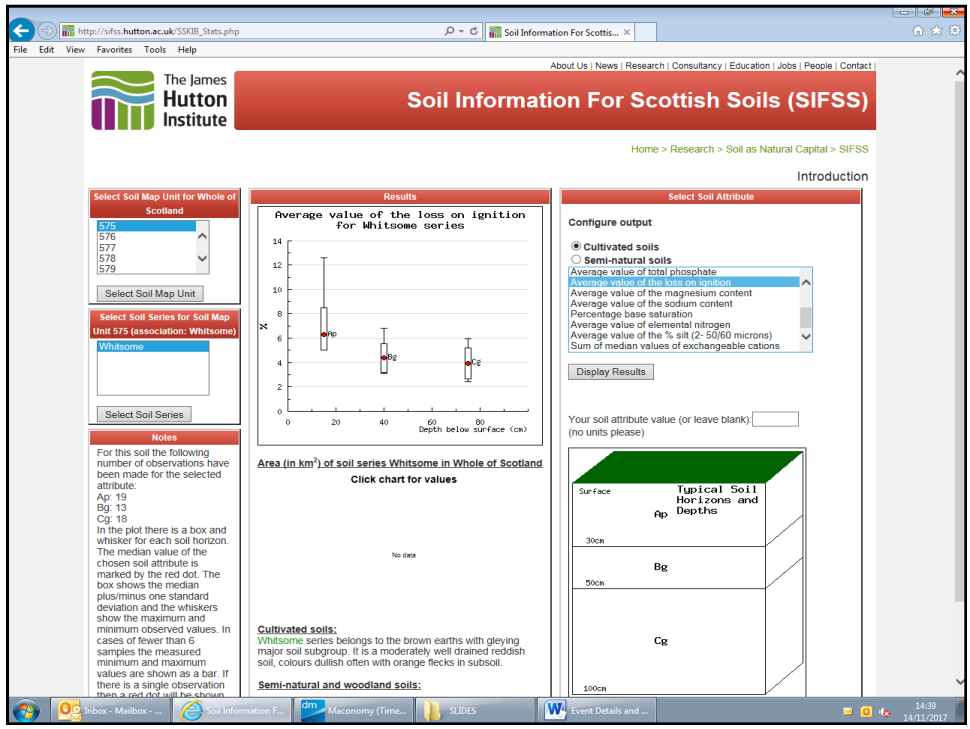
http://www.crew.ac.uk/publication/valuing-your-soils

https://dairy.ahdb.org.uk/resources-library/technical-information/grass-management/healthy-grassland-soils-pocketbook/#.WeSwYv6WymQ

https://www.opalexplorenature.org/earthwormguide

https://www.sruc.ac.uk/info/120625/visual_evaluation_of_soil_structure


http://sifss.hutton.ac.uk/SSKIB_Stats.php
Soil Information For Scottis...
File Edit View Favorites Tools Help
About Us | News | Research | Consultancy | Education | Jobs | People | Contact
The James Hutton Institute
Soil Information For Scottish Soils (SIFSS)
Home > Research > Soil as Natural Capital > SIFSS
Introduction
Select Soil Map Unit for Whole of Scotland
1
2
3
4
5
Select Soil Map Unit
Select Soil Series
Notes
Instructions
This site uses a map and a series of menus to give you access to soil information from the Scottish soils archive which is hosted by and belongs to The James Hutton Institute.
Start the process by using the map on the right. After a few seconds the 1:250,000 soils polygons will be displayed, zoom in further and the map unit number will be displayed. Navigate by panning and zooming to your location. You can enter postcode, coordinate or zoom and pan around the map. Once you have centred the map with your location of interest under the '+' in the middle of the map click on the button below the map to find the soil unit at the location. Alternatively if you already know the soil map unit you can select it from the menu to the left of this text.
When SIFSS has identified the soil map unit it will display a menu with the soil types that make up the map unit. The soil types are named after the area where they were first found, thus Forfar soils were first mapped around Forfar.
In the results section, you will see a brief description of the different soils found in that area to allow you to select the one that most closely matches your own sample. You are then able to select a range of soil properties for that specific soil type and choose whether to display results for cultivated or semi-natural soils.
If your soil sample has a value for a specific soil property that lies within the box surrounding the red dot (which is the median value), then your soil has a value in the same range as 66% percent of all those particular soil types. If it is outwith the box but lies along the line then it is close to the maximum (above the box) or minimum (below the box) values recorded in our database.
For properties such as pH, carbon content, loss on ignition and calcium content which all affect plant growth, it is important to try to maintain these at optimum levels. If your sample is below the box on the graph, particularly for topsoils (Ap horizons) then you may need to think about adding lime or organic matter to you soil.
You can restart the process by selecting from any menu or by reloading the page.
Identify Location
Enter your postcode or latitude/longitude or National Grid or just use the mouse.
Postcode: OS (e.g. NJ905047):
Latitude: Longitude:
Zoom to location
Map Satellite
Preston
Chirnside
Edrom
Foulden
Allanton
Duns
Whitsome
Fishwick
Hornchiffe
Swinton
Norham
Swintonmill
Simprim
Lennel
Castle Heaton
Coldstream
Google
Map data ©2017 Google Terms of Use Report a map error
Get soil unit of map centre


http://sifss.hutton.ac.uk/SSKIB_Stats.php
Soil Information For Scottis...
File Edit View Favorites Tools Help
About Us | News | Research | Consultancy | Education | Jobs | People | Contact
The James Hutton Institute
Soil Information For Scottish Soils (SIFSS)
Home > Research > Soil as Natural Capital > SIFSS
Introduction
Select Soil Map Unit for Whole of Scotland
575
576
577
578
579
Select Soil Map Unit
Select Soil Series for Soil Map Unit 575 (association: Whitsome)
Whitsome
Select Soil Series
Notes
For this soil the following number of observations have been made for the selected attribute:
Ap: 19
Bg: 13
Cg: 18
In the plot there is a box and whisker for each soil horizon. The median value of the chosen soil attribute is marked by the red dot. The box shows the median plus/minus one standard deviation and the whiskers show the maximum and minimum observed values. In cases of fewer than 6 samples the measured minimum and maximum values are shown as a bar. If there is a single observation then a red dot will be shown
Results
Average value of the loss on ignition for Whitsome series
X
Ap
Bg
Cg
Depth below surface (cm)
Area (in km²) of soil series Whitsome in Whole of Scotland
Click chart for values
No data
Cultivated soils:
Whitsome series belongs to the brown earths with gleying major soil subgroup. It is a moderately well drained reddish soil, colours dullish often with orange flecks in subsoil.
Semi-natural and woodland soils:
Select Soil Attribute
Configure output
Cultivated soils
Semi-natural soils
Average value of total phosphate
Average value of the loss on ignition
Average value of the magnesium content
Average value of the sodium content
Percentage base saturation
Average value of elemental nitrogen
Average value of the % silt (2-50/60 microns)
Sum of median values of exchangeable cations
Display Results
Your soil attribute value (or leave blank):
(no units please)
Typical Soil Horizons and Depths
Surface
Ap
30cm
Bg
50cm
Cg
100cm

Examples of information

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The benefits of improving soil quality…

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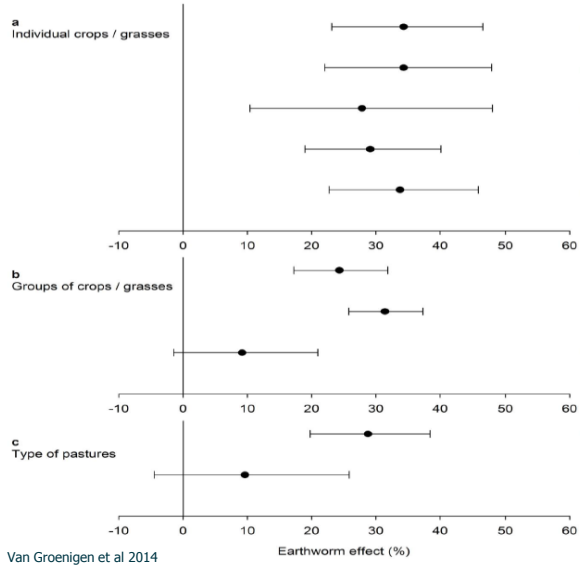
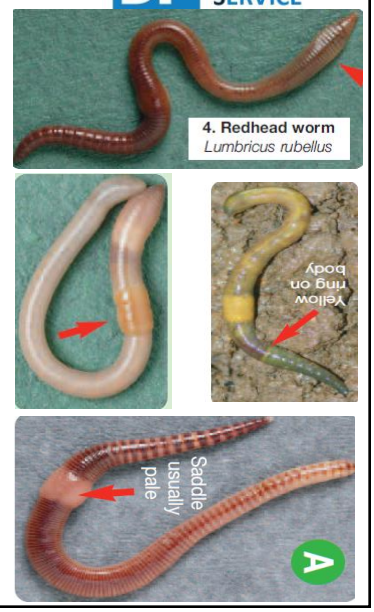
Positive effects of earthworms on yield



Van Groenigen et al 2014

Earthworm types

- Red worms – vertical burrowers and surface living
- Pale (+green) worms – soil feeding
- Stripy worms – compost worms



One Spade of Soil

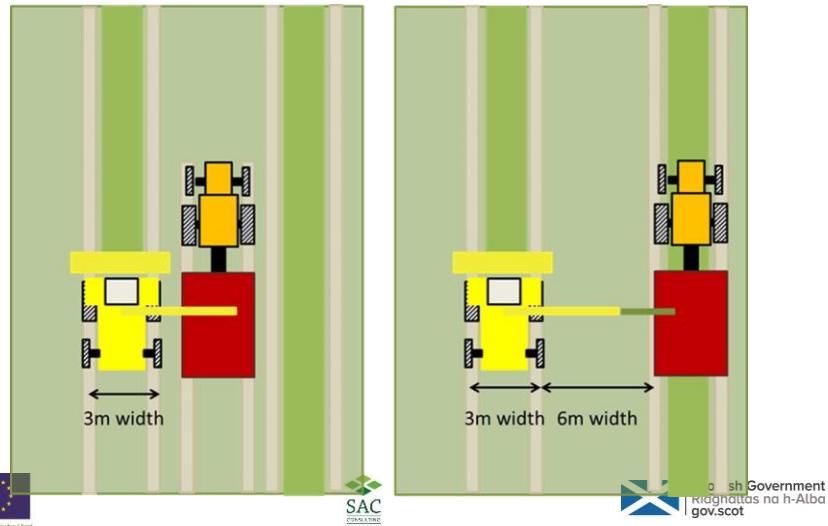
Potential for Controlled Traffic Farming (CTF) in Grassland

Paul Hargreaves
(SRUC Crichton Dairy Centre)

Experimental Work

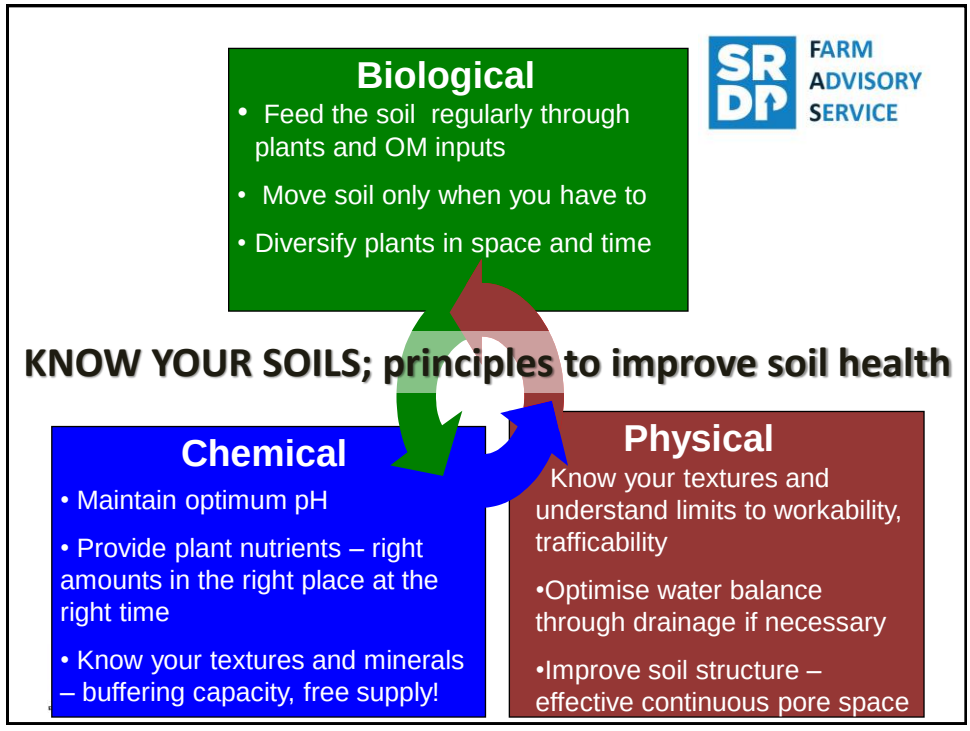
- An 8 ha perennial ryegrass field at SW Scotland split into two
- Two traffic management treatments: normal (N) and CTF
- 3-cut silage system
- 9 m triple gang mower (9 m working width)

Controlled Traffic Farming – Working widths



Results of Experimental Work

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



Developments in measuring soil quality

- More background information – AHDB

AHDB

GREATSOILS

- Thresholds and database – BBSRC-SARIC
- Putting it together – RESAS

The Scottish Government

SARIC: SUSTAINABLE AGRICULTURE RESEARCH & INNOVATION CLUB

Europe investing in rural areas

SAC

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Why measure soil quality?

- Think of it in terms of:

- An MOT for your soil Or A check up at the doctors
- Working towards
  (i) rolling out soil quality testing
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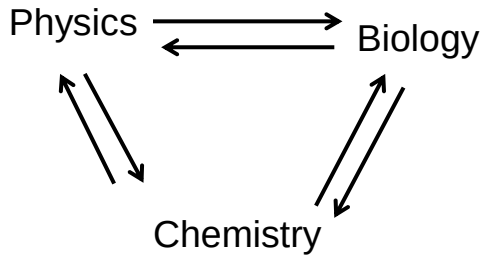
First questions

- What is the state of my soil?
- Depends on
  - Soil type
  - What you do with it
- How do I tell?
  - Need indicators as can't measure everything

Components of soil quality



Current soil reports
pH
Routine nutrients

Components of soil quality

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Physics ⇄ Biology

Chemistry

Current soil reports
pH
Routine nutrients

Putting it all together will need a different approach to sample collection – linking physical observation and soil samples sent for testing

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Rolling out soil quality testing Scorecard threshold values

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Based on proposals for soilquality.org.uk (based on the Australian model - http://www.soilquality.org.au/) to enable utilisation of a wider database for benchmarking and ultimately advice.

The traffic light sytem represents:

RED (High risk, need to investigate urgently)
AMBER (Moderate risk, need to investigate further)
GREEN (Low risk, continue to monitor)

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Potential scorecard...

ACME SOIL ANALYSIS COMPANY

Report for Mr A. Farmer
(who has a grassland field that needs some lime, has had a fair bit of P added and is compacted)

pH	
P	
K	
Mg	
Potentially Mineralisable Nitrogen	
Loss on Ignition	
VESS	
Earthworms	
DNA measures	

Would be followed with links to or hard copy of background information on the parameters measured, especiallyif red or amber.

Backed up by details...

Scotland – Extractable P (Modified Morgan's)

Bar chart classes	Traffic light colour	Description of this class (e.g. toxic)
0-1.7		VL – risk to production
1.8-4.4		L – potential risk to production
4.5-9.4		M-
9.5-13.4		M+
13.5-30.0		H – potential risk to environment
> 30.0		VH – risk to environment

Links to information sheets, websites, apps.

Hardcopy options

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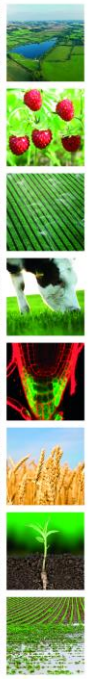

Making more of the results

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soilquality.org.uk

Potential for benchmarking

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- As in the current SRUC ‘agricalc’ where you can see your carbon footprint in relation to others
- You will be able to see how your soils perform against comparable soils and over time
- Benchmarking will improve the more data is entered

The European Agricultural Fund for Rural Development: Europe investing in rural areas

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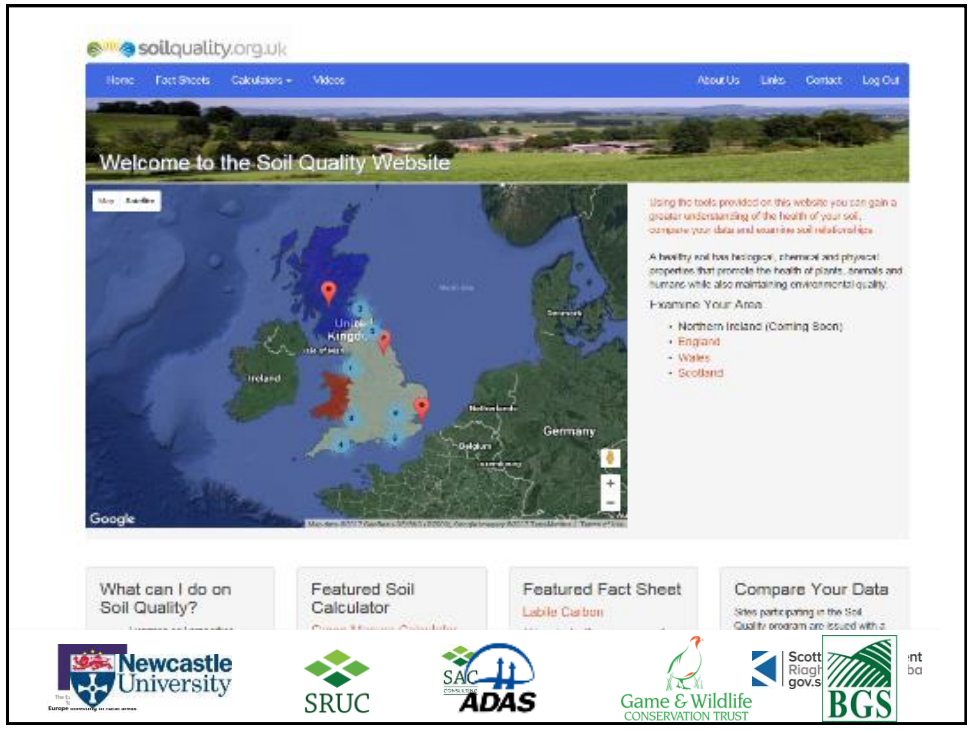
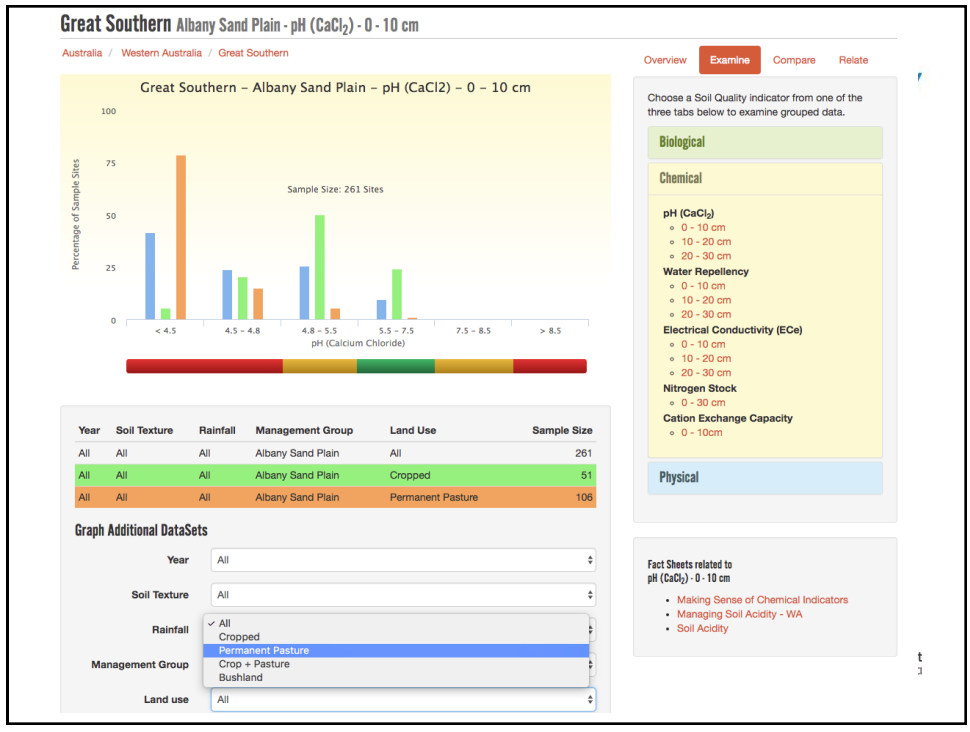
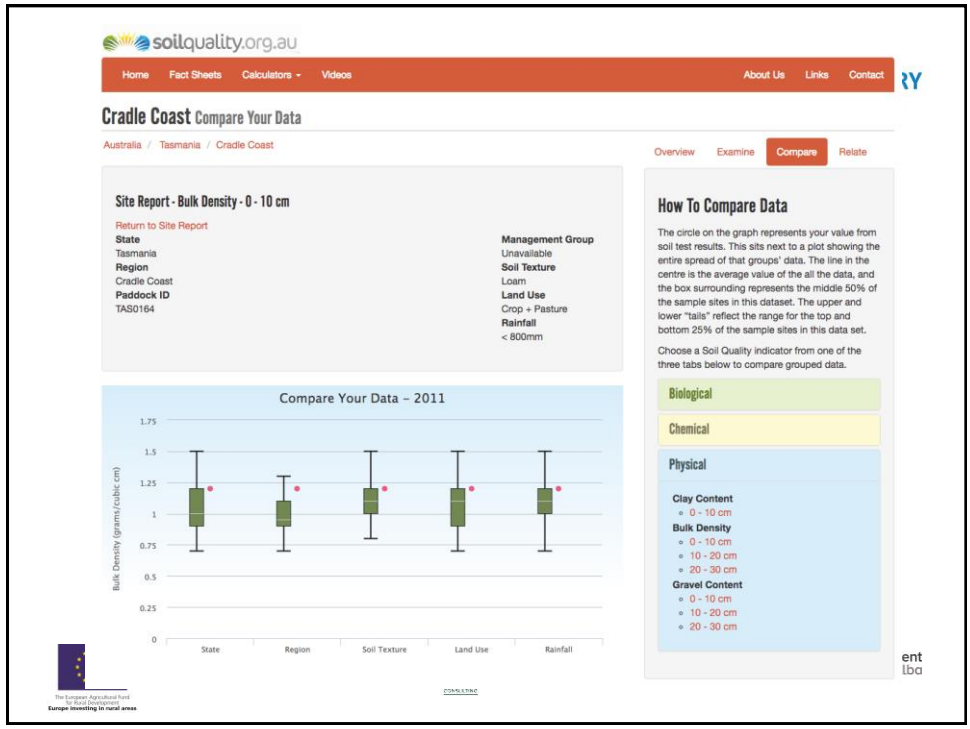

soilquality.org.uk
Home
Fact Sheets
Calculators
Videos
About Us
Links
Contact
Log Out
Welcome to the Soil Quality Website
Using the tools provided on this website you can gain a greater understanding of the health of your soil, compare your data and examine soil relationships
A healthy soil has biological, chemical and physical properties that promote the health of plants, animals and humans while also maintaining environmental quality.
Examine Your Area
Northern Ireland (Coming Soon)
England
Wales
Scotland
Ireland
Germany
Google
What can I do on Soil Quality?
Featured Soil Calculator
Featured Fact Sheet
Labile Carbon
Compare Your Data
Newcastle University
SRUC
SAC
ADAS
Game & Wildlife
CONSERVATION TRUST
BGS


Great Southern Albany Sand Plain - pH (CaCl2) - 0 - 10 cm
Australia / Western Australia / Great Southern
Overview
Examine
Compare
Relate
Great Southern – Albany Sand Plain – pH (CaCl2) – 0 – 10 cm
Percentage of Sample Sites
100
75
50
25
0
Sample Size: 261 Sites
< 4.5
4.5 – 4.8
4.8 – 5.5
5.5 – 7.5
7.5 – 8.5
> 8.5
pH (Calcium Chloride)
Year
Soil Texture
Rainfall
Management Group
Land Use
Sample Size
All
All
All
Albany Sand Plain
All
261
All
All
All
Albany Sand Plain
Cropped
51
All
All
All
Albany Sand Plain
Permanent Pasture
106
Graph Additional DataSets
Year
All
Soil Texture
All
Rainfall
All
Cropped
Permanent Pasture
Crop + Pasture
Bushland
Management Group
Land use
All
Choose a Soil Quality indicator from one of the three tabs below to examine grouped data.
Biological
Chemical
pH (CaCl2)
0 - 10 cm
10 - 20 cm
20 - 30 cm
Water Repellency
0 - 10 cm
10 - 20 cm
20 - 30 cm
Electrical Conductivity (ECe)
0 - 10 cm
10 - 20 cm
20 - 30 cm
Nitrogen Stock
0 - 30 cm
Cation Exchange Capacity
0 - 10cm
Physical
Fact Sheets related to pH (CaCl2) - 0 - 10 cm
Making Sense of Chemical Indicators
Managing Soil Acidity - WA
Soil Acidity



Questions

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- Would that be useful?
- Would the ability to relate values regionally and/or over time be useful?

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Why measure soil quality?

- Think of it in terms of:

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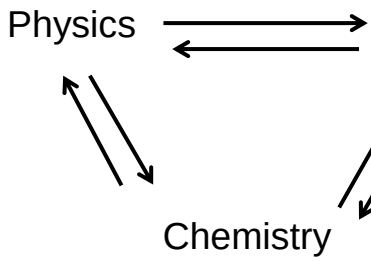
- Working towards
  (i) rolling out soil quality testing
  (ii) 'what if' model for knowledge exchange

'what if' model for knowledge exchange

- To get across the interactions that go towards soil quality
- To present some basic scenarios for management change
- Lead you to other sources of information

Interactions within soil quality



No perfect solution
Just different solutions
With varying outcomes

Too much
Loss of £
Pollution

Just right
Good for £

Too little
Loss of £

'Goldilocks' scenario

Background information – effects of general management options

DRIVER				Reduced Tillage
EFFECTS	Biology	+ve	Earthworms	+
			Microbial biomass	+
			Enzyme activity	+
			Biodiversity	+
			Natural enemies	+
		-ve	Slugs	+
			Weeds	+
			Diseases	+
	Chemistry	+ve	Soil Organic Matter	+
		-ve	Nutrient Loss	-
			Herbicide Use	+
			Pesticide Loss	
			Nutrient Immobilisation	
	Physics		Soil Structure	+/-
			Trafficiability	+
			Water infiltration	+
	Margin		Yield	-
			Short Term	-
			Long Term	+

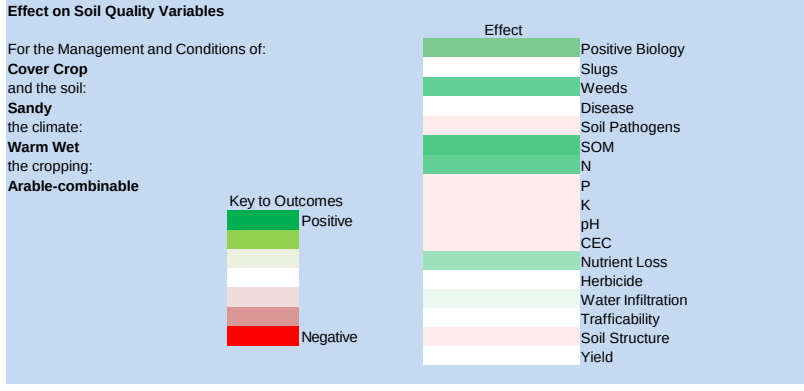
Similar tables for:
No-till
Cover crops
High N amendment
High C amendment

Knowledge introduction – visual tool

- Rationale was to visualise those complex interactions
- To give rapid overview of the general responses to expect

Knowledge introduction – visual tool

I'd like to know about the effects of changing management to.....



Question

- Would that be useful as a way to think about soil quality?

Thank You

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.

AARHUS UNIVERSITET · UEM · SRUC

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.

Bruce Ball, SRUC (bruce.ball@sruc.ac.uk),
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Tom Batey, Independent Consultant (2033@tombatey.f2s.com) and
Lars Munkholm, University of Aarhus, Denmark (Lars.Munkholm@agrsci.dk)

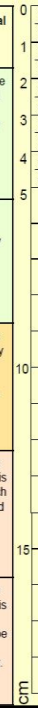
Method of assessment:

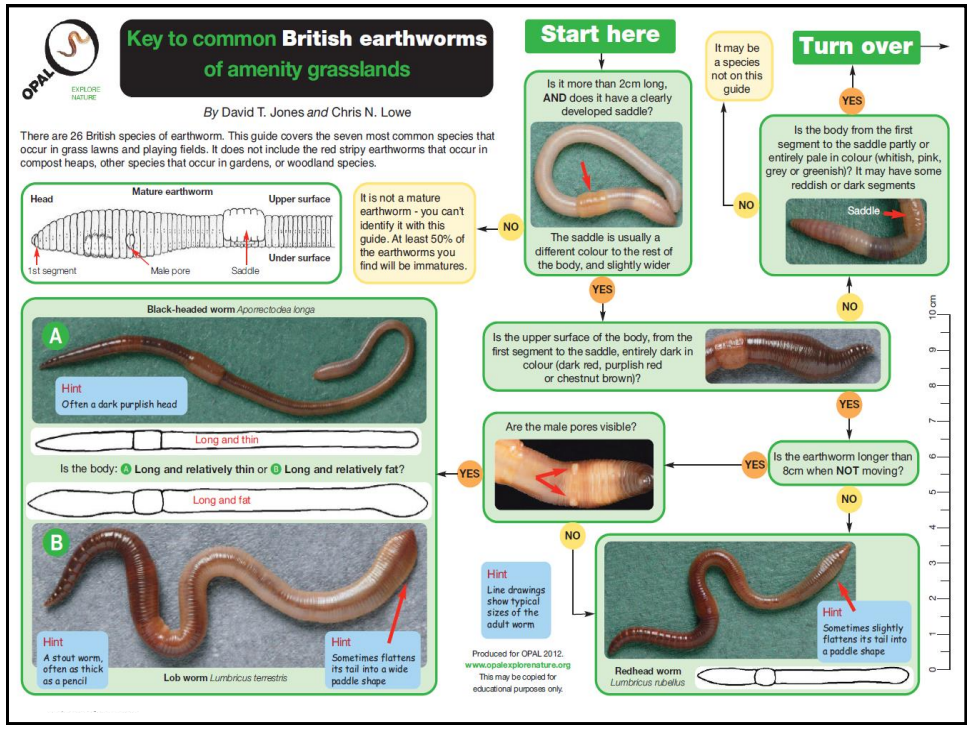
Step	Option	Procedure
Block extraction and examination		
1. Extract soil block	Loose soil	Remove a block of soil ~15 cm thick directly to the full depth of the spade and place spade plus soil onto the sheet, tray or the ground
	Firm soil	Dig out a hole slightly wider and deeper than the spade leaving 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.

16 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.




Key to common British earthworms of amenity grasslands
By David T. Jones and Chris N. Lowe
There are 26 British species of earthworm. This guide covers the seven most common species that occur in grass lawns and playing fields. It does not include the red stripy earthworms that occur in compost heaps, other species that occur in gardens, or woodland species.
Start here
Is it more than 2cm long, AND does it have a clearly developed saddle?
The saddle is usually a different colour to the rest of the body, and slightly wider
NO
It is not a mature earthworm - you can't identify it with this guide. At least 50% of the earthworms you find will be immatures.
Mature earthworm
Head
Upper surface
1st segment
Male pore
Saddle
Under surface
YES
Is the upper surface of the body, from the first segment to the saddle, entirely dark in colour (dark red, purplish red or chestnut brown)?
NO
It may be a species not on this guide
Turn over
YES
Is the body from the first segment to the saddle partly or entirely pale in colour (whitish, pink, grey or greenish)? It may have some reddish or dark segments
Saddle
NO
Black-headed worm Aporrectodea longa
A
Hint
Often a dark purplish head
Long and thin
Is the body: A Long and relatively thin or B Long and relatively fat?
Long and fat
B
Hint
A stout worm, often as thick as a pencil
Lob worm Lumbricus terrestris
Hint
Sometimes flattens its tail into a wide paddle shape
YES
Are the male pores visible?
YES
Is the earthworm longer than 8cm when NOT moving?
YES
NO
NO
Hint
Line drawings show typical sizes of the adult worm
Hint
Sometimes slightly flattens its tail into a paddle shape
Redhead worm
Lumbricus rubellus
Produced for OPAL 2012.
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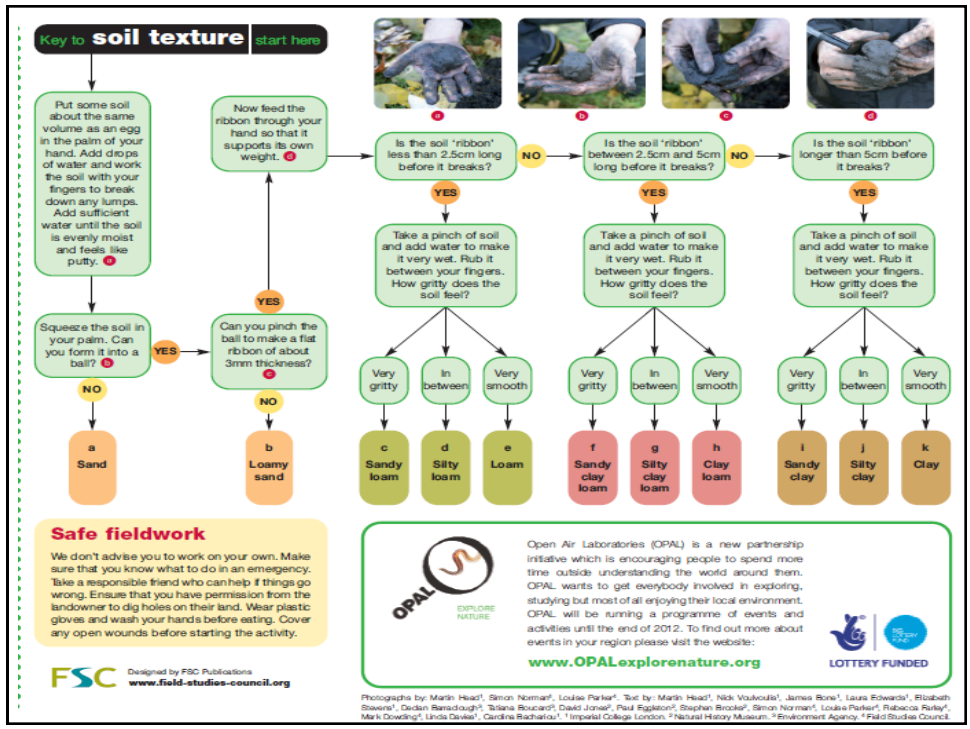
10cm
9
8
7
6
5
4
3
2
1
0


Key to soil texture start here
Put some soil about the same volume as an egg in the palm of your hand. Add drops of water and work the soil with your fingers to break down any lumps. Add sufficient water until the soil is evenly moist and feels like putty. e
Squeeze the soil in your palm. Can you form it into a ball? A
YES
NO
a Sand
Can you pinch the ball to make a flat ribbon of about 3mm thickness? c
YES
NO
b Loamy sand
Now feed the ribbon through your hand so that it supports its own weight. d
Is the soil 'ribbon' less than 2.5cm long before it breaks?
NO
YES
Take a pinch of soil and add water to make it very wet. Rub it between your fingers. How gritty does the soil feel?
Very gritty
In between
Very smooth
c Sandy loam
d Silty loam
e Loam
Is the soil 'ribbon' between 2.5cm and 5cm long before it breaks?
NO
YES
Take a pinch of soil and add water to make it very wet. Rub it between your fingers. How gritty does the soil feel?
Very gritty
In between
Very smooth
f Sandy clay loam
g Silty clay loam
h Clay loam
Is the soil 'ribbon' longer than 5cm before it breaks?
YES
Take a pinch of soil and add water to make it very wet. Rub it between your fingers. How gritty does the soil feel?
Very gritty
In between
Very smooth
i Sandy clay
j Silty clay
k Clay
Safe fieldwork
We don't advise you to work on your own. Make sure that you know what to do in an emergency. Take a responsible friend who can help if things go wrong. Ensure that you have permission from the landowner to dig holes on their land. Wear plastic gloves and wash your hands before eating. Cover any open wounds before starting the activity.
FSC
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OPAL
EXPLORE NATURE
Open Air Laboratories (OPAL) is a new partnership initiative which is encouraging people to spend more time outside understanding the world around them. OPAL wants to get everybody involved in exploring, studying but most of all enjoying their local environment. OPAL will be running a programme of events and activities until the end of 2012. To find out more about events in your region please visit the website:
www.OPALexplorenature.org
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Earthworm types

- Red worms – vertical burrowers and surface living
- Pale (+green) worms – soil feeding
- Stripy worms – compost worms