Module 3 Soil and water management

Soil Texture

Texture describes the physical composition of the soil
Note – 'composition' not 'condition' (structure)
Relative proportions of sand, silt and clay within a soil
Sand: 2 mm – 0.05 mm
Silt: 0.05 mm – 0.002 mm
Clay: <0.002 mm

Hand Texturing

- Primary Questions (is it sandy, silty, medium or heavy)
- Predominantly Rough and Gritty? • *sandy*
- Predominantly Smooth and Silky? • *Silt loam*
- Takes a polish, sticky when wet? • *No – medium* • *Yes - heavy*
- Secondary Questions (What's the texture category?)
- Does it Stain Fingers? Does it roll into a ball? Some Rough and Gritty? Some Smooth and Silky?

Why is texture important

Water Holding

- Texture determines the characteristics of a soil

e.g. soil pore space = the air and water holding capacity of a soil

- Sandy Soils have more macropores (>0.05 mm), usually *between* aggregates and free to drain under gravity
- Clay Soils have more micropores (<0.05mm), usually *within* aggregates that may require suction pressure to remove water

Texture determines soil water retention and hydraulic conductivity

Nutrient Holding   Cation (+) Exchange

- Clay particles have a negative surface charge
- Attract positively charged cations. Example K+, NH4+, Mg2+, H+
- CEC is total negative charge of soil. Its ability to bind or hold cations
- There is a constant interchange between cations in the soil (water) solution and those held by the soil particles
- Roots exude H+ which exchange with cations on the particles

Sandy Soils Coarse – rough granular particles 2.00 – 0.06mm – gives a gritty feel

Pros

- Free draining
- Easy workable
- Warm up quicker
- Good seed to soil contact

Cons

- Poor soil structure
- Leaching of nutrients
- Abrasive on machinery
- Run off
- Wind erosion
- Low organic matter
- Capping potential
- Dries out quicker in drought
- Low CEC

Management Consideration

- Less tillage
- Timing of drilling
- Organic manure applications
- Little and often nutrient
- No bare soil

Typical Cropping

- Potatoes
- Root crops
- Vegetables
- Short term crops

Silt Soils

Smooth – spherical particles – 0.06 – 0.002mm gives a smooth silky feel

Pros

- Hold moisture
- Fertile
- Light
- Well drained
- Good rooting

Cons

- Erosion wind and water
- Easy compaction
- Capping
- Slumping

Management Considerations

- Workability
- Leaving bare problem
- Rotation
- Drains and ditch maintenance
- Water table level

Typical Crops

- Brassicas
- Vegetable – Carrots
- Cut Flowers
- Wheat

Clay Soils

Flat – plate like particles < 0.002mm – gives a sticky feel

Pros

- Good water retention
- Low risk of erosion
- Nutrient retention
- More drought resistant
- Self-structuring

Cons

- Difficult to work
- Late drilling difficult
- Not free draining
- Black grass problem
- Picks up on machinery tyres
- Cold and wet
- Structure damage with compaction

Management Considerations

- May require drainage
- Timing for drilling and working
- Cultivation
- May require gypsum

Typical Cropping

- OSR
- Wheat
- Late drilled spring cereal

Organic Soils (> 20% organic matter)

Pros

- Good water & nutrient retention
- High N content
- Easy to cultivate
- Strong structures

Cons

- Prone to wind erosion
- Trace element deficiencies
- Weed problem
- Prone to shrinkage

Soil has 3 key properties

Physical

- Know soil texture and understand limits to workability and trafficability
- Optimise water balance through drainage (if necessary
- Minimise compaction and improve soil structure

Chemical

- Maintain optimum pH
- Apply nutrient in the right amount, at the right time
- Know soil textures and minerals (buffer capacity)

Biological

- Feed the soil regularly
- Move soil only when necessary
- Diversity plants in space and time

Soil Structure

- Compaction
- Panning
- Capping
- Slumping
- Poaching

Porosity and Bulk Density

- Porosity, gaps between the particles and aggregates
- Created by structural formation processes (shrink-swell etc.)
- Pore space affected by texture, OM, soil depth and management
- Pores characterised in terms of their size, shape and arrangement:
- Micropores <30µm (<0.03mm) – micro-organism habitat
- Mesopores 30-100µm (0.03-0.1mm) – air/water storage
- Macropores >100µm (>0.1mm) – rapid drainage
- Bulk Density is the weight of a soil in each volume, and relies on the porosity of a soil
- Greater bulk density can restrict root growth, limit aeration and reduce infiltration and water retention
- Low bulk density can reduce soil cohesion, and increase susceptibility to erosion

Soil Type	Ideal for Plant Growth (Kg/l)	Restrict Plant Growth (Kg/l)	Bulk Density Range
Sand	1.6	1.8	1.2-1.8
Silt	1.4	1.65	1.1-1.7
Clay	1.2	1.47	1.0-1.6

Gley Soils

Poorly drained soils – periodic or permanent waterlogging
The lack of oxygen in the soil pores leads to anaerobic conditions
Chemical reduction reduces Iron from Fe2O3+ to Fe2+ Insoluble Ferric Oxide to Soluble Ferrous Iron Grey/Blue colour of subsoil

Mottling

- In water- logged soils. Fe can be reduced to a soluble form and removed turning the soil grey.
- When a root or worm channel opens up and aerates the soil
- The reduced Fe oxides turning red in colour (like rust)

Good Soil Structure…

- Facilitates movement of Air and Water through soil
- Allows root growth and nutrient extraction
- Facilitates cultivations
- Provides a habitat for biodiversity
- Reduces risk of soil erosion

Structure Formation

Soil aggregates are formed from primary soil particles (sand, silt clay) bound to each other by:

- organic matter, root and microbial exudates, fungal hyphae, flocculating agents (e.g. gypsum)
- These form peds.
- In a disturbed/man-made system these as clods
- Soil with great structure can be broken down into smaller stable aggregates

Effect of Tillage on Structure

+ breaks up large clods
- increased aeration = increase decomposition = increased OM metabolism (structural consequences)
- Kills some of the micro, meso and macro fauna, or destroys habitats

Therefore, best management practice:

- Minimise tillage
- Till at right time, moisture and soil friability
- Increase OM = Incorporate OM residues, include rotations with grass, cover crops, green manures
- Gypsum ($CaSO_4$) can be used to help structures in sodic (Na) soils and high Mg soils

Degradation of soil structure

Major causes of soil physical degradation.

- Compaction
- Tillage – heavy machinery, over cropping, disturbance
- Declines in organic matter
- Silt and salt in irrigation water
- Erosion

Soil Management Plan- why?

- To prevent soil degradation
- To help create optimum conditions for plant growth = Soil Structure.
- To minimise risk of run-off and Erosion
- To protect long term productivity and Organic Matter.

Soil Management Plan - What documents useful

- Hand texture chart
- Recent soil analyses and rainfall data
- Current and previous cropping
- Livestock systems, slurry and manure storage
- Historic maps of drains, old field maps etc
- Maps showing sensitive sites – waterways, SSSIs etc

Preparing a Soil Management Plan

- **Field by field**, consider and list soil improving measures that are needed.
- **Short term** – eg corrective cultivations, subsoiling tramlines or headlands, cover cropping.
- **Longer term** – change to min-till, contour ploughing, crops e.g. arable to grass, wind breaks, housing stock, increasing grazed area.
- **Consider increasing OM** – e.g. straw, crops residues, manures. (Remember to allow for nutrients and follow NVZ timings.)
- **Field by field** (or part), identify how other aspects will be managed. Consider risks and issues as outlined in the XComp Guidance.
- **Consider risk of run-off and erosion** between current or intended rotation.
- **Map wind erosion risk areas**. Review simple measures such as wind breaks, timing of cultivations, use of cover crops, to help prevent this.
- **If needed, change rotation**, remove areas from production, buffer strips (add to farm map)
- **Consider new gateways**, shelter belts, roadways to reduce risk of erosion and to enhance the environment.
- **Protect water courses** from livestock eg fencing, bridges and alternative water.
- **Prepare field by field description** of specific management that will be required or must be avoided to minimise runoff and erosion whilst maintaining or improving soil conditions.
- **Record additional management operations** required to correct soil problems during the crop cycle.
- **Repeat soil risk assessment each year**, reviewing the impact of soil management observed during the year. Update and modify the plan.

Soil Management Plan – What to include

- Consideration of archaeology.
- Due consideration of relevant publications.
- Risk map of run-off and erosion, including roads, gateways and tracks.
- Assess each field (spade) for structural condition, problems and solutions.
- Consider if action needed to increase OM.
- Match land use to capability of the soil.
- Record for the following year, planned steps to control erosion, run-off, good soil structure and good infiltration of rain.
- During the year record problem such as ponding, poor growth.
- Review the plan annually to address problems.
- Collect background data.
- Prepare a risk map of the whole farm, showing risk of run- off and water erosion, based on soil texture, slope and field history.

- Changes in cropping should be considered, especially if high risk crops are involved.
- Which rules require farmers to have maps?
- Indicate on the map any flow pathways where water runs across the soil surface, including water coming from off farm.
- Include surface water features and likely risk of flood or overflow.

Soil risk assessment - observations

Signs of erosion that may be associated with each of the risk classes are described below. Such observations should override an assessment derived solely from the table.

- **Very High-Risk Areas** – Rills are likely to form in most years and gullies may develop in very wet periods.
- **High Risk Areas** – Rills are likely to develop in most seasons during wet periods.
- **Moderate Risk Areas** – Sediment may be seen running to roads, ditches or watercourses and rills may develop in some seasons during very wet periods.
- **Lower Risk Areas** – Sediment rarely seen to move but polluting runoff may enter ditches or watercourses.

Soil risk assessment – water erosion – inherent risks

NB NVZ slope
'Very Steep' – 12 degrees
'Low risk', below 3 degrees, mark green of no drains, >50m from water course

Soil Erosion Features

- Sheet Erosion
- Soil Wash
- Rills
- Gullies
- Deposition

Cation Exchange Capacity

- Degree of exchange depends on the bonding (adsorption)strength of a particular cation
- Monovalent cations (Na+, K+, H+) tend to be easily replaced by divalent cations (Mg2+, Ca2+); Ca2+ being the dominant cation;
- Potassium is preferentially adsorbed (non-exchangeable K+ is held between the clay lattices) over other cations

What does soil biota do?

Healthy soil biological systems is essential for soil function, particularly:

- Carbon Dynamics – decomposing plant residues
- Nutrient Cycling – decomposition, N-fixing, mycorrhizal associations

- Soil Structure Maintenance – aggregation, pore space, channels
- Pest Regulation – beneficial predators

Structural development Biological Process

- Roots, animals (burrowing) and micro-organisms
- Roots can hold soil together, create structure as they separate, compress and dry soil during growth
- Root channels allow infiltration, aeration and break up clods
- Decomposing roots form organic matter, and as binding agents
- The rhizosphere (root zone) is an important are to kick off biological food webs in the soil

The Water Environment (Water Framework Directive)

- Is the most substantial piece of EC water legislation to date.
- Requires all inland & coastal waters to reach "good status" by 2015 (and ongoing to 2027).
- In England and Wales, the **EA** is 'the responsible body'
- The Directive came into force in 2000 and became part of UK Law in December 2003.
- Covers *surface*, *ground* and estuarine water.
-

Through River Basin Management Plans and Programmes of Measures to:

- Enhance the status and prevent further deterioration of aquatic ecosystems and associated wetlands which depend on the aquatic ecosystems
- Promote the sustainable use of water
- Reduce pollution of water, especially by 'priority' and 'priority hazardous' substances
- Ensure progressive reduction of groundwater pollution

Water Framework Directive takes a 'River Basins Approach

- Each River Basin covers an entire catchment from source to estuary
- 110 identified in Europe
- Danube largest
- 11 River Basin Districts in the E & W

Surface waters

For surface waters there are two quality classifications for water bodies, ecological and chemical. To be in overall 'good' status both ecological and chemical status must be at least 'good'. Principle of one out, all out.

Ecological classification comprises:

condition of biological elements, e.g. fish
concentrations of supporting physio-chemical elements, e.g. oxygen or ammonia
concentrations of specific pollutants, e.g. copper.
and for high status, largely undisturbed hydro morphology
Ecological - Five levels - High, good, moderate, poor or bad. 'High' = largely undisturbed conditions.

Objectives of Water Framework Directive

- 'Successful implementation of the WFD will go a long way to protecting all elements of the water cycle and enhancing the quality of our groundwaters, rivers, lakes, estuaries and seas for now and for future generations.'

Water Protection Zones could be used to implement change

- The statutory instruments are already in place to implement Water Protection Zones.
- The EA could use WPZs to achieve the WFD objectives.
- WPZs provide the EA with additional powers to use positive and prohibitive measures
- So far only been imposed once.
- EA introduced a WPZ on the River Dee (Wales) in 1999.
- This controls point sources of industrial chemical pollution in the river.
- P options might include detailed NMPs, licences for septic tanks, high P requiring crops (potatoes?) cannot be farmed.
- Roads and industry equally targeted

Ground Water

- Once contaminated harder to clean than surface water consequences can last decades.
- Frequently used for the abstraction of drinking water, for industry and for agriculture, so pollution can endanger human health and threaten those activities.
- Provides the base flow for many rivers (up to 90% of the flow in some watercourses) and can thus affect the quality of surface water systems.
- Acts as a buffer through dry periods, essential for maintaining wetlands.
- For groundwater, good status has a quantitative and a chemical component.
- Quantity and over abstraction are important.
- Groundwater must not be polluted at all (WFD takes a precautionary approach).
- Pollution must be detected and measures taken to prevent it.
- Quality must not deteriorate.
-

Why not an ecological status for groundwater

Water Chemical Pollution

Most standards are set to support EU directives, such as:

- Groundwater Directive
- Dangerous Substances Directive
- Nitrates Directive
- Drinking Water Directive
- Many directives are coming under the WFD umbrella as 'dighter directives'

Example standards (Drinking water):

- Pesticide: max concentration = 0.1um/l or 0.1ppb
- Total Pesticide = 0.5um /l or 0.5ppb
- Nitrate: maximum concentration = 50mg/litre

Water Quality - Nutrient & Manure Management

- Nutrient and manure plans
- Utilisation of organic amendments
  - manure
  - sewage sludge
  - green waste
- Low emission spreading techniques

Sediment – why it matters

- Loss of soil
- Carries P
- Ecology
- Navigation
- Flood Risk
- Water Pollution
- Amenity

Phosphorus and silt summary

- Only small amount is found in soil solution.
- Most strongly bound to soil particles or organic matter.
- Gets into water primarily attached to soil and organic particles it becomes available for plant growth

Minimise risk of P losses to soil at several stages in the P cycle.

- Land Use
- Soil Management
- Livestock Management
- Fertiliser Management
- Manure Management
- Farm Infrastructure

Rural Sustainable Drainage Systems (Rural SUDS)

Landscape scale soft engineering:

– Small ponds to catch fast flow (could be grassed,CS)– Simple sediment traps
– Buffer strips
– In-ditch Wetlands ie widened vegetated areas
– In-ditch see page barriers
– Bunds

Nitrogen – the Challenge

- Agriculture's contribution to diffuse pollution is estimated to be:
- 60 per cent of nitrate emissions to water.
- 80 per cent of UK ammonia gaseous emissions; and
- 5-10 per cent of ammonium-N in water standard failures.

Failure points and solutions – FYM

- Excessive amounts of FYM and fertiliser
- Excessive amounts of FYM and fertiliser
- Insufficient allowance for nutrient value of FYM
- Livestock depositing manure directly into water

Rectify by

- Efficient diet formulation
- Manure storage
- Spreading eg rapid incorporation
- Correct application amount and accounting

Manure Management Plan

1. Produce a map showing the risk of spreading manure on the area of land
2. Identify areas where manure/slurry should never be spread – account for soil type, slope, proximity to watercourses, housing
3. Calculate the minimum area of land needed for spreading the manures
4. Identify the area of land needed for spreading sewage sludge or other organic waste.
5. Update the plan if the area of land changes.
6. Assess whether extra storage is needed for slurry and dirty water.
7. Update the plan if slurry or dirty water production increases.

Risk Assessments in NVZs Organic N

Produce a risk assessment and map to show suitable locations for spreading manures.
Manures must NOT be spread:

- Steep sloping land (>12degrees where there is a significant risk of causing water pollution
- Within 50m of a spring, well or borehole
- Within 10m of surface water or (dry ditches)

Risk Assessment map

- **RED: NO spreading: steep sloping land, within 50m of a spring, well or borehole, within 10m of surface water**
- **Orange: very high risk: fields next to a water course, spring or borehole at field capacity and a steep slope; fields likely to flood in the winter**
- Yellow: **high risk: moderate slope and well drained or slight slope with slowly permeable soil**
- Green: **low risk, tolerating year-round application**

Types of Pollution

Point-Source:

- Pollution from a single point, often the farmyard eg. spillage, leakage
- c.80% of all pesticide pollution is thought to be due to point- source pollution.
- Introduction of Control of Pollution Silage, Slurry and Fuel Oil Reg. 1991 led to point pollution from these sources falling from 3,000 to 1,000 incidents/year

Diffuse:

- Can arise from many sources eg. leaching, drain-flow, surface run- off, spray drift etc.
- Individual impact can be small but collective impact damaging

Key Diffuse Pollutants

POLLUTANT	IMPACT
Sediment (eg silt)	carry adsorbed pollutants eg pesticides
Phosphate	eutrophication
Toxic materials (eg pesticides)	danger to aquatic organisms and public health
Nitrate	eutrophication
Faecal Organisms	potential danger to public health
High BOD materials eg. milk, silage effluent, slurry	oxygen depletion

Most sediment entering catchments is from agriculture as is 40-50% of phosphate and about 70% nitrogen. 84% of SSSIs show signs of eutrophication.
Agricultural pollutant cleaning cost from drinking water is more than £250m/annum.
(Agriculture also contributes to air pollution through emissions of ammonia and the greenhouse gases methane and nitrous oxide.)

Diffuse Pollution
- Comes from many fields or sources in a catchment.
- Individually may be minor, but cumulatively can be a problem
- **Source – Pathway – Receptor**

Water Quality - Reduce Diffuse Pollution
- Mitigation techniques:
- Rotation
- Farm Infrastructure
- Yard & track management
- Buffer strips
- Beetle banks
- Sediment trap

Point Source Pollution
- Comes from a single identifiable source such as a store or field.
- Includes pesticides, nutrients, oil, sheep dip.
- May be attached to soil, or in solution or direct

Eutrophication
- Nutrient enrichment of ecosystem disturbing balance and quality.
- Mainly caused by P & N
- Max Nitrate 50mg/l

Landscape – Slope

Steep fields can cause water runoff at a rapid rate, especially where water percolation is slow

- **HIGH RISK** >7 degrees
- **MODERATE SLOPE** 3 – 7degrees
- **GENTLE SLOPE** 2 – 3 degrees

Water can still flow on gentle slopes especially where **percolation** is slow

Always Remember the Principle

Source	Tackle this first
Pathway →	(Sometimes this is a road)
Receptor	Protect this as a last resort, if source and pathway measures may fail.

Water Quality - Plant Protection Products

- Choice
- Storage
- Transportation
- Filling
- Application

Farm Biobed Systems - to limit point source pollution from pesticide handling and washdown areas.
Background Research Summary
Pesticides in water:
sources of contamination

Catchment Sensitive Farming

- Targets areas at risk for WFD, due to agriculture.
- Advice NOT Regulation
- Helps target Countryside Stewardship
- Joint NE, EA and DEFRA project

Sources in the Peak District Dales

- Livestock Production -
- Nutrients
- Sheep Dip

Water Quality - Livestock Management

- Medication – Zinc from sheep
- Sheep Dips
- Worming Agents
- Animal Feed
- Grazing Management
- Water course access

Farming Rules for Water April 2nd, 2018

Assess pollution risks

You must consider the risks of runoff and soil erosion from these factors:

- the angle of slopes, if angle is > 12 degrees amount of ground cover
- distance to inland freshwaters, coastal waters, wetlands, springs, wells or boreholes
- soil type and condition presence and condition of land drains
- You must identify the risks that apply to your land and your activities.

Before you use manure or fertiliser

You must plan each application of manure or fertiliser on your land.

Applying includes:

- spreading on the surface of the land
- injecting into the soil
- mixing manure or fertiliser with the surface layers of soil

For all farming and hortic. land you must plan how much fertiliser or manure to use, so you do not use more than your crop or soil needs

- by assessing the pollution risks
- by considering the weather conditions and forecasts at the time you want to apply manure or fertiliser on your land

Soil tests for cultivated agricultural land

- If you're applying manure or fertiliser to cultivated agricultural land, you must also plan by **using the results of soil tests.**

Cultivated agricultural land is both or one of the following:

- land you've ploughed, sowed or harvested at least once in the last year
- land where applied organic manure or fertiliser at least once in the last 3 yrs

Results of soil tests must show the pH and levels of:

- **N** – you can use the soil nitrogen supply calculator instead of a soil test
- **P, K** and **Mg**
- Soil test results must be no more than **5 years old** at the time of application.

You must not use fertiliser:

- on **waterlogged**, **flooded** or **snow-covered** soil when the soil has been frozen for **>12 hours** in the past **24 hours**
- within **2m of inland freshwaters, coastal waters, a spring, well or borehole**
- where risk factors mean there's a **significant risk of pollution**

Must not use manure:

- on waterlogged, flooded or snow-covered soil
- when soil **frozen for > 12 hours in the past 24 hours**
- **within 50m of a spring, well or borehole**
- **within 10m** of inland freshwaters or coastal waters **unless you're using precision** equipment or you're managing land for specific environmental benefits
- where risk factors mean there's **a significant risk of pollution**

6m exception for precision equipment

Can apply manure no closer than **6m** from inland freshwaters/coastal waters if use:

- a trailing hose or shoe band spreader
- a **shallow injector** (no deeper than **10cm**)
- a dribble bar applicator