The contributions of organic additions on soil quality

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Contents

Summary

This report looks at the role of organic matter within soils and reviews the effect organic additions have on soil quality.

It separates the organic additions that a grower may generate on their own holdings, such as livestock manures, cover crops and plant residues, to those which may be imported as a by-product from an industrial process including compost, digestate, green waste and other biosolids.

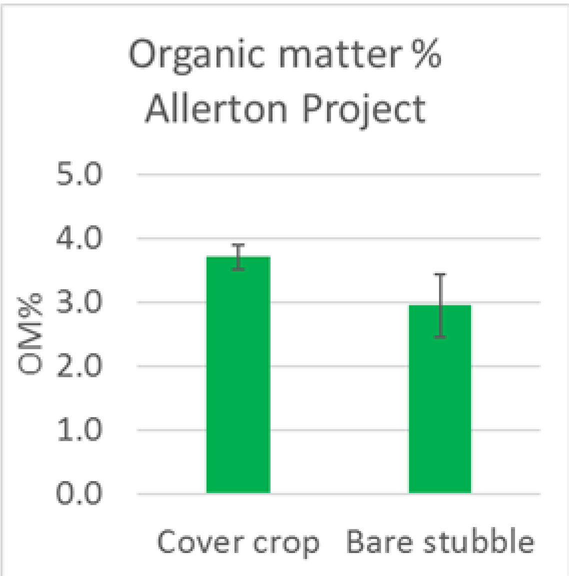
Understanding the Carbon: Nitrogen ratio within soils is key to successful crop production. Easily degradable organic additions and those that lock up nitrogen are part of this process.

The recently updated 'RB209' (May 2017) gives a comprehensive nutrient management guide and is a clear starting point from which UK growers can calculate organic and in-organic fertiliser.

Whilst organic additions have a large part to play in soil health, other factors such as crop rotation, inorganic fertiliser use and cultivations also play a role in maintaining soil organic matter. Minimising soil erosion, the role of biomass crops and woodland also has an influence on organic matter within a wider landscape. These can be additional management practices to help soil organic matter.

Introduction

Soil and water are essential for most agricultural production systems and soil resilience is becoming increasingly important. There are several global challenges facing farmers if they are to feed a growing world population. The changing weather and climate patterns require an evolving soil management strategy. In the UK between 1980 and 1995, organic matter in arable soils that were ploughed out of grassland, fell from 3.4% to 2.8% (Webb *et al.*, 2001). In the 2016/2017 harvest year at the Allerton Project organic matter levels were recorded on a field of Denchworth/Banbury soil series. This data builds on previous measurements, which are used to establish, the consequences of the Project's soil management. The single stands of buckwheat, oats, vetch, phacelia and oil radish were compared against bare stubble and the results are shown in the graph below.



Allerton Project 2016/17 soil organic matter in cover crop trial; Dr Felicity Crotty

Falling soil organic matter, because of cultivations, oxidisation and crop residue removal have many implications for soil quality. As mixed farming in the United Kingdom has declined (Boatman et al., 2007), the availability of organic manure from livestock has also reduced. Organic matter has several benefits to the soil;

- Increases soil carbon.
- Helps provide a food source for soil organisms.
- Provides a source of plant nutrients.
- Assists soil structure which can aid drainage.
- Can help moisture retention.

There are a numerous avenues available for farmers to increase the organic content of their soil which can lead to the benefits listed above. However, management of such organic additions is required to reduce any negative impacts, which might include;

- Excessive nutrient run-off.
- Build-up of heavy metals.
- Excessive greenhouse gas emissions.
- Locking up of nitrogen.
- Soil borne diseases and pathogens.

What are organic additions?

Organic additions consist of plant and animal residues at various stages of decomposition. When applied to soil they become part of soil organic matter providing soil stability and a source of crop nutrients. Soil organic matter is a key indicator of soil quality and fertility (Nicholson *et al*, 2015).

Produced on Farm

There are many sources of organic matter, some will be produced on farm such as livestock manures, slurries, crop residues and cover crops. Around 90 million tonnes of farm manures (Williams et al., 2000) is spread on UK farms per year.

1. Farm yard manure

Farm yard manure is often associated with cattle and sheep bedding, predominantly straw based, but can be sawdust and wood chippings mixed with animal faeces. Such manure can have different plant nutrient availability depending on how long it has been stored.

There are currently no closed periods for spreading this type of manure, but nutrient calculations are required under current Nitrate Vulnerable Zone (NVZ) rules. These include recording total organic manure spread and spreading and storage rules. Limits of organic matter are 250kgsN/ha for a field limit and 170kgs N/ha farm limit as set out in current NVZ section of United Kingdom Cross Compliance regulations.

Pig and poultry litter has high nitrogen contents and has stricter rules on storage and spreading than farm yard manure. There is a closed period when such manures cannot be spread. Farmyard manures are typically between 25-35% dry matter.

Farm yard manure can increase organic carbon can by 0.71% per year in arable top soils in the UK (Webb *et al*., 2001) and provide valuable sources of potassium, phosphate, sulphur and magnesium. Whilst organic carbon can increase in the short term, it is continually being broken down by biological processes and long term increases in organic carbon will be smaller. Livestock manures can provide a source of leachable nitrogen and volatilisation can release nitrous oxide into the environment. Effective utilisation of these nutrients, by crops and grass, is essential to reduce this negative impact.

2. Livestock slurry

In general, these organic additions have high nitrogen, phosphorous and potassium content and are also controlled by (NVZ) regulations. Livestock farmers, in the UK, need to be able to store slurry for 5-6 months and there are closed periods when spreading is prohibited. Water protection zones exist as do numerous other application guidelines. Slurries are typically between 3-10% dry matter. Such slurries are often applied to grassland after a first cut of silage has been taken. Slurries will also have varying nutrient composition depending on the animal source and its diet.

3. Cover crops, grassland and arable crop residues

Cover crops can prove to be useful on lighter soils where organic matter is an issue and where previous levels have been falling. The heavier the soil, then the greater the cover crop management becomes, in particular cover-crop destruction, slugs and seedbed preparation.

Typically, 'nitrate leaching' loss reductions have been estimated in the range 10-45kgN/ha (Cuttle *et al*., 2007, NIAB, 2015). The nature of cover crops mean that they decompose quickly and organic matter improvements can be small. However, cover crops can cut potassium loss by 25% on sandy loam and 35% on clay loam.

Including medium term, 3-5 year, grass leys into arable rotations can improve organic matter to soil through grass root growth but also the excrement of the animals grazing on the pasture. It also offers an opportunity for grass weed control.

The use of arable crop residues to return organic carbon to soil is a common practice on many arable farms. Some 15 million tonnes of carbon, as straw, is spread over 5 million hectares is returned to UK soils per year (Bhogal *et al*., 2009). This represents 0.41 % of carbon content of the top 25 cms of the arable topsoil in England and Wales (Webb *et al*., 2001). However, straw has a strong cell wall and can cause short term immobilisation of nitrogen (Webb *et al*., 2001). Whilst straw provides this uplift in carbon, mineralisation will eventually break down organic matter and net gains may be minimal.

Produced off Farm

Organic additions that are usually produced off farm include green waste, wood and paper compost, digestate and other biosolids. Some 3-4 million tonnes of biosolids (Water UK, 2010) and 1.9 million tonnes of compost are applied (on a fresh weight basis) annually to agricultural land in the UK (WRAP, 2012), (Chambers & Bhogal, 2012).

Digestate and compost certification

Digestate or compost that is certified under the Bio-fertiliser Certification Scheme 1 and the Compost Certification Scheme 2 does not normally need an environmental permit or exemption to be in place for their application to land. In other words, waste-derived digestate and compost become products (i.e. they are no longer wastes) once certified under the relevant scheme.

A core requirement of each certification scheme is compliance with the baseline quality specifications, set by the British Standards Institution's:

- Publicly Available Specification 1103 (PAS110) for anaerobic digestate and;
- Publicly Available Specification 1004 (PAS100) for compost. While each PAS specifies minimum quality criteria, they also allow customers to specify higher quality thresholds. Users can specify digestate or compost quality that has a higher quality threshold than the PAS110 or PAS100 baselines, and this should be agreed in writing with the supplier.

4. Green waste compost

Compost is both a soil conditioner and a source of major plant nutrients, including readily available potash, made from the controlled biological decomposition of either solely green waste (e.g. lawn clippings, prunings, woody material) or from a mix of green waste and food waste. Compost usually contains little readily available nitrogen, although soil nitrogen supply can be increased over the long term following its repeated use. This increase in soil organic matter improves workability and water retention properties (WRAP, 2016)

Many green waste composts are associated with municipal composting by local authorities. This waste has commonly had some primary separation and shredding before composting. However, plastic and other foreign bodies can be difficult to completely exclude and care should be taken in inspecting such waste before spreading.

Composting can have the advantage of delivering a beneficial carbon to nitrogen ration giving a balanced diet to soil microorganisms (See Carbon: Nitrogen ratios later in report).

5. Wood and paper

This organic addition can come in the form of sawdust, wood chips and shredded paper. The high carbon content of such material may well lock up a certain amount of plant available nitrogen. The breakdown by soil biology often requires additional nitrogen to breakdown this high carbon content. It has been shown that high paper and wood content can reduce nitrogen leaching from the soil.

6. Other biosolids

Biosolids are a valuable source of two major crop available nutrients - nitrogen and phosphorus (plus sulphur, potassium, magnesium and trace elements etc.), stable organic matter and lime, which can be beneficially recycled to agricultural land to improve soil quality and fertility, and to complete natural nutrient and carbon cycles. Biosolids can derive from drinking water treatment works, vegetable and root washing processes or more commonly form sewage treatment works.

Digestate (also known as 'anaerobic digestate' or 'bio-fertiliser') supplies readily available nitrogen that allows farmers to reduce their inputs of conventional fertiliser. It is one of the products of anaerobic digestion (AD), which is the controlled biological decomposition of biodegradable materials such as food wastes and animal manures in the absence of oxygen. Digestate is normally produced 'whole' (a slurry with a dry matter content of around 5%), but this can be separated into fibre and liquid fractions (WRAP, 2016).

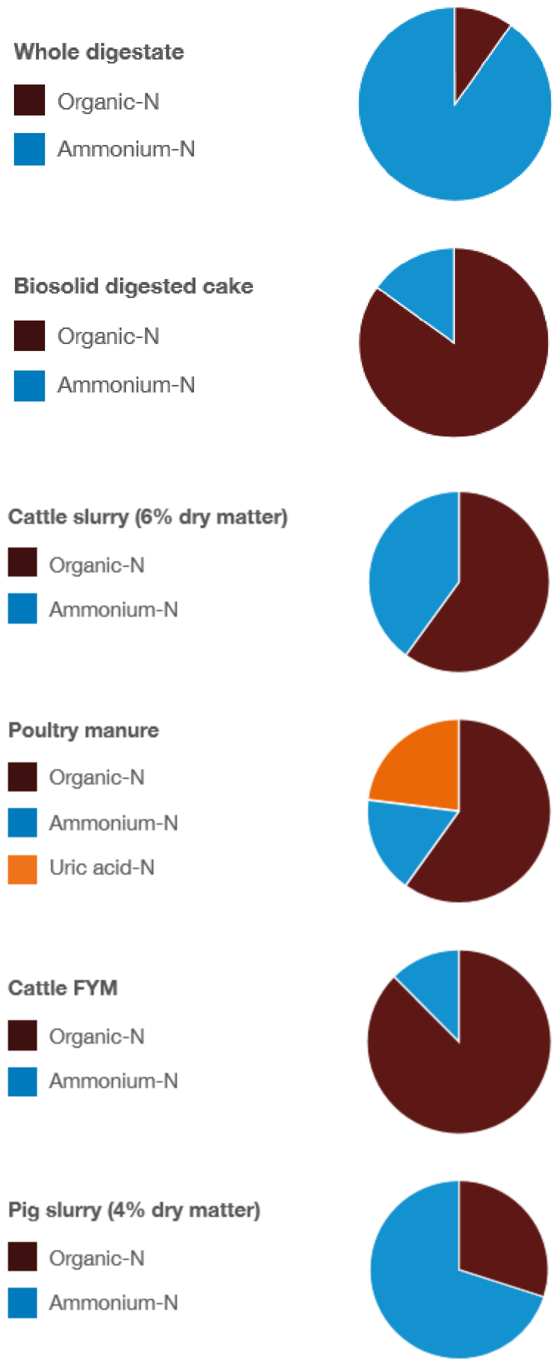
Approximately 1.0 million tonnes (dry solids) of biosolids recycled annually (2008) in the UK and make up less than 5% of total organic material going to agricultural land (Water UK, 2010).

When you can use treated sludge	
On growing crops	Restrictions
Cereals, oilseed rape	No restrictions
Grass	No grazing or harvesting within 3 weeks of use
Turf	No less than 3 months before harvest
Fruit trees	No less than 10 months before harvest
Before planting crops	Restrictions
Cereals, grass, fodder, sugar beet, oilseed rape, fruit trees	No restrictions
Soft fruit and vegetables	No less than 10 months before harvest if crops are normally in direct contact with soil and may be eaten raw
Potatoes	No less than 10 months before harvest. Don't spread on land that's used or will be used for a cropping rotation that includes basic seed potatoes or seed potatoes for export
Nursery stock	Don't spread on land that's used or will be used for a cropping rotation that includes basic nursery stock or nursery stock (including bulbs) for export

Source DEFRA, 2017.

When you can use untreated sludge	
Injected into soil with growing crops	Restrictions
Grass	No grazing or harvesting within 2 weeks of application
Turf	No less than 6 months before harvest
Worked or injected into soil before planting crops	Restrictions
Cereals, grass, fodder, sugar beet, oilseed rape, fruit trees	No restrictions
Soft fruit, vegetables	No less than 10 months before planting if crops are normally in direct contact with soil and may be eaten raw
Potatoes	No less than 10 months before planting if crops are normally in direct contact with soil and may be eaten raw. Don't spread on land that's used or will be used for a cropping rotation that includes seed potatoes

Source DEFRA, 2017.



Source AHDB RB209, 2017.

Physical characteristics

The organic material listed below have differing physical characteristics, nutrient composition and require differing management to maximise the benefits and minimise the detrimental effects. The table below summarises the nutrient content of the commonly applied organics additions and give a quick reference for growers who may be planning such operations.

		DRY MATTER (%)	AVAILABLE N (Kg N/t)		AVAILABLE P (Kg P2O5/t)	AVAILABLE K (Kg K2O/t)
			FRESH	STORED		
FYM	Cattle	25	0.6	1.2	1.9	7.2
	Pigs	25	1.0	1.8	3.6	7.2
	Broiler	60	10.5		15	16.2
SLURRY	Cattle	6	1.2		0.6	2.9
	Pigs	4	3.6		0.9	2.2
COMPOST	Green	60	0.2		3.0	5.5
	Food	60	0.6		3.8	8.0
PAPER	Chemical	40	2.0		0.4	0.2
(Treatment)	Biological	30	7.5		3.8	0.4
BIOSOLIDS	Digested Cake	25	1.6		9.0	0.5

Typical proportions of nitrogen in livestock manures, Source RB209.

Carbon: Nitrogen ratios

A clearer understanding of organic matter can be obtained by looking at the microorganisms that exist in the soil and the relationship between carbon and nitrogen (the C:N ratio). Such organisms are usually composed of 8 parts carbon to one part nitrogen, they burn carbon as energy and as a result C02 is produced during respiration. A perfect diet for such creatures is 24:1 C:N ratio, 16 parts of carbon for energy and 8 parts for maintenance (USDA, 2011).

The C:N ratio from different organic matters varies widely, wheat straw at 80:1 relies on the organisms finding more nitrogen in their immediate environment to consume the straw. Nitrogen is therefore immobilised and not available in the short term for crop nutrition. When microorganisms die and decompose they release plant available nitrogen into the soil by a process of mineralisation. Vetches have a ratio of 11:1 and are consumed leaving excess nitrogen in the soil which is available for plants to use and assist in the breakdown of 'higher C:N ratio crop residues'. Composting operations strive for a 30:1 ratio, with 24 parts of C available for microorganisms and the rest available for crops.

When planning crop rotations and cover cropping, a mix of such high and low C:N ratio crops will achieve more balanced soil biology activity. In general, higher C:N ratios will decompose over a longer period, whilst those with a lower ratio will breakdown much quicker.

Some typical C:N ratios are shown in the table below;

Organic addition	**C:N ratio**
Microorganisms composition	8:1
Microorganisms preferred diet	24:1
Farm yard manure	17-20:1
Livestock slurries	4-10:1
Wheat straw	80:1
Oat straw	70:1
Pea straw	29:1

Vetches	11:1
Green wastes and Composts	30:1
Paper waste	150-200:1
Biosolids	14:1

**Figures shown are approximations and will dependant on source material, processing, and additional additives included in any composting process (Adapted from USDA, 2011).*

Other factors affecting soil organic matter

Choice of rotation and cultivation method is essential to protect and enhance soil quality and aid profitable crop production (Jordan & Leake, 2004). The mixture of crops with different C:N ratios allows a balanced decomposition of organic matter.

The less intrusive cultivations are, the slower the rate of mineralisation of organic matter is. Reduced tillage has a role in this process.

The amount of inorganic fertiliser used can affect the decay and decomposition of organic matter.

Protecting soils from erosion is a fundamental management practice, as soils leave the field, so does organic matter and crop nutrients.

Biomass crops and woodland also have a role to play in both wider landscape management and the organic matter of soils in non-food crop production (Bhogal *et al*,2009). A holistic approach to such management, or example the positioning of new woods, can break up slopes and keep both soil and organic matter within catchments.

Conclusions

The predominant justification for returning organic materials to soil should be for maintaining and enhancing existing soil organic carbon levels and reducing/replacing manufactured fertiliser use, rather than carbon storage for climate change mitigation per se (Chambers & Bhogal, 2012).

The relaunched RB209 (May 2017) gives a comprehensive guide to organic additions applied to land on pages 5-39. This document should be used by UK growers as the basis for all fertiliser and organic application information.

The application of such organic matter has many rules, regulations and guidelines for the grower. Land managers should be aware of their soil nutrient status, the additional nutrition that is being applied as an organic addition and the regulations applicable to that addition.

Cover crops, grassland and arable crop residues offer growers the opportunity to incorporate organic matter into their soils without additional mechanical operations associated with spreading and applying organic manures.

There is much variability in composition and nutrient content and higher carbon organic additions will often tie up nitrogen and as such this will not be readily available to growing crops. Understanding the principles behind a balanced Carbon: Nitrogen ratio within soils can aid successful crop production.

Crop rotation, cultivation type and controlling soil erosion can complement organic additions as good arable management practices.

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