NUTRI • KNOW

Nutrient Management in Organic Farming





Imprint

Authors:

Stephen Meredith and Jane Shackleton
Irish Organic Association, Unit 13, Inish Carraig, Golden Island,
Athlone, Co. Westmeath, Ireland
www.irishorganicassociation.ie
info@irishoa.ie

Acknowledgements:

Special thanks are due to Patrick Forrestal (Teagasc); Allan Leck Jensen and Sven Gjedde Sommer (Aarhus University); and Andrea Casadesús Cabral and Diana Jiménez De Santiago (BETA) for their comments on earlier drafts. We are also indebted to Knut Schmidke (HTW Dresden) as well as staff and members from the Irish Organic Association for their helpful feedback and suggestions on the booklet during its development.

Production support and design:

Daniel Hölle, Larissa Markus and Anna Müller
European Science Communication Institute (ESCI) gGmbH

Picture Credits:

All images belong to **Irish Organic Association** with the exception of Page 9 - Envato Elements; Pages 8, 11 - AHDB; Page 10 - SRUC; Page 11 - Pfiffner; Page 17 - Biogas-E;

Published as part of the European research project Nutri-Know in November 2025.

Table of Contents

Nutrient Management in Organic Farming

1.1 Introduction

"Nutrient cycling" is an integral part of the farmed landscape on organic farms, referring to the movement of nutrients, such as nitrogen (N), phosphorus (P) and potassium (K) between the land, plants and livestock, and the atmosphere.

Every input or product brought in or sold off a farm influences its nutrient balance. A good understanding of the nutrient cycle and a farm's specific nutrient needs is therefore critical to maintaining optimal nutrient availability and minimising environmental losses. To maintain and enhance soil fertility, farmers commonly apply inorganic fertilisers, organic manures, and other media such as composts, tailoring nutrient inputs to the specific requirements of the crops or grasslands within their system.

While nutrient management on non-organic farms tends to focus on crop nutrition using a wide range of fertiliser sources, in organic production farmers and growers must consider several factors (*see Box 1*).

Box 1: *Key nutrient management considerations on organic farms*

- Developing and maintaining a healthy 'living soil' and nutrient budget that effectively helps to recycle soil nutrients and make them available to future crops;
- A strong knowledge of how to optimise crop rotation design and the use of N-fixing plant species such as clover and grain legumes;
- Knowing how to minimise any losses as well as maximise returns through the recycling of organic manures and other organic materials; and
- Being aware of which crops remove the most nutrients, particularly where crops are part of an arable rotation.

Source: *Own compilation*

Mixed livestock and arable farms are well-placed to directly recycle nutrients between the different enterprises on-farm. In addition to the recycling of nutrients, these farms often use green manures, biological nitrogen fixation

(BNF) and, due to increasing farm specialisation, imported organic manures and other organic materials from off-farm sources. This can include inputs such as pelleted organic manures and composts, as well as inputs from additional handling and processing steps on-farm, like composting and anaerobic digestion.

As a result, soil and nutrient management considerations are strongly interconnected in organic farm and land management systems, with the emphasis being on the enterprise operating as far as possible within a circular system at both farm and regional level. To this end nutrient management on organic farms relies on a combination of management practices that not only help to ensure the supply of essential nutrients but also support broader environmental goals (see *Figure 1*).

Figure 1: *Nutrient management practices supporting broader environmental goals* ***Source:*** *Own compilation*

1.2 How to Use This Booklet

This booklet has been developed as part of the NUTRI-KNOW project and is designed as a guide to help existing or prospective organic farmers develop and implement soil and nutrient management strategies tailored to their farm, covering key topics of relevance to livestock, tillage and mixed organic farming systems.

Understanding soil health and quality

Managing manures and other fertilisation strategies

Fertility-building crops and rotation design

Farmers are encouraged to use this booklet in conjunction with their own experiences and to seek information from their organic certification body to ensure compliance with the latest organic standards, or guidance from a farm advisor or other professional to take advantage of best practice.

1.3 Understanding Nutrient Need and Availability on the Farm

A sound understanding of the essential nutrients for crops and livestock on the farm is an important part of organic farm and land management. *Table 1* provides a short overview of the key macronutrients - N, P and K, sulphur (S), calcium (Ca) and magnesium (Mg) – which are needed to support crop production. In addition, trace elements such as manganese (Mn), copper (Cu), zinc (Zn), boron (B), and molybdenum (Mo) are also needed, with farmers and growers often able to rely on soil reserves in many cases, although amendments may be required in certain circumstances. It is important to note that the availability of these nutrients is often dependant on the climatic and site conditions and soil properties such as soil organic matter and soil pH.

1.4 Nutrient Budgeting

Nutrient budgeting is a valuable tool for understanding and managing nutrient flows in organic farming systems. It can help farmers and growers evaluate the nutrient status of individual fields and/or the farm as a whole, in the medium to long term, by indicating where there is a nutrient surplus or deficit. Like a financial budget, it tracks inputs (e.g. purchased seed, livestock, feed, straw, as well as biological N fixation from legumes) and outputs (e.g. crop sales, animal products). This is designed to maintain total and plant available nutrients, identify potential surpluses or losses and work towards ensuring a more balanced system.

Nutrient budgeting can be performed at different levels (*see Table 2*) to inform farm and land management decisions using various tools, with examples illustrated below.

***Table 1:** Role and source of key nutrients*

	Role	Primary Sources
Nitrogen (N)	Plays a central role in the productivity of organic farming systems. Critical nutrient for photosynthesis and plant growth.	Use of N-fixing legumes, animal manures, composted organic materials, and crop residues. Soil N mineralisation – linked to soil health, pH management, soil type and aeration.
Phosphorus (P)	Plays a pivotal role in plant growth, root development and energy storage and provision. It is also a crucial nutrient for optimising N-fixation by Rhizobium bacteria within legume root nodules.[1]	Primarily sourced from organic manures, straw, and rock phosphate, commonly applied as ground rock phosphate (GRP). More recently, struvite has become available for use as a P-recycling fertiliser in organic farming.
Potassium (K)	Essential for plant health, regulating physiological processes such as photosynthesis and stomatal function, which influence carbon dioxide (CO_2) uptake. Root crops have a particularly high demand, making it important to apply before planting these crops in the rotation.	Imported materials such as forage, grain and straw can also contribute to K levels. Supply of K from the soil, differs across soils. Soil testing indicates the potential of a soil to supply crop requirements – important to bear the target yield goal in mind. Straw, hay or silage removal will remove significant amounts of K (up to 200 kg per ha per year).
Sulphur (S), calcium (Ca) magnesium (Mg) and other trace elements	S, Ca, and Mg are considered secondary macronutrients to N, P and K, but are nevertheless important for plant growth and development. Other trace elements or micronutrients, such as Manganese (Mn), Copper (Cu), Zinc (Zn), Boron (B) and Molybdenum (Mo), although not required in large quantities, are also important for plant and animal development and interact closely with macronutrients.[2]	Organic manures, inherent in soil, but it can vary depending on the soil type.

***Source:** Own compilation*

1 As P is often present in an unavailable form, mineralisation from the organic soil P pool is the desired outcome, with soil testing giving an indication of the ability of soil to supply plant P requirements.

2 Note that forage legumes in organic farming can suffer from S deficiency

Table 2: Different approaches to nutrient budgeting

Farm-gate budget	Tracks all nutrients entering and leaving the farm, helping identify overall nutrient surpluses or deficiencies.
Field-level budget	Focuses on specific fields or crop rotations, guiding localised nutrient management.
Whole-farm system budget	Integrates both farmgate and field-level data for a comprehensive nutrient balance.

***Source:** Watson et al. 2009*

Box 2: Taking advantage of nutrient budget tools

While farmers and growers can decide to produce their own nutrient budgets, there are tools available to help farmers with this process. Each tool has its own level of simplicity and sophistication, depending on the needs and objectives of the nutrient budget. Some examples are outlined below.

- **NutriGadget:** An open-source, excel-based tool, NutriGadget was created by researchers at the University of Hohenheim as part of the EU RELACS project (2018-2022). The tool is designed to calculate a farm gate nutrient budget with all nutrient inputs and outputs quantified and the difference between them indicating the surplus or balance The farm gate nutrient budget is calculated based on the inputs of the farm's specific data in terms of inputs and outputs and standard values for nutrient contents of common inputs and outputs as well as BNF. This tool does not require any specific knowledge other than good farm documentation and access to a personal computer.
- **NMP Online:** An Irish-based tool, Nutrient Management Planning (NMP) Online, is developed by Teagasc, allows farm advisors in Ireland to create a nutrient management plan to optimise soil fertility. The plan is based on the results of a farm's soil samples as well as other information about the farm enterprise such as the type of crops, animal numbers, and stocking rate. The online digital platform also provides a full picture of the nutrient status on the farm and at the field level, showing the nutrient demand of the crops and thereby informing the development of a nutrient management plan. The plan is available to the farmer via their advisor.

***Sources:** Reimer et al., 2020 and Teagasc, n.d.*

NUTRI•KNOW

2

Starting With **Healthy, Biologically Active Soils**

Healthy, biologically active soils are the basis for supporting a high level of inherent nutrient supply from soils and guides further nutrient management on organic farms.

Soil organic matter (SOM) is central to maintaining and building soil fertility as it not only supports good physical conditions in soil but is an important nutrient bank containing most of the soil reserve of N and large proportions of other nutrients such as P and S. In addition, SOM contains readily available energy in the form of simple organic compounds such as sugars, amino acids and organic acids, which serve as immediate energy sources for soil macro- and microorganisms, who make up the soil food web (*see Figure 2*).

Although soils can differ in their ability to grow crops, understanding the nature of soil and how to optimise its quality, while avoiding compaction, can assist in enhancing and maintaining the productivity of organic crops and livestock in the medium to long-term.

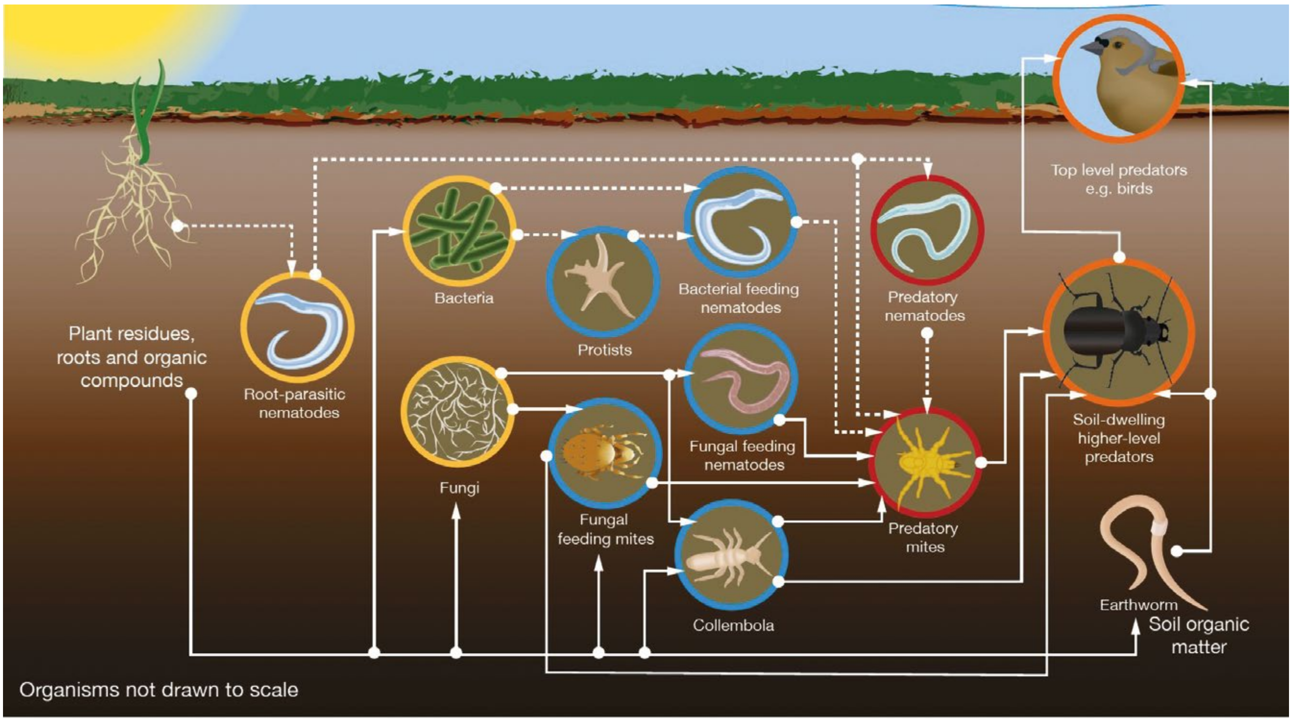


Figure 2: *The soil food web - Relationship between organic matter decomposition and the types of microorganisms and animals that inhabit soils*

Source: *AHDB, 2019*

2.1 Assessing and Evaluating Soil Health & Fertility

There are several ways farmers and growers can assess and evaluate the health and fertility of their soil, from conducting basic visual assessments of soil structure, texture, and other direct observations of soil conditions, to basic or more complex soil testing and sampling in a laboratory. Some useful assessments are outlined below (*Table 3*).

Table 3: *Overview of useful soil assessments*

Spade diagnosis/Visual Assessment (depth 30cm)	Easy, quick, good indication of soil health, fast general impression of the soil status, in particular soil structure, detection of compaction and make-up of the soil.
Plant health monitoring (current and previous crop, weeds)	Early signs of nutrient deficiencies or soil compaction.
Earthworm count	Good indicator for soil structure and health, soil life and activity, and soil biodiversity.
Standard Soil Chemical Test (macronutrients and pH)	Directly informs nutrient management strategy with an overview of soil nutrient content. Test methodologies vary from country to country.
Other Soil Health Tests	Measures micronutrients/trace elements, texture, total SOM, respiration rate, bulk density, cation exchange capacity, soil biology, etc.

Source: *Own compilation*

2.2 Visual Assessment

Visual assessments of 2-3 test samples using a spade are a cost-effective way that farmers and growers can simply and quickly assess soil structure and texture based on the appearance and feel of the soil. Visual assessments can also highlight root development as well as earthworm and other biological activity.

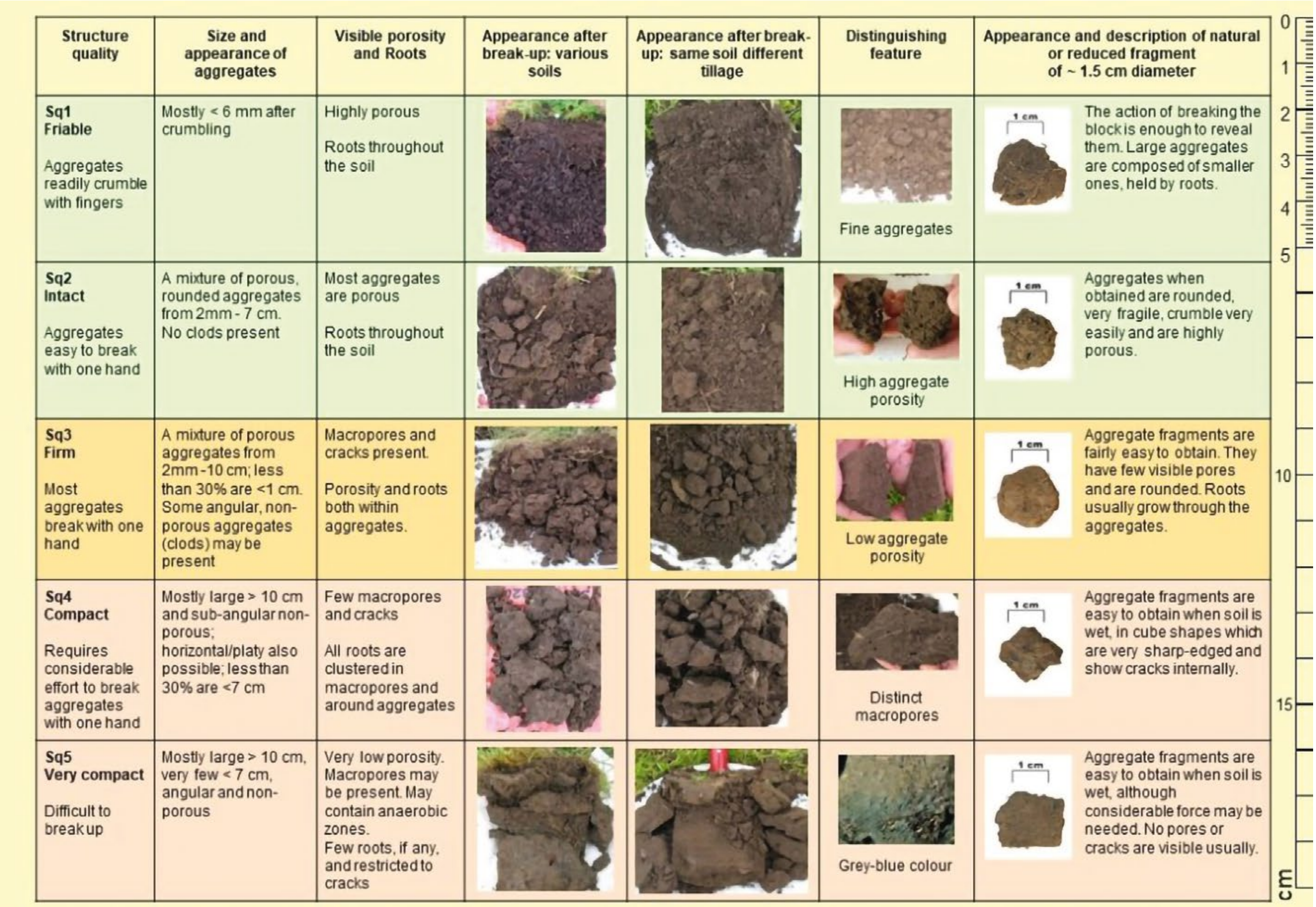
2.2.1 Soil Structure

Soil structure describes the spatial arrangement of different soil particles (sand, silt, and clay) and organic matter to form aggregates or clumps to make up the overall architecture of the soil. These aggregates vary in size, shape, stability and distribution, and their arrangement determines key physical properties of the soil.

Good soil structure promotes water infiltration, root penetration, and microbial activity- essential processes for soil health and plant productivity. One of the consequences of soil structure is porosity, which refers to the network of empty spaces or pores between and within aggregates. These pores control the movement of water, air and microorganisms within the soil.[3]

The quality of soil structure can be visually assessed in the field by removing and turning up blocks of representative soil ~15 cm thick directly to the full depth of a spade, looking at different features as outlined in *Figure 3*.

3 This subsequently influences soil temperature as well as redox conditions, which is the balance between oxygen-rich (aerobic) and oxygen poor (anaerobic) environments in the soil.



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.

Figure 3: *Visual Evaluation of Soil Structure (VESS) Chart* — ***Source:*** *SRUC, 2012*

2.2.2 Soil Texture

Soil texture refers to the different properties that make up soil in the form of clay, silt and sand. While soil texture will be unique to the soil and cannot be changed, it gives farmers and growers a greater insight into how their soil can be managed. Understanding soil texture is an important factor when considering nutrient management needs, as soil texture influences nutrient retention, drainage, and pH, and frequently nutrient mineralisation potential.

For instance, clay and silty soils have a greater water holding capacity than sandy soils, which can be a benefit during dry periods, but results in slower warmup of soil in spring and thereby reduced N mineralisation and early

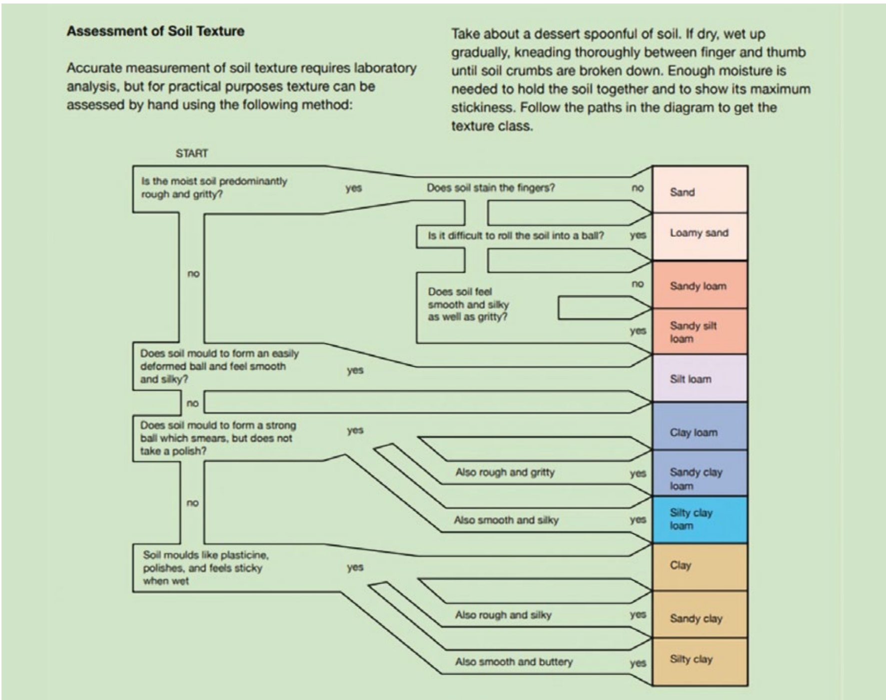


Figure 4: *Assessment of soil texture* — ***Source:*** *SRUC, 2014*

growth. In addition, soil texture can affect the ease with which soil can be cultivated. Soil texture can be measured accurately in a laboratory test. However, hand assessments can also provide a useful and practical guide to assess the composition of a soil – *see Figure 4*.

2.2.3 Earthworm Counts

Earthworms are vital indicators of soil health, contributing to soil structure, aeration, the incorporation of organic matter (OM), water infiltration, nutrient cycling, and biological activity. As a result, their presence reflects a well-functioning soil ecosystem, and conducting a basic earthworm count can be a useful exercise to better understand their presence in the field (*see Box 3*).

Earthworms are classified into three main ecological groups, each playing a distinct role, with distinctly different feeding and living habits (*see Table 4 and Figure 5*).

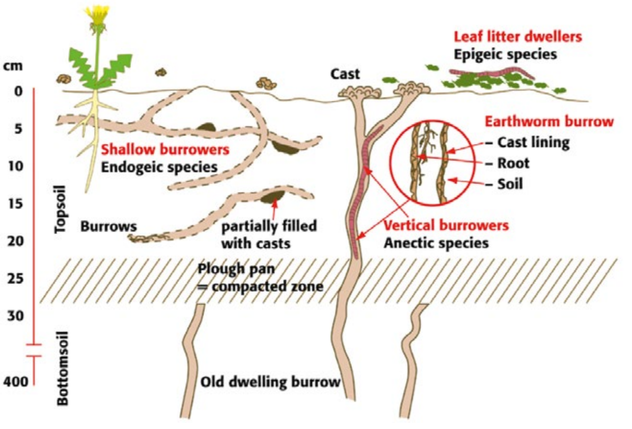


Figure 5: *Worm feeding and living habits* ***Source:*** *Pfiffner, 2022*

Table 4: *Main worm ecological groups*

Epigeic (surface-dwelling)	Endogeic (topsoil-dwelling)	Anecic (deep burrowing)
		
Small, pigmented worms that live in plant litter and aid in OM decomposition	Unpigmented worms that create horizontal shallow burrows and mix organic and mineral soil layers.	Large worms that build vertical burrows and drag surface residues deep into the soil, enhancing nutrient cycling and structure.[4]

Source: *Own compilation based on AHDB, 2024*

Earthworm populations thrive in soils rich in OM and typically decline with intensive tillage or compaction. As a result, it is important to use light machinery where possible and keep ground pressure to a minimum by reducing tyre pressure. Fertiliser inputs can also influence earthworm communities, with organic amendments generally supporting higher abundance and diversity. Furthermore, practices such as diversified crop rotations, with deep-rooting catch crops, including clover and other green manures, and rotating grass-clover leys and arable crops, especially a 2-year ley within a rotation, help to restore earthworm populations. Plant residues left on the soil surface are particularly important for anecic earthworms. Therefore, especially on arable land, care must be taken to ensure that dead plant biomass remains on the soil surface even after tillage.

4 These worms leave behind vertical continuous pores that extend deep into the soil, which are particularly important for water infiltration, soil aeration and deep root growth.

Box 3: Assessing earthworm populations in the field

Below are some basic tips for counting earthworms in different parts of fields and margins:

- The optimal time to do a count is in warm and moist (but not waterlogged) soils during spring or autumn.
- To count and record worms and assess their ecological types, it is best to hand sort them from soil samples (e.g., 20 cm × 20 cm × 20 cm depth).
- Sampling can range from 10 samples, following a standard 'W' field sampling pattern or 3 samples from a representative area.
- Surface casting counts are also an indicator of activity, especially for anecic species.

Source: *AHDB, 2024*

2.3 Laboratory Soil Testing

Laboratory testing is a cost-effective way to assess soil physical characteristics, such as soil texture, and chemical properties, such as pH, nutrient status (extractable P and K), trace elements, texture, and OM content.

Other soil tests are available to measure respiration rate, bulk density, cation exchange capacity, soil carbon, depending on the needs of the farmer and ability to assess the results.

Box 4 provides a useful step-by-step guide outlining best practice for collecting soil samples.

Box 4: Steps for collecting a soil sample

1. **Use the right tools:** Collect samples to a consistent depth (100 mm) in grasslands/pastures and up to 250 mm on arable land using a clean, non-contaminated soil corer (preferably stainless steel).
2. **Divide fields appropriately:** Sample areas of ~ 2 ha (up to 4 ha if uniform in soil type and history). Map and label fields clearly.
3. **Account for variation:** Sample separately from areas with different soil types, history, slopes, drainage, or yield issues.
4. **Avoid Unusual Spots:** Steer clear of old ditches, troughs, gateways, dung patches, etc.
5. **Timing of Sampling:** Wait 3-6 months post P/K application and 2 years after liming before sampling.
6. **Number of Cores:** Collect at least 20 cores per area and mix to create a composite sample.
7. **Sampling Patterns:** Use 'W' or grid patterns to ensure broad field representation.
8. **Consistency in Timing:** Try to sample at the same time of year or in a similar stage of the rotation to enable comparable results.
9. **Avoid Extreme Soil Conditions:** Do not sample in very dry or very waterlogged conditions.
10. **Labelling:** Use clean containers and label each sample with the field number, date and other relevant details.

Source: *Adapted from Wall and Plunkett, 2020*

Managing Manures and Other **Fertilisation Strategies**

The management and recycling of manures and utilisation of other organic materials is a fundamental practice on organic farms for building nutrient reserves to feed crops, whilst preserving and enhancing soil health and quality. These materials originate from a variety of sources, with livestock manures and slurry being the most predominant part of the manurial strategy in livestock and mixed farming systems.

Other notable sources include crop residues, green compost, spent mushroom compost, and organic residues from appropriately managed industrial or municipal origins (e.g. dairy sludge, food processing by-products, household waste, green waste), along with digestates from biogas plants (not of factory farming origin).

The overarching aim of recycling organic materials is to improve soil quality and optimise nutrient uptake by crops, whilst minimising nutrient losses to the environment. Furthermore, all manure treatments, storage systems and applications must conform to statutory requirements applicable at the national or regional level.

3.1 Livestock Manures

Livestock manures, such as slurries, farmyard manure and poultry litters, are valuable by-products of livestock production systems. The composition of these manures can, however, vary and is dependent on the animal species, diet, housing system and bedding materials, all of which influence their nutrient content and availability.

Manure management practices must aim to retain plant-available nutrients, particularly N, and minimise emissions of ammonia and greenhouse gases, as well as leached N losses to water. Fresh manure, slurry and poultry litter contain significant amounts of readily available N. This available N can be beneficial during early crop growth when nutrient demand is high. However, if not applied appropriately under suitable weather and soil conditions, and at the right time of the year and plant growth phase, this N is at risk of being lost through volatilisation or leaching. These manures also contribute to SOM, although to a lesser extent than composted manures, as concentrated P and K deposits are finite resources. Furthermore, K, although abundant in clay structure, is often present in forms unavailable to plants

Attention should be placed on maximising retention and recycling within the farming system to reduce dependency on external nutrient inputs. Good handling and storage facilities, together with effective use, are essential to minimise losses and get the most out of farmyard manures. They should be ideally stored and managed on a concrete pad that is roofed, or the manure should be covered to reduce losses of N and K, with an adjoining effluent tank to collect seepage. Where raw manure or waste-derived materials are used, it is essential to ensure they are free from contaminants and pathogens (see section on composting below). A biogas plant, in which the farm's manures and plant biomass are fermented, offers the best option for almost completely avoiding nutrient losses during fermentation and storage (see *Box 7*).

3.2 Composting Manures

Composting manures can help produce a more stable nutrient-rich material that improves soil structure, increases SOM content over time, while improving microbial activity and diversity. On-farm composting goes beyond basic handling and moving manure, typically involving the aerobic treatment of organic manure, requiring the regular turning of developing composts.

Where possible, manure cleared from sheds or imported should be heaped in the shape of a windrow (about 4 m wide and 2 m high) in a dedicated area where it can be regularly handled and turned. The windrow should ideally be turned about 2-3 weeks after creation, followed by a further turning after about 4-5 weeks and again after about 8 weeks and utilising it within 10-12 weeks.

Compost heaps typically reach internal temperatures of 55–65 °C, maintained for at least three consecutive days. These high temperatures are essential for killing weed seeds and pathogenic organisms. Composting can change the physical and chemical composition of organic materials - particularly N - into forms less plant available and prone to leaching.

At the same time, the process is associated with substantial C and N losses primarily through carbon dioxide evolution and ammonia volatilisation, with potential for further emissions of methane and nitrous oxide. Despite these potential losses, the remaining nutrients in compost are released more slowly and often in greater synchrony with crop demand, thereby supporting long-term soil fertility. See *Box 5* with considerations for effective composting. On-farm composting is typically an aerobic process, requiring regular turning to introduce oxygen for optimal microbial activity; on the other hand, no-turn anaerobic composting processes, such as the Static Pile Inoculated Compost Extension - SPICE method or the Johnson-Su composting method, may also be considered.

***Box 5:** Considerations for composting*

While composting offers clear benefits, it can be a time-consuming and expensive operation that can bring some practical challenges for farmers and growers, including:

- **Equipment and costs:** Composting can require machinery for turning and handling, which may be costly, especially for smaller farms without access to shared equipment.
- **Availability and transport:** Compost is bulky and heavy, making it expensive to transport over long distances. Availability can also vary by region.
- **Quality concerns:** Compost must be well-made to avoid issues such as weed seeds, pathogens, or contaminants like microplastics or heavy metals.[5]
- **Knowledge and skills:** Effective composting requires understanding the process, including how to manage temperature, moisture, and turning.
- **Application:** As composts do not have readily available N, they should be used primarily to support P and K levels and the build-up of SOM on targeted fields

***Source:** Own compilation*

5 Materials from municipal waste streams must meet organic standards.

3.3 Nutrients in Organic Manures

To optimise nutrient management, it is useful to analyse the N, P, and K content of manure alongside soil test results, results of nutrient balancing from individual fields and crop nutrient requirements. This ensures that crop demand is met effectively while complying with regulatory requirements, such as national and regional nitrate action programmes as well as organic standards. Organic manures can also provide secondary nutrients and micronutrients like sulphur and magnesium or molybdenum, contributing to crop nutrition and symbiotic N-fixation via rhizobial bacteria.

National and regional guidelines on the typical nutrient content of manures are often a useful general point of reference. However, in practice, manure nutrient contents have a wide range. Farmers and growers can opt to test their own manures to form nutrient management and crop husbandry decision-making (*see Table 5*).

Table 5: *Testing organic manures*

Basic laboratory analysis for organic manures consists of the following tests: dry matter (DM), nutrients, OM, pH and C:N ratio and content. Depending on needs, additional tests are offered by laboratories for parameters such as electrical conductivity (EC), heavy metals/potentially toxic elements, pesticides and pathogens. Regular testing of manure and slurry helps to better match nutrient applications to crop needs. Follow the steps below to ensure accurate sampling and reliable laboratory results.

Guidelines for solid manure	Guidelines for liquid manure (slurry)
• Take at least 10 subsamples of approximately 1 kg each from different parts of the heap or store, ensuring the heap is dry and safe to walk on before sampling. • Remove any surface-weathered material using a spade or fork. • To a depth of 50 cm, either dig or use a soil auger to collect subsamples. • Place subsamples on a clean, dry surface (e.g. tray or sheet). • Break up lumps and mix thoroughly to create a uniform sample. • Take a representative sample of about 500 g from the mixed material for analysis. • Place the sample in a strong plastic bag, expel excess air, and seal securely. • Label clearly, including all required information as specified by the laboratory's sample submission form.	• Collect at least 5 subsamples of 2 litres each from different parts of the tank or store. • Combine all subsamples in a clean container and mix thoroughly. • Fill a 250 ml screw-top plastic container, leaving a 2–3 cm air gap to allow for shaking during laboratory analysis. • Label the container clearly and submit it along with the laboratory request form. • Send the sample as soon as possible to ensure accuracy of results.

Source: *Adapted methods from MOPS, 2021*

3.4 Guidelines for Applying Manures

To maximise nutrient availability and minimise losses, effective in-field application is critical. Taking account of the practices outlined below can help support good nutrient management. These include:

- **Application timing:** Apply manures during periods of high crop demand, such as spring months, to maximise nutrient uptake and minimise leaching risks. Aim to complete 70% of applications at this time of the year. Avoid application on waterlogged, frozen or snow-covered soils or when heavy rain is forecast.
- **Application conditions:** Favour cool, overcast, or misty weather over warm, sunny conditions to reduce ammonia losses.
- **Application methods:** Use low-emission slurry spreading (LESS) methods like band spreading, trailing shoe, or shallow injection to limit ammonia losses and maximise N availability.
- **Incorporation speed:** For tillage, manure should be incorporated immediately after application (within 1 hour), as significant ammonia losses occur almost instantly.
- **Application rates:** This will depend on the enterprise type and supplies of manure available. For instance, there is often a high demand for slurry and/or manure to replace P and K, especially after silage cuts, as well as to support other crops at different stages of an arable rotation.[6]
- **Regulatory compliance:** All manure applications must comply with national and regional set legal limits on timings, rates, buffer zones and application periods.

3.5 Importing Manures and Other Approved Sources

In organic farming, the importation of manures and other approved sources can play an important role in supporting soil fertility and yields by supplementing on-farm nutrient supply (particularly when soil tests indicate a need) as well as building SOM over time. As the availability of organic manure may be limited, manures from non-organic holdings - not of factory farming origin - may be used under strict conditions.

6 For illustrative purposes, see *Table 8* in the next section.

***Box 6:** Considerations when importing manures and other organic waste*

Importing of manures and other organic waste on the farm should be carefully planned and considered. A farm's nutrient management strategy should place a strong emphasis on the resources available to the farm in the medium to long term. In particular, it is important to understand:

- the estimated nutrient content, composition, and treatment of imported manures and waste. For example, livestock slurries, poultry manures and digestate are readily available in N and more prone to losses.
- Imported materials should be carefully managed to minimise nutrient losses to the environment. The total N content from manures (both on-farm and imported) must not exceed 170 kg of N/ha/year to ensure compliance with organic standards.
- Non-organic sources are recommended to be composted on-farm for a minimum of three months before use, while livestock slurry should be applied following aeration and/or appropriate dilution.
- Farmers should have clear agronomic justifications for use (e.g. soil analysis, results of nutrient balancing, nutrient management plan) and maintain records and documentary evidence of import quantities, dates of application, and field parcels.

***Source:** Own compilation*

In addition to animal manures, a range of other sources are permitted under organic standards with conditions. These sources can be particularly useful when livestock manures are unavailable or in short supply. Examples include dairy sludge from approved dairy processors, commercial composts, untreated straw, woodchips, or sawdust, green waste compost, food industry by-products, spent mushroom, composted or fermented separated household waste and digestates derived from biogas plants.

For a comprehensive overview and conditions for use, please refer to the organic standards available from your organic certification body.

Over the last 20 years, bio-based fertilisers (derived from waste and residues, particularly societal waste streams) have emerged commercially, which can support improvements in yield and soil fertility. However, their application may involve the risk of spreading organic and inorganic pollutants and pathogens, and as a result, their use in organic production remains limited and is being reviewed and evaluated on a case-by-case basis.

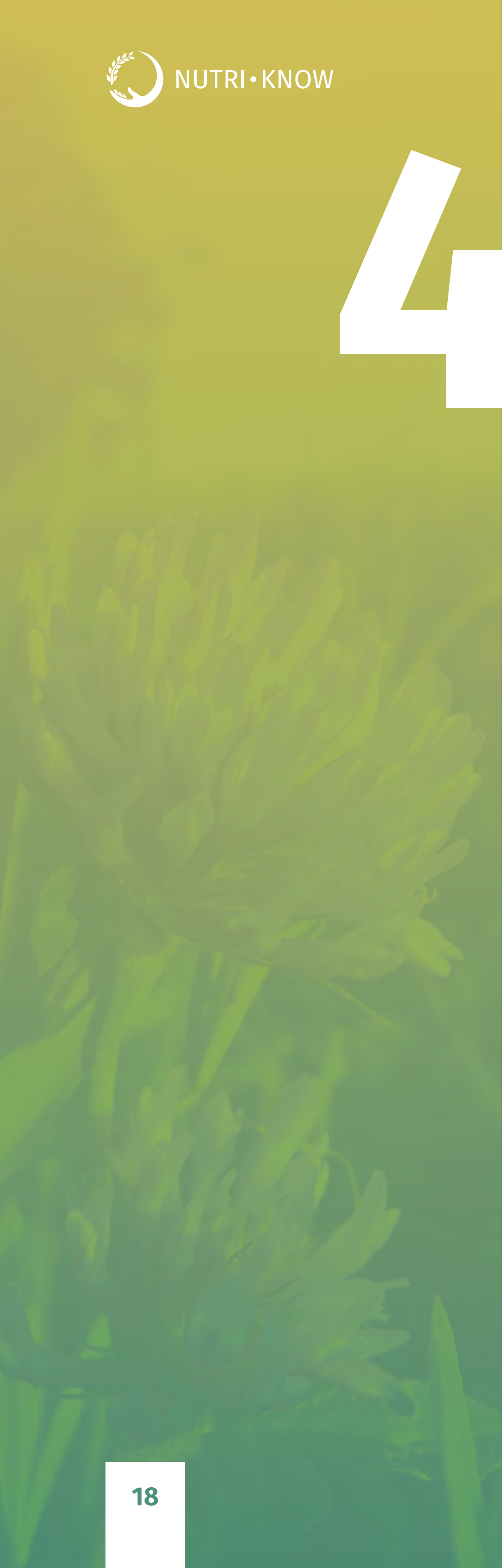
For example, following a recommendation from the EU Expert Group for Technical Advice on Organic Production (EGTOP), 'recovered struvite and precipitated phosphate salts' were authorised for organic production in 2023 in the EU, defined as 'slow-release P fertiliser'. Such fertilisers can help to reduce the use of non-renewable sources of P and close nutrient cycles. In addition biopreparations, biostimulants and microbial inoculants are emerging areas that can potentially help enhance nutrient uptake, stimulate plant establishment and growth, and/or improve stress tolerance.

***Box 7:** Biogas plants as an energy and nutrient source in organic farming*

Anaerobic digestion is increasingly being considered as an option on organic farms to produce renewable energy as well as improve the soil nutrient supply, and can help to sustainably increase crop yields.
Small to medium scale anaerobic digesters (<100 kW up to 200 kW) on organic farms are designed to be closely linked to the farm enterprise, with feeding substrates mainly supplied in the form of livestock manures and slurries, catch crops like clover-grass, and other organic materials, based on the resources available on the farm, with no feedstocks of factory farming origin.

Anaerobic digesters not only produce biogas that can be used to provide heat and electricity, but also a digestate by-product can be used as a fertiliser, containing readily available N and other nutrients to support a farm's nutrient balance. Overall, biogas production on organic farms, adapted to the availability of appropriate substrates, has significant potential to displace fossil use, reduce GHG emissions, support nutrient recycling and increase cash crop output.

***Sources:** SUSTAINGAS, 2013 and Biogas-E, n.d.*



Fertility-Building Crops and Rotation Design

Fertility-building crops are the cornerstone of organic production, whether that is to produce high-quality forage for livestock or to fix N for succeeding cash crops within a rotation. For mixed and specialist tillage organic farms, rotation planning and design is not only important for minimising weed, disease and pest problems, but for supporting soil quality and nutrient availability.

4.1 Importance of Legumes for Fertility

Legumes play a central role in nutrient management within organic systems, contributing significantly to N supply through biological nitrogen fixation (BNF), while supporting soil health. They are utilised across a range of systems, including grassland and tillage management, and depending on the objective that the farmer or grower wishes to achieve are grown over a certain period (*see Box 8*).

***Box 8:** Types of legumes in rotation*

- long-term crops of 2-3 years (e.g. red and white clover leys or multi-species swards);[7]
- annual crops (e.g. peas, beans);[8] and
- short-term crops 2-6 months as components of cover crops or green manures (e.g., Persian and crimson clovers, vetch).

***Source:** Own compilation*

The primary agronomic value of legumes lies in the symbiotic relationship with Rhizobium spp., which enables the fixation of atmospheric N into plant-available forms. This N is stored in their biomass, which is later mineralised into plant-available forms such as ammonium and nitrate. A proportion may also be transferred below ground via rhizodeposition to companion grass or herb species.

The mineralisation process is temperature-dependent, with N release typically peaking in warmer periods. This

7 In mixed livestock and arable systems long-term leys can be up to 5 years, depending on the species grown.

8 Note that while grain legumes will fix a certain amount of N a large proportion (60 to 80 %) is removed by the grain. This may be recycled if used for on-farm feed, but if sold the N will be lost to the rotation.

seasonality can potentially lead to early-season N deficits, therefore necessitating a strategic integration of legumes into the cropping sequence.

As well as increasing the availability of N, the inclusion of legumes also provides other functions such as weed and pest suppression, disease management, adding SOM, improving soil structure, biodiversity and pollinator abundance, and providing supplementary forage for livestock (if applicable). Moreover, forage legumes, in particular, help to maintain and build soil carbon content through root biomass and rhizodeposits.

4.2 Roles of Fertility Building Crops

While the main role of fertility-building crops is to contribute to a farm's N supply through BNF and productivity more broadly, farmers and growers may have different objectives for growing them depending on the farm enterprise.

In **grassland systems**, for instance, a key objective is providing high-quality forage protein for ruminant livestock, while a proportion of the fixed N can be transferred below ground to companion grass or herb species. In such systems, particularly those used for grazing, white clover is commonly combined with a grass species due to its tolerance to grazing and its ability to persist for several years.

Red clover, while less persistent under grazing, is highly productive in silage-based or stockless systems due to its higher BNF capacity and superior biomass yields, and when sown with a companion grass species, can produce large quantities of herbage.

The further inclusion of herb species such as chicory and ribwort plantain to these mixtures (i.e. multispecies swards) can further increase herbage production. Their deep roots can also improve soil structure and drought tolerance, while contributing to improved herbage mineral content and quality.

Box 9: *Optimising soil pH for legumes in grassland and arable systems*

> As legumes are highly sensitive to soil pH, to ensure persistence and to optimise BNF of legumes, soil pH must be in focus, targeting a soil pH in the range 6.5 to 6.8 for clay or silty dominated soil textures, and 5.5 to 5.9 for sandy soils. This will also ensure that P is available to the legumes from the soil pool will be comparatively high enough. K is also needed in high levels by legumes, with cattle slurry often a good source for grass-clover mixtures in grassland systems. For arable systems, as slurry contains a significant proportion of plant available N, such applications can reduce the overall N-fixation potential in the fertility-building phase of an arable rotation.
>
> ***Source:*** *Own compilation*

On the other hand, within **organic cropping systems**, N cycling is managed through a balance between restorative and exploitative phases. The inclusion of legumes in a 'ley phase' of a carefully designed crop rotation, along with optimal soil management, plays an important role in sustainable N cycling.

Following this ley phase, subsequent crops benefit from the residual N released by mineralisation of the plant biomass from the legumes. The efficiency of N transfer is influenced by several factors, including soil microbial activity, soil temperature, moisture, and the timing and intensity of tillage.

Livestock only and mixed livestock and crop enterprises have the direct benefit of being able to utilise a

long-term fertility building phase for livestock and complement soil and nutrient management with available farmyard manure slurry.

In contrast, a long-term fertility-building phase may not be financially viable in a stockless tillage system if an optimal price cannot be achieved for cash crops in the rotation. Therefore, as legume-grass mixtures are often not directly used as fodder crops on stockless farms, other strategies are needed. This should include feed-manure cooperation with a neighbouring livestock farm or the temporary grazing of livestock on-farm where possible.[9]

***Box 10:** Advantages of intercropping for improving productivity and quality*

Cultivating two or more crop species simultaneously within a field, known as intercropping or bi-cropping, is a proven management practice that can help to increase yields and crop stability in organic production. A common example is the intercropping of legumes (e.g. peas or beans) with cereal crops. In these mixtures, the legume contributes to fertility through BNF, which the companion cereal crop may utilise. European trials have also found that the overall yield of species mixes is higher than the average yield of individual crops. In addition, these legumes can contribute to increased protein content, while increased crop diversity helps to suppress weeds, reduce pests, and mitigate diseases. As a result, appropriate mixes can be of benefit both to increase organic cereals and grain legumes for animal food, as well as the production of high-quality food-grade grains.

***Source:** ReMIX, 2020*

Green manures and cover crops used regularly in the rotation for short periods of up to six months between cash crops can be effective at maintaining soil N as well as grain legume or cereal/pulse mixtures (*see Box 10*).

Furthermore, with the undersowing of clover in arable crops, a common practice amongst organic farmers, semi-permanent clover understories known as living mulches are an emerging practice that can have the dual benefit of supporting nutrient management and reduced tillage. It involves a cereal being drilled, after shallow tillage, into a clover understory, 1 year after its establishment. The practice can help to support N accumulation and soil microbes that enhance soil ecology and nutrient cycling, as well as provide other benefits such as weed suppression.

At the same time, it is critical to ensure crop diversity within the rotation in order to avoid disease complications.

4.3 Cover Crops and Green Manures

Cover crops and green manures can play an important role in supporting soil fertility management in organic farming systems. This involves the use of specific plant species or mixtures to enhance soil quality, structure, and nutrient cycling. Although the terms are sometimes used interchangeably, they serve slightly different purposes, but can frequently achieve both objectives to varying degrees depending on the species selection and overall aims (*see Box 11 and Table 6*).

The choice of species, management practices, and incorporation techniques should be tailored to the specific needs of the farming system, ensuring that the benefits outweigh the challenges. In stockless systems, such as horticulture or tillage cropping without livestock, green manures can be a key source of N. However, these systems often require additional N and other nutrient inputs from sources such as compost or manure to balance the N budget and other nutrient budgets to sustain yield levels over the long term.

Nevertheless, the potential benefits of cover crops and green manures mean that there remains a huge scope for them to be used more effectively in tillage and horticulture systems. Below, we highlight some common

9 Note that strategies such as the mulching of forage legumes in the field are not effective since they can lead to lower N-fixation, as the nutrient-rich mulch promotes further growth of non-leguminous species in a sward.

issues farmers and growers should consider when incorporating cover crops and green manures into their rotations (*see Table 6*).

Box 11: *Agronomic objectives of cover crops and green manures*

- **Cover crops** are primarily grown to protect and cover the soil, preventing erosion, suppressing weeds, and reducing nutrient leaching, without necessarily being incorporated back into the soil.
- **Green manures**, on the other hand, are grown with the specific intent of being incorporated into the soil to increase OM and provide nutrients, particularly N, to the subsequent crop.

Source: *Own Compilation*

Box 12: *Improving soil and nutrient management in organic horticulture - an Irish case study*

- The Irish Organic Association worked with 11 Irish organic horticulture growers nationwide to optimise production methods and improve the continuity of short supply chains through grower collaboration. As part of the project, a multi-annual investigation of the effects of short-term green manures on summer and winter cash crops in organic vegetable production was conducted (July 2018 - August 2021).
- Over 3 years, different summer and winter green manure mixes were sown and grown for 2 and 6 months respectively alongside control plots and subsequently incorporated into the soil, followed by the establishment of cash crops. Green manure application before cash crops over the three years achieved overall beneficial effects, including better weed control, more beneficial insects, more and greater functional diversity of soil bacteria, greater SOM content, and earlier developing crops compared to control plots.
- For instance, low-growing green manures (e.g., clover, ryegrass) helped to support more beneficial insects, while high-biomass green manures (e.g., cereals, phacelia, and buckwheat) helped to increase SOM.
- Integration of green manure mixes into rotations accelerated the growth of all four cash crops and thus demonstrated the potential for growers to extend the growing period for crops under Irish conditions.

Source: *MOPS, 2021*

Table 6: Utilising cover crops and green manures

Species selection		• Leguminous species, such as clovers, peas and beans, are excellent for fixing atmospheric N, contributing to the soil's N pool, while cereal crops, such as oats, wheat, and barley, are useful for their biomass production and their role in scavenging soil nutrients. • Green manures with deep taproots, like certain brassicas, legumes or herbs, can help improve soil structure, while shallow-rooted cover crops, like grasses, protect the soil surface. • Cold-hardy species are vital for winter green manuring, whereas fast-growing crops may be used during periods of fallow in the growing season to prevent nutrient loss and soil erosion. • Species should be selected carefully to prevent disease build-up or the transfer of disease to the following cash crop (e.g., club root, oat mosaic virus, take-all).
Establishment		• Spring and autumn are the best seasons for sowing green manures (with suitable soil temperatures, moisture content), especially clovers (April/May or August), though short-term summer green manures can be sown in June with irrigation where needed. • A suitable seedbed should be prepared in the usual way. If the site has a serious weed seed bank problem, consider using the stale seedbed technique, surface cultivating the soil 10-14 days after the initial cultivation, to kill off the first flush of weeds. • Clovers have small seeds and can be slow to establish, so a clean seedbed and seeding depth of 0.5 to 1.5 cm is important. Seed can be broadcast (needs a higher seeding rate) or drilled, and seeds can be covered by surface cultivation. • After sowing, the seedbed should be rolled under dry soil conditions to increase seed-soil contact, especially for the smaller-seeded green manures like clovers. • Green manure mixtures can be problematic in terms of consistency of seed delivery and seed depth, especially in grass/legume mixtures, such as large-seeded rye and small-seeded clovers.
Incorporation Methods	**Grazing**	• Grazing offers the advantage of accelerating decomposition in the animal's digestive tract, which allows for quicker nutrient release compared to microbial decomposition in the soil. • However, grazing can result in lower SOM gains compared to mechanical destruction, as much of the C content is lost through respiration and consumption by livestock. • The rapid breakdown of OM by grazing is particularly beneficial for materials with high C ratios, such as cereals.
	Mechanical Incorporation	• Before incorporation of the green manure into the soil, the shoots should be removed and cut up with a mulcher or flail mower. If the green manure is very leafy, it should be allowed to wilt for a few days. High-N (e.g., clovers) or leafy (e.g., mustard) green manures decompose faster than crops such as rye or ryegrass. • The faster the decomposition, the earlier the cash crop can be planted. Rather than incorporation with traditional deep ploughing, the aim is to incorporate through the top 10-15 cm of the soil, with several passes using a cultivator or rotavator. • During incorporation, one or more 0.5 m wide strips of the green manure, connected to a headland or hedgerow, can be retained as a refuge for beneficial insects, like ground beetles, allowing green manure plants to flower to attract pollinators and beneficial insects, such as hoverflies.

Source: *Maximising Organic Production Systems Project, 2021*

A crucial benefit of cover crops and green manures is their ability to manage soil N. Different crops and mixtures have varying N release dynamics based on their C:N ratio. Legumes typically have a low C ratio and release N quickly upon decomposition, providing an early-season N boost to subsequent crops. On the other hand, cereal crops or those with higher C ratios (e.g. straw or mustard) decompose more slowly, resulting in a delayed release of N.

This slower mineralisation helps balance the N supply throughout the growing season, reducing the risk of N leaching or losses. Species selection and careful management of green manure incorporation can help avoid a N flush.[10]

4.4 Crop Rotation Design and Nutrient Management

A well-designed crop rotation - along with the inclusion of fertility-building crops - is essential for maintaining soil health and quality. It supports nutrient availability/supply, particularly N, while helping to minimise losses. However, crop rotations should not be planned solely for nutrient management purposes.

Farmers and growers must also consider other objectives, such as reducing weed pressure and controlling pests and diseases. As all these components are interconnected and should not be considered in isolation.

The sequence of crops is designed to maximise the use of nutrients by aiming to match nutrient release - particularly N - to the demands of the specific crop. Nutrient-demanding crops, such as wheat and root vegetables, are typically grown first, followed by less demanding crops like brassicas, and finally, nutrient-scavenging species such as oats or N-fixing legumes.

Table 7: *Example of cattle manure prioritisation in mixed organic rotation*

Priority	Crop	Guidance Application Rate (t FYM/ha)
1	Silage and hay crops	15t/ha for first cut, 8t/ha for second cut
2	High-value arable crops (potatoes, brassicas) in the second or later course of the arable phase of rotation	15-20t/ha
3	Cereal crops in the second or later course of the arable phase of rotation	8t/ha
4	High-value arable crops (potatoes, brassicas) in the first arable course of rotation	5t/ha if sufficient manure available
5	Winter cereal crops in the first arable course of rotation (spring top dressing)	5t/ha if sufficient manure available
None applied	Grazed grass	
None applied	Spring cereals in the first arable course of rotation	

Source: *Younie, 2012*

10 A N flush may lead to losses if it is not synchronised with the nutrient demands of subsequent crops.

Crop selection and planning should be revisited annually, based on soil nutrient levels, pest and disease presence, weed pressure, and market demands. This flexibility ensures rotations are dynamic and adapted to changing conditions, rather than being rigidly pre-set. *Table 8* outlines some of the soil and nutrient management characteristics for individual crops that should be considered as part of rotation design. At the same time, nutrient planning must consider not only N, but also P and K, as different cops have varying requirements.

4.5 Nutrient Management in the Rotation

Periodic inputs of organic materials such as slurry, farmyard manure and other approved inputs are required at different stages of the rotation, based on the resources available to the farm (see example of cattle manure in Table 7). Composts, where available, should be applied to forage and grain legumes as they have low plant available N and their application will avoid undermining N-fixation. On the other hand, solid farmyard manure should be ideally applied to all other non-legume crops, while slurry is appropriate for potatoes or cereals in the spring, especially before other winter crops are sown which require significant N.

The legume-grass ley phase is an opportune time to apply P and lime, as these inputs enhance BNF and optimise soil pH under the ley, promoting maximum pasture productivity. Applying P at the start of the ley phase supports microbial activity, aiding the conversion of mineral P into plant-available forms for subsequent crops. Similarly, incorporating lime early allows it to adjust soil pH effectively and minimises the risk of lime damage to sensitive crops, such as potatoes, planted after pasture.

For green manures, on the other hand, it is better to apply lime prior to establishing lime-tolerant species to optimise soil pH before the succeeding crop is sown or planted. For K, application at the start of the ley phase can support early root development and pasture growth, while contributing to the accumulation of K. However, where soil K levels are already adequate, deferring applications until later in the rotation, particularly for high-demanding crops such as root vegetables, may improve nutrient use efficacy and reduce the risk of environmental losses.

Table 8: *Characteristics of some crops in the context of rotation design*

Crop	Rooting depth	Residual biomass (tDM/ha)	Soil Structure	Contribution to Organic Matter	Nitrogen Balance	Weed Control	Pests and Diseases		Winter Soil Cover
							Self-tolerance	Break (years)	
Wheat	0/+	0.9-1.7	-/+	-/0	-	-/0	-	2-4	-/+
Barley	0/+		-/+	-/0	-	-/0	-/0	2-4	-/+
Oats	0/+		-/+	-/0	-	-/+	--	5	-/+
Rye/spelt	0/+		-/+	-/0	-	0/+	+	1	-/+
Field beans	0	0.5-2.3	0	0	+	-/0	-/+	4-5	-/+
Field peas	0		0	0	+	--	--	6-7	-
Potatoes	-	0.6-1.0	-/0	--	--	-/+	--	4-5	--
Beet	-		-/0	--	-	-/+	--	4-5	--
Carrots	-		-/0	--	-	-/+	-	3-4	--
Maize	0	1.8-2.2	--/0	0	--	-/+	+	-	--/+
Rape	0	1.3-1.5	0	0	-	+	--	3-4	-/+
Turnips	0		0	0	-	-/+	--	3-4	-/+
Green manures - non-leguminous	-/+	0.9-3.0	0/+	0/+	-/0	+	+/-	-	+
- leguminous	-/+		0/+	0/+	0/+	+	+	-	+
Red-clover based short-term ley	+	4.5-5.5	++	++	+++	++	--	6	++
White-clover based longer-term ley	0	6.0-8.0	++	+++	++	++	0/+	-	++
Lucerne	++		++	+++	+++	+/-	--	5	++

Notes: *+++ Excellent, ++ Very good/very deep/very large, + Good/deep/large, 0 Neutral/average/medium, - Bad/shallow/small, -- Very bad*

Sources: *Lampkin, 2002 and Briggs, 2008*

5

References and **Further Reading**

- AHDB (2024). *How to count earthworms*. Agriculture and Horticulture Development Board.
- Ball, B., et al. (2012). *Visual Evaluation of Soil Structure*. Aarhus University, UEM and SRUC - Scotland's Rural College.
- Barry, P., and Merfield, C. (2008). *Nutrient Management on Organic Farms*. Teagasc.
- Briggs, S. (2008). *Organic Cereal and Pulse Production: A Complete Guide*. Marlborough: Crowood Press.
- Clavin, D., and Leavy, E. eds. (2017). *Nutrient management on organic cattle farms. In: Guidelines for Successful Organic Beef Production*, 2nd ed. Teagasc.
- Danú (2024). *Transition to Biological Farming: End of Project Report*. Danú EIP.
- Gerlach, F., et al. (2013). *Sustainable biogas production: A handbook for organic farmers*. SUSTAINGAS, FiBL – Research Institute of Organic Agriculture.
- Griffiths, B., et al. (2019). *The soil food web*. Great Soils Factsheet, Agriculture and Horticulture Development Board.
- Lampkin, N (2002). *Organic Farming*. Ipswich: Old Pond Publishing.
- Lea, M., et al. (2025). *Living Mulches Technical Guide: How to get started with living mulches*. Organic Research Centre.
- MOPS (2021). *Maximising Organic Production Systems: Growers' Report*. MOPS EIP, Irish Organic Association.
- Pfiffner, L. (2022). *Earthworms - architects of fertile soils: Their significance and recommendations for their promotion in agriculture*. FiBL – Research Institute of Organic Agriculture.

- Reimer, M., et al. (2020). *Farm gate nutrient budgets for organic farming*. University of Hohenheim, University of Copenhagen, and FiBL – Research Institute for Organic Agriculture.
- Sinclair, A., et al. (2014). *Assessment of Soil Texture In: Soils information, texture and liming recommendations*. SRUC – Scotland's Rural College.
- Snauwaert, E., et al. (2017). *On Farm Tools for accurate fertilisation*. EIP-AGRI Focus Group – Nutrient recycling.
- Wall, D. P., & Plunkett, M. (2020). *Major and micronutrient advice for productive agricultural crops, 5th ed*. Teagasc.
- Watson, C. et al. (2020). *Intercropping grain-legumes and cereals for improved protein concentration in the cereal*. IFOAM EU Group, SRUC – Scotland's Rural College and Aristotle University of Thessaloniki.
- Watson, C., et al. (2010). *A Guide to Nutrient Budgeting on Farms*. IOTA - Institute of Organic Training & Advice.
- Younie, D. (2012). *Grassland Management for Organic Farmers*. Marlborough: Crowood Press.

Follow our journey!

Learn more about us at
www.nutri-know.eu

@NutriKnow

NUTRI-KNOW

@nutriknoweu

Nutri-Know

Project **partners**

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authority can be held responsible for them.