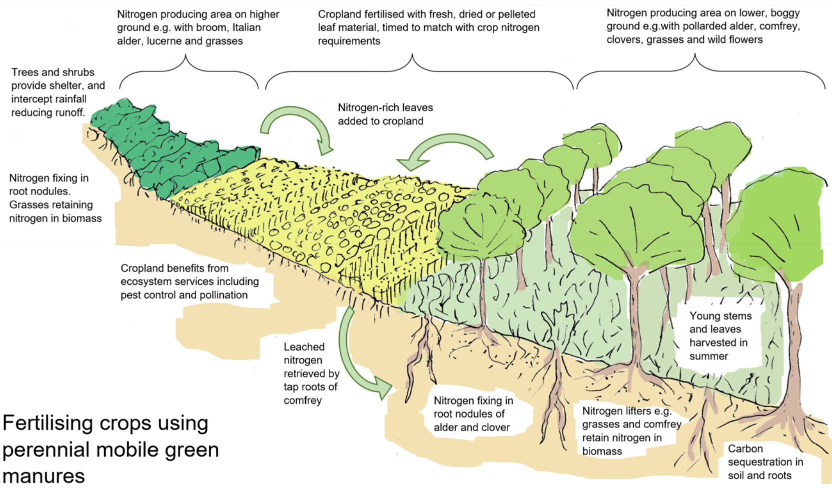
Tackling the nitrogen problem – how best to manage this brilliant but volatile element?

I face a dilemma when growing vegetables. If I pile on the compost or dig in lots of lush green manure, my crops will grow fast. But am I really 'feeding the soil to feed the crops' as the organic mantra goes? Or am I feeding the crops directly, just like in a non-organic system? In natural systems there is a steady trickle of plant-available nitrogen due to microbes processing organic matter in the soil. Soil doesn't suddenly gain a load of easily available nitrogen like floppy bright green plant material, or rich dark compost unless humans are around.

Nitrogen losses from cropping systems

Adequate nitrogen is key to good yields but supplying the right amount at the right time is tricky. When it's in a form available to plants, it's also easily lost from the soil. At the risk of humanising a chemical element – nitrogen is a difficult one to manage. It's well-behaved and stable when in the form of dinitrogen gas in the air, but it's changeable, unpredictable and prone to damaging outbursts when contained within soluble compounds in soil.



Fertilising crops using perennial mobile green manures

The decomposition and cycling of organic materials by soil fauna and microbes is what organic growing is all about – necessary for a healthy functioning soil. After organic materials are added to soil the nitrogen within leaf proteins is decomposed, releasing ammonium and nitrate which are taken up by crops. When managed well, we really are feeding the soil which feeds the crops, but with some organic materials it doesn't take that much microbial action to release the nitrogen. The ammonium and nitrate from organic matter decomposition are the same compounds as are added as manufacture fertiliser. If there is more in the soil than the crop can use, the nitrogen is prone to leaking out of the agricultural system by leaching of nitrate or as the very powerful greenhouse gas nitrous oxide[1]. Nitrous oxide accounts for a third of the UK's greenhouse gas emissions from agriculture. It is a well-known effect of manufactured fertilisers and due to this (as well as high fertiliser prices) inorganic farmers are recommended to add nitrogen in stages over the growing season to match the crop demand, with methods of precision agriculture being developed to further reduce excesses in soil[2].

With bulky organic materials, it can be difficult to add the right amount of nitrogen at the right time. The ploughing in of green manures is a bit of a blunt tool, so the leaf material may well decompose to available nitrogen before the crop is ready to take it up. Nitrous oxide emissions are higher in warm wet conditions, and leaching is a risk after heavy rains. Therefore, a good soil structure which is not prone to waterlogging will help reduce losses, but organic growing is not, unfortunately immune to nitrogen loss. The increasingly unpredictable weather makes it harder to estimate the speed of green manure decomposition and crop growth, so climate change is making nitrogen management even more tricky.

Environmental impact of nitrogen fixing

The other big issue with nitrogen use is where it comes from. Nitrogen in organic matter and fertilisers has at some point been 'fixed' from atmospheric nitrogen gas, a process which requires a large amount of energy. Fertiliser nitrogen has been fixed by use of fossil fuels (the product of historical photosynthesis) and is responsible for 1 to 2% of the world's carbon emissions. As organic growers, we instead use today's photosynthetic energy to power nitrogen-fixing bacteria in root nodules. The nitrogen within any organic material added to soil has got there by one of these two routes, for example, nitrogen in animal manure has come from the animals' food. That food, whether it was grazed from a hillside or fed from a trough has been grown by use of either manufactured fertiliser or biological nitrogen fixing.

A drawback of biological nitrogen fixing though is that it needs space to capture the sunlight energy. Even growers very skilled in nutrient management need to put land down to a fertility building leys in rotations, not just for cover cropping over winter, but to make use of summer sun for nitrogen fixing. If an organic farm is not buying in nitrogenous materials, then typically at least a quarter of the land will be used for fertility building at any one time. This restricts options for growers, and overall reduces the productivity of the farm. It is also an argument made against organics that the extra area needed competes with the availability of land for habitat restoration.

Nitrogen-smart organics and a new role for trees?

To manage organic nitrogen more efficiently, some growers use 'cut-and-carry' or 'mobile' green manures, by harvesting nitrogen-rich leaf matter from green manures grown in a separate field and adding it to cropland. This allows the additions to be better timed to match with the nitrogen demand of the crop preventing excesses in the soil. This cutting and mulching strategy also fits in well with no-till systems. Another technique to help retain nitrogen excess in soil e.g. when ploughing in lush green manures or crop residues, is to mix in high carbon materials such as straw or wood chip to make use of the nitrogen-lock up effect. The nitrogen immobilised will then be gradually released over time.

Traditionally, green manures are non woody plants as they need to be dug in, but cutting and adding leaf nitrogen opens up possibilities of utilising other nitrogen-fixing plants including the leaves of trees and shrubs as is practiced in some tropical farming systems. Could we, therefore, have a system of nitrogen-fixing coppiced woodland areas, from which nitrogen rich foliage is harvested and added to fertilise cropland? A nitrogen producing agroforestry system? The huge leaf area and large root systems of trees, make great use of above and below ground space. Though fertility building leys used in rotations can be very species-rich providing good ecosystem services, creating permanent N fixing areas offering a range of habitats and carbon sequestration in trees, roots and undisturbed soil, may offer higher ecological value in the right situations.

Various nitrogen-fixing species thrive in situations where crops don't, so perennial nitrogen producing areas could be situated on less productive land such as boggy areas or steep slopes. In our temperate climate there are a variety of nitrogen-fixing perennials which may be suitable. Alder (*Alnus glutinosa)* for example, is a nitrogen-fixing tree which grows happily in flood-prone soil and is tolerant of repeated cutting. Other species of alder grow on drier ground, as do the native nitrogen fixing shrubs gorse and broom.

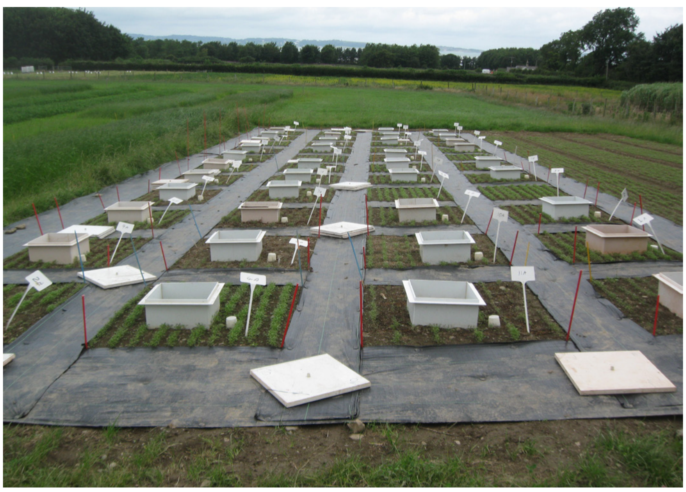
N fixing nodules Alnus glutinosa

Long-lived traditional green manures such as clovers and alfalfa could also be included as ground covers, and just as traditional fertility building leys benefit from a mix of N fixers and N lifters, which intercept leachate and retain nitrogen in the system, so would permanent nitrogen producing areas. Therefore, non-nitrogen fixing species such as fast-growing willows and deep-rooted comfrey and grasses could be intercropped with the nitrogen fixers.

On arable farms, nitrogen fixing areas could be designed to be multifunctional, with trees serving as windbreaks, helping flood prevention, and reducing nitrogen loss by intercepting leachate from field boundaries[3]. On land not suited to arable crops it could be possible to produce dried or pelleted leaf material as an organic fertiliser for arable or horticultural producers. A new non-timber forest product (NTFP) and another alternative land use for land which is currently considered only suitable for grazing?

Perennial Mobile Green Manures (PMGMs)

To see if such systems could work in real life, the local environmental group Ecodyfi in mid-Wales has recently been awarded funding by the Co op Carbon Innovation Fund to work with local growers and farmers to conduct crop trials[4]. The trials follow on from research I did for a PhD which began back in 2016. I tested what I termed perennial mobile green manures (PMGMs) in pot, field and lab studies in comparison with ammonium nitrate fertiliser, and the traditional green manure, red clover. Fertilisation by alder leaves, in particular, gave good yields with lower nitrous oxide emissions or risk of nitrate leaching than either red clover (used in the traditional way) or ammonium nitrate[4].



Photos: Clo Ward

PGM trial at Bangor University

Different species of PMGM release nitrogen at different rates depending on the leaf chemistry, including the carbon content, and chemicals which resist decomposition. Tougher leaves and some leaf-parts break down very slowly. Some are more readily incorporated into organic matter, improving soil health and releasing nitrogen bit by bit, and others break down quickly with nitrogen fast released to feed crops. Knowledge of the characteristic of each green manure species allows for strategic use, for example, alder leaves which supply nitrogen fairly slowly, could be added to soil before planting a long-lived crop to build up soil organic matter and release nitrogen slowly. Later in the growing season at times of high nitrogen demand, small additions of dried clover or comfrey could be added for a quick nitrogen boost. The PMGMs could be used in combination with other soil additions such as crop residues, animal manures or winter cover crops. Strategic use by skilled growers of dried or pelleted green manures of known macro nutrient content may also help tackle 'soil obesity' and maintain balances of other nutrients e.g. P, K or Mg addressing issues highlighted in the Organic Grower[5].

For the farm trials we are collecting foliage of a range of species this summer, which will be dried or pelleted for use in 2023. Local growers will experiment with using single species or mixes of PMGMs compared to their usual method of crop fertilisation. I hope that by combining growers' knowledge, with some basic science we will gain insights into the feasibility of the technique and how it could work in specific situations. The results of the trials will be used to inform the design of new perennial nitrogen fixing areas to be planted on each farm in winter 2023/4. If you are a grower based in mid-Wales and would be interested in taking part, please see details below and get in touch.

Clo Ward

Clo (Chloe) Ward is currently the researcher for the Perennial Green Manures project, run by Ecodyfi. See https://www.dyfibiosphere.wales/perennial-green-manures for more on the project

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