Improving biodiversity through soil health with microbial rich compost

A SHF Project 2024

1. Why did we start this project?

The Klompe Farm, the partner farm of the Soil Heroes Foundation, were struggling with accessing good quality compost. As regenerative farmers, they were aware of the vital importance soil biology has in regenerative farming systems and overall soil health and knew that this was linked to improving the soil organic matter in their soils, and increasing the fungal to bacterial ratio in the soil biology. In order to achieve these objectives, they chose to apply high quality microbial rich solid compost.

However, accessing good quality compost – i.e. compost that is nutritionally balanced, based on a high percentage of carbon inputs, free of contaminants, and possessing a rich microbial community, and permitted for use on farmland, was difficult to access, and expensive. Over the last 5 years the Klompe Farm have applied 1300 tonnes of compost per year at a rate of €22-23 per m3 and a total cost of €40,000 per annum. Such a large investment in compost is not financially viable for a large percentage of farmers, and can dissuade potential regenerative farmers from transitioning their own farms.

Manure, another source of organic matter (and nitrogen) is also limited. With the livestock sector having become increasingly intensive and streamlined, most farms – especially in intensive livestock producing regions -such as the Netherlands, Northern France, Northern Belgium etc., produce slurry – which farmers are paid to inject into the soils[1]. Thus getting hold of (and conversely paying for) manure – i.e. mixed with bedding material – is difficult. To give an indication, manure costs €12-14 per m3 + transport, yet farmers are paid €13/m3 of slurry injected into the soil. Thus the difference in price between a farmer choosing to buy manure rather than accept slurry is €27/m3.

In addition to the scarcity and price of good quality compost, many regenerative farms are having to balance the important benefits of cover crops against the difficulty of managing the large amounts of biomass on the fields prior to seeding.

All these aspects – the expense of quality compost, the limited access to manure and the difficulty managing biomass on the fields - led us to question if it could be possible to develop a business model that allowed regenerative farmers to make quality microbial rich compost from

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[1] The injection of slurry can lead to the acidification of the soil which will negatively impact the soil biodiversity (Zireeni, Y., Jones, D. and Chadwick, D. 2003. Influence of slurry acidification with H_2SO_4 on soil pH, N, P, S, and C dynamics: Incubation experiment. Environmental Advances. Vol14.)

the cover crop biomass, in addition to other farm residues (straw, maize stalks etc. + animal manure if the farm was mixed), thus solving a series of challenges at once.

2. The approach

This project was not a scientific academic study, rather we aimed to draw upon the knowledge of experts in the field through interviews, farm visits, conferences etc as well as delving into the academic literature (see annex 1 for those consulted during this project). The goal was to consult experts and practitioners in the field to identify the best approach to designing an on farm compost production process for microbial rich compost - looking into the logistics, access to materials, machinery and the financial implications of the approach (including person hours, machinery, input costs etc.). And to do this within the regulatory framework, using easily and sustainable inputs from the farm, and accessible for the farm. We then aimed to use this plan for a second project: to apply this plan on the Klompe Farm to test the theory against real time management and compost testing, and in doing so develop a step by step composting plan for farmers. In doing so we hoped to show farmers a cost effective way of producing quality microbial rich compost for their farms, and thus remove a key cost barrier for regenerative agriculture.

Originally we had envisaged that the project would follow the steps outlined below:

- We would understand the regulations surrounding making on farm compost
- Working within these parameters, we would talk to a series of experts taking a range of approaches to on farming composting
- Going into each of the processes – we would identify the most appropriate for a large arable farm – based on the inputs, processes, labour input, and costings. This would be the end of this project.
- Then, in 2025 we would fundraise to take this plan and trial it as a proof of practice project on the Klompe Farm. Using the data developed in this project – including practical lessons learnt, compost testing, soil testing and financial data, we would write a composting manual for farmers – including a breakdown of the time and costs.

However, through our research we quickly identified that the regulatory system in the Netherlands would make such an approach non-viable – both in terms of logistics and costs. It also led us to question if the annual application of solid manure on an arable farm was indeed the most cost effective way to address the objectives identified by the Klompe Farm for the application of the compost, namely improving the soil organic matter, the overall soil biology and fungal:bacterial ratios of the soils.

3. The Findings

3.1 Regulations

The first part of the project was to understand what regulations the on farm composting would need to work within. This very quickly identified that creating adequate solid compost on the farm to meet the needs of 200ha of regenerative land, and replace the bought in compost, was not possible.

The regulations in the Netherlands, and in many members states of the EU are extremely restrictive vis a vis on farm composting. On farm composting is regulated by two legislations: the manure legislation (if the compost is to contain animal manure), and the Soil Protection Act.

According to the Soil Protection Act legislation, compost is divided into two categories: GFT (household organic waste) and green waste compost. As GFT may contain animal residues such a meat, fish and egg waste, as well as plastics and heavy metals, compost from GFT is not allowed to be applied to agricultural land, and thus we will deal only with compost from green waste in this document.

Green waste compost under the soil protection act

- Compost must be heated above 80 Celsius (for commercial enterprises) to prevent pathogen contamination and destroy weed seeds
- Farms may only produce on farm up to **600m3 per batch of compost** without requiring location and production permits and certifications.
- They may only use green residues from the farm's operation and are not allowed to include external materials sourced from outside the farm - such as leaf mould, wood chip or manure (batches of up to 3m3 can be produced without the restrictions on adding in external material).
- Storage of compost – if over 3m3, compost must be stored at least 50m from houses, and 5 meters from waterways. It can only be kept on fields for between 2 and 6 months.

The limitation of 600m3 of compost is severely limiting for a large arable farm. As noted above, the Klompe Farm applies over 1700m3 per year to its fields. Whilst a farm may produce several batches of 600m3 to reach 1700m3, the multiplication of the batches greatly increases the manpower hours required to mix and turn the compost. It also presents logistical and regulatory issues of where to store the made compost until it is needed (and the expenses of ensuring said compost is correctly stored within line with compost storage regulations). In addition, there is the issue of storing the mown cover crops if they cannot be composted immediately, which would likely have to involve a complex process of managed fermentation.

Therefore the restrictions included in the Soil Protection Act for Green Waste means that whilst it maybe possible to make enough on farm compost, without having a specialist waste processing certification, the cost and complexity of logistics involved for multibatch production makes it non viable. And therefore, the business case of using farm biomass to replace bought in compost is not possible.

Companies who know of the need of farmers for quality compost, and aware of these stringent regulations in the Netherlands have attempted to find ways around them. One such example is the Agricyling initiative in Friesland which now has 160 farmers involved. Agricyling aims to make on farm composting more accessible to farmers by processing their compost for them on their farms – under their own waste processor certification (thus getting around the restrictions applied to farmers such as not bringing on farm external inputs or limitations on quantities). They take responsibility for setting up the winrows, and organise the inputs such as road grass cuttings, test the inputs and set up the plan and logbook for the farmers. The farmers then turn and monitor the winrows according to Agricycle's instructions. Upon completion, the compost is analysed and certified by Agricycle to ensure it meets the stringent regulatory requirements, before the farmer can apply it to their fields.

Another example set up in October 2023, as part of the Hoeksche Waard Area Program, a was an farmer led initiative (by Gert-Jan Dueren den Hollander) to process green waste streams into bokashi, which could then be applied as organic matter to their fields. Again, due to complex legislation and regulations, it was decided to partner with GKB Barendrecht for the project implementation. All activities were thus managed under GKB's permits and regulatory processes. [More information on GKB Barendrecht's natural waste program]

However even these initiatives which partner with waste processors to in order to operate under the complex regulations are under threat. They have gained a great degree of resistance from the traditional green waste processing companies in the Netherlands who see this approach as undercutting their own businesses, and claim that the approach is less stringent than their own and have threatened to take [such initiatives to court.]

This is an evolving story, as are the stringent compost regulations that will no doubt evolve as the circular economy develops. But for now, and at least in the short term, developing enough solid compost on farm in a financially viable way is not an option.

This led us to relook at the need to apply solid compost to the fields and ask the question if this is this best approach for a farmer to improve soil organic matter and boost soil biology.

3.2 Increasing the fungal:bacterial ratio in soils

The Klompe Farm was advised to apply *fungal dominant solid compost* on an annual basis to improve the fungal:bacterial ratio of their soils alongside the soil organic matter content.

Fungal dominance in soils is increasingly being seen as a key indicator of soil health, primarily led by the Elaine Ingham Soil Web school of thought (in addition to the growing body of research regarding the role fungal dominance in soils has on carbon sequestration).

A wide range of bacteria and fungi play crucial roles in breaking down organic matter in the soils. Fungi primarily decompose complex organic matter like lignin, which is found in woody plant materials. They are more efficient at breaking down carbon-rich compounds and play a key role in building stable soil carbon stores. Fungi also forms beneficial relationships with plant roots (mycorrhizae), helping plants absorb nutrients like phosphorus. Bacteria specialize in breaking down simpler organic compounds, such as sugars and proteins. They thrive in soils rich in nitrogen and help in quick nutrient cycling but do not contribute as much to long-term carbon sequestration.

Both fungal and bacterial communities are significantly influenced by agricultural management practices and in general it can be said that soils that are regularly ploughed/ are compacted and or have regular applications high nitrogen fertilisers maybe more bacterial dominant which may lead to more rapid nutrient cycling but may also lead them to lose organic matter faster and thus make them more prevalent to erosion and nutrient leaching. Whereas fungal dominant soils are often found in soils that are not or less disturbed and tend to store more carbon and have greater resilience, structure, and moisture-holding capacity, which makes them more sustainable over the long term[2]. There is also the argument from the Elaine Ingham soil food web that says that more bacterial dominant soils lead to greater weed growth. But it is not clear if this is to do with soil disturbance or the fungi.

There are thus three ways to improve the fungal to bacteria ratio in the soil:

- Through farm management practices (no till, reduction of nitrogen applications etc.).

[2] Khmelevtsova LE, Sazykin IS, Azhogina TN, Sazykina MA. Influence of Agricultural Practices on Bacterial Community of Cultivated Soils. *Agriculture*. 2022; 12(3):371. https://doi.org/10.3390/agriculture12030371

- Through increasing the carbon content in the soils (manure, compost, composting mown cover crops on the field, biochar, keeping crop residues on the field etc.).
- Through the actual plants grown on the fields, as the plants themselves will influence the fungi:bacterial – woodland and woody perennials producing (and preferring greater fungal dominance), annuals such as corn, less.

What comes across as universally agreed from what we read, and those we spoke to, is that fungi thrive in carbon rich soils, and thus, the application of carbon rich compost onto soil encourages the growth of fungi in the soils, if done in conjunction with other regenerative practices.

Therefore, the practices that Klompe Farm are already applying – no tillage, no use of synthetic N fertiliser applications and the application of organic matter – will improve the fungi-bacterial ratio.

To verify this, we tested the fungi -bacteria ratios on the regeneratively managed soils versus the conventionally managed soils using the microbiometer. The figures in the table below are an average of the 3 repetitions of test plots that we are running for a project on nutritional density.

As you can see after only one year there are already differences with the test plots. Over all, the regeneratively managed plots show a higher microbial biomass than the conventional plots, and a higher fungal to bacteria ratio. But even within the regeneratively managed plots we can see the positive impact no tillage has on microbial biomass and fungi:bacteria ratios. And whilst the plots that had organic matter added (manure and compost) had the highest microbial biomass, the difference with the biofertilizer/compost tea is marginal and indeed the fungi:bacteria ratio is higher on the biofertilizer/ compost tea plot than the organic matter plots.

	No Till	**Till**	**No Till**	**Till**
Practice	**Microbial biomass (ug C/g)**		**Fungi:Bacteria ratio**	
Organic matter	334	241	0,53	0,33
Biofertiliser + compost tea	324	217	0,60	0,30
Companion crop	280	219	0,53	0,33
Mulch	263	211	0,40	0,23
Reference (organic atter+biofertiliser +compost tea)	311	226	0,57	0,23
Conventional (till, slurry, NPK fertiliser etc.)	165		0,13	

Figure 1: Microbiometer results of Soil Heroes Foundation test plots summer 2024.

How to measure the fungi:bacteria ratios in soils remains greatly debated in the scientific community, as does what the results actually represent, and there is no specific ratio that farmers should aim for. Whilst this area of science is still in its infancy. After discussing fungi:bacteria ratios (and the need to focus on increasing them) with those consulted, we came to the conclusion that we should not focus on improving fungi:bacteria ratios per se. Rather, we should focus on the range of regenerative practices to improve all aspects of soils health, and we would then see these improvement likely reflected in the fungi:bacteria ratios as the soil improved i.e. to see the improvement in the ratio over time as an indicator of overall soil health, rather than an objective in itself.

We could find no evidence that the application of specifically fungal dominant compost improved the fungi:bacteria ratio in the soils (as the Klompe Farm had been advised), and indeed only one of those we consulted saw the link between fungal dominant compost and fungal dominant soils.   Rather it was the addition of carbon rich compost – as one way of increasing soil organic carbon – which would increase the fungi in the soil, when done in conjunction with other practices (soil organic matter is a primary source of carbon (C) which gives energy and nutrients to soil organisms. This supports soil functionality because it improves the activity of microorganisms in the soil and it can enhance biodiversity).

In addition, all but one of those we spoke to were not systemically applying solid compost year on year. Rather, the general consensus was that whilst there is an important benefit in applying solid compost to accelerate the improvement in soil biology in poor soils in the early years, once improved, the soil biology could then be maintained or gradually improved by the application of regenerative practices that reduce disturbance (chemical or physical), improve diversity and increase soil organic carbon.

When asked how many years a farmer regenerating his/ her soils should apply compost, the answer came down to price. Great if you can afford to apply solid compost year on year at least in the early years. However if you can't, try every other, or every three years. Equally it is also an option to rely on less costly measures such as composting cover crops on field, no till, leaving crop residues etc. However, the soil will regenerate at a slower rate.

In summary, the general consensus was that when balancing the cost versus the benefit of the systematic application of solid manure year on year infinitum, in addition to a combination of other regenerative practices, the cost to benefit was too high.

However, the systematic application of compost tea[3] was seen as an important on farm practice to support soil biology. As compost tea is based on small quantities of quality compost, farmers can easily make the compost themselves within the regulations – if necessary bringing material from offsite. There are well documented methods such as the Johnson-Su method which require little investment or time.   This is one area that we are keen to explore further, trialling different compost tea methods and the impact on the soil, potentially in collaboration with a research institution, bringing together their scientific testing expertise for soil and crop testing, with a proof of practice project which would look into the real costings and time required for making the tea and repeated applications.

The final way to improve the fungi:bacteria ratio, as mentioned, is by the plants themselves. Such as cover crops mixes (below) that focus on improving the fungal to bacterial ratios.

[3] **Compost tea:** Derived from compost, it contains soluble nutrients as well as useful compounds like metabolites and microorganisms such as bacteria, actinomycetes, filamentous fungi, yeasts and oomycetes and has been shown to both improve plant growth and disease resistance. https://www.best4soil.eu/assets/factsheets/22.pdf

mix 11		Ik zaai:	
soort		advies hoeveelheid/h	
blauwe lupine	Lupinus angustifolius	5,0	kg/ha
lupine winter hard	ras Orus (/Magnus/Ulysse	20,0	kg/ha
winterwikke	Vicia sativa	10,0	kg/ha
perzische klaver	Trifolium resupinatum	5,0	kg/ha
inkarnaat klaver	Trifolium incarnatum	10,0	kg/ha
winter rogge	Secale cereale	50,0	kg/ha
Winter gerst	Hordeum vulgare	20,0	kg/ha
zomer gerst	Hordeum vulgare	20,0	kg/ha
zomer haver	Avena sativa	20,0	kg/ha

mix 2		Ik za	
soort		advies hoeveelheid	
Winter erwten	Pisum sativum	30,0	kg/h
Tillage Radisch	Raphanus sativus var. Lo	0,3	kg/h
zomer haver	Avena sativa	5,0	kg/h
wintergerst	Hordeum vulgare	20,0	kg/h
winterrogge	Secale cereale	20,0	kg/h
Winter wikke	Vicia sativa	10,6	kg/h
Facelia	Phacelia tanacetifolia	1,0	kg/h
Gele mosterd	Sinapis alba	0,3	kg/h
Ethiopische moste	Brassica carinata	0,3	kg/h
Alexandrijnse klav	Trifolium alexandrinum	1,0	kg/h
Perzische klaver	Trifolium resupinatum	5,0	kg/h
platte erwten	Lathyrus sativus	3,0	kg/h
(Paarse) wikke	Vica benghalensis	2,0	kg/h
Olievlas	Linum usitatissimum	2,0	kg/h
Tuinkers	Lepidium sativum	1,0	kg/h
Zonnebloem	Helianthus annuus	5,0	kg/h
Boekweit	Fagopyrum tataricum	2,0	kg/h
voeder linze	Lens nigricans	4,0	kg/h
fenugreek	Trigonella foenum-graec	1,5	kg/h
Blauwe lupine	Lupinus angustifolius	1,0	kg/h
lupine winter harc	ras Orus (/Magnus/Ulyss	5,0	kg/h

Figure 2: cover crop mixes developed by Stefan Muijtjesn of Landbouwadviseur to improve the fungal:bacterial rations in the soils

3.3 Increasing Soil Organic Matter

Soil Organic Matter (or Soil Carbon)[4] is crucial in order to provide the related benefits of improved soil aeration, water holding capacity and root penetration, as well as providing a nutrient supply (primarily P and K), carbon sequestration, pest and disease suppression, soil workability, biodiversity, water holding capacity and reduced erosion[5]. These benefits in turn can improve crop yield, resilience and the ability of the farmer to reduce additional synthetic inputs, as well as secure the long term resilience of his soils for future crops.

Years of conventional agriculture have created a deficit in soil organic matter by gradually over time, removing more organic matter than is added. Indeed, in 2002, the European Commission identified declining soil organic matter content as one of the most serious causes of soil degradation[6].

[4] **The difference between Soil Organic Matter (SOM) and Soil Organic Carbon (SOC):** Soil organic matter is the collective term for all the material found in the soil that comes from microorganisms, plants and animals. Organic matter consists largely of complex molecules of carbon (C), oxygen (O) and hydrogen (H). It also contains other organic substances (e.g. proteins and amino acids) which include nitrogen (N), phosphorus (P) and sulphur (S).As a guideline, soil organic carbon makes up about 50% of the organic matter, however, this percentage varies widely (between 30 and 70%). The actual soil organic carbon content depends on factors such as the origin of the organic matter and the type of soil.

[5] EIP-Agri. Soil organic matter matters Investing in soil quality for long-term benefits. European Union. https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_brochure_soil_organic_matter_matters_2016_en_web.pdf

[6] Ibid

This has occurred through the use of the following practices:

- The **removal of the crop during harvest.** This is the very nature of agriculture based on annual crops (rather than perennial agriculture), and thus is in essence, inevitable, but is more so when the plant residues are also removed.
- **Tillage** – this I thought to be the most impactful practice on organic matter loss. Tillage aerates the soil with oxygen, thereby accelerating decomposition and resulting in the release of SOM in the form of carbon dioxide. As the decomposition of organic matter and the liberation of C are aerobic processes, the oxygen stimulates or speeds up the action of soil microbes, which feed on organic matter. This means that when ploughed, the residues are incorporated in the soil together with air and come into contact with many micro-organisms, which accelerates the carbon cycle. The decomposition is faster, resulting in the formation of less stable humus and an increased liberation of CO2 to the atmosphere, and thus a reduction in organic matter.[7]
- **Bare soils** contribute to organic matter loss in the same way, exposing the soil organic matter to oxygen and thus the loss of the soil organic carbon component.
- The **overuse of nitrogen fertilisers over time**. This is thought to boost the micro-organism activity and thus decomposition of organic matter. The chemicals provide the microorganisms with easy-to-use N components[8].

The table below gives an indication of how soil disturbance can affect the loss of organic matter.

Type of tillage	Organic matter lost in 19 days (kg/ha)
Mouldboard plough + disc harrow (2x)	4 300
Mouldboard plough	2 230
Disc harrow	1 840
Chisel plough	1 720
Direct seeding	860

Figure 3: Tillage induced flush of decomposition or organic matter[9].

The previous decades of agriculture have predominantly been defined by increased mechanisation, including ploughing, bare soils and a widespread reliance on synthetic inputs. In addition, farms have become more specialised and the traditional integration of livestock and arable farming has become mostly separated – thus the tradition of replacing lost organic matter with manure (as opposed to slurry) and crop residues has largely declined.

Regenerative agricultural practices, when combined, improve soil organic matter, precisely because they largely reverse the very practices that are leading to organic matter loss. When combined, the effect is multiplied.

- Reducing soil disturbance through no or reduced till – with a preference for direct sowing

[7] https://www.fao.org/4/a0100e/a0100e07.htm
[8] UNFAO. Technical Papers Factors that affect the amount of organic matter. Ch4 https://www.fao.org/4/a0100e/a0100e07
[9] Glanz, J.1995.Saving our soil: solutions for sustaining earth's vital resource. Boulder, USA, Johnson Printing.

- Cover cropping – aiming for year round soil coverage with multispecies cover crops (variated rooting) and on field cover crop composting.
- Diversifying crop rotations and different rooting systems
- Residue incorporation
- The addition of organic matter

All above are practiced by the Klompe Farm and are integral practices in regenerative agriculture. One of the aspects that makes testing on the Klompe Farm especially useful is that whilst they farm their own land regeneratively, they contract farm additional land for neighbouring farmers according to the instructions on those landowners – i.e. conventionally. This allows us to compare and contract aspects of soil and crop growing of the different management practices. In a study we ran with Wageningen Environmental Research (WER) between 2019 and 2022 the WER team tested the conventional and regenerative soils for soil organic matter (SOM) as part of a water holding capacity project. The graph below shows that the long term regeneratively managed fields consistently had more SOM that the conventionally managed soils.

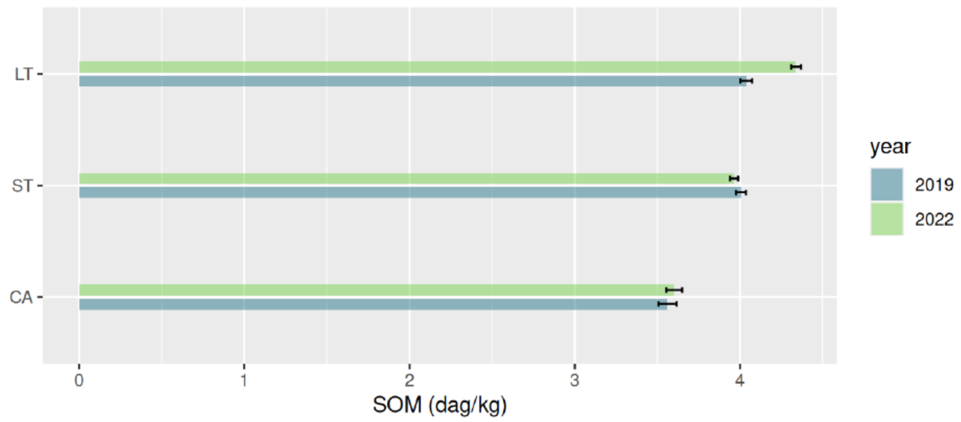

Figure X:

Figure 4: Soil Organic Matter measurements of the regenerative versus conventional plots of Klompe Farm. LT represents those fields under regenerative management since 2010 and ST, those under regenerative management since 2015. CA is conventional[10]

There is no doubt that the addition over those years by Klompe Farm of solid compost made a significant impact in the increase in the resulting SOM – see below in figure 5.

[10] Dik, P., Teuling, W. and Knotters M. 2023. A case study on the efficacy of regenerative agriculture: a comparative study in the Hoekswe Waad, the Netherlands. Wageningen Environmental Research. Commissioned by the Soil Heroes Foundation.

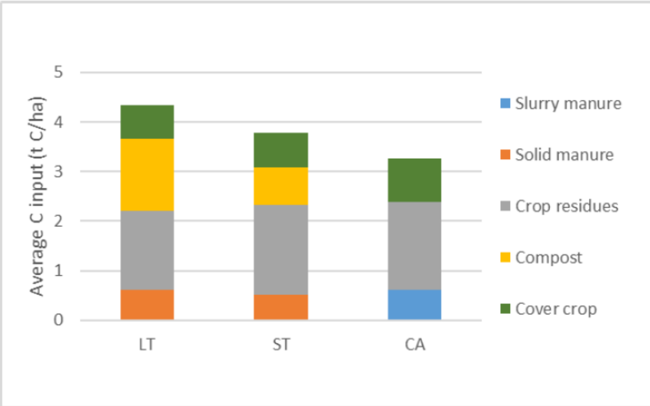

Figure 5: The carbon input on the fields with different management types[11]

There are trade offs involved for a regenerative farmer in the transition stage. Do farmers spend money on compost to accelerate the process, or take the less costly approach which will include an early adoption of no till, which may, especially in the early years come at the expense of weed management.

The question vis-à-vis the use of solid compost to increase the SOM of the soils comes down to a case of diminishing returns. In the early days of application to soil with low levels of SOM due to decades of conventional management, the benefits maybe significant (as always, the extent of benefit depending on the state of the soil and the soil type). But year on year it is likely to be a case of diminishing returns.

However, even when the SOM of the soil is improved, there will still be annual loss – firstly from the removal of the crop, and secondly because whilst most organic matter is stable, a percentage of the organic matter will decline with time as it is decomposed by soil life, and thus needs to be supplemented by additional carbon matter.

The consensus from our discussions with experts is the following:

- That the use of compost in the early days can accelerate soils improvement
- That as soils increase SOM, it becomes a case of diminishing returns
- That the application of the range of regenerative practices (mentioned above) is equally important to sustain SOM levels.
- The application manure is a useful annual addition (cheaper/ fertiliser AND carbon).

The questions here for us thus is, are the activities of no till, composting cover crops on field, leaving crop residue on field and compost tea, enough? Or is the addition of a significant carbon source such a manure enough? If manure is N rich, how does this affect the fungal:bacteria ratio and therefore accelerate the nutrient cycling leading to an increased loss in organic matter? If you are applying compost to regenerate soils, when can you stop? When has it reached a healthy threshold?

3.4 Biomass on the fields

In the spring of 2023 when we wrote the application we were hearing of many farmers struggling seeding into the large amounts of biomass on the fields. The wet winter of 2022, followed by a warm spring produced excellent growing conditions for cover crops, especially for those on the

[11] Ibid.

regenerative fields. The cover crops were mown and left to compost on the fields – which was a success, but it meant reduced soil contact for small seeds, such as carrots, and thus issues of germination.

As this project has shown us, the removal of the cover crops from the fields to make solid compost would be costly, and not necessary. Their added value is to remain on the fields providing an excellent mulch. But the issue of sowing into composting remains. Whilst it remains outside the scope of this project to go into detail on this issue, we have been exploring talking to other farmers regarding how they are getting around this issue. The main solution at this point seems to be machinery. Currently we see two possible solutions. The first is through machinery that will 'mulch' the cover crops down into much smaller pieces enabling it to break down more quickly, and the second is a form of brush add on to th seeding machine to 'brush' the mulch out of the way of the narrow seed bed, so that the seed has a chance to germinate and grow before taking advantage of the mulch properties of the cover crops.

This is an issue we will continue to explore in 2025, and share any conclusions we develop.

4. Conclusions

The main conclusions of this report are the following:

- That the application of solid compost to a large number of hectares will, at least in the short term, remain expensive.
- That there is no business case to replace expensive bought compost with on farm production of compost because of the strict legislation regarding inputs, storage and the quantity that can be made. In addition, even alternative solutions to work with these legislations, such as by agricycle, may not be available for long.
- However, we have summarised the information collected during the project on compost making and have shared this in annex 2.
- With the price of quality compost likely to remain high, and the option of making on farm compost not possible, we questioned wheathr the application of solid compost on the farm was indeed required to improve fungi:bacateria ratios and overall soil biology and soil carbon.
- The conclusion here was firstly that it was the addition of the organic carbon to the soils that improved the fungi:bacteria ratios – not the fungi in the compost – as the Klompe Farm had been led to believe.
- That buying expensive quality compost (see annex 2) to improve soils with low soil organic matter (and biology) made financial sense to increase SOM more rapidly for a limited number of years in the beginning of the transition, but the cost:benefit of this for annual application led over time to diminishing returns and the holistic approach of regenerative practices would be sufficient.
- That the addition of solid compost was not the only way to improve soil organic matter and farmers who could not afford compost could opt for manure in conjunction with a range of regenerative practices such a no till, leaving on crop residues, multi species cover cropping etc.
- *That rather than removing the biomass from the fields, the on field composting of the biomass would be more beneficial and therefore **we need to investigate further how to work with large amount of biomass in the field and look potentially to mechanised solutions***

- That whilst we cannot produce sufficient compost for field application, we can produce small batches for compost tea. Compost tea is an application used on the Klompe Farm already, but little is understood vis a vis the extent of its impact on soil biology – this is another area we would like to ***explore further – both looking into different recipes and their impact on soil biology, and the practical aspect for farmers to find the most cost and time efficient ways to produce and spray their compost teas.***

With thanks for the financial support for this project to:

patagonia

WWF

Annex 1: experts consulted

- Marianne Hoogmoed: Louis Bolk Institute
- Leendert Janmaat: Louis Bolk Institute
- Siemen Cox: Compostandig
- Nikki Daniels: Compostandig
- Gert Jan den Hollander: Bokashi Hoeksche Waard Initiative
- Wiart Visser: Polder Buijtenland
- Agricycling Foundation
- Marc Verhofstede: bio-HUMUS
- Tim Williams, Earth Farmers
- Dan Kiddredge of the Bionutrient Food Institute
- Gert Kopper: Bij de Oorsprong
- Jan Duijndam: Hoeve Biesland

Annex 2: Composting

Whilst the project identified that producing on farm compost was not the most cost effective approach for a large regenerative arable farm in the Netherlands, small farms may still benefit from making their own compost if:

- They require under 600m3 per annum
- Have adequate biomass on their farm to produce enough compost without bringing in external sources
- Carry out a cost analyse of inputs/ water/time for turning/ machinery/ storage installation versus annual purchasing of quality compost.

What is good compost

Not all compost is equal – both in terms of quality, and usability – which can have a significant impact on both the results of the application, and the cost. The quality of compost will depend on the following:

1. Input materials

The correct mix of materials at the start of the process.

2. The process

If the compost is left to get too hot for too long, it will kill of the essential microbial life in the compost. Yet if it not hot enough the resulting compost can contain weed seeds, and potential pathogens that have not been destroyed by the pile reaching a temperature of above 55C. If it doesn't have a high enough moisture content the microbial activity in the heap will be insufficient, if the water content is too high, it can lead to anaerobic conditions.

3. Maturity

If the compost contains only recently decomposed material, or still decomposing material, it may contain nutrients, but also phytotoxic compounds that can harm plants. If the process is cut short if may not have had been left long enough or the process of humification to be complete. If the decomposition of material is still incomplete, bacteria may draw nitrogen from the soil to continue the decomposition process.

4. Physical Properties

Particle Size: fine compost is good for seed starting and as a soil amendment, while coarser compost is better for mulching and improving soil structure.

5. Nutrient Content

A compost maybe too nitrogen-rich if derived from food waste and manure without being properly balanced with brown inputs.

6. Contaminants

May contain weed seeds, pathogens, or pollutants, often resulting from poor composting practices or contaminated source materials.

Types of composting

Generally speaking, composting can be broken down into 3 types: aerobic, anaerobic and vermicomposting. Whilst certain experts will advocate one approach over another, the general opinion of experts we spoke to during the course of this project was that there was no 'ideal' approach to composting. The approach taken will depend on the use, the amount required to be made, the inputs available and the time available within the farm team.

Thermophilic composting (aerobic)

This is perhaps the most common form of composting on farm. It is a form of aerobic composting i.e. composting that requires oxygen for the microorganisms to breakdown the organic matter.

There are three main phases to this process. The first, the mesophilic phase (lasting 2-3 days) is the initial decomposition phase where by mesophilic microorganisms rapidly breakdown the soluble and readily degradable compounds. This process produces heat, rapidly warming up the pile. As the temperature rises above 40C, the mesophilic microorganisms become less competitive and are replaced by thermophilic microorganisms. During this phase the proteins, fats and complex carbohydrates such as the cellulose, are broken down. As the supply of high energy compounds becomes exhausted, the temperature gradually decreases and once again, the mesophilic microorganisms take over for the final phase.

<u>Winrow composting</u>

Winrow composting works well when composting larger amounts of compost. A mixture of carbon rich and nitrogen rich inputs are mixed into rows (winrows) which are turned to control the temperature of the rows and ensure adequate oxygen and water for the aerobic process. If well managed it should reach 65°C, which ensures weed seeds as well as plant and human pathogens are killed or deactivated (which happens from 55°C).

This approach of composting its taken by farmers and large waste processors alike, but the resulting compost quality can differ greatly.

Advantages:

- Easy to monitor (no microscopy skills or expensive lab work needed), monitoring can be done with relatively cheap and easy to use equipment
- Can include and be adapted to any input
- Well managed a heap should run at up to 65°C (at 55°C, many human or plant pathogens are destroyed).
- If managed well, it can develop a strong microbial community.

Challenges:

- Accessing sufficient organic matter of the right proportions (green and brown)
- The time required to turn the compost
- Storage and production facilities
- Cost of equipment
- Regulation limits
- The potential variable nature of the compost, if not done by a certified waste processor.

Points to consider:

Location is very important to consider

- The site should be accessible, even in periods of heavy rainfall i.e. when you do not need machinery on the land, but need to access the site to turn the compost and/or add materials. It is possible to put a compost site on a field, but access will be limited (unlike a concrete base).
- You will also need to consider space to collect the inputs prior to mixing as it will be very unlikely that all inputs will arrive at the same time, and will need to be stored separately. If you need to store green inputs (such a mown cover crops) until mixing, it is best to inoculate them with lacto basilic acid and cover them to promote fermentation (and thus avoid liquidation).
- Be near a water supply/ or the farm have access to a water trailer
- Not near dwellings (to avoid disruption through noise, vermin and or smell)
- Able to catch any run off water

The mix

This differs between compost maker but the general rule of thumb amongst all those we talked to was at least 60% carbon (or brown) inputs and 40% green.

Brown inputs are those that are carbon rich woody dry plant material: straw, hay, wood chips, brown leaves, wood chips corn stalks and dried bean stalks.

Green inputs re those that will generally be processed quickly – grass, mown cover crops, manure

Aside from this general rule, there are specificities among composters

- Two of those we spoke to highlighted clay as fundamental to the compost. They said all compost should include10% clay soil. *The clay has small particles which the micro organisms attach to and allow them to be easily spread through the compost.*
- 10% of the previous compost was also highlighted *to inoculate the compost with the microbes.*
- One person advised that 10% of the green inputs should be nitrogen rich (legumes) such a alfalfa or clovers). This allows the bacteria to be more active early on, thus heating up the compost more rapidly which can in turn extend the composting season when the outside temperatures are lower.

100vol input makes 50-60vol compost. So it reduces in size by about 40%.

The process and equipment

There are three crucial elements to managing a compost to ensure that it produces good quality, uniform compost: oxygen, water and temperature control. And this is all about maintaining humidity in the pile and turning

- **The size** – the compost should be limited in size to fit the compost turner, but also because if too large the weight will force out the air and crate anaerobic conditions. As a rough estimation calculate for winrows 2m wide and 1.2 tall. The maximum you can really go to is 3m wide and 1.4 high. You don't want to go much larger. It obviously depends on the max capacity of your turning machine.

- **The turning** of the row is perhaps the most crucial part of the process, and the first two weeks are the most important. If temp reaches 60 degrees turn. In simplistic terms, if it reaches 70C then it is too high and can kill important biology. As a very general guide, the heap will need turning more often in early phases, and less as time goes on i.e. around 3 times a week in the first week, 2 in the 2nd and 3rd, once in the 4th etc. After 8 weeks (or earlier) no turning is needed. A compost turner of some form was crucial. A front loader would not create a uniform mix. It takes about 30mins to turn a 100m winrow. A tractor with a very slow drive is essential for a compost turner.
- **Covering:** it is advised to cover the compost in a water permeable fleece.
- **Water:** estimate 5000l water per row of 100m
- **The monitoring**. Using a water probe, and a compost thermometer, the heap should be continuously monitored.
- **When it is ready.** The compost should be ready in 8-12 weeks. The amount of time will be entirely dependent on the amount and type of carbon materials in the pile. I.e. if composting woodchips, the process will take longer.
  Whilst most home gardeners will test their compost using smell, sight and feel (earthy smell, crumbly moist texture, no visible plant material) or a jar or germination test, farmers may want to take a more assured scientific approach. The easiest, and cheapest way of doing this is to test the Carbon Dioxide and Ammonia emissions from the pile. There are special probes, such as those of Solvita, made especially for this which offer a clear graph as to when the compost is ready based on the readings.

Equipment

- Tractor (with v slow drive function)
- Compost turner (€25 to €30K)
- CO_2 and NH_3 probe
- Moisture probe
- Compost thermometer
- Water permeable fleece.
- Storage and composting space.

Small batch composting

Two other forms of thermophilic composting – most suited for small batch composting, are the Johnson Su composting approach or the Elaine Ingham approach. Both are very suitable for either for a small area, or for farms producing small amounts for bio primer for the seed (5-10kg/ha) or compost tea.

As an example, for compost tea, the Klompe Farm uses just 60litres of compost to make 1000liters of compost tea. This is applied at a rate of 200l/ha between 3-5 times per year. This works out at roughly 36-60kg of compost per ha – a manageable amount when using Johnson Su – whereby each container can make around 800l of compost.

The advantage of both is that once set up, the process is very hands off and thus doesn't require many man hours. It does however take time – sometimes up to a year before it is ready compared to the weeks it takes to produce winrow compost.

Vermicomposting

This process involves the use of earthworms—typically red worms—to perform the decomposition process. The method is, in a way, still mostly bacteria based, and occurs in the gut of the worm. The end product is worm casts, coated with mucus consisting of polysaccharides that make them into somewhat stable aggregates.

The system requires bedding materials like newspaper strips, cardboard hay and similar carbonaceous materials that mimic the decaying dried leaves that worms find in their natural habitat. The process is fast and efficient: worms can process half their weight in organic material in one day.

Vermicomposting methods can be made in small batches but can also be applied to larger operations. Two main approaches are used: windrows or raised beds. With windrows, new materials are added on one side of the bed, and the other side is harvested for compost after about 60 days. With the raised-bed or container system, which is preferred for indoor operations in colder climates, the worms are fed at the top of the beds and the castings are removed at the bottom.

Fermenting compost (Bokashi) (anaerobic)

Bokashi is a form of anaerobic composting that does not require oxygen. Fermenting composting, or bokashi, is an anaerobic composting methodology developed in Korea and Japan. The organic feedstock is inoculated with lactobacilli bacteria that generate a fermentation process under anaerobic conditions, converting a fraction of the carbohydrates to lactic acid

Advantages:

This approach can produce large amounts of compost, with very little input. It is particularly suitable to those farms with livestock (thus manure) or large amounts of brown and green matter than need to be disposed of, but instead can be inoculated and covered and left to slowly ferment for the following year.

Disadvantages:

Pathogens and seeds: The lack of heat can mean that pathogens and weed seeds may not be destroyed. In addition the farm applying this approach must have adequate and well managed storage space to store the material for up to a year, as the process is long. It should also be noted that the Bokashi method releases quite a lot of methane. When anaerobic digestors carry out anaerobic digestion, this methane is captured and used as energy, but it is not captured in the Bokashi method and thus has been questioned if it is the most appropriate method for farms managing large amounts of compost.