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North Sea Region
Carbon Farming
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Five promising measures to protect the climate by Carbon Farming

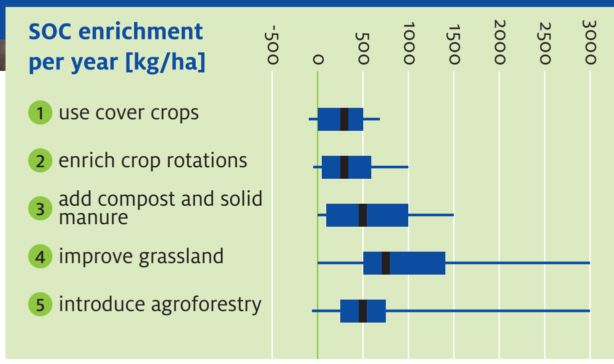
Carbon farming means to enrich *soil organic carbon* (SOC) by improved land management in a long term approach. Goal is to reduce *carbon dioxide* (CO_2) in the atmosphere and to fight climate change. Additionally Carbon Farming will improve soil fertility and biodiversity.

Potential of carbon sequestration

The potential for *carbon* (C) sequestration in soils is variable according to climate, soils, sites and management. Exhausted soils need more SOC and well supplied soils need specific management to maintain the high level of SOC. With a system change over 10 - 20 years it is possible to accumulate between 50 - 1000 kg/ha SOC per year, or even more in the case of grassland, see the graph at the right. This means that you, as a farmer, can reduce 80 - 3600 kg CO_2 in the atmosphere each year.
To generate this net effect for the climate, the goal of Carbon Farming is to increase the amount of carbon in agricultural soils by the application of specific techniques.

Costs and benefits/revenues

When Carbon Farming is done according to good agricultural practice, additional energy use, unwanted nutrient losses and related green-house gas emissions can be avoided. Additional biomass used as renewable resource for energy production or as building material, will diminish the use of fossil energy in the process chain. This is also the case when synthetic fertilisers are replaced by *nitrogen* (N) from biological N fixation with newly introduced legumes. This saves further greenhouse gas emissions. There are several forms of revenues possible, e. g. from state programs, CO_2-business models and better soil fertility or new products. Others can be explored.



Expected ranges and extreme values for the accumulation of through various agricultural measures

How to

This leaflet contains ideas and information on measures you can take to combine food and biomass production with Carbon Farming. Important is a constant and consequent management on your farm, due to the reversibility of SOC binding. Best is to try a a combination of different new approaches!

One of eight soil health experience groups in Norway performing the underwear test - testing their decomposition in soil.

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1 Cover crops

Continuous plant cover is the best insurance for soil health and function and draws carbon down into the soil as a source of energy to the soil ecosystem, which has a large impact on atmospheric CO_2 concentrations.

More photosynthesis

Cover crops are grown for the purpose of protecting the soil surface from erosion and nutrients from leaching while the plants sequester carbon and create habitat for microorganisms. Cover crops can be adapted to fit in almost any production system. By integrating cover crops the grower can have an overlap of living plants when cash crops are harvested. Cover crops can be sown before, undersown, interplanted, or sown after the main crop. It can be annual or perennial species.
The choice of species or mixes depends on the objectives of the growers. Deep rooted plants like radishes help to solve compaction damages while legumes are great nitrogen fixers, and grasses prevent nitrogen and minerals from leaking out. Plant diversity has a major impact on disease prevalence and every plant has unique effects. In a multi species mix, variation in the sizes and forms of leaves and roots will increase the total production, boost nutrients and improve soil structure.

Good Potential

According to studies, the potential of soil carbon enrichment with properly established cover crops, is between 100 and 460 kg C ha/yr in the topsoil and 10 and 320 kg C ha/yr in the subsoil. This is when cover crops are regularly introduced. Annually enriching soil with 100 kg additional carbon through newly introduced cover crops on 10% of the EU's arable land (100 million ha), would stochastically correspond to a reduction of 3.67 million t of CO_2. That is about 1% of the EU's annual greenhouse gas emissions that are related to agriculture.

Active soil life

A Norwegian cover crop enthusiast:
"I use cover crops, so I don't starve my soil microbes and leave the soil naked. Diversity in the cover crop is an insurance that some of them will succeed. I am happy for all the services I can get for free from the active soil life."

Hellek Berge is growing cereals and peas on his farm in Norway. He always plants cover crops a week after seeding his oats. This year he has chosen a multi species mixture as sub sawn plant cover. In this way he gains extra photosynthesis for several months in autumn and spring.

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2 Enriching crop rotations to improve SOC stocks

Organic carbon in agricultural soils is mainly brought in by roots, root exudates and aboveground biomass remaining on the field. On the other hand frequent soil tillage enhances decomposition of organic matter. Crops with a dense and deep root system, of variable composition, covering the soil and that are leaving a high level of biomass on the field are positive for the C balance.

Practical implementation

Binding carbon in the soil is a reversible process. An improved crop rotation, as proposed here, must therefore be implemented permanently to prevent the stored carbon from escaping again. Some important points:

- N from legumes in the crop rotation saves the use of mineral fertilisers and additionally SOC can effectively build up.
- Multiannual crops can be easily integrated in systems with livestock or biogas, e.g. grass-clover.
- The area of potatoes, carrots and other root crops in rotations should be reduced in dense crop rotations.
- Use winter- and also spring crops to create space for cover crops and to break peaks in workload and machinery use. Avoid bare soil - also between rows, be active in re-greening after harvest.
- Field margins might be used to enrich crop rotations. Here you can effectively improve biodiversity, protect water against nutrients and pesticides combined with SOC enrichment.

Potential of carbon sequestration

Estimates for additional SOC enrichment per year under successful management: integrate grass-clover 500 kg/ha C, replacing root crops by cereals 100 kg/ha C, leave straw in the field 50 kg/ha. This different material input would be equivalent to a range of 0.18 and 1.8 t/ha CO_2 bound from the atmosphere per year.

Costs and benefits/revenues

Variable: Evaluate market options for the increased range of crops. Maybe expand your crop rotation in close cooperation with other farmers. Use also programs for increasing biodiversity.

We have changed the system

North German farmer producing biogas, potatoes and grain crops:
"Since we have under-sown grass, e.g. in oats it is always green. My people like to plough this well-structured soil. We have partly replaced maize in the crop rotation by this grass and, when needed, we also prepare whole crop silage from the cereals. In my farm biogas increased the options I have to care for the soil."

3 Grassland management

Estimates of the proportion of the earth's land area covered by grasslands vary between 20 and 40 percent. Improved grazing management, adapted fertilization, sowing legumes, improved grass species tend to lead to increased SOC. Very high rates of SOC enrichment can be expected when arable land is converted into grassland and also by elevated water tables in grassland.

Grazed pastures may sequester more C than grasslands used for silage or hay production, due to the recycling of organic matter and nutrients (C and N) from faeces and plant residues (ungrazed leaves and roots). The *composition* of the sward has a major influence on SOC in various ways. Grassroots are the main source of organic matter to the soil. Species with a high root density are therefore beneficial for the build-up of SOC. Generally creating a biodiverse lush sward should be the goal which shouldn't be broken by intensive tillage for reseeding.

Potential of carbon sequestration

Especially permanent grassland has a high potential for sequestering carbon because of its extensive rooting system and high turnover of crop residues. It should not be disturbed. Red clover is known as a keystone of grassland and has high potential to enhance C sequestration.
C accumulation rate was found to be within the annual potential of soil C input by roots (between 56 and 400 g C/m^2 per year i.e. up to 4 t C/ha per year in the topsoil) in temperate grasslands that are species rich. Generally with improving sward and management around 1 t C/ha might be enriched per year. This would equivalent more than 3.5 t CO_2/ha per year taken from the atmosphere.

Costs and benefits/revenues

The costs are variable, depending on the impact of land use. Keeping permanent grass or turning arable land into grass, doesn't cost a lot. If you have to sow grass-clover, the cost for seed is €250-300 per ha.

Henning Knutzen, organic farmer in Hürup, North Germany:
"For me, mob grazing is one of the most effective measures to build up organic matter in soil."
Henning Knutzen grazes his clover grass areas for short periods with high stocking densities. The excrements and trampling of the farm animals result in an effective input of biomass. When grazing overripe swards with his cattle high levels of biomass with high C/N ratios are incorporated into the soil.

4 Compost and solid manure

The carbon content in the soil can be increased by adding compost and solid manure. Both contain organic matter in variable stage of decomposition and have variable and different C/N ratios. This is influencing their decomposition in soil. For application fertilization standards must be taken into account.

To create a C-sequestration effect, the used materials have to be additional compared to the situation before and an increase in SOC in one place should not lead to a decrease in another. Solid manures and compost should be produced by additional biomass grown for that purpose or transported from places with nutrient and soil organic matter overflow to farms with soils where organic matter can effectively be build up and nutrients are needed. A positive side effect could be, that an increase in the demand for good solid manure can lead to an increased supply and to adaptation of housing systems.

Potential of carbon sequestration

Theoretically, adding compost and solid manure can lead to an increase in soil carbon in wide ranges. This depends on the quality (C/N ratio) and the amount added. When applying animal manures a C retention coefficient of 12% was derived from worldwide studies over mean times of 18 years. So, applying 10 t stable manure with 25% *dry matter* (DM) and 0.5 kg C per kg DM would mean an input of 1.25 t/ha C and a retention of 150 kg/ha C. This equivalents to 550 kg/ha CO_2.

Costs and benefits/revenues

Nutrient values of compost and solid manure have to be considered in your economic calculations. Relatively high additional costs will occur for storage, special preparation and application. Maybe you can cooperate with local livestock, compost or biogas producers and provide them additional material produced on your farm and get a backflow of high quality materials for organic fertilisation.

Activating soil life

A fruit grower in Zeeland Province, the Netherlands, on clay soils:
"By using compost and good quality solid manure, I have seen the top layer of my soil change, which activates the soil life and improves moisture regulation."

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5 Agroforestry

Agroforestry systems include hedgerows, shelterbelts, orchard grazing, alley cropping, poultry combined with short rotation coppice or fruit trees etc. The integration of trees and/or shrubs with crop and/or animal systems leads to many beneficial ecological and economic interactions.

Potential of carbon sequestration

The cultivation of woods results in carbon enrichment in the soil due to their long lifetime and missing soil disturbance. The roots reach very deep soil layers and leaf litter will remain on the field, enriching SOC at the soil surface layer. When organised in hedges or alleys in arable fields, parts of the leaf litter enter the adjacent cropland soil and can be incorporated there. Under favourable conditions under woody crops, replacing arable crops, a SOC-enrichment can be achieved up to 1.5 t/ha C per year, including deeper soil layers. For longer periods a reasonable estimate for North Europe is 0.5 t/ha C per year, i.e. 1.8 t/ha CO_2. In addition to the SOC, carbon will be stored in the woody biomass above and below ground. Depending on the rotation period of the trees and shrubs and the harvesting scheme a mean abovegound carbon stock can be calculated. Until half of the final stock is reached, an average annual sequestration rate of 4 t CO_2/ha can be assumed for strips mixed with trees and shrubs.

Costs and benefits/revenues

The establishment and management of agroforestry systems for timber, fuelwood, fruit and/or nut production is quite a big and long-term investment, depending on the method chosen. But it may pay off not only by its products. In addition, it can reduce losses in agricultural production due to wind and water erosion and drought. Thereby it may overcompensate the losses of agricultural production on the woody strips and nearby. In total, the productivity per hectare is higher under agroforestry than in conventional systems. In silvopastoral systems livestock production benefits from shadow and from leaves as additional feed component offered by the trees.

Adding a dimension for growth

Hennig Söffker, farmer near Bremen (Germany): "I was tired of growing asparagus and strawberries all the time and doing all the boring paperwork for this only. Hence, I let these fields for rent and started two hectares of experimental agroforestry plantation with many kinds of berry bushes, fruit trees, and kiwi with vegetables, potatoes, etc., as well as clover-grass with geese in between. It is an interesting challenge to optimize the production of such systems."