Can carbon farming improve soils and help fight climate change?

By building up humus, farmers want to store carbon dioxide in their fields, promote biodiversity and ideally earn money in the process. This concept of carbon farming has been tested on farms for several years. How does it work? And is it worth the effort?

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A dark brown color and a loose, crumbly structure are characteristic of humus-rich soils *© Rüdiger Braun*

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The summers are hot in Riedlingsdorf, a village in southeastern Austria. In the midst of three-meter-high piles of rotting plant residues, biochar and sand, Gerald Dunst pushes his wide-brimmed leather hat back and wipes the sweat from his forehead. The air smells of earth. His artfully twirled black mustache quivers when he speaks. "Sonnenerde" (sun soil) is emblazoned on his dark green T-shirt, the name of his 22-person company. The 58-year-old entrepreneur's enterprise converts biomass such as garden waste, tree and shrub cuttings or wood residues into around 30 different types of soil and biochar.

Even before studying gardening and agriculture, he was fascinated by the topic of compost. "It's my thing," says Dunst. He has researched, given lectures and written widely acclaimed books about it. In 1998 he founded Sonnenerde, and in 2007, together with his brother Rainer, he initiated the municipal climate protection program "Kaindorf Ecoregion" and the associated "HUMUS+" project. It is the first initiative in Europe that aims to build humus on agricultural land. It started with five participants, and today more than 400 farmers in Austria and Slovenia are involved.

"We have the problem that in recent decades many fields have been farmed in a way that depletes humus," Dunst says. "We have used up the soil reserves instead of caring for the soil ecosystem and building humus sustainably." A healthy, diverse mix of soil organisms – especially earthworms and fungi – are essential for this. "We are trying to optimize the humus buildup," says the compost expert, "in order to store more carbon, counteract climate change and at the same time improve the soil."

Gerald Dunst, the initiator of the "Humus+" project, checks the quality of a compost heap

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Ways to get more humus

Soils have the potential to bind carbon dioxide from the atmosphere by building humus. The rate of humus formation depends on how much carbon is in the organic soil material relative to nitrogen. A ratio of around 10:1 is optimal. Too much unbound nitrogen slows the formation of permanent humus, which gives the soil its dark, crumbly structure, remains in the soil for a long time and thus acts as a carbon sink. Easily soluble nitrogen fertilizers and large amounts of manure that are commonly added to fields limit the soil's ability to store carbon.

Many farming practices can promote humus formation and carbon storage: leaving crop residues in fields, planting cover crops year-round, frequent crop rotations and undersowing crops, in which a new crop is sown into a current crop before harvesting. Cultivating the soil carefully, ideally without a plow, is also important. Some farmers also spread biochar and compost on their fields to speed up the process at the beginning. Ideally, Dunst says, fields should never lie "naked and bare," otherwise the soil biology suffers and nitrogen is lost.

In addition to increased carbon storage, the HUMUS+ organization highlights other advantages of humus creation: The soil becomes more stable and more fertile, absorbs more water, is easier to work and is better protected against erosion. And, the organization says, overall soil health improves thanks to the increasing number and diversity of soil organisms.

After initial success on the HUMUS+ test areas, the non-profit association soon came up with the idea of trading CO_2 emission certificates. They hoped that the farms participating in the project could benefit from the marketplace in which industry pays to offset some of its unavoidable emissions.

This concept is now known as carbon farming and is being tested worldwide. It is a key part of the "4 per 1000" initiative, which was proposed by France during the 2015 Climate Change Framework Convention in Paris and supported by many countries, including Germany and Austria. The countries signed a target agreement based on the theoretical projection that nearly all anthropogenic carbon emissions could be offset if the carbon content in soils increased by 0.4% per year.

Carbon farmers need patience

The HUMUS+ certificate system works as follows: A farmer signs a contract with the association in which he or she promises to build humus on an area of at least one hectare over the next five years. The contract requires that the farmer pay for the soil condition to be checked by an independent laboratory, which costs around 900 euros. This includes sampling, analysis and an advisory service.

A technician uses GPS to locate 25 sampling points in the field. (The farmer does not know the sampling sites, to prevent possible manipulation.) The individual samples are mixed together and sent to a state laboratory where they are analyzed for their acidity as well as their carbon, nitrogen, phosphorus, potassium and calcium carbonate content. After five to seven years, samples are taken again at the same locations and the results are compared with those from the initial samples. If the carbon content in the soil has increased significantly, this increase is converted into equivalent tons of carbon dioxide. The laboratory feeds all the data directly into a database.

The farmer then receives a certificate that precisely documents the level of carbon increase. He or she must then keep the humus content in the field stable for at least five more years. Each ton of carbon dioxide is currently worth 57 euros. HUMUS+ pays out two thirds of the certificate value immediately. The remaining third is only paid if the humus content remains steady or increases over the final five years.

HUMUS+ sells the CO2 certificates for 126 euros per ton of carbon dioxide to companies that strive for climate neutrality. The buyers must first prove that they have already implemented other measures to avoid greenhouse gas emissions in their operations. The system allows a cement manufacturer, a bank or a paint company to compensate for unavoidable carbon emissions.

The hope that farmers could generate significant additional income in this way has not yet been fulfilled. However, the experience of the past 16 years shows that most HUMUS+ participants end up earning a small profit with the certificates. "Over 500,000 euros have been distributed to the participating companies so far," says Jochen Buchmaier, the association's managing director. "The whole process requires a lot of patience, but the farms ultimately benefit from the continuous improvement of their soil."

The balance on the project area, which now covers over 5,300 hectares, is impressive: on average, just over five tons of carbon dioxide per hectare per year were bound in the HUMUS+ fields. This corresponds to an increase of almost 0.1 percent. Over a period of ten years, that is almost one percent more humus, but the value is

below the ambitious Paris target of 4 per mille or 0.4% per year. Nevertheless, according to the association, a total of 16,500 tons of CO2 have been stored since the start of the project. This corresponds to the average greenhouse gas emissions of around 100 people over the same period.

There are now a number of similar projects that are based on the Kaindorf model, such as the "Bopen Op – Humusreich" association in Hürup, near Flensburg in northern Germany. Some certification companies have now discovered carbon farming as a business model. There are also regional EU initiatives that promote humus creation, such as the INTERREG Carbon Farming project.

Permanent greening of the soil, as here in an orchard near Kaindorf, is one of the essential prerequisites for a rapid and sustainable humus build-up
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No easy answers?

As popular as the carbon farming system is among participating farmers and some investors, it is increasingly being criticized by scientists. In March 2020, the BonaRes Center for Soil Research published the study "CO2 certificates for carbon sequestration in soils: methods, management practices and limitations." Authors from the Leibniz Center for Agricultural Landscape Research (ZALF), the Thünen Institute, the Helmholtz Center for Environmental Research, the Research Institute for Organic Agriculture and the Technical University of Munich contributed to the study.

The researchers came to the carefully-worded conclusion that private-sector humus certificates may be unsuitable as an incentive instrument for more climate protection in agriculture - at least at this point in time. Although the study emphasizes the positive effect of humus buildup on soil fertility and water-holding capacity, it criticizes the test methods that are commonly used to measure carbon sequestration, saying the measurements are not very meaningful. The analysis makes it clear that "all enrichments are completely reversible," says Carsten Paul of ZALF, one of the study authors. "It's also not clear how much additional carbon is actually being stored and whether it is sustainable over the long-term. In the end it is difficult for certificate providers to ensure that the positive climate impact is real."

Axel Don, deputy head of the Thünen Institute for Agricultural Climate Protection, also sees humus buildup on arable land as only a very small contribution to the fight against climate change. He says that even if a majority of farmers were to specifically increase humus and also expand hedgerows and grassland, a maximum of three million tons of carbon dioxide could be stored in German soil per year. "This would only offset 5% of agricultural greenhouse gas emissions in Germany," he says. It would be much more effective, he says, to focus on building up humus in wetlands. A rewetted moorland could store 35 tons of carbon dioxide per hectare per year, significantly more than a field.

The problem with laughing gas

And then there is the nitrous oxide problem: If there is too little oxygen in a field and a lot of unbound nitrogen, microbial processes in the soil can release large amounts of nitrous oxide. As a greenhouse gas, this is around 300 times stronger than carbon dioxide and can quickly negate any climate protection effect of humus buildup. This fact has so far not been taken into account at all in humus certification, says soil scientist Don: "The buildup of humus in fields is fundamentally a good thing. However, its actual climate impact cannot be determined precisely, which is why serious certification is difficult."

Martina and Johann Höfler are not unsettled by the scientists' skepticism. The couple have been taking part in the HUMUS+ program since the beginning with their 50 hectare farm on the edge of Kaindorf and are now running carbon farming on 20 hectares. On their first test area they initially recorded a humus content of around 2%, similar to most of the region's arable land, but most recently, after almost 16 years, it had more than doubled to 4.7%. This is a relatively high value for arable land, although grassland can reach 15% or more.

The farmers Martina and Johann Höfler from Kaindorf are very satisfied with the increased amount of humus in their test area © Rüdiger Braun

The Höflers say they don't think there is any significant formation of nitrous oxide on their HUMUS+ areas. "We take great care to ensure that our soils are well aerated, and as far as possible we avoid any compaction caused by heavy machinery," Martina Höfler says. To illustrate this, her husband digs a block of earth out of the demonstration field with his spade. The fine-pored, crumbly structure of the soil is striking, and a rich, dark brown color extends to a depth of 30 centimeters. Both are signs of high humus content. Several earthworm burrows are clearly visible. The sample smells fresh, with a pleasant whiff of fungi. "The picture of ideal soil," says Johann Höfler, visibly proud.

On a steeply sloping field, the Höflers try out the most challenging of soil-friendly cultivation methods, direct sowing. The remains of

The corn plants on the no-till area still appear sparse at the beginning of July. By September they were nearly 2 meters tall. © Rüdiger Braun

the previous crop, in this case a mixture of rye, vetch, crimson clover and rapeseed, are simply rolled over and left in the field. Using a special seed drill, the farmer then barely scratches the surface to plant the seeds. The corn that emerges from the straw carpet at the beginning of July is still a bit behind for the time of year, in spite of the good soil. "We had a long period of bad weather with a lot of heavy rain, but the corn is catching up," Johann Höfler explains confidently. "When we had very heavy rains one day, the water poured out of the field down the slope," he says. "From the neighbor's field it was a brown broth, but from ours it was crystal clear." From his point of view, this is a decisive advantage of the increased humus: "It holds the soil together."

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