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How to climate-proof crops: scientists say the secret's in the dirt

Evidence is building that regenerative agriculture boosts soil health, which, in turn, could bolster food security.

By Alix Soliman

Agronomists examine a field where the cash crop, maize, has been harvested and a cover crop, radishes, has been planted to protect soil health. Credit: Paul Chiasson/The Canadian Press/Alamy

As climate change threatens farmers' ability to produce the world's food, researchers and environmental advocates think they have a solution: playing in the dirt.

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Experimental evidence is accumulating, they say, that by improving soil health, crops can be made more resilient to drought and extreme weather — and they want governments to offer financial incentives to farmers who use 'regenerative' practices to climate-proof farmland. These agricultural practices include boosting the soil microbiome — that is, its microbial community — by rotating crops between fields, rather than repeatedly planting the same crop in the same field, and by adding 'cover crops' to fields. These comprise plants that won't necessarily be harvested, but that prevent soil erosion and boost soil nutrients.

"There are lots of ripple effects from the changing climate that are creating challenges for our food system," says Rob Myers, the director of the Center for Regenerative Agriculture at the University of Missouri in Columbia. "The ways we combat that are with biological diversity, more organic matter in the soil — and more integrated approaches."

But switching to such practices requires upfront investment. Researchers and farmers who spoke to *Nature* say that regenerative agriculture does work, but it can take a few years of implementing it before farms start to see a profit. In the United States, advocates are calling on the US Congress to include more subsidies for regenerative agriculture in the Farm Bill, a massive piece of legislation that is updated every five years or so and includes funding for disaster aid and farmer training. The most recent version expired on 30 September. Meanwhile, the latest version of the European Union's Common Agricultural Policy entered into force last year, and included funding for farmers using these types of sustainable practice.

Nurturing the soil

Industrial agriculture usually relies on fertilizers, pesticides and mechanical equipment to produce high-yielding monocultures — single crops such as maize (corn) or wheat. Excessive use of chemicals on these crops disrupts ecological processes in the soil and is one of the

leading causes of water pollution in the United States. Unhealthy soil struggles to soak up water or retain nutrients.

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An estimated 8,505 million tonnes of topsoil on US farmland was lost to erosion between 2013 and 2017. The United Nations Food and Agriculture Organization warns that more than 90% of Earth's soils are at risk of becoming degraded by 2050; this could lead to a rise in famine.

Regenerative agriculture lacks a formal definition, but scientists who spoke to *Nature* say that its general goal is to rebuild healthy soil. That starts with increasing the proportion of organic matter — including living roots and manure — to feed the soil microbiome and recycle nutrients for plants.

Although the term is modern, regenerative principles are ancient. Implementing them means "returning to some of the practices that we've relied upon as a human species for thousands of years", says Rich Smith, an agricultural ecologist at the University of New Hampshire in Durham.

Keeping cover

One practice that is considered regenerative is cover cropping: planting species that typically won't be harvested, such as crimson clover, when the cash crop is out of season instead of leaving the soil bare. Roots from the cover crop prevent erosion and take up excess nitrate from fertilizers that would otherwise leach into streams and groundwater. When a farmer cuts down the cover crop to prepare for the next round of cash-crop planting, they work it into the soil where it feeds the bacteria and invertebrates underground, improving soil fertility. Only about 5% of cultivated land in the United States was cover cropped in 2022, but that figure has been increasing: by 2022 it was 17% higher than in 2017.

Farmer Brandon Kaufman plants the grain kernza on his fields in Moundridge, Kansas, as a cover crop and grazes cattle on it to fertilize the soil. Credit: Brandon Kaufman

During a major drought that destroyed maize and soya bean crops across the US Midwest in 2012, Myers heard farmers say that cover-cropped fields hadn't been hit as hard as fields without the extra plants. So he worked with the Conservation Technology Information Center, a non-profit organization in West Lafayette, Indiana, that promotes conservation in agriculture, and a sustainable farming programme funded by the US Department of Agriculture (USDA) to launch the National Cover Crop Survey. Researchers polled roughly 700 farmers, and found an average 9.6% greater maize yield and 11.6% greater soya bean yield during the drought on fields in which cover crops had been grown.

This was surprising, because "at the time, many people thought that cover crops would take moisture away" and not leave any for the cash crops, Myers says.

The USDA has offered subsidies to farmers who use cover crops. Of the farmers who responded to the 2022–23 National Cover Crop Survey and had received payments to plant cover crops, 90% said that they would probably continue the practice after the funding stopped.

Valuing variety

There is also evidence that crop rotation can improve soil health and resilience. Swapping out crops, rather than growing the same monoculture on the same field for years on end, can improve soil health without sacrificing productivity, Smith says.

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This can be done by rotating different crops, including cover crops, on the same field over time, or by planting several crops on the same field at the same time, including the 'three sisters' trio of maize, beans and squash that has been grown by some Native American tribes for centuries.

A review of 20 studies that analysed the effects of crop rotation on soil life found that rotating various species increased the amount of microorganisms in soil by about 15% compared with monoculture fields, and boosted microbial diversity by more than 3%[1]. Rotating two or more different crops also generates more of the nutrients carbon and nitrogen in soil than does monoculture[2]. A review of 33 papers that assessed fields in which legumes and grains were grown together revealed an increase in the stability of yields year-to-year compared with those of monoculture fields[3], suggesting that biodiverse farms could improve food security.

"Those types of systems can often be more resilient to weather variation and have some enhanced disease resistance," Smith says. "The evidence is relatively strong that they maintain, if not increase, yields."

Seeding incentives

But the switch to regenerative agriculture can take about three years to pay off, say farmers and researchers who spoke to *Nature*.

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Brandon Kaufman, a fourth-generation farmer in Moundridge, Kansas, rotates crops and also grazes cattle on fields in the autumn and winter to fertilize the soil. When he got started with regenerative agriculture at the industrial operation he inherited, he "didn't have a safety net to fall back on", he says. Government subsidies "incentivized me to try some things, and I've gained a tremendous amount of knowledge because of that".

Federal, state and business programmes that incentivize cover cropping usually stop after farmers make the transition. To support producers supplying the nation's food who institute these practices over the long term, the US Farm Bill should include a measure to reduce farmers' federal crop insurance premiums, Kaufman and others say. The USDA trialled this idea during the COVID-19 pandemic by offering farmers who planted cover crops an insurance discount of US$5.00 per acre. The federal programme has now ended, but states including Iowa, Wisconsin and Illinois have implemented their own versions.

Farms can move away from industrial agricultural practices and move towards healthier soil, Kaufman says. "It just takes time" and financial incentives to get producers to change, he says. But it's important, he adds, because "if you think about your kids and your grandkids … where's their food going to come from in 100 years?"

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