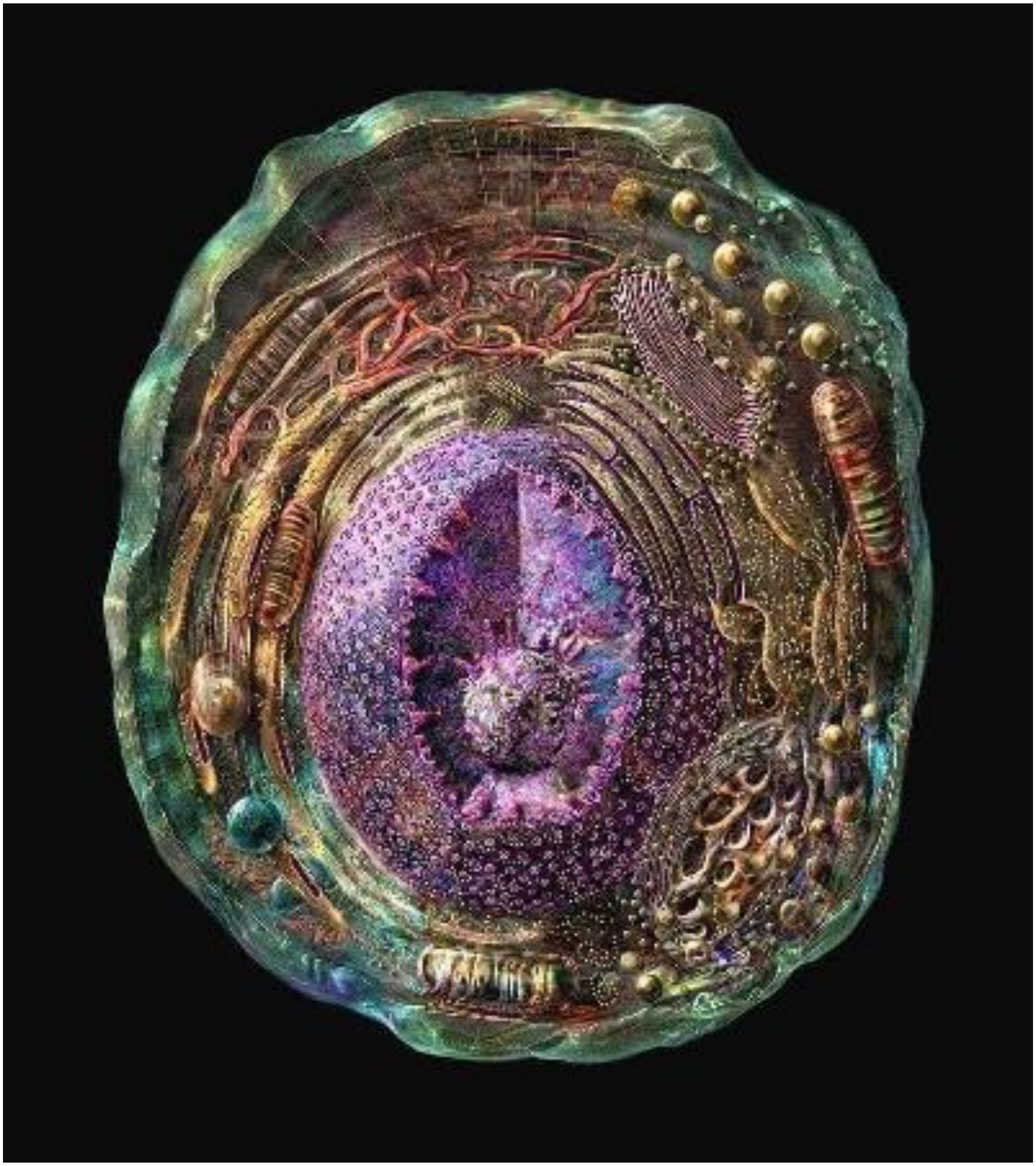
Ode to Happiness for Sunday April 25 2021

A Human Cell



The most detailed representation of a human cell to date, obtained by radiography, nuclear magnetic resonance and cryoelectronic microscopy.

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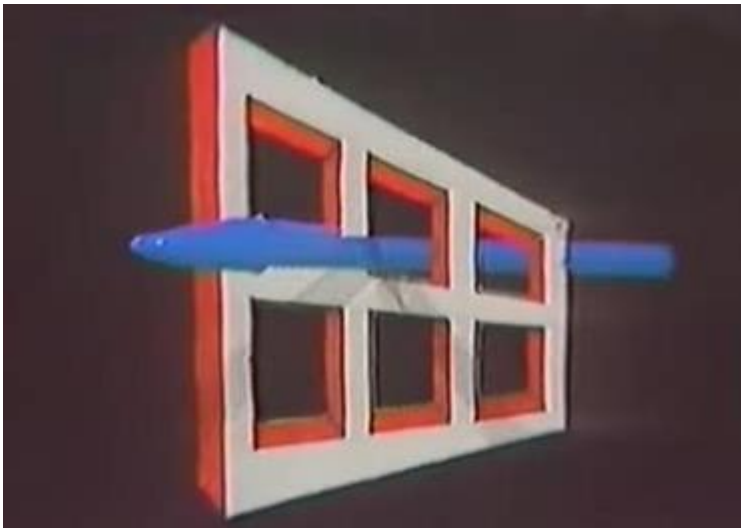
The Ames Window illusion



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The illusion only some can see

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Dirt for Today…and Tomorrow

[This is long but it's worth your time to consider both the facts and implications in the state of dirt. Why? History tells a story of civilizations lost in the dusts of time.

I have a deep interest in this article and the message it contains because of my stint as the initial editor of the groundbreaking publication, Erosion Control, we at Forester Media started in 1992.]

Do we only have 60 harvests left?

by Hannah Ritchie

World in Data presents the data and research to make progress against the world's largest problems.

Acknowledgements: Many thanks to Dr. Daniel Evans for providing feedback and inputs on this article.

Summary

The stark claim that the world has only 100; 60 or even 30 years of harvests left often hits the headlines. Although they continue to be repeated, there is no scientific basis to them. While the claims are overblown, soil erosion is an important problem. Erosion rates from across the world span five orders of magnitude. Some are eroding quickly: 16% of soils are estimated to have a lifespan of less than 100 years. Others are eroding slowly: half have a lifespan greater than 1000 years; and one-third have over 5000 years. To protect our soils we must adopt better agricultural practices – such as cover

cropping, minimal or no tillage, and contour cultivation. This way we can extend the lifespan of the soils that we all depend on.

If one reads the newspaper headlines on the state of the world's soils it is easy to be convinced that we are only decades away from global famine:

"The world's top soil could be gone within 60 years" says a senior UN official;

"Britain has only 100 harvests left" writes the Independent newspaper;

"UK is 30 to 40 years away from the 'eradication of soil fertility' warns Gove" [the former Environment Secretary].

The good news is that these claims are overblown. The bad news is that this doesn't stop them being repeated over and over. The "60 harvests left" statistic seems to be one that just won't die.

And while the headlines are exaggerations it shouldn't take away from the fact that many of our soils are degrading and we need to take action to restore them.

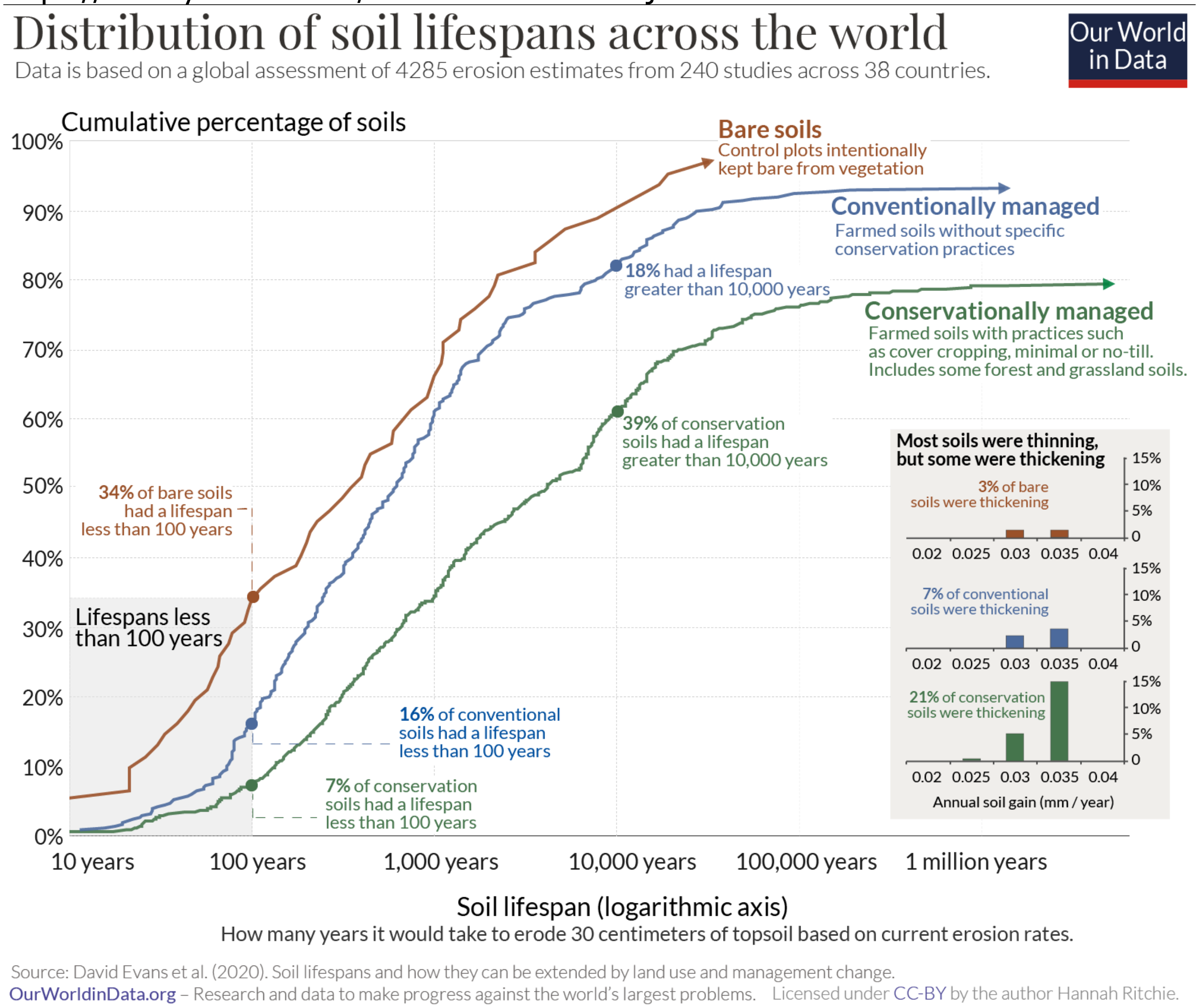
Where do these claims come from?

The honest answer is that we don't know. Botanist and science communicator, James Wong, tried to trace these claims back to their roots for an article in the New Scientist.1 We know that a senior official at a UN FAO farming conference was quoted with the "60 harvests" figure and that Michael Gove mentioned a 30 to 40 year deadline. But we don't know what they based their assessments on.

The "100 harvests" figure seems to link back to a study in the UK conducted by researchers at the University of Sheffield.2 I say "seems to" because there appears to be no mention of the 100-year figure in the paper. James Wong failed to find where this number came from; I also spent a lot of time digging and did no better.

In any case, this study looked at the difference in soils properties of city allotments in Leicester, a city in the UK, and soils from some surrounding farms. It concluded that the soils in city allotments had more organic matter, higher nitrogen levels and a better soil density. Not exactly informative for the larger and more urgent question on the state of the world's soils.

https://www.youtube.com/watch?v=wMnOo2zcjXA



➔ Explore an interactive version of this chart.

There is no single lifespan of the world's soils

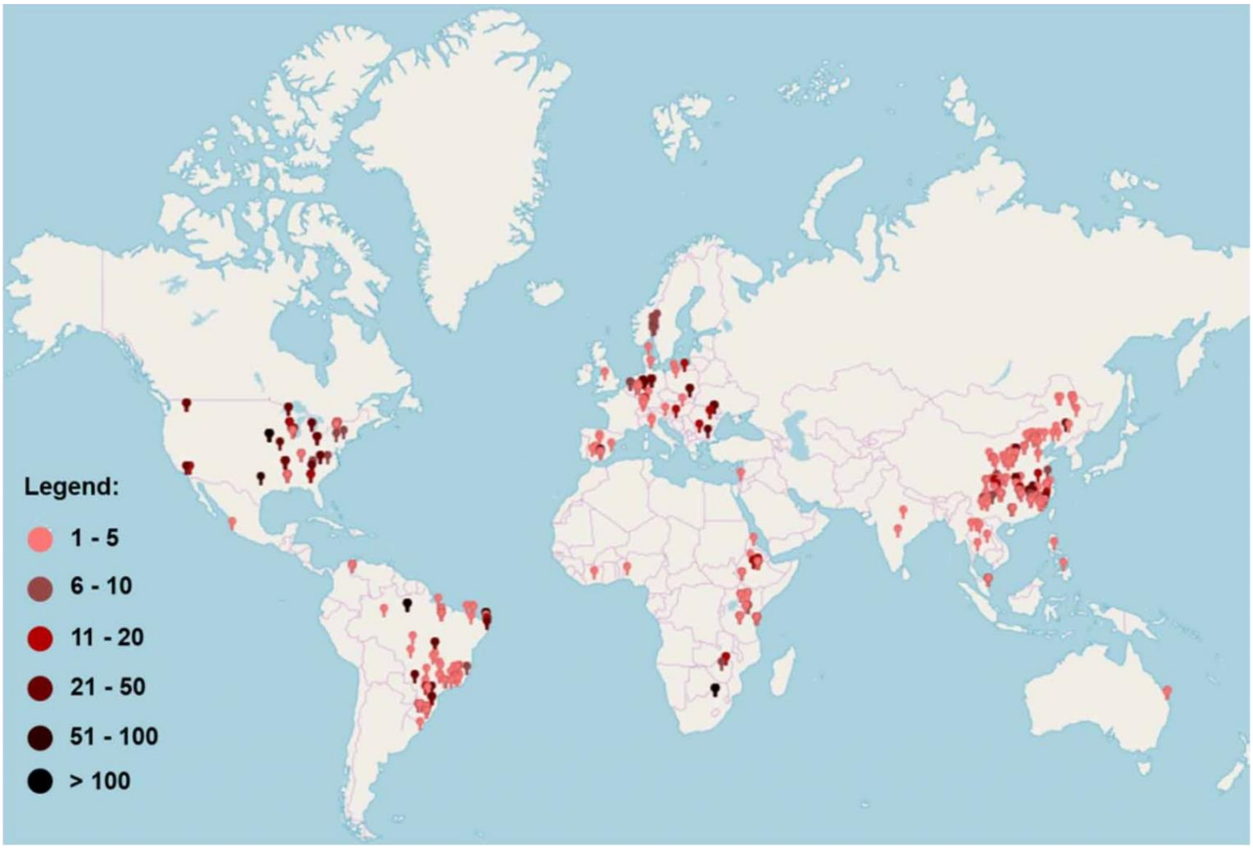
What do we know about the state of the world's soils?

A recent study by Daniel Evans and colleagues gave us a first assessment of the range of soil lifespans across the world.3 This drew upon a database of 4285 measured soil erosion rates, from 240 studies, covering 255 unique locations across 38 countries. As shown in the map, these 255 locations span all continents of the world.

How would we estimate the 'lifespan' of a soil? There is no single metric to do so: soils are complex and have a range of properties from nutrient balance, to density, and structure. The best proxy – and the metric that Daniel Evans and his colleagues used – was net erosion rates of the crucial topsoil layer, the topmost layer that is around 30 centimeters thick [in reality, this thickness varies from soil to soil, but 0.3m is the most commonly adopted figure for this upper productive layer]. Crops need this layer to grow: it's where the carbon, water and nutrients get stored.4

Depending on how the soil is managed, this topsoil can thin or thicken. If we know what rate it's thinning, we can estimate how long it would take for this layer to disappear. For example, if a topsoil was thinning by 0.5 centimeters every year, it would take 60 years to lose 30 centimeters.5 If you want a more detailed understanding of soil lifespans and how they're calculated, the lead author explains this here.

It's not the only metric that determines soil productivity, but it's a meaningful metric that tells us something valuable about the state of the world's soils.



Number and spatial distribution of plot years for the 255 unique locations in the study.

The lifespans of the world's soils span five orders of magnitude

What did this study tell us about the lifespan of our soils?

Soils from the 4285 data points in the study were grouped into three categories.

- 'Bare' soils are plots of land which are deliberately kept free from any crops to determine erosion rates of soils without vegetation. These are used to assess a 'worst-case scenario'.
- Conventionally managed soils are those which are actively farmed, without implementing notable conservation practices. These are used to represent a 'business-as-usual scenario'.

- Conservation management soils were those that had been subject to soil conservation techniques such as land use change (to forests and grasslands) or improved agricultural practices such as intercropping, no-tillage, or contour farming. We will look at the impact of these techniques later.

In the chart here we see how the distribution of estimated soil lifespans in these three categories varied across the global dataset. On the x-axis we have the lifespan in years and on the y-axis we have the cumulative percentage of soils that were found to have that lifespan. Notice that the scale on the lifespan axis is logarithmic and stretches from 10 years to 10 million years. This further demonstrates how citing a single lifespan for the world's soils is inaccurate and nonsensical.

Let's focus on the 'conventionally managed' soils, shown in blue. These data are relevant for understanding many of the world's farming practices. We will look at conservation techniques later.

Many of these soils are thinning; some very quickly. 16% have a lifespan of less than 100 years if they continue to erode at their current rates. This is not a local problem: there are examples of soils with lifespans shorter than a century on all continents, including the United States, Australia, Spain, Italy, Brazil and China. The longevity of these soils is concerning and we should be acting quickly to preserve them.aes

But the "60 harvests" claim is quite clearly false. More than 90% of conventionally managed soils had a 'lifespan' greater than 60 years. The median was 491 years for thinning soils. Half had a lifespan greater than 1,000 years, and 18% exceeded 10,000 years. There were also some soils that were not eroding at all. Where soil formation rates exceeded erosion rates, soils thickened. In fact, some were thickening – soil was forming quicker than it was eroding. In the bottom-right of the chart we see the rates of soil gain. 7% of conventionally managed soils were thickening.

If we were to keep our land completely bare – by removing any vegetation and preventing any natural regrowth through pesticides – our soils could erode more quickly. One-third (34%) of bare soils had lifespans less than 100 years.

There is no single figure for how many harvests the world has left because there is so much variation in the types, quality, and management of our soils. It's just implausible that they would all be degrading at exactly the same rate. As these results show: some soils are eroding quickly while others are thickening.

What can we do to slow erosion and restore our soils?

It's concerning that so many of our soils are thinning. Some, very quickly.

But, there are things we can do to extend the lifespan of our soils. Take a look at the 'conservation' curve in the previous chart. It's shifted far to the right – even more so because the lifespan scale is logarithmic – meaning these soils are eroding much more slowly than conventionally managed soils, if at all. In fact, one-fifth were actually thickening (meaning soil was forming faster than it was eroding).

A comparison of these two groups is shown in the table. The share that had a lifespan less than 100 years was less than half that of conventionally-managed soils – 7% versus 16%. Half of the soils managed with conservation management had a lifespan greater than 5000 years; and 40% exceeded 10,000 years.

This sounds promising, but what does 'conservation' actually mean? What practices should we put in place? There are four interventions we should consider according to Evans et al.7

We could switch from agricultural land use to forest or grassland. This is the most effective way to extend soil lifespans, but it reduces the land available for farming. As the global population increases, and demands for food rise, we need to find ways of protecting our cultivable soils. If we can increase crop yields we have the opportunity to reduce the amount of arable land we need to meet this demand.

We can plant cover crops during the non-harvesting season. If we need to use our land for farming, cover cropping can be effective in improving soil quality. None of the plots that used cover cropping in the study had a lifespan of less than 100 years.

This is a practice that involves growing a crop for the purpose of maintaining a vegetative cover and preventing soils from becoming bare and susceptible to erosion between growing seasons.

We know from our comparisons above that 'bare' soils erode much more quickly. To prevent this, you can plant a cover crop during the off-season, which maintains soil structure, fertility and enhances organic matter.

Cover crops consist of leguminous plants such as peas, beans and lentils. Cover cropping has been shown to be effective in reducing soil erosion.8, 9,10

We can use minimal or zero tillage practices. Conventional 'tillage' is a common practice where farmers will mechanically agitate and overturn the soil using ploughs.

This is done to mechanically dislodge and destroy weeds; aerate the top layer of soil, and mix the nutrients evenly throughout the soil profile.

But this also creates negative impacts: it can damage the soil structure, leading to soils becoming more susceptible to erosion. Increasing soil erosion can lead to a loss of nutrients and organic matter; it may increase chemical run-off from the land; and may reduce water infiltration.

Minimal or zero-tillage practices try to manage soils without this mechanical overturning of the soil. This reduces soil erosion but has its own trade-offs: because weeds are not disturbed by ploughing, it often requires more herbicides to kill them. Some of these trade-offs can be reduced by combining it with cover cropping. Cover crops such as legumes add nitrogen to the soil, and can protect the soil from weeds and pests.

We can implement contour cultivation or terracing on hillslopes. The gradient of the land makes a big difference to the susceptibility of the soil to erosion. Soils on a steep slope erode much more quickly. 37% of soils which were cultivated up-and-down the slope had a lifespan less than 100 years. Contour cultivation – where you grow crops perpendicular to or across the slope – reduced this to 7%.

Contour cultivation is not always practical on very steep gradients. In this case, terracing can be effective. Only 2% of terraced plots had a lifespan less than 100 years. The downside to terracing is that it can reduce the amount of land you have available to grow crops. In some cases the benefits of reduced soil erosion, and improved water and nutrient management will outweigh this cost.

The agricultural practices that are most effective will be location-specific. They will depend not only on the environmental qualities of the land, but also on the social and economic constraints of the farmer. There's no universal solution, but it is clear that there are plenty of opportunities to increase the lifespans of soils across the world.

Soil management	% < 100 years	% >5000 years	% >0,000 years
Conventional	16%	23%	18%
Conservation	7%	48%	39%

Extreme headlines could do more harm than good

People will often argue that while extreme headlines may be untruthful, they are worth it if they force people to take action. I don't buy it. It can be damaging in many ways.

Firstly, it forces some people towards solutions that are ineffective or counterproductive. Some blame the decline in soil fertility on the use of fertilizers and other chemical inputs. The "60 harvests" claim from the UN senior official has been used many times to argue for a switch to organic farming systems [here is it being used at a UN International Year of Soil conference]. Michael Gove said the UK had only 30 to 40 years of harvests left because it was "drenching them with chemicals". But many of the conservation techniques have nothing to do with organic farming. In fact, shifting to a no-tillage approach often requires more pesticides and fertilizers, not less. Since average yields tend to be lower in organic farming, it requires more agricultural land. This is in obvious conflict with the best way to reduce soil erosion: have as little cropland as possible. In some contexts organic farming can play a role, but it's not the ultimate solution. Misleading headlines convince people that it is.

Exaggeration also creates the opposite problem: apathy. Many people don't take it seriously and dismiss that there's any problem. The headlines might be overblown, but this shouldn't detract from the fact that soil erosion is a serious problem. It's one we can't afford to ignore and as I have shown it is a problem that we can do something against.

Endnotes

James Wong interviewed a number of soil scientists and asked if they had seen a credible single figure for the number of "harvests left" in the scientific research. None of them had. Their responses to this metric ranged from "hardly useful" to "almost insulting".

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We can calculate this as [30 centimeters / 0.5 centimeters per year = 60 years].

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Evans, D. L., Quinton, J. N., Davies, J. A. C., Zhao, J., & Govers, G. (2020). Soil lifespans and how they can be extended by land use and management change. Environmental Research Letters, 15(9), 0940b2.

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Verstraeten, G., Van Oost, K., Van Rompaey, A., Poesen, J., & Govers, G. (2002). Evaluating an integrated approach to catchment management to reduce soil loss and sediment pollution through modelling. Soil Use and Management, 18(4), 386-394.

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Poetry for Today

The Highwayman By Alfred Noyes

The wind was a torrent of darkness among the gusty trees.
The moon was a ghostly galleon tossed upon cloudy seas.
The road was a ribbon of moonlight over the purple moor,
And the highwayman came riding—
Riding—riding—
The highwayman came riding, up to the old inn-door.

He'd a French cocked-hat on his forehead, a bunch of lace at his chin,
A coat of the claret velvet, and breeches of brown doe-skin.
They fitted with never a wrinkle. His boots were up to the thigh.
And he rode with a jewelled twinkle,
        His pistol butts a-twinkle,
His rapier hilt a-twinkle, under the jewelled sky.

Over the cobbles he clattered and clashed in the dark inn-yard.
He tapped with his whip on the shutters, but all was locked and barred.
He whistled a tune to the window, and who should be waiting there
But the landlord's black-eyed daughter,
        Bess, the landlord's daughter,
Plaiting a dark red love-knot into her long black hair.

And dark in the dark old inn-yard a stable-wicket creaked
Where Tim the ostler listened. His face was white and peaked.
His eyes were hollows of madness, his hair like mouldy hay,
But he loved the landlord's daughter,
        The landlord's red-lipped daughter.
Dumb as a dog he listened, and he heard the robber say—

"One kiss, my bonny sweetheart, I'm after a prize to-night,
But I shall be back with the yellow gold before the morning light;
Yet, if they press me sharply, and harry me through the day,
Then look for me by moonlight,
        Watch for me by moonlight,
I'll come to thee by moonlight, though hell should bar the way."

He rose upright in the stirrups. He scarce could reach her hand,
But she loosened her hair in the casement. His face burnt like a brand
As the black cascade of perfume came tumbling over his breast;
And he kissed its waves in the moonlight,
        (O, sweet black waves in the moonlight!)
Then he tugged at his rein in the moonlight, and galloped away to the west.

Part Two

He did not come in the dawning. He did not come at noon;
And out of the tawny sunset, before the rise of the moon,
When the road was a gypsy's ribbon, looping the purple moor,
A red-coat troop came marching—
        Marching—marching—

King George's men came marching, up to the old inn-door.

They said no word to the landlord. They drank his ale instead.
But they gagged his daughter, and bound her, to the foot of her narrow bed.
Two of them knelt at her casement, with muskets at their side!
There was death at every window;
And hell at one dark window;
For Bess could see, through her casement, the road that *he* would ride.

They had tied her up to attention, with many a sniggering jest.
They had bound a musket beside her, with the muzzle beneath her breast!
"Now, keep good watch!" and they kissed her. She heard the doomed man say—
Look for me by moonlight;
Watch for me by moonlight;
I'll come to thee by moonlight, though hell should bar the way!

She twisted her hands behind her; but all the knots held good!
She writhed her hands till her fingers were wet with sweat or blood!
They stretched and strained in the darkness, and the hours crawled by like years
Till, now, on the stroke of midnight,
    Cold, on the stroke of midnight,
The tip of one finger touched it! The trigger at least was hers!

The tip of one finger touched it. She strove no more for the rest.
Up, she stood up to attention, with the muzzle beneath her breast.
She would not risk their hearing; she would not strive again;
For the road lay bare in the moonlight;
    Blank and bare in the moonlight;
And the blood of her veins, in the moonlight, throbbed to her love's refrain.

Tlot-tlot; tlot-tlot! Had they heard it? The horsehoofs ringing clear;
Tlot-tlot; tlot-tlot, in the distance? Were they deaf that they did not hear?
Down the ribbon of moonlight, over the brow of the hill,
The highwayman came riding—

Riding—riding—
The red coats looked to their priming! She stood up, straight and still.

Tlot-tlot, in the frosty silence! *Tlot-tlot*, in the echoing night!
Nearer he came and nearer. Her face was like a light.
Her eyes grew wide for a moment; she drew one last deep breath,
Then her finger moved in the moonlight,
Her musket shattered the moonlight,
Shattered her breast in the moonlight and warned him—with her death.

He turned. He spurred to the west; he did not know who stood
Bowed, with her head o'er the musket, drenched with her own blood!
Not till the dawn he heard it, and his face grew grey to hear
How Bess, the landlord's daughter,
The landlord's black-eyed daughter,
Had watched for her love in the moonlight, and died in the darkness there.

Back, he spurred like a madman, shrieking a curse to the sky,
With the white road smoking behind him and his rapier brandished high.
Blood red were his spurs in the golden noon; wine-red was his velvet coat;
When they shot him down on the highway,
Down like a dog on the highway,
And he lay in his blood on the highway, with a bunch of lace at his throat.

. . .

And still of a winter's night, they say, when the wind is in the trees,
When the moon is a ghostly galleon tossed upon cloudy seas,

When the road is a ribbon of moonlight over the purple moor,
A highwayman comes riding—
Riding—riding—
A highwayman comes riding, up to the old inn-door.

Over the cobbles he clatters and clangs in the dark inn-yard.
He taps with his whip on the shutters, but all is locked and barred.
He whistles a tune to the window, and who should be waiting there
But the landlord's black-eyed daughter,
Bess, the landlord's daughter,
Plaiting a dark red love-knot into her long black hair.

I've loved The Highwayman from the moment I first encountered it more than 70 years ago. It was just a little book from the bookcase in my father's study that I sat down to read while he listened raptly to the Metropolitan Opera Hour on the radio. It was our ritual.

Almost instantly I was captivated by Alfred Noyes' epic poem . It made no difference I didn't know what a highwayman was, nor a moor, nor what made a poem a poem, but after I reading it once, I read it again, my excitement catching my father's attention.

"What," he asked indicating that I was intruding upon the broadcast.

"The moon was a ghostly galleon," was my answer.]

Suddenly the opera was forgotten and to my amazement he recited the first stanza by heart. Then he took the book from me and read it aloud from cover to cover. Aloud is what it requires and deserves.

*Over the cobbles he clattered and clashed…*my God! Talk about hooked.

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NASA's Perseverance Pays Off Back Home

NASA has been exploring Mars since the 1960s, pushing the frontier of innovation to get to the red planet and discover its secrets. This new technology has often found other uses here on Earth as well. Credit: NASA

Even as the Perseverance rover approaches Mars, technology on board is paying off on Earth.

A laser-light sensor that can identify bacteria in a wound may sound far-fetched, but it's already becoming a reality, thanks in part to NASA's Mars Exploration Program. The technology is going to Mars for the first time on Perseverance, which will touch down on the Red Planet this month, but it's already detecting trace contaminants in pharmaceutical manufacturing, wastewater treatment, and other important operations on Earth.

That's not the only technology headed to Mars that's already paying dividends on the ground. Here on Earth, these innovations are also improving circuit board manufacturing and even led to a special drill bit design for geologists.

Honeybee Robotics designed its rotary percussive corer drill to collect rock samples on Mars. The version that's flying on the Perseverance rover has key differences, but they share a novel technology for breaking off core samples, which Honeybee has now made available to geologists on Earth. Credit: Honeybee Robotics

Giving Geologists a Break

Honeybee Robotics has been working on robotic missions to Mars and other planetary bodies since the 1990s, including a number of projects funded by Small Business Innovation Research (SBIR) contracts from NASA's Jet Propulsion Laboratory in Southern California. One of the key contributions to come from that work has been sample collection technology, including a drill bit for extracting rock cores. Half a dozen coring bits developed from research that started more than 20 years ago are now in space for the first time, ready for use in the rover's turret, or "hand," at the end of its robotic arm.

On Earth, after drilling a core with a hollow bit, a geologist usually uses a screwdriver or other tool to break the sample off and pull it out. This can result in a fragmented or even contaminated sample. A robot required something different.

New York-based Honeybee came up with a breakoff tube nested within a coring bit. After the core has been drilled, the breakoff tube rotates relative to the bit, shifting its central axis and snapping off the core. Unlike other breakoff methods, such as pinching the base of the core, the breakoff tube applies pressure along the length of the sample, reducing the risk of fragmentation.

Honeybee has supplied grinders, scoops, and other sampling systems that flew on previous Mars missions. This is the first time the company's coring bit technology is going to Mars, because it's the first time NASA has planned a future mission to bring samples of the Martian surface back to Earth. Perseverance will collect and package those samples.

https://youtu.be/NRoTyDLN2Uc

Even as NASA's Perseverance rover approaches Mars, technology on board is paying off on Earth. Credit: NASA Spinoff

"It's the key part of the sample return mission," said Keith Rosette, who managed the rover's sampling and caching system for JPL. "You truly can't collect a sample on Mars if you don't have a drill bit that can retrieve it."

While getting a sample return vehicle home from Mars will pose a host of challenges, it will let researchers do virtually unlimited testing with a wide array of instruments, Rosette said. "Rather than trying to bring all those instruments to Mars, it's less challenging and even more valuable to bring samples back."

Meanwhile, Honeybee has commercialized its patented breakoff bits in coring toolkits for geologists on Earth. The bits can be used with a standard drill, making the technology easy and affordable, said Kris Zacny, Honeybee vice president and director of exploration technology.

More than 20 years of NASA funding has helped Photon Systems bring down the cost of deep-ultraviolet (UV) spectroscopy and shrink it to a handheld size. One of the company's deep-UV lasers is flying to Mars for the first time aboard Perseverance.

Credit: Photon Systems

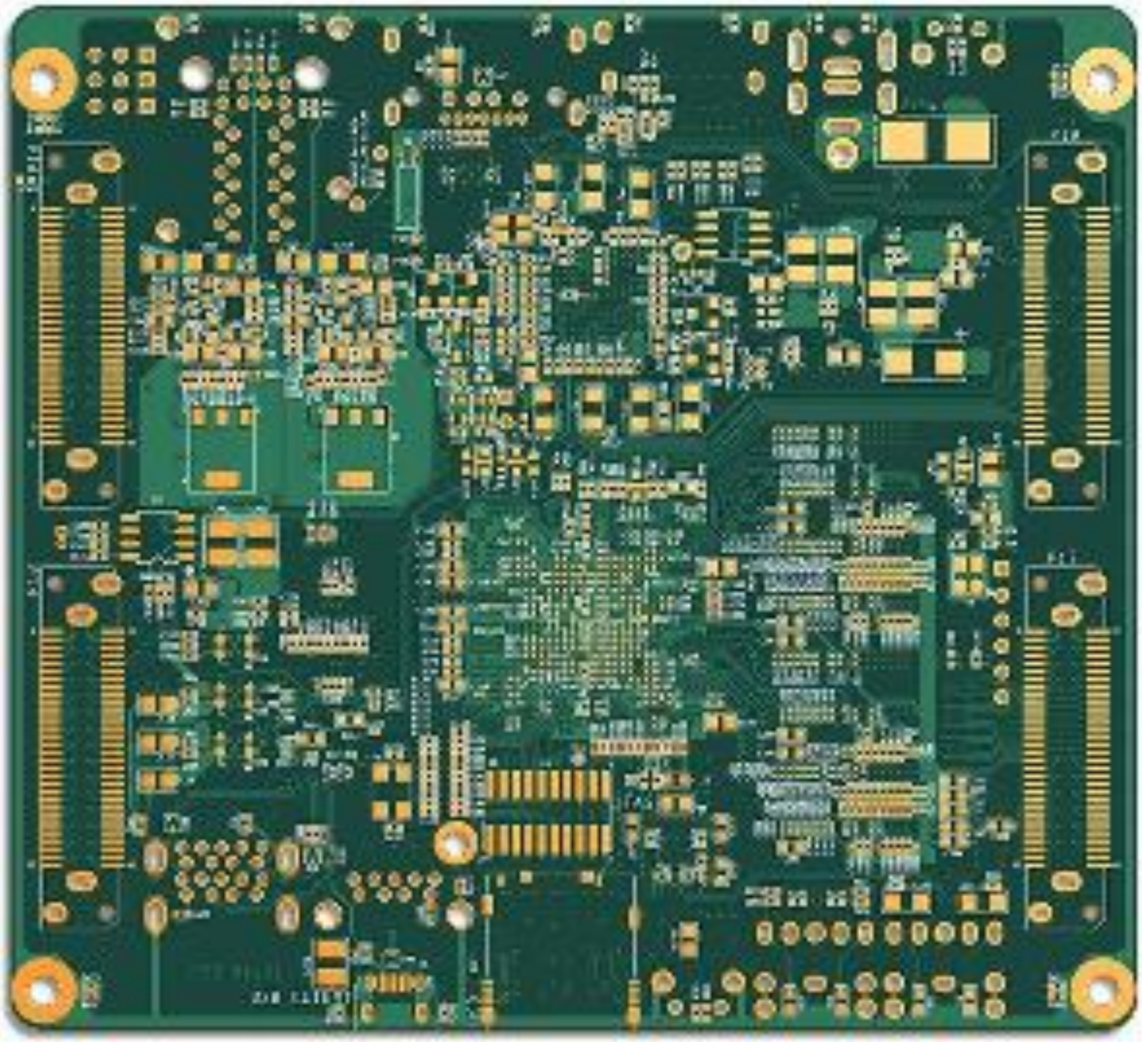
Honeybee has also been in talks with companies interested in using the bits for nuclear disaster remediation where it is too dangerous to send in human investigators, Zacny said. “If there are concrete tanks that are leaking, for example, then robots can go in and take samples to check radiation levels.”

The technology was invented by Honeybee’s late Chief Engineer Tom Myrick. “Tom would have been extremely proud that his invention made a difference to planetary missions,” said Zacny.

Home Videos from Mars

Collecting samples for return to Earth isn’t the only first that engineers have planned for Perseverance. For the first time, NASA has built a system that could send back high-quality video of a rover’s dramatic entry and landing sequence.

While the Curiosity rover sent back a series of compressed images showing the Martian surface during descent, Perseverance’s entry, descent, and landing package includes six high-definition cameras and a microphone that aims to capture all the drama of the “seven minutes of terror” between hitting the outer atmosphere and touching down. In addition to watching the planet’s surface, the cameras are positioned to watch the parachutes unfold and also to look back at the descent stage and down at the rover as the two separate.



What looks like a photo of a printed circuit board is actually a computer-generated simulation based on computer-aided design files for a board-to-be. Tempo Automation developed this "fabrication simulation" capability while working on a circuit board for the system of cameras and a microphone designed to record the Perseverance rover's Mars atmospheric entry, descent, and landing.
Credit: Tempo Automation

The camera components are off-the-shelf models, but the circuit board that manages their interface and power was designed by JPL. It was then built by San Francisco-based Tempo Automation. Founded in 2013, just after NASA announced the Mars 2020 mission, Tempo used the work to improve its manufacturing processes.

As its name suggests, Tempo Automation's focus is rapid, automated production of printed circuit boards, even in small batches. One set of tools the company offers to that end is the process for making every component "traceable," to keep track of who touched it and what was done to it at each point in the board production process, as well as which component lot the piece came from. This information makes it easier to zero in on the cause of a problem and see what other boards might have been affected, said Tempo cofounder Shashank Samala.

To meet JPL's stringent documentation requirements, Tempo added X-ray images, ionic cleanliness data, and data from an automated optical inspection for every component, all of which is now part of the company's standard procedure.

A tool unique to Tempo is what it calls fabrication simulation – software that translates a computer-aided design (CAD) model into a photorealistic representation of what the final board will look like. A team was prototyping the tool when the JPL work began in early 2018, and that work helped them complete it, said Samala. It debuted the following year.

The simulation lets customers check their designs for any issues or flaws before production begins, he said. "A simple mistake can cost a lot of money and time."

While it was conceived to help customers finalize their designs, the company discovered that it was useful in-house as well. The manufacturing process can result in discrepancies between the original CAD model and the final product, Samala explained. The simulation "serves as a source of truth on the factory floor, to communicate the designer's intent. The first thing we look at is the simulation."

He said delivering a product that met NASA standards has helped the company get into several other space systems, including satellites and rockets.

Meanwhile, Chris Basset, who designed the circuit board at JPL, looks forward to the moment the camera footage is beamed back from Mars after Perseverance's landing Feb. 18, 2021. "This is so far outside of what we usually do that it's super-exciting," he said. "I can't wait to see those images."

Ultraviolet Lasers Scan for Chemical Clues

Another technology whose roots reach far back into NASA's Mars Exploration Program is also flying for the first time on Perseverance and has many potential applications here on Earth.

When two longtime colleagues founded Photon Systems in 1997, research showed incredible promise for spectrometers – devices that use light to determine a sample's composition – operating at deep-ultraviolet (UV) wavelengths. These had the potential to identify a bacteria or detect even the slightest chemical traces. But sources for light in the 220- to 250-nanometer range were too large, heavy, and sensitive to environmental interference, and had many other issues.

William Hug and Ray Reid set out to develop a miniature, lightweight, rugged deep-UV laser source for spectroscopy in the field. Their first outside investment came in 1998 from a pair of SBIR contracts with JPL, which was interested in a spectrometer that could detect nucleic and amino acids, organic materials that are foundational to all known life. Since then, the Covina, California-based company has received a number of NASA SBIRs, mostly with JPL, as well as funding from NASA programs aimed at developing instruments for planetary and astrobiology science.

Now the space agency will get the first big returns on its long investment in the technology: Perseverance is equipped with the Scanning Habitable Environments with

Raman and Luminescence for Organics and Chemicals (SHERLOC) instrument, which uses a Photon Systems laser to spot previously invisible clues in its search for signs of past life on Mars.

While the team doesn't expect to find bacteria on Mars, organics that exist in the near surface can be identified using SHERLOC. On Earth, the same technology can be used to identify organics for a variety of other purposes.

Deep-UV photons interact strongly with many materials, especially ones containing organic molecules. This results in higher detection sensitivity and greater accuracy when compared with infrared or even visible-light laser sources.

Deep-UV spectroscopy has been done in research labs, but Hug and Reid came up with a construction that was far smaller, simpler, and cheaper to build than any existing alternative. "Deep-UV lasers start at $100,000. That's why they're not used in industry," Hug said, noting that laboratory instruments using the technology might take up three laboratory tables and take a month to set up.

One major challenge has been the level of perfection the technology requires. The same sensitivities that enable tiny, high-energy wavelengths to detect even a virus make them vulnerable to the slightest defects. A microscopic imperfection in a lens or other surface can disrupt or scatter them, and Hug said it has taken advances across multiple industries to meet the necessary standards.

Photon Systems focuses on two types of spectroscopy where deep-UV laser sources provide major advantages over longstanding spectrometer technology, and SHERLOC will use both. Fluorescence spectroscopy observes the light that most organic and many inorganic materials emit when excited by certain ultraviolet wavelengths, just like detergent glowing under a black light. Each emits a distinct spectral "fingerprint."

Raman spectroscopy, on the other hand, observes the light that a molecule scatters, some of which will shift to different wavelengths due to interaction with molecular bond vibrations within the sample. These shifts in wavelength can be used to identify the materials in a sample. The higher-energy photons of UV light elicit a much stronger Raman scattering signal from organic molecules than lower-frequency light. And because deep-UV light isn't present in natural fluorescence or in sunlight, using these very short wavelengths eliminates sources of interference.

In recent years, the company has started developing the technology into products, including handheld sensors and devices that monitor personal exposure to contaminants, as well as lab equipment. Their biggest markets now are in the pharmaceutical, food processing, and wastewater treatment industries, said Hug. Deep UV can identify and measure certain compounds at much lower concentrations than any other method, offering unprecedented precision in quality control, whether measuring the active ingredients in pharmaceuticals or ensuring the cleanliness of machinery and facilities.

In wastewater treatment, the technology can identify and measure contaminants, letting the operator tailor the treatment process and save on power for ozone infusion and aeration. “For a small wastewater treatment plant, the whole system pays for itself in less than a month,” Hug said.

An application the military has invested in is identifying bacteria and viruses. Figuring out which bacteria are present in a wound, for example, would help pinpoint the right antibiotic to treat it, rather than using broad-spectrum antibiotics that risk causing drug resistance.

And rapid, affordable deep-UV spectroscopy holds promise for medical research, from diagnostics to identifying proteins, peptides, and other biological material.

“NASA has been a constant companion in our journey to date, and the laser is only part of the story,” said Hug. “It’s also the deep-UV Raman and fluorescence instruments we built for NASA and the Department of Defense over the years that are now providing breakthroughs for pharma, wastewater, and water quality in general, and now clinical testing for viruses.”

On Mars, SHERLOC will look for organic materials and analyze the minerals surrounding any possible signs of life so researchers can understand their context, said Luther Beegle, principal investigator for SHERLOC at JPL. This will provide more details about the history of Mars and also help to identify samples for return to Earth. The instrument, which also includes a camera capable of microscopic imaging, will be able to map a rock’s mineral and organic composition in high detail, providing lots of important data.

“We’re going to make a brand-spanking-new measurement on Mars,” Beegle said. “This is something that’s never even been attempted before. We think we’re really going to move the needle on Mars science and find some great samples to bring back.”

NASA has a long history of transferring technology to the private sector. The agency’s Spinoff publication profiles NASA technologies that have transformed into commercial products and services, demonstrating the broader benefits of America’s investment in its space program. Spinoff is a publication of the Technology Transfer program in NASA’s Space Technology Mission Directorate.

For more information on how NASA brings space technology down to Earth, visit: *spinoff.nasa.gov*

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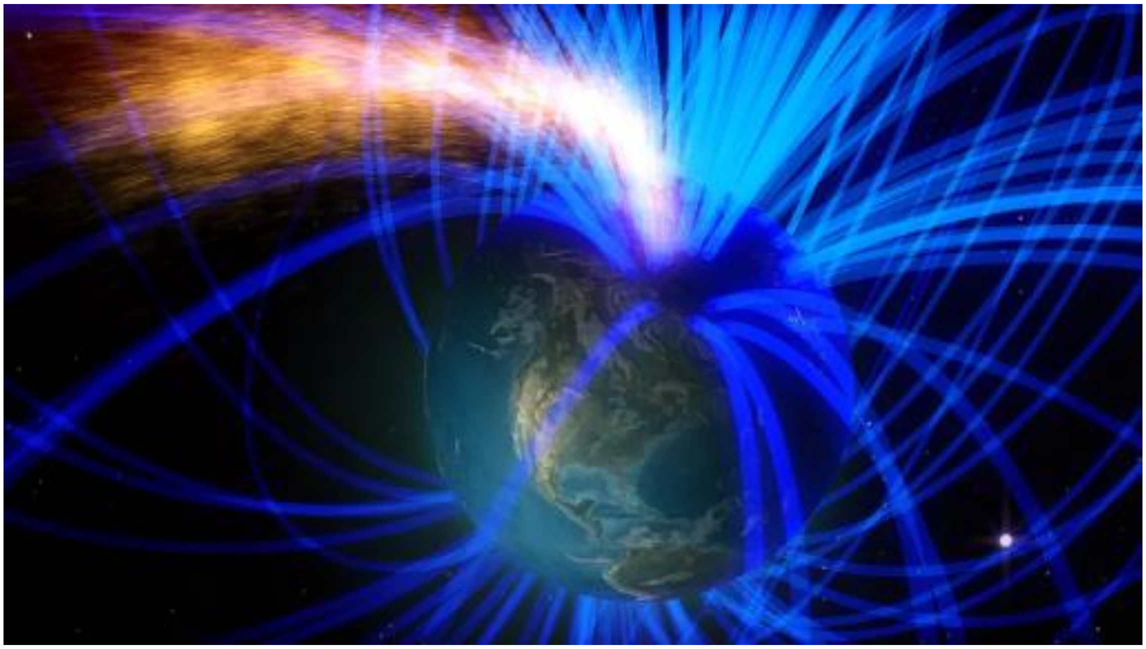
Earth's Magnetic Field Flipped 42,000 Years Ago, Creating a Climate 'Disaster'

By Mindy Weisberger - Senior Writer Live Science



On the day side of Earth, magnetic reconnection funnels material and energy from the sun into Earth's magnetic environment.
(Image credit: NASA's Goddard Space Flight Center)

A reversal in Earth's magnetic field thousands of years ago plunged the planet into an environmental crisis that may have resembled "a disaster movie," scientists recently discovered.

Our planet's magnetic field is dynamic and, numerous times, it has flipped — when the magnetic North and South Poles swap places. In our electronics-dependent world, such a reversal could seriously disrupt communication networks.

But the impact could be even more serious than that, according to the new study. For the first time, scientists have found evidence that a polar flip could have serious ecological repercussions. Their investigation connects a magnetic field reversal about 42,000 years ago to climate upheaval on a global scale, which caused extinctions and reshaped human behavior.

Earth's magnetosphere — the magnetic barrier surrounding the planet — originates from the churning of hot, molten metal around its iron core. This perpetually sloshing liquid flow generates electricity that in turn produces magnetic field lines, which curve around the planet from pole to pole, according to NASA.

Like a protective bubble, the magnetic field shields Earth from solar radiation. On the planet's sun-facing side, constant bombardment from solar winds squishes the magnetic field, so that the field extends to a distance no more than 10 times Earth's radius. However, on the side of the planet facing away from the sun, the field extends much farther into space, forming an enormous "magnetotail" that reaches beyond our moon, NASA says.

Marking the two spots on Earth where arcing magnetic field lines converge are the magnetic North Pole and South Pole. But while these positions are relatively stable, the poles — and the magnetic field itself — aren't fixed in place. About once every 200,000 to 300,000 years, the field weakens enough to reverse polarity completely. The process can take hundreds or even thousands of years, according to NASA.

Magnetic molecules preserved in volcanic deposits and other sediments tell scientists when past reversals happened
those molecules align with the magnetic field at the time that they were deposited, so they indicate the location of the magnetic North Pole, said lead study author Alan Cooper, an emeritus professor in the Department of Geology at the University of Otago in New Zealand.

Recently, researchers questioned whether a relatively recent and brief polarity reversal called the Laschamps Excursion, which took place between 41,000 and 42,000 years ago, could be linked to other dramatic changes on Earth from that time, which had not previously been attributed to activity in the magnetosphere. They suspected that during a time when our protective magnetic field was reversing — and thereby weaker than normal — solar and cosmic radiation exposure could affect the atmosphere enough to impact climate, the study authors reported.

Clues in "biscuits"

Prior studies of Greenland ice cores dating to Laschamps didn't reveal evidence of climate change, according to the study. But this time, the researchers turned their attention to another potential source of climate data: bog-preserved kauri trees (Agathis australis) from northern New Zealand.

They cut cross-sections, or "biscuits," from the preserved trunks, and looked at changes in levels of carbon 14, a radioactive form of the element, over a period that included the Laschamps reversal. Their analysis revealed elevated levels of radioactive carbon in the atmosphere during Laschamps, when the magnetic field was weakening.

"Once we worked out the exact timing from the kauri record, we could see that it coincided perfectly with records of climatic and biological change all over the world," Cooper told Live Science in an email. For example, around this time, megafauna in Australia began to go extinct and Neanderthals in Europe were dying out
their decline may have been accelerated by climate-related changes to their ecosystems, Cooper said.

The authors then used computer climate models to test what may have caused widespread climate upheaval and related extinctions. They found that a weak magnetic field — operating at about 6% of its normal strength — could lead to major climate impacts "via the ionizing radiation strongly damaging the ozone layer, letting in UV [ultraviolet rays] and altering the ways in which the sun's energy was absorbed by the atmosphere," Cooper explained.

A heavily ionized atmosphere could also have generated brilliant auroras around the world and produced frequent lightning storms, making skies look like "something similar to a disaster movie," Cooper said.

Another significant shift around that time was in Homo sapiens, with cave art beginning to appear in locations around the world. This included the first examples of red ochre hand stencils, "which we suspect is actually a sign of the application of sunscreen," a practice still seen in modern Indigenous groups in Namibia, Cooper said. Higher UV levels from a weak magnetic field could have driven humans to seek shelter in caves, or forced them to protect their skin with sunblocking minerals, he said.

Scientists can't predict precisely when the next reversal of our magnetic field might happen. However, some signs — such as the North Pole's current migration across the Bering Sea area and the magnetic field itself weakening nearly 10% over the past 170 years — suggest that a flip may be closer than we think, making it more urgent that researchers fully understand how big shifts in our magnetic field could shape environmental changes on a global scale, according to the study.

"Overall, these findings raise important questions about the evolutionary impacts of geomagnetic reversals and excursions throughout the deeper geological record," the scientists wrote.

The findings were published online Feb. 18 in the journal Science.

Originally published on Live Science.

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Food for Remembrances

Food City is a Southern grocery store chain, and this is their one-minute commercial.

Not a word is spoken and none is needed. As squadron mate Holly Clayson says, "Perhaps I am partial but I love it. Reminds me of some of the old USAA commercials when they were a smaller company.

https://www.youtube.com/embed/uoABty_zE00?rel=0

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Chop Chop
Recycling for the Asian Trade

https://www.youtube.com/watch?v=bCPlSw0p1is

Attempting to tackle the immensely small, and intolerably ignored problem of chopstick waste, a BC resident created a startup that recycles used chopsticks into bespoke furniture and other useful items like tablet stands.

In 2016, Felix Böck, a doctoral student in the faculty of forestry at the University of British Columbia, estimated that 100,000 pairs of chopsticks were being sent to landfills every day in Vancouver alone.

Now in its fourth year, ChopValue has exploded into success. Böck employs 40 people, and using his special methods of steam and press machines, he has recycled 32 million pairs of chopsticks.

Armed with a mindset of German engineering and Canadian sustainability, Böck not only created a flourishing business, but a new model of production for a circular economy.

The furniture and other items he creates like shelves, cutting boards, coasters, and hexagonal decorative blocks often contain thousands of chopsticks per item, a good thing, since billions of chopsticks are used across the Western Hemisphere every year.

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Bricks of Fast-Growing Mushrooms Are Stronger than Concrete

By Andy Corbley for Good New Network

Copyright Philip Ross, Mycoworks

While there aren't any species of mushroom large enough to live in, one Bay-area designer thinks he can make one if he only cranks out enough of his patented "mushroom bricks."

In fact, he knows he can do it, because he's already build a showpiece called "Mycotecture"—a 6×6 mushroom brick arch from Ganoderma lucidum or reishi mushrooms.

Phil Ross doesn't use the mushroom, or fruiting body of the reishi
he uses mycelium, the fast-growing fibrous roots that make up the vast majority of fungus lifeforms.

Mycelium grows fast, and is incredibly durable, waterproof, non-toxic, fire-resistant, and biodegradable.

Ross uses it to build bricks by growing mycelium in bags of delicious (to mushrooms) sawdust, before drying them out and cutting them with extremely heavy-duty steel blades.

This works because mushrooms digest cellulose in the sawdust, converting it into chitin, the same fiber that insect exoskeletons are made from.

"The bricks have the feel of a composite material with a core of spongy cross grained pulp that becomes progressively denser towards its outer skin," explained Discover Magazine. "The skin itself is incredibly hard, shatter resistant, and can handle enormous amounts of compression."

One design/architecture website described these mushroom bricks as "stronger than concrete," while another quotes Ross in an interview suggesting that it could replace all manner of plastic polymer building materials.

Indeed, designers have already used mycelium to make cloth hats, sea-worthy canoes, and eco-friendly coffins. Ross' next plan, according to the same interview, is to build an entire house for 12-20 people out of reishi mycelium.

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Nanotubes Assemble into Black Strands...

In April of 2016, a team of scientists at Rice University announced that that they had discovered that the strong force field emitted by a Tesla coil causes carbon nanotubes to self-assemble into long wires, a phenomenon they call "Teslaphoresis." The paper's authors described the nanotube wires as growing and acting like nerves.

The system works by remotely oscillating positive and negative charges in each nanotube, causing them to chain together into long wires. This force-field effect on matter had never been observed on such a large scale. "With Teslaphoresis, we have the ability to massively scale up force fields to move matter remotely," said the team's chief scientist, Paul Cherukuri.

https://youtu.be/w1d0Lg6wuvc

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Betcha the Welsh Figured it Out.

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Game Changers

NASA Satellites Detect Signs of Volcanic Unrest Years Before Eruptions

New research methods may lead to earlier predictions of volcanic eruptions.

Photo of eruption at Mount Redoubt in Alaska in 2009.

Although there are telltale signs that a volcano is likely to erupt in the near future – an uptick in seismic activity, changes in gas emissions, and sudden ground deformation, for example – accurately predicting such eruptions is notoriously hard.

This is, in part, because no two volcanoes behave in exactly the same way and because few of the world's 1,500 or so active volcanoes have monitoring systems in place. Under the best of circumstances, scientists can accurately forecast an eruption of a monitored volcano several days before it happens. But what if we knew months or even years in advance?

Using satellite data, scientists at NASA's Jet Propulsion Laboratory in Southern California and the University of Alaska, Fairbanks have developed a new method that brings us closer to that reality. The research was recently published in Nature Geoscience.

"The new methodology is based on a subtle but significant increase in heat emissions over large areas of a volcano in the years leading up to its eruption," said lead author Társilo Girona, formerly of JPL and now with the University of Alaska, Fairbanks. "It allows us to see that a volcano has reawakened, often well before any of the other signs have appeared."

The study team analyzed 16 ½ years of radiant heat data from the Moderate Resolution Imaging Spectroradiometers (MODIS) – instruments aboard NASA's Terra and Aqua satellites – for several types of volcanoes that have erupted in the past two decades. Despite the differences between the volcanoes, the results were uniform: In the years leading up to an eruption, the radiant surface temperature over much of the volcano increased by around 1 degree Celsius from its normal state. It decreased after each eruption.

"We're not talking about hotspots here but, rather, the warming of large areas of the volcanoes," said co-author Paul Lundgren of JPL. "So it is likely related to fundamental processes happening at depth."

In particular, the scientists believe that the heat increase may result from the interaction between magma reservoirs and hydrothermal systems. Magma (molten rock below Earth's surface) contains gases and other fluids. When it rises through a volcano, the gases diffuse to the surface and can give off heat. Similarly, this degassing can facilitate the up-flow of underground water and the elevation of the water table, as well as hydrothermal circulation, which can increase soil temperature. But scientists say other processes may also be at play, because while their understanding of volcano behavior is improving, it remains limited.

"Volcanoes are like a box of mixed chocolates: They may look similar, but inside there is a lot of variety between them and, sometimes, even within the same one," Lundgren said. "On top of that, only a few volcanoes are well monitored, and some of the most potentially hazardous volcanoes are the least frequently eruptive, which means you can't rely strictly on historical records."

Combining Data

The new method is significant on its own, but it may provide even more insight into volcano behavior when combined with data from models and other satellites.

In a study published in Scientific Reports last summer, Lundgren used interferometric synthetic aperture radar (InSAR) data to analyze long-term deformation at Argentina's Domuyo Volcano. At the time, scientists weren't certain whether Domuyo was a dormant or extinct volcano, or whether it was just a mountain. Lundgren's research cleared that up quickly. He unexpectedly detected a period of inflation, which is when part of a volcano expands as a new mass of magma moves upward and pushes rock out of the way. It turns out that Domuyo is very much a volcano – and an active one.

Next, Lundgren compared this deformation time series to the thermal time series Társilo Girona created for Domuyo Volcano. Lundgren's goal: to determine whether the two processes – an increase in both radiant surface temperature over large areas of the volcano and deformation – were connected.

"We found that the thermal time series very much mimicked the deformation time series but with some time separation," said Lundgren. "Even though it remains unclear which process is likely to happen first, by showing the correlation, we can connect the processes through physics-based interpretations rather than simply relying on what we are able to observe at the subsurface."

In other words, combining the datasets provides clues about what's happening deeper inside the volcano and how the various processes influence and interact with each other – data that can improve the accuracy of models used to forecast eruptions.

"Although the research does not answer all of the questions, it opens the door to new remote sensing approaches – especially for distant volcanoes – that should get us some fundamental insights into competing hypotheses for how volcanoes behave in general dynamic terms over timescales of a few years to decades," Lundgren added.

Looking Ahead

Moving forward, the scientists will test the thermal time series method on more volcanoes and continue to fine-tune its precision.

"One of the goals is to one day have a tool that can be used in near real-time to check for volcanic activity in volcanic areas," said Girona. "Even for small eruptions, there is evidence of thermal unrest before the initiation of the eruption event, so the new method helps bring us a little closer to that goal."

The data help to supplement existing tools used at monitored volcanoes. But they also greatly increase the number of volcanoes for which potentially life-saving data can be made available.

"Using the new thermal method that detects changes in the surface temperature around volcanoes and the InSAR ground-surface deformation measurements helps enable volcano observatories around the word to identify which volcanoes are the most likely to erupt and which volcanoes should be instrumented for closer observations," Lundgren said. "In using satellite data, you increase the scope of what can be monitored on a regular basis."

As for the once-largely-ignored Domuyo, the story is still evolving: It is one of several volcanoes recently prioritized by the Argentine government to be outfitted with a monitoring system.

NASA JPL

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