Living Soil

Carolyn Lebel looks at the state of soil in France, Europe's leading agricultural producer

We live on a rock.

Well, not exactly. We are 7 billion to have settled the Earth and made it a place of our own, gathering in cities and vacationing along the seaside. On the neatly stocked shelves of our supermarkets, we find foods sourced from around the world. And we have commodities markets, drive-throughs, prescription drugs and strawberries year round. But for all the sophistication of our modern world, there is still the wild, teeming with exotic life. In lush tropics or barren tundra, millions of species find their homes. But were it not for the thin crust of dirt that coats the surface of our mother rock, there would be none of this.

We may sit as kings on top of a richly diversified food chain, but our existence depends on soil and the hidden life that dwells within it. A vast habitat that evolved inch by inch over time spans scientists qualify as geological, ultimately making life on Earth possible. Or, as Rachel Carson, founder of the environmental movement, wrote in 1962, "without soil, land plants could not grow, and without plants no animals could survive."

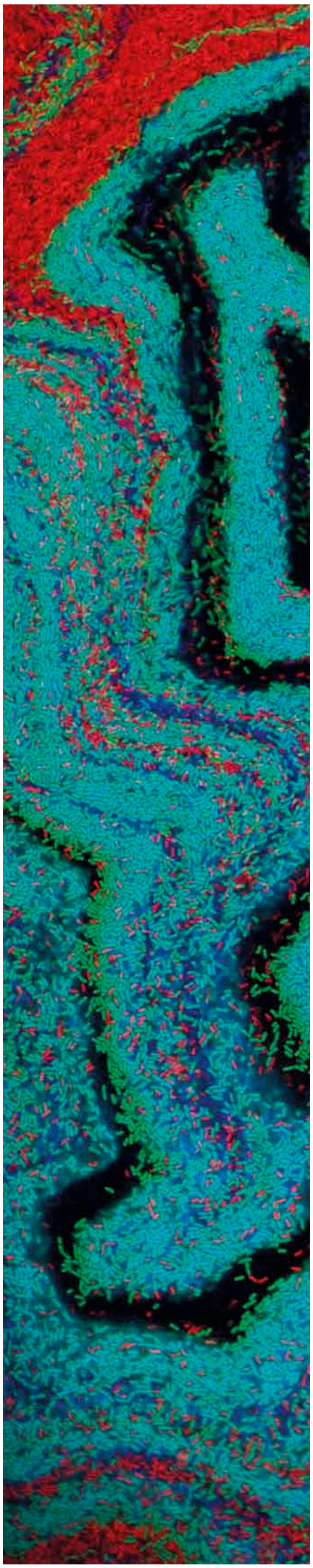
Soil is not an inert substance, but a vast repertoire of hidden life. Billions of microorganisms are present in just a gram of dirt, while one hectare can hold up to five tonnes of animal life. Some, like toads, snakes and ants, are visible to the naked eye, but the vast majority – microbes, fungi, bacteria – are invisible. This dark domain harbours a quarter of all known biodiversity on Earth, and a staggering 80% of its biomass. Yet for all of its abundance and proximity, the ground beneath our feet is more unknown than the depths of the ocean floor and the heights of the tropical canopy. Only 10% of the 2 million species of bacteria and fungi have been catalogued to date.

It's easy to understand why. There's something lacklustre about worms, fungi and tiny crustaceans. If I were a biologist, I too would opt for Jane Goodall's binoculars or Sylvia Earle's deep-sea gear, over the humble microscope. Dig a little deeper into dirt, though, and you discover an intricate and fascinating universe brimming with activity. Our underground biota may largely be single-celled, but their communities administer the very building-blocks of life, delivering food, inspiring medicine and purifying water. There may be little intelligent life afoot, but there is a collective intelligence.

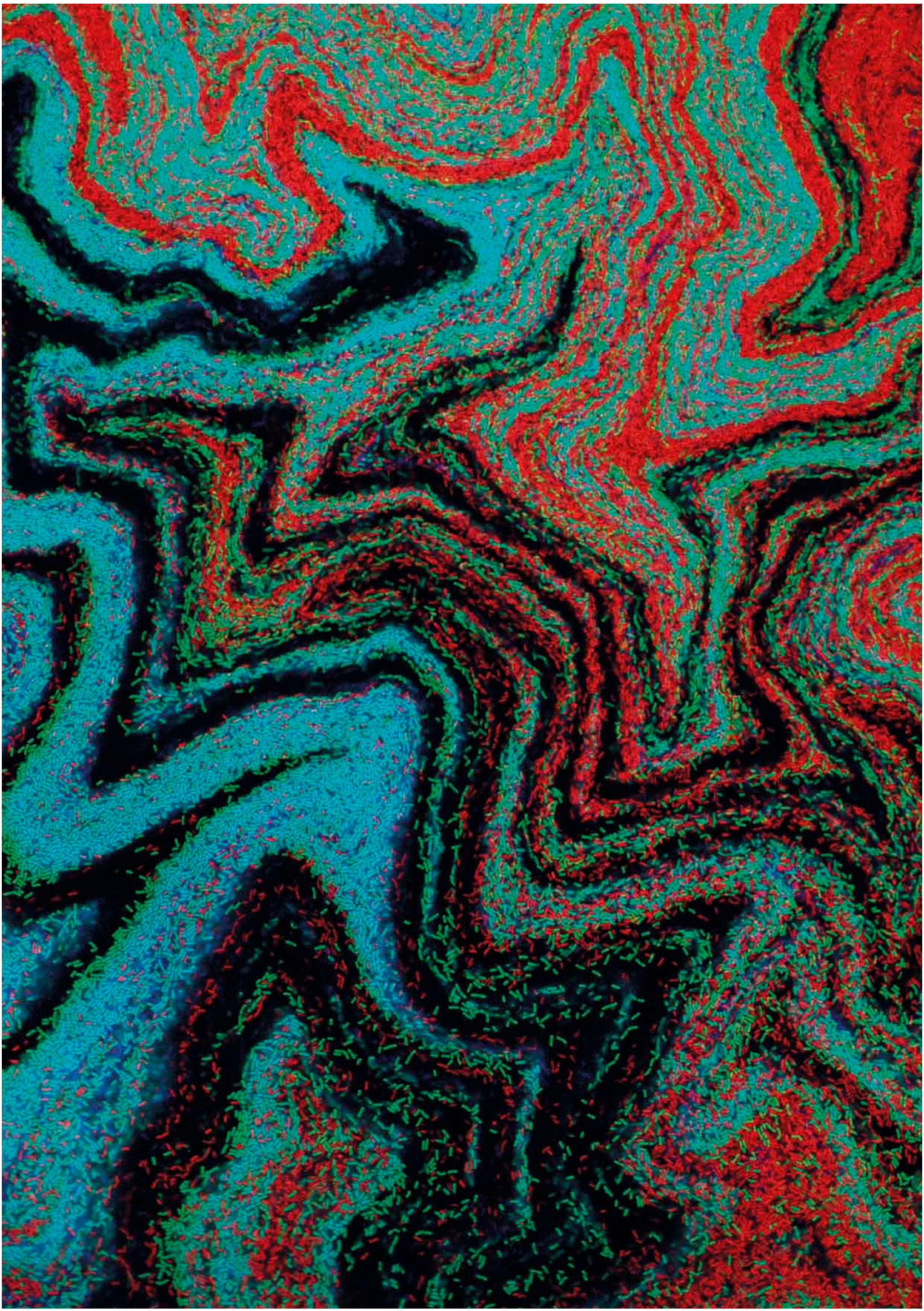
Our sustenance depends on a world that is itself ravenous. The primary role of soil organisms is to decompose organic matter that falls to the ground: dead leaves, crop residues, forest litter and animal waste. Worms and bacteria eat away this debris, grinding it up, decomposing it, reducing it to its most basic elements, and thus releasing the essential nutrients needed – nitrogen, potassium, phosphorus and other minerals – for plants and crops to grow.

Understanding this process is awakening to the simple reality that nothing in this world is ever really new. Only recycled. In the span of a year, soil organisms can decompose about 25 tonnes of organic matter on a surface about the size of a football field. They are the engine of an endless reincarnation process through which land fertility is maintained.

In France, a country whose culinary tradition has been declared a world heritage by UNESCO, the divide between fine dining and famine is rooted in about a metre thick of this dirt. Thin-skinned but fertile, French lands, along with the tools of modern agriculture, have made the country Europe's leading agricultural producer across many sectors.



This confocal micrograph shows 'Bacillus subtilis', a Gram-positive, rod-shaped bacterium that is commonly found in soil. Bacteria biofilm – Fernan Federici, Tim Rudge, PJ Steiner and Jim Haseloff, University of Cambridge. From the Wellcome Image Awards 2012, on display until the 31 December 2012 www.wellcomeimageawards.org



In 1946, France was producing a mere 16 quintals (1,600kg) of wheat per hectare. Fifty years later, yields surpassed 75 quintals.

During the past decade, however, agricultural production has been stagnating. Crop yields also plateaued across the whole of the European Union during this period; and many agro-economists, including Marc Dufumier of the Paris Institute of Technology for Life, Food and Environmental Sciences (AgroParisTech), believe this to be a lasting structural shift under way in all countries that benefited from the Green Revolution. Or, as Lester Brown calls it, the food bubble.

If this only meant that production would stabilise at about 75 quintals per hectare, all would not be so grim. France is a country largely capable of food sovereignty, making up in quantity what it might lack in variety. And globally there are more than enough calories produced worldwide to feed the planet's 7 billion inhabitants. But stability is not where things seem to be headed. A landmark study on the state of soil in France published at the end of 2011 suggests that several of the elements compromising food security around the world are at play here too, from soil erosion and degradation to the loss of agricultural lands for development.

Cities along with their infrastructures are steadily encroaching on the most fertile farmlands. For it's no accident that these are the places the country's forefathers chose to settle. In France, it is estimated that some 6,000km² is lost to urbanisation every 7 to 10 years. "The priority is always given to development," says Lionel Vilain, an agronomist with France Nature Environnement, an environmental protection group. "Disneyland, for instance, is located on the country's best [farm]lands."

With steady population growth in France, it's only natural that more space might be needed for housing. But the rate of land take appears to be outpacing that of urbanisation. And once the earth has been paved over, "the loss is often irreversible," says Dominique Arrouays, a director at the French National Institute for Agricultural Research, who headed up the study on French soils. Soil sealing, as it's called, not only compromises food supplies for future generations, but also renders cities impermeable. Which is very bad news in a world already and increasingly subject to extreme climatic events.

A report published by the Intergovernmental Panel on Climate Change in November 2011 was unequivocal: climate change will bring more dangerous and extreme weather events. The message came at a time when several regions in Southern France, as well as in Thailand (including Bangkok) and a score of other Southeast Asian countries, were grappling with catastrophic flooding. While experts emphasise the difficulty in attributing specific weather events to climate change (with the exception of Bangkok, which is being submerged by rising tides), these events were clearly aberrations. For hundreds of communities in France, and millions of Asians too, climate change has become very real.

The state of our soils will play an important role in whether we can mitigate and buffer the effects of this climate chaos. Soil is a potentially vast carbon sink, second only to the world's oceans. Yet on the whole, French farms have become net carbon-emitters. And while soils cannot entirely avert the worst flooding, their capacity to absorb water plays a role in dictating the extent to which a deluge might turn to flood.

On a given parcel of land, the fertility of soil determines whether water is more likely to infiltrate the Earth's crust, slowly percolating down to the aquifer, being purified along the way by microorganisms specifically designed for the task, or whether it will run off the land, potentially washing away largely non-renewable topsoil into rivers and waterways. This kind of soil erosion represents a permanent loss of soil capital, a problem that affects a fifth of French territory and about a third of the world's cropland.

> This kind of soil erosion represents a permanent loss of soil capital

"On 20% of our lands, soil loss is superior to what Nature can generate by alteration. Which means this is not sustainable. Will it take a hundred years or a thousand? We don't know but one day, there'll be nothing left," says Arrouays.

Villagers in Alsace's Sundgau district, as in many other parts of this eastern French region, now look upon the spring's thunderous skies with a measure of dread. On 9 May 2009 50mm-worth of heavy rains pelted down upon 500ha of denuded farmland within the span of about an hour. Unable to soak up the rain, the earth instead followed the water's course, pouring down the hill towards the village below. As the muddy blend followed the path of least resistance, streets were inundated, basements were saturated and villagers faced a heavy loss that has become a recurring menace every spring.

Over the past decade, increasingly fierce and frequent thunderstorms, of a scale seen in tropical countries, have struck the region's erosion-prone farmlands. One hundred and fifty communes succumbed at least once to muddy flows, but despite all appearances, these were not truly acts of God. They were man-made disasters.

According to Paul van Dijk of Alsace's Association for Agronomic Renewal (ARAA), changes in the types of crop produced in the region, along with the gradual exodus of animals on farms, which contributes to the depletion of soil organic matter, are among a host of factors "all headed in the wrong direction". He explains: "In this area, there's a tendency towards an

increased use of summer crops such as corn. So many of the fields are now without cover when the storms come in the spring." Bare lands mean there's nothing to hold the soil down. "Crop choices are dictated by the market and aid systems. Awareness of problems comes with a delay."

Charles Darwin spent his last days scrutinising the humble earthworm, observing its single-minded busy work that keeps soil freshly tilled. He regarded earthworms as Nature's gardeners. Soil biologists today assign them to a community they fondly refer to as "soil engineers" for their role in creating galleries that allow water to infiltrate, oxygen to circulate and roots to penetrate in the confined darkness of the underworld. Worms belong to that category of subterranean fauna whose role it is to maintain the structure of the soil. And while their abundance may not always be a perfect indicator of healthy soil – some highly contaminated lands abound with earthworms – their declining numbers are a cause for concern.

The earthworm is one reason why a group like van Dijk's encourages farmers in Alsace to adopt reduced- or no-till practices. For it's easy to imagine that the plough literally turns a worm's world upside down. "It destroys their habitat," says Antonio Bispo, of the French Agency for Environment and Energy Management (ADEME). "It can obliterate entire populations."

After 50 years of deep ploughing, heavy fertiliser use and chemical warfare on French farms, the 'green' revolution has taken its toll on life underground.

"Farmlands are for the most part biologically dead," Claude Bourguignon, a renowned soil biologist, told the country on the evening news on 15 October 2008. "We've destroyed about 90% of biological activity on our lands. Take a species like the earthworm. In 50 years we've gone from 2 tonnes per hectare to 50 kilos. The destruction is profound," he warned.

Not all share this view on the death of dirt. The study on the state of French soils, which included an impressive coverage of DNA samplings of soils across the whole of the country over a 10-year period, confirms the presence and diversity of microorganisms in the soil. "There are plenty of people who say that soils are dead. We've shown that despite the degradation, no soils are completely sterile," says Arrouays.

These are perhaps differences of opinion to be settled between scientists who observe life through a microscope, and those who track its DNA in the form of a barcode.

According to Vilain, about 40 tonnes per hectare of organic matter have been lost in the great cereal plains of France: "In thirty years, organic matter content has gone from about 3–4% to about 1–1.5%. Below 1% is when we start having real problems with infertility. We are not there yet. But that's where we're slowly headed."

Aerial photo of the Colorado River Delta showing soil erosion/Aeroservice/Science Photo Library

Soil organisms may well be going hungry for want of organic matter. 'Malnourished' is perhaps a better term, for variety is sorely lacking in fields that cultivate the same crops year after year. "The more we have monocultures, the more we deplete microbial presence. Vineyards present the lowest microbial biomass," says Lionel Ranjard, Director of Research at the French National Institute for Agronomic Research (INRA), who participated in the sampling of some 2,200 soils in France. "At what point do we lose so much biodiversity that the soil shuts down from a functional point of view? This is an important question."

With average yields still reaching an impressive 70 quintals per hectare, it's difficult for farmers to really see there's a problem. Heavy fertiliser use over the past half-century has masked fertility problems. Soil has come to be looked upon as a mere physical support for crops – a factory floor of sorts. But the world must prepare, in agriculture as in other industries, for a dearth in the natural resources that have sustained a half-century of growth in wealth and waistlines. "Phosphorus is scarce on large parts of French territory, and we know world reserves will run out over the course of the century," says Arrouays, of the mineral fertiliser mined in just three countries – Morocco, China and the US. Production of synthetic fertilisers is also dependent on oil reserves that are also peaking. "The day will come when we'll have to limit fertiliser use," says Bispo. "We'll have to depend on the biology of the soil to take over. We'll have to supply the organic matter."

In other words, we'll have to feed the life that feeds us. R

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