SOIL ATLAS

Facts and figures about a vital resource

2024

HEINRICH BÖLL STIFTUNG

(TMG) ThinkTankforSustainability
Töpfer Müller Gaßner

IMPRINT

The **SOIL ATLAS 2024** is jointly published by Heinrich-Böll-Stiftung, Berlin, Germany, and TMG – Think Tank for Sustainability, TMG Research gGmbH.

Executive editors:
Lena Luig, Heinrich-Böll-Stiftung (project management)
Larissa Stiem-Bhatia, TMG Research gGmbH

Managing editor, graphics research: Martin Eimermacher
Art direction, graphic development: STOCKMAR+WALTER Kommunikationsdesign
English editing: Paul Mundy, Stephen Roche; Joanna Trimble, TMG Research gGmbH
Proofreading: Paul Mundy; Joan Lanfranco, Heinrich-Böll-Stiftung European Union

Contributors: Axel Anlauf, Kader Baba, Lena Bassermann, David Betge, Jan Brunner, Victor Castillo, Júlia Dolce, Inka Dewitz, Lucas Gattai, Roman Herre, Mawa Karambiri, Frederike Klümper, Serah Kiragu-Wissler, Jenny Lay-Kumar, Gesine Langlotz, Lena Luig, Anne Neuber, William Onura, Marlene Ohlau, Ashok Patra, André Prescher-Spiridon, Olivia Riemer, Pratik Ramteke, María José Sanz Sánchez, Sophie Scherger, Larissa Stiem-Bhatia, Mark Schauer, Christian Sonntag, Lisa Tostado, Gideon Tups, Ronald Vargas, Harun Warui, Jes Weigelt

The views do not necessarily reflect those of the partner organisations. The maps show the areas where data are collected and do not make any statement about political affiliation.

Cover image: © STOCKMAR+WALTER Kommunikationsdesign

Editorial responsibility (V. i. S. d. P.): Annette Maennel, Heinrich-Böll-Stiftung

1st edition, November 2024

ISBN: 978-9-46494422-8
Legal deposit D/2024/11.850/1

Print: MURIEL sprl, Rue Emile Banning 96, 1050 Brussels, Belgium

FOR DOWNLOADS

Heinrich-Böll-Stiftung, https://eu.boell.org/SoilAtlas
TMG – Think Tank for Sustainability, TMG Research gGmbH, https://tmg-thinktank.com/soil-atlas-2024

SOIL ATLAS

Facts and figures about a vital resource

2024

TABLE OF CONTENTS

FOREWORD

Soil is the foundation of life on Earth. Its beauty and complexity as a living ecosystem are vast, and its functions are integral to our lives. For example, 95 percent of global food production depends on healthy soils, making access to fertile soil essential in the fight against hunger. Soils are also a crucial ally in adapting to climate change, as they help buffer the effects of droughts and floods.

Yet, climate change and competing global demands on soils place immense pressure on this invaluable resource, leading to soil erosion, biodiversity loss, and degradation. Indeed, a staggering one-third of the world's soils are degraded. Meanwhile, land demands have yet again skyrocketed, inciting land grabs and human rights violations. Within Europe, this increasing land demand makes it difficult for young farmers to find affordable land.
In the face of waning political will to protect this precious asset – even as climate change impacts increase and land use competition intensifies – our Soil Atlas is much more than an act of defiance. It offers a critical scrutiny of the diverse challenges we face in nurturing the very foundation that sustains us: the ground beneath our feet. It also showcases practical solutions. For example, how farmers in the Sahel turned barren land into productive landscapes, and how agroforestry systems, by integrating trees and hedges into crop cultivation, can enhance biodiversity, soil health, water storage capacities, and carbon sequestration simultaneously.

The Soil Atlas 2024 also highlights key areas where collaborations and new alliances can be established to protect our soils. It also proposes a bottom-up approach to implementing joint actions and advocates for better natural resource governance, grounded in robust protection of human rights and land rights, particularly for women and local communities at heightened risk.

> Soil is a vital, finite, non-renewable, and irreplaceable resource. And in many cases contested

In the current political climate, global agreements on biodiversity, climate change, and the fight against desertification are under local pressure from political forces and often from economic interest groups. It is vital, however, that we insist on fulfilling multilateral commitments to push for policy change at both the European and international levels.

In 2006, the European Union (EU) introduced an ambitious Soil Framework Directive that aimed at harmonising soil protection strategies across EU Member States. However, in 2014, it was withdrawn due to strong opposition by Austria, France, Germany, the Netherlands, and United Kingdom.

This came at a price. Ten years later, the state of Europe's soils remains dire. About 60 percent of soils are classified as damaged. Between 2012 and 2018, EU Member States lost around 450 square kilometres of soil per year to settlements and infrastructure. These developments threaten the continued provision of soil ecosystem services and thereby the very basis of the food we eat and the water we drink.

Yet, this year, instead of a comprehensive directive that aims to achieve 100 percent healthy soils in Europe by 2050, agreement was reached only to adopt a new Soil Monitoring Law that outlines a set of principles for sustainable soil management and aims to make soil health monitoring obligatory. While a modest step in the right direction, its targets are not legally binding, and the law misses opportunities to ensure integrated soil management. Moreover, the European Climate Law foresees the sequestration of 310 million tonnes of carbon through improved or changed land use. This requires protecting and rewetting peatlands in the EU, and a comprehensive directive could have made that clear.

Thirteen EU Member States are already affected by desertification. Yet, the European Court of Auditors has concluded that the steps taken by states to fight desertification lack coherence, and there is neither specific EU legislation addressing desertification, nor any integrated legislation on soil.

Globally, the demand for food, housing and infrastructure will increase as the population grows, with urbanisation and agriculture driving more land consumption, thereby increasing pressures on fertile soils. Climate action and environmental measures also make a claim on land. At the Montreal-Kunming Conference on Biodiversity in 2022, 196 countries committed to placing 30 percent of the global land area under protection to halt and reverse biodiversity loss. This remarkable commitment entails more land demands, as many national policies rely on land-based carbon sequestration in natural ecosystems.

> Soil protection has often been neglected up to now, making a regulatory framework urgently necessary

In fact, estimates suggest that more than one billion hectares of land are needed to meet these targets. These trends underscore the urgent need for better governance of soils and land resources.

In this way, while the Soil Atlas 2024 reveals the hidden and often underrated living layers beneath us, it also forewarns of the cost of inaction to the environment – and to our very life on Earth.

Preventing further soil degradation and restoring degraded soils is far more cost-effective than to deal with the severe consequences of soil loss. Yet, this perspective rarely takes centre stage in societal and political debates.

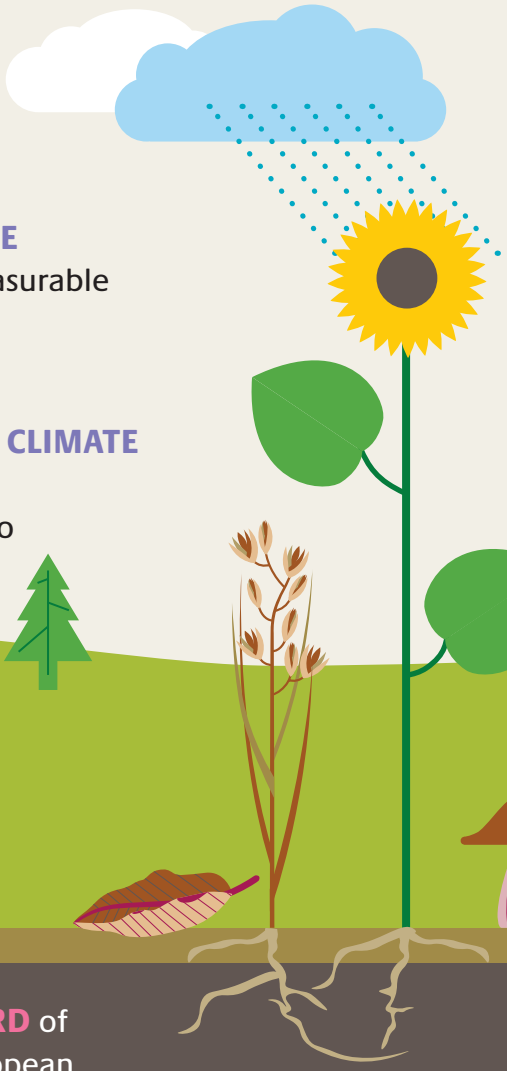
With the Soil Atlas 2024, we aim to change that. We welcome your engagement and collaboration to protect our soils and safeguard a just and sustainable future for all.

Dr. Imme Scholz
Heinrich-Böll-Stiftung

Dr. Jes Weigelt
TMG – Think Tank for Sustainability, TMG Research gGmbH

12 BRIEF LESSONS

ABOUT SOILS



1 The soil is the **MOST BIODIVERSE HABITAT** on Earth. It is of immeasurable value and is vital for our survival

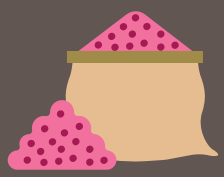
2 Healthy soils are key for **CLIMATE** action. They store more **CARBON** than forests do

3 Soils are **NATURAL WATER RESERVOIRS.** They help mitigate the impacts of the climate crisis, such as droughts, heavy rains, and floods

4 **WORLDWIDE** around **ONE-THIRD** of soils are **DEGRADED.** In the European Union (EU), more than 60 percent of soils are now classified as **DAMAGED**

5 Europe has the highest rate of **SOIL SEALING** of all continents. Once soil is sealed, it can no longer absorb water, contributing to **FLOODS**

6 Industrial agriculture often contributes to the **LOSS OF FERTILE SOIL.** Monocultures and the excessive use of chemical fertilisers and pesticides harm soil life



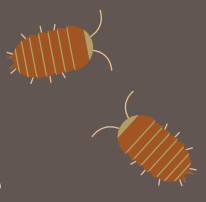
7 A significant portion of scarce agricultural land is currently used to cultivate **FEED FOR LIVESTOCK.** A plant-based diet can help save land

8 The climate crisis and unsustainable agriculture drive **DESERTIFICATION,** causing soils to dry out. Thirteen EU Member States join the growing list of countries experiencing it

9 There are **AGRICULTURAL PRACTICES** to protect and use soils more **SUSTAINABLY.** Policies must support and strengthen their implementation, including through the EU's Common Agricultural Policy

10 **ONE PERCENT** of the world's farms manage more than **70 PERCENT** of agricultural land. For investors, soils are a lucrative investment. Instead, policies should treat soils as a **COMMON GOOD**

11 Land grabs are on the rise in the name of climate action, often displacing Indigenous Peoples and local communities. **PROTECTING LAND RIGHTS** must therefore be an integral part of future climate policy



12 Between 2012 and 2023, more than 2,100 people were killed in land conflicts. **PROTECTING** people's **HUMAN RIGHTS** help ensure people are not murdered and can stay on their land

THE FOUNDATION OF LIFE

Soil – sometimes referred to as the planet's skin – takes hundreds or thousands of years to form, making it a non-renewable resource on a human timescale. It provides the basis for human life, and its health affects the food we eat, the water we drink, and the air we breathe.

Soils are composed of minerals, organic matter, gases, and water. Organic matter includes living organisms such as bacteria, fungi, earthworms, insects, microbes, and plant roots, as well as decomposing material such as animal waste and plant residues. Soil particles are formed through the gradual weathering and breakdown of rocks and minerals. These particles combine with decomposed organic matter and atmospheric depositions to create an ecosystem that supports plants, animals, and humans. Soil types and properties are highly diverse, reflecting the wide range of landscapes and climates on Earth. Nearly two-thirds of all living organisms are found in soils.

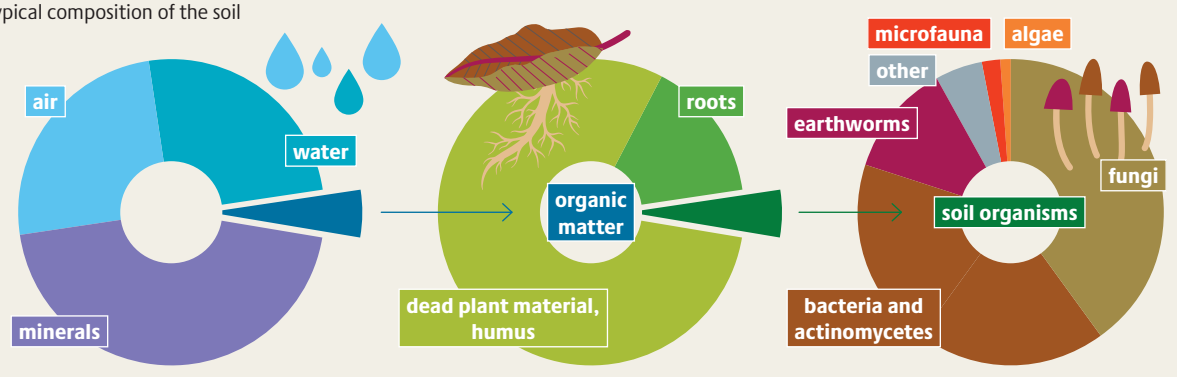
Roughly 95 percent of the world's food is grown on soils. Healthy soils function variously as a sponge, a buffer, and a filter that traps pollutants like heavy metals and pesticides. Within the soil, millions of microorganisms, including bacteria and fungi, work tirelessly to break down harmful substances. These microbes can transform dangerous chemicals into less toxic compounds, thus making our food safer.

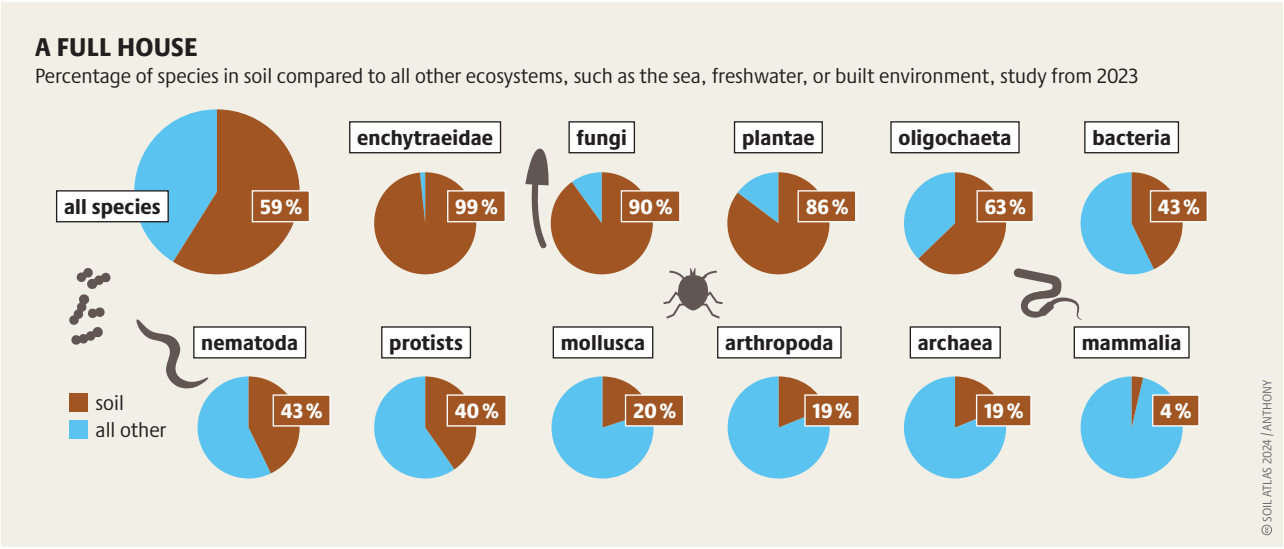
Soils also play a major role in nutrient cycles, storing, transforming, and recycling the elements essential for life, such as calcium, carbon, magnesium, nitrogen, phosphorus, potassium, and sulphur. Soil nutrients originate from decomposed organic matter, weathered rocks, and atmospheric deposition. When plants grow, they absorb these nutrients from the soil through their roots. One of the most critical nutrient cycles supported by soils is the nitrogen cycle. Nitrogen is essential for plant growth, yet most plants cannot harness atmospheric nitrogen. Soil microorganisms convert atmospheric nitrogen into usable forms, like ammonia and nitrates. Plants absorb these nutrients to produce essential molecules. When plants and animals die, nitrogen returns to the soil through decomposition, completing the cycle.

Soils also contribute to flood regulation and water quality by storing, filtering, and purifying rainwater, and making it available to plants. Excess water filters down into aquifers. However, soil compaction, caused by overgrazing and the use of heavy agricultural machinery, hinders water infiltration, leading to run-off that causes floods and landslides. As droughts and water scarcity occur more frequently, sustainable soil management becomes increasingly important: healthy soil can store 250 litres of rainwater per cubic metre. A one-percent increase in organic matter enables soil to retain an additional 150,000 litres of water per hectare. Furthermore, healthy soils are a prerequisite for clean air, as water and wind erosion lead to dust and sand being carried by the wind, diminishing air quality.

Many of the soils in northern Europe have developed since the last Ice Age and are strongly influenced by human activities

LIVING SOIL
Typical composition of the soil





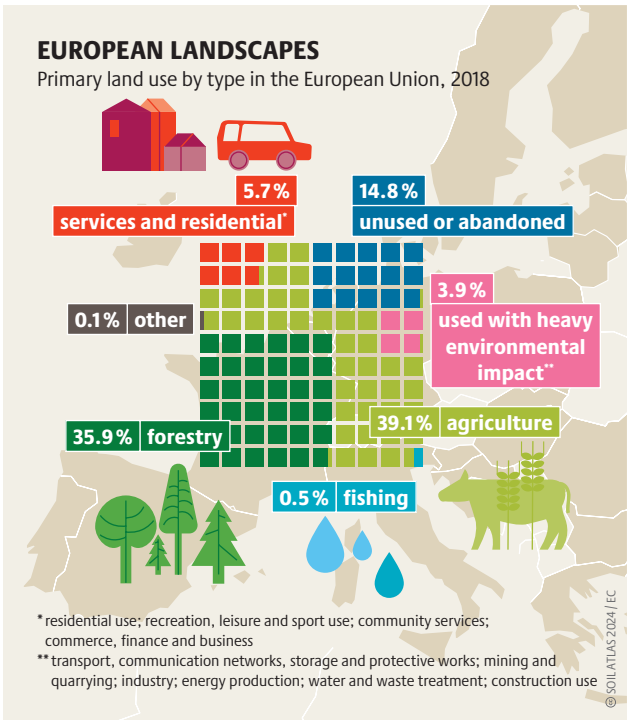
Soil provides a home for a vast number of species: It is the most biodiverse habitat. Almost two-thirds of all species worldwide reside there

Soils are also indispensable in the fight against climate change. They store more carbon than vegetation and the atmosphere combined. Carbon is absorbed from the atmosphere by plants and then stored in soils through the plants' roots. The top 30 centimetres of soil alone hold approximately 694 gigatonnes of carbon. If soils are not managed properly, this carbon may be released into the atmosphere as the greenhouse gas carbon dioxide (CO_2). For example, as a result of peatland drainage and forest clearing for agricultural use, cultivated lands have lost between 50 to 70 percent of their original carbon stocks.

Soils, and the plants and animals they support, not only sustain us physically but also enrich our wellbeing and culture in many ways. Soils offer aesthetic and recreational value for people to admire the wealth and beauty of nature. There is growing evidence to support the therapeutic value of direct human contact with soil. A therapy known as grounding, or earthing, has been shown to support wellbeing, relieve mental and emotional distress, and produce positive physiological changes. In many cultures, the soil itself holds profound spiritual and religious significance, serving as the foundation for belief systems. The Indigenous Peoples of the Andes regard soil as a living entity through the spiritual concept of Pachamama. Before undertaking any activity involving soil, they hold a ceremony to feed and honour the living soil. Moreover, soils serve as repositories for the heritage of past civilisations, preserving artifacts and structures that offer insights into our shared history.

The overall health of soils relies on a balance in their physical, chemical, and biological properties. However, this balance can be disrupted in several ways. Misuse and overuse of fertilisers can render soils acidic, saline, or polluted. Intense ploughing damages the soil structure, contributes to the breakdown of organic matter and the release of carbon dioxide, and exposes the surface to erosion. These threats emphasise the need for sustainable soil management. Although some land use change and soil disturbance are necessary for food production, housing, and road construction, it is vital that we minimise negative impacts on soils. If we look after the soil, the soil will look after us.

Around 80 percent of Europe's land is impacted by human activities like urbanisation and agriculture, driving environmental degradation and climate change



THE SILENT GLOBAL CRISIS

Soil degradation is a major but largely neglected global problem that threatens agricultural productivity, food security, and ecosystem health. Around one-third of soils worldwide are degraded, with over 40 percent located in Africa.

The extent and severity of soil degradation are influenced by both natural processes and human activities, such as deforestation, farming practices, overgrazing, and urbanisation. Key forms of soil degradation include erosion, salinisation, acidification, compaction, nutrient depletion, and contamination by heavy metals.

Erosion, primarily caused by water and wind, is one of the most widespread and severe forms of soil degradation. It carries away the nutrient-rich topsoil that is essential for plant growth. Soil erosion leads to the loss of an estimated 75 billion tonnes of soil a year, which in turn causes financial losses of around 400 billion US dollars annually. These alarming statistics underscore the profound economic and ecological consequences of soil degradation on a global scale.

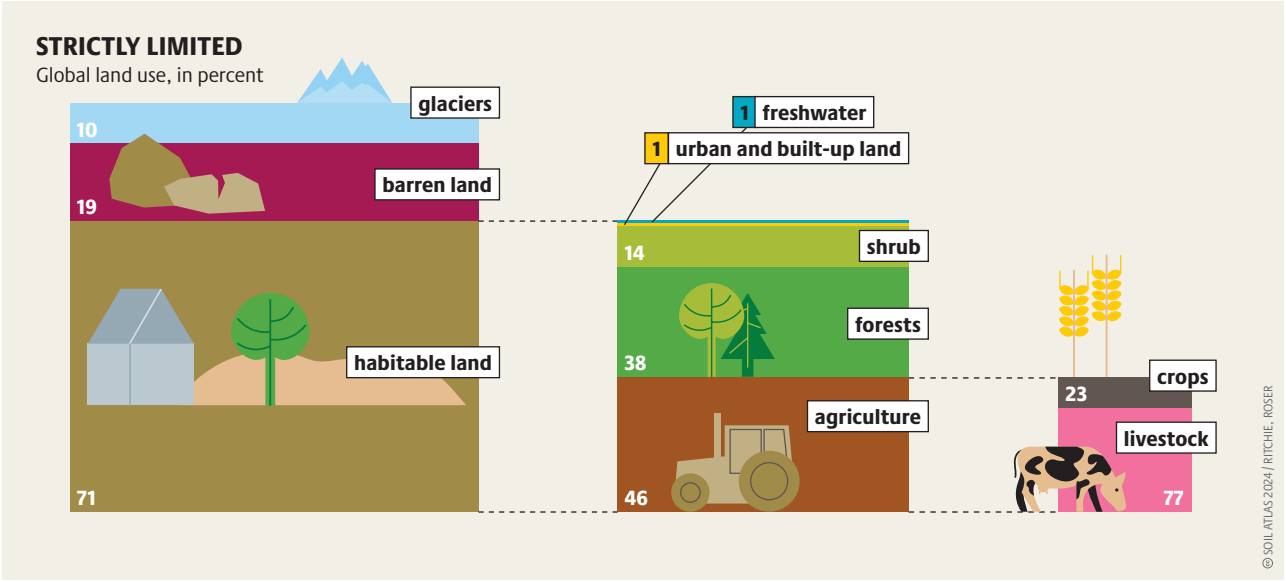
Another critical problem is salinisation: the accumulation of salts in soil. This often results from improper irrigation practices. When irrigation water containing salts evaporates, it leaves the salt behind in the soil, which can accumulate to levels that harm plant growth. A significant portion of irrigated lands globally are affected by salinity, with some estimates suggesting that from 20 to as much as 50 percent are impacted, particularly in arid and semi-arid regions. In northern India, soil salinity is particularly severe and impairs wheat and rice yields.

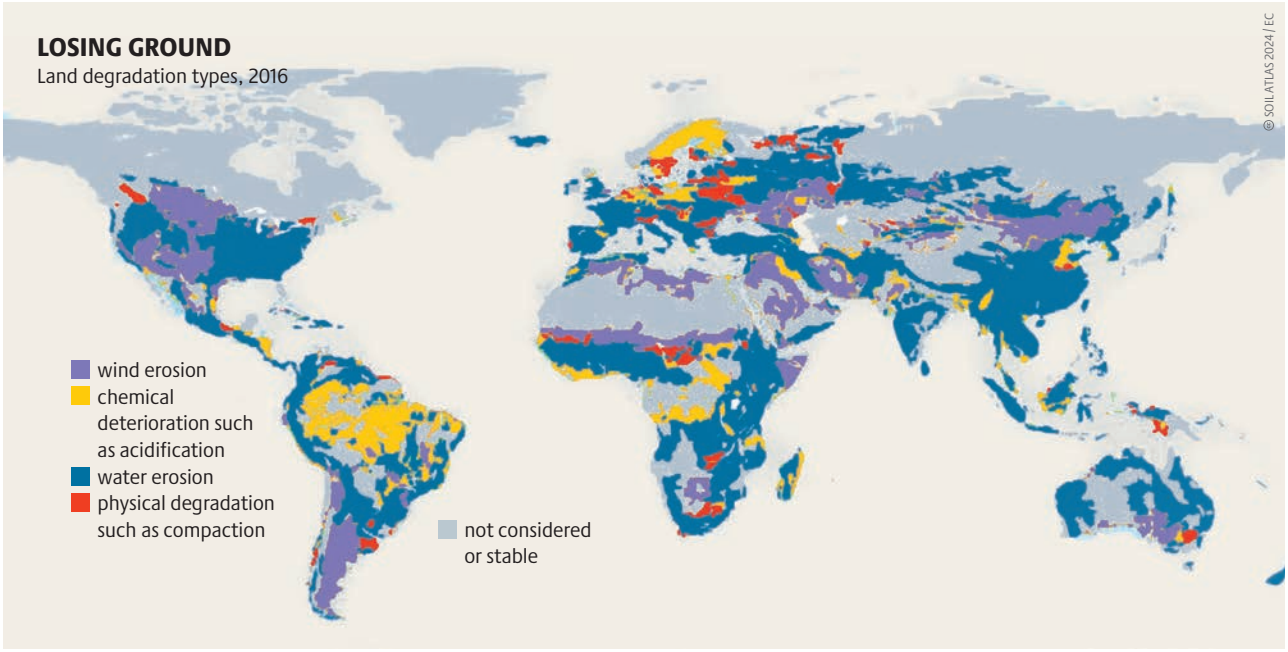
Acid rain, excessive nitrogen-fertiliser use, and intensive agricultural practices are all primary causes of soil acidification. This is increasingly common in Asia, Europe, and North America, where industrial emissions of sulphur dioxide and nitrogen oxides react with water vapour in the atmosphere. In Europe, soil acidification – exacerbated by the inefficient use of nitrogen fertiliser – is diminishing crop yields, necessitating costly lime applications to temporarily alleviate the resulting acidity.

Compaction occurs when soil particles are pressed together, reducing the pore spaces between them and decreasing aeration and water infiltration in the soil. Compaction is often caused by heavy machinery and intensive livestock grazing. It cuts yields and makes crops more vulnerable to drought, as compacted soil hold less water.

Soil contamination by heavy metals, pesticides, and industrial chemicals, poses risks to plants, animals, and humans. It arises from industrial activities, improper waste disposal, the excessive use of agrochemicals – and even warfare. The ongoing Russia's war of aggres-

Only a limited portion of the Earth is suitable for agriculture, and this area is shrinking further as a result of escalating soil degradation





Degradation strips people of their livelihoods, particularly in rural areas where many rely on agriculture

sion against Ukraine has contaminated one-third of the agricultural land, while the use of white phosphorus bombs has poisoned farmland in southern Lebanon.

Soil degradation leads to nutrient depletion and a decline in soil biodiversity, damaging microorganisms that are essential for breaking down organic matter, recycling nutrients, and maintaining soil health and fertility for sustainable plant growth. This hinders processes such as nitrogen fixation and phosphorus solubilisation, resulting in nutrient-poor soils and lower crops yields. Moreover, healthy soil microbiomes protect plants from diseases. These vital soil functions are disrupted by soil degradation, increasing plants' susceptibility to diseases.

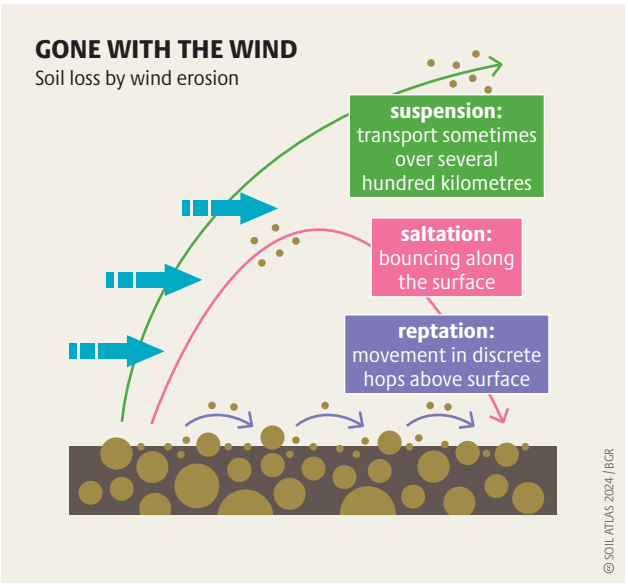
Globally, around 18.1 million square kilometres of land are degraded. Some 62 percent of this area is damaged by unsustainable practices, such as improper agricultural methods, deforestation, and poor land management, while 38 percent is subject to overgrazing that exceeds the land's capacity to recover and maintain its productivity.

In Sub-Saharan Africa, soil erosion can reach up to 100 tonnes per hectare annually, reducing crop yields by 30 to 50 percent in severely affected areas. Approximately 65 percent of arable land in the region is now classified as moderately to severely degraded, posing a significant threat to food security. In Europe, 61 percent of soils are currently unhealthy, primarily due to organic carbon loss, biodiversity loss, and peatland deterioration. Due to gaps in data on soil contamination, the overall extent of degradation is likely to be even more severe. In South Asia, soil degradation is driven by the cultivation of steep lands, excessive ploughing, flood irrigation, removing or burning crop residues, unbalanced fertiliser use, and uncontrolled grazing.

These practices reduce crop growth and yields. Moreover, irrigated lands suffer from salinisation and groundwater depletion. Land degradation costs South Asia an estimated 10 billion US dollars annually.

Concerted efforts that address the drivers of soil degradation are needed. The fight against soil degradation is a battle for the very foundation of life on Earth.

Open farmland is particularly threatened by wind erosion, which harms soil quality and reduces harvest yields in the long term



DESERTIFICATION

EUROPE IS DRYING OUT

While desertification is a problem most commonly associated with Africa or Asia, it is not limited to these regions. Intensive agriculture and the climate crisis have also led to severe soil degradation and desertification in Europe. And not just in southern Europe: even countries with temperate and humid climates, such as Hungary and Bulgaria, are affected.

Desertification occurs mainly in regions marked by persistent water scarcity. Known as drylands, these regions cover more than 40 percent of the world's land surface. Desertification threatens 24–29 percent of the global land area, impacting about 500 million people in 2015 according to the Intergovernmental Panel on Climate Change. This threat has intensified in recent decades, mainly due to climate change and human activity. Urban areas have expanded by approximately 250 percent globally over the past 40 years, while the area of irrigated cropland has more than doubled over the past 40 to 50 years. Among the most at-risk areas for desertification are the Sahel, the drylands of East Africa and Central Asia, the Indo-Gangetic Plain, and the North China Plain.

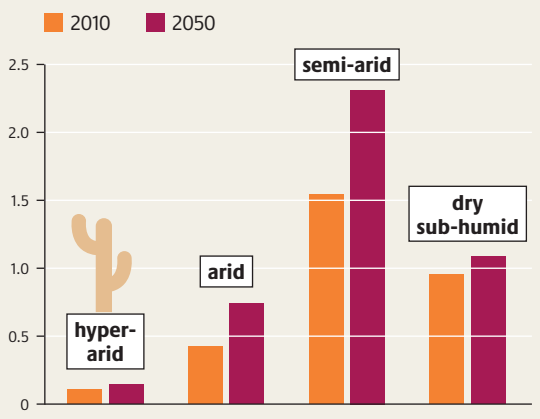
Desertification is a severe form of land degradation that predominantly occurs in arid, semi-arid, and sub-humid regions in the world. This process is primarily driven by human activities such as deforestation, livestock overgrazing, and unsustainable agricultural practices that lead to vegetation loss and soil degradation. Without the protective cover of plants, the soil is increasingly susceptible to both wind and water erosion, processes that strip away the nutrient-rich topsoil that is essential for plant growth. As this topsoil is eroded, the land gradually loses its productivity, eventually transforming once fertile land into barren, desert-like landscapes where little to no vegetation can survive. Climate change intensifies the problem by disrupting weather patterns, particularly by altering rainfall distributions and increasing the frequency and severity of droughts.

The effects of desertification are significant. It drastically lowers the productivity of farmland and limits its capacity to sustain populations and livelihoods. Scientists have found that agricultural productivity has fallen on around 23 percent of the world's farmland due to land degradation.

Soils are also drying out in the European Union (EU). Thirteen EU Member States – not just in the South but also in Central and Eastern Europe – are affected by desertification. Across the EU, around 23 percent of the territory is moderately sensitive to desertification, with eight percent highly susceptible. Hungary, Bulgaria, Spain, and Italy are among the countries most affected. Land degradation in the EU is caused largely by intensive agriculture, which degrades soils through erosion, salinisation, and compaction. Overexploitation of water resources, depletion of the groundwater table, and reduction of water quality due to excessive fertiliser use are other factors that contribute to desertification. The increasing risk of heatwaves and wildfires also play a role. Copernicus, the EU's Earth Observation Programme, recorded nearly four times as many wildfires during the first half of 2022 compared to the average of the previous 15 years. The risk of desertification is expected to worsen due to increased intensity and frequency of extreme climatic events.

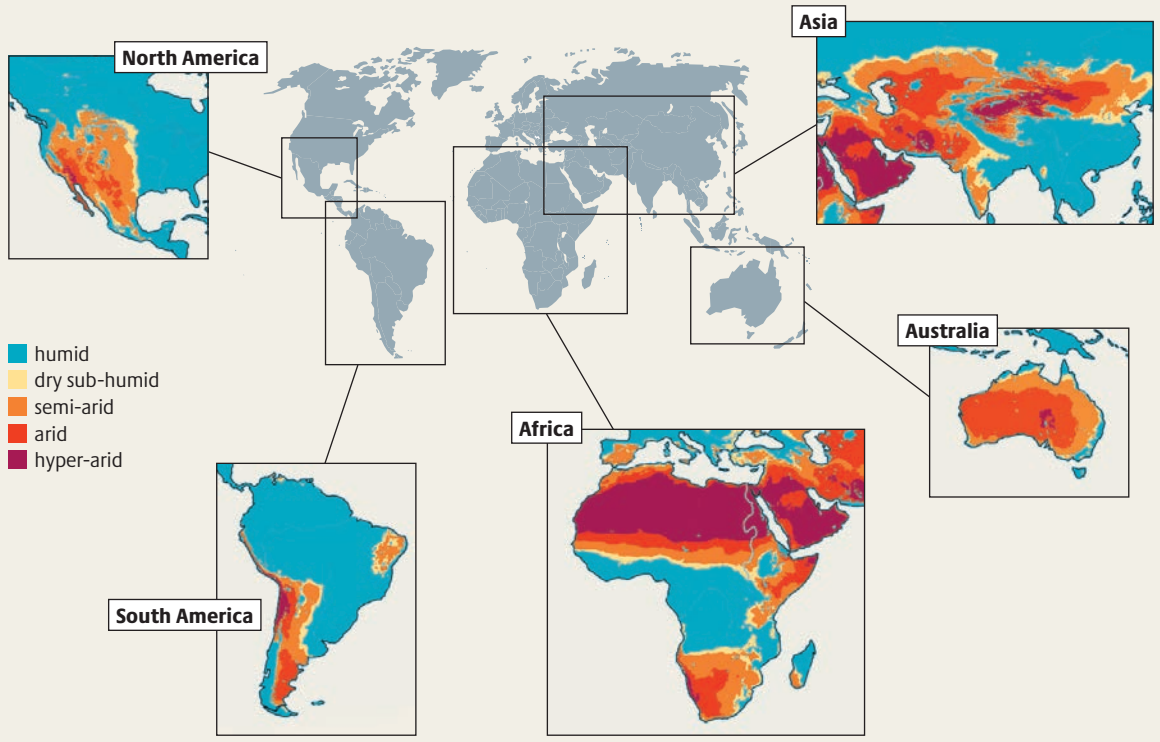
Intensive agriculture is one of the key drivers of desertification. In Spain, for example, more and more water, much of it extracted from aquifers, is being used to grow fruit and vegetables for the European market.

LIVELIHOODS UNDER THREAT
Global population in drylands, billion people



Not only is the world's population growing, but dry areas are also expanding due to the climate crisis and overexploitation

A GLOBAL ISSUE
Distribution of drylands, 2018



Approximately 3 billion people inhabit drylands, with 70 percent of these regions located in Asia and Africa

And the industry increasingly relies on groundwater. Between 2010 and 2016, groundwater consumption for the irrigation of highly profitable products, such as strawberries, lettuce, or broccoli, increased more than fivefold – from four to 22 percent. This overuse of water resources, coupled with water table decline and water quality deterioration due to excessive fertiliser use, is driving desertification.

Highly intensive berry farming in Portugal's Alentejo region has led to significant soil destruction and erosion. To make way for large-scale greenhouses, multinational companies levelled the ground, drained the soil, and covered it with plastic, which severely damages the soil structure. The soil under the greenhouses becomes so degraded that restoring it becomes nearly impossible. Water scarcity exacerbates the situation, as parts of Portugal are facing its driest weather conditions in the past 1,200 years due to the expansion of the Azores High, a high-pressure system over the North Atlantic. Climate change has intensified this expansion, causing more frequent heatwaves and prolonged droughts. Experts warn that large swathes of the country are at risk of desertification by the end of this century.

The climate crisis and desertification are interrelated. Desertification is not only accelerated by the climate crisis; it also contributes to CO_2 emissions. As soils degrade, they lose organic matter, resulting in higher carbon emissions and lower capacities to absorb carbon.

Depending on its composition, healthy soil can store up to 3.75 million litres of water per hectare. However, desertification significantly impairs this capacity: for every gram of organic matter lost, the capacity of soil to retain water diminishes by 10 millimetres, according to several studies. This exacerbates the risk of flooding and leads to further water shortages. In response to the growing threat of desertification, the United Nations adopted the goal of so-called Land Degradation Neutrality. Similar to carbon offsetting, this approach stipulates that any unavoidable land degradation must be compensated for by restoring soil and ecosystem services in another location. However, the EU currently lacks a concrete strategy for achieving Land Degradation Neutrality by 2030.

In a recent report, the European Court of Auditors points out that progress towards this goal is inadequate. An important step would be an EU-wide agreement on common methods for assessing desertification. Understanding where desertification is likely to take place would help combat soil degradation before it becomes irreversible.

CLIMATE ADAPTATION

SOIL AND WATER, A CRUCIAL SYMBIOSIS

As the climate crisis intensifies around the world, severe storms and flooding are becoming more frequent. Healthy soils can help buffer the effects of extreme weather. For that reason, soil protection is more important than ever. Yet, it is still neglected.

Healthy soils with a well-balanced pore structure act like a sponge, absorbing water and releasing it when needed. Soils also filter out pollutants, thereby maintaining and improving the quality of groundwater. Soil organisms such as fungi and bacteria break down certain pollutants and convert them into non-toxic compounds. Soils are best able to fulfil these functions when properly managed.

Without the ability of soil to store water, farming would be impossible. Around 80 percent of the world's cultivated area is not artificially irrigated but relies on rainfall alone. The water storage capacity of the soil plays a vital role in farming because it enables crops to survive periods of drought. It is essential to protect the soil and practise sustainable agriculture so that as much rainfall as possible can percolate through the soil, making it available for plants. If soils are compacted by heavy machinery, less water can seep through, and heavy rains may result in localised flooding. Cover crops, such as clover and lupins, help to ensure that soil is not washed away in downpours and that less water evaporates in hot weather. In hilly areas, terraces – steps carved into the hillside – reduce surface runoff and help retain water on the land.

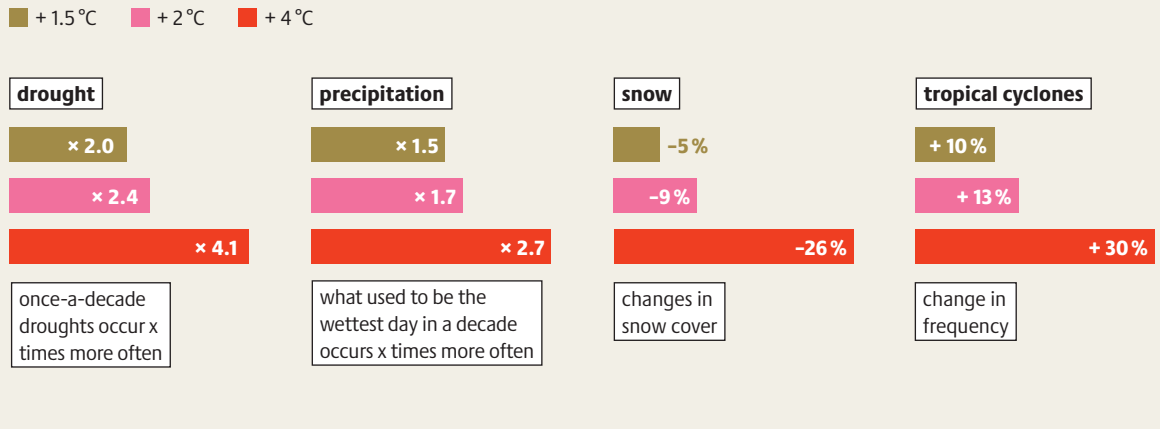
Dense urban infrastructure may also prevent soil from acting as a water reservoir. When large areas of towns and cities are sealed by asphalt or concrete, rainwater must be channelled into drains, and heavy downpours can overwhelm the drainage system and cause flooding. Europe is the continent with the highest rate of such soil sealing. Between 1990 and 2006, the area of land in the European Union (EU) used for urban development increased by 1.5 million hectares, an area half the size of Belgium. If this trend continues, an area the size of Hungary will be sealed within 100 years.

In the face of the climate crisis, the importance of sustainable urban development is increasing. The city of Copenhagen has become a pioneer in this regard. In response to several severe flooding incidents over the last decade, the city has been transformed into what it terms a sponge city. A major part of this

In the future, droughts and harvest failures will occur more frequently. Healthy soils must be protected; degraded ones must be restored

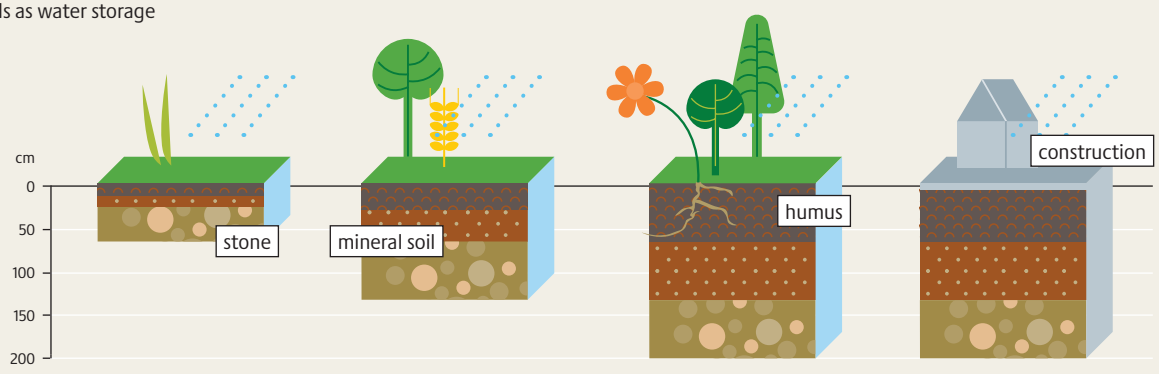
LONG SHADOW OF EXTREMES

Weather extremes expected to increase with global temperature rises, scenarios compared to pre-industrial era



CONTRIBUTIONS TO GROUNDWATER, FLOOD MITIGATION, AND MORE

Soils as water storage



Well-developed, deep soils can store large amounts of water, some of which seeps further down to form groundwater

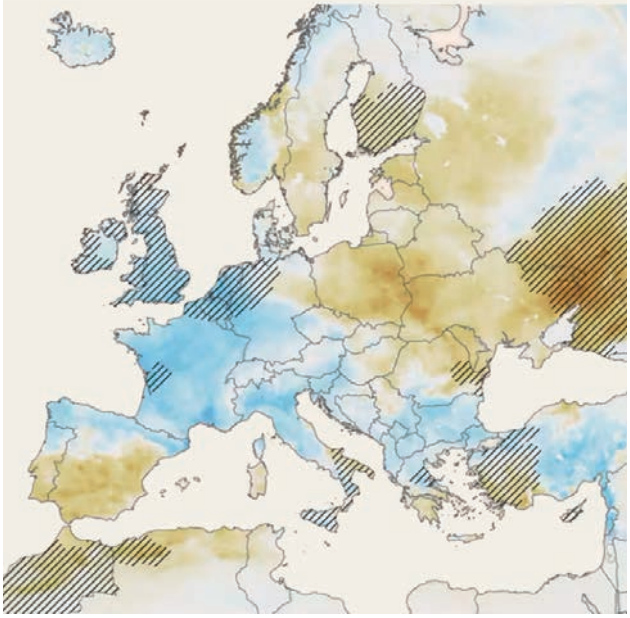
process has been the greening and unsealing of built-up and asphalted areas. Unsealed soils play an indispensable role in flood control. During heavy rains they absorb water, thus reducing the pressure on surrounding areas. In addition to sponge cities, sponge landscapes are also needed. Low-lying areas and wetlands, such as floodplains and peatlands, serve as natural flood defences and cool their vicinities through evaporation during heatwaves. But human activities have severely damaged them. In the EU, around half of all peatlands are now degraded, having in most cases been drained for agriculture, forestry, or peat extraction. Yet only 120,000 hectares, representing less than one percent of the total drained area, have so far been rewetted.

Legally binding targets for the sustainable use, protection and regeneration of soils are needed as vital water reservoirs. Farming, which accounts for more than 40 percent of land use in the EU, can play a key role. Funding from the Common Agricultural Policy could be used to incentivise the switch to soil-friendlier agriculture. In June 2024, the European Council adopted the Nature Restoration Law (NRL), which obliges Member States to restore Europe's degraded landscapes. The law includes a target to restore at least 30 percent of their drained peatlands by 2030, and 50 percent by 2050, of which at least one third must be rewetted. Yet, the NRL includes an exemption for farmers and private landowners, for whom the rewetting of peatlands will be voluntary. Similarly, the targets for restoring agricultural ecosystems may be temporarily halted under exceptional circumstances if they are found to significantly reduce the land required for sufficient food production. ●

The climate crisis severely impacts agriculture. In Europe, maize, rice, soybean, and wheat harvests are expected to be the hardest hit

OUT OF BALANCE

Climate change-related soil moisture anomaly, May 2024



WHEN CULPRITS BENEFIT

Overuse of artificial fertiliser is bad for soils and, in the case of nitrogen fertilisers, for the climate as well. Moreover, pesticides deplete the soil of beneficial organisms. Yet these products earn big money for big companies, which influence governments, often blocking policy changes needed to protect people and the environment.

In 2023, almost 73 billion US dollars' worth of pesticides and more than 200 billion dollars of artificial fertilisers were sold worldwide. In 2022, high market prices meant that the largest agrochemical manufacturers increased their profits significantly over the year. Both the pesticide and fertiliser industries have become more concentrated since the mid-1990s. Between 1996 and 2009, hundreds of seed and pesticide companies merged to form six major corporations. The four largest – Syngenta, Bayer, Corteva und BASF – accounted for 62 percent of the global market in 2020. The fertiliser industry has also become highly concentrated in the last two decades, with numerous mergers and takeovers giving rise to corporations like Nutrien, CF Industries, Mosaic and Yara.

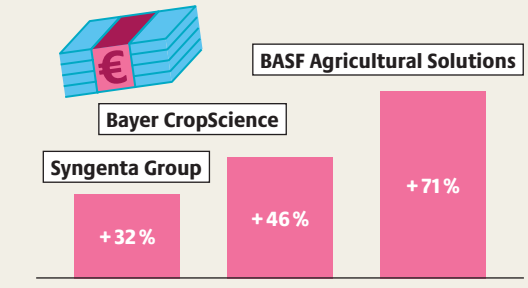
The highly profitable fertiliser and pesticide business has led to a dramatic increase in production costs for farmers. In Europe, the price of nitrogen fertiliser rose by 149 percent between September 2021 and September 2022. One reason the trade is so lucrative for the corporations is that their bottom line does not account for the ecological costs that arise from the use of their products – biodiversity loss, depletion of soil organic matter, and rising soil salinity and acidity. In the European Union (EU), many pesticides are banned because of their known risks to human health and the environment. But they continue to be sold nonetheless, mainly in countries of the Global South. In 2018, EU Member States plus the United Kingdom (UK) approved the export of 81,000 tonnes of pesticides that are banned in Europe. The three top exporters were the UK, Italy, and Germany.

In addition, corporations often use their market power to influence policies. In the EU, pesticide and fertiliser companies have for years lobbied against the European Commission's so-called Farm to Fork Strategy, which is a key pillar of the European Green Deal. A vital element of this strategy was the proposed Regulation on the Sustainable Use of Plant Protection Products (SUR), which aimed to cut pesticide use by 50 percent by 2030. Investigative research revealed that representatives of pesticide firms and agribusiness associations met with key conservative members of the European Parliament more than 400 times between January 2020 and July 2023. Scorecards of the voting on the SUR in November 2023 show how conservative parliamentarians, who were particularly targeted by lobbyists, opposed key aspects of the pesticide reduction law. In this way, the industry contributed to the European Parliament's rejection of the regulation. It remains to be seen whether the new Commission will make another attempt to restrict the use of toxic chemicals in the EU.

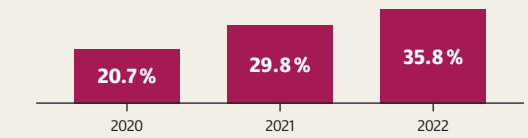
The pesticide industry gained political influence through a new strategic partnership between the Food and Agriculture Organization of the United Nations (FAO) and CropLife International, an association representing the five leading pesticide companies: BASF, Bayer, Corteva, FMC, and Syngenta. This partnership, instituted by a letter of intent signed in 2020, has been criticized by numerous civil society organizations who regard it as incompatible with FAO's support for agroecology. In May 2024, the FAO officially ended its partnership with CropLife.

MONEYMAKERS

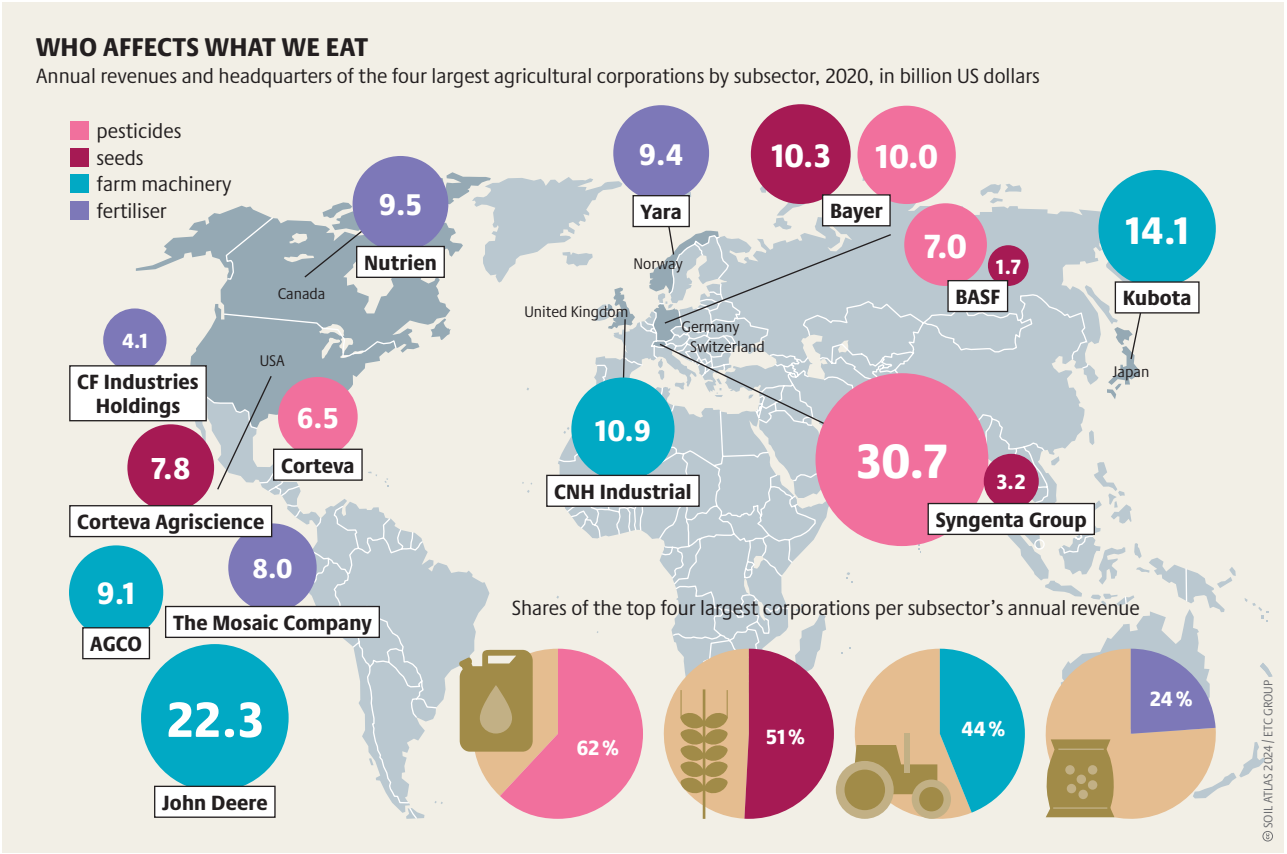
Profits of the world's three largest pesticide manufacturers, 2022, compared to previous year



Profit margins of the nine largest fertiliser companies



BASF, Bayer, and Syngenta also generate income by selling dangerous pesticides banned in the EU to countries in the Global South



The market power of a few large corporations has steadily increased over the years, with the combined sale of pesticides and seeds proving profitable

At the same time, the fertiliser industry is increasingly making its presence felt at international climate policy gatherings. At the 28th United Nations Climate Change Conference in Dubai, the International Fertiliser Association hosted several events at the Food Systems Pavilion. Moreover, fertiliser companies OCI, OCP, Nutrien, and Yara, along with pesticide companies BASF, Bayer, and Syngenta, supported a so-called Soil Health Day at the conference, promoting themselves as contributors to improving soil health.

The pesticide and fertiliser industry has responded to growing political pressure, especially from civil society, with various strategies and is exploring new revenue streams. The fertiliser company Yara, which also operates the world's largest ammonia trading network, has, for example, announced that it aims to decarbonise its production by reducing its emissions of carbon dioxide. It plans to use renewable energy to generate so-called green hydrogen, which will be used to produce green ammonia. For this industry transition, Yara has asked the German government for state support to convert its plant in Brunsbüttel in northern Germany, despite the fertiliser giant's record profits. But the process of synthesising ammonia requires a lot of power, whether green or not. Instead of decarbonising fertiliser production, it would often be more cost-efficient, climate-friendly and no less productive to simply use less fertiliser. In 2022, British farmers were able to slightly raise their yields, even though they used 25 percent less mineral fertiliser than the average of the previous decade. Merely decarbonising production by changing farm production methods instead of drastically reducing the use of chemical fertiliser and pesticides would allow the industry's core business to continue unimpeded.

Digital agriculture, on the other hand, is a completely new business model. Bayer, with its digital platform FieldView, is the current market leader, while Yara has already announced its intention to build the largest digital platform in the agricultural sector in cooperation with IBM. Multinational companies such as Google and Amazon are also pushing into this market.

Pesticide and fertiliser companies have been investing heavily in so-called precision farming. This allows GPS-guided, self-driving field robots to identify weeds and apply pesticides in a targeted way. This promises to reduce the overall amount of pesticide used. But experts warn that the digitalisation will contribute to further market concentration, as the most digital platforms are already in the hands of the leading pesticide, fertiliser and farm equipment manufacturers. These platforms, in turn, have partnerships with other corporations in related fields and in agricultural trade, and so can expand their influence over individual farm enterprises.

GLOBAL DEPENDENCIES

Synthetic fertilisers harm the climate, but industrial farming relies heavily on them. Additionally, higher fertiliser prices have pushed up prices for food commodities. African countries, where food crises intersect with debt crises, are hit especially hard.

Between 2019 and 2022, synthetic fertiliser prices have tripled for several reasons. During the COVID-19 pandemic, Russia and China imposed export bans on fertilisers to certain regions, including Western Europe and India, to protect their domestic agriculture from higher fertiliser prices. The interruption of supply chains during the pandemic also led to temporary shortages in fertiliser supplies on the world market. Moreover, since mid-2021, Russia had restricted its exports outside the Eurasian economic area. Then, after Russia's full scale invasion of Ukraine, battles around the Black Sea ports, which are important for the fertiliser trade, led to an abrupt stop in many trading activities. At the same time, the European fertiliser industry temporarily reduced its production by up to 70 percent due to rising prices of natural gas. Another key driver of fertiliser price increases were price spikes in the costs of fossil fuels such as natural gas, oil, and coal that are needed to produce nitrogen fertilisers.

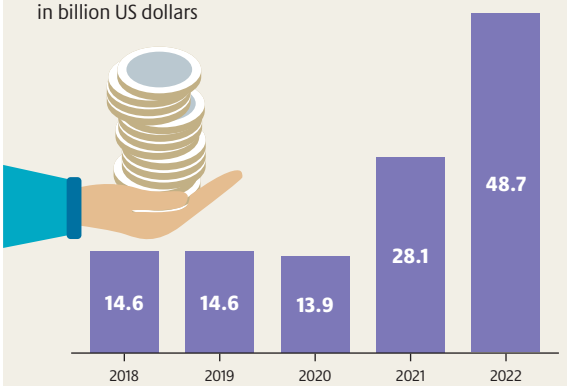
The effects of higher fertiliser prices can be seen at the supermarket checkout. In March 2022, the worldwide Food Price Index, which tracks the prices of food commodities, hit an all-time high. In the food crisis of 2007 and 2008, one study found that the doubling of fertiliser prices pushed up the price of food commodities such as grain, vegetable oils, and milk by an average of 44 percent. As a result, up to 100 million additional people worldwide suffered from hunger. But while price increases affect the global market and average consumers, the fertiliser industry benefited the most from alongside the oil and gas industry. In 2022, the nine largest fertiliser manufacturers registered an average profit margin of 36 percent. With decarbonisation plans and gas prices in the European Union (EU) still at a comparatively high level, some fertiliser companies are now moving their production to the United States, where natural gas is cheaper and government subsidies higher.

In addition to issues of price volatility, fertiliser production contributes to the climate crisis. The Haber-Bosch process, developed at the start of the 20th century, is central to the production of nitrogen fertilisers. Under temperatures of up to 500 degrees Celsius and high pressure, synthetic ammonia is produced from hydrogen and nitrogen. No other process to produce industrial chemicals emits more carbon dioxide (CO_2). The nitrogen fertiliser value chain alone is responsible for 2.1 percent of global greenhouse gas emissions. About one-third of these emissions result from the production process. In addition, ammonia synthesis contributes between one and three percent to worldwide energy consumption every year. Due to its energy-intensive production, the price of nitrogen fertiliser is linked to the price of natural gas by around 90 percent.

The uneven distribution of fertiliser production capacity means that the Global South depends on imports of synthetic fertilisers. In Sub-Saharan Africa, countries import an average of 80 percent of their fertiliser needs. That leaves them particularly exposed to price spikes. In Kenya, fertiliser prices rose over 150 percent from 2020 to 2022, increasing staple food prices. To partially alleviate the impact of these costs on farmers and the food industry, many African governments subsidise fertilisers. But such emergency subsidies are a heavy burden on the public wallet, demonstrating the risks and hidden costs of relying on synthetic fertilisers produced with fossil fuels. In Malawi, rising costs of fertiliser dur-

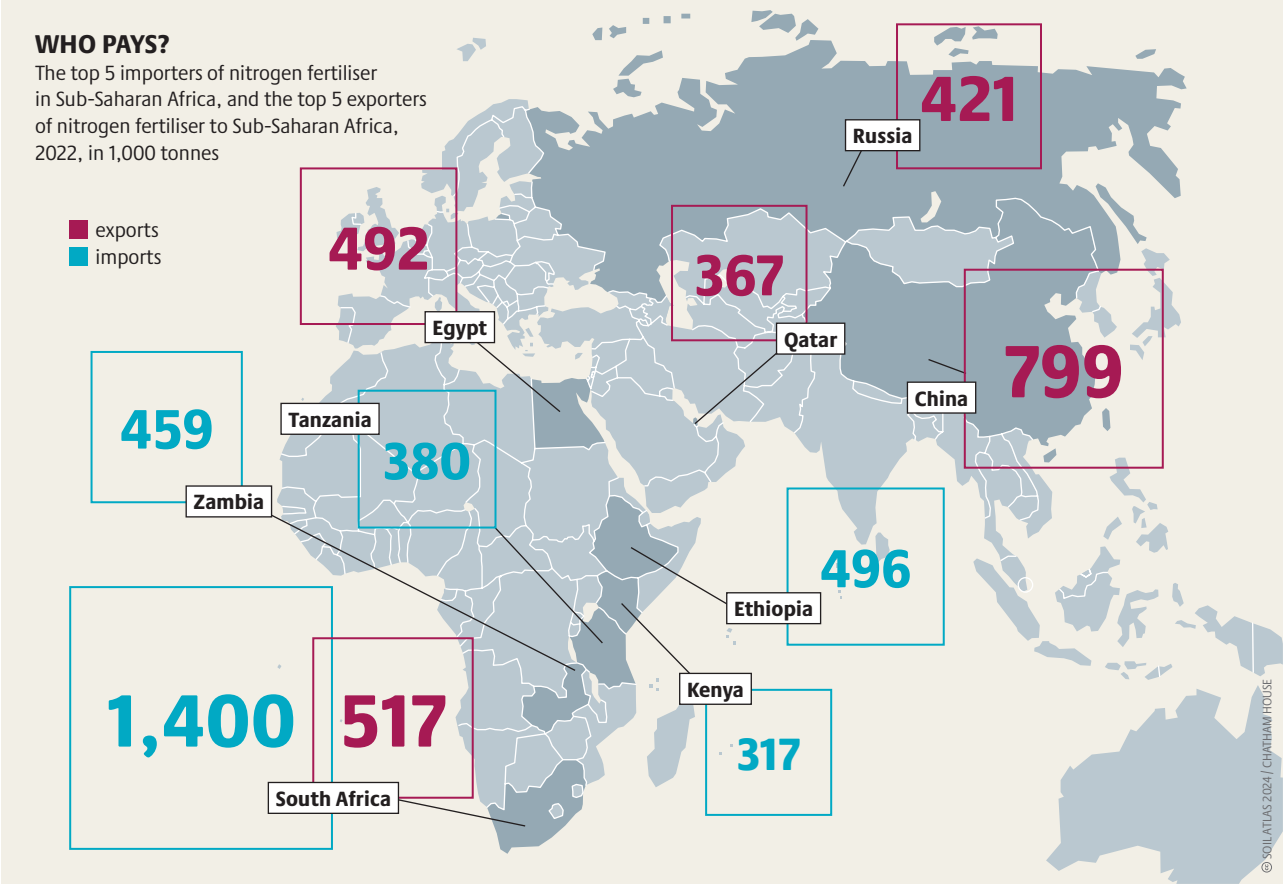
RINGING THE TILLS

Profits of the world's nine largest fertiliser producers, in billion US dollars



before interest, tax, and depreciation

The pandemic, Russian aggression and inflation set the scene for fertiliser companies to raise their prices far above their production costs



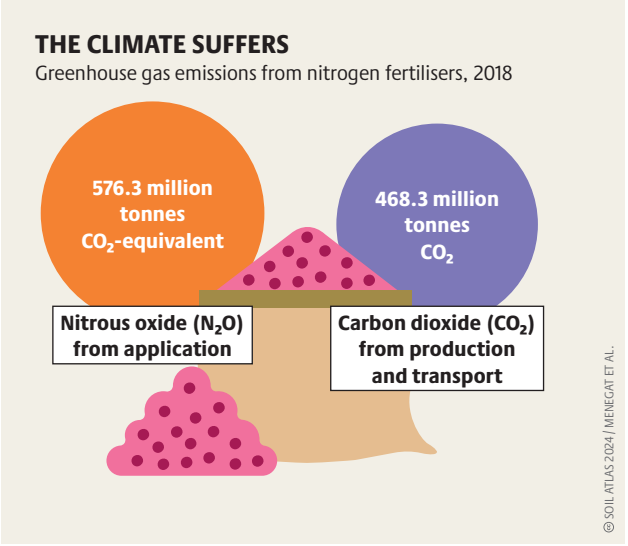
ing the food crisis of 2007 and 2008 meant that fertiliser subsidies rose from 8 to 16 percent of the total national budget. Moreover, the percentage of low-income countries that are under debt distress, or threatened with bankruptcy, has almost tripled since 2013. According to the International Monetary Fund, around 20 countries, including Cameroon, Ethiopia, Somalia, and Sudan, face simultaneous debt and food crises.

There is a widespread assumption that high yields attained by applying synthetic fertilisers and pesticides lead to less hunger. But in fact, the connection is far from clear. This is illustrated by the case of Zambia: a country with the highest fertiliser use in all of Sub-Saharan Africa, heralding a five-year average of 65 kilograms per hectare. Zambia is among the top six African countries in terms of grain yields per hectare. However, the 2022 Global Hunger Index ranks Zambia at 110 out of 125 countries for which data is available. The large-scale industrial cultivation of maize and soybean in Zambia does not contribute to its food security.

The 2024 African Fertilizer and Soil Health Action Plan highlights that more fertiliser alone cannot solve the global food crisis. African heads of state stress improving soil health through holistic methods. The Action Plan promotes organic fertilisers and integrated approaches, but not the phasing out of conventional fossil fuel-based fertilisers. Major civil society organisations have welcomed this shift towards sustainability, but its impact hinges on implementation. ●

Many small farmers have incurred significant debt due to the high costs of synthetic fertilisers, jeopardizing their financial stability

Globally, the production and use of nitrogen fertiliser contribute to greenhouse gas emissions that exceed those generated by all of Germany



EXTRACTIVIST AGRICULTURE

Phosphorus is bioessential, meaning that all living organisms require it. Yet, despite its presence in soils, it is a relatively rare element on Earth and is not always found in a form that plants can absorb. The fertiliser industry produces easily soluble phosphorus but depends on a finite, non-substitutable resource: phosphate rock.

As the use of agrochemical inputs became global after 1950, the mining of phosphate rock increased dramatically. Today, in fact, it is one of the most intensively mined substances on Earth, with production running at over 200 million tonnes per year, ten times more than copper. For close to half a century, phosphate rock and fertilisers were treated as a low-cost, bulk commodity before becoming a strategic resource as a result of hikes in fertiliser prices between 2007 and 2012. At that time, some scientists calculated that the world would soon reach a point of peak phosphorus, when production would start to decline.

Since then, several researchers have rebutted these predictions. While phosphate rock reserves are expected to last at least several hundred years, their geographic distribution is highly concentrated in the Middle East and North Africa. Nearly 70 percent of the world's phosphate reserves are located in Morocco, which also extracts phosphate rock in the Western Sahara. Another 10 percent is concentrated across Algeria, Egypt, and Tunisia. Other significant reserves are found in China and Russia.

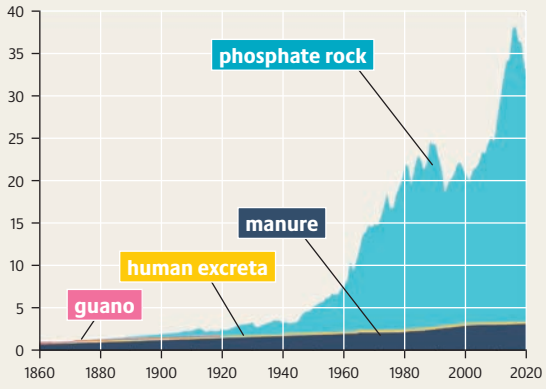
Despite having just one percent of global phosphate reserves, the United States dominated the industry in the 20th century. It was the largest, most technically advanced producer and controlled fertiliser production and trade. Then, following a series of mergers and acquisitions, the North American phosphate industry was reduced to just two major companies, Mosaic and Nutrien, based in the United States and Canada. This high market concentration affords these companies immense power to set prices, leaving farmers, especially those in the Global South, vulnerable to fluctuations. Based in Central Florida next to the large-scale phosphate deposits and with major operations in Peru, Brazil, and Saudi Arabia, Mosaic alone controls 13 percent of the global phosphate market.

However, since the 1990s, the dominance of North American firms has been increasingly challenged by by state-owned or state-controlled companies from emerging economies. China's phosphate industry is comprised of various companies, including the Yuntianhua Group, which is formally private but subject to significant state influence. China extracts almost half of the world's phosphate rock and processes it all domestically to produce fertilisers. Although China exports

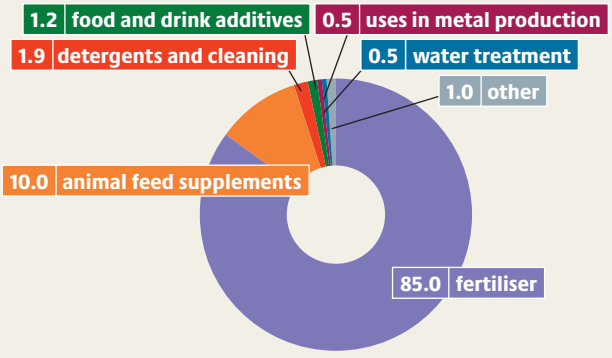
Along with nitrogen and potassium, phosphorus is one of the most important elements for plant life. About 85 percent is used for fertiliser

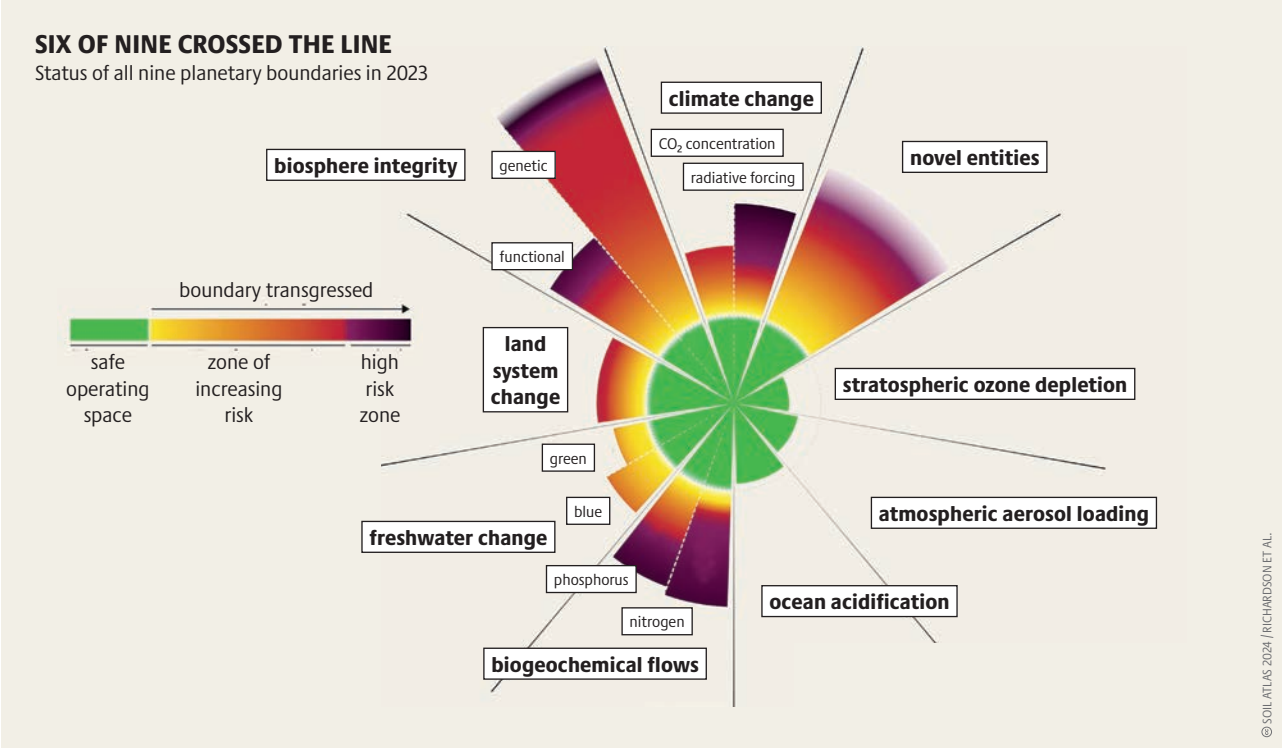
AN ESSENTIAL

Sources of phosphorus for anthropogenic use, in million tonnes per year



Worldwide use of phosphorus mined from phosphate rock, in 2014 in percent





Exceeding the planetary boundary for phosphorus raises the risk of irreversible environmental changes and threatens the Earth system's resilience

some of its output, the focus is on the domestic market, and this is reinforced by trade barriers imposed during price hikes. In Morocco, the state company OCP Group dominates the phosphate sector and accounts for more than one-third of global phosphate rock exports.

The declining dominance of North American companies is caused by geological factors and more costly environmental regulation. Every tonne of phosphate fertiliser results in the production of five tonnes of phosphogypsum, a toxic and mildly radioactive by-product. In the United States, phosphogypsum has to be stored in enormous stacks, whereas in other countries, such as Morocco, it can be dumped into the sea. Most phosphate rock is extracted in open-pit mines, leading to significant land-use changes and conflicts.

Although phosphate reserves are finite, phosphorus as an element does not deplete on Earth. Most mined phosphorus ends up in water bodies due to nutrient losses in the fertiliser value chain, and soil erosion, as well as through sewage systems. In aquatic ecosystems, phosphorus contributes to excessive growth of algae, which produces dead zones largely devoid of marine life. The planetary boundary for phosphorus has already been transgressed to a point where the environment can no longer self-regulate.

Recycling phosphorus helps overcome the dual problem of finite resources and water pollution. In many European cities, phosphorus is extracted from food waste in large-scale composting facilities, but on average only 30 percent of all organic waste is recollected. Recent recycling efforts have focused on human excreta. For instance, in Germany, the recycling of phosphorus in municipal sewage facilities will be mandatory as of 2029. However, this approach focuses solely on recycling phosphorus from existing sewage systems, which ignores other nutrients like nitrogen. More encompassing methods can be found in the Saint-Vincent-de-Paul urban development project in the heart of Paris. It will use toilets that separate urine from solid waste with water-saving flush systems. The collected urine will be processed into a fertiliser and used to enrich urban green spaces.

Bones are often overlooked as a source of phosphorus. Yet, they contain the highest concentration of phosphorus among organic materials. In the EU, more than 4 million tonnes of animal bones are discarded each year. This translates to 294,000 tonnes of phosphorus – one-third of the EU's overall demand. In contrast to recycling human excreta, the re-use of animal bones has not yet been broached politically.

The phosphorus issue should be addressed not only through technological innovation, but also through social change. Plant-based diets require less land and thus reduce overall demand for crops and fertilisers. Agroecological techniques do not depend on mineral fertilisers, and instead, use organic sources to improve soil health and fertility. Moreover, applying green manure both increases biodiversity above ground and microbial life in the soil, which makes phosphorus more readily available to plants.

GREEN FERTILISERS

NOT A QUICK FIX

The production of synthetic nitrogen fertiliser using renewable energy instead of fossil fuels can reduce greenhouse gas emissions upstream. But it does not solve the problems associated with excessive use of synthetic fertilisers, such as diminished soil health, biodiversity loss, on-field greenhouse gas emissions, nitrate pollution, and overdependency on external inputs.

Synthetic fertilisers add the major soil nutrients – nitrogen, phosphorus, and potassium – necessary for plant growth. Phosphorus and potassium are mined, whereas nitrogen, which accounts for over half of all synthetic fertilisers, is synthesised from natural gas and coal.

While sectors such as energy or transport have begun to decarbonise, chemicals used in the agrifood sector – above all food-related plastics and nitrogen fertilisers – remain key drivers of demand for fossil fuels. Both the agrifood and energy sectors are dominated by a small number of large multinational corporations, which have a vested interest in maintaining an industrial food system that depends on fossil fuels.

The production and use of fossil-based nitrogen fertiliser creates several problems. First, greenhouse gas emissions and other environmental impacts arise throughout the life cycle of nitrogen fertilisers, starting with gas or coal extraction, continuing through the production of ammonia, all the way to the farm. The production based on fossil fuels is incompatible with the Paris Agreement on climate change. In addition to the greenhouse gases emitted during production, fertiliser use leads to the emission of nitrous oxide. Finally, the price of nitrogen fertilisers – and thus of food – is closely linked to the volatile price of internationally traded fossil fuels. This has important geopolitical repercussions. The COVID-19 pandemic and Russia's full-scale invasion of Ukraine are examples of recent events that have sent fertiliser prices soaring.

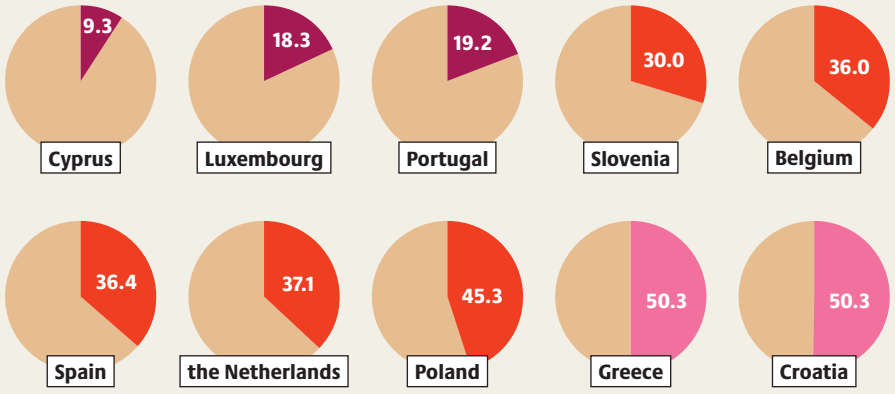
One proposed way to reduce dependency on fossil fuels is to produce so-called green fertilisers. In this process, hydrogen is first generated via electrolysis using renewable power, and then is used to synthesise ammonia. Increased production and use of green fertilisers would allow for a wider geographical distribution of producers and reduce dependency on imported, price-volatile fossil fuels. Green fertiliser can be produced wherever sun, wind, and water are abundant. Several African countries, including Egypt and Kenya, have begun to build production facilities.

Yet, many challenges remain. Currently, just 0.3 percent of the ammonia used to produce nitrogen fertiliser globally can be described as green. While this share is projected to increase, green fertilisers are unlikely to be

Climate crisis: fertilisers applied to fields release a substantial portion of their nitrogen as nitrous oxide into the atmosphere

BIG LOSS

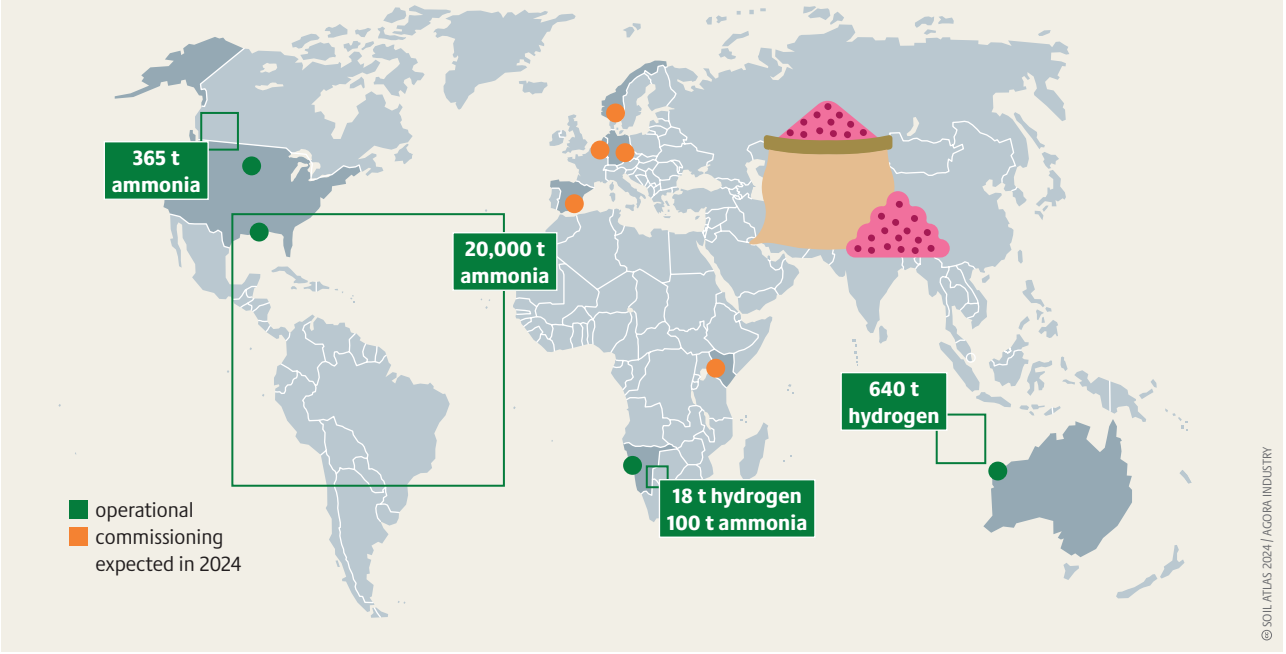
Share of nitrogen absorbed by crops following fertiliser application in 2014, in percent



ten EU Member States with the worst nitrogen use efficiency

JUST A DROP IN THE OCEAN

Green fertiliser production sites in 2024 and output in tonnes (t) per year



globally available at competitive prices soon. Green hydrogen could also generate new problems, as it requires land for solar power plants or wind farms. This increases the threat of land grabbing and land use changes that conflict with livelihood activities. Countries with a history of inequitable land ownership and illegal land appropriation, such as Brazil and Nigeria, are at heightened risk. Water consumption is often discussed as a potential future problem related to the production of green hydrogen. An electrolyser needs a minimum of 9 litres of water to produce one kilogram of hydrogen; however, due to inefficiencies in purification and cooling, electrolysis requires between 20 and 30 litres of water per kilogram of hydrogen. This issue is particularly problematic in regions with high renewable energy potential, which often suffer from water scarcity.

While the production process for green fertilisers has a lower impact on the climate, the impact of the product is the same. Globally, twice as much nitrogen is released into the environment than it can absorb, mostly due to the overuse of fertilisers. This excess nitrogen has a range of damaging impacts. First, soil microbes convert nitrogen into nitrous oxide, a greenhouse gas 300 times more powerful than CO_2. Second, nitrogen-tolerant species outcompete more sensitive wild plants and fungi, reducing biodiversity and harming plant health. Third, nitrates find their way into groundwater and the ocean, creating oxygen-depleted dead zones. Fourth, both nitrates in drinking water and ammonia in the air are harmful to human health. Finally, excessive use of synthetic fertilisers acidifies soils and damages soil health.

At 61,000 a year, the renewable production capacity for ammonia fertilisers is minimal: just 0.3 percent of global ammonia consumption

Unless the overall volumes of nitrogen fertilisers are reduced, especially in countries with extreme overuse, such as China, Egypt, and the United Kingdom, the nitrogen surplus will still damage water bodies, soils, and ecosystems, irrespective of how the fertilisers are produced. Green fertilisers that have a lower climate impact during the production phase do not address the more significant emissions that arise in the usage phase. At best, they can reduce emissions related to nitrogen fertilisers by about one-third. Lastly, green fertilisers are still external chemical inputs, which can trap farmers in dependency and debt.

Scenarios that try to keep global temperatures below 1.5 degrees Celsius include steep and immediate reductions in global synthetic fertiliser use and a near phase-out by 2050. However, governments have a primary responsibility to safeguard food production. They must therefore avoid sudden shocks, as occurred in Sri Lanka in 2021, when the government banned the import of agrochemicals. Instead they should promote a managed transition to more sustainable, agroecological farming systems. Locally, sustainably produced, green fertilisers can facilitate this transition. But they are not a panacea. Instead of substituting fossil-based fertilisers with green fertilisers, the focus should remain on longer-term goals, such as improving soil health, reducing waste, and promoting more efficient nitrogen use by producing food rather than animal feed.

LAND GRABBING

THE RACE FOR HECTARES

Land has been heralded as a crisis-proof investment around the world. However, these deals often make money for the wealthy few, while pushing local people off their land and into poverty. Countries like Germany, Singapore, and the United States are complicit in such land grabs.

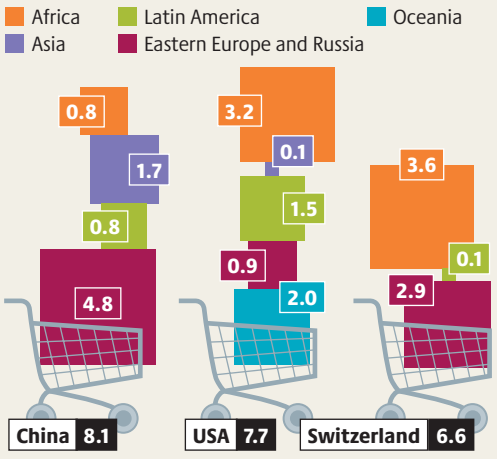
Since the turn of the millennium, the world has been gripped by various interconnected crises. Starting in 2007, the financial crisis shook the world; the price of oil almost tripled between 2007 and 2008, while soaring food prices led to food riots in at least 40 countries. The search for new, safer investments and the lure of profits from food price increases caused investors' gaze to turn to fertile farmland. As an investment, land promised a double bonus: the rising value of the land itself and a profitable area for growing food, animal feed, and energy crops for biofuels. In the name of climate action, land is also being acquired for industrial tree plantations, which play a big role in global carbon trading schemes. The same is true for biodiversity: designating land to expand protected areas often violates the rights of people who already live on or use the land. The acquisition of land by corporations, banks, and investment funds – frequently hand in hand with national elites – is commonly referred to as land grabbing.

Due to these crisis-inducing economic dynamics, land ownership has increasingly concentrated in the hands of a few investors since the 2000s. For example, the Singapore-based food giant Olam International now claims to control over more than 3 million hectares of land. Between 2006 and 2014, 300 investors acquired almost 2 million hectares of land in Cambodia. That is around half of Cambodia's total arable land. Between 100 and 213 million hectares worldwide are estimated to have changed hands through land deals since the turn of the millennium. To put that in perspective: the European Union (EU) has a total of 157 million hectares of agricultural land. In many cases, landgrabbing involves the forced displacement of local populations. Peasant and Indigenous communities are hit especially hard. They may lose access to pasture, forests, rivers, and fields, and therefore their livelihoods. Moreover, their houses or entire villages are often destroyed. Such actions constitute an array of human rights violations, including the right to food, water and housing, and systematically undermine specific Indigenous and peasants' rights: for example, any relocation must involve both free, prior informed consent and adequate compensation.

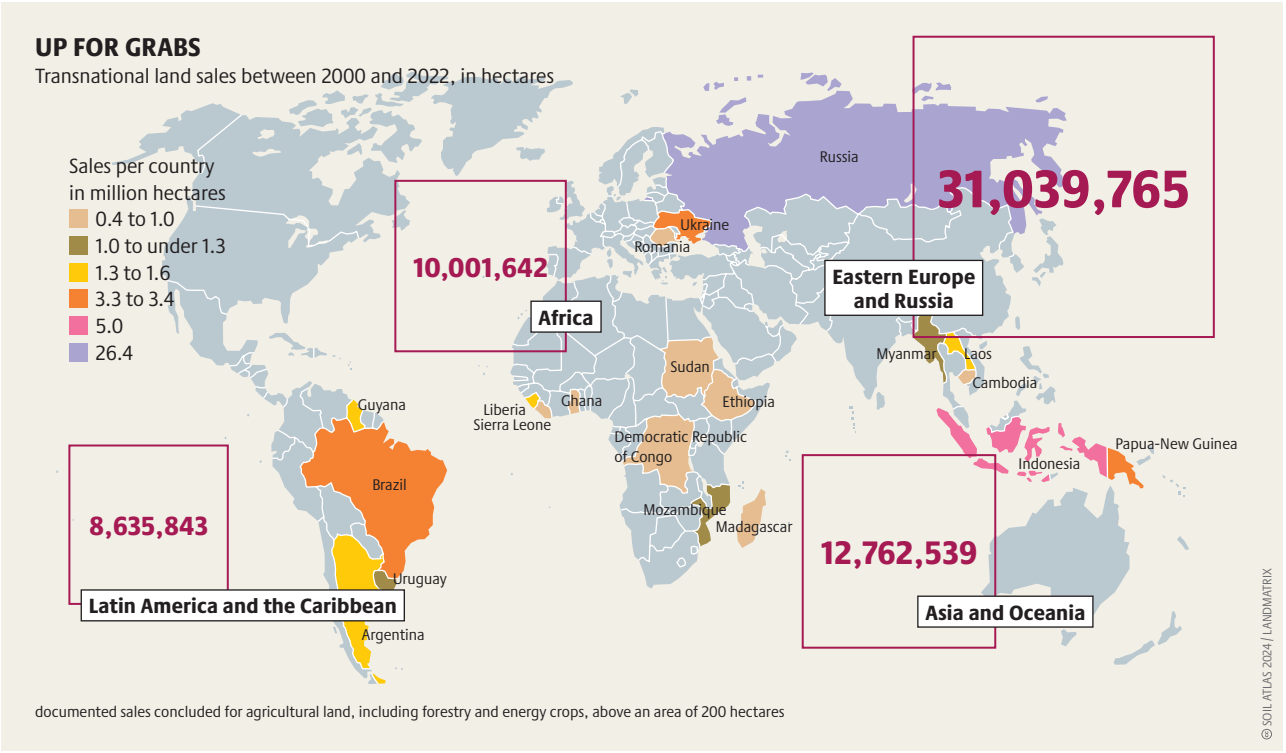
Many governments and investors justify land grabbing as a way to fight poverty and develop rural areas. However, it often achieves the very opposite: very few people find work on the newly established mega-plantations. For instance, mechanised sugarcane production in São Paulo, Brazil, requires only a single sugarcane cutter per 400 hectares, leading to a substantial loss of jobs compared to the small-scale farms these plantations replace. Moreover, mega-plantations typically prioritise cash crops, such as sugarcane, soybean, or oil palm, over food crops needed to sustain local communities. The combined cultivated area of these three commodities alone grew by 57 million hectares between 2007 and 2021, an area larger than Spain. Such land use change has driven displaced people to either relocate again or emigrate altogether. At the same time, the majority of profits generated from land deals flow to the urban elite and international investors, leaving little benefit for the local economy.

SPENDING SPREE

The three countries with the largest investments in land between 2000 and 2020, by target region, in million hectares



There are 570 million small farms worldwide. They rely on land that is increasingly affected by global trade dynamics, impacting their economic stability



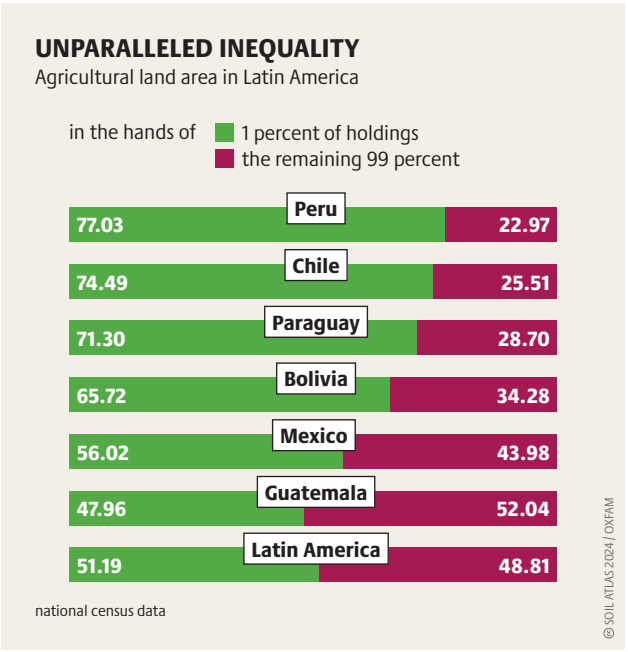
How countries of the Global North are complicit in these land grabs can be illustrated by the case of Germany. For example, the Berlin investor Amatheon has acquired over 40,000 hectares of land in Zambia. In 2009, Deutsche Bank invested at least 279 million euros through its subsidiary DWS in firms that bought or leased cultivable land, resulting in the acquisition of over 3 million hectares of land in Africa, South America, and Southeast Asia. The Ärzteversorgung Westfalen-Lippe, a pension fund for doctors, invested 100 million dollars in a global land fund, which, in Brazil alone, acquired 133,000 hectares of land, in particular for large-scale soybean monocultures.

Pressure on land is also rising due to so-called green grabs. For instance, the Italian oil giant ENI purchases forest certificates globally to portray its business as climate neutral or achieving so-called net zero emissions. In 2022, it bought 1.7 million carbon credits from a 940,000-hectare forest offset scheme in Zambia. In parallel, it continues to invest in biofuel production, including a 22,000-hectare land deal in the Democratic Republic of the Congo, to replace some of its fossil inputs.

According to the current legal interpretation of the United Nations on land and human rights issues, countries involved in land deals should undertake measures at three levels. First, they should ensure that their own actions, such as through development banks, do not violate legitimate land rights. Second, through appropriate regulation, countries must prevent violations by firms based in their territories. Third, governments must collaborate internationally to address land concentration and strengthen access and rights to land for marginalised groups. There is still much to be done on all three counts. ●

Regions with weak state institutions are vulnerable to land grabbing by international investors, causing displacement of local communities and loss of livelihoods

Unequal land ownership in Latin America has historically led to hunger, poverty, and violence: issues that continue to affect the region today



LAND SALES

JUST ANOTHER COMMODITY?

The phenomenon of large companies and investors buying up vast tracts of arable land in the Global South has long been seen as a problem. In Germany, too, this kind of land grabbing is on the rise, with small and medium-sized farms pushed out. A reorientation that prioritises the common good is needed.

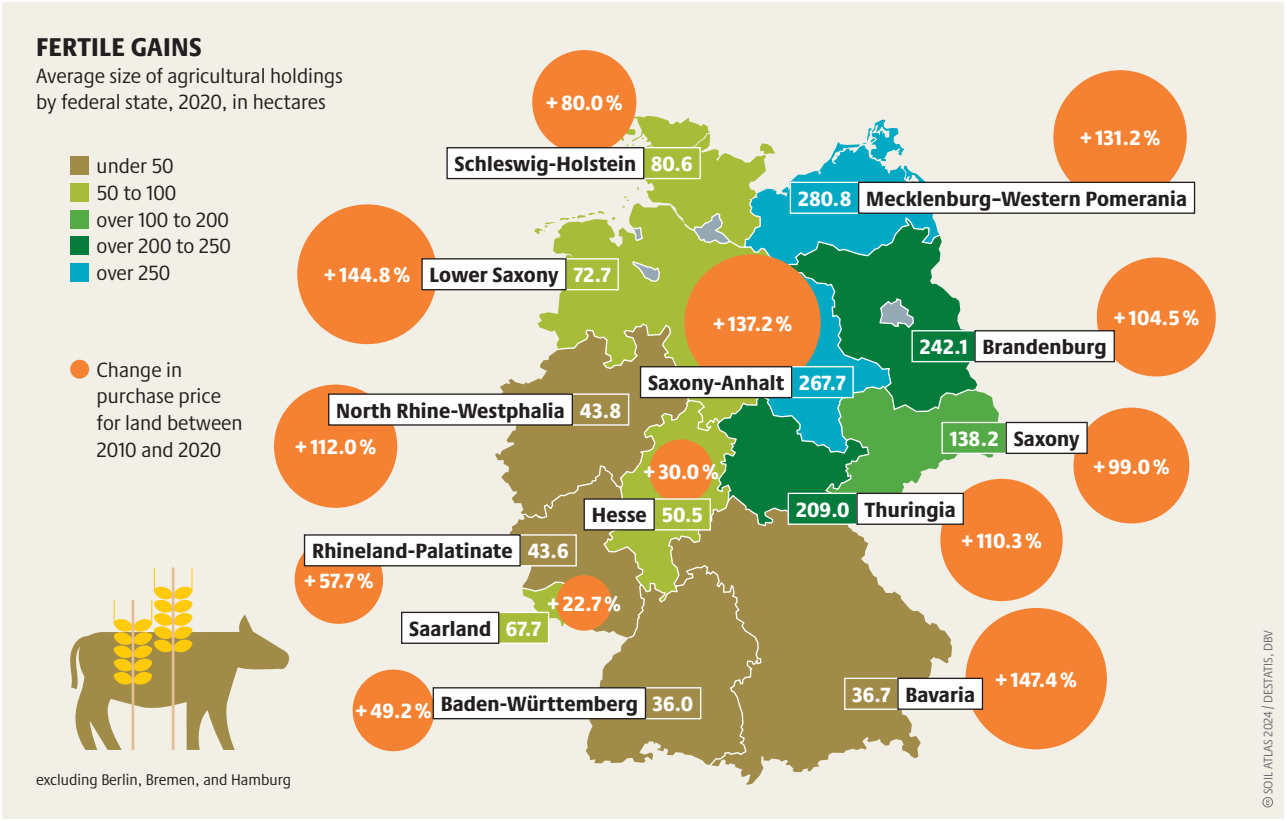
For years, the land market in Germany has had a similar dynamic to the housing market: rising prices and the concentration of resources in ever fewer hands. Now, the two markets increasingly overlap. Take for example the sale of Röderland, an agricultural enterprise in the eastern state of Brandenburg, south of Berlin. A farmer was willing to pay 8 million euros for Röderland's holding of approximately 2,500 hectares, but was outbid by Quarterback Immobilien, a property developer that plans to install a photovoltaic plant on part of the land. Quarterback is 40 percent owned by Deutsche Wohnen, a property management firm that merged with real-estate multinational Vonovia in 2021. Together, these companies own around 10 percent of all rental accommodation in Berlin and over 550,000 apartments throughout Germany.

A further similarity between the two markets is their lack of transparency. Ownership structures and corporate interdependencies are rarely recorded by the authorities or in public databases. Moreover, share deals are poorly regulated in both markets: buyers benefit from legal loopholes and can avoid the land transfer taxes they would incur when buying property or land directly.

Land purchases by investors outside the farming sector are far more common in eastern Germany than in the west. Investors such as Munich Re (an insurance company), the Lukas Foundation (part-owners of the Aldi retail chain) and the Gustav Zech Foundation (part of a major property development group) have bought up farms and leased land across eastern Germany over the last 15 years. The differences in the land markets in eastern versus western Germany are due to structures that have evolved over time in each region. Under the collectivization policy of the former East Germany (GDR), private farms were merged – often forcibly – into large agricultural cooperatives. After 1990, these collectives were generally transformed into companies under West German law, such as limited liability companies (GmbH), registered cooperatives (eG) or joint stock corporations (AG). These companies now control around 50 percent of all agricultural land in eastern Germany. Because of this history, farm enterprises in the east are on average significantly larger than in the west – and the larger the farm, the more attractive it is for investors and industrial agriculture. Small and medium-sized farms, on the other hand, lack the financial means to buy up large tracts of land.

Since 1962, the Land Transfer Act has enshrined a right of first refusal for leaseholders of agricultural land. This is based on the idea that agricultural land should belong to those who work it, and should be distributed among as many people as possible. A scenario in which a farm might be owned by a legal entity rather than an individual was not considered at the time. Today, share deals often mean that firms buy shares in a farm enterprise, giving them access to the land. Because the land was purchased indirectly, the right of first refusal for agricultural businesses and the notification requirement can be avoided. Revising the relevant laws would close these loopholes, first by recording and second by regulating the purchase of shares. This could act as a brake on rising land prices. Several of the federal states in eastern Germany are currently working on laws to this effect. More transpar-

Housing prices and rents are skyrocketing; so too are the costs of agricultural land. Both markets drive unequal access and exclusion



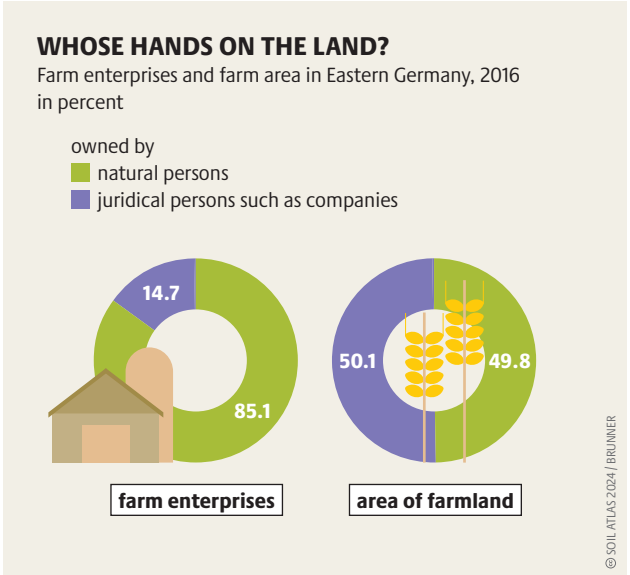
Farmland is increasingly viewed as an investment. Many farmers struggle to keep pace with rising prices, making it more challenging to establish a farm

ency and better regulation of investors and land prices could also be achieved at the level of the European Union (EU) through an EU-wide land observatory and European land directive. However, both projects are still in their infancy.

Another lever to ensure that more farmers have access to land is the idea of a progressive land transfer tax. This would mean that smaller enterprises pay no, or lower, land transfer tax – in contrast to those with large property portfolios.

Organisations that serve the common good, such as Kulturland-Genossenschaft and Ackersyndikat – both associations that buy land and hold it in trust – aim to ensure that smaller farm enterprises can access land despite high prices. They purchase land in close collaboration with the farmers, then make this available to them at the lowest possible leasehold rates. These and similar initiatives could pave the way to rethink how land is allocated to serve the common good. After all, land, like water, is a core basis of existence for people around the world and must be protected and shared. AbL, an association of conventional and organic producers on small and medium-sized farms, has developed a catalogue of criteria that can help ensure that land does not merely become a commodity concentrated in the hands of a few large investors. Among these criteria is the stipulation that the determining factor in the sale of agricultural land should not be the highest bid, but rather the type of intended cultivation. This would favour farm enterprises that pursue soil conservation, promote biodiversity, and protect the climate. ●

In eastern Germany, farms owned by juridical persons average 762 hectares, while in the west, the average is only 56 hectares



CONFLICTS BETWEEN DEMAND FOR LAND AND PEOPLE'S RIGHTS

Soil plays a major role in protecting the environment. It serves as carbon reservoirs, the plots into which trees are planted, and a steward for producing climate-neutral fuels. But land-intensive climate action can give rise to conflicts and erode people's rights. Even so, there is yet to be a resolution for this mounting global challenge in sight.

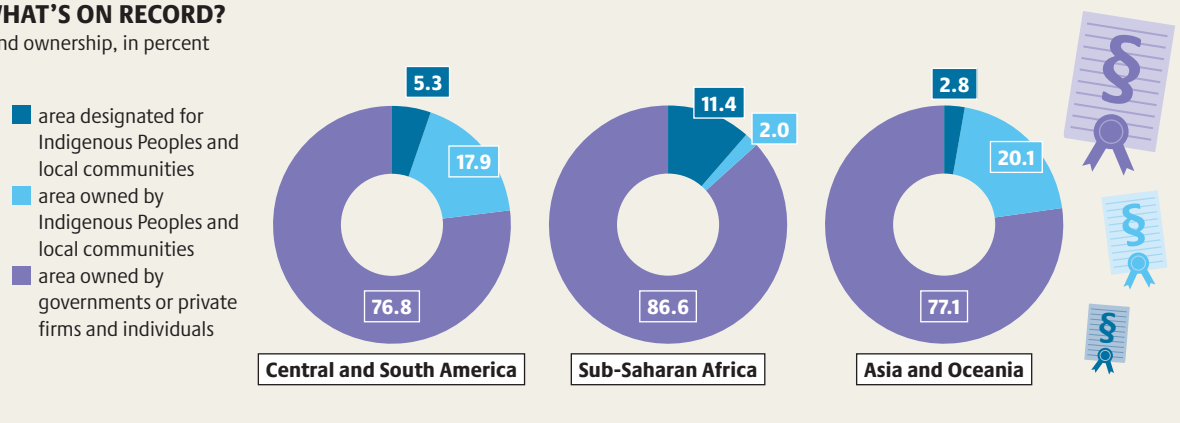
At the heart of the Paris Climate Agreement rests the goal of limiting the average global warming to 2 degrees Celsius compared to the pre-industrial era. Such efforts aimed at realizing a climate-neutral economy are founded on two principles. First, greenhouse gas emissions, such as carbon dioxide (CO_2), must be significantly reduced. Second, these climate-damaging gases must be removed from the atmosphere and sequestered. The central goal of this combined approach is to achieve net zero, which requires striving to both curb emissions and compensate for those that may be unavoidable by storing them in trees, soil or by other means. Greenhouse gases, for example, could be sequestered using the carbon capture and storage (CCS) process. In the CCS process, CO_2 is removed during industrial processes, transported, and stored in underground reservoirs instead of being released into the atmosphere. Other potential options to reduce greenhouse gases, which environmental associations favour, centre on nature-based carbon removal: rewetting peatlands, reforestation and afforestation, and sustainably managing pastures and agricultural land.

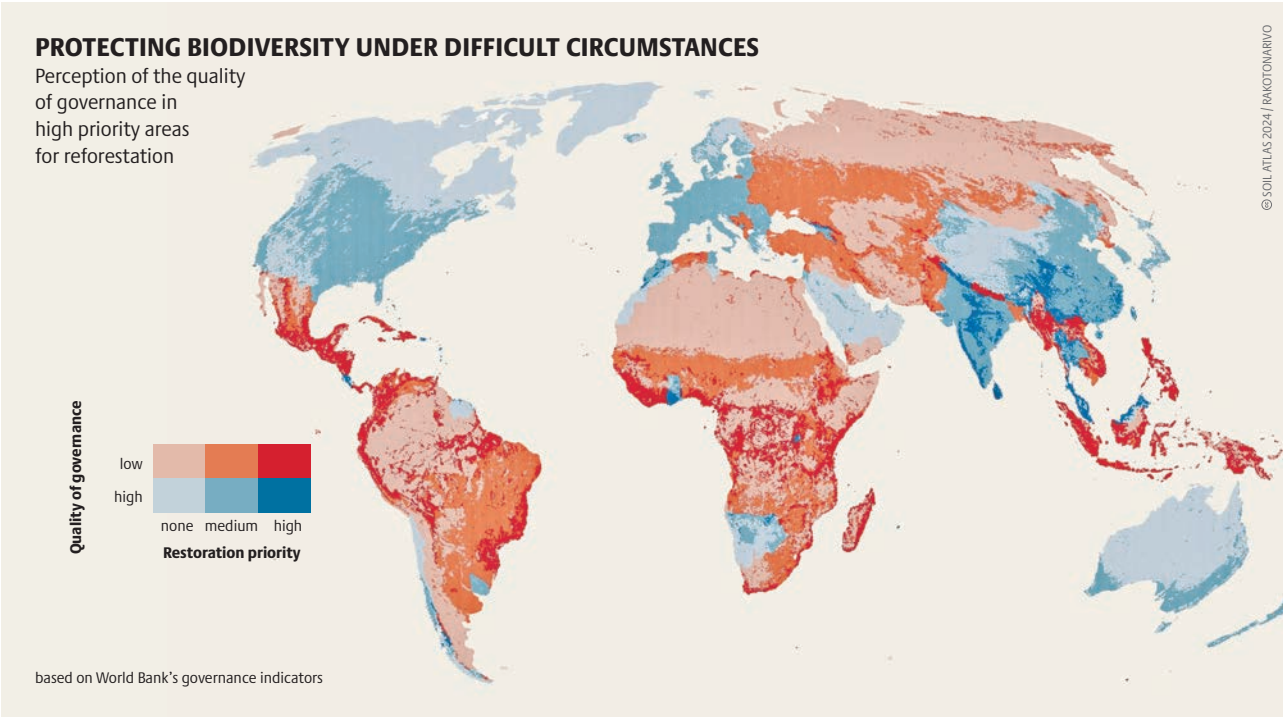
As large-scale CO_2 offset measures, governments and firms employ similar nature-based carbon removal tactics, such as protecting forests and planting trees on fallow land. Large German corporations are also investing in projects that depend on land-intensive climate action to offset their emissions. For example, cosmetics producer Beiersdorf promotes such initiatives in Paraguay. Moreover, nearly all Member States party to the United Nations Framework Convention on Climate Change have agreed to national climate commitments that include nature-based climate action. However, meeting these pledges require 1.2 billion hectares of land – almost three times the total area of the European Union.

Indeed, to make progress on achieving the net zero target, over 630 million hectares of land is expected to undergo land-use change and over 550 million hectares of degraded ecosystems must be restored. This overreliance on land-based carbon removal poses risks for local communities. For example, land-use change could mean converting agricultural land into forest, which can subsequently erode pre-existing land rights for farmers, herders, and Indigenous Peoples. More-

Legitimate but not legally recognised: Indigenous lands are often disputed, also in the name of climate action

WHAT'S ON RECORD?
Land ownership, in percent





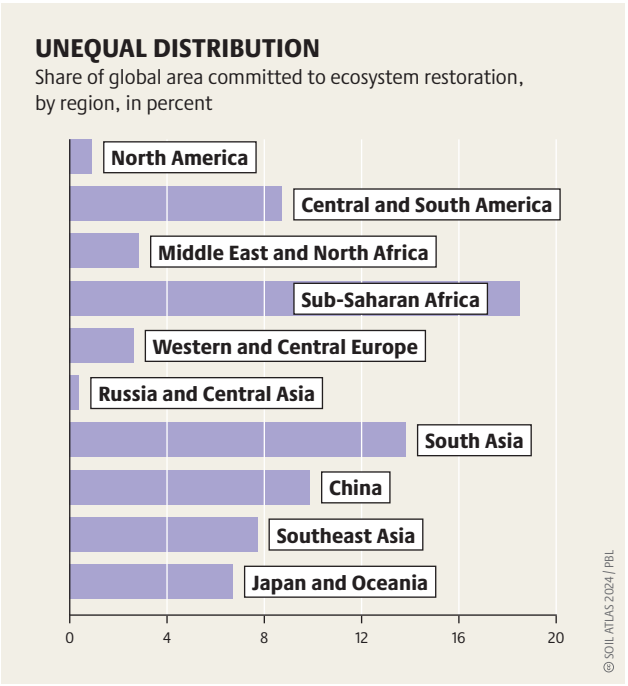
Many countries that have committed themselves to protect biodiversity lack supportive frameworks for reforestation

over, conflict arose between local communities during prior land-intensive climate projects, which aimed to minimise emissions released by deforestation and forest degradation. In light of this, governments must uphold their human rights commitments, which entail protecting the land rights of local communities and Indigenous Peoples. At its essence, implementing net zero measures responsibly therefore requires well-functioning state and civil society structures.

Colombia and the Democratic Republic of the Congo are heralded as countries with the greatest potential for nature-based climate action. However, state institutions in rural areas of both countries are often not sufficiently equipped to manage the land demand arising from climate projects. In addition, the countries in the Congo Basin and Amazon are home to massive rainforests, often described as the Earth's lungs. However, forestry projects in these areas repeatedly violate the rights of local communities and Indigenous Peoples, hindering their access to forests: a critical source of food, traditional medicinal plants, and cultural sites. Furthermore, there are recurrent cases of violent expulsions and targeted killings of land rights defenders.

As it stands, there is no comprehensive international approach that would regulate the extraordinary land demand arising from climate commitments. Future climate policy must account for this by featuring land rights as an integral component. This will ensure communities made vulnerable by these commitments are protected, as well as globally agreed climate goals can be achieved. As many studies have shown, secure land rights provide an incentive to sustainably use and manage land and forests. Without those rights, that incentive is lost. So too are the hopes invested in the success of nature-based climate action. ●

Pressure on the land: many African governments have promised to use their soils and forests to store carbon



SOIL CARBON CREDITS

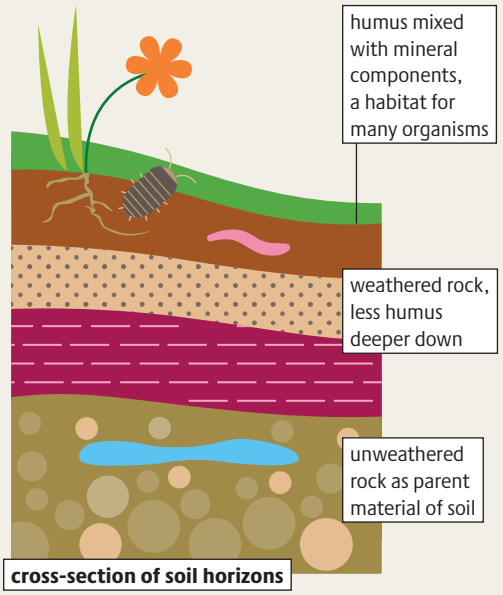
BLESSING OR CURSE?

The world's soils store more carbon than its forests, and this storage capacity is increasingly discussed as a contributor to climate protection. Tradable carbon credits were designed to incentivise the build-up or retention of carbon in the soil. However, they may in fact undermine efforts to reduce emissions.

Soils contain vast amounts of carbon, mainly in the form of humus, the organic matter formed from decomposed plants and animals. It is estimated that the top 30 centimetres of the Earth's soil contain close to 700 billion tonnes of carbon, exceeding the 560 billion tonnes stored by plants, especially in forests. As a natural sink for the greenhouse gas carbon dioxide (CO_2), soils are an important factor in climate mitigation policy. Modelling suggests that between 2 and 5 billion tonnes of carbon could potentially be sequestered in soils each year. However, this potential depends on future land use and the progression of the climate crisis. Today, in many parts of Europe, soils are net carbon sources: they emit more carbon than they absorb. For example, drained peatlands are significant carbon emitters.

ONE ON TOP OF THE OTHER

Structure of soils in temperate regions

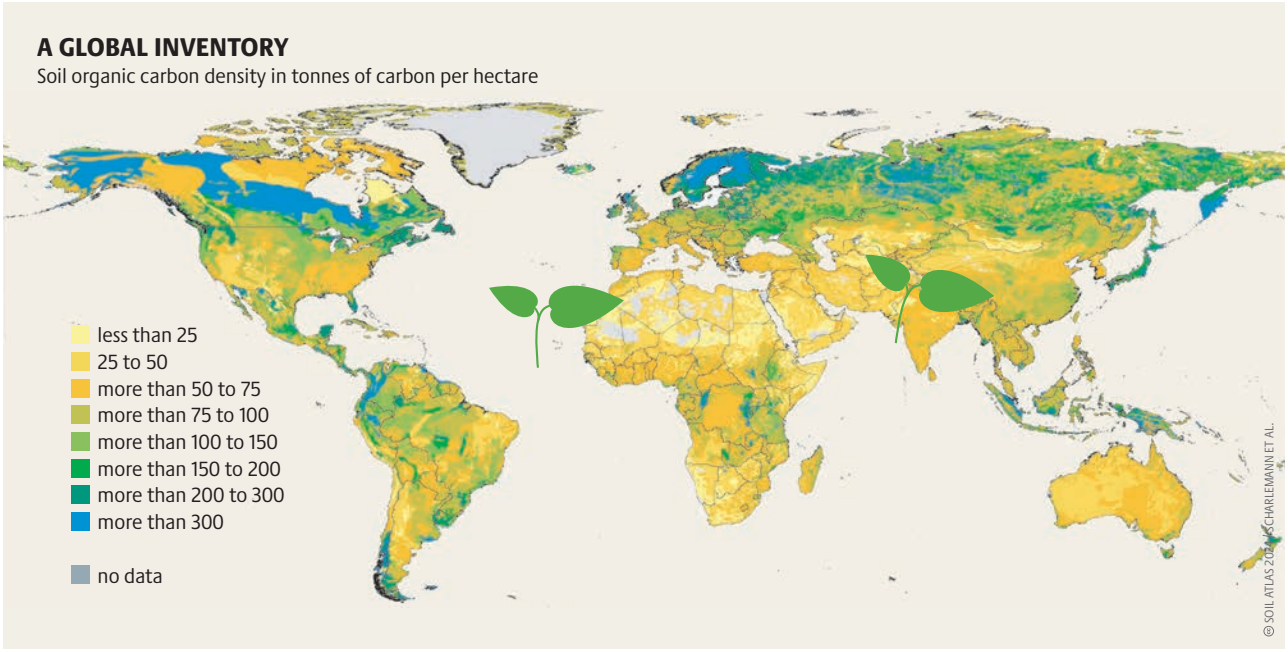


Reducing emissions must remain the priority for achieving the Paris Agreement's climate goal of limiting global temperature rise to well below 2 degrees Celsius. In addition to deep emission cuts, sequestering carbon in soils can play a limited but important role in climate policy. Beyond climate mitigation, building up carbon in soils is crucial for adapting to the climate crisis and restoring healthy soils. Consequently, scientists, practitioners, and policy makers are increasingly exploring the potential of soils as natural carbon sinks. One such approach is carbon farming, which encompasses a range of activities that aim to increase the amount of carbon in soils and forests. Practices include improved crop rotation, direct seeding, mulching, rewetting drained peatlands, planting trees on deforested land, as well as agroforestry – an approach that integrates trees and crops on the same area of land.

Carbon farming is expected to be financed through the sale of so-called soil carbon credits, which would compensate for the emission of greenhouse gases like CO_2. The European Union (EU) is currently attempting to outline a legal framework for carbon offsetting, including through storing carbon in soils. The principle is simple: farmers commit to increasing the carbon content of their soil over a certain period of time using specific methods. For each tonne of CO_2 they store, they receive a carbon credit. Companies can then purchase these credits to offset their own emissions and claim their products or services as climate neutral. But this approach to carbon offsetting is controversial. Research has shown that many companies rely heavily on carbon offsetting to meet their climate action goals. By buying credits, they can continue emitting greenhouse gases as usual while still claiming to be climate neutral – a practice often criticised as greenwashing.

Carbon offsetting is based on the idea that each credit represents a tonne of carbon that is stored in the ground. However, a precise and standardised method for measuring soil carbon sequestration does not yet exist. Soil organic carbon content can vary greatly, even within the same field, and it is never certain that the stored carbon will remain in the soil indefinitely. To genuinely compensate for CO_2 emissions, the carbon would need to stay in the ground for the same period of time that CO_2 remains in the atmosphere.

Humus, derived from the Latin word for Earth, is a crucial component of soil formed when microorganisms decompose organic material and other substances



Most soil organic carbon is stored in northern Permafrost regions and boreal forests. Tropical rainforests store most carbon above ground in plants

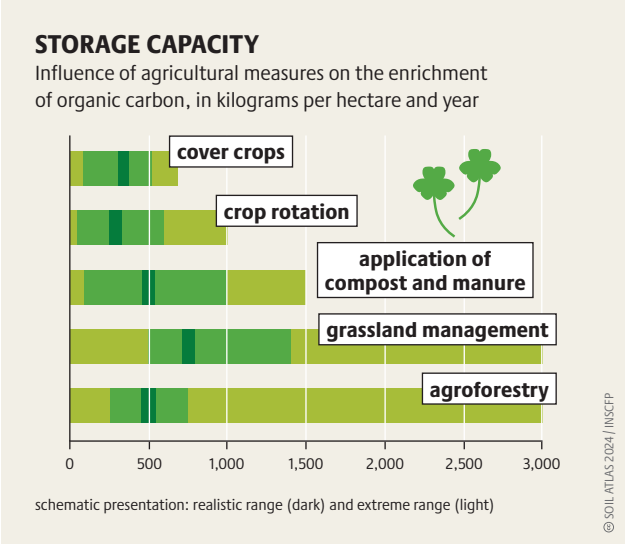
But long-term or permanent sequestration cannot be guaranteed, as the carbon content of the soil is easily reversible. Changes in cultivation practices or extreme weather – occurring more frequently due to the climate crisis – can release the stored carbon at any time.

Criticism of carbon trading schemes has led to new proposals, such as retaining a portion of the sequestered carbon as a reserve rather than selling the entire amount as credits. However, experience with the trade of forest carbon credits has shown that this approach also entails serious risks. In California, forest fires have already consumed up to 95 percent of carbon credits reserves in less than a decade – reserves that were intended to compensate for carbon releases over the next century. As climate change continues to intensify, the likelihood that sequestered carbon will be released back into the atmosphere increases. The EU hopes to tackle this problem by creating carbon credits that expire after a certain period of time. This approach will create new challenges in overseeing the use of credits.

In countries like Australia and Scotland, trading soil carbon credits has driven up land prices, making it harder for young farmers and smallholders to access land. Years of experience with forest carbon credits have also demonstrated that the potential for financial gain from selling carbon credits has incentivised land grabbing in various regions. In Uganda, thousands of people have been displaced for tree plantations established by a Norwegian company. The international trade in carbon credits thus runs the risk of perpetuating neo-colonial structures, allowing companies from the Global North to maintain their climate-damaging business models by appropriating land and soil from communities in the Global South.

Sustainable soil management can sequester CO_2 from the atmosphere. But land use change and extreme weather events threaten this carbon storage

A robust humus layer is essential for resilient ecosystems that ensure food security, support biodiversity, and mitigate droughts and floods. However, soil protection measures should neither replace measures for deep emission cuts, nor restrict human rights or people's right to land. It is crucial that any efforts to enhance soil carbon sequestration are integrated into broader strategies that prioritise social equity, environmental sustainability, and the long-term well-being of communities.



RIGHTS VERSUS REALITY

Equitable access to land and fertile soil is fundamental to realising human rights, such as the right to food. Although numerous United Nations declarations on land rights have been ratified by national governments, deadly land conflicts persist throughout the world.

Land distribution is highly unequal. Just one percent of farming enterprises control more than 70 percent of the world's agricultural land. Moreover, land ownership is often poorly recorded, masking the true extent of this growing inequality. In many countries, people who suffer land rights violations are often marginalised and subjected to other forms of discrimination. For example, in Kenya, widows are often driven from their land by male relatives. In the Brazilian Amazon, deforestation and illegal gold mining continue to destroy and endanger the traditional lands of Indigenous communities. And in Cambodia, the expansion of large-scale agricultural operations violates the rights of smallholder farmers. Conflicts over land often become violent. Between 2012 and 2023, more than 2,100 people were murdered worldwide for defending land and the environment.

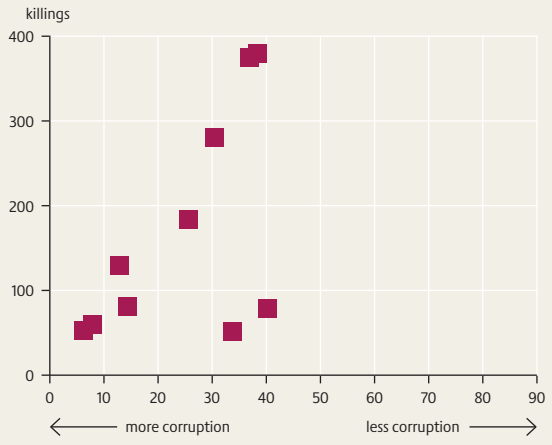
Many international human rights instruments recognise the right to land for certain population groups whose rights are particularly under threat. Among these are the United Nations Declaration on the Rights of Indigenous Peoples, the Convention on the Elimination of All Forms of Discrimination against Women, and the Declaration on the Rights of Peasants and Other People Working in Rural Areas. Another key human rights instrument is the International Covenant on Economic, Social and Cultural Rights, which includes the right to adequate food. Adopted by the United Nations General Assembly in 1966 and coming into force in 1976, this Covenant has been ratified by 176 states. According to the Covenant, states have a duty to respect the legitimate land rights of citizens, actively protect these rights, and ensure they are not violated by third parties. This obligation is particularly indispensable for women's land rights, which are frequently neglected and violated.

Legitimate land rights go beyond formal rights recognised by the state and include rights acknowledged under informal land tenure systems. These systems can encompass customary and communal land rights, and their scope extends beyond the Western concept of individual ownership. Legitimate land rights also include those derived from tradition, long-standing practices, and extended periods of occupancy. In practical terms, this means that Indigenous groups have a right to their traditional areas of settlement and land use. However, progress in recognising and protecting these rights is often slow and inconsistent. A step forward in one region may be often matched by setbacks or stagnation in another. For example, in a landmark case in September 2023, Brazil's Supreme Court upheld Indigenous Peoples' rights to their traditional lands, ruling against the prior government's attempt to delegitimatise their land rights. Conversely, in Bangladesh, Indigenous land rights have been stalled for decades.

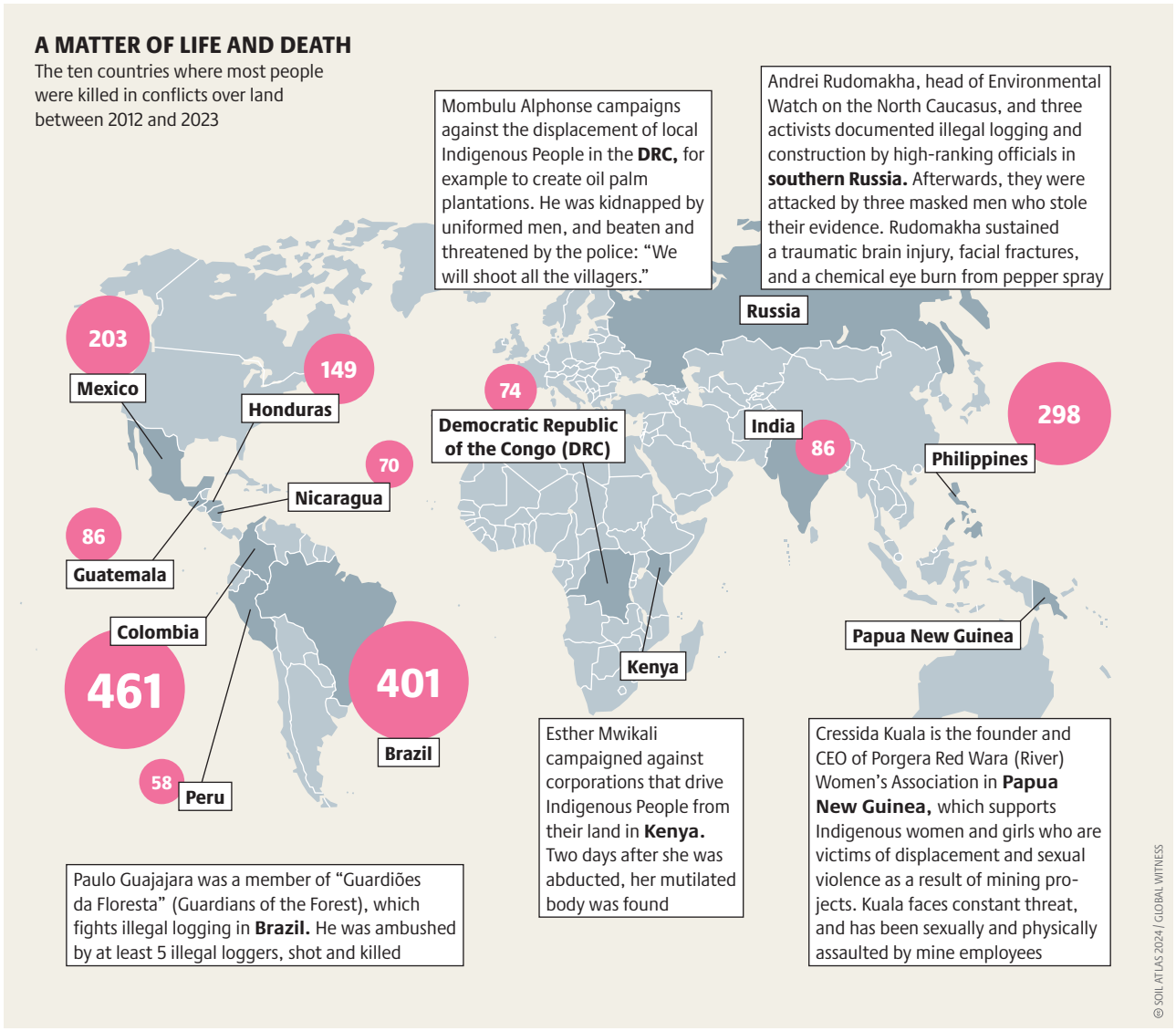
The duties of states to protect land rights do not end at national borders. For the European Union (EU), this means ensuring that EU-based firms or organizations investing in land in other countries adhere to these obligations. This responsibility applies regardless of whether these investments concern the protection of biodiversity, agricultural production, or other land uses.

CROOKED COPS, BENT JUSTICE

Level of corruption in ten countries with the highest rates of murder due to land conflicts between 2012 and 2022



Left defenceless: land rights defenders face greater dangers in countries where corruption is common



In 2012, the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests (VGGT) were endorsed by 124 member states. By 2015, over 140 countries had endorsed them. The VGGT set a global precedent for land tenure and are heralded as an influential framework for promoting equitable land access and securing land rights. Although voluntary, the guidelines are grounded in legally binding human rights instruments and reinforce the link between land tenure security, human rights, and environmental protection.

Access to land is essential for rights, such as the right to food, housing, and income. Secure land tenure incentivises people to invest in sustainable land management, which is crucial for a clean, healthy, and sustainable environment. Healthy soils improve agricultural productivity and food security. Together, tenure security and human rights frameworks underscore states' obligations to their citizens' and show how fulfilling these rights can benefit the environment.

Although they make up only six percent of the world's population, Indigenous People accounted for one-third of those killed in land conflicts in 2022

Despite the benefits of equitable land distribution, sustainable land use, and protective laws, enforcement is often weak. This is particularly evident in issues of inheritance or co-determination over land ownership, where land reform measures often encounter significant resistance. For example, efforts to guarantee land ownership rights to women are often opposed by patriarchal norms embedded in legal structures or cultural practices, as well as by large landholders wielding considerable political influence. Civil society organisations play a critical role in advocating for necessary reforms and are frequently at the forefront of advancing the application of internationally recognised human rights standards. Their efforts deserve the full support of organisations, institutions, and political bodies, such as the EU, to ensure these rights are more effectively – and equally – upheld and enforced.

PROTECTING RIGHTS, PROTECTING SOIL

Secure land access is essential for long-term soil protection because it enables land users to implement practices that enhance soil health and maintain its productivity over time. However, in many African countries, women's land rights remain precarious, creating significant barriers to investing in sustainable soil management.

In Africa, an estimated 65 percent of productive land is degraded, while 45 percent of the continent is affected by desertification. Various initiatives have sought to restore and protect agricultural soils, often targeting smallholders with less than 2 hectares of land, who make up 80 percent of African farmers. These initiatives provide training on crop rotation, planting cover crops, and other practices to boost soil fertility, as well as promote natural measures to fight soil erosion, such as hedges, earth bunds, terraces, and agroforestry. They also offer direct inputs such as seeds, tree seedlings, and agricultural equipment.

But farmers often stop applying such practices once a project ends. There are many reasons for this, including a lack of access to advisory services, markets, and agricultural inputs. Moreover, farmers who lack secure tenure have little incentive to invest in practices that enrich their soil in the long term, such as agroforestry and terracing, because these may bear fruit only after several years.

Both women and young farmers are particularly affected by insecure access to land. Estimates by the Food and Agriculture Organization of the United Nations (FAO) suggest that in Sub-Saharan Africa, around half of the workforce in agriculture are women, yet they control around 15 percent of farmland. Women may have the right to use or manage the land, but they do not own it. Their power to decide what to grow, or whether to lease or sell the land, is therefore limited. Traditionally, women's land rights are tied to those of their husbands or other male relatives. And the plots allocated to women are usually small and less fertile.

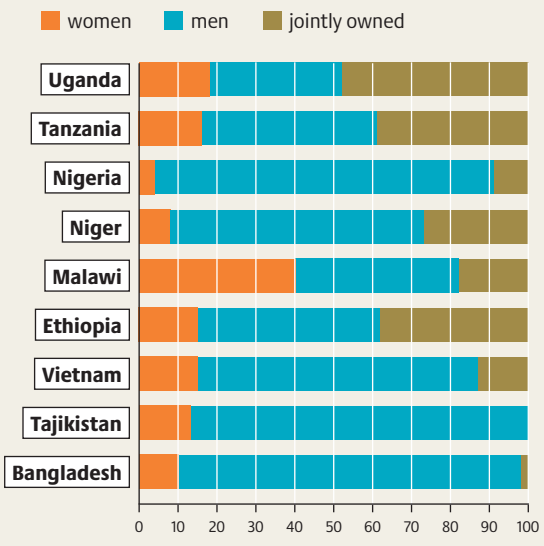
Research in Burkina Faso revealed a paradox: the efforts of women farmers to improve the soil health and productivity may actually increase the risk of losing their tenure. This phenomenon, known as forced rotation, sees landowners – often husbands – reclaiming the most productive land from women to grow cash crops such as cotton.

Similar to Burkina Faso, women in Kenya traditionally gain access to land through their menfolk. Despite the existence of laws and policies for gender equality, many women farmers in Kenya are vulnerable and marginalised. Widows, in particular, often struggle to retain control over land they legally own. It is still common for a woman to be forced to give up her land if her husband dies. Women therefore often resort to leasing land to feed their families or generate income. Yet such leasehold agreements are typically short term and orally agreed, denying women the ability to invest in long-term practices, such as soil conservation.

To counter this, local initiatives have been developed to bolster women's land rights. In Southwestern Burkina Faso, one such initiative tackles the issue of forced land rotation. Building on traditional govern-

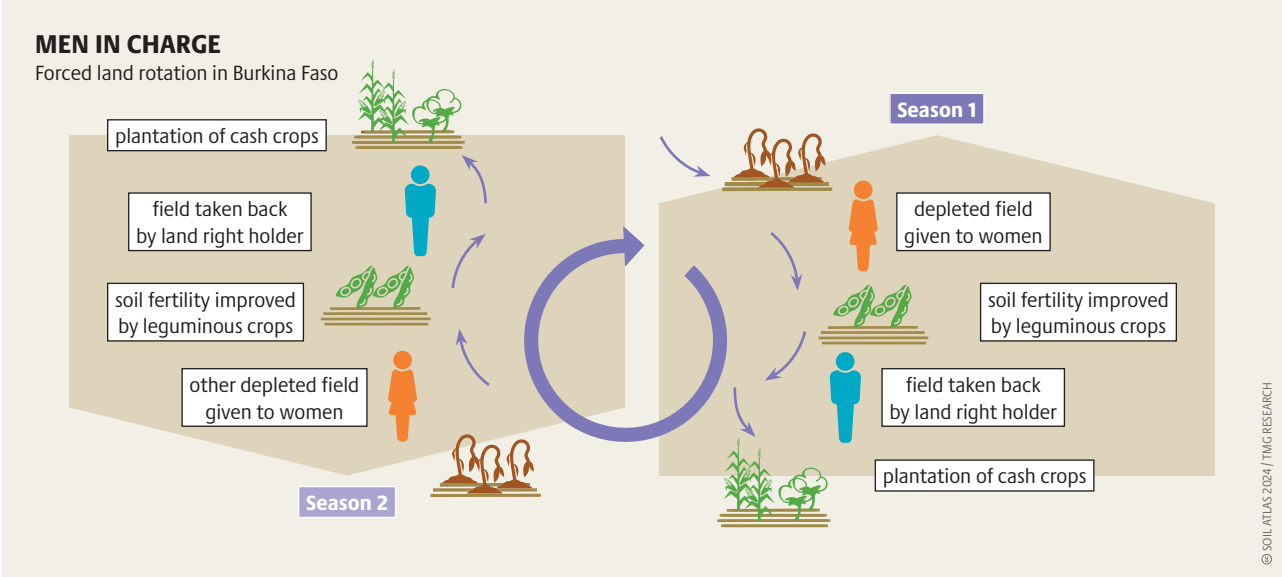
IT'S A MAN'S WORLD

Agricultural land owners, by gender in percent



figures published in 2018

Holding land titles doesn't always guarantee secure land rights. Women often fear losing their land after divorce or their husband's death



In Burkina Faso, women often receive low-fertility land. After improving it with leguminous crops, husbands may take it for cash crops like cotton

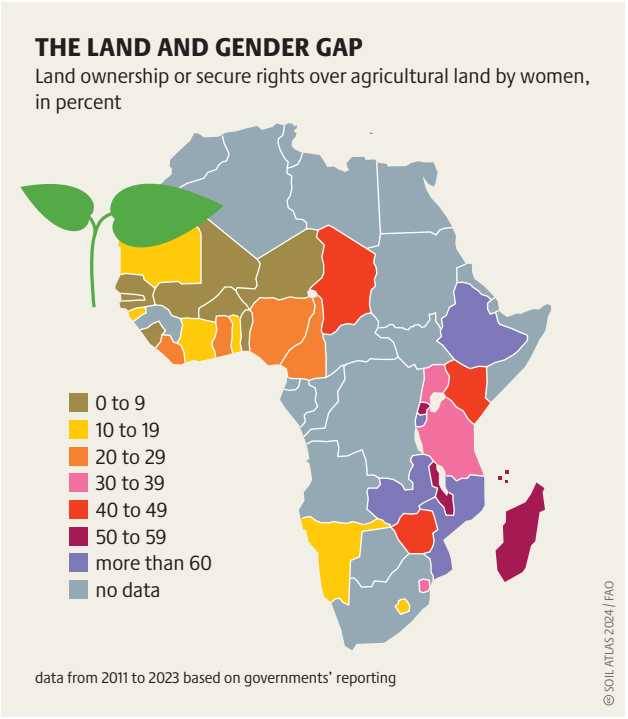
ance models, it helps families and villages reach consensus on tenure arrangements. The aim is to make such arrangements more equitable and secure for women. Following a multi-phase negotiation process involving a range of stakeholders, including traditional village chiefs, the male heads of households agree to transfer long-term land usage rights to their wives or other female relatives.

In Kakamega County in western Kenya, a grassroots, women-led initiative developed guidelines that provide transparent and mutually agreed terms for leasing land. An evaluation in 2021 found that this initiative improved land access for women and also led to more sustainable soil management. Tenants who followed the new leasing guidelines were twice as likely to apply sustainable practices, such as cover crops, mulching, and crop rotation, compared to those who followed the previous, informal leasing arrangements.

To address gender gaps in land restoration, political decision-makers need to engage more with communities. This will give them a better understanding of issues around women's access to land and soil management practices, both of which vary locally. Only then can solutions be devised that genuinely respond to local needs. Grassroots organisations can help identify such solutions by facilitating dialogue between communities and institutions.

Internationally, tenure security is now broadly acknowledged as a critical basis for sustainable land and soil management. The United Nations Convention to Combat Desertification (UNCCD) passed a resolution in 2019 recognising responsible land governance as essential to sustainable land management, and emphasising its role in combatting desertification, land degradation, and drought. Women are often the primary stewards of land and natural resources, and therefore play a central role in promoting agricultural productivity and natural resource management. It is essential that they enjoy equitable access and rights to land. Good intentions are not enough: political will and widespread action are needed to ensure gender justice in land governance. ●

The United Nations estimates that if women had the same access to agricultural resources as men, production could increase by 20 to 30 percent

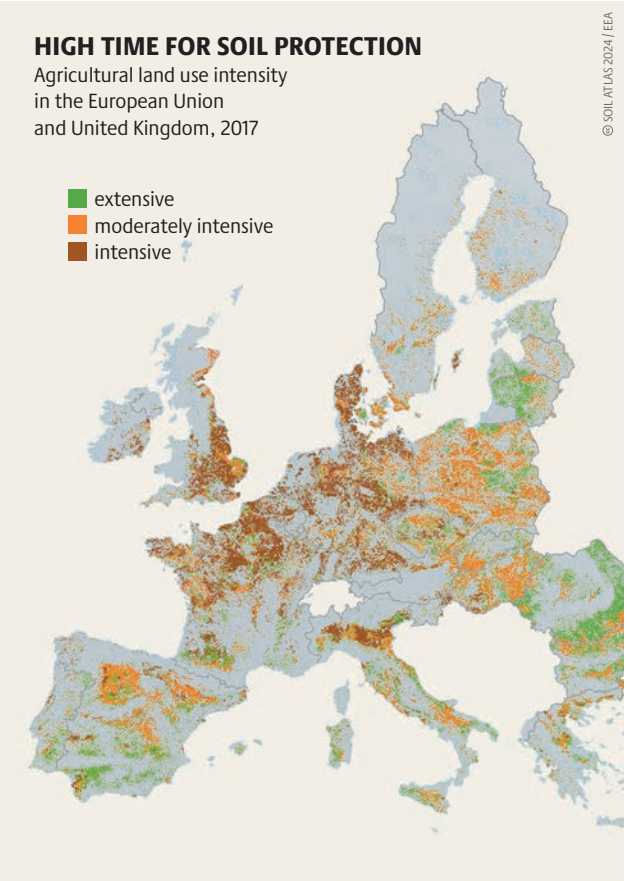


EUROPEAN UNION

SOIL PROTECTION? WANTED!

Protection measures for climate, water, and biodiversity have been enshrined in EU law – in some cases, for decades. But a comprehensive legal framework for soil protection is still lacking. Previous attempts to create one have been torpedoed, while most existing policies are toothless.

It wasn't until 2006 that the European Commission launched a comprehensive soil protection initiative. This called on European Union (EU) Member States to incorporate soil protection measures into national policymaking to prevent further soil deterioration. While a majority in the European Parliament supported a framework directive on soil protection, the EU Council was for years unable to agree on a common position. Austria, Germany, and the Netherlands were among the countries that blocked the necessary resolution on the grounds that the proposed law would violate the principle of subsidiarity. This principle stipulates that the Union may intervene only if member states cannot deal with an issue satisfactorily, or if an EU-wide measure would offer a better alternative. On this basis, the European Commission abandoned its attempt to pass a Soil Framework Directive in 2014.

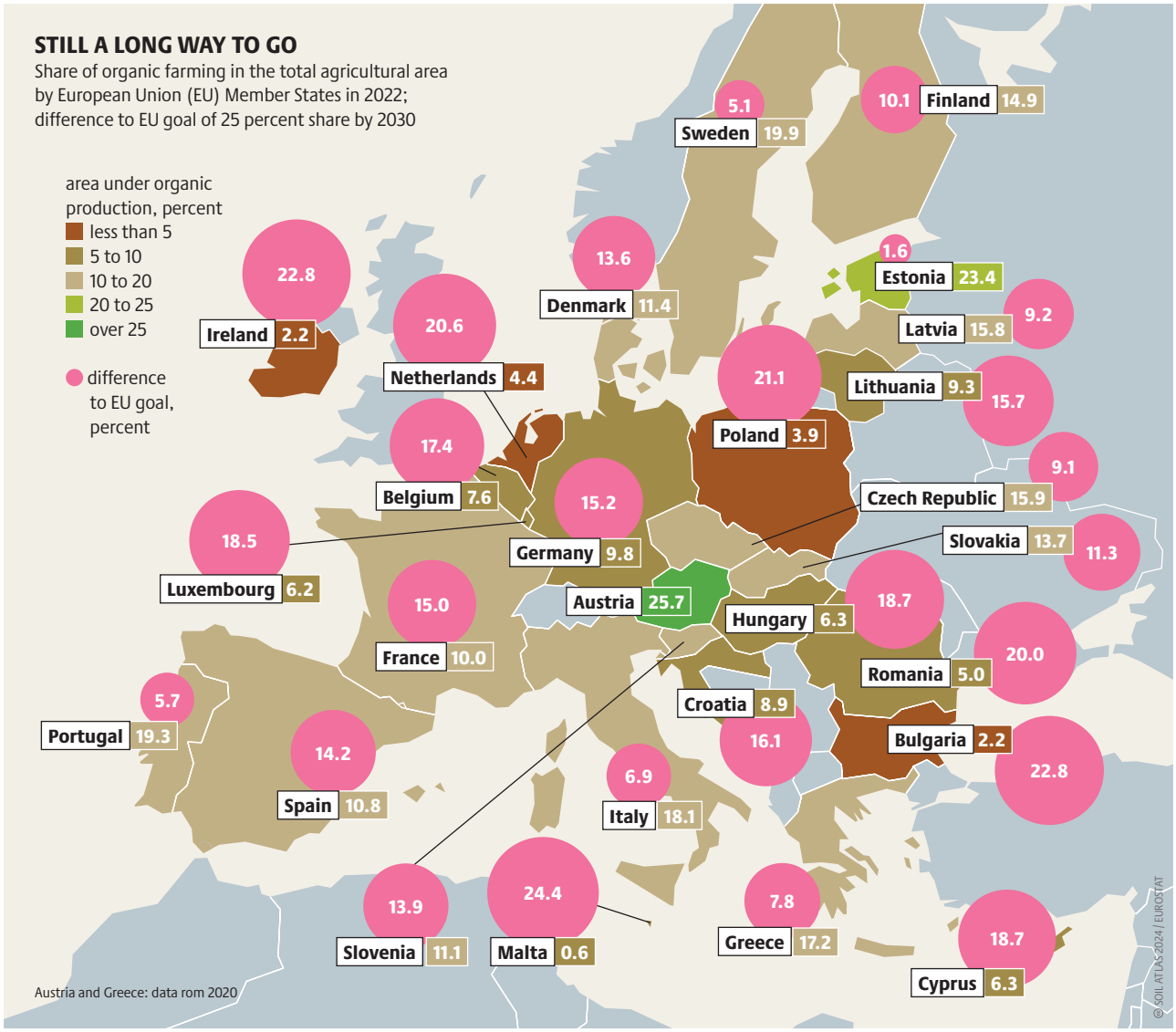


The only standardised legal framework for soil protection at EU level is the Common Agricultural Policy (CAP). Farm enterprises that receive payments under this scheme must comply with a series of requirements. For example, they are not allowed to burn cereal stubble after harvest, and they must practise a minimum level of crop rotation. They can also receive extra funding if they apply additional voluntary measures.

Even so, the CAP has been heavily criticised in the past, and experts question whether it is capable of promoting sustainable soil management. As a result of various exemptions and deflated reference values, the requirement to diversify crops has so far only led to a change in cultivation on just 2 percent of the entire arable land in the EU. Additionally, there is often very little funding available for voluntary environmental subsidy schemes. Moreover, although the CAP has incorporated slight improvements in the protection of natural resources, it is still harshly criticised by environmental groups. One recent analysis of the CAP found its environmental protection measures to be woefully inadequate: for example, the period during which soil must remain covered over winter according to EU environmental regulations is too short, and Germany's ban on ploughing in areas at risk of water erosion applies only during a very short period from December to mid-February.

Soil protection regulations are needed now more than ever. Until last year, two important, though insufficient, EU regulations were in place that attempted to protect soils and biodiversity. The first was a minimum standard on crop rotation, requiring one change in crop per year. However, this requirement did not

In the EU, more and more fertile soil is lost each year, while the ecological functions of remaining soils are often reduced by intensive agriculture



Organic farming in the EU has steadily grown, increasing from 5.9 percent of agricultural land in 2012 to 9.9 percent in 2021

clearly stipulate which crop to rotate. In addition, EU Member States had the option to permit exceptions regarding crop selection, including for smaller farms. Requiring the main crops to change from one year to the next would have promoted soil protection more effectively. This requirement was suspended in 2023, in the wake of Russia's full-scale invasion of Ukraine. The second was a requirement to reserve at least 4 percent of arable areas for fallow and hedgerows. Yet, in the aftermath of the farmers' protests in early 2024, both requirements have been permanently abolished.

Implementation of voluntary measures is also sorely lacking. Experts note that roughly half of all soil protection measures are largely ineffective. A special report by the European Court of Auditors came to the same conclusion.

For a while it seemed that the European Green Deal would breathe new life into the issue of soil protection. When the European Commission presented its Soil Strategy for 2030, environmental organisations hoped for an improved version of the failed Soil Framework Directive and for greater coherence with the CAP. They were disappointed. The European Commission's draft Soil Monitoring Law, tabled in the summer of 2023, proposes neither quantitative goals nor concrete measures. It almost completely ignores the problem of urban sprawl and lacks binding targets to limit soil sealing. It also has no binding requirements for sustainable soil management. Instead of protecting the soil, the draft law merely aims to standardise the Europe-wide inventory of soil health.

Mandatory minimum standards to protect soils are needed for the new CAP funding period which begins in 2028. Loopholes should be closed and exemptions restricted. Improved quality standards for voluntary subsidy schemes are also needed – and those schemes should be thoroughly analysed for effectiveness before public money is spent.

POLICIES THAT KEEP SOIL ALIVE

Agroecology is a response to an industrial model of agriculture that exploits people and damages soils. In Brazil, agroecology is making significant breakthroughs in social and environmental terms. But one thing is already clear: government policy is needed to promote agroecology and confront the agroindustrial model.

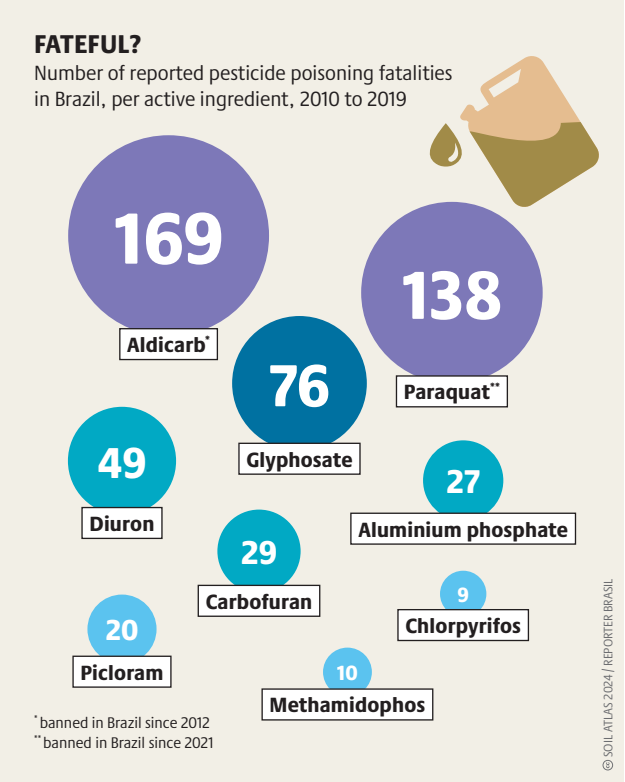
Industrial agriculture relies on extensive monocultures, immense chemical inputs, and heavy machinery. This model originated in the Global North. Beginning in the 1960s, it was exported to Asia, Latin America, and later Africa. This much vaunted Green Revolution has taken a heavy toll on soils: excessive pesticide use reduces microbiological life in the soil and contaminates water, and machinery compacts the soil and hinders drainage. Moreover, the agroindustrial model works best on large farming units, fostering concentration of ownership and rural depopulation, while monocultures diminish dietary variety.

Agroecology arose as an alternative to this model. Farming in Brazil offers plentiful examples of both the impacts of agro-industrial practices and attempts to create alternatives based on agroecology. Over the last four decades, Brazil has emerged as a major exporter of agricultural commodities, especially beef, coffee, maize, soybean, and sugar. In the course of this expansion, vast areas have been deforested, desertification has accelerated, water resources have been depleted or contaminated, and biodiversity has declined. In response, social movements, researchers, and small-scale farmers are coming together under the umbrella of agroecology to revive and expand a series of farming practices that traditional communities never stopped using.

Agroecology is a bundle: it is a multidisciplinary science, a social movement, and a set of agricultural practices focused on the interaction of plants, animals, and humans. Its aims are to preserve natural resources and sustain agrifood systems. Healthy soils are the foundation of this approach since they support diverse microbial life and the nutrient cycle essential for plant growth. By prioritising soil conservation and biodiversity within soil ecosystems, agroecology aims to increase productivity while minimising environmental impact. It involves soil management methods, including the use of green manure, crop rotation and intercropping, the integration of native trees, erosion control, and the use of crop varieties adapted to local conditions. Agroecological coffee farming, for example, has increased plant biodiversity and improved soil quality in Brazil's Atlantic forest, and agroforestry systems have enhanced soil fertility and soil health.

Agroecology is not only based on ecological principles; it also promotes social, economic and territorial values that apply grassroots solutions to local problems. It promotes the self-management and autonomy of family farms, and independence from seed and agrochemical companies. It respects the traditional knowledge and cultural dynamics that were systematically erased by colonial structures.

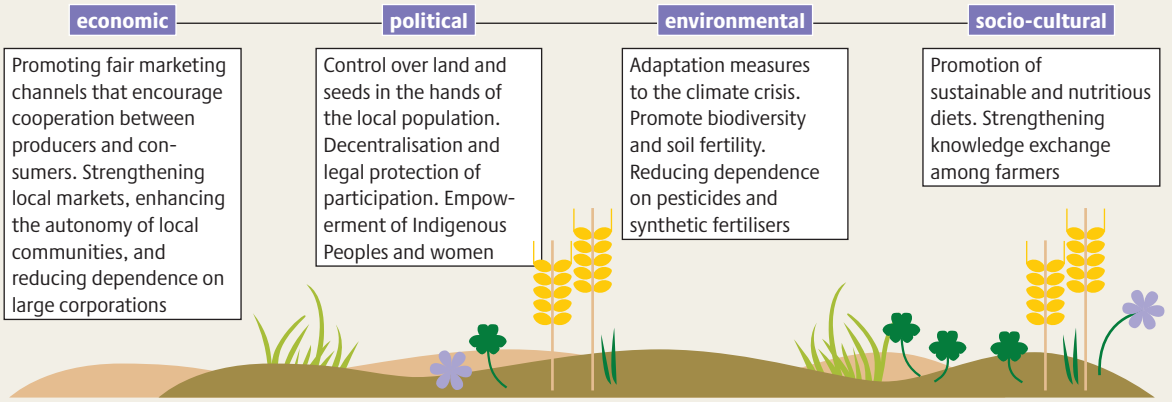
As a social movement, agroecology also advocates for better access to land, environmental justice, as well as age, racial, and gender equity. These principles seek to integrate and empower social groups that have historically been exploited by the industrial food system. The latest agricultural census reveals that men manage 81 percent of Brazilian farms. Women have been large-



Data from Brazil's Ministry of Health show high numbers of poisonings. Land use change policies are considered as reasons for increased pesticide use

THE WHOLE PICTURE

Principles of agroecology



ly restricted to the household, and their farming activities to the vicinity of the house. For this reason, one of the priorities of agroecology has been to recognise women's backyard production and help them commercialise it. The number of women who lead production and marketing initiatives is increasing. Women also take the lead in Brazil's largest pro-agroecology grassroots demonstration, March of the Daisies, which takes place every four years. In 2023, this brought more than 100,000 women smallholders to the streets of Brazil's capital, Brasília.

Agroecology initiatives in Brazil used to be fragmented, but since the turn of the century they have influenced policy to upscale production so that more people have access to food produced through agroecological methods. Two such policies are the federal Food Acquisition Programme (PAA) and the National School Feeding Programme (PNAE). In 2009, PNAE began to prioritise family farms in sourcing food for more than 40 million students in over 160,000 schools. The PAA focuses on buying produce from family farmers and distributing it to social assistance organisations. Since December 2023, changes in the guidelines of school feeding in Brazil further encourage the consumption of organic and agroecological products.

Another example of policies promoting agroecology is the National Policy for Agroecology and Organic Production (PNAPO). Established in 2012, this aims to promote an agroecological transition. For example, the PNAPO lowered interest rates on loans for farmers who produce items in a basic nutritional food basket using agroecological methods, as well as increased rural technical assistance. A change in government in 2016 prevented the plan from getting off the ground, but since the end of the Bolsonaro presidency in 2023, the PNAPO has resumed. Another initiative, the National Programme to Strengthen Family Farming (PRONAF), provides loans to agroecological family farms. Despite its importance, the PRONAF budget is still dwarfed by the finance available to large-scale agribusiness in Brazil.

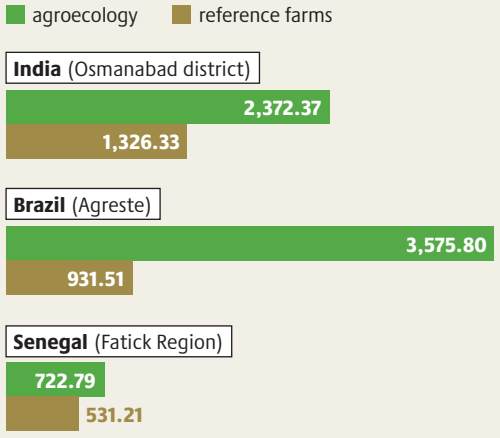
Brazil has shown that public institutions play a key role in promoting agroecology. The dominant model still regards soil merely as an inert input. Agroecology, which puts soil in its rightful place – as a living, central part of the food cycle – is still underrepresented within the policy architecture. ●

The rights to self-determination, land, and resources form the foundation of the agroecology movement dedicated to transforming our food systems

According to a study, 10 percent of the poorest smallholders increased their annual income by 65 to 650 dollars with agroecology

LEAVING POVERTY BEHIND

Median income of agroecological farms, 2018, in US dollars



HIDDEN EFFECTS

Land degradation has numerous invisible costs – environmental, health, social, and economic. True Cost Accounting renders these costs visible, offering a clearer picture of the impact of land degradation.

Every continent on Earth is affected by human-induced land degradation. The global cost of lost ecosystem services, for example due to desertification and land degradation, may be as high as US 10.6 trillion dollars per year. These ecosystem services include water filtration and retention, flood regulation, nutrient cycling, and waste decomposition. Land degradation can also have serious knock-on effects on human health, since it reduces food production and dries up water sources, which lead to food insecurity and malnutrition. In the European Union (EU), where land degradation affects 61 to 73 percent of agricultural soils, almost 3 million tonnes of wheat and 600,000 tonnes of maize are lost every year due to erosion alone. Degradation can also restrict access to clean water, resulting in the spread of water- and food-borne diseases.

Furthermore, land degradation exacerbates social inequalities, as it disproportionately affects rural, land-dependent households in low- and middle-income countries. The situation is particularly alarming in Africa, where about 65 percent of productive land is already degraded. In the Central African Republic, for instance, where 71 percent of the population works in agriculture, the average losses due to land degradation are equivalent to 40 percent of the country's gross domestic product (GDP). Asia and Africa bear the highest costs of land degradation, estimated at US 84 billion dollars and US 65 billion dollars per year respectively .

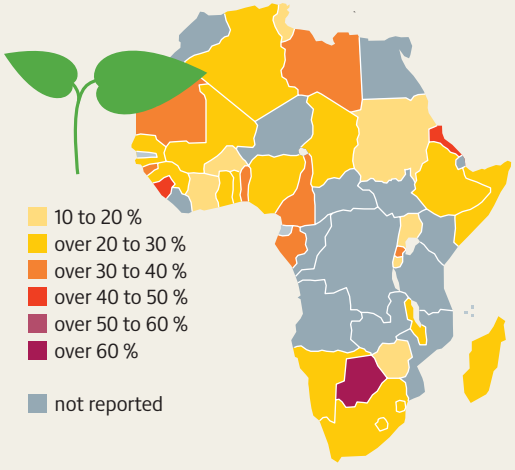
Conventional metrics for economic performance – such as GDP and earnings – fail to take account of the long-term consequences and hidden costs of land degradation. This is a fundamental flaw of the current economic system, where corporations are able to privatise profits but leave societies and future generations to bear the environmental costs. This distorts economic signals and decision-making and incentivises practices that prioritise short-term gains at the expense of long-term planetary and human health.

One way to address this issue is to incorporate the full costs of land degradation and the true value of sustainable land management into macroeconomic analyses and corporate accounting and reporting. This approach is called True Cost Accounting (TCA). Businesses, policymakers, and other stakeholders in the food system can use TCA to measure, monetise and disclose the full costs and benefits of corporate practices. In the case of land management, this means calculating the environmental, health, social, and economic costs of land degradation, and putting a value on the benefits of sustainable land management. One study that assessed the hidden costs and benefits of maize production in Zambia found that common agricultural practices cause the loss of up to 16 tonnes of topsoil per hectare each year through erosion. The externalised environmental costs are 2 to 2.5 times higher than what it currently costs farmers to produce maize. But if farmers adopt more sustainable farming practices, small-scale mixed cropping can reduce environmental costs to almost zero.

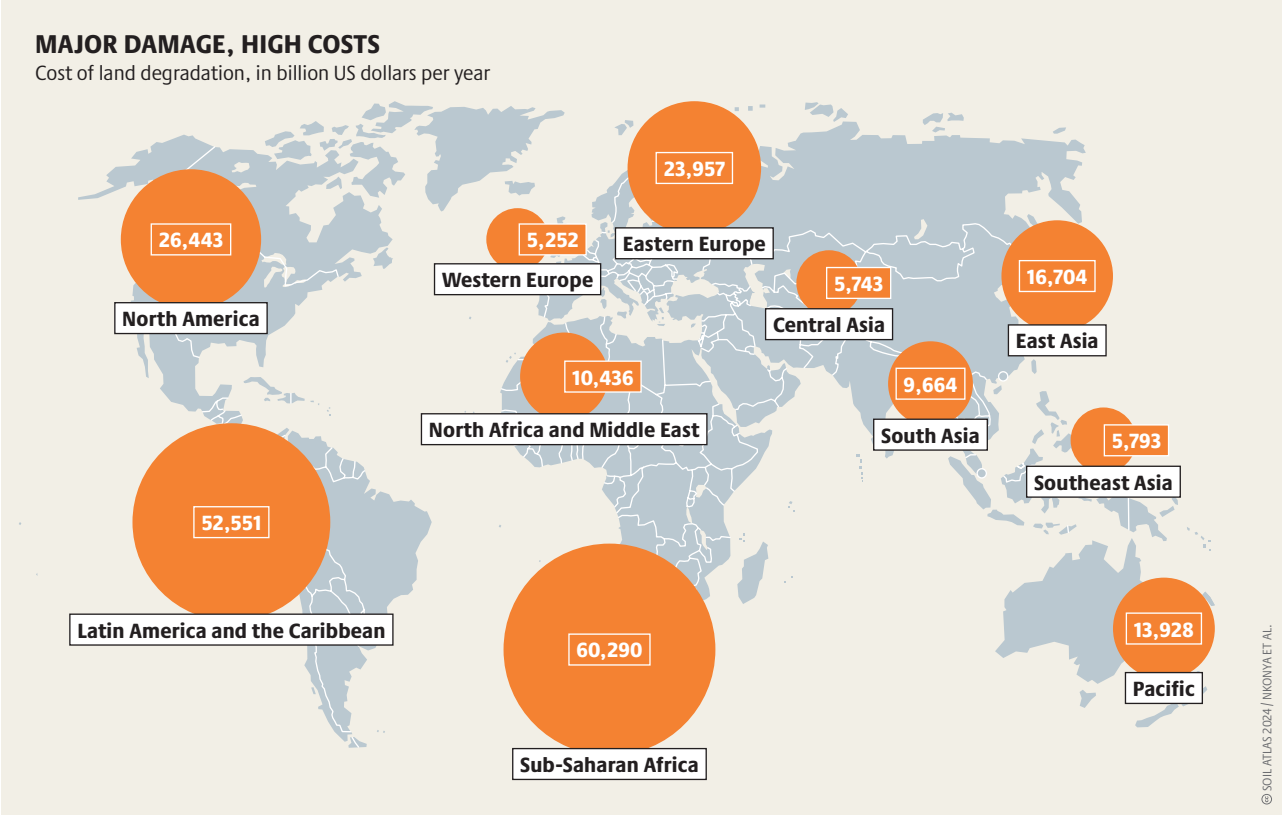
TCA reveals the benefits of investing in sustainable practices, thereby encouraging investments in sustainable transitions. Calculations that value ecosystem services and ecological restoration show that restoration projects not only slow down biodiversity loss and absorb carbon dioxide but are also economically viable. On average, the benefits of restoring degraded land are ten times greater than the costs of restoration.

LIVES AT RISK, FUTURE AT STAKE

Proportion of the reported population exposed to land degradation, 2019



Land degradation affects 3.2 billion people globally, disproportionately harming rural communities, smallholder farmers, and the extremely poor



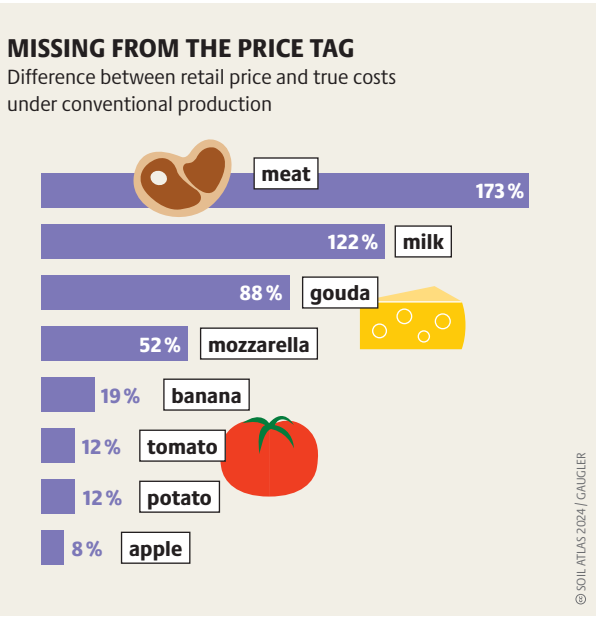
By quantifying the environmental, health, social, and economic impacts of land degradation in monetary terms, TCA also makes it easier to incorporate sustainability information into financial reporting, such as balance sheets and management reports. This allows sustainability-related values to be viewed on an equal footing with other economic values, and the results can be used to hold businesses accountable. For example, in its 2022 annual report, Olam, an international agrifood corporation, published a natural capital profit-and-loss statement for ten selected farmer groups and processing facilities, quantifying their positive and negative impacts on climate and water.

For TCA to become an effective accounting and reporting tool and transform the way companies operate, it needs to be complemented by additional policy measures, such as linking executive bonuses, dividends, taxes, and subsidies to a company's sustainability performance. The current voluntary nature of TCA allows those who cause the most external costs, particularly unsustainable companies, to avoid transparency and accountability. Further necessities include standardising TCA methods to support more efficient implementation and consistent comparison of assessments. But even without such improvements,

External costs of meat and dairy products are higher compared to plant-based products due to the energy-intensive rearing of livestock

Worldwide, land degradation harms ecosystems, amounting to at least 230 billion US dollars of damage per year

TCA can be used today to identify the hidden costs and benefits of land degradation and sustainable land management practices. As the first pilot projects have shown, these calculations can inform policy and business considerations, thereby helping to solve the problem of land degradation. ●



REVIVING INDIA'S SOILS FOR A BETTER FUTURE

Modern farming techniques were introduced to India during the Green Revolution of the 1960s to meet the needs of a rapidly growing population. However, the overuse of chemical fertilisers and pesticides, alongside the cultivation in monocultures, severely damaged soil health. In response, many farmers are moving back to alternative soil management practices. Political support for this transition is growing, but requires more flame to ignite change.

Over the past 50 years, India's agricultural production has almost tripled, even as the area of available farmland has decreased due to urbanisation, infrastructural development, and industrialisation. However, there is a heavy downside to the intensification of agriculture. The excessive use of chemical fertilisers and pesticides had negative impacts on India's soil. It is estimated that 37 percent of India's land is affected by degradation. Furthermore, a study of 50 million soil samples collected across India between 2015 and 2019 found that over two-thirds of samples were deficient in key nutrients such as nitrogen, phosphorus, and potassium, and 85 percent contained too little organic carbon for functional soil ecosystem. Reduced soil fertility hinders plant growth, leading to knock-on effects such as erosion and increased greenhouse gas emissions. Moreover, depleted soils respond poorly to the application of chemical fertilisers. For example, in the 1970s, India's farmers produced 15 kilograms of grain per kilogram of fertiliser used; by 2015 that ratio has fallen to 5 kilograms of grain per kilogram of fertiliser.

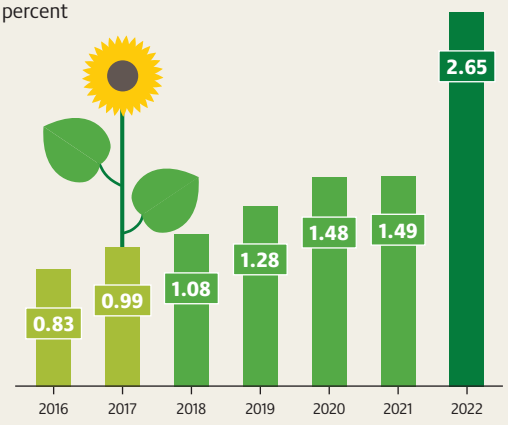
Farmers across India are now turning to a range of sustainable methods to revive their soils. Sustainable soil management (SSM) aims to maintain or improve soil health, productivity, and ecosystem functions while minimising negative environmental impacts. Various plant- and animal-based techniques can be used to improve the biodiversity, structure and fertility of the soil: fertilisers such as compost and manure, bone meal and fish emulsion, cover crops such as beans, and mulching with plant residues. Unlike chemical fertilisers, organic fertilisers nourish the soil microbiome and help crops grow without harming the environment. Practices like minimum tillage, hedge planting, and combining trees with crops in agroforestry systems, not only help combat erosion but can reverse or mitigate soil carbon depletion, reduce greenhouse gas emissions, and conserve water. Healthy soils also increase the resilience of agricultural systems to climate-related shocks and stresses.

Organic farming methods are also on the rise. While the share of total farmland under certified organic methods is still low, it has grown rapidly in recent years, from 0.7 percent in 2015 to 2.7 percent in 2022. In terms of numbers of producers, India leads the world, with over 1 million organic food producers. While the total number of uncertified organic growers is unknown, some numbers do exist. For example, community-managed natural farming, which emphasises sustainable and chemical-free agricultural practices, covers about 6 million households and 6 million hectares of farmland in just one state, Andhra Pradesh.

Policymakers have noted this trend and have begun taking steps to encourage the transition to SSM. For ex-

SLOW BUT STEADY

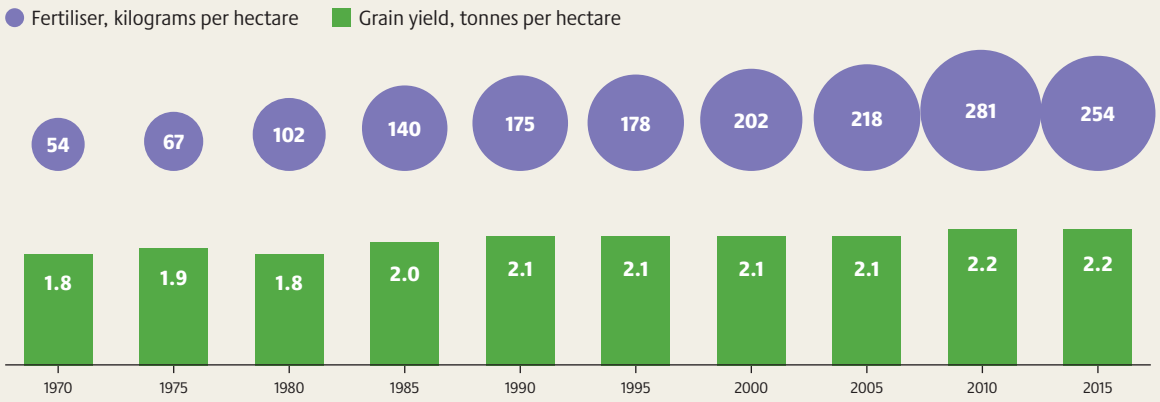
Area under organic farming in India, in percent



In 2022, India ranked second globally, with 4.7 million hectares of land under organic farming, trailing only Australia, with over 53 million hectares

MORE IS NOT ALWAYS BETTER

Fertiliser use and crop yields in India, from 1970 to 2015



Using more fertiliser does not necessarily lead to higher yields. But it does result in higher costs and environmental damage

ample, in 2015 the Government of India launched the Soil Health Card scheme. This service advises farmers on the types and amounts of fertilisers to use in order to safeguard soil health. The scheme reduced the use of chemical fertilisers by 8 to 10 percent while increasing productivity by 5 to 6 percent .

The use of chemical fertilisers is declining. Meanwhile, the organic fertiliser industry in India has experienced significant growth in recent years; production more than doubled from 28 million metric tonnes in 2016 and 2017 to 61 million tonnes in 2019 and 2020. This market is expected to grow at an annual rate of 13 percent until 2030, with revenues projected to reach 826 million US dollars. Demand for organic fertilisers is driven mainly by changes in consumer behaviour, as more Indians favour sustainably sourced food.

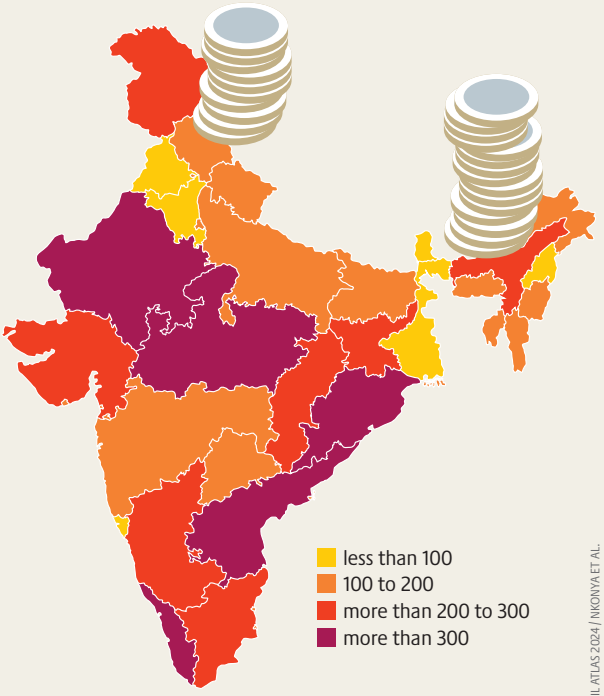
The government, non-governmental organisations, farmer cooperatives, and community-supported programmes are helping farmers learn about and use organic farming methods. But problems persist, including limited availability of inputs such as seeds, insufficient composting, and fragmented landholdings. Chemical fertilisers are still being heavily subsidised, and erosion, salinisation, and nutrient depletion continue to threaten soil health.

A multi-pronged approach is needed to address these problems: more and better training for farmers; improved research on sustainable land management including long-term impact assessment studies; the adoption of advanced technologies such as remote sensing for resource management; and the application of the best practices in organic farming. Changes are also needed at policy level, including the transfer of subsidies from chemical to organic fertilisers, financial incentives for farmers who implement SSM, and technical assistance for farmers transitioning to conservation tillage. Yet, policies need to translate into action. Concerted efforts by government, research institutions, and farmers are needed for the long-term health of India's soils.

Land degradation costs India millions of US dollars every year and threatens agriculture, which supports the livelihoods of two-thirds of the population

INDIA'S COSTLY SOIL CRISIS

Annual cost of land degradation, by Indian state in million US dollars



LAND AND SOIL RESTORATION IN THE SAHARA AND SAHEL

The Sahara Desert is expanding, thereby threatening millions of people's lives and livelihoods. While many large-scale initiatives have been launched to combat desertification, most lack secure funding. Bottom-up techniques, implemented by local farmers, show how Indigenous knowledge can drive restoration.

Once lush and densely populated, the Sahara is now the world's largest hot desert. Rainfall is scarce, with most areas receiving just 25 to 50 millimetres per year. The desert extends across northern Africa, covering over 9 million square kilometres, nearly one-third of the African continent. Despite its harsh climate, sand seas, and high dunes, the Sahara has verdant oases and lakes. It is home to a variety of species of flora and fauna, as well as around 2.5 million people.

Yet the region is under threat. The climate crisis, coupled with population growth, extensive farming, and overgrazing, have eroded the soil and degraded ecosystems. Such human activities combined with repeated droughts and dry Harmattan winds have caused the desert to expand south into the Sahel, a 6,000-kilometre belt of semi-arid savannah stretching from Senegal to Sudan. The Sahel is home to some 400 million people and provides a sanctuary for wildlife, such as the African spurred tortoise and the Saharan cheetah.

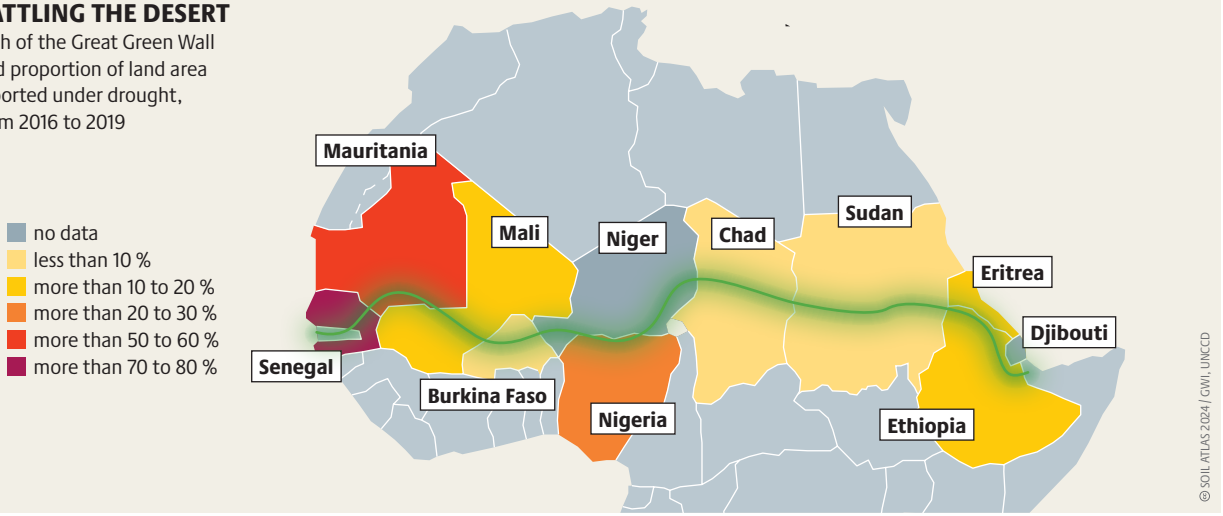
In the Sahel, desertification contributes to humanitarian crises, famine, and starvation. The number of people living on the brink of starvation in the region rose tenfold between 2019 and 2022, according to the World Food Programme. This dramatic rise can be attributed to a combination of factors, including desertification, conflict, and rising food prices. Biodiversity is declining and water bodies are shrinking. Lake Chad, a critical source of water for animals, plants, and over 30 million people, is drying up.

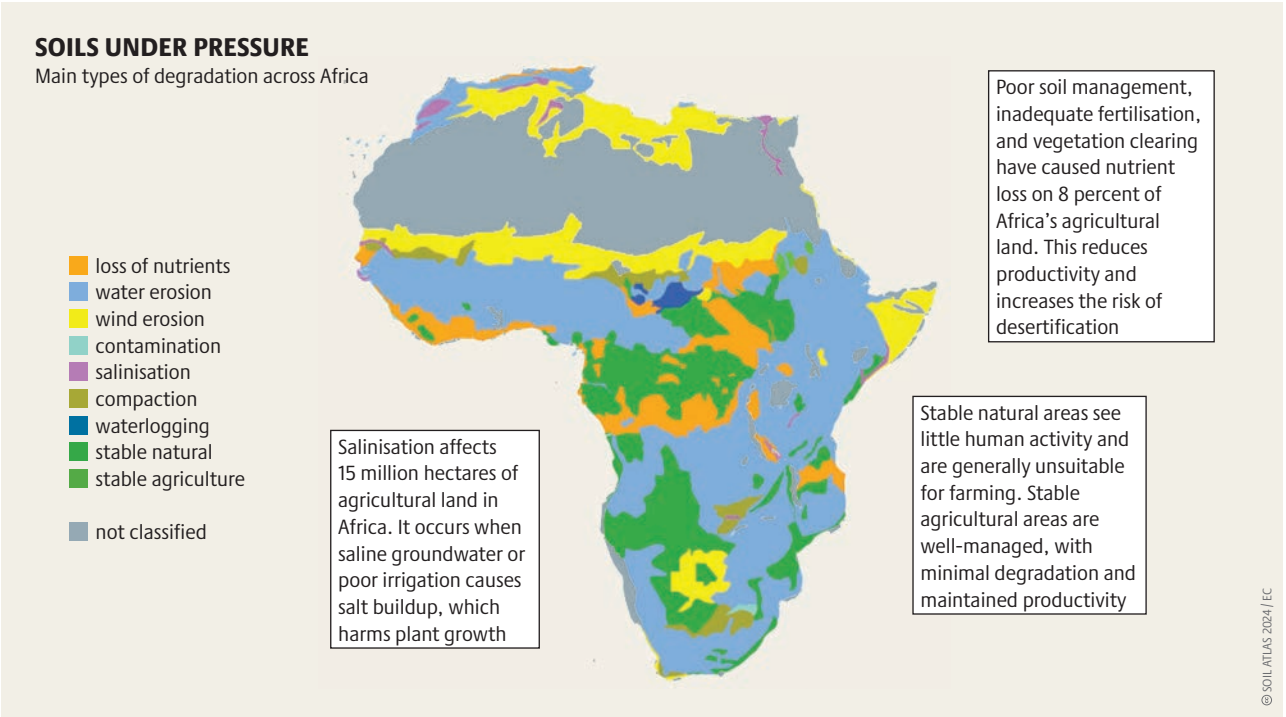
The Great Green Wall is one of many efforts to regreen the Sahara and Sahel. Led by African governments, this initiative seeks to stop the desert's advance by restoring the fertility of degraded agricultural and pastoral lands. It uses a range of approaches: tree planting, assisted natural regeneration (which supports the growth of naturally germinated seedlings), water conservation, and sustainable land management. However, there have been setbacks. Many trees have died due to lack of water or poor adaptation to local conditions, and scientists have expressed concerns about the

First envisioned in 2005, the Great Green Wall is an African-led initiative aimed at combatting desertification, climate change, and poverty

BATTLING THE DESERT

Path of the Great Green Wall and proportion of land area reported under drought, from 2016 to 2019





ecological impacts of introducing non-native species. However, the Great Green Wall has since been refined to emphasise sustainable and locally adapted practices.

Progress has been made in raising global awareness and generating funding for restoration efforts on the ground. One such initiative is the Regreening Africa programme, which has engaged over 500,000 households across eight African countries in land restoration efforts. This programme provides training in sustainable land management, tree planting, climate-smart agriculture, and soil and water conservation techniques.

Yet many challenges remain. According to the United Nations, the Great Green Wall initiative needs at least another 33 billion US dollars in funding to achieve its 2030 target. While many governments have pledged support, action on the ground is hampered by inadequate funding from international donors and Sahel countries, many of which are beset by political tensions, instability, and terrorism.

Away from these large, public programmes, local farmers have initiated bottom-up projects that have seen considerable success. A prominent figure in this movement was Yacouba Sawadogo, a farmer from Burkina Faso who single-handedly planted over 25 hectares of forest with over 60 species of trees and shrubs. He used the ancient zaï technique, where small pits filled with manure and dead vegetation capture scarce rainwater and concentrate soil nutrients. Trees and crops are then planted in the pits. This technique improves yields, enhances soil fertility, and helps farmers adapt to climate crisis. With support from non-governmental organisations, the zaï technique has improved food security for some 3 million people in Burkina Faso, raised household gross incomes by an average of 18 to 24 percent, reversed environmental degradation and desertification on 6 million hectares of land, and resulted in the planting of around 200 million new trees.

Land degradation drives migration and conflicts. In Africa, up to 60 million could be displaced in the next decade due to worsening land conditions

Farmers across the Sahara and Sahel are tackling land degradation by putting their Indigenous knowledge into practice. Farmer-managed natural regeneration is another similar approach, which involves farmers nurturing trees in degraded areas to help vegetation recover. This helps communities adapt to the climate crisis by boosting agricultural production even in drought years, which in turn increases incomes and strengthens community cohesion. In Niger, trees planted without the participation of local farmers often fail to thrive; however, those grown by local farmers have a significantly higher survival rate. Over 6 million hectares – about 50 percent of the country's cultivated area – have been restored in this way. In neighbouring Mali, village self-help groups implement traditional techniques combining agriculture and forestry. These techniques spread through learning exchanges among farmers, local radio programmes, and contests rewarding the most successful farmers.

It is clear that a combination of approaches is needed to halt the advance of the Sahara. The problem is too big for communities to tackle alone, and too complex for national and international actors to manage without the input of local farmers. ●

SOILLESS AGRICULTURE

REVOLUTION OR ILLUSION?

Vertical indoor farming enables crops to grow all year round. It requires less space and promises to reduce water, fertiliser, and pesticide use, thus protecting both climate and soil. But this must be part of a larger transformation of food systems.

With rapid urbanisation, the idea of soilless crop cultivation is gaining traction. Vertical indoor farming, a prominent approach in controlled environment agriculture (CEA), enables the effective cultivation of lettuce, leafy green vegetables, and herbs in closed buildings. Warehouses or specially designed buildings are filled with multi-tiered structures that resemble shelves or racks. These vertical layers, sometimes stretching from floor to ceiling, are lined with rows of plants growing in carefully controlled environments. Instead of soil, the plants are rooted in nutrient-rich water solutions, which are circulated through the system to provide the essential minerals and hydration the plants need to grow. Alternatively, the roots are suspended in air or a growing medium like coconut fibre or perlite, with the nutrient solution delivered directly to them.

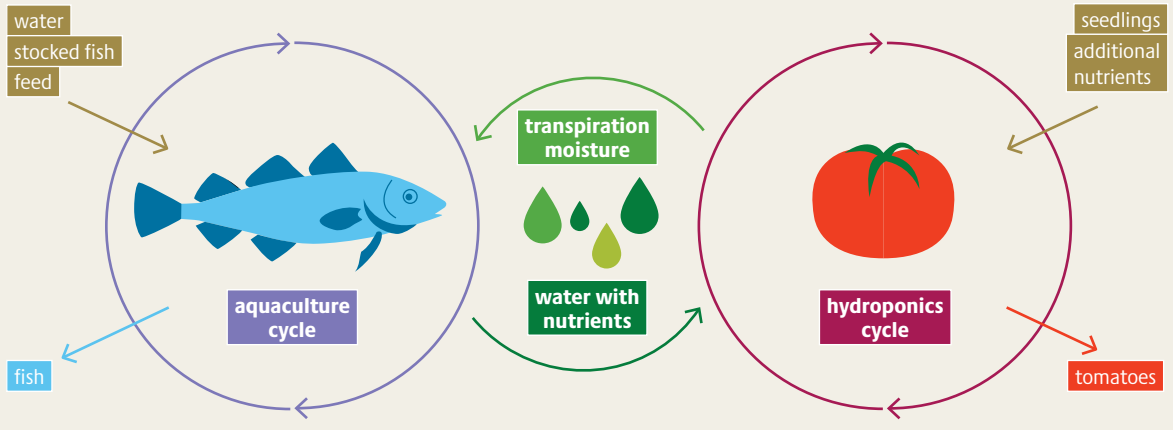
The closed systems ensure that no or few pollutants, such as fertiliser runoff or pesticide residues, escape from indoor farms into the soil or groundwater. Because the plants are exposed to fewer pathogens, pesticide use is also greatly reduced. Computers control LED lighting, water, temperature, and nutrient levels, enabling the plants to grow quickly with yields up to ten times higher than those achieved using conventional production methods. Such methods also save water. At Nordic Harvest, Europe's largest vertical farm in Denmark, the plants require 95 percent less water thanks to a recycling system. This low water requirement is a major benefit in the context of the climate crisis, and the reduced need for space also relieves the burden on land and soils. In recent years, vertical indoor farming has experienced a boom, with supermarket chains, such as Walmart based in the United States or Lidl and Rewe based in Germany, investing billions.

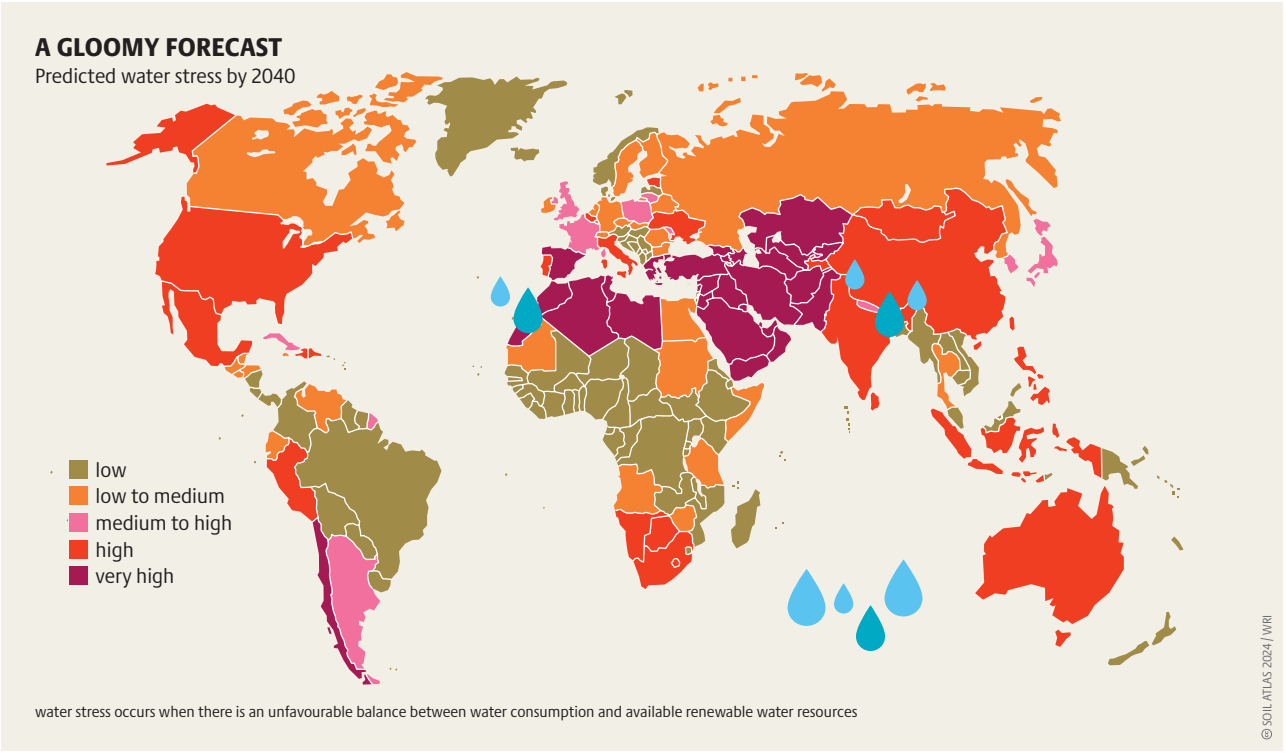
However, vertical farming uses significant amounts of energy, making it uneconomical due to high energy prices. As of 2022, several North American and European start-ups exited the market due to high electricity and gas costs. In the Global North, a high-tech system that creates the perfect growing conditions from lighting and temperature to water supply costs at least 300 US dollars per square metres. A study conducted in Arizona found that hydroponic lettuce required 82 times more energy than conventional production methods, though milder climates reduce this need.

In an eco-friendly cycle, the fish faeces provide nutrients for the plants, which in turn filter water for the fish

CLOSED CYCLES

The "tomatofish" is an example of aquaponics, where plants and fish are raised together in a common closed system





Agriculture uses 70 percent of the world's freshwater. This can lead to water shortages for household consumption

Moreover, if that energy comes from fossil energy sources, indoor farms are responsible for higher emissions of carbon dioxide. A 2022 study compared emissions from outdoor cultivation with those from a vertical farm in the Netherlands. It found that growing vegetables in a vertical facility produced up to 16 times more emissions than field cultivation. Higher energy and labour costs pushed production costs up, resulting in higher prices for vertically produced food. Even so, vertical farms may be economical in densely populated cities, such as Hong Kong or New York, where land prices are very high. Proponents argue that shorter transport routes and the elimination of intermediaries can save as much as 60 percent of the overall costs. However, even where cost-efficient models exist, technical expertise and a continuous supply of water and energy are essential.

A look at the types of crops grown shows that soilless agriculture can make an important contribution to the provision of micronutrients and can help avoid harmful pesticide residues. Yet, it cannot replace the field cultivation of potatoes, rice, or other cereals – crops that have high energy requirements and need more macronutrients than lettuce. In theory, vertical farms could produce wheat under optimal conditions. One study estimated that a 10-storey vertical farm built on an area of one hectare could produce between 700 and 1,940 tonnes of wheat a year. This is 220 to 600 times the average global wheat yield of 3.2 tonnes per hectare. However, production costs might be enormous. In 2020, an art installation calculated the price of wheat grown in a closed, one-square-metre space with an artificial supply of light, water, heat, and nutrients at 200 euros per kilogram.

Hydroponic systems in controlled environments have also been tested in informal urban settlements in the Global South to analyse their potential to contribute to food security through the local production of selected vegetables. Several projects run in Nairobi, Kenya achieved high levels of local participation resulting in significant knowledge transfer. These projects highlighted the specific functions of CEA, such as adaptation to climate change and enhancing the production of nutritious food for urban communities in challenging environments with scarce resources.

Critics argue that CEA approaches such as vertical indoor farming, while interesting, cannot meet global agricultural challenges. Up until now, vertical farming seems to be suited only to water-rich fruits and leafy vegetables, which are low in calories despite being important for a balanced diet. In order to reduce the land consumption for agricultural production, agriculture must be restructured to create a more just and sustainable food system. In Europe, over 63 percent of arable land is currently used to grow fodder, highlighting the need for change so that land is used more efficiently to provide healthy food for people, while saving natural resources. Nonetheless, soil depletion and the climate crisis may make soilless farming indispensable in the long run.

TO READ AND STUDY

AUTHORS AND SOURCES FOR DATA AND GRAPHICS

All online links were last checked in September 2024. See page 2 for the websites where you can download a clickable PDF of this atlas. Lengthy links have been shortened using the bit.ly web address conversion service.

10–11 ECOSYSTEM SOIL

THE FOUNDATION OF LIFE
by Ronald Vargas

p. 10: Diedrich Schroeder, Bodenkunde in Stichworten, 1992.
p. 11 top: Mark A. Anthony et al., Enumerating soil biodiversity, 2023, https://bit.ly/3Xb4NT4.
p. 11 bottom: European Commission, Land use statistics, 2018, https://bit.ly/4driiDO.

12–13 SOIL DEGRADATION

THE SILENT GLOBAL CRISIS
by Harun Warui

p. 12: Hannah Ritchie, Max Roser, Half of the world's habitable land is used for agriculture, 2024, https://bit.ly/3TSJuUb.
p. 13 top: European Commission (EC), Global Soil Biodiversity Atlas, 2019, p. 19, https://bit.ly/47jFSPT.
p. 13 bottom: Bundesanstalt für Geowissenschaften und Rohstoffe, Bodenerosion durch Wind, https://bit.ly/3SVIPl9.

14–15 DESERTIFICATION

EUROPE IS DRYING OUT
by Victor Castillo and María José Sanz Sánchez

p. 14: Intergovernmental Panel on Climate Change (IPCC), Climate Change and Land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, 2019, p. 257, https://bit.ly/49NPTGH.
p. 15: Intergovernmental Panel on Climate Change (IPCC), Climate Change and Land, an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, 2019, p. 254, https://bit.ly/49NPTGH.

16–17 CLIMATE ADAPTATION

SOIL AND WATER, A CRUCIAL SYMBIOSIS
by Larissa Stiem-Bhatia and Inka Dewitz

p. 16: Intergovernmental Panel on Climate Change (IPCC), Climate Change 2021: The Physical Science Basis, 2021, p. 89, https://bit.ly/4dt61xS.
p. 17 top: Umweltbundesamt, Bodenfunktionen, https://bit.ly/46zS0ed.
p. 17 bottom: Financial Times, Climate graphic of the week: Record rainfall in UK and France batters wheat crops, 2024, https://on.ft.com/46VjXix.

18–19 CORPORATE POWER

WHEN CULPRITS BENEFIT
by Lena Luig

p. 18: Annual reports. https://bit.ly/47I3cqe. https://bit.ly/3GlbBEh. https://bit.ly/3QWyKCd. GRAIN, Institute for Agriculture and Trade Policy (IATP), A corporate cartel fertilizers food inflation, 2023, https://bit.ly/46vKzF8.
p. 19: ETC Group, Food barons 2022: Crisis Profiteering, Digitalization and Shifting Power, 2022, pp. 7, 14, 16, 43, 69, https://bit.ly/49IPQvI.

20–21 NITROGEN FERTILISER

GLOBAL DEPENDENCIES
by Lena Bassermann and Gideon Tups

p. 20: GRAIN, Institute for Agriculture and Trade Policy (IATP), A corporate cartel fertilizers food inflation, 2023, https://bit.ly/46vKzF8.
p. 21 top: Chatham House, Resource Trade.Earth, https://bit.ly/40PGCdb.
p. 21 bottom: Stefano Menegat et al., Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture, 2022, https://go.nature.com/3sNEuWC.

22–23 PHOSPHORUS

EXTRACTIVIST AGRICULTURE
by Axel Anlauf

p. 22: W.J. Brownlie et al., Our Phosphorus Future, 2022, p.25, https://bit.ly/3YMeGI9.
p. 23: Katherine Richardson et al., Earth beyond six of nine planetary boundaries, 2023, https://bit.ly/4dNF6xt.

24–25 GREEN HYDROGEN AND FERTILISERS

NOT A QUICK FIX
by Lisa Tostado

p. 24: Hannah Ritchie, Can we reduce fertilizer use without sacrificing food production?, 2021, https://bit.ly/3uBRVtf.
p. 25: Agora Industry, Global Green Fertiliser Tracker, https://bit.ly/3yO9I30.

26–27 LAND GRABBING

THE RACE FOR HECTARES
by Roman Herre

p. 26: Landmatrix, https://bit.ly/3GjIktC.
p. 27 top: Landmatrix, https://bit.ly/3GjIktC.
p. 27 bottom: Oxfam, Desterrados: Tierra, poder y desigualdad en América Latina, 2016, p. 25, https://bit.ly/3RdvFij.

28–29 LAND SALES

JUST ANOTHER COMMIDITY?
by Jan Brummer, Gesine Langlotz and Anne Neuber

p. 28: Deutscher Bauernverband (DBV), Situationsbericht 2021/2022, Trends und Fakten zur Landwirtschaft, 2021, p. 84, https://bit.ly/3QWFpfB.
p. 29 top: Deutscher Bauernverband (DBV), Situationsbericht 2021/2022, Trends und Fakten zur Landwirtschaft, 2021, p. 84, https://bit.ly/3QWFpfB. Statistisches Bundesamt, https://bit.ly/3STYz8i.
p. 29 bottom: Jan Brunner, Land Grabbing in Ostdeutschland. Ursachen, Auswirkungen, Widerstand, 2019, p. 3, https://bit.ly/47MDfpD.

30–31 CLIMATE POLICY

CONFLICTS BETWEEN DEMAND FOR LAND AND PEOPLE'S RIGHTS
by David Betge, Frederike Klümper and Jes Weigelt

p. 30: Anne Larson et al., The Land Gap Report, 2022, p. 57, https://bit.ly/48648Fl.
p. 31 top: Sarobidy Rakotonarivo et al., Resolving land tenure security is essential to deliver forest restoration, 2023, https://go.nature.com/3uBK3b7.
p. 31 bottom: PBL Netherlands, Goals and Commitments for the Restoration Decade, 2020, p. 19, https://bit.ly/3MXuQrk.

32–33 SOIL CARBON CREDITS

BLESSING OR CURSE?
by Sophie Scherger and Larissa Stiem-Bhatia

p. 32: Interreg North Sea Region Carbon Farming project, Five promising measures to protect the climate by Carbon Farming, 2021, https://bit.ly/3MjGv2R.
p. 33 top: Jörn Scharlemann et al., Global soil carbon: understanding and managing the largest terrestrial carbon pool, 2014, https://bit.ly/4dLyX4K.
p. 33 bottom: Werner Klohn, Hans Windhorst, Physische Geographie, 1999, p. 13. Diedrich Schroeder, Bodenkunde in Stichworten, 1992.

34–35 HUMAN RIGHTS

RIGHTS VERSUS REALITY
by Jes Weigelt and Frederike Klümper

p. 34: Global Witness, Standing firm, 2023, p. 29, https://bit.ly/47KRb3t. Transparency International, https://bit.ly/3QShbmA.
p. 35: Global Witness, Defending Tomorrow, 2020, p.14, https://bit.ly/3GhMx1b. Global Witness, Standing firm, 2023, https://bit.ly/46stR9G. Global Witness, Challenging polluters, championing people, 2024, https://bit.ly/3XMwVwg.

36–37 WOMEN AND LAND

PROTECTING RIGHTS, PROTECTING SOIL
by Larissa Stiem-Bhatia, Kader Baba, Serah Kiragu-Wissler and William Onura

p. 36: Food and Agriculture Organization of the United Nations (FAO), The gender gap in land rights, 2018, p. 4, https://bit.ly/3WW1LAT.
p. 37 top: Larissa Stiem-Bhatia et al., Making sustainable land management work for women, 2019, p. 7, https://bit.ly/4dQWrpu.
p. 37 bottom: Food and Agriculture Organization of the United Nations (FAO), SDG indicator, https://bit.ly/3AZzXE9.

38–39 EUROPEAN UNION

SOIL PROTECTION? WANTED!
by André Prescher-Spiridon

p. 38: European Environment Agency (EEA), Agricultural land use intensity, 2015, https://bit.ly/3sDMRUU.
p. 39: Eurostat, https://bit.ly/3N2D4hV.

40–41 AGROECOLOGY

POLICIES THAT KEEP SOIL ALIVE
by Júlia Dolce and Lucas Gattai

p. 40: Repórter Brasil, https://bit.ly/34oMBMY.
p. 41 top: CIDSE, https://bit.ly/40V2vYy.
p. 41 bottom: Misereor, Agroecology as a Pathway towards Sustainable Food Systems, 2018, p. 36, https://bit.ly/3AxnqrD.

42–43 TRUE COSTS

HIDDEN EFFECTS
by Olivia Riemer, Marlene Ohlau, Jenny Lay-Kumar and Mark Schauer

p. 42: United Nations Convention to Combat Desertification (UNCCD), Proportion of the population exposed to land degradation, https://bit.ly/4fVHZho
p. 43 top: Ephraim Nkonya et al., Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development, Chapter Global Cost of Land Degradation, 2015, Table 6.15, https://bit.ly/3WR3Qhw.
p. 43 bottom: Universität Augsburg, Die wahren Kosten von Lebensmitteln, https://bit.ly/46T2Dut.

44–45 SUSTAINABLE SOIL RESTORATION

REVIVING INDIA'S SOILS FOR A BETTER FUTURE
by Pratik Ramteke and Ashok Patra

p. 44: Forschungsinstitut für biologischen Landbau (FiBL), Data on organic area in worldwide, https://bit.ly/3TxyRGh.
p. 45 top: S.K. Chaudhari et al., Integrated soil, water and nutrient management for sustainable agriculture in India, 2015.
p. 45 bottom: Gurumurthy Mythili, Jann Goedecke, Economics of Land Degradation in India, 2015, https://bit.ly/3Xcbtk3.

46–47 REGREENING THE DESERT

LAND AND SOIL RESTORATION IN THE SAHARA AND SAHEL
by Mawa Karambiri

p. 46: United Nations Convention to Combat Desertification (UNCCD), The Great Green Wall Implementation Status and Way Ahead to 2030, 2020. https://bit.ly/4etxII3.
p. 47: European Commission, Soil Atlas of Africa, 2014, chapter 3, p. 149, https://bit.ly/4dxiVMc

48–49 SOILLESS AGRICULTURE

REVOLUTION OR ILLUSION?
by Lena Luig and Christian Sonntag

p. 48: Leibniz-Institut für Gewässerökologie und Binnenfischerei (IGB), https://bit.ly/49Okjsm.
p. 49: World Resources Institute, https://bit.ly/47tB3Uj.

SOILS EXPLAINED:
A SOURCE OF LIFE AND A CLIMATE PROTECTOR

Healthy soils are essential for life on Earth. They are home to countless creatures and provide us with healthy, diverse food.

By storing carbon that would otherwise enter the atmosphere as greenhouse gas, soils limit global warming. At the same time, they help us adapt to the climate crisis because intact soils can store large quantities of water and release it when needed.

Soils are highly endangered by human intervention and unsustainable agriculture. The effects of climate change are further exacerbating the situation!

Our explanatory video shows what soils can do, why healthy soils are becoming increasingly scarce, and why soil protection concerns us all.

**TO WATCH THE VIDEO,
ENTER THE FOLLOWING LINK:
eu.boell.org/soils-explained**

HEINRICH-BÖLL-STIFTUNG

The Heinrich-Böll-Stiftung is a German political foundation affiliated with the German Green Party (Alliance 90/The Greens). Its primary task is political education and advocacy in Germany and abroad. Our main tenets are ecology and sustainability, democracy and human rights, non-violence and justice. In our work, we place particular emphasis on gender democracy, equal rights for minorities and the political and social participation of migrants.

Our namesake, the writer and Nobel Prize laureate Heinrich Böll, personifies the fundamental principles we stand for: defence of freedom and human dignity, civic courage, open debate and the acknowledgement of art and culture as independent spheres of thought and action. As a think tank for green visions and ideas, we are part of an international network with 34 offices worldwide and with partner projects in more than 60 countries.

The Heinrich-Böll-Stiftung European Union represents the foundation vis-à-vis European and international institutions, associations, non-governmental organisations and media based in Brussels. The office is a main point of contact for individuals, groups and organisations from around the world interested in EU politics and policies. The future of the European project and the role of the European Union in the world are at the centre of our activities and efforts.

Heinrich-Böll-Stiftung
Schumannstraße 8, 10117 Berlin, Germany
www.boell.de

Heinrich-Böll-Stiftung European Union
Rue du Luxembourg 47-51, 1050 Brussels, Belgium
https://eu.boell.org

TMG – THINK TANK FOR SUSTAINABILITY

TMG Research is dedicated to driving just and sustainable transitions through action research and advocacy. Committed to a rights-based approach, our programmes focus on land governance, food system transformations in rural and urban settings, and adaptation to climate change.

At TMG, science with society is more than a principle; it's how we work to ensure equitable pathways to sustainable development. We explore how local innovations and global policies intersect to drive systemic change, ensuring that international frameworks are both inspired by and responsive to community-led transformations. Our research projects and advocacy are co-developed with civil society, policymakers, scientists and the private sector to ensure international sustainability efforts are informed by emergent innovations and forge real-world solutions.

TMG is headquartered in Berlin, with a team in Nairobi. Our research focuses primarily on the European Union and Africa, including Benin, Kenya, Madagascar, Malawi, and South Africa.

TMG – Think Tank for Sustainability
EUREF Campus 6-9, 10829 Berlin, Germany
www.tmg-thinktank.com

SOIL ATLAS PODCAST SERIES

Why are healthy soils important for climate action and food security?
What role do healthy soils play in adapting to the climate crisis?
What are the impacts of synthetic fertilisers on soils, climate and geopolitics?
Why is land ownership such a crucial issue, especially in Eastern Europe?

Answers to these questions and approaches for fair access to land and the sustainable use of soils can be found in three podcast episodes on the Soil Atlas, based on interviews with experts from politics, agriculture and civil society from various European countries as well as Ghana and Kenya.

This and other podcasts from the Heinrich-Böll-Stiftung can be found on our website, and on Podigee, Soundcloud, Spotify, Apple Podcasts or in the podcast app of your choice.

To listen to the podcast on the Soil Atlas, enter the following link:
https://eu.boell.org/podcast

PUBLISHED IN ENGLISH

PEATLAND ATLAS 2023
European Union
Further editions:
German: Federal Republic of Germany, Austria
eu.boell.org/en/PeatlandAtlas

INSECT ATLAS 2020
European Union
Further editions:
Czech: Czech Republic
German: Federal Republic of Germany, Austria
Portuguese: Brazil
Spanish: European Union
boell.de/insectatlas

AGRICULTURE ATLAS 2019
European Union
Further editions:
French: European Union
Spanish: European Union
German: Federal Republic of Germany, Austria
Italian: Italy
Polish: Poland
boell.de/agriculture-atlas

AGRIFOOD ATLAS 2017
European Union
Further editions:
German: Federal Republic of Germany
Portuguese: Brazil
boell.de/agrifood-atlas

PESTICIDE ATLAS 2022
European Union
Further editions:
English: Kenya, Nigeria
German: Federal Republic of Germany, Switzerland, Austria
Spanish: European Union
Italian: Italy
French: France
Chinese: China
Portuguese: Brazil
Turkish: Turkey
eu.boell.org/en/PesticideAtlas

PLASTIC ATLAS 2019
United States of America
Further editions:
German: Federal Republic of Germany
English: Asia, Nigeria, Palestine
French: France, Morocco, Senegal, Tunisia
Spanish: El Salvador
Portuguese: Brazil
Arabic: Palestine
Burmese: Myanmar
Bulgarian: Bulgaria
Chinese: China
Georgian: Georgia
Greek: Greece
Khmer: Cambodia
Russian: Russian Federation
Czech: Czech Republic, Slovakia
boell.de/plasticatlas

ENERGY ATLAS 2018
European Union
Further editions:
German: Federal Republic of Germany
French: France
Czech: Czech Republic
boell.de/energy-atlas

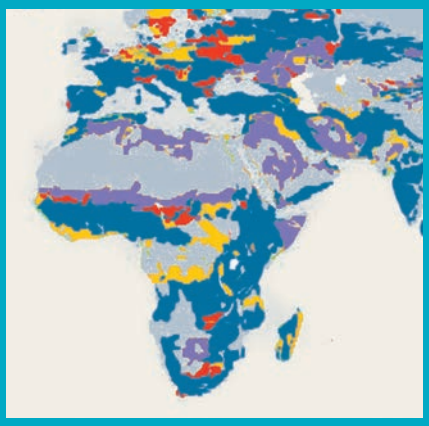
COAL ATLAS 2015
European Union
Further editions:
English: Nigeria
German: Federal Republic of Germany
Spanish: Latin America
Bosnian: Bosnia and Herzegovina, Macedonia, Albania
Czech: Czech Republic
Polish: Poland
boell.de/coalatlas

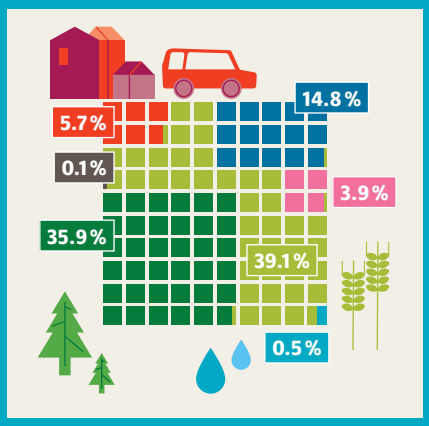
MEAT ATLAS 2021
European Union
Further editions:
German: Federal Republic of Germany
Polish: Poland
Hungarian: Hungary
eu.boell.org/meatatlas

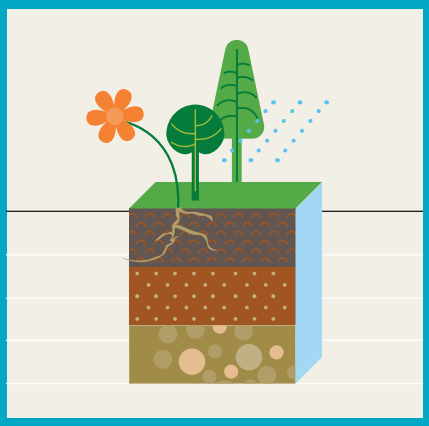
EUROPEAN MOBILITY ATLAS 2019
Further editions:
German: Federal Republic of Germany
Translated to: French, Italian, Spanish, Portuguese, Czech, Greek
eu.boell.org/european-mobility-Atlas

OCEAN ATLAS 2017
United States of America
Further editions:
German: Federal Republic of Germany
French: France, Senegal, Tunisia
Spanish: Latin America
Arabic: Palestine
Chinese: China
Khmer: Cambodia
Russian: Russian Federation
Turkish: Turkey
boell.de/ocean-atlas

MEAT ATLAS 2013
European Union
Further editions:
German: Federal Republic of Germany
French: France
Portuguese: Latin America
Spanish: Latin America
Czech: Czech Republic
Turkish: Turkey
boell.de/meat-atlas







Soil is the most species-rich habitat on Earth.
Almost two-third of species are found in soils.
from: THE FOUNDATION OF LIFE, page 10

Healthy soils store vast amounts of water. They mitigate the impacts of heavy rainfall and other consequences of the climate crisis.
from: SOIL AND WATER, A CRUCIAL SYMBIOSIS, page 16

Ensuring gender justice in land governance plays a crucial role in soil protection.
from: PROTECTING RIGHTS, PROTECTING SOIL, page 36

The unequal distribution of land frequently leads to violence. Over 2,100 individuals have lost their lives in land-related conflicts since 2012.
from: RIGHTS VERSUS REALITY, page 34