SOIL ATLAS

Facts and figures about a vital resource

2025

KENYA EDITION

HEINRICH BÖLL STIFTUNG

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FOREWORD

Soil is the foundation of life. It nourishes crops, filters water, stores carbon, and sustains biodiversity. As the outermost layer of our planet, soil forms a fragile yet vital ecosystem that supports all terrestrial life. In Africa, soil is particularly essential for livelihoods, agriculture, and food security, directly supporting millions of farmers and rural communities.

Despite its critical role in sustaining ecosystems and human well-being, soil remains one of the most overlooked and undervalued resources. The Soil Atlas 2025 aims to change this narrative by highlighting the urgent challenges affecting soil health and the need for immediate action, both in Kenya and globally.

Soil degradation is accelerating worldwide due to unsustainable agricultural practices, deforestation, pollution, and climate change. Often referred to as a 'silent crisis,' its effects may not be as immediately visible as deforestation or ocean pollution, yet its consequences are profound and far-reaching.

As highlighted in this atlas, one-third of the world's soils are degraded, with significant impacts across Africa, Europe, and beyond. In Kenya, soil degradation is worsened by land overuse, deforestation, and climate variability, threatening agricultural productivity and rural livelihoods.

While these challenges are deeply felt locally, they are part of a broader global issue – one that affects food security, deepens social inequalities, and complicates efforts to address climate change. Yet, soil health often remains absent from policy discussions and corporate agenda.

> In Kenya, soil degradation is worsened by land overuse, deforestation, and climate variability, threatening agricultural productivity and rural livelihoods

This atlas provides both global perspectives and Kenya-specific insights into the state of soil health. Some articles focus on the unique challenges and solutions within Kenya, while others examine soil degradation as a worldwide concern. It explores how industrial agriculture, excessive use of synthetic fertilisers, and corporate interests contribute to soil depletion.

The overuse of artificial inputs like nitrogen and phosphorus not only weakens soil resilience but also accelerates climate change through greenhouse gas emissions. Additionally, soil erosion and desertification continue to threaten fertile lands, disrupt livelihoods, and drive migration.

The atlas also sheds light on how land degradation and the commodification of land increase inequalities, often displacing smallholder farmers and indigenous communities – in Kenya and around the world – who have been stewards of the land for generations.

Amid these challenges, promising solutions are emerging. A growing movement is advocating for sustainable land management and agroecology, placing emphasis on soil health, biodiversity, and climate resilience.

Across Africa, there is increasing recognition of soil health within policy frameworks, including initiatives by the African Union (AU). The Fertiliser and Soil Health Action Plan, launched by the AU, seeks to improve soil fertility, promote sustainable land management, and support smallholder farmers through better soil testing and mapping.

However, challenges such as limited access to soil data and insufficient testing capabilities continue to hinder progress. Globally, farmers and communities are adopting regenerative agricultural practices, replenishing organic matter, and integrating traditional knowledge to restore soil fertility.

In Kenya, community-driven initiatives are demonstrating how soil health can be restored through practical, locally adapted solutions. Agroforestry practices have helped reduce soil erosion, improve soil fertility, and increase crop yields, particularly for staple foods like maize.

In many regions, local conservation efforts have played a crucial role in rehabilitating degraded land, increasing vegetation cover, and enhancing biodiversity.

Community-led reforestation projects have restored lost forest cover, strengthened climate resilience, and provided sustainable livelihoods. These examples highlight the power of grassroots action in protecting and revitalising soils. However, expanding such efforts will require sustained investment, supportive policies, and strong partnerships.

> Soil is not an infinite resource – It is a living, breathing system that requires care, investment, and respect

Soil is not an infinite resource – It is a living, breathing system that requires care, investment, and respect. Recognising soil as more than just dirt under our feet is essential; it is, in fact, the very bedrock of life. The Soil Atlas 2025 serves as both a wake-up call and a guide for action. However, meaningful change happens from the ground up.

Collaboration, innovation, and the integration of traditional knowledge will be key to restoring soil health. Individuals, communities, and organisations all have a role to play-by promoting sustainable practices, raising awareness, and incorporating soil health initiatives into education and policy-making.

By working together, we can inspire action, encourage accountability, and safeguard this invaluable resource for future generations. We hope this atlas will inform, inspire, and help place soil protection at the centre of environmental and agricultural policies.

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Lead Coordinator, Agroecology and Food Rights
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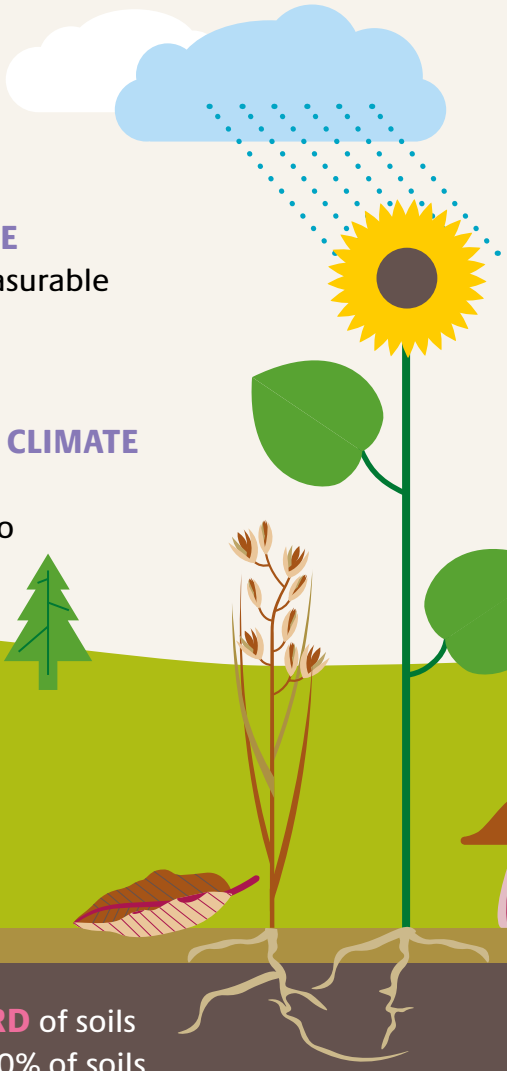
12 BRIEF LESSONS

ABOUT SOILS



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

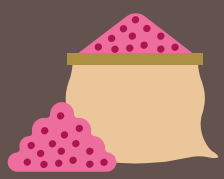
2 Healthy soils are key for **CLIMATE** action. They store more **CARBON** than forests do

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 Kenya over 40% of soils are affected by land degradation, high proportions are acidic and saline.

5 Only 20% of Kenya's land is arable, losing 26 tons of soil per hectare annually through **EROSION**.

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



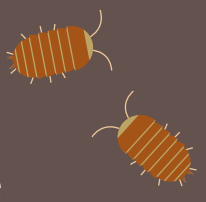
7 A significant portion of scarce agricultural land is currently used to cultivate **FEED FOR LIVESTOCK.**

8 Declining nutrient levels in food, partly impacted by degraded soils, contributing to **RISING MALNUTRITION** and **HIDDEN HUNGER**.

9 There are **AGRICULTURAL PRACTICES** to protect and use soils more **SUSTAINABLY.** In Kenya, policies must support and strengthen their implementation through the recently launched National Agroecology Strategy as well as the Kenya Agricultural Soil Management Policy 2023.

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.

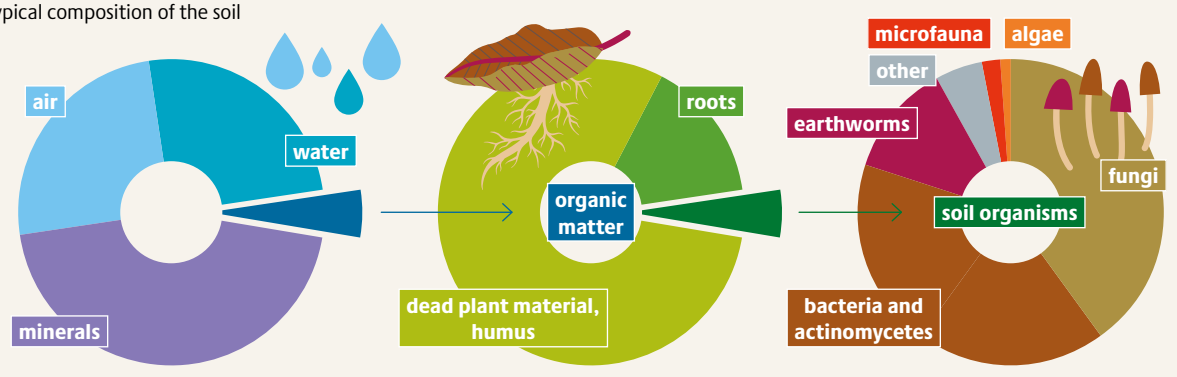
Roughly 95 percent of the world's food is grown on soils. Healthy soils function variously as a sponge, a buffer, and a filter that traps pollutants like heavy metals and pesticides. Within the soil, millions of microorganisms, including bacteria and fungi, work tirelessly to break down harmful substances.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

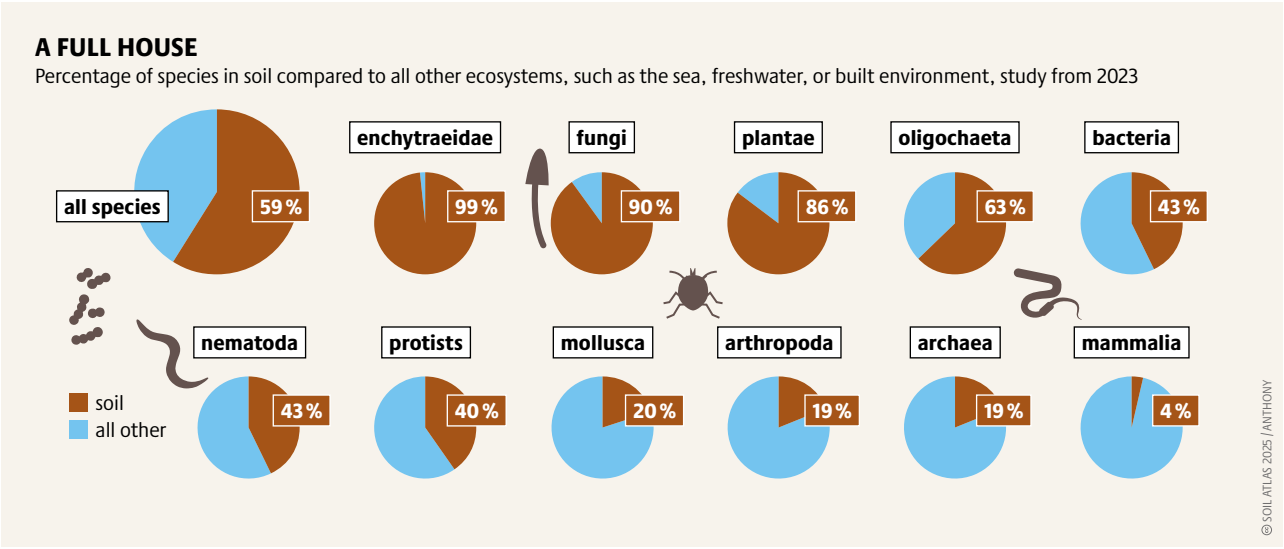
Soils also play a major role in nutrient cycles, storing, transforming, and recycling the elements essential for life, such as calcium, carbon, magnesium, nitrogen, phosphorus, potassium, and sulphur. Soil nutrients originate from decomposed organic matter, weathered rocks, and atmospheric deposition. 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





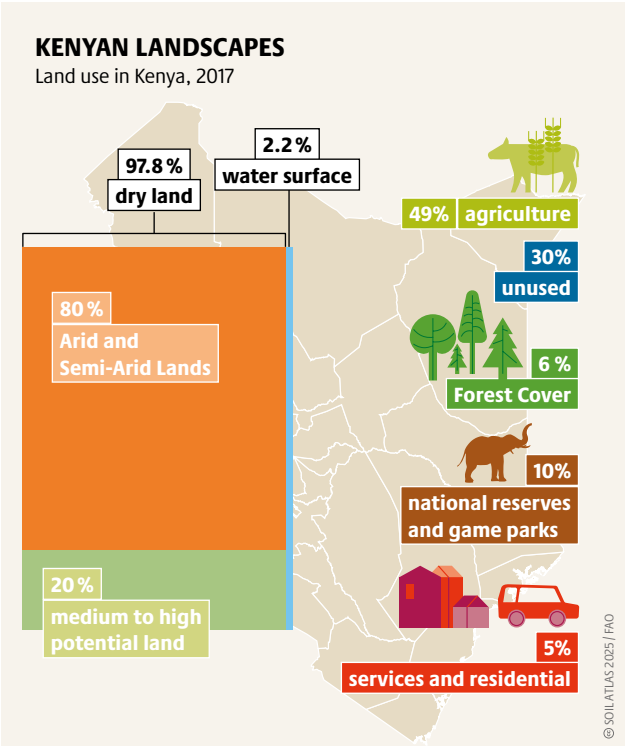
Soil provides a home for a vast number of species: It is the most biodiverse habitat. Almost two-thirds of all species worldwide reside there

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.

Only 20% of Kenya's land is suitable for agriculture. Most of the agricultural land lies in dryland areas.



A SILENT CRISIS IN EAST AFRICA

Soil degradation poses a global crisis as it jeopardises food security, livelihoods, and ecosystem health. The situation is worse in East Africa, where over 40 percent of soils are degraded, threatening the region's agricultural foundation and resilience.

A combination of human activities and natural processes drive this crisis. Overgrazing, unsustainable farming practices, deforestation, and increasingly erratic weather patterns contribute to the depletion of soil quality.

One of the most visible signs of degradation is the erosion of nutrient-rich topsoil, largely caused by water and wind. In Kenya, for example, croplands lose an average of 26 tons of soil per hectare annually to water-induced erosion, with some areas experiencing losses exceeding 90 tons. Overgrazing, especially in dry areas, exacerbates the problem by removing vegetation that protects the soil. Without this cover, the soil becomes vulnerable to erosion and compaction, reducing its ability to absorb water and sustain plant life. Climate change compounds these challenges, as heavy rainfall accelerates soil erosion. Globally, soil erosion costs 400 billion US dollars annually.

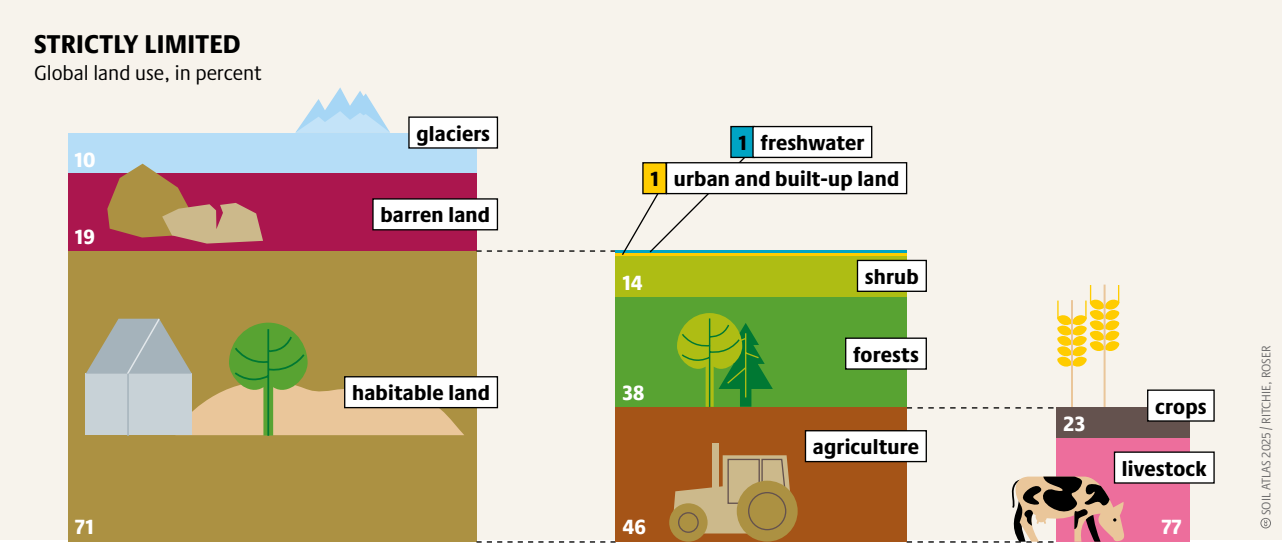
In the arid and semi-arid landscapes of northern Kenya and Tanzania, salinisation – the buildup of salts in the soil – is another concern. Poor irrigation practices, such as the use of low-quality water, contribute to this issue. When the water evaporates, it leaves behind salts that gradually accumulate to harmful levels. High evaporation rates and waterlogging also intensify the problem. Approximately 40 percent of irrigated land in Kenya is affected by salinity making it difficult to meet agricultural demands.

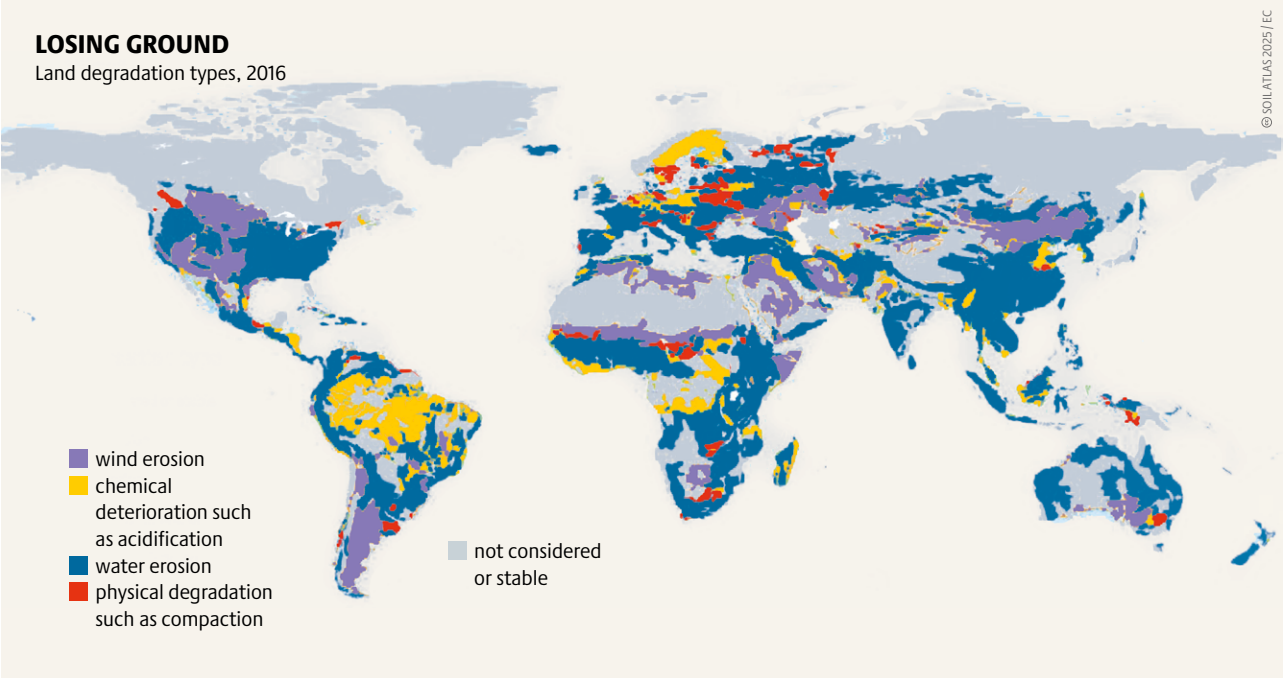
Nutrient depletion is another challenge to soil health across East Africa, with over 85 percent of soils being nutrient-deficient. Continuous farming without replenishment, combined with rising soil acidity and poor management practices, has worsened the problem. Organic carbon levels, important for maintaining healthy soil ecosystems, are low. In Kenya, 75 percent of soils fall below sustainable thresholds. This depletion weakens the soil, disrupts microbial communities, and leaves crops vulnerable to disease.

Another issue is soil contamination, hazardous chemicals and heavy metals not only degrade soil health but also pose risks to ecosystems and people. Some of the pesticides used in Kenya are classified as highly hazardous, with long-term consequences to soil productivity and environmental integrity.

Soil degradation has a far-reaching impact on communities in East Africa. With over 70 percent of the population relying on agriculture, declining soil fertility threatens food security and livelihoods. In Kenya, degraded soils are estimated to reduce agricultural out-

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





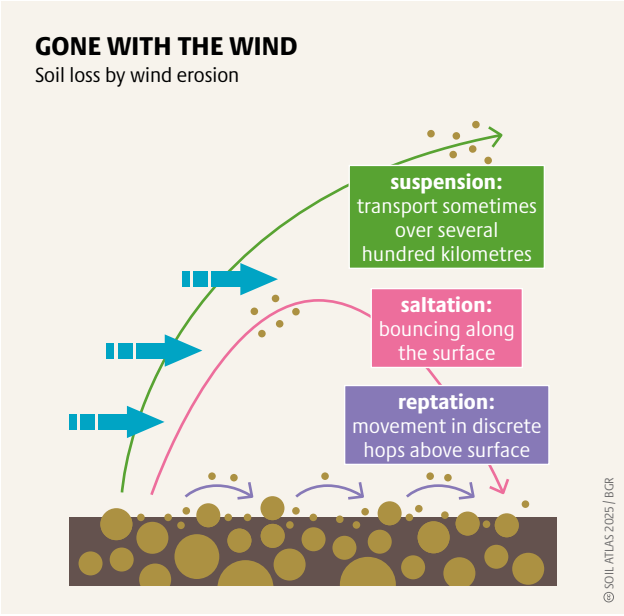
put by 30 percent, leading to dependency on imports. Land degradation costs the region over 65 billion US dollars annually in lost productivity.

Despite these challenges, there are efforts to counteract soil degradation, with governments, communities, and international organisations working to promote sustainable practices that can help restore degraded landscapes and enhance productivity. Agroecological methods, such as minimising soil disturbance, incorporating organic matter, and diversifying crops, have shown promising results. For instance, agroforestry initiatives taken by the Kenya Agricultural Carbon Project (KACP) in Kenya's highlands, have reduced soil erosion and improved maize yields, unlike conventional farming methods. Similarly, community-driven conservation efforts like terracing and reforestation, are producing positive results. In northern Tanzania and Kenya's Rift Valley, such practices have increased crop yields by up to 20 percent, while in Mirema, in Kenya's Migori County, a Community Forest Association regenerated 50 percent of their denuded forest by planting over 300,000 trees in five years. These examples demonstrate the potential of collaborative approaches to land restoration. However, sustaining these initiatives requires supportive policies and committed investments as well as a strong global partnership.

Innovative technologies are also beginning to play a role as soil mapping and satellite monitoring offer new opportunities for targeted interventions. These technologies can enhance soil restoration efforts despite being in the early stages of development. Programmes such as Kenya's National Soil Health and Fertility Management Strategy are promising, but achieving meaningful and lasting results will require continued emphasis on restoring soil biodiversity and fertility through sustained policy and financial support. Without this focus, the region risks further degradation which will continue to threaten the resilience of its agricultural systems and the well-being of millions of people. ●

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

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



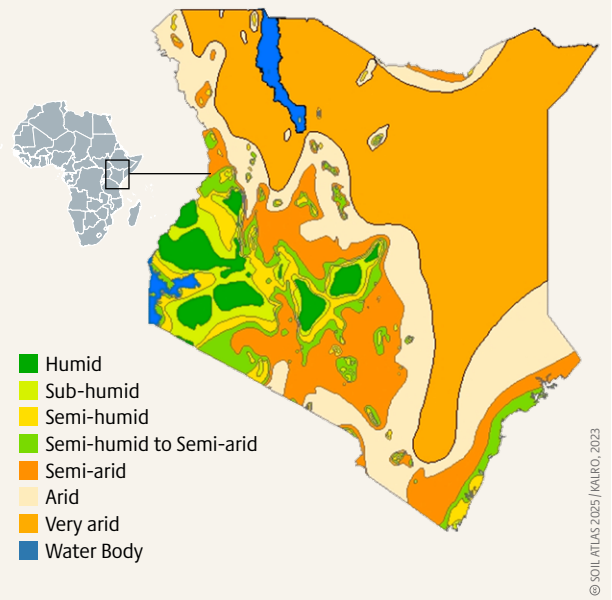
KENYA'S DIVERSE SOILS

Kenya's diverse soils face interconnected challenges that require tailored solutions for sustainable productivity. Simply increasing the use of synthetic fertilisers is not enough.

Each soil tells a unique story, shaped over thousands – sometimes hundreds of thousands – of years. Most of Kenya's soils can be classified as tropical due to the country's warm climate and location near the equator. Tropical soils differ significantly from temperate soils as they are heavily weathered by high temperatures and intense rainfall. These conditions lead to nutrient-leaching, making the soils acidic, with low levels of essential nutrients like nitrogen, phosphorous, calcium, magnesium, and potassium.

Soils appear red or brown because they are dominated by iron and aluminum oxides. Their low cation exchange capacity limits their ability to retain nutrients. Organic matter in tropical soils breaks down easily, leading to reduced natural fertility and low organic carbon levels. Their texture makes them prone to compaction and erosion if not properly managed. All these challenges require thoughtful interventions for the soils to be productive.

AGRO-ECOLOGICAL ZONES
Kenya's agroclimatic zones



Although 80 percent of Kenya's soils are classified as tropical, they have diverse qualities shaped by factors such as geology, climate, and landscape. These soils range from sandy to clayey, shallow to deep, and vary in fertility. Each type has unique challenges and benefits. For example, sandy soils may drain quickly but struggle to retain nutrients, while clayey soils often hold water and nutrients, but are prone to compaction and poor drainage.

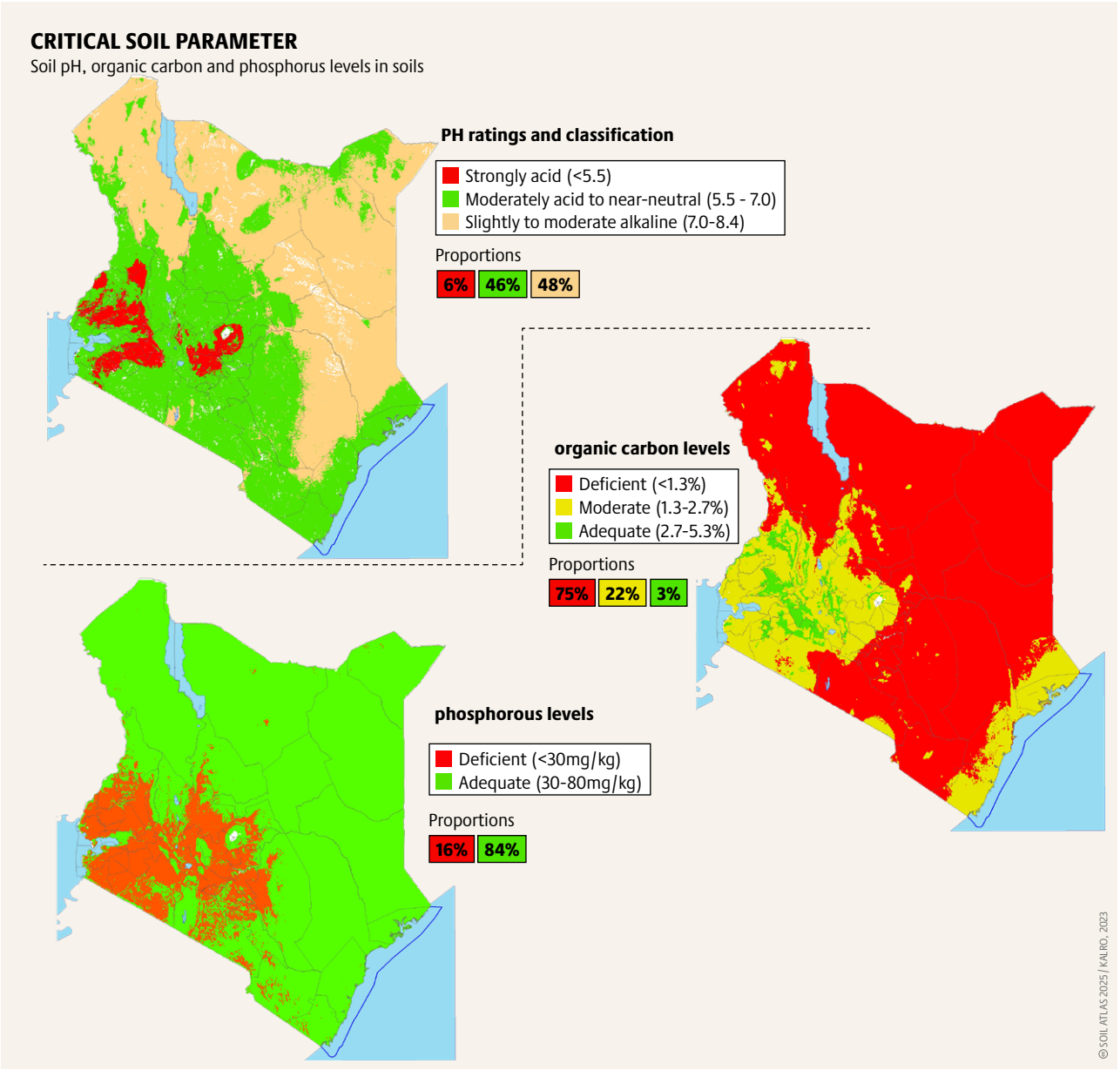
Of the 23 soil types in Kenya's seven agro-climatic zones, only a few support food production. Zones I-IV, covering 20 percent of the land, receive higher rainfall and have more fertile soils that can support diverse crops. The remaining 80 percent of the land lie in the drier Zones V-VII and can only support drought-tolerant crops. Volcanic soils in high-rainfall areas, fertile highland soils, clay-rich soils in hilly areas, old, weathered soils and heavy clay soils in flat areas are the most farmed among the 23 types.

The volcanic soils are porous and retain water well but are acidic and prone to erosion. They are used for farming tea, vegetables, and pyrethrum. The acidic but fertile highland soils, common in mountainous areas, have good water retention and support crops such as maize, potatoes, bananas and coffee. Sub-humid and hilly zones have clay-rich soils that are compact below the surface. They make farming and root growth harder, but with proper management, can be productive. The old, weathered soils common in parts of western Kenya are nutrient-poor but can yield good crops if nutrients are added and erosion is controlled. Heavy clay soils are found in flood-prone, flat semi-arid regions. They tend to crack when dry and require careful management.

These soil types have diverse shortfalls and addressing them needs site-specific, locally adapted solutions and not a one-size-fits-all approach.

In Kenya, 63 percent of arable land has acidic soils, and 32 percent of that has soils classified as strongly acidic. While some soils are naturally acidic, overuse of synthetic fertilisers has exacerbated the problem. Studies in Kenya's central highlands and western region show that even high nitrogen fertiliser application in the acidic soils with low organic matter does not boost maize yields above two tons per hectare. However, soils

The majority of Kenya's agroecological zones are characterised as arid or semi-arid. Dryland farming is a challenge.



Kenyan soils face various challenges at the same time-acidic soils often overlap with deficient organic content and phosphorus levels.

with higher organic carbon and a pH above 6, can produce up to 3.5 tons per hectare, even with lower fertiliser use. Acidic soils fix phosphorus, making it unavailable to plants, and reduce the availability of other key nutrients like potassium. Continuous cropping and incorrect application of fertilisers have also depleted nitrogen, potassium, and micronutrients like zinc. To address soil acidity, adding lime or phosphate rock can effectively reduce pH and increase the availability of phosphorus and other nutrients. Balanced fertilisers, combined with organic inputs like compost, can replenish nutrients, improve soil structure and help restore fertility.

Organic carbon deficiency, which affects 75 percent of Kenya's soils, reduces soil health and productivity. Adding organic matter through compost or biochar is an effective solution.

Salt-affected soils, covering about 40 percent of Kenya's arid and semi-arid regions. Accumulation of ions such as sodium, calcium, magnesium, and chloride, often caused by poor water management, harden the soil, reduce drainage, and impair crop growth. Addressing these issues involves leaching salts with proper water management, improving drainage, adding gypsum and organic manure, and using deep tillage to enhance soil structure and fertility.

Kenya's diverse soils face various challenges, but integrated steps such as agroforestry, agroecology, and regenerative agriculture can address these challenges simultaneously. Prioritising them in future soil health policies and management plans can effectively achieve soil health.

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.

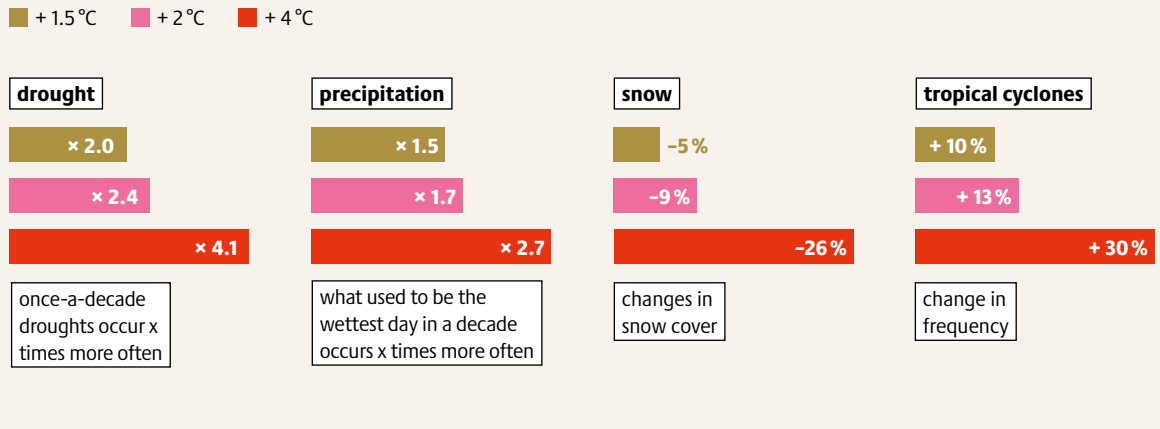
Dense urban infrastructure may also prevent soil from acting as a water reservoir. When large areas of towns and cities are sealed by asphalt or concrete, rainwater must be channelled into drains, and heavy downpours can overwhelm the drainage system and cause flooding. Europe is the continent with the 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

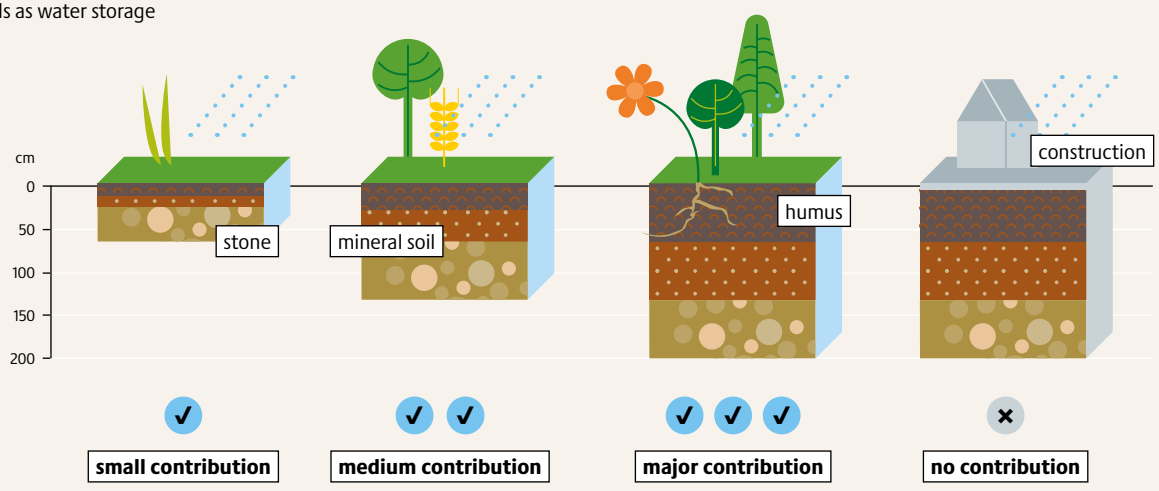
LONG SHADOW OF EXTREMES

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

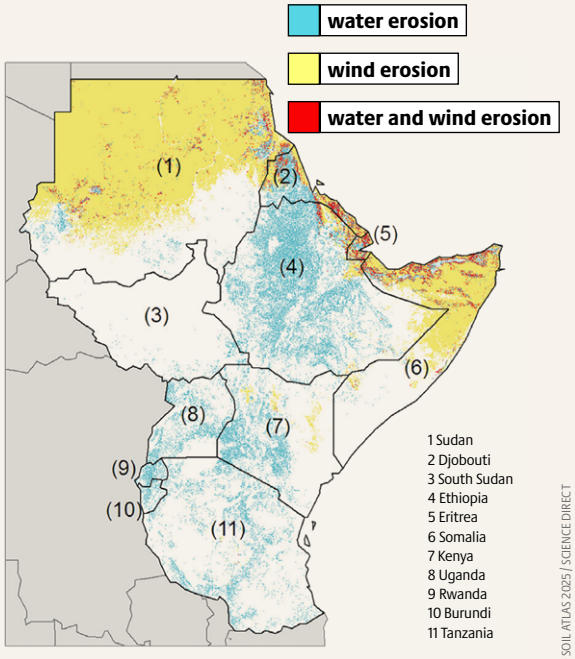
process has been the greening and unsealing of built-up and asphalted areas. Unsealed soils play an indispensable role in flood control. During heavy rains they absorb water, thus reducing the pressure on surrounding areas. In addition to sponge cities, sponge landscapes are also needed. Low-lying areas 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, marked by extreme rainfall and droughts, accelerates soil degradation, exacerbates erosion, and poses a growing threat to East African agriculture.

SOIL EROSION

Areas susceptible to water and wind erosion risks in the East Africa region as a result of increased rainfall and desertification



WHEN CULPRITS BENEFIT

The overuse of artificial fertilisers harms soils, nitrogen fertilisers contribute to climate change and pesticides kill beneficial organisms. Despite this, companies profit from these products and influence governments, blocking essential environmental policies.

In 2023, almost 73 billion US dollars' worth of pesticides and more than 200 billion dollars of artificial fertilisers were sold worldwide. High market prices in 2022 meant that the profits of the largest agrochemical manufacturers rose significantly. Since the mid-1990s, the pesticide and fertiliser industries have undergone significant consolidation. Between 1996 and 2009, hundreds of seed and pesticide companies merged into six dominant corporations. By 2020, Syngenta, Bayer, Corteva, and BASF together controlled 62% of the global market. The fertiliser sector has also seen extensive mergers over the past two decades, resulting in major players like Nutrien, CF Industries, Mosaic, and Yara.

While fertiliser and pesticide companies are reaping huge profits, farmers are bearing the brunt of the high cost of production. Between September 2021 and September 2022, the price of nitrogen fertiliser in Kenya increased by 30 percent. To cushion farmers against losses, the government launched an expanded fertiliser subsidy programme with a budget of 23 million US dollars. This significant expenditure limits funds available for other essential public needs.

One reason the trade is so lucrative for the corporations is that their bottomline does not take into account the ecological costs that arise from the use of their products – biodiversity loss, depletion of soil organic matter, and rising soil salinity and acidity.

Many pesticides are banned in the European Union because of their known risks to human health and the environment. But they continue to be sold nonetheless, mainly in the Global South. In 2020, 44 percent of the pesticides used by farmers in Kenya – where Syngenta and Bayer were the main sellers – had been banned in the EU and other countries.

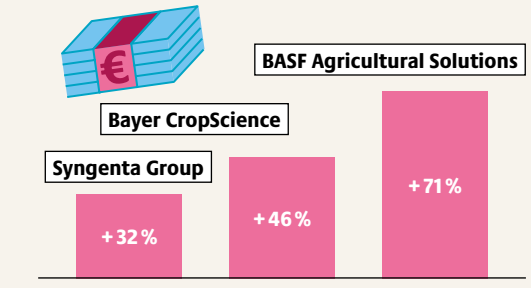
Corporations often use their market power to influence policies. Pesticide and fertiliser companies in the EU have been lobbying against the European Commission's so-called Farm to Fork Strategy, which is a key plank of the European Green Deal. The agrochemical lobby is influential in Kenya too. It took the country's regulatory body four years to announce plans to withdraw eight harmful active ingredients after local Non-Governmental Organisations (NGOs) called for a ban on toxic pesticides that are prohibited in other countries. The industry pushed back, claiming the ban would reduce yields and farmers' incomes, yet it was clear they wanted to protect their profits without considering the harmful effects of their products.

Globally, the pesticide industry gained more political influence through a strategic partnership between the United Nations' Food and Agriculture Organisation (FAO) and CropLife International, an association representing BASF, Bayer, Corteva, FMC, and Syngenta – the top five pesticide companies. The partnership, instituted by a letter of intent signed in 2020, was criticised by numerous civil society organisations that considered it incompatible with FAO's support for agroecology. In May 2024, the FAO ended its partnership with CropLife.

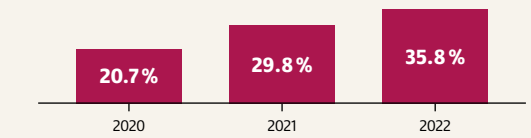
The fertiliser industry is increasingly making its presence felt at international climate policy gatherings. At the 28th UN Climate Change Conference in Dubai, the International Fertiliser Association hosted

MONEYMAKERS

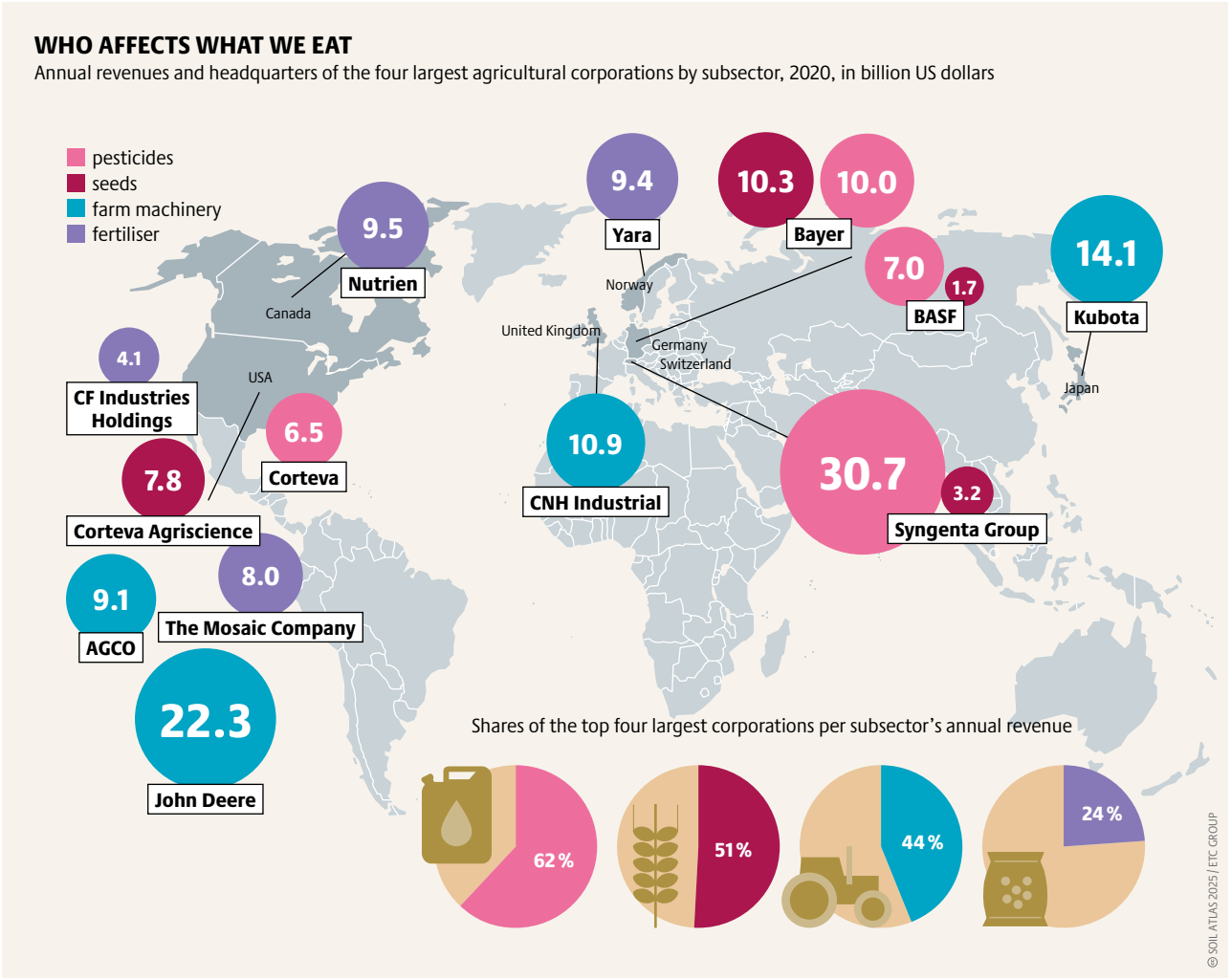
Profits of the world's three largest pesticide manufacturers, 2022, compared to previous year



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

several events at the Food Systems Pavilion. Fertiliser companies OCI, OCP, Nutrien, and Yara, and pesticide companies BASF, Bayer, and Syngenta, supported a so-called Soil Health Day at the conference, posing as supporters of initiatives aimed at improving soil health. Some of these companies also participated in the 2024 African Fertiliser and Soil Health Summit in Nairobi.

The pesticide and fertiliser industry has responded to growing pressure from civil society and politicians with various strategies while seeking opportunities for profits. Yara, the Norwegian fertiliser company which also operates the world's largest ammonia trading network, has, for example, announced that it aims to decarbonise its production by reducing carbon dioxide emissions. It plans to use renewable energy to generate green hydrogen, which is used to produce green ammonia. In Kenya, green hydrogen fertiliser production is a central strategy for reducing reliance on synthetic fertiliser imports and lowering agriculture's carbon footprint.

Several large-scale projects are planned, including two major plants near Lake Naivasha, where a green hydrogen fertiliser plant is already operational. Norwegian investment funds and development corporations are also backing green hydrogen projects in Uganda. However, focusing solely on decarbonising production without substantially reducing the use of chemical fertilisers and pesticide risks – or creating the space for more sustainable alternatives – would allow the industry's core business to continue unhindered.

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 intends to build the largest digital agriculture platform in collaboration with IBM. Multinational companies such as Google and Amazon are also pushing into this market.

While precision farming technologies, such as GPS-guided robots, promise to reduce pesticide use, experts warn that control over digital platforms by large pesticide and fertilizer companies may limit farmers' access to affordable solutions and increase their dependence on these corporations.

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.

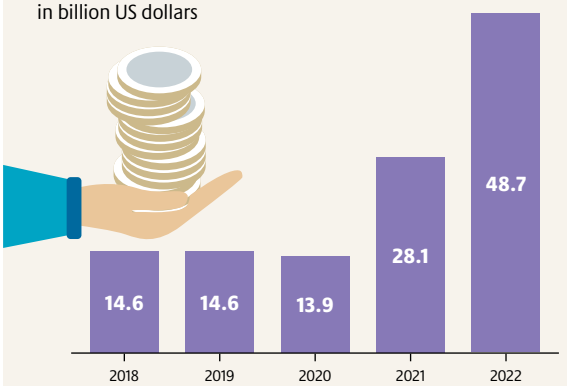
The effects of higher fertiliser prices can be seen at the supermarket checkout. In March 2022, the worldwide Food Price Index, which tracks the prices of food commodities, hit an all-time high. In the food crisis of 2007 and 2008, one study found that the doubling of fertiliser prices pushed up the 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-

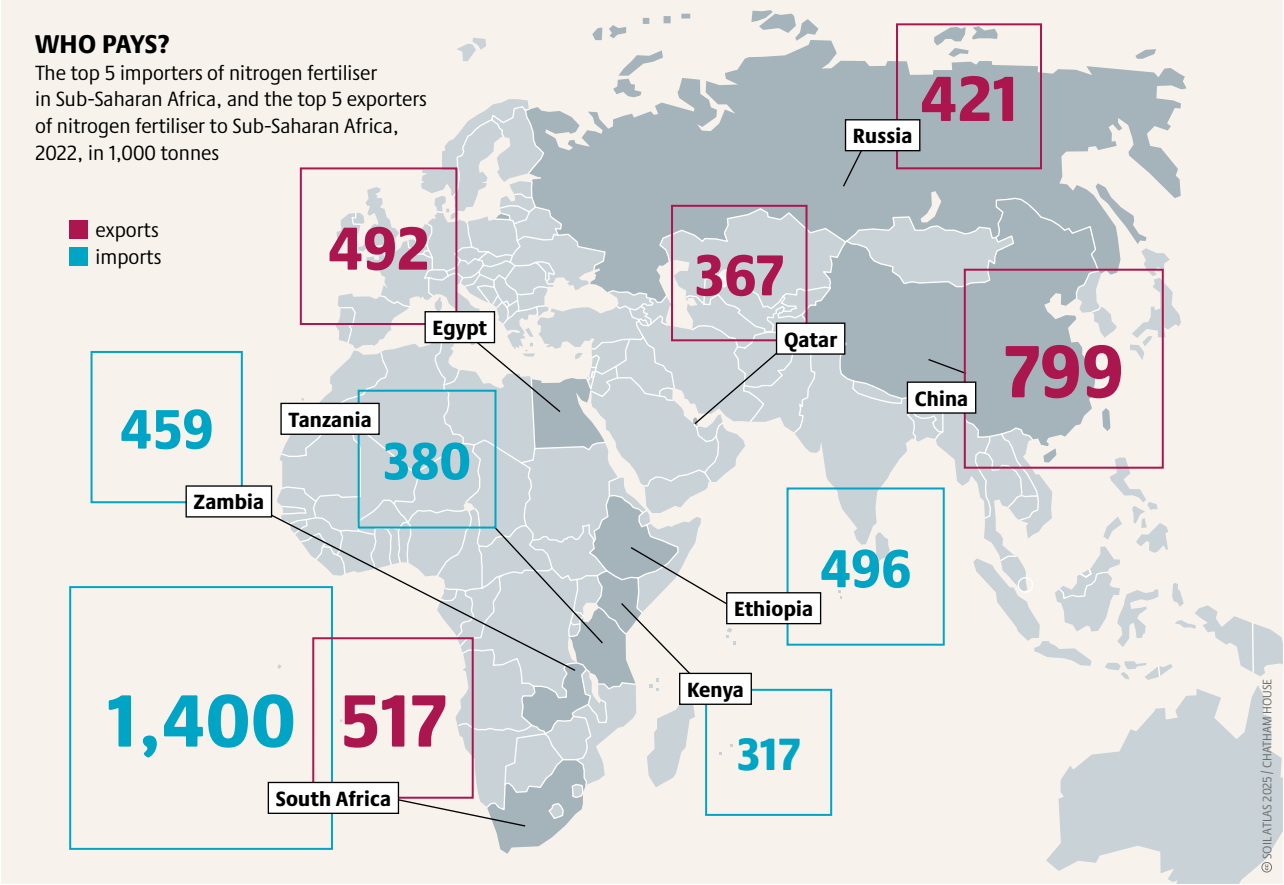
RINGING THE TILLS

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



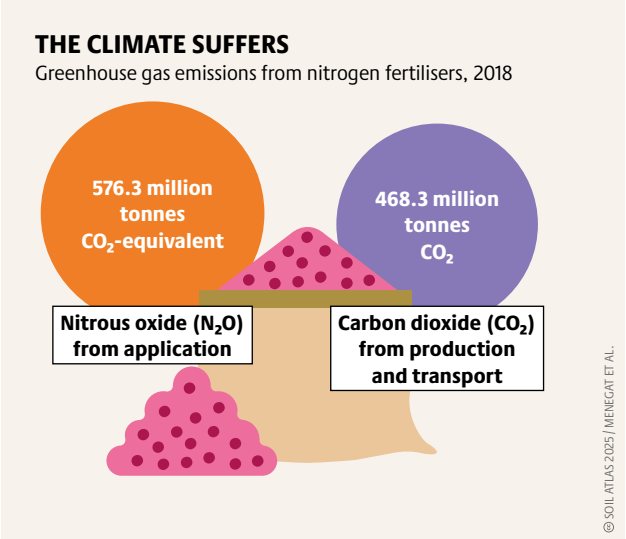
ing the food crisis of 2007 and 2008 meant that fertiliser subsidies rose from 8 to 16 percent of the total national budget. Moreover, the percentage of low-income countries that are under debt distress, or threatened with bankruptcy, has almost tripled since 2013. According to the International Monetary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

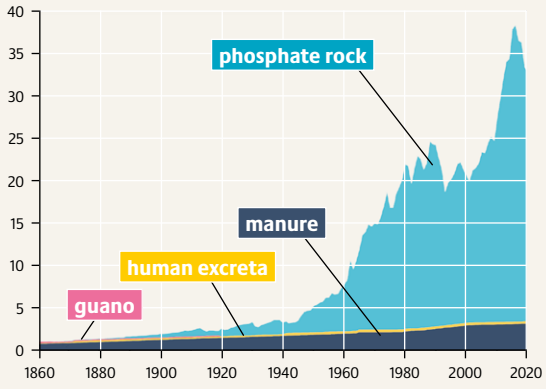
Despite having just one percent of global phosphate reserves, the United States dominated the industry in the 20th century. It was the largest, most technically advanced producer and controlled fertiliser production and trade. Then, following a series of mergers and acquisitions, the North American phosphate 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

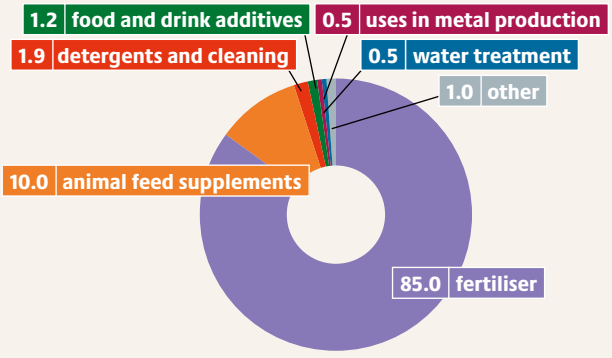
Along with nitrogen and potassium, phosphorus is one of the most important elements for plant life. About 85 percent is used for fertiliser

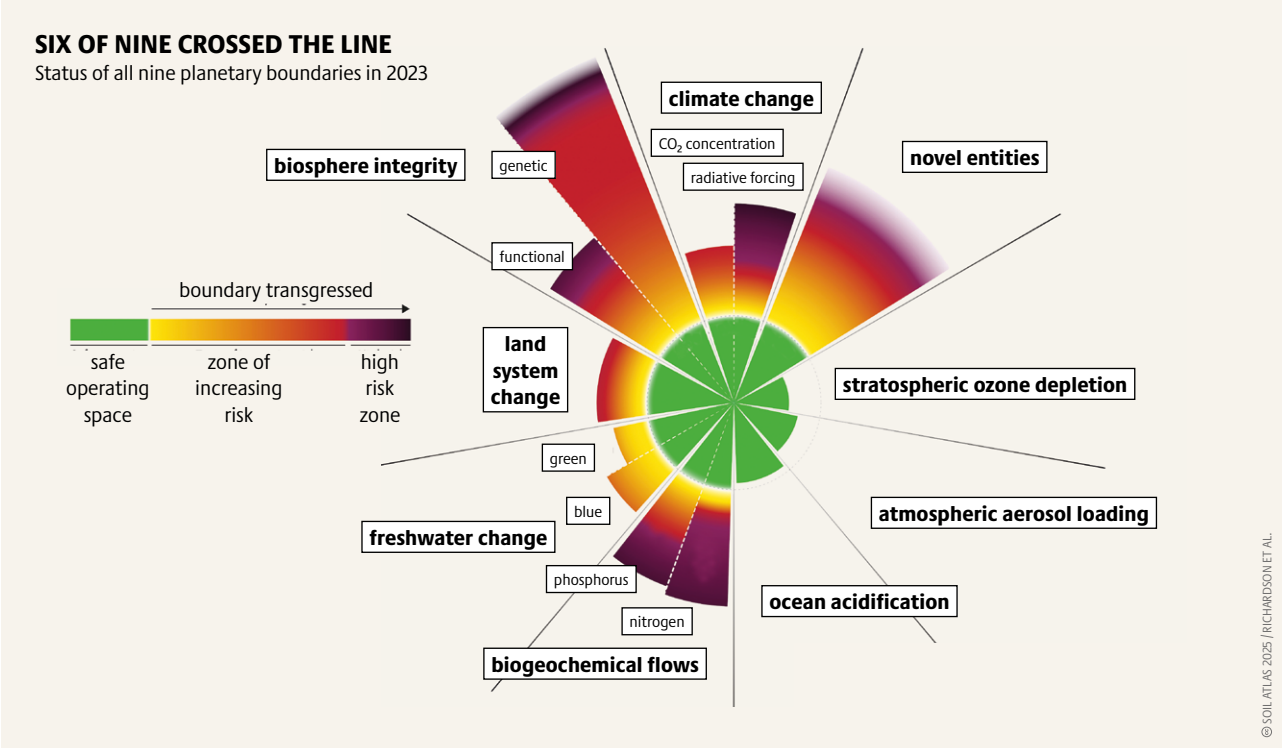
AN ESSENTIAL

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.

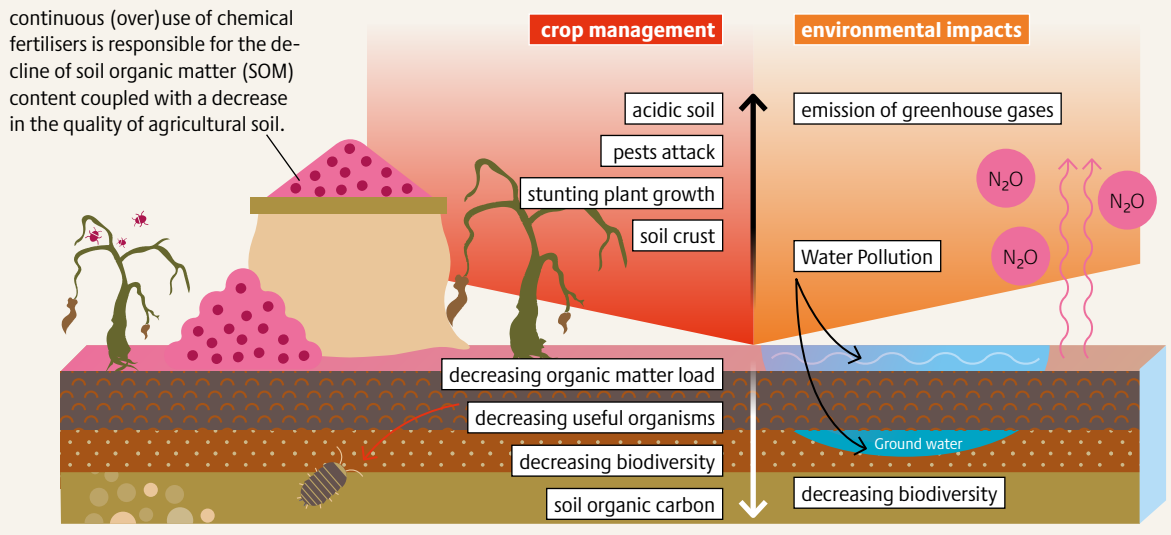
While sectors such as energy or transport have begun to decarbonise, chemicals used in the agrifood sector – above all food-related plastics and nitrogen fertilisers – remain key drivers of demand for fossil fuels. Both the agrifood and energy sectors are dominated by a small number of large multinational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

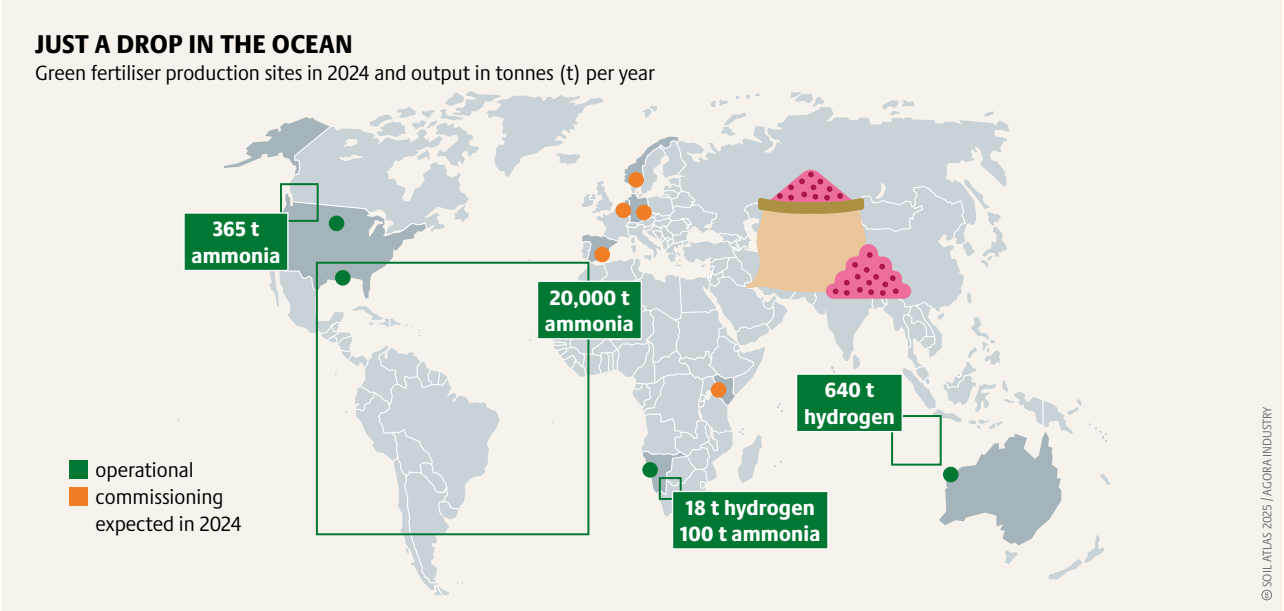
The production and use of fossil-based nitrogen fertiliser creates several problems. First, greenhouse gas emissions and other environmental impacts arise throughout the life cycle of nitrogen fertilisers, starting with gas or coal extraction, continuing through the production of ammonia, all the way 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,

Synthetic nitrogen fertiliser, including "green" nitrogen fertiliser, contribute to soil degradation, water pollution, biodiversity loss and climate change.

SYNTHETIC NITROGEN FERTILSER USE
Environmental impacts and impacts on crop management





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

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 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.

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.

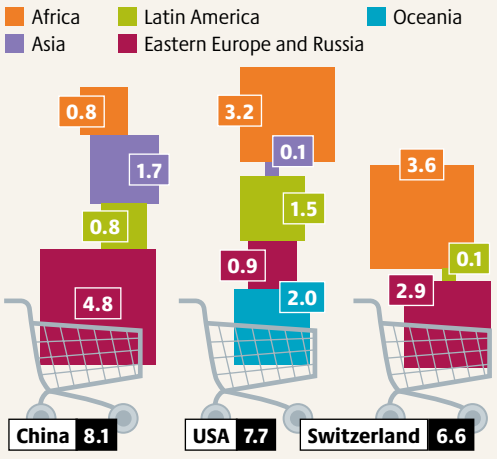
Since the turn of the millennium, the world has been gripped by various interconnected crises. Starting in 2007, the financial crisis shook the world; the price of oil almost tripled between 2007 and 2008, while soaring food prices led to food riots in at least 40 countries. The search for new, safer 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.

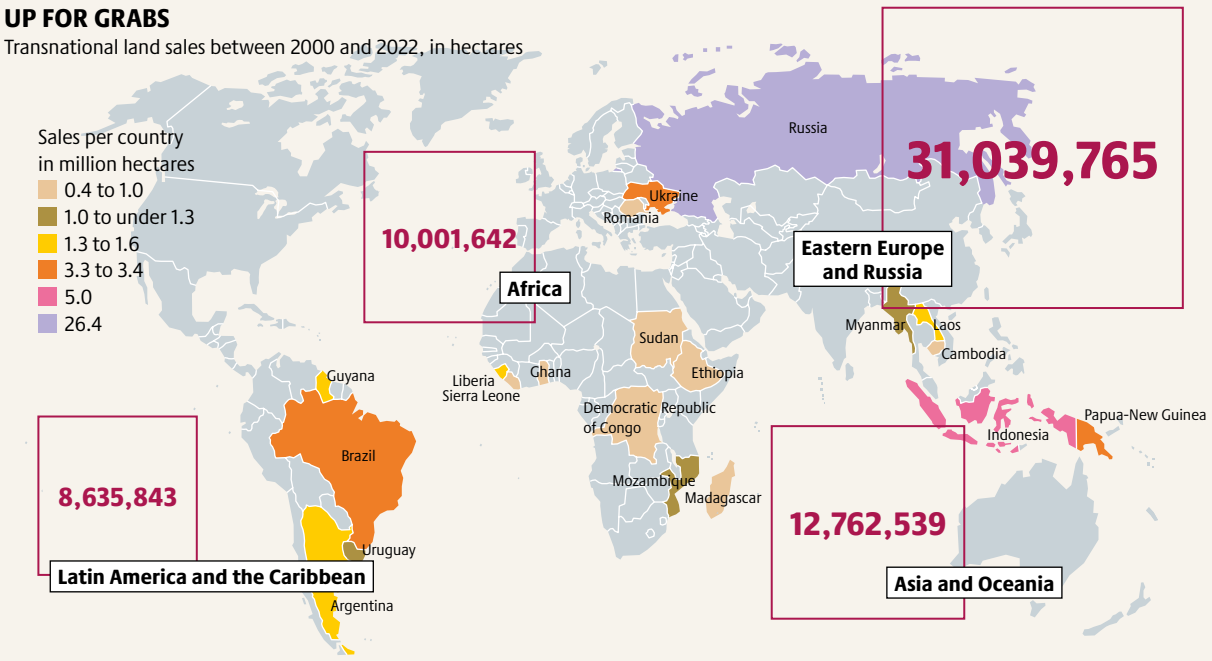
Many governments and investors justify land grabbing as a way to fight poverty and develop rural areas. However, it often achieves the very opposite: very few people find work on the newly established mega-plantations. For instance, mechanised sugarcane production in São Paulo, Brazil, requires only 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



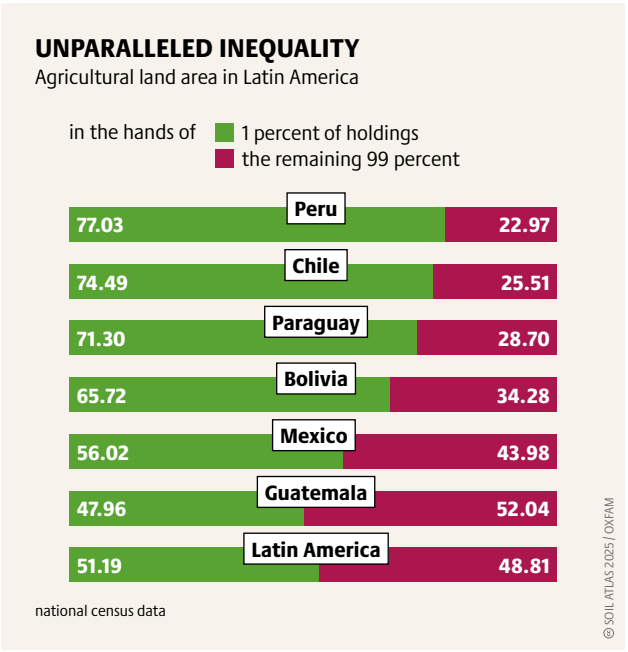
How countries of the Global North are complicit in these land grabs can be illustrated by the case of Germany. For example, the Berlin investor Amatheon has acquired over 40,000 hectares of land in Zambia. In 2009, Deutsche Bank invested at least 279 million euros through its subsidiary DWS in firms 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



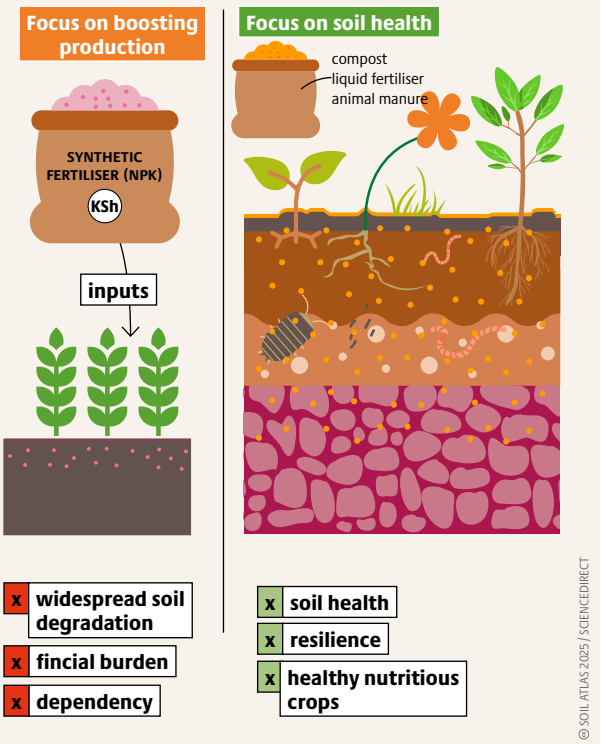
BEYOND FERTILISERS

Kenya's worsening soil degradation poses a serious threat to its agricultural future. Redefining soil health through policies that support site-specific solutions is essential for meaningful change in soil management.

In May 2024, the African Soil Health and Fertiliser Summit (ASHF) took place in Nairobi, underscoring the importance of soil health in addressing food security challenges on the continent. For the first time, stakeholders shifted their focus beyond increasing fertiliser use, recognising that tackling hunger and malnutrition requires a deeper and comprehensive approach. Historically, organisations such as the Alliance for a Green Revolution in Africa (AGRA) and the Gates Foundation have promoted a strategy centered on boosting agricultural inputs to solve these problems.

PRODUCTION VS SUSTAINABILITY

Comparison of plant-focused fertilisation versus soil-centered nutrient enrichment.



This approach has, however, led to widespread soil degradation, created financial strain on governments through fertiliser subsidies, and plunged many farmers into debt.

One of the resulting guidance documents of the summit, the African Fertiliser and Soil Health Action Plan (2023-2033), aims to increase agricultural production without expanding the area under cultivation, an objective that requires addressing issues like biodiversity loss and environmental degradation. Kenya, which is grappling with unpredictable rainfall, persistent droughts, and degraded soils, is bearing the brunt of these challenges. While the ASHF summit acknowledged the urgency of halting soil degradation, its Soil Health Action Plan offers little concrete guidance for countries to develop long-term sustainable strategies. Instead, the plan seems to favour powerful industrial players like AGRA and the fertiliser giant YARA, sidelining organic solutions that could be more beneficial in the long run.

The ASHF summit's goal of tripling the production and the use of both synthetic and organic fertilisers by 2034, raises concerns about its true commitment to soil health. Increasing fertiliser use on such a scale seems to contradict the efforts to improve soil health. This raises doubts whether initiatives like the Nairobi Declaration, the 10-Year Action Plan, and the Soil Initiative for Africa can address land degradation and promote sustainable food production.

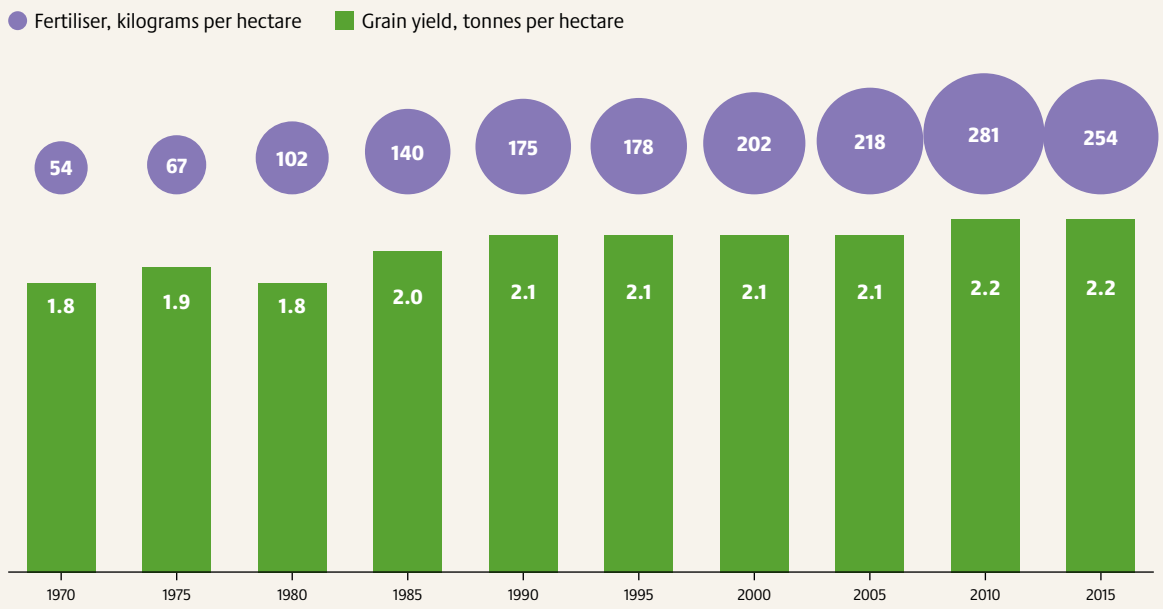
In 2023, an estimated 298 million Africans experienced undernourishment, a crisis worsened by the COVID-19 pandemic, conflicts, and the ever-growing threat of climate change. Approximately 75 percent of Africa's land is already degraded, and agricultural GDP is shrinking at a rate of 3 percent annually. The need for sustainable, long-term solutions is urgent.

There is ample evidence suggesting that increasing fertiliser use does not automatically result in better agricultural yields. For instance, despite applying 57 kilogrammes of fertiliser per hectare, Kenya produces less grain than Uganda, which uses only two kilogrammes per hectare. This stark contrast highlights the limitations of relying solely on fertilisers to achieve food security. Furthermore, studies of AGRA projects in Burkina Faso and Ghana reveal that the focus on chem-

Synthetic fertilisers provide short-term plant nutrition, while organic fertilisers nourish the soil, enhancing plant resilience

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

ical inputs and high-yield seeds has not significantly improved production or increased farmers' incomes. Instead, many farmers find themselves trapped in a cycle of debt and poverty due to the rising costs of fertilisers and pesticides. Even Zambia, one of Africa's highest fertiliser-consuming nations, continues to rank poorly on the Global Hunger Index.

One of Kenya's priorities has been to reduce reliance on imported fertilisers. The 2023 Kenya Green Hydrogen Strategy and Roadmap aims to replace up to 50 percent of nitrogen fertiliser imports with locally produced green hydrogen-based alternatives by 2032. While this strategy appears to support a cleaner energy transition and reduce import dependency, it raises several red flags. Notably, the plan does not address the role of organic fertilisers, overlooking an essential component of sustainable agriculture. The involvement of international partners, including Germany, introduces additional complexities. Germany's interest in developing green hydrogen markets as part of its energy transition strategy, partly influenced by geopolitical shifts, raises questions about the long-term viability of green hydrogen-based fertilisers. Will these solutions genuinely contribute to Africa's food security, or will they simply reinforce harmful agricultural practices under a new label?

Encouragingly, several initiatives in Kenya and East Africa are exploring sustainable pathways to improve soil health. Murang'a County's Agroecology Policy and Strategy focuses on promoting organic fertilisers, crop diversification, and soil conservation practices. It represents a model for other counties in Kenya to follow. Conversely, Kenya's National Agroecology for Food System Transformation Strategy (NAS - FST) emphasises the use of organic fertilisers, crop rotation, and integrated pest management to restore soil fertility. Neighbouring Ethiopia has demonstrated the success of community-driven land restoration through its Sustainable Land Management Program (SLMP) which integrates agroforestry and terracing to combat soil erosion and improve fertility. Kenya and other East African countries could adopt similar practices in their degraded regions. Uganda's vermicomposting projects, which leverage organic waste to produce high-quality fertilisers, provide cost-effective and environmentally friendly solutions. Replicating such efforts in the region could improve soil health and reduce dependency on chemical fertilisers.

The path forward for Kenya, and indeed for Africa, lies in a genuine commitment to transformative agricultural policies that prioritise soil health. While the ASHF summit may have marked an important step in the right direction, it is crucial to remain vigilant and ensure that the policies discussed translate into tangible actions. Real improvements in soil health, tailored to local conditions and needs, are key to ensuring long-term food security and restoring the dignity and independence of Africa's farmers.

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.

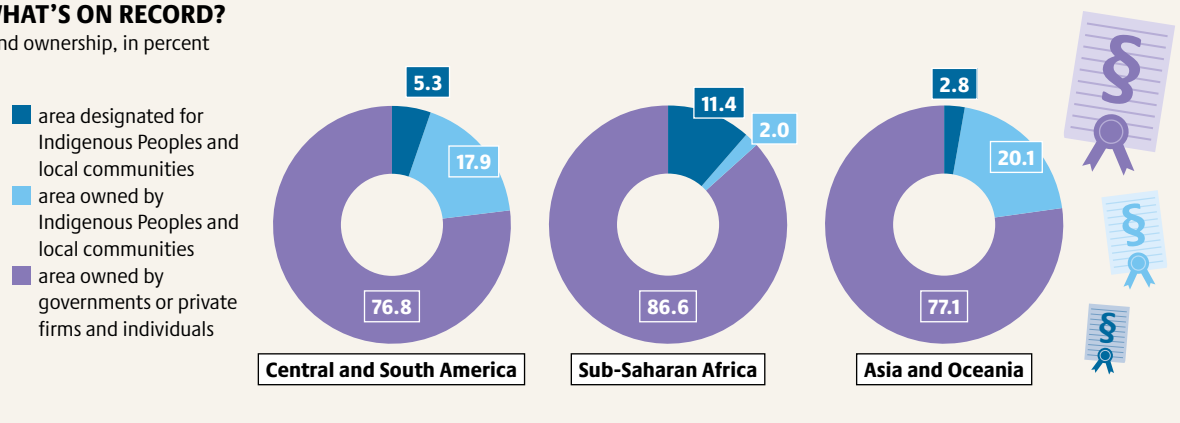
At the heart of the Paris Climate Agreement rests the goal of limiting the average global warming to 2 degrees Celsius compared to the pre-industrial era. Such efforts aimed at realizing a climate-neutral economy are founded on two principles. First, greenhouse gas emissions, such as carbon dioxide (CO_2), 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-

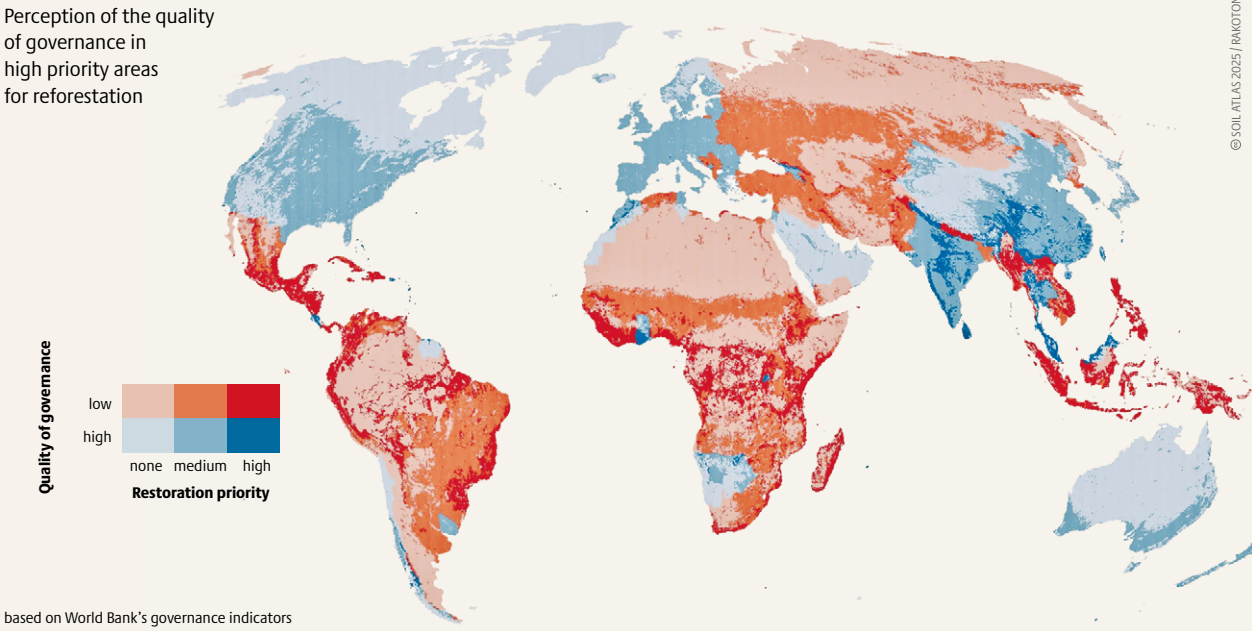
Legitimate but not legally recognised: Indigenous lands are often disputed, also in the name of climate action

WHAT'S ON RECORD?
Land ownership, in percent



PROTECTING BIODIVERSITY UNDER DIFFICULT CIRCUMSTANCES

Perception of the quality of governance in high priority areas for reforestation



based on World Bank's governance indicators

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.

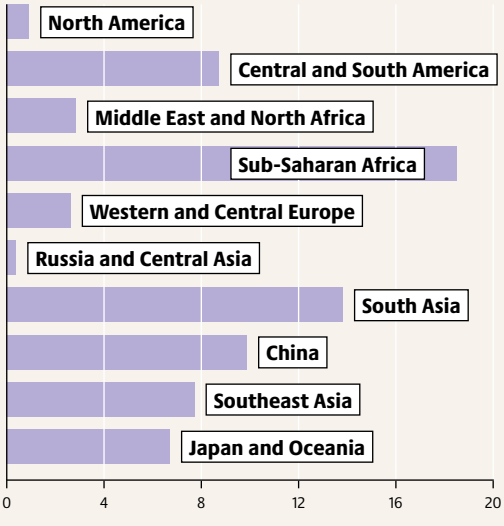
Colombia and the Democratic Republic of the Congo are heralded as countries with the greatest potential for nature-based climate action. However, state institutions in rural areas of both countries are often not sufficiently equipped to manage the land demand arising from climate projects. In addition, 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

UNEQUAL DISTRIBUTION

Share of global area committed to ecosystem restoration, by region, in percent



SOIL CARBON CREDITS

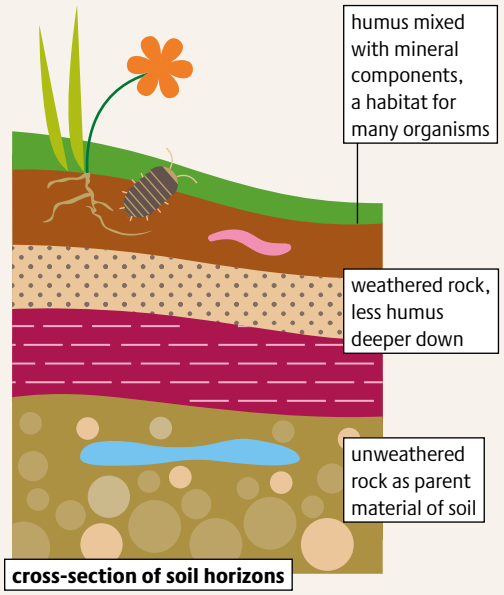
BLESSING OR CURSE?

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



cross-section of soil horizons

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.

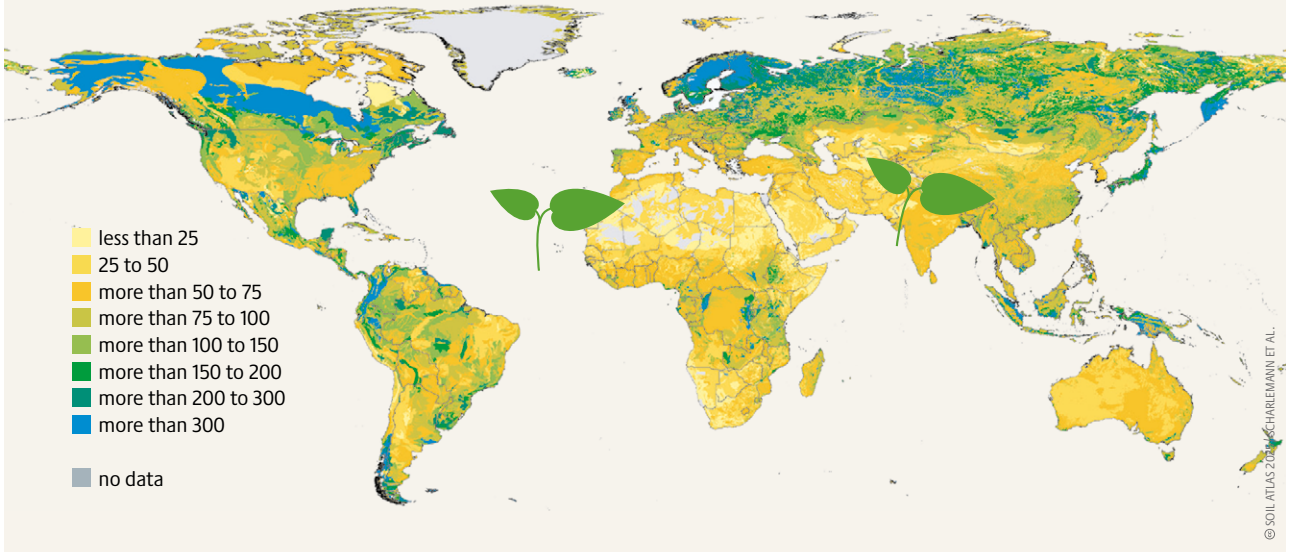
Carbon farming is expected to be financed through the sale of so-called soil carbon credits, which would compensate for the emission of greenhouse gases like CO_2. The European Union (EU) is currently attempting to outline a legal framework for carbon offsetting, including through storing carbon in soils. 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

A GLOBAL INVENTORY

Soil organic carbon density in tonnes of carbon per hectare



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.

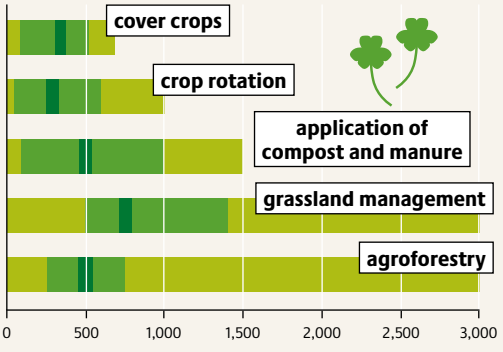
In countries like Australia and Scotland, trading soil carbon credits has driven up land prices, making it harder for young farmers and smallholders to access land. Years of experience with forest carbon credits have also demonstrated that the potential for financial gain from selling carbon credits 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.

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.

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

STORAGE CAPACITY

Influence of agricultural measures on the enrichment of organic carbon, in kilograms per hectare and year



schematic presentation: realistic range (dark) and extreme range (light)

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.

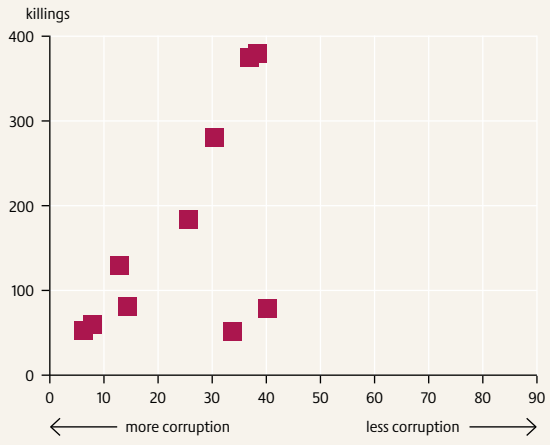
Many international human rights instruments recognise the right to land for certain population groups whose rights are particularly under threat. Among these are the United Nations Declaration on the Rights of Indigenous Peoples, the Convention on the Elimination of All Forms of Discrimination against 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.

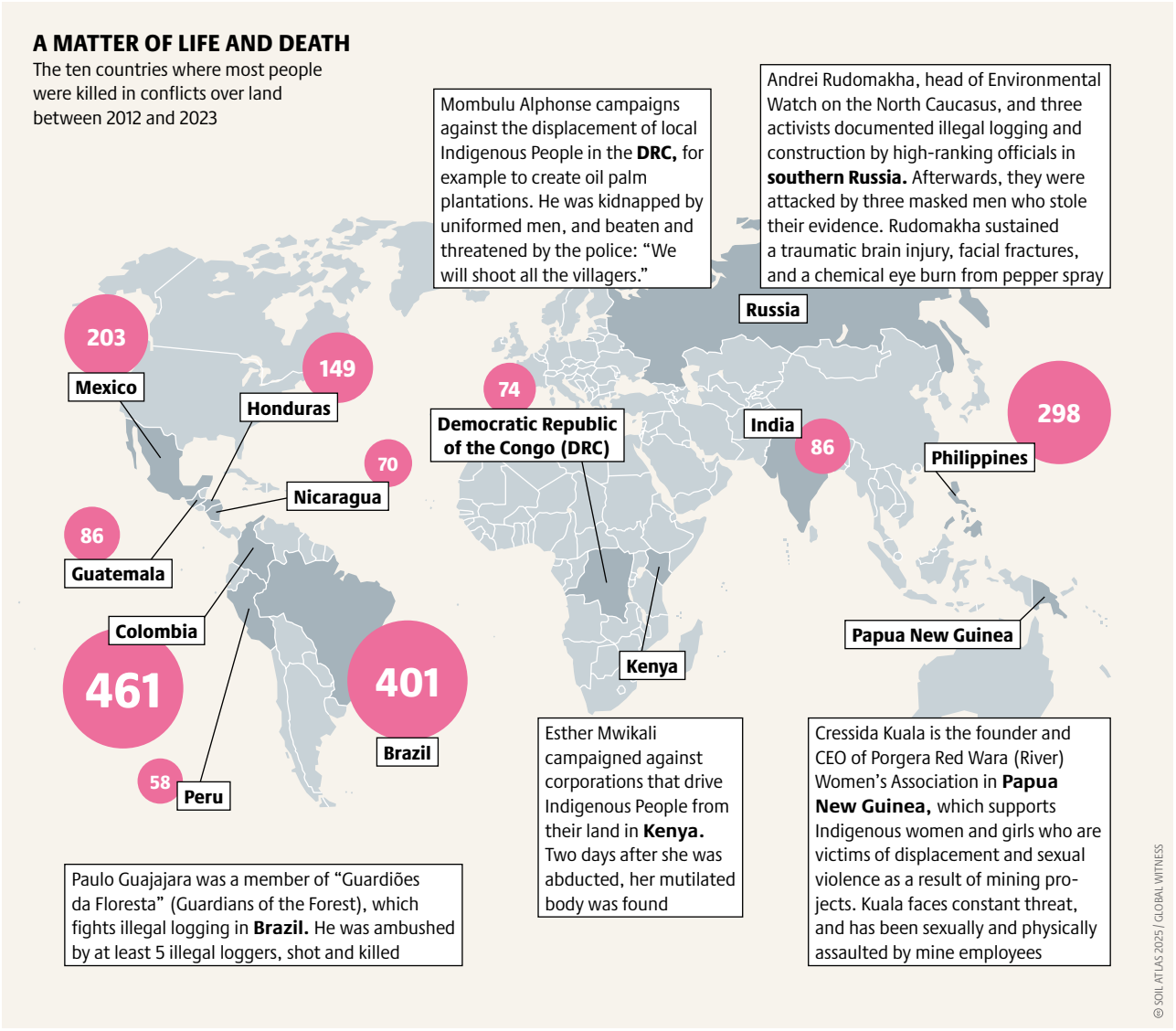
The duties of states to protect land rights do not end at national borders. For the European Union (EU), this means ensuring that EU-based firms or organizations investing in land in other countries adhere to these obligations. This responsibility applies regardless of whether these investments concern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

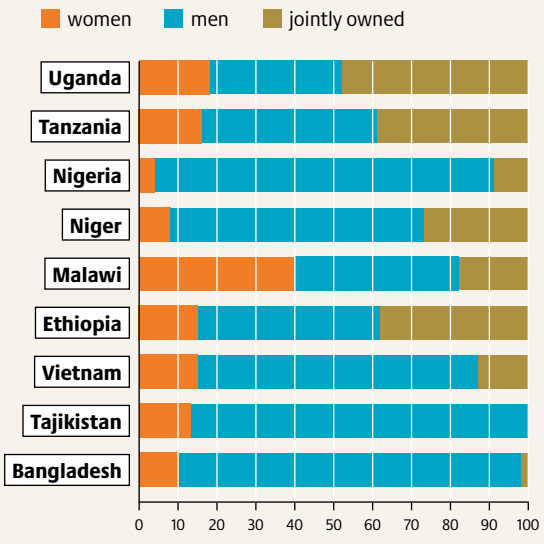
Research in Burkina Faso revealed a paradox: the efforts of women farmers to improve the soil health and productivity may actually increase the risk of losing their tenure. This phenomenon, known as forced rotation, sees landowners – often husbands – reclaiming the most productive land from women to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

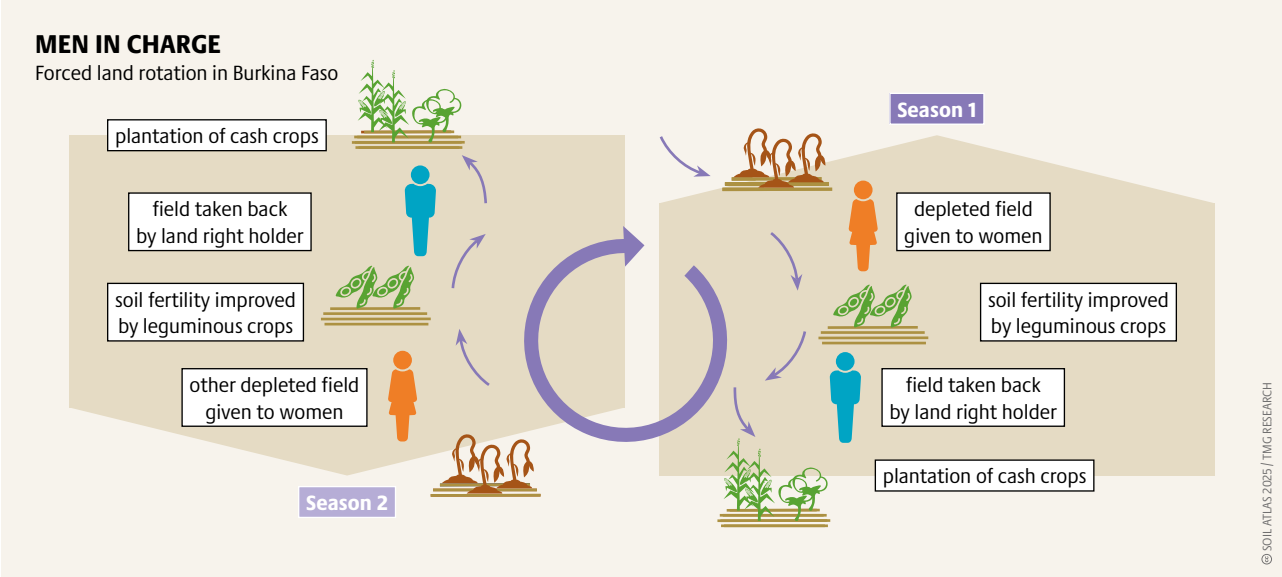
IT'S A MAN'S WORLD

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

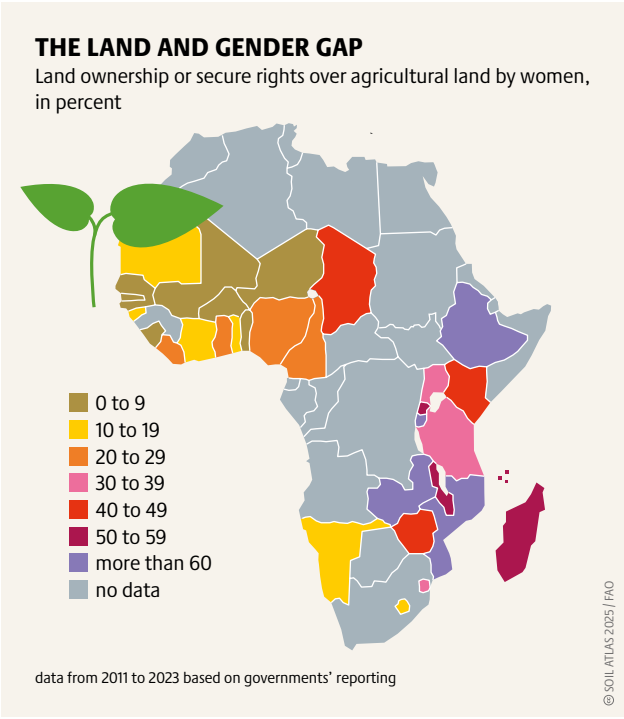
ance models, it helps families and villages reach consensus on tenure arrangements. The aim is to make such arrangements more equitable and secure for women. Following a multi-phase negotiation process involving a range of stakeholders, including traditional village chiefs, the male heads of households 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



SOIL HEALTH AND NUTRITION CRISIS

Soil to plate: Kenya's mandatory fortification policy aims to tackle hidden hunger, but true nutritional security lies in restoring soil health and embracing diverse diets for lasting solutions.

When you pick up maize or wheat flour, breakfast cereal, or edible oil, you may notice claims of added vitamins or nutrients. This fortification process has been essential in combating nutrient deficiencies and improving public health. In Kenya, this initiative aligns with the National Food and Nutrition Security Policy (2011), whose aim is to address widespread micronutrient deficiencies stemming from food insecurity, limited diet diversity, and nutrient-scarce soils. However, food nutrient scarcity is directly linked to the state of nutrient deficiency in soils through both mineral uptake and phytochemical production, which in turn influences mineral and vitamin density in food.

Plants need 18 essential nutrients to grow, 15 of which come from the soil. These nutrients include macronutrients such as potassium, nitrogen, and phosphorus, secondary elements such as calcium and magnesium, and micronutrients such as zinc, iron, and molybdenum. During the growing season, crops strip the soils of these nutrients and soil health directly influences the availability of these nutrients to crops. Inadequate nutrients in the soil directly affect food nutrition content; for example, crops grown in nitrogen-poor soils will have lower protein content. Additionally, studies have also demonstrated a geographical overlap between zinc, selenium, and iodine deficiencies in cultivated soils and the respective deficiencies of the populations in those regions.

Research shows a significant decline in the nutrient levels of crops over the past decades. Studies comparing crops found reductions of between 6 and 38 percent in calcium, phosphorus, iron, riboflavin, and Vitamin C. Protein content in maize dropped by 20 percent between 1921 and 2001 and magnesium levels fell by 25 percent. Declines in zinc, copper, and nickel have been documented in vegetables since the 1970s. These trends highlight the urgent need to address soil health to preserve nutrient density in food.

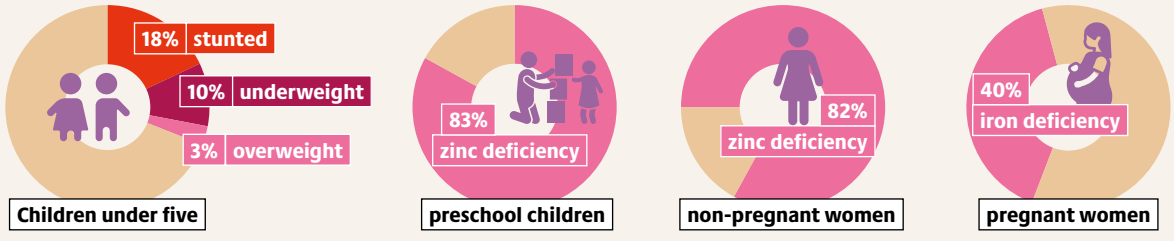
Nutrient deficiencies, or 'hidden hunger,' affect billions worldwide, with severe health consequences. Micronutrients are often neglected in this context. Zinc deficiency impairs immune function and growth, Vitamin A deficiency causes preventable childhood blindness and increases infection risks, and iron deficiency leads to anaemia, affecting cognitive function and maternal health. Nutrient demands are high during early development, pregnancy, and lactation, making deficiencies in these periods critical.

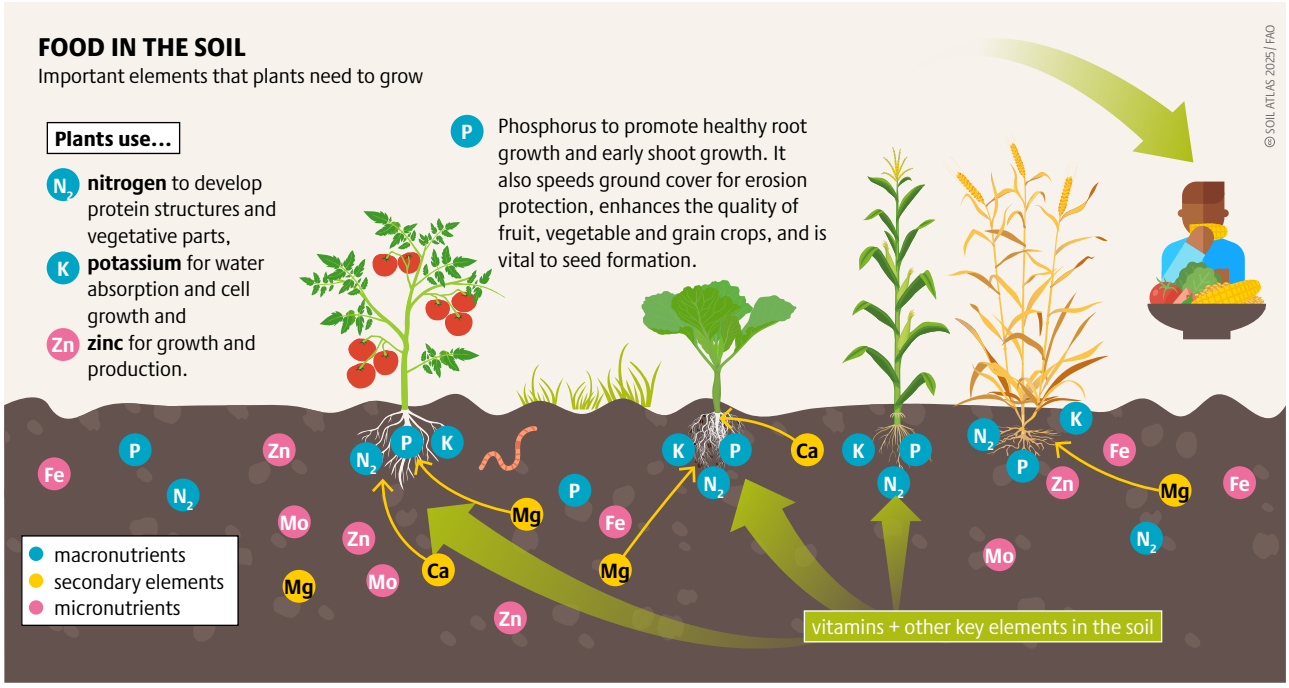
The immediate stop-gap measures by the Kenyan government's approach to addressing nutritional se-

Kenya faces a double burden of malnutrition, disproportionately affecting vulnerable groups, especially women and children

NUTRITION IN KENYA

Health survey findings on various demographic groups





Over-supplementation risks arise when cumulative nutrient intake from all sources is not monitored– these include the flours and oils being fortified and other home fortification strategies

curity have been four fold: mandatory large-scale food fortification; biofortification of crops at the production level (iron-rich Nyota beans and Vitamin A/beta-carotene-rich orange-fleshed sweet potatoes); supplementation for at-risk groups (iron and folic acid supplements for pregnant women and Vitamin A supplements for infants), and home fortification using nutrient powders or sprinkles for at-risk children. Since 2012, Kenya implemented mandatory large-scale fortification (MLSF), to enrich wheat and maize flours with zinc, iron, and vitamins (A, B1, B2, B3, B6, B12, and folic acid), and edible oils with Vitamin A.

While fortification is a cost-effective way to reach large populations without the need for major dietary changes, it still raises concerns. Over-supplementation risks arise when total nutrient intake from all sources is not monitored because, for most nutrients, fortified food is not the only source of the nutrient. For example, local home fortification methods like mixing grains of maize, groundnuts, sorghum, and millet with legumes in porridge or ugali are popular in many Kenyan households. Moreover, MLSF often fails to reach rural populations reliant on small-scale millers who do not have to comply with fortification regulations.

Lastly, fortification relies on industrial processes, increasing costs and environmental impacts, and fails to address systemic agricultural issues or the root cause of nutrient loss. We risk fortifying food for every nutrient or mineral while missing the point of the food matrix. Food, not nutrients, is the foundation of nutrition.

Sustainable solutions require addressing nutrient deficiencies in the soil, where food production starts. Improving soil health involves sustainable agroecological practices such as companion planting, crop rotation, conservation tillage, and incorporating organic matter. Organic input, including organic matter, not only enriches the soil with nutrients but improves water retention and transmission, improves soil aeration, and fosters microbial diversity, which is critical for nutrient cycling. Healthy soils lead to nutrient-dense crops, which produce equally nutrient-dense food, reducing the need for external fortification.

Agroecological practices also promote crop and livestock diversity on the farm, which ensures a steady supply of different foods and promotes a balanced diet with a wide range of nutrients for communities. A link between crop diversity on the farm and the diet diversity of local communities is well established among subsistence-oriented households and small-scale farmers.

Dietary diversification boosts micronutrient intake by encouraging varied plant- and animal-based foods and should not be neglected. Unlike fortification, it provides a broad spectrum of nutrients and supports human health. Indigenous foods, like African leafy vegetables, are rich in protein, vitamins, and minerals. Farm diversity and agroecological practices support dietary diversity and nutrition sustainably.

Fortification and supplementation do not address the root causes of nutrient deficiencies and hidden hunger. Agricultural policies must consider their impact on nutrition, while health policies must recognise the agrarian origins of many nutrition challenges.

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.

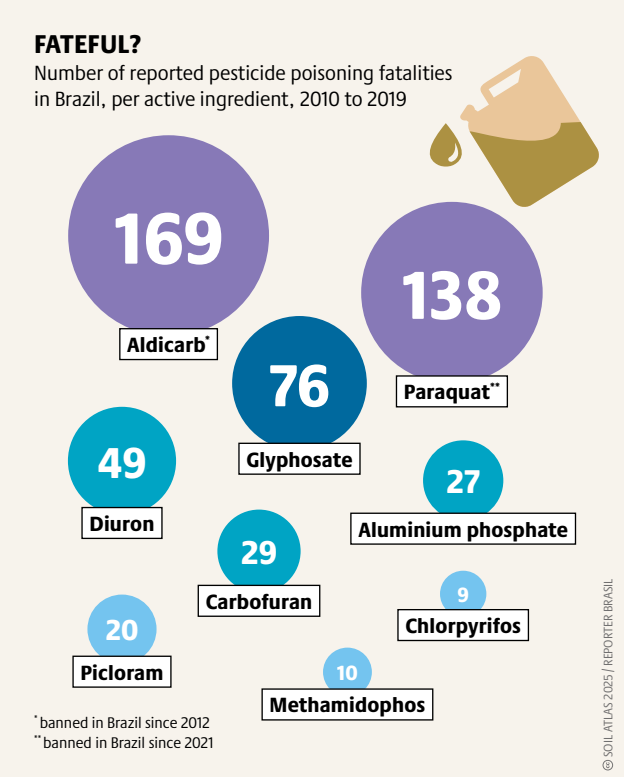
Industrial agriculture relies on extensive monocultures, immense chemical inputs, and heavy machinery. This model originated in the Global North. Beginning in the 1960s, it was exported to Asia, Latin America, and later Africa. This much vaunted Green Revolution has taken a heavy toll on soils: excessive 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.

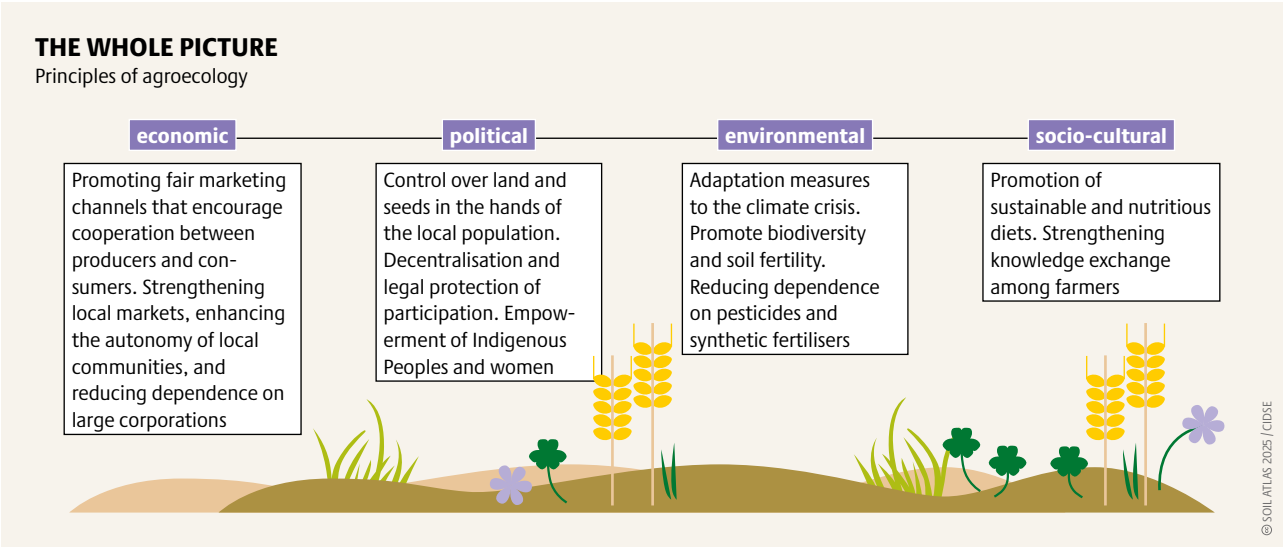
Agroecology is a bundle: it is a multidisciplinary science, a social movement, and a set of agricultural practices focused on the interaction of plants, animals, and humans. Its aims are to preserve natural resources and sustain agrifood systems. Healthy soils are the foundation of this approach since 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



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.

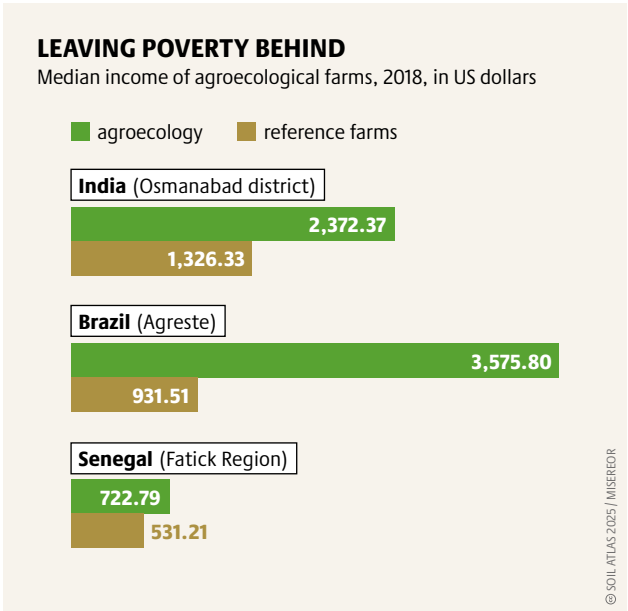
Agroecology initiatives in Brazil used to be fragmented, but since the turn of the century they have influenced policy to upscale production so that more people have access to food produced through agroecological methods. Two such policies are the federal Food Acquisition Programme (PAA) and the National 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



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 .

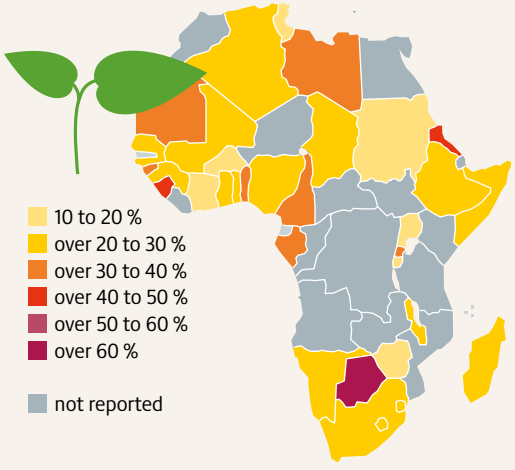
Conventional metrics for economic performance – such as GDP and earnings – fail to take account of the long-term consequences and hidden costs of land degradation. This is a fundamental flaw of the current economic system, where corporations are able to privatise profits but leave societies and future 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.

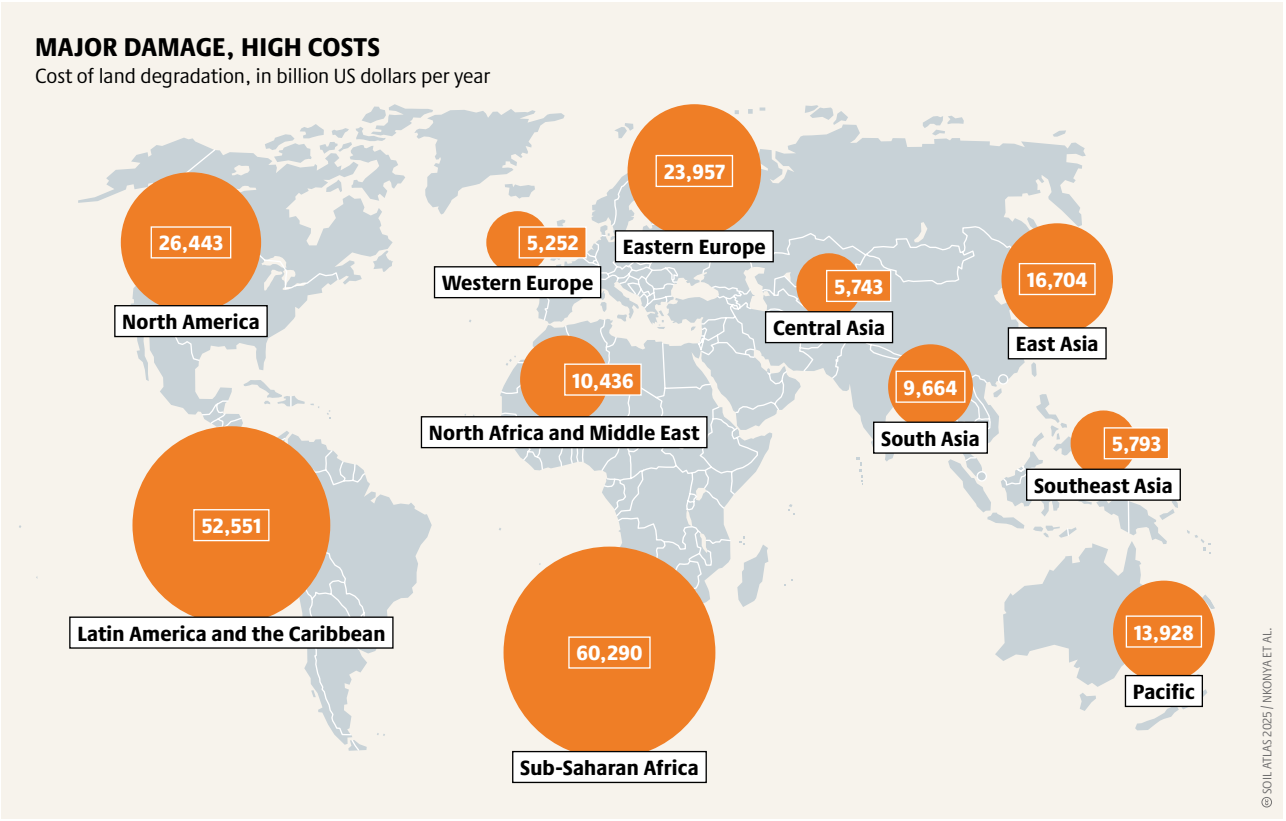
TCA reveals the benefits of investing in sustainable practices, thereby encouraging investments in sustainable transitions. Calculations that value ecosystem services and ecological restoration show that restoration projects not only slow down biodiversity loss and absorb carbon dioxide but are also 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



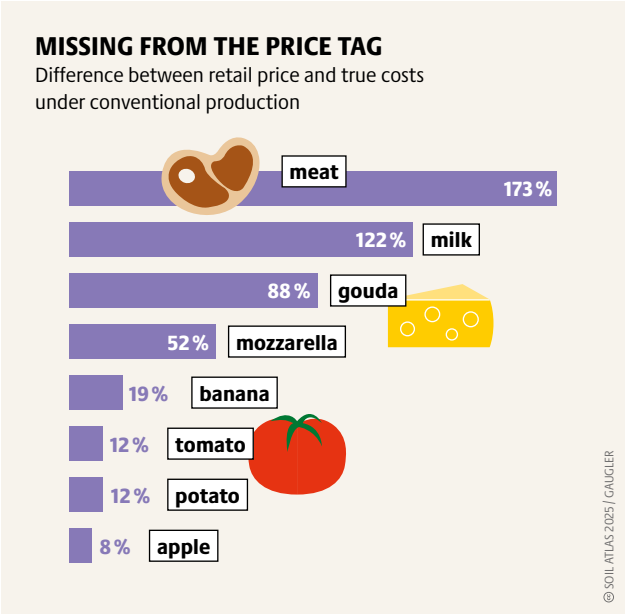
By quantifying the environmental, health, social, and economic impacts of land degradation in monetary terms, TCA also makes it easier to incorporate sustainability information into financial reporting, such as balance sheets and management reports. This allows sustainability-related values to be viewed 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

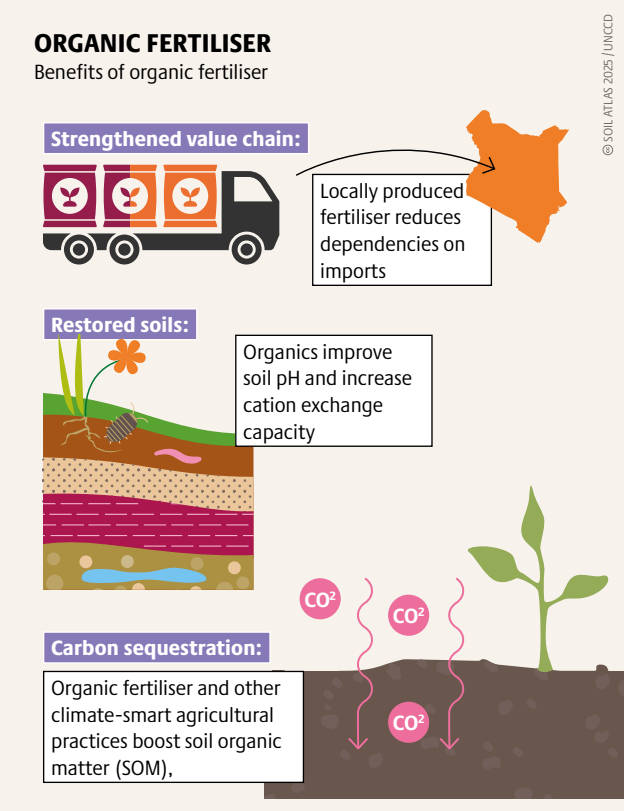
TCA can be used today to identify the hidden costs and benefits of land degradation and sustainable land management practices. As the first pilot projects have shown, these calculations can inform policy and business considerations, thereby helping to solve the problem of land degradation.



SOIL HEALTH REVOLUTIONS

The future of agriculture is at stake as soil health continues to degrade. Practices like monoculture, plowing, and overuse of chemical inputs have depleted soil nutrients and structure, prompting farmers to explore alternative soil management strategies. While upscaling these solutions shows promise, policy, and financial support remain insufficient.

If agriculture is a body, soil is its soul. Soil health is the cornerstone of sustainable agriculture, influencing food security, water regulation, and ecosystem resilience. In East Africa, soil degradation is driven by unsustainable farming practices, deforestation, and over-reliance on chemical inputs. This has resulted in severe soil erosion, nutrient depletion, and declining agricultural productivity. The Green Revolution initially boosted crop yields in the region through chemical fertilisers, but their overuse has led to nutrient imbalances, soil acidification, and reduced microbial activity. Studies in Kenya's Rift Valley show continuous nitrogen fertiliser application depletes soil fertility and increases nitrate leaching into water sources.



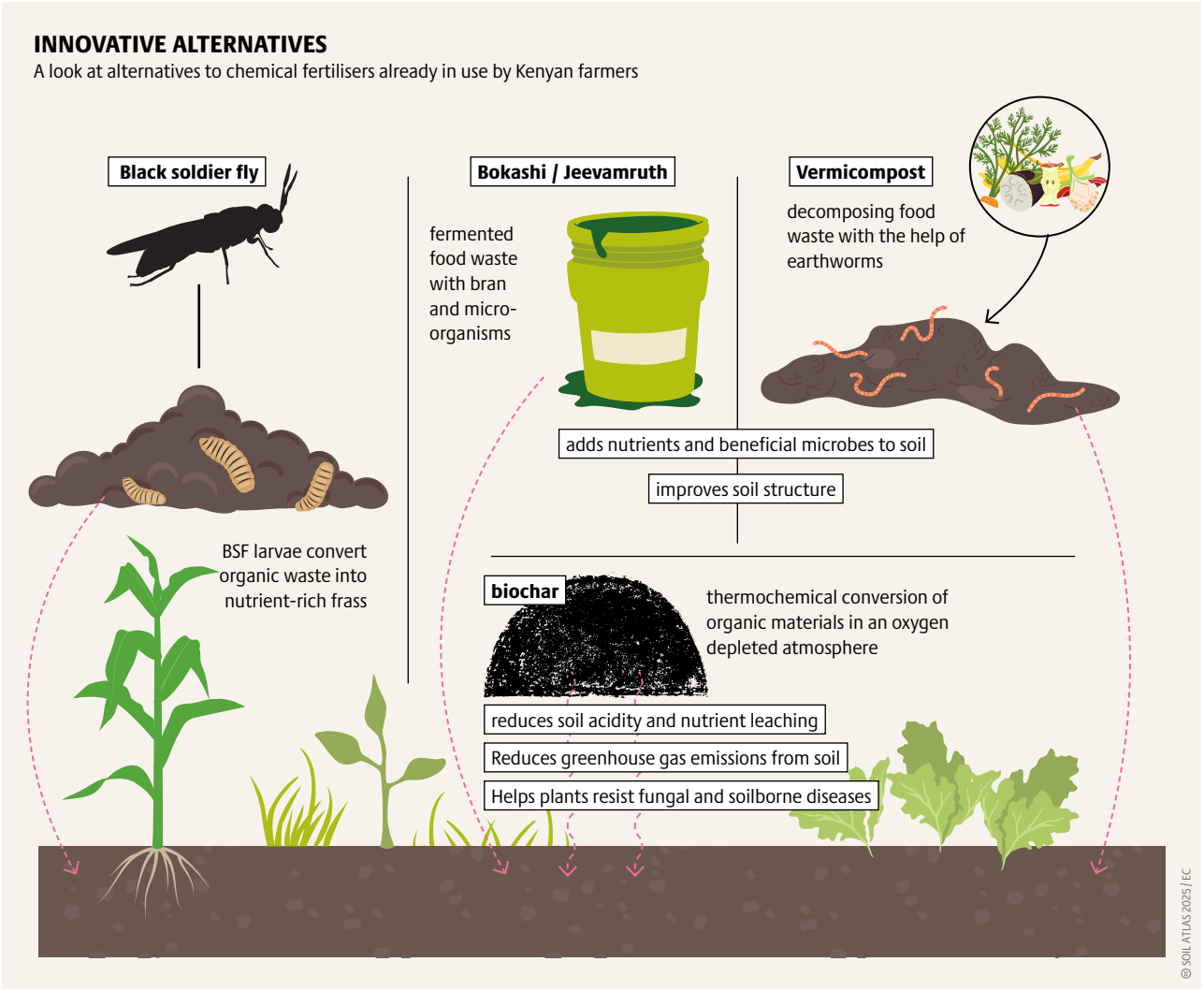
Organic fertiliser has many benefits beyond improving soil health

Healthy soils encompass nutrient availability, structure, organic matter, water retention, and microbial activity. Unlike chemical fertilisers that focus on single-nutrient supplementation, alternatives aim to enhance overall soil fertility and microbial diversity, ensuring long-term soil vitality with minimum cost. Smallholder farmers mostly use compost, green manure, and compost tea to enrich the soil. Compost, derived from decomposed organic waste, improves nutrient content, microbial activity, and water retention. Green manure, such as cover crops like clover and cowpeas, protects soil from sun exposure and boosts organic matter and nitrogen. In Kenya, green manure has been shown to increase maize yield by up to 25 percent. Compost tea, a liquid extract of compost, introduces beneficial microbes directly to the soil.

Biofertilisers play a crucial role in sustainable agriculture. Rhizobia converts atmospheric nitrogen into plant-usable forms, while mycorrhizal inoculants enhance nutrient and water uptake. These microbes also contribute to soil structure by producing glomalin, a glycoprotein that binds soil particles. In Tanzania, applying biofertilisers has led to 30 percent higher legume yields. Biochar, a stable, charcoal-like material produced by burning organic matter in low-oxygen conditions, reduces acidity, retains moisture and nutrients and supports beneficial soil microorganisms.

Farmers in East Africa are also increasingly using black soldier fly (BSF) compost and vermicompost as sustainable alternatives. BSF larvae convert organic waste into nutrient-rich frass, enhancing soil fertility and increasing maize yields. Vermicomposting uses earthworms to break down organic matter into nutrient-rich compost. The saying 'fertiliser feeds the plant, while vermicompost feeds the soil' highlights its holistic benefits.

Jeevamruth, a fermented cost-effective biofertiliser, provides nutrients and beneficial microbes to the soil. It improves soil structure, water retention, and nutrient availability. Though the use of jeevamrut in East Africa is still limited, it is gaining popularity due to its affordability and ease of production. A similar biofertil-



Farmers using already various alternatives for soil health management. Policies and investments need to support the availability of these fertilisers and science need to optimize their efficiency

iser, bokashi, has been used by smallholder farmers to restore degraded soils in Kenya's Tharaka Nithi County.

Rice husk ash, rich in silica and potassium, improves aeration and root penetration, while seaweed extracts, containing micronutrients and bioactive compounds, stimulate plant immunity. Rock dust, sourced from natural rock formations, enhances soil fertility by slowly releasing essential minerals like magnesium, calcium, and silicon. It also improves soil texture, aeration, and microbial activity, supporting nutrient cycling and organic matter decomposition.

A supportive policy environment is essential for the successful adoption of alternatives. The Kenyan Agricultural Soil Fertility Policy, introduced in 2023, marks a promising step forward. It explicitly recognises Kenya's soil degradation challenges and emphasises the use of biofertilisers as a core element of the mitigation strategy. The policy outlines the government's key responsibilities, including the development of a regulatory framework for biofertilisers, supporting capacity-building programs for their effective use in soil management, and strengthening institutional support to develop a robust value chain that ensures biofertilisers' availability.

Alternative effective soil inputs accessible to farmers at low costs should be integrated into resilient agricultural systems. Agroforestry and strategies like intercropping and crop rotation combine plants with different nutrient needs and enhance soil fertility and ecosystem balance. By embracing both innovative and traditional practices, farmers in East Africa can revitalize degraded soils, increase productivity, and support environmental conservation. Scaling these solutions requires strong policy support, improved resource availability, and strengthened value chains. With collective efforts, these approaches can transform agriculture, ensuring food security and sustainability for future generations. ●

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.

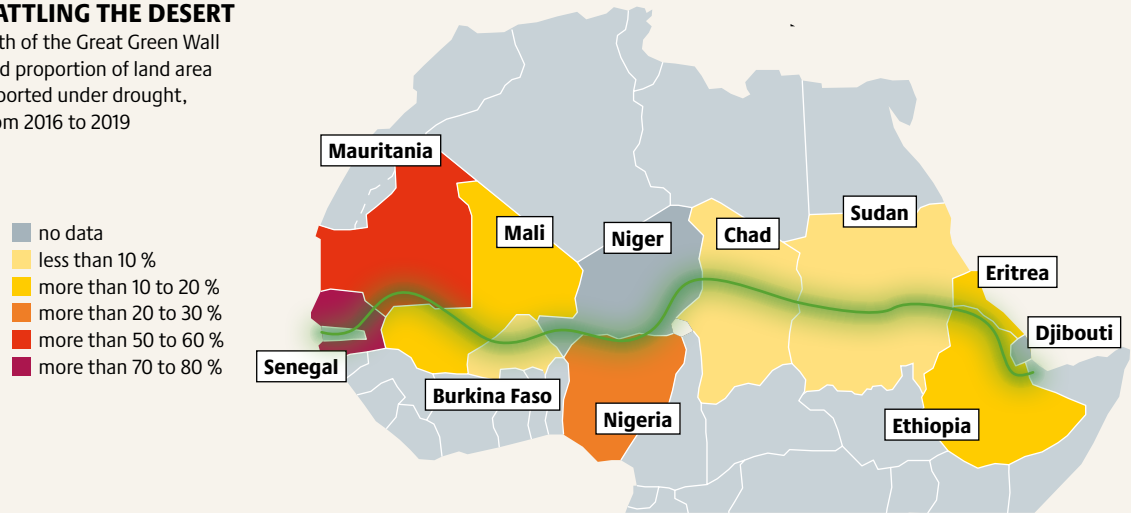
In the Sahel, desertification contributes to humanitarian crises, famine, and starvation. The number of people living on the brink of starvation in the region rose tenfold between 2019 and 2022, according to the World Food Programme. This dramatic rise can be attributed to a combination of factors, including 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.

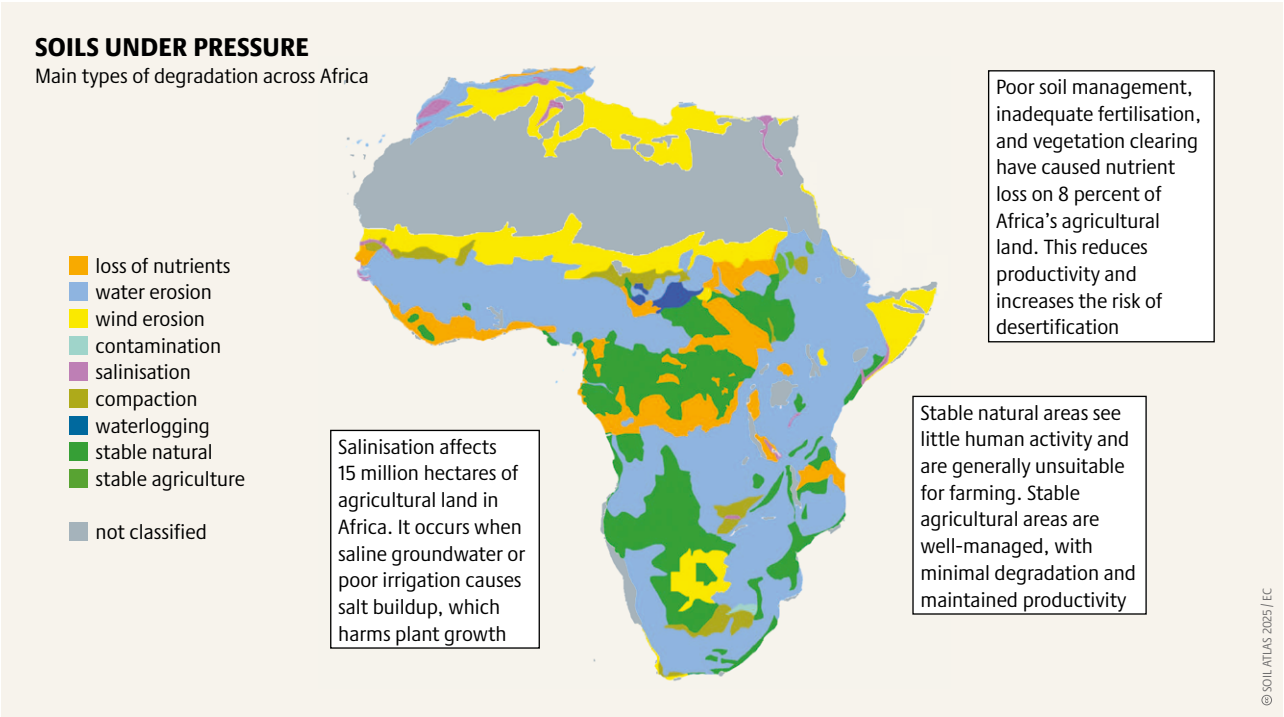
The Great Green Wall is one of many efforts to regreen the Sahara and Sahel. Led by African governments, this initiative seeks to stop the desert's advance by restoring the fertility of degraded agricultural and pastoral lands. It uses a range of approaches: tree planting, assisted natural regeneration (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.

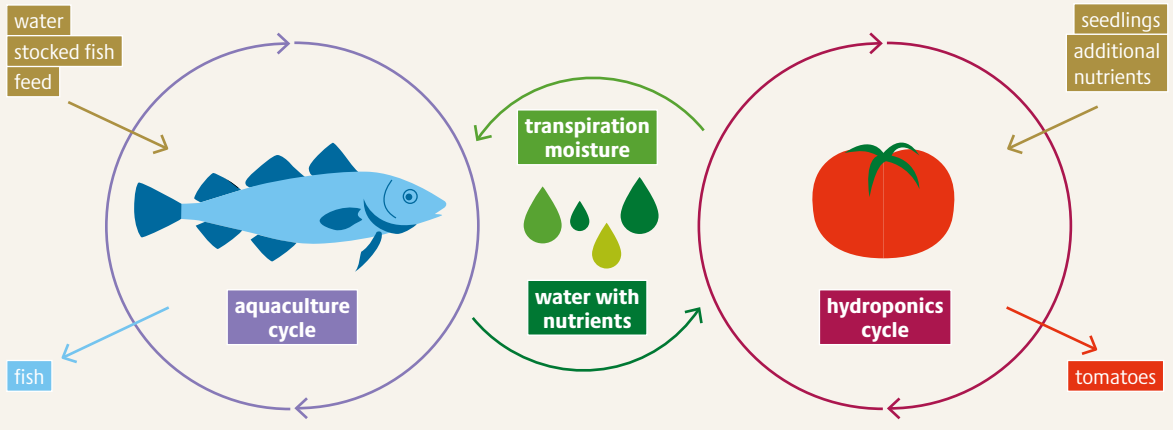
The closed systems ensure that no or few pollutants, such as fertiliser runoff or pesticide residues, escape from indoor farms into the soil or groundwater. Because the plants are exposed to fewer pathogens, pesticide use is also greatly reduced. Computers control LED lighting, water, temperature, and 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

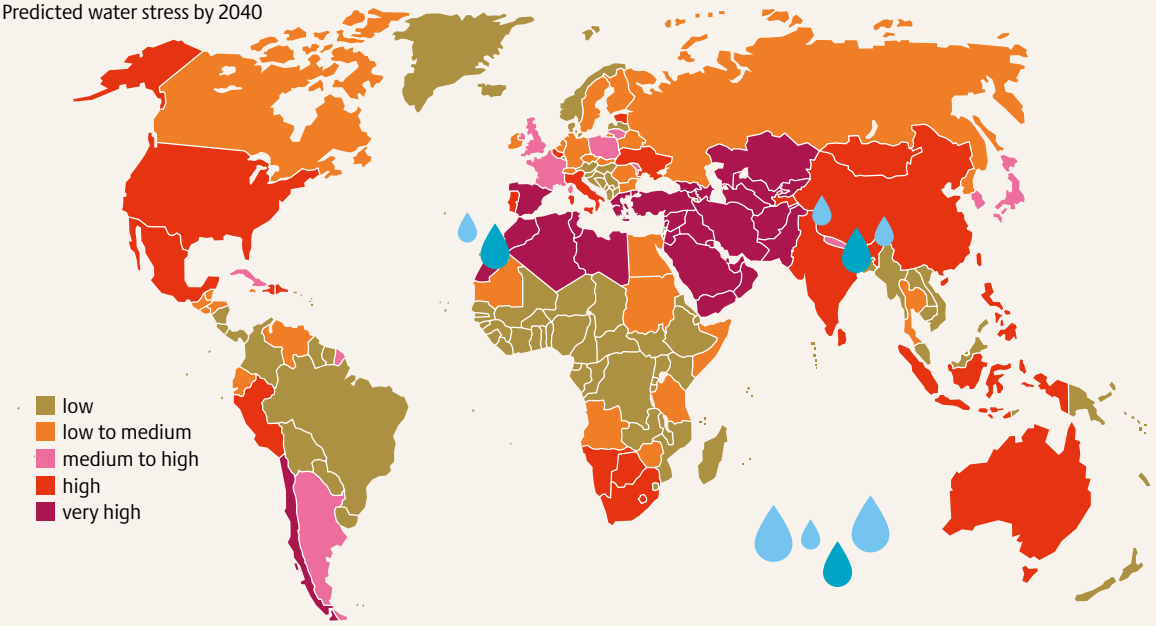
CLOSED CYCLES

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



A GLOOMY FORECAST

Predicted water stress by 2040



water stress occurs when there is an unfavourable balance between water consumption and available renewable water resources

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

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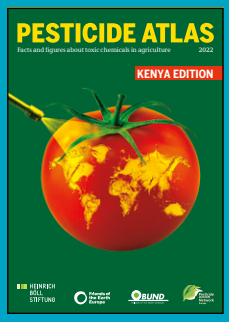

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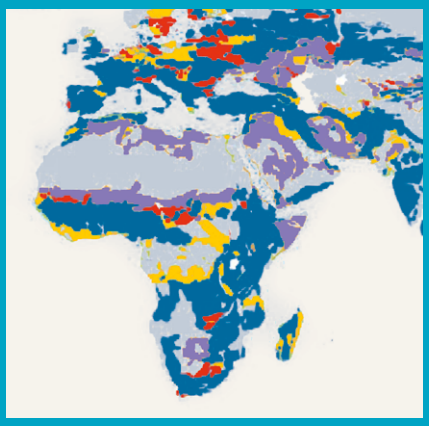

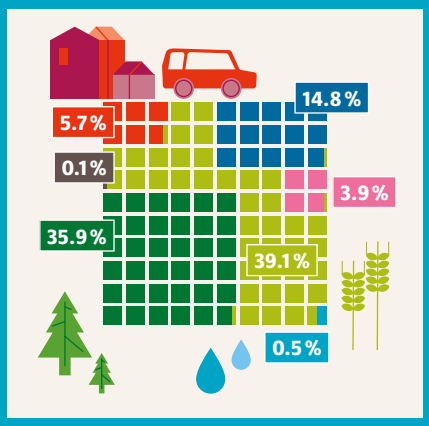

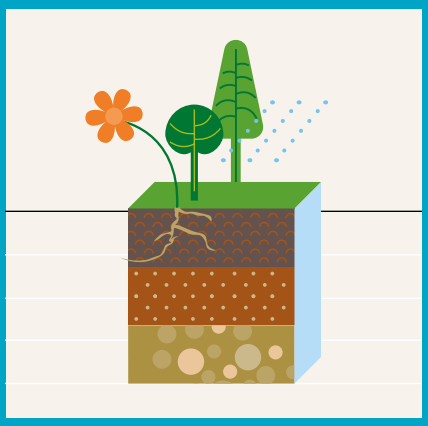

Soil is the most species-rich habitat on Earth.
Almost two-third of species are found in soils.
from: THE FOUNDATION OF LIFE, page 10

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.
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