

Soil Health: A Security Threat Profile

Report by the Food & Global Security Network
Compiled by Farmwel
Supported by FAI Farms



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INTRODUCTION

FOREWORD

This profile report is about food **and** security – about the impact that food scarcity has on peace and stability; on infrastructure and society.

It is about the ecological crises we face, and how a focus on the restoration and regeneration of one of the Earth's most essential organs – its soil – can achieve so much to reverse the decline in nature, to mitigate the impacts of extreme weather, and to underpin food and societal security for everyone.

This report profiles the critical importance of soil health through the writings of 22 experts – military minds, NGO leaders, scientists and practical farmers.

Together, we aim to alert policy-makers and civil society to the security threats posed by declining soil health, and to the remarkable opportunity that soil regeneration provides.

Global security is maintained by taking steps to mitigate future threats. Now, in addition to traditional state-on-state or intra-state threats, we face non-traditional threats, the most important of which can be characterised as 'ecological breakdown'. The extreme weather events associated with global warming, coupled with the loss of biodiversity and soil structure, could have devastating impacts on harvests around the world. While access to food is a recognised accelerant of instability, it is soil biodiversity in particular that is critical in minimising and mitigating this risk.

The right to affordable nutrition underpins peace and civil stability, but ecological breakdown is already affecting food production. If we see a two degree rise in global temperatures, which now seems increasingly likely, we could experience extreme disruption in global food supplies. When food is scarce, prices rise, inequality increases and simmering resentments can turn rapidly into conflict and even war. Healthy soil and a balanced ecosystem are critical for food sovereignty and a peaceful society.

We urge governments to take the security risks associated with soil degradation and ecological breakdown extremely seriously.

We offer agroecology as a low risk and low cost solution that can mitigate the security threats connected with poor soil health. With COP26 in sight, agroecology and regenerative farming can produce great food locally and at scale, while greatly accelerating carbon drawdown, regenerating biodiversity, and managing precipitation to provide greater drought resilience and better flood protection.

I hope that you will find this collection of articles inspiring and informative – and that you will support us as we work to restore soil health and transform food production, in order to build peace and maintain global security.



ffinlo Costain
Founder, Food & Global Security Network
<https://www.foodandsecurity.net/>

PUBLISHING NOTE

This profile report has been published by the Food & Global Security Network, a project of Farmwel, supported by FAI Farms.

Our advisors are Rear Admiral Neil Morisetti, Dr Ashleigh Bright, Reginaldo Haslett-Marroquin, Clare Hill, Roland Bonney and ffinlo Costain,

Farmwel is a think tank working for sustainable agricultural land use and food production. Our priorities are to mitigate global warming, integrate agriculture with biodiversity, and ensure that good, nutritious food is available for all. We have given evidence to Parliamentary committees and helped UK Government develop farm animal welfare and sustainability metrics. We have advised on global warming mitigation pathways and have highlighted the importance of the revised metric, GWP*, which accurately assesses the warming impact of methane. Farmwel and FAI also produce the popular Farm Gate podcast: <https://www.faifarms.com/podcasts/>

FAI are a global team of farmers, veterinarians, scientists and strategists with first-hand experience of food production and its challenges. We have people and offices in the UK, US, Brazil, Germany, Norway and New Zealand. Through strategic partnerships with leading food brands and organisations we implement better farming practices and improvements in commercial supply chains. FAI are thought leaders in agriculture's opportunity to tackle the two most pressing issues facing humanity: biodiversity loss and climate change. Our regenerative agriculture work encompasses transition both at farm level and strategically through supply chains. www.faifarms.com

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Many people have contributed their time and expertise for this report, for which we are extremely grateful.

EXECUTIVE SUMMARY

We face two concurrent crises in nature: climate change and the loss of biodiversity. Both threaten the availability of food and water, endangering global supply chains. Human access to affordable nutrition and potable water are critical in maintaining peace and security. Global warming, biodiversity loss, food and water – they are connected, above all else, by soil health.

Overview

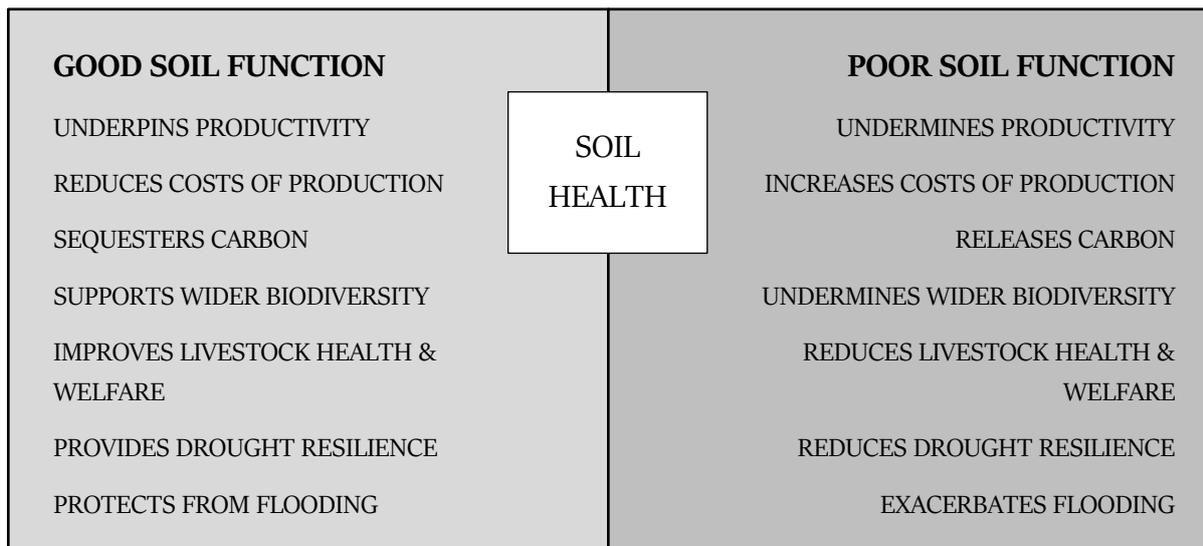
Soil health and productivity is under threat. In a warming world, excellent soil health helps to ensure access to good quality nutrition while protecting communities from the impacts of extreme weather. By contrast, poor soil health undermines access to nutrition and threatens national resilience to increased drought and flooding.

The rights to affordable nutrition and a secure home underpin peace and civil stability. The impacts of climate disruption and biodiversity loss are already affecting global production and the availability of staple ingredients, which in turn is forcing migration, and leading to trapped populations. These impacts are set to increase as

temperatures continue to rise and while biodiversity remains in a state of crisis. This will strain global supply chains and international trading relationships, leading to greater national protectionism, prices rise, and supply chain instability.

Soil health should therefore be considered a security priority.

Governments and food businesses should take action to restore soil biodiversity in order to maintain peace and security. Action must centre on practical strategies to regenerate soil health, including farm level behaviour change, and steps to improve nutritional knowledge and diversity for citizens.



Uncharted territory

We are moving into uncharted territory in terms of both climate and biodiversity breakdown. There is an urgent need to consider key impacts on society, with fair, continuous access to good nutrition being one of the most critical.

In the USA, the Centre for Climate & Security (now part of the Council for Strategic Risks), investigated the link between climate and conflict. Their recent World Climate & Security report places water and food availability as the top climate-related accelerant of instability.

The availability or scarcity of staple ingredients can mean the difference between a civilised society and civil conflict. Interruptions in food supply may lead to nutritional insecurity, emphasising inequality, and acting alongside other social undercurrents to build resentment and increase the threat of civil unrest. At the more extreme end, this could lead to individuals or communities defending food supplies from other citizens.

Healthy soils, rich in biodiversity, directly underpin access to high quality affordable nutrition. Periods of extended international disruption, linked to extreme or cascading weather events, will undermine the global supply of staple ingredients, increase prices, and act as accelerants to migration, nationalism and protectionism. The health of a nation's soil, and its capacity to provide nutrition for citizens, is highly likely to become fundamental to its future success or failure.

Underscoring this basic truth, **Reginaldo Haslett-Marroquin**, president of the Regenerative Agriculture Alliance, writes in this report about how as a child growing up in war-torn Guatemala he became aware of the importance of soil regeneration.

Soil health also directly impacts a society's resilience to extreme weather events, such as drought and flooding. Good soil management helps to ensure safe, continuous access to fresh water, and reduces the likelihood of population

displacement due to the flooding of homes and population centres.

Food and security

The old approach to food security, based around volume, supply and calorific intake, must rapidly change. The post-Second World War drive to produce food abundantly and cheaply for citizens has led directly to a dangerous reliance on large company investment, government subsidies and the widespread use of petrochemicals. While this approach has been successful when assessed against its own objectives, it has had devastating impacts on the environment, rural resilience, and animal health and welfare. As **Vicki Hird** from UK Sustain writes, 'food' security is no longer enough, we now need 'nutritional' and 'soil' security.

The perceived duty to maximise carbon emissions reduction presents a new threat. As with the drive for cheap food, it is dangerous to over-simplify land use challenges and opportunities. A strong focus on emissions reduction creates additional imbalance in already teetering ecosystems. Pressure to increase forestry, biofuel production and rewilding is further restricting the availability of land for food production. This is contributing to the collapse of smaller farm businesses and an even greater consolidation, commodification and intensification of farm systems.

The separation of land use for different activities is inefficient and leads to increased external costs. For example, intensive forestry can greatly reduce biodiversity and exacerbate flood risk. Rewilding can reduce employment and undermine rural economies. Meanwhile the resulting further intensification of livestock agriculture requires industrial-scale land use to produce cereal and proteins such as soy, leading to high chemical and water use and additional land use change, all of which lock us into additional biodiversity loss and increased global temperatures linked to long term 'stock' greenhouse gases.

Dr Ashleigh Bright calls for a renewed focus on holistic solutions and metrics which account for the multitude of benefits that crops and livestock provide in the long term.

Holistic management is a more efficient approach to agricultural land use, designed to deliver multiple ‘public good’ outcomes together. This can be achieved partly through a shift in focus, from emissions reduction to warming mitigation, which recognises the ‘flow’ effect of short term greenhouse gases such as ruminant methane. By using accurate global warming metrics we can show the positive impacts of agroecological farm systems, which can produce high quality nutrition affordably and at scale, while regenerating soil health and biodiversity, delivering warming mitigation and adaptation, improving the potential for good animal health and welfare, and supporting a diverse and vibrant rural economy where profits are recycled around countryside communities.

This transition will also require behavioural change at citizen level. While the cost of meals must remain affordable for all, the price of some ingredients will need to rise. Governments and food businesses should become less cautious in directing people to reduce the carbon intensity of their diets. This will require advice and incentives to replace high impact diets with extensively and agroecologically produced meat, dairy and cereal products, as well as seasonally and nationally produced fruits, vegetables and pulses.

The historian **Edmund Simons**, from the Royal Agricultural University, writes that past civilisations have faced ecological and food system collapse many times before. He asks whether this time, as our global civilisation faces the greatest of ecological crises, we will take the steps necessary to avoid our own demise.

To achieve this, we will need a new definition of food security, based on Colin Tudge’s principle of ‘good food for everyone forever’, rather than on ‘cheap food for everyone today’.

Soil must become a global security priority

Global security is maintained by taking steps to mitigate future threats. As **Rear Admiral Neil Morisetti** says, ‘traditional’ threats are ‘either state on state or intra state, frequently with a military component.’ However, we also face ‘non-traditional’ threats, the most important of which can be characterised as ‘ecological breakdown’.

In their article for this report, the **Council for Strategic Risks** writes that, ‘Global ecological disruption is arguably the 21st Century’s most underappreciated security threat. Human societies are producing rapid, novel, and foundational changes across multiple Earth systems with concomitant—and sometimes severe—consequences for people, societies and security worldwide.’

Over the last decade, work has been undertaken globally to understand the security threats associated with climate change. As **Jimmy Woodrow** from the Pasture-Fed Livestock Association reminds us in his article, the US intelligence community currently anticipates a mix of direct and indirect threats associated with global warming, including ‘risks to the economy, heightened political volatility, human displacement, and new venues for geopolitical competition that will play out during the next decade and beyond.’

But climate change is not an ecological threat in isolation. Despite this, the Council for Strategic Risks notes that the parallel threat from biodiversity loss has ‘seemingly made no waves within the security community.’ They write that, ‘Recognition of these issues is growing, but there is currently little indication that the scale of the threat is broadly understood or that mitigating policy actions are likely to follow without a change in course.’

We have chosen to focus on soil health in this report because it is at the nexus of ecological breakdown.

Its health is already greatly diminished, and without it all life on Earth is severely threatened.

But much as soil health is at risk from climate change and biodiversity loss; from extractive agriculture and ‘more-for-less’ food systems – soil also provides clear and achievable pathways out of crisis.

Healthy soil in regeneratively-managed, agroecological production systems can store carbon, restore biodiversity, manage water, produce abundant food, provide the multitude of jobs that keep rural economies viable, and ensure greater resilience and security for societies around the world.

In his article, **Johnnie Balfour** tells us that the fortunes of his 1350 hectare farm, and the people who depend upon it, were transformed by the implementation of holistic management and the adoption of regenerative agricultural principles.

Broader context

The climate disruption witnessed around the globe in 2021 has been remarkable. The Center for Disaster Philanthropy records that 45,350 wildfires in the USA have burned more than 6.4 million acres, while data from the Russian Forestry Agency shows 45m acres on fire in Russia. Zhengzhou, in China’s Henan province, received 24.2 inches of rain (a year’s worth) in just four days in July. A swathe of land collapsed in catastrophic flooding in Germany’s Rhein-Erft-Kreis district, while unprecedented levels of rain also fell in over Belgium, France, Luxembourg, the Netherlands and Switzerland. In Australia, in New South Wales, extreme flooding followed a record-breaking bushfire season that had swept the region the previous year. In February a polar vortex brought freezing weather to Texas, Arkansas, Louisiana, Mississippi and Alabama. Meanwhile, drought continues to contribute to the humanitarian crisis in Ethiopia, while Northern India has been hit by severe cyclones. In July, Reuters reported that, Aon, a London-based insurer, had estimated that global natural disaster-insured losses would reach \$42bn (£31bn) for the first six-months of the year.

This catalogue of disruption should come as no surprise. The IPCC Sixth Assessment report, released in August, concludes that it is ‘unequivocal’ that human beings have caused ‘widespread and rapid’ changes to Earth’s oceans, ice and land surface. Many of these changes are irreversible and abrupt changes and tipping points, such as rapid permafrost melt and forest dieback, ‘cannot be ruled out’.

As **Sue Pritchard** from the Food, Farming and Countryside Commission notes, ‘The IPCC Sixth Assessment report makes it clear we are failing to grasp how serious this crisis really is. Not only will we fail to meet the 1.5 degree target in the Paris Agreement, but, in their most likely scenario, we will exceed 2 degrees of global warming and could reach 3.5 degrees by 2080.’

While increased global ambition on global warming is welcome, the biodiversity crisis is just as serious. In May 2019 the UN reported that, ‘Nature is declining globally at rates unprecedented in human history – and the rate of species extinctions is accelerating, with grave impacts on people around the world now likely.’ A report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) noted that three-quarters of the land-based environment and about 66% of the marine environment have been significantly altered by human actions.

In 2017, shortly before the IPBES report was published, a German study showed a ‘more than 75 per cent decline over 27 years in total flying insect biomass.’ The decline in insect populations is emblematic of the reduction in biodiversity more broadly, and even more worryingly this study was carried out in a protected area. Of equal concern, in 2020, WWF reported statistics that showed ‘the population sizes of mammals, birds, fish, amphibians and reptiles have seen an alarming average drop of 68% since 1970.’

Biodiversity loss is also a root cause of the current pandemic.

Zoonotic viruses such as Covid-19 are directly linked to humanity's on-going assault on the natural world.

History is littered with examples of zoonotic disease transmission from livestock (Ebola, Marburg, Hendra, Nipah, Sars CoV1, Sars CoV2 etc.) as our production systems have intensified and our encroachment into wildlife habitats has increased, permitting more opportunities for cross-species transmission.

As **Laura Higham** says in her article, 'The evidence shows that healthy wildlife populations help protect us from infectious disease. When we interfere with biodiversity and wildlife habitats, we threaten species that each serves a vital role in the ecosystem.'

Soil biodiversity

While access to food and water is a recognised accelerant of instability, it is soil biodiversity in particular that is critical in minimising and mitigating these risks. Healthy soil is both protection from, and an indicator of, the impacts of the twin crises we face in nature.

Regenerative soil management and agroecological farm systems are critical if we are to successfully mitigate global warming. (The components of regenerative land management are described later in this report by **Caroline Grindrod** from Roots of Nature.) Soil can act as a powerful carbon sink, locking in carbon for many generations to come. In regenerative agroforestry systems, where trees are integrated with crops and livestock, levels of carbon sequestration can surpass draw-down rates associated with traditional broadleaf woodland. Conversely, intensively managed soil leads to erosion, compaction, poor water filtration and the loss of soil organic matter, while degradation from ploughing, the use of toxic agri-chemicals and over-grazing all contribute to higher carbon dioxide emissions.

Good soil management also restores the building blocks of biodiversity and is integral to successful climate adaptation. Biodiverse soils, rich in nutrients and micro-fauna, retain water in the soil carbon sponge and help to ensure water availability, land resilience, and continued food production even in times of drought. By contrast, compaction and poor soil biodiversity negatively impact the soil carbon sponge, leading to rapid water loss, flooding, and reduced resilience to long dry periods. **Graeme Willis** from CPRE details the importance of soil biology later in this report.

As we face up to the twin crises of global warming and biodiversity loss, farmers are our first responders. The choices they make will establish a narrative of human success or failure as we move towards the middle of the century. Degraded soils must be regenerated; retrofitted with abundant biodiversity, so that carbon and water can be harnessed, stored and released efficiently and effectively.

Soil habitats

Martin Lines from the Nature Friendly Farming Network reminds us many people still see soil as little more than dirt; a functional day-to-day reality. We walk on it, we build on it, and we plough into it. Like the ocean, our eyes skate across the surface with little understanding of the vibrancy of life beneath.

But for farmers like **Nikki Yoxall**, soil is an exciting, thriving and highly complex ecosystem; the bedrock of human society. It provides the living basis for all nature, combining minerals, organic matter, water, air, and living organisms including fungi, nematodes, arthropods and earthworms. Soil types and habitats vary enormously, but a single teaspoon of healthy soil will typically be home to 10,000 different species, with more individual organisms than there are people on planet Earth.

In his article, **Øistein Thorsen** reminds us of David R. Montgomery's description of our planet as 'an

oasis in space rendered hospitable by a thin skin of soil that, once lost, rebuilds only over geologic time.’ In the eighty or so years since the start of the Green Revolution, agriculture has treated this vital organ, which takes centuries and millennia to form, as an infinite and expendable resource. We have stripped away our soil’s natural goodness; we have purged the life that once flourished inside it.

Crucially, farming alone is not to blame.

Society more broadly has delighted in cheaper and more plentiful food. Governments have supported production systems that seek to simplify Earth’s systems while subsidising the production and use of synthetic agri-chemicals that strip essential virtue from complex soil environments. Agriculture has been caught in an ever-decreasing circle – its base material has become unhealthy and depleted, and its prescribed medicine has masked the symptoms while depleting soil habitats ever further.

The good news is that cures are available. Soil health and organic matter can be regenerated relatively quickly. These regenerative processes provide pathways to large-scale carbon storage, biodiversity restoration, greater resilience to extreme weather events, and a potentially fairer global distribution of more diverse and higher quality nutrition for humans around the world. But government policy and investment from public and private sources will be needed to mobilise and support agroecological transition at scale.

And there is an active choice to be made by political leaders and by society, as **Chantal Clément** and **Nick Jacobs** from IPES Food explain. Will we choose to allow powerful actors to appropriate and control the Earth’s productive resources, or will we work together to build the foundations for new, more sustainable and regenerative food systems?

Soil benefits

Carbon – Soil is one of our planet’s great carbon sinks and sources. A data visualisation, presented by a US Government soil scientist in the recent Netflix film, *Kiss The Ground*, shows enormous plumes of CO₂ rising into the atmosphere during the springtime ploughing season, and the reverse process occurring during the summertime as plants grow and absorb carbon.

By reducing soil disturbance and improving the cycling of organic matter – for example through Adaptive Multi-Paddock grazing of ruminants or by integrating more livestock within agroecological arable rotations – we are able to accumulate rather than deplete these carbon stores. Assessments vary, but there is common agreement that the regeneration of soil health around the world could deliver a third of the carbon drawdown necessary to mitigate climate change, with no adverse impact on biodiversity. As **Patrick Holden** reminds us, after the ocean, the soil is Earth’s largest carbon store.

An indicative study in the USA shows sequestration rates in AMP systems of an additional 9t/C/ha/yr, down to 1m depth, compared to conventional grazing systems. Although direct comparison between soil and trees is extremely tricky and should be heavily caveated, we can put this into some kind of context by noting that the UK Forestry Commission expects sequestration rates of around 1.6tC/ha/yr from trees growing in standard broadleaf woodland (unmanaged sycamore ash/alder/birch).

This is not to suggest that soil is a better solution than trees, but to show that both have good carbon storage potential, and to make the point that regeneratively-managed pasture should be considered a hugely important carbon asset. Any choices about the right mix of soil management and tree planting should be land appropriate. Our view is that most farmland should include trees, hedges and ponds, ideally integrated within the farm system, to enhance carbon sequestration, as well as biodiversity and hydrology.

To ensure rapid drawdown, **Thomas Gent** proposes on-farm carbon accounting and payments.

Hydrology – The capacity of healthy soil to hold and slowly release water is critical. **Walter Jehne**, the Australian soil microbiologist and climate scientist, notes in his article that the soil carbon sponge has an exceptional capacity to ‘infiltrate, retain and make available water to extend the longevity of green plant growth, its transpiration and its natural physical cooling or ‘air conditioning’ of the climate.’

By contrast, degraded soils cannot hold water, and compacted soils cannot absorb water. In both instances, farmers are unable to utilise precipitation effectively. Run-off washes vital minerals and other nutrients away, and over a larger land area this poorly managed water can become a substantial flood problem further downstream. Poor quality soil on farms can lead directly to the flooding of homes and businesses and the devastation this causes to people's lives.

Farmers who understand and work to improve the natural hydrology of their land can benefit greatly in times of drought. In regions of Australia that have seen decades of low rainfall, much of the land can be brown and arid for much of the year – and yet regeneratively managed farms in the same region remain green and productive for all seasons. When it does rain, the water is held in the land, and then released optimally as plants grow.

Functioning hydrology, linked with good levels of soil organic carbon, result in little or no soil erosion even during heavy storms, and ensure that water and nutrients are accessible for food production throughout the year.

Healthy, functioning soil, alongside low impact land interventions such as leaky dams, provide a low cost alternative to expensive concrete flood prevention infrastructure. In some places this natural approach can all but eliminate flood risk.

Biodiversity – Soil is also critical for biodiversity restoration. Soil, with its micro world of fungi, arthropods, bacteria, nematodes and earthworms is the basis for all life above ground. Soil provides the

foundation of the food web, supporting the life on which all other species depend. While much attention has been placed on the protection and restoration of individual species that people love to see, such as the skylark, it is the soil, ultimately, that supports the habitat on which the skylark depends. All conservation efforts must place soil health at the very baseline of their strategy.

In this report **Clare Hill** describes the explosion of biodiversity at FAI Farms in Oxfordshire since the team began its transition to regenerative grazing.

Oceans – Although we do not touch on the oceans in this report, it is important to note the strong interconnectivity between agricultural land use and the health of lakes, rivers, estuaries, coastlines and the ocean itself. Pollution from the land and destructive practices in rivers and at sea have led to a dramatic decline in water-based ecosystems, and in the life and food systems that once thrived around us. Pollution from farms can negatively impact water quality, but regenerative practices that cycle nutrients and reduce run-off can have a positive effect. Regenerative food production is also possible at sea.

In summary – Healthy soil sequesters and locks in carbon, which is imperative if we are to constrain temperature rises and mitigate climate change.

Healthy soil is the foundation of life on earth, and is essential if we are to restore biodiversity.

Healthy soil provides protection against drought, and against flooding.

Healthy soil can produce high quality nutrition and support the livelihoods of billions of people around the world.

In short – healthy soils are essential for life on Earth.

Cop 26 and beyond

As we look not only towards COP26, but to future policy-building to mitigate global warming, it is critical that our efforts to rapidly combat climate

change do not further damage and destroy the health and functionality of our soil habitats.

The benefits of mass tree-planting to sequester carbon, for example, must be balanced against the impacts on soil health, biodiversity, functioning hydrology and the capacity for people to grow nutritious land-appropriate food.

Humanity faces an enormous and interconnected ecological crisis. Our solutions must seek to rebalance nature as a whole. We must question and sometimes resist well-intentioned actions focussed on single ecological outcomes, because these could tip humanity further into the arms of ecological and societal peril.

To achieve this we must use the latest science, even when it is inconvenient and does not fit the prevailing political narrative. For example, as **Ffinlo Costain** writes later in this report, current carbon

assessments, particularly of livestock systems, are inaccurate due to a structural misunderstanding of the role of ruminant methane. The science has been corrected and accepted by the IPCC in AR6, but we must rapidly embed this knowledge into our assessments of the global warming impacts of land use, to better inform decision-making.

Land is finite, and we rebalance ecological systems most successfully when we plan and deliver for multiple outcomes from all land, rather than sparing, or zoning, different sections of land for different functions.

Nature is diverse and interconnected, and so our responses to ecological threats and opportunities must be diverse and interconnected too.

As the farmer, **George Young**, says at the end of this report, 'Soil is everything.'

CHALLENGES

THE SECURITY IMPLICATIONS OF A CHANGING CLIMATE

REAR ADMIRAL NEIL MORISETTI

Neil was Commander UK Maritime Forces and Commandant of the Joint Services Command and Staff College. Between 2009 -2013 he acted as the UK Government Climate and Energy Security Envoy, and then the Foreign Secretary's Special Representative for Climate Change. Neil is also an advisor to the Food & Global Security Network.

'Nations need to minimise the damage caused by climate change, resulting from historical emissions. In part this will require richer nations to help more vulnerable ones to develop the capacity and resilience to address the stresses that they will face, but it will also require all nations to tackle the loss of biodiversity and in particular the damage that has been done to soil health and water quality. The restoration of national soil health, and increased food sovereignty, should be seen as a security priority by all nations.'

Experience and evidence over the last few years has reinforced what many in the security community have long acknowledged; the impact of a changing climate is much more than an environmental issue.

Today we are seeing many threats to our prosperity and wellbeing, which underpins our national security. Some are well known and can be categorised as 'traditional' threats, either state on state or intra state, frequently with a military component. Examples might include the risks resulting from increased tension in the China Seas or the Eastern Mediterranean.

But we are also seeing an increase in 'non-traditional' threats. Frequently transboundary and without a military origin, this category includes cyber threats, organised crime, people trafficking and pandemics such as the one we are still living through, Covid 19. However, the one that probably poses the greatest challenges over an extended period is the consequences of a changing climate, especially when it impacts on the availability of key natural resources, such as food, water and land.

Climate change is different from other drivers of instability because it impacts countries through multiple routes simultaneously. It pushes natural systems outside historical ranges and in doing so stresses existing managerial regimes, at local, national and international levels; regimes that have evolved to deal with only limited climate fluctuations.

That is not to say that the physical changes alone, either as a result of the onset of long term warming trends, or the increased frequency and intensity of extreme weather events, are going to be the direct cause of conflict. Rather, it is the second and third order consequences, including loss of land or livelihood, that are contributing to increased instability and risk of conflict.

Whilst the consequences will vary from country to country, community to community, the effects are already being felt globally. Loss of land as a result of rising sea level and ingress of salt water into the aquifers, decreasing crop yields due to increased temperature or extreme drought, combined with

reduced water availability and subsequent pressure on existing water treaties, are testing the resilience of society.

Examples of regions where the impact is greatest include, the Middle East and North Africa (MENA), the Sahel, Caribbean and Asia (South and South East). The UNDP has calculated that in the MENA region by 2025 the water supply will only be 15% of 1960 levels, whilst the population is growing at 3% per annum. The probability of the most serious types of droughts in countries such as Syria will triple.

In Iraq water is critical to the government's plans for providing its citizens with a brighter future, specifically to support increased agricultural jobs to reduce incentives to (re-)join insurgent groups. A combination of increased demand due to population growth, temperatures rising at twice the rate of the world average and upstream damming of the Euphrates and Tigris by Turkey and Iran is impacting on agriculture (which uses 80% of the country's water and employs 30% of the population) and economic development. Climate change is increasing both domestic pressures due to drought, external pressures as Turkey withholds a larger proportion of dwindling river resources, and by raising the risk of external food price spikes.

Frequently the countries and regions where this happening are already suffering from other stresses (health issues, demographic challenges due to population growth and greater longevity, existing food and water shortages, etc) and poor governance; countries that have neither the capacity or the resilience to look after their citizens. Hence, the description of climate change as a 'stress multiplier'.

So what are the likely consequences of this increased stress? Based on past experience, it will either be:

- a. Large unplanned movements of populations, principally within countries, as was the case in Syria, where because of a prolonged drought, in part a result of the changing climate, there

was movement from rural to urban areas, exacerbating existing tensions. Where large areas are affected, i.e. the Sahel or Bangladesh, trans-boundary movements can be expected, which raise international tensions.

- b. Trapped populations, who do not have the ability to move and, in their search for an alternative livelihood, may turn to communal conflict over resources (as seen in Chad and Nigeria) and become susceptible to becoming involved in organised crime or supporting violent extremist organisations, such as Al Shabaab or Boko Haram.

In both cases, such conditions have the potential to increase the risk of instability or conflict.

However, the problem is wider than just in these regions, on two counts. Firstly, today the physical effects of climate change are impacting on food production on a global basis and compounding the problems that were already there as a result of historical poor land and water management. Something that is happening at a time when populations are still rising and communities have greater aspirations.

Secondly, by the very nature of the interconnected world that we live in events in one region have the potential to impact on another. Instability induced volatility in prices of food and raw materials, especially fungible products such as wheat or hydrocarbons, will impact on the economic security and growth of all countries.

The impact on richer nations, such as Great Britain, should not be under-estimated, as demonstrated by the 2011 Thai floods and more recently during the current pandemic, our supply chains are very vulnerable to disruption. Extreme weather can quickly disrupt the 'just enough just in time' supply chains, with the attendant knock on impact to profitability and in the medium-term withdrawal of foreign investment from vulnerable regions, further undermining their stability. Climate induced water shortages in regions such as the Horn of Africa can contribute to increased risk of disruption of the

trade lines of communication, including the Straits of Bab El Mandeb, which in turn will result in reduced Suez Canal receipts and further pressure on the Egyptian economy.

These multiple impacts present a risk of ‘social tipping points’ where repeated crises cause countries to restrict core commodity exports and reduce investment and cooperation abroad. This will increase the vulnerability of fragile countries, reduce incentives for cooperation and raise political tensions. The dynamic between India and Bangladesh over economic migration, and resulting deaths on India’s border fence, are an example of how tensions linked to environmental change – in this case flooding – can be magnified by badly managed responses.

So what do we need to do to reduce the risks to our prosperity and wellbeing posed by a changing climate? We need to address the root cause of the problem and success here will only be achieved when sufficient action has been taken to avoid a dangerous rise in global temperatures; as identified in the 2015 Paris Agreement, this will require nations to reduce future GHG emissions to net zero by 2050.

At the same time nations need to minimise the damage caused by climate change, resulting from historical emissions. In part this will require richer nations to help more vulnerable ones to develop the capacity and resilience to address the stresses that they will face, but it will also require all nations to tackle the loss of biodiversity and in particular the damage that has been done to soil health and water quality. The restoration of national soil health, and increased food sovereignty, should be seen as a security priority by all nations.

The specifics of how this is done will vary from region to region but it must be done in a manner that does not increase the risks of climate change and undo the good work in other areas. This is particularly the case in terms of land use and agriculture. It is essential that efforts to mitigate global warming, adapt to climate change and restore biodiversity and soil health are complementary. This will require nations and communities to work together and share best practice, for only when all have access to secure, sustainable, and affordable supplies of food and water will we have the basis for prosperity and wellbeing, which in turn will contribute to reducing the security risks associated with a changing climate.

PASTURE IS A STRATEGIC ASSET

JIMMY WOODROW

Jimmy is the Executive Director of Pasture for Life / Pasture-Fed Livestock Association

‘Pasture and its underlying soil, when properly considered, should be a vital strategic asset in a world that is becoming more and more resource constrained, elevated alongside forest and peat bog for its upcoming role in both nature recovery and food production.’

Imagine a future in which resources are increasingly scarce due to the pervasive effects of environmental degradation. Food, currently traded internationally as if geography and seasonality are no barrier, might reasonably be a much more local affair; in the UK, this could mean 80%, perhaps even 90%, produced here. In this context, imagine that there was a habitat from which it was possible to produce one of the most nutrient dense foods with little to no fossil fuel inputs, instead just the renewable resources of sunlight, water, perennial plants and herbivores. Imagine that this habitat, if managed sensitively, could at the same time deliver multiple other public goods, such as dense above- and below-ground biodiversity, flood mitigation through water storage, carbon capture and storage, and provide livelihoods for people in a world in which work was increasingly automated.

A habitat like this would surely be considered extremely valuable in such a scenario. Not just in economic terms but in social and cultural ones too. This habitat already exists and the geographical area in which we live – the British Isles – has a climate perfectly suited to its existence. It is grassland, what I will call pasture in its species-rich form, and we humans have been deriving some of our staple crops from it, in the form of meat, milk and fibre from ruminant animals, for thousands of years.

Somehow we have become so divorced from our means of food production that the above imaginative foreplay may take some people by

surprise. The dominant narratives positioning certain herbivorous animals – that in some form pre-date our existence on this planet – as the causes of climate and biodiversity breakdown, rather than us humans who have been responsible for the management of them, are persuasive and have led us away from a basic understanding of one of our primary habitats here in the British Isles. Industrialisation has led to a divorce of food production and nature, and a dwindling understanding of anything different in the first person has allowed these narratives to take hold in our public imagination. It is this same industrial paradigm that would have us eating synthetic plants and meat products in the race to net zero. If you pick up a newspaper you will likely read that pasture should be rewilded or reforested, is inefficient in its use of land, or perhaps should even be protected from the animals it evolved alongside.

A truly sustainable food system, however, particularly in temperate climates like Northern Europe, will need to rely on habitats like pasture; habitats that can deliver so much without fossil fuel inputs and, critically, without degrading the underlying asset, in this case the soil. This is impossibly hard to achieve in arable and horticultural systems at scale and when the dominant driver is yield, which advocates of further differentiation between ‘nature’ and ‘agriculture’ are pushing for. Pasture, when properly considered, should be a vital strategic asset in a world that is becoming more and more resource constrained,

elevated alongside and perhaps above forest and peat bog for its upcoming role in both nature recovery and food production. To be clear, we need all of these habitats but the support for pasture is critically lacking at governmental level.

The reason that pasture, and low input farming systems in general, are not getting the attention they deserve is, in part, explained by the stranglehold that techno-industrial systems and narratives have on us. I believe there are also other factors at play that are clouding policy-makers' ability to make informed long-term decisions: an absence of consensus around the problem; lack of policy co-ordination, and; underlying fear of statism. I will consider those here as I make the case for pasture as a strategic asset.

The vital role of pasture

Two thirds of the world's farmland is perennial pasture, in one form or another, and often found on areas unsuitable for annual cultivation. The grazing ruminants that live on them eat grasses, herbs, forbs and leguminous plants that humans cannot, not to mention trees and hedges, thus miraculously transforming vast unproductive tracts, as far as food production goes, into potential havens of biodiversity *and* food production. If soil is the world's largest terrestrial store of carbon, the world's grasslands are likely the largest terrestrial solar panel, efficiently transforming solar energy into food for all life with little input from humans needed. While it is true that efforts to increase yield have led to unsustainable outcomes in the livestock sector, including in the development of chemical-driven, monocultural grassland systems, a return to first principles suggests that an agroecological, low input approach should be synonymous with and a cornerstone of a sustainable food system.

Ecologically managed pastoral systems provide a number of critical outputs, all of which will be increasingly important as we seek to wean ourselves off fossil fuels. Environmental outputs include: the preservation and restoration of fungal

and biological communities in the soil and the below and above-ground insects, birds and mammals that feed off them; more efficient infiltration and storage of water, essential in managing the extreme seasonal surpluses or deficits we increasingly see and, finally; the contested area of carbon capture and storage. On this last point, and irrespective of what is or isn't being captured, the preservation of current carbon stocks under pasture must be paramount. In addition, in advocating for the role of pasture I am not suggesting that trees are excluded, the two could and should go hand in hand and the return of trees and hedgerows to our pastoral landscape in the UK is well underway and should be accelerated.

As we struggle to define what constitutes a sustainable fashion industry it is likely that natural fibres such as leather and wool see a renaissance, both key pastoral outputs; at the moment these are primarily unwanted by-products from our food system, often with a cost to destroy rather than a value. Finally, the meat and milk generated by these systems is nutritionally dense and bio-available, particularly in trace minerals and omega-3. Comparisons of carbon emissions from food production rarely factor this into their analyses, instead comparing kg with kg.

Rather than celebrate these systems, what we have seen is pasture and the myriad goods it produces, many of which are difficult to quantify by conventional metrics, reduced to mere expressions of food production efficiency. Instead, pastoral ecosystems ought to be managed for their own sake with the grazing animals judged for their ability to provide food and play a diverse ecological role, something industrially managed livestock cannot do. Conventional wisdom significantly undervalues pastures and grazing animals when compared to highly productive but input intensive farmland and is leading to perverse policy outcomes whereby systems dependent on fossil fuels are being championed in our search for net zero.

My colleague John Meadley likes to ask the question, 'What would happen if we took all the grazing

ruminants away?’ This is an outcome not explicitly but perhaps implicitly arrived at by many of the anti-meat narratives. The question, while abstract, seeks to get at first principles and ultimately a bigger question: what would happen to the habitats these animals have evolved alongside, the pasture?

It is likely that replacing lost animal protein and fibre would see pasture increasingly ploughed, with a loss of carbon to the atmosphere that is well documented. Not only contributing to climate change, this act would lead to a further loss of soil. Yale Environment 360 reported that the world's cultivated soil has lost as much as 70% of its soil organic carbon since pre-industrial times, primarily through cultivation, with the resulting loss of structure causing soil to be literally washed away and with it its ability to store water and provide life to plants. Not only that, taking away the ruminants that graze these ecosystems would remove one of nature's supreme digesters, the rumen, with its ability to turn plant material into digestate in 24 hours, surely even a match for nutrient cycling in the tropics. The invertebrates, bird and mammal life that thrives in this grassland ecosystem would, according to keystone species theory, also come under threat, further endangering biodiversity. This also doesn't take into account the socio-economic effects; public health would be even more challenged with a nutritional deficit from the loss of animal protein, particularly in the economically developing world, and a loss of rural jobs.

Thinking long-term, we would also lose something more important and perhaps more intangible: the ability to produce food without fossil fuels. While the recent IPCC report made clear that methane needs to be reduced if we are to stay within 1.5 degrees, we must assess ruminant warming impacts accurately, and would be making the same short-sighted mistakes of the past 70 years if we balanced the books by removing ruminants and de-prioritising pastures, not least given ruminant numbers have decreased by 22% since 1996*. It would not only bring about a major reduction in food security, as currently defined, in the UK but

make it harder for us to deliver on the wider environmental and social outcomes we are seeking. [**See article by ffinlo Costain.*]

In many respects, food security is at the heart of this conundrum. A full appreciation of food security would consider national availability – the proportion of our food produced domestically as currently defined – as well as nutrition, access and the ability to deliver food to the population without compromising other competing aims, such as biodiversity recovery and climate change mitigation. This is not currently happening; I would argue that food security as a term is academic and politically subverted to wider economic analyses that see food as commodity to be traded freely in a globalised economy. In the UK, Henry Dimbleby's National Food Strategy did attempt to draw these strands together but until food security is taken seriously as an issue, these broad analyses will not gain traction. Until it is, narrowly defined questions will continue to lead to perverse policy and ultimately short-sighted outcomes. The UK Climate Change Committee's land use framework is a case in point in its inability to consider these wider issues and resulting view of pasture as something to be rewilded or to produce bioenergy crops.

To the advocates of agroecological solutions this narrow focus can lead to head-scratching and even soul-searching. There are some lessons to be learnt, however, in why we are in this situation from the environmental crisis, which could point the way forward.

Environmental security and its implications for food security

15 years ago this month I completed my postgraduate dissertation on the subject of environmental security and why this term, and the study of it, was not included in mainstream security or strategic studies, traditionally the preserve of military and economic threat analyses. With a focus on China's emergence as a great power, I showed how international relations theories tended to

overlook the environmental threat posed by China to the world order, focusing instead on their militarist policies and likelihood of overtaking the US as the world's largest economy. At that time, climate change, while on policy-makers' radar, was simply not considered an existential security threat. By this I mean the issue was not securitized, the method by which state actors transform political issues into matters of national security and take extraordinary measures to respond. Thankfully, over the course of 15 years this has changed and climate change is now seen as a national security threat, such that the US intelligence community currently assess that the 'effects of a changing climate and environmental degradation will create a mix of direct and indirect threats, including risks to the economy, heightened political volatility, human displacement, and new venues for geopolitical competition that will play out during the next decade and beyond.'

At the time, there were some key reasons environmental security appeared to be stumbling as a concept. Firstly, there was a lack of accepted causality between environmental issues and violent conflict or existential threat. While there are some who still deny the existence of existential climate change, the threat is now elevated to such an extent that it is getting universal attention from policy-makers. One could even make an argument that the once primary question of whether or not climate change is anthropogenic is now lost in the noise of the debate around how we respond to the urgent need to reduce emissions. In the same vein, a lack of a shared understanding of what constitutes food security may be hampering efforts to find long-term solutions. Food security as a percentage of national production is clearly inadequate, not least in hyper-connected regional markets such as the European Union, but the difficulty of coming up with something better sees progress kicked into the long grass.

Secondly, securitisation can often appear an over-reaction, meaning policy-makers approach it with caution. While I would have celebrated the

securitisation of climate change 15 years ago, the last 20 years since 9/11 have seen the terror threat as the primary security issue, not because it presents a bigger threat, per se, but because it is a more acceptable issue to securitise in the eyes of a public concerned about being caught up in terrorist incidents. Climate change, likely to impact many more people, has historically struggled for immediacy and it has taken the extremes of weather and other physical symptoms, like the melting of the ice sheets, in recent years to change this. While it remains to be seen if the current petrol, HGV and CO₂ crises change the view on food security, there is an inherent aversion to stateism in western democracies that can lead to warning signs being ignored until it is very late in the day. This also appeared to be as true of Covid as the climate crisis, with government awareness of the inadequacy of the pandemic response systems apparently no justification for preventative action.

Finally, with climate change thought of as a transnational issue and therefore difficult to deal with unilaterally at nation-state level, it has been approached multilaterally through global institutions like the UN. The horse-trading that goes on in these forums might work for classical issues of diplomacy – territorial disputes, for example – but with environmental issues, particularly climate change, it has had the effect of reducing the issue to a lowest common denominator, fuelled by the inability to agree on cause and effect. As a result, we have little to show for decades of UN environmental summits. This has relevance to food security; the issue has no clear owner, instead involving multiple departments, from DEFRA, to DHSC and Trade & Industry and resulting intra-governmental tug of war leads to the perversity of a trade deal with Australia serving to undermine the concurrent Agriculture and Environment Bills. The rapid set up of a Brexit department to manage our exit from the EU shows what is possible if an issue is taken seriously and perhaps this is needed to ensure coherent policy-making.

It is not hard to imagine the future outlined in the opening paragraph of this piece: one that is resource constrained, shaped by bread basket failure and mass migrations, and increasingly food insecure. If we paint a slightly rosier picture it is still likely to be one in which food insecurity is rife but perhaps of a socio-economic rather than geopolitical nature. The cautionary tale of environmental security suggests that focusing government attention in the face of impending security threats is challenging and often comes only when the threat is upon us. Now with food security as then with environmental security the issue remains marginalised and not thought of as a conventional security threat.

What would it take for pasture for be considered as a strategic asset?

This all needs to change if we are to take the problem of food security seriously and, perhaps more importantly, coalesce behind the right solutions, of which sensitively-managed pasture is one. I see the two as inextricably linked; the practical whole-farm solutions offered by agroecology require equally broad-based policy thinking to support them. Narrow, siloed thinking inevitably prefers simplistic single metric solutions and that is the current state of policy-making in the UK on the issue of food security. The hurdles we need to overcome to get there are high and include, as with climate, long time horizons that are not easily contained within standard political cycles. The farming cycle, in particular, is shaped not only by the seasons but also political and policy pressures and widespread change realistically requires a decade to germinate.

Public perception needs to change too; it has taken the impacts of climate change to become real to ordinary citizens to advance that issue up the political agenda and it remains to be seen whether the current food shortages due to the lack of lorry

drivers is the start of a similar process for food security. The evidence of the pandemic, in which supermarket, just-in-time supply chains recovered from their initial problems and were ultimately lauded for keeping the nation fed, suggests we may have some way to go before food shortages reach a level that drives change. It could well be deteriorating public health that is the trigger for food security to be taken more seriously by the public and policy-makers. This issue was clearly identified in the UK National Food Strategy and I meet more and more GPs who are making the link between ill health and food and seeking to understand farming systems in the search for answers.

For many of us who advocate for agroecological solutions to our parallel environmental and health crises, the key asks typically revolve around subsidy support, infrastructure, land access, transparent data capture and labelling and perhaps true cost accounting. The inherent and perhaps hidden risk here is that these are solutions to a problem – food security – that in many ways doesn't exist right now. In providing a holistic analysis and solutions to multiple problems we are perhaps not focused enough on any of the single issues that are carrying the day and our arguments fall on deaf ears.

In this context it is essential that food security – access to food that nourishes the planet and ourselves – is properly securitised so it sits alongside climate change as a threat.

This might be the only way in which we will be able to tackle the issues in our food system in the round and with a long enough time horizon. You simply cannot approach the food system through a single lens, whether it is climate change, nutrition or access, the trade-offs are unsustainable. If this happens, we might be able to look at species-rich pastures and see them for what they are: a rich, biodiverse ecosystem that supports a range of public goods, including food production. In simple terms, a strategic national asset.

THE SECURITY THREAT THAT BINDS US

COUNCIL FOR STRATEGIC RISKS

The CSR incorporates the Center for Climate & Security. This extract is from The Security Threat That Binds Us (February 2021), and is reproduced by kind permission.

‘Ecological factors can contribute to a number of outcomes that most experts would recognize as ‘traditional’ security threats. These include state conflict, political instability, resource disputes, and transnational organized crime. The changing nature of the risk landscape argues for a doctrinal reboot that infuses ecological concerns into security to better anticipate and address the challenges ahead.’

Global ecological disruption is arguably the 21st Century’s most underappreciated security threat. Human societies are producing rapid, novel, and foundational changes across multiple Earth systems with concomitant – and sometimes severe – consequences for people, societies, and security worldwide. These changes are significant and globally consequential, and include the transformation of the atmosphere’s composition, overloaded and depleted soils, toxified and acidified oceans, and reconfigured freshwater systems. Due to human activities, the biosphere—the Earth system that encompasses all living entities—is destabilizing rapidly and fraying the ecological fabric on which human society depends. Many scientists warn that Earth is entering a sixth mass extinction, a period of rapid loss of biodiversity so consequential that it affects the fate of the majority of multicellular organisms on the planet.

Humanity’s alteration of the Earth’s climate, driven primarily by the discharge of greenhouse gases into the troposphere, is now receiving well-deserved and long-overdue attention from the media, governments, security institutions, and publics worldwide. Broader activities related to ecological or natural security – ones that more directly alter ecosystems and transform the biosphere – have been no less dramatic or consequential but have

been absent from most of these discussions. Further, both climate and broader ecological security risks continue to be under-recognized as issues with tangible and present consequences for safety, security, and strategic interests.

The national security structures and agencies of many countries were designed to protect their respective citizens against malign nation-state actors, having shifted over the past few decades to also recognize threats from non-state actors. Actorless security threats, or threats without ‘proximate’ actors or explicit actor intention, such as infectious disease outbreaks, pandemics, and intensified natural disasters that harm people and infrastructure, present threats to which national security structures and agencies must adapt, and restructure where necessary, in order to meet their missions in the coming years and decades.

The term *ecological security* describes the elements of human, national, and global security that arise from ecological destruction and disruption, and the collapse of ecosystems.

National security must adapt to an era of ecological stress

The January 2020 World Economic Forum report on global risk perceptions identified, for the first time, biodiversity loss as one of its Top 5 Global Risks in terms of both likelihood and impact over the next ten years. The same report also identified the failure of climate action, extreme weather, natural disasters, human-made environmental disasters, and water crises as top risks. Those who closely monitor the global risk landscape increasingly recognize the deepening relevance of ecological and environmental stressors.

But ecological disruption affects people and societies in the context of other dynamic risks. Biophysical pressures from climate change, ocean acidification, and toxification intermingle with social stress factors such as economic instability, national and global governance failures, pervasive inequality, and the retrenchment of both information integrity and expertise. Unmitigated, these compounding factors portend a worrying period of global turbulence and shocks with high geographic variability. The complexity of the Earth, and the deep interconnectedness of its living and non-living components, will stymie efforts to address any of these stressors in isolation.

Ecological factors can contribute to a number of outcomes that most experts would recognize as ‘traditional’ security threats. These include state conflict, political instability, resource disputes, and transnational organized crime. However, the amalgamated risks that nations face over the next several decades are arguably more diffuse, obfuscated, and actorless than those experienced by previous generations. The changing nature of the risk landscape argues for a doctrinal reboot that infuses ecological concerns into security to better anticipate and address the challenges ahead.

What constitutes ‘national security’ has evolved since World War II, especially in the aftermath of the Cold War. This is especially true as the United States and its allies have grappled with a number of threats that stemmed not from conflict or Cold War rivalries, but that still challenged the nation at the strategic level, such as those arising from energy and economic crises, and drug trafficking concerns. In a ground breaking 1974 Foreign Affairs article, former Chairman of the United States Joint Chiefs of Staff Gen. Maxwell D. Taylor warned that ‘the most formidable threats to this nation are in the non-military field.’ Indeed, the systemic shock arising from COVID-19 throughout 2020 and likely beyond is a brutal illustration that nations can incur mass casualties, economic devastation, and social disruption that surpass violent conflicts.

Despite such calls to widen the security aperture, attention to environmental and ecological threats nearly always lags attention compared to more traditional security frameworks. In 2019, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) released an exhaustive global level assessment report by 145 authors from 50 countries that clarified the unprecedented degree and pace of ongoing ecological damage, with startling details about species extinctions, population declines, land degradation, overexploitation of resources, and overall degradation of ecological processes worldwide.

Despite its disquieting implications for humanity itself, the release of the IPBES report seemingly made no waves within the security community, where it remains essentially unknown.

Recognition of these issues is growing, but there is currently little indication that the scale of the threat is broadly understood or that mitigating policy actions are likely to follow without a change in course.

A SOIL-FIRST APPROACH TO SECURITY

ØISTEIN THORSEN

Øistein Thorsen is the chief executive of FAI Farms.

'By 2080, we might have run out of soil – the foundation of all life on Earth. Where the fall of Egypt and Rome took millennia of bad soil management, modern Western civilization, and the global food chains we rely on, might collapse in decades. Against this backdrop it is not hard to imagine how the loss of such a strategic resource – soil – will emerge as a geo-political, international security issue, more important than oil.'

Our collective challenge to nourish ourselves in a changing climate, is often misdiagnosed as big food's responsibility to 'feed the world' through increased intensification of an extractive form of agriculture. The pressure of this 'responsibility' is channeled from financial and commodity markets, to corporate board rooms, and eventually down to farmers in the form of new requirements stipulating how to produce more, with less.

For over a century the dominant assumption of conventional agriculture has been that we can produce more by reducing complexity. This reductionist and extractive mindset is not only putting our food system at risk, but our entire civilization as we know it. Soil erosion and water depletion is happening at an alarming rate and is costing us an annual \$400 billion globally. With 1.9 billion hectares of degraded topsoil worldwide, that's an area the size of China and the US combined, the world could run out of topsoil within 60 years (Project Drawdown).

It's worth repeating this oft-cited fact: by 2080, we might have run out of soil – the foundation of all life on Earth.

In his seminal book *Dirt, The Erosion of Civilizations*, David R. Montgomery described our planet as 'an oasis in space rendered hospitable by a thin skin of soil that, once lost, rebuilds only over geologic time.' Against this backdrop it is not hard

to imagine how the loss of such a strategic resource – soil – will emerge as a geo-political, international security issue, more important than oil.

This should not come as a surprise. It has been in the making for 7000 years. In the late 1930s, American soil scientist W.C. Lowdermilk traveled across Europe, North Africa, and the Middle East to investigate the role of agricultural practices and soil erosion in the rise and fall of civilizations. Lowdermilk, like Montgomery, traced the roots of demise of great civilizations, from ancient Egypt, Babylon and Jordan, the Mayan Kingdom and the Roman Empire, to topsoil erosion and degraded soil fertility.

The introduction of more and more intensive practices, technology and inputs has only accelerated this process of degradation. Where the fall of Egypt and Rome took millennia of bad soil management, modern Western civilization, and the global food chains we rely on, might collapse in decades. The IPCC says unequivocally that human activity in the last 150 years has caused irreversible impact on our planet. Due to human-induced environmental impacts, globally, species are going extinct at 1000-10,000 times the ecologically normal 'back ground rate'. These drastic losses in biodiversity are reducing the resilience of ecosystems and their ability to cope with ecological

shocks, like increasingly frequent extreme weather events caused by climate change.

Alan Savory has said, ‘The greatest danger to humanity is our inability to manage complexity.’ To reverse the trend of degeneration, food industry executives and financiers have a responsibility and unique opportunity to support regeneration. In the European Union, for example, 40% of agricultural land is influenced by the purchasing practices of the top 10 fast moving consumer goods companies (FMCGs) and major retailers. Regeneration is the practice of aligning agriculture with natural principles. By putting life at the centre of every act and decision we are learning how to live and grow better food in ways that are more productive, safer and more resilient.

Nicole Masters suggests the logical place to start this process is to ‘no longer treat soil like dirt.’ Instead, she says, ‘we must take a soil-first approach to regenerate landscapes, restore natural cycles, and bring vitality back to ecosystems.’ Project Drawdown demonstrates that if we could just regenerate a quarter of the already degraded farmland globally, we stand to generate massive returns on our investment: 14.1 gigatons of combined emissions impact, \$1.3 trillion in financial returns and 9.5 billion tons of food.

But like the solution itself (soil regeneration) the implementation of the bold action needed must come from the ground up. To avoid the pitfalls and limitations of ‘sustainable’, ‘organic’ and other initiatives before it, corporate leaders must first listen, in order to find the best ways to mobilise their resources in support of farmer and broad-based community action. This includes creating what the Ellen MacArthur Foundation calls ‘a new collaborative dynamic with farmers.’ From the Arctic to the Amazon, indigenous people are leading

the way in ecological restoration and climate resilience. While we are all indigenous to the Earth, we must take inspiration from those who recognize their indigenoussness, and the fact that we belong to the world, not the world to us.

The goal of regenerative agriculture is not to establish another certification scheme, a differentiated or premium market. Rather, it is to bring about greater understanding of the fact that the health of the ecosystems where we live is the foundation of our own health. Thus, for improved soil health to realise its full potential – to heal nature and secure our place within it – regenerative practices must become the new conventional agriculture.

When farmers see the benefits on their balance sheet, adoption at scale and replication will grow naturally – farmer to farmer. Unfortunately, we don’t have time to wait for natural transition – instead food businesses, supported by governments, must show leadership. In this new brave world, the role of corporate food chains will not be to make commitments on others’ behalf, but rather to show through practice that they can support life-centric de-commodified supply networks that nourish people and nature.

As daunting as this may seem for corporate leaders under pressure to deliver quarterly earnings, it is important to stress that regeneration and re-alignment with nature is not a radical idea that corporations can chose to ignore. It is necessary, logical, rational, reasonable, and natural.

As Chief Luther Standing Bear, Sicangu and Oglala Lakota Chief, said, ‘man’s heart away from nature becomes hard; lack of respect for growing living things, soon leads to a lack of respect for humans too.’

A LONGER-TERM PERSPECTIVE

EDMUND SIMONS

Edmund Simons is an historian, a Fellow at the Cultural Heritage Institute (Royal Agricultural University) and Head of International Heritage at Wessex Archaeology.

'We have been telling cautionary tales of lost Eden's since the earliest times, but 'collapse' is not an inevitable part of the human condition. Now, as we face the consequences of the Anthropocene, perhaps those populations that see themselves least at risk will be hardest hit – for the people who work the land, as always, have better capacity to ride a civilisation's collapse. If however our complex societies can repair their relationship with the land, perhaps then we will be able to arrest collapse before our systems crumble.'

As an archaeologist and historian, it may seem curious that I have been asked to contribute to this document – the twin climate and biodiversity crises are very current, and the results are something which we perceive as happening now or lying in the future. This is true, but I believe that those who study the past in a holistic way and look at very long-term trends, can provide insight into what may happen and help develop ways to help prevent some of the more damaging effects of the current crises.

It is, of course, very clear that the factors which caused the current situation lie in our history, in our reliance on fossil fuels since industrialisation and in the tendency of our species to over-exploitation of and disregard for, the natural environment. Data from numerous sources from ice cores to pollen analysis allows us to establish when these changes happened and to map their effect on even the most remote and 'pristine' places. Science has provided a mass of data on what effect the Anthropocene has had on our environment from profound changes to our atmosphere to soil health, deforestation and even sea chemistry, these are all archaeological events with a cumulative effect on the planet. With new research we are starting to understand how and when they happened and how

they relate to changing technologies, population growth and exploitation of resources.

How then can our understanding of our history inform how we deal with these crises, and how can looking at the past help us plan for the results of climate change and biodiversity loss, particularly food security? The answer, of course, is remarkably simple, it has all happened before, numerous times over many millennia, in societies of all types, complexities and cultures. To a large extent humans react to stresses caused by internal and external factors in a way which is universal and even predictable.

This isn't the place to explore this history in any depth, you may be familiar with many of the examples already, the dust bowls of the US in the 1930s, the Irish Potato Famine, the 1984 Ethiopian Famine, even recent history, and current events are littered with examples we can learn lessons from. Food insecurity and famine have been with us since antiquity and have shaped who we are, we have been telling cautionary tales of lost Eden's since the earliest times. This does not mean it is an inevitable part of the human condition, yet, again and again, we ignore the lessons of the past and do often not see the conditions in which these horrors occur until it is too late.

It is useful to understand how examples from the past can help us plan and how we, as a species, react to changes, particularly in food security. Looking to history is sometimes already used in disaster management planning and in planning for humanitarian relief, but the focus tends to be on relatively recent events and on creating good outcomes for individual scenarios. If we are to really understand the implications for the species, we need to look further, both forwards and backwards in time and to understand the complexity we are dealing with, only then can we produce data which will be genuinely useful.

If we concentrate on food security, understanding the individual causes which could lead to problems is, of course essential. Drought, excessive rainfall, soil health, conflict and war are all decisive factors, and we are familiar with the vicious cycle of events any of these can bring about. Soil scientists can develop ways of preserving fertility, engineers can build irrigation systems or dams, military planners can develop strategies and contingencies. This is what we must do, what we urgently need to do, but it deals only with what we archaeologists think of as the very short-term (anything under 150 years), it is tactical rather than strategic and may only postpone outcomes.

We must also ask, what we are trying to avoid? We like to divide time into named societies or events we can understand terms like 'the Tang Dynasty, The Roman Period, The Inca Empire', we like these to have start and end dates we can define, and this allows us to understand history a little better and give rather random events meaning and we are doing it now, as we enter the Anthropocene. One product of this is the concept is that societies, or Empires or cultures somehow 'collapse' or 'fall'. To an extent this is true and can happen because of cataclysmic events, but of course the people generally remain the same and the world goes on, they may move away, who they think they are may change, but we adapt and change continuously. What can be lost during a 'collapse' are factors such as urbanism, technology and, most importantly,

concepts of freedom. Food security is generally the main factor in 'collapse' and 'fall', without secure food people simply move or perish and this pattern can be seen repeatedly throughout history.

Interconnectivity and complexity are key factors to understand. Almost all human societies rely on a complex series of connections, interactions, and relationships between groups. The complexity of these connections massively increases as a society grows, spreads or influences others around it. Interconnectivity often leads to inter-reliability and whilst this is a strength, it is also a weakness.

The 'collapse' of societies is almost never a one-off event, elements may take place surprisingly quickly, but they are often just a tipping point caused by many factors over a long period of time. This is why traditional planning and analysis which looks mainly at the short-term cannot really assess the complexity of unfolding events over the longer-term.

An example (amongst many) is the 'collapse' of Roman North Africa. These Roman colonies were once part of a thriving agricultural landscape of immense sophistication, where there are now ruined cities sitting in the desert. What happened should be easy to understand there is a mass of historical accounts, archaeological sites and environmental evidence but recent work has shown something of just how drawn out this process was.

The political factors were significant, but, in the past, have been overplayed to suit foreign narratives and even colonialism. Invasion by the Vandals certainly had an effect in the 5th century, as did the later Umayyad conquest in the 7th, the agricultural machine which existed to serve the Empire was no longer connected to its key markets, these all contributed to decline. Other factors were the marginalisation of native Berbers and a crisis within the church.

Recent work has shown that many urban centres were still flourishing at a late date (and continue to this day), whilst others were vanishing. The end (if there is ever such a thing) when it came, may have

been more sudden than we had previously expected, grazing by pastoralists and herders on arable land at just the same time as drought meant that complex irrigation systems ceased to be maintained. It is also probable that the clearing of forests for agriculture at the very start of Roman exploitation effectively started a cycle which reduced rainfall and the seeds for eventual collapse were there from the beginning. From an incredibly sophisticated rural and urban society to desertification and population movement may have been incredibly quick, but it is important to remember this was only the end of a process which has been developing for several centuries and which created a cumulative fragility in systems which would not have been apparent at the time. In addition, the nature of settlement and agriculture changed to more sustainable locations and in many areas continued uninterrupted until the present day.

There are numerous similar examples. The end of the civilisation of the Maya of Central America is also in recent years becoming far better understood, partly due to satellite imaging, analysis of lake deposits, luminescence in stalactites, remote sensing as well as conventional archaeology. These all give evidence of prolonged and severe droughts. Here again the 'collapse' takes place over several centuries. An important factor appears to have been pressure on farmers to produce more to support an ever-growing population; fields which were formerly left fallow to recover become over exploited. The scale of the farming and the deforestation is so great that it affects the climate, particularly rainfall. This was a society with considerable engineering skills and attempts are made to hold and harness water, but it is too late. As with North Africa, lack of food security is borne from a massive population growth which is ultimately unsustainable by the agriculture of the time. Such insecurity causes populations drift away and cities simply become superfluous. The Maya thrive today, but their incredible civilisation simply ceased to exist and the causative factors start centuries before the 'end'.

There are many hundreds, if not thousands, of analogues from prehistory onwards and throughout the archaeological record again and again we see a very similar pattern of causative factors building up, with environmental changes, leading to changes in society. The idea of 'collapse' is often overstated, particularly in rural settings the same people often continue similar lives, but on a smaller scale. Understanding the timescale is the key to understanding the sequence of events and this may be far longer than one would imagine.

Part of the study and analysis of history and archaeology is looking at questions such as these again and again. The data we produce is used by futurologists and by politicians and other scientists; it is compared to data produced by soil scientists, agronomists and climatologists. We do, however perhaps tend to look at our numerous case studies in isolation, as discrete events which happened in the past and in different parts of the world and which we can draw lessons from.

I think this approach isn't entirely helpful – we are no longer looking at countries or even regions being harmed by localised change – we all belong to an intricately connected technological world; we are now all part of a single civilisation with all the strengths and weaknesses that affords. The environmental change is no longer localised, it is in the atmosphere of the entire planet, in the most remote places and it is far greater than any which faced the many hundreds of past societies which underwent 'collapse' or 'fall'.

Whatever is achieved to combat climate change, if we want to keep something of our 'civilization' the most important step must be establishing the conditions for soil and food security. I am reminded of a set of frescos in Sienna's Palazzo Pubblico in Italy, painted in 1338 and 1339 by Ambrogio Lorenzetti. They are an allegory of good and bad government, the panels showing 'Good Government' depict a city with overflowing granaries, there is dancing in the street and building work, the countryside is rich and peaceful. In 'Bad Government', the countryside is bare and

stalked by armies and in the town the buildings are ruined, the granaries empty and people are simply leaving to make a better life elsewhere. In 2021 we are still faced by the same food security alternatives as in the 1330s and, as always, it is useful to look at the past when looking to the future.

In conclusion, perhaps those populations that see themselves least at risk will be hardest hit. For the people who work the land, as always, have the capacity to ride the collapse of our own civilisation. If our complex societies can repair their relationship with the land, perhaps we will be able arrest collapse before our systems crumble. As we look to the future however, we have two great advantages over the societies that preceded us, firstly, thanks to archaeology, we know far more about past events, we have a mass of data which we can use to model possible futures and secondly, we have developed over the last 100 years the science and engineering which can perhaps help us understand and counter some of the worst effects. We are also a world-wide society where decision makers and scientists can communicate instantly and where public opinion

can be world-wide. We need to act now though and become one of those few societies which were able to break the familiar cycle which leads only to collapse.

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- The concept of 'futuology' has a very long history and researchers tend to illustrate possible scenarios with examples from human history. In recent years 'Collapseology' a multi-disciplinary systemic approach has gained acceptance and takes a view that industrial society may already be in collapse. See, Servigne, Pablo; Stevens, Raphaël (2020). *How Everything Can Collapse*. Cambridge: Polity
- The study of the end of civilisation has a long history and arguably starts a eschatology (the theological study of the end of humanity), works of apocalyptic literature, the early sociological and historiographical research of the likes of Sima Quian and Ibn Khaldun.
- The author is working on a long-running project investigating human impact on the remote sub-Antarctic island of South Georgia. Traditionally the impact has been considered as buildings, wrecks, the remains of the whaling, sealing and fishing industries, the reality is far more complex. The real effects are the massive changes wrought by climate change and pollution, this is evidenced in the glaciers, the soils, the lakes and most importantly in the sea. Even this most remote and supposedly 'pristine' of places has been massively directly impacted by human activity.

NATURE AND FOOD SYSTEMS IN THE POST-COVID-19 WORLD

LAURA HIGHAM

Laura is a programme manager and veterinary Consultant at FAI Farms.

‘Coronavirus is a One Health disaster presenting a colossal challenge to human civilisation. It is costing lives, devastating livelihoods, threatening food security, crashing markets and widening the socioeconomic inequalities that plague our society.’

This pandemic emerged as a consequence of human behaviour at the interface with wildlife. Once the storm has passed, we will have a once-in-a-lifetime opportunity to bring about systemic change that renews our relationship with the natural world, and to redesign our food system to work for animals, people, and our shared environment. Without reflection and adaptation, this infectious disease outbreak will not be the last.

We must cease the destruction of nature

75 per cent of new infectious diseases are zoonotic, transmitted from animals to people, and most of these zoonoses originate in wildlife. These new diseases emerge when they have the opportunity to spill over from one species to another, for example when people capture, transport, trade, consume, and encroach upon the habitats of wild animals.

AIDS arose through human contact with chimpanzees, probably when hunters targeted them for food. Ebola has also been linked to the wild animal meat trade, emerging in humans from an infection reservoir in bats. Nipah virus originated in the tropical forests of Malaysia in fruit bats, whose natural habitat had been destroyed by deforestation. Regardless of their source, these disease events are our collective responsibility.

Coronavirus is the global pandemic currently gripping the world. A novel viral disease first diagnosed in the city of Wuhan in China, it was traced back to a cluster of patients following their visits to a seafood and wet animal wholesale market. Genomic sequence analysis indicated that the virus probably spread to humans from bats via other wildlife species.

The close confinement of animals of different species creates the ideal conditions for existing viruses to form novel strains and jump between hosts. This pattern of transmission is reminiscent of related diseases, like SARS-CoV, associated with bats and civet cats, and MERS-CoV, transmitted by bats via dromedary camels. These conditions are created in different guises in many settings across the world.

Failing to protect wild spaces can also increase the risk of spreading existing diseases. In the Amazon, an increase in deforestation by four per cent can escalate malaria incidence by 48 per cent, and the risk of Lyme disease also increases when wildlife reservoirs are depleted by deforestation.

The evidence shows that healthy wildlife populations help protect us from infectious disease. When we interfere with biodiversity and wildlife habitats, we threaten species that each serve a vital role in the ecosystem. As well as buffering the spread of diseases to humans, healthy ecosystems

support us by pollinating crops, draining and filtering water, decarbonising the atmosphere, recycling nutrients, forming and maintaining healthy soils, regulating climatic temperatures, suppressing pests, and producing the food, fibre, fuel and energy resources that we depend on. By ceasing the destruction of nature in all its guises, we would be protecting the biodiversity that enriches our shared environment, and also helping the natural world to protect us.

We can (and must) decarbonise

The pandemic has been characterised by a downturn in economic activity, and as a result, drastic reductions in climate emissions and air pollution have been observed in countries in lockdown. China's CO₂ emissions were reduced by a quarter during the crisis, and emission reductions in the country are said to have saved the lives of at least 1,400 children under five and 51,700 adults over 70. Satellite imagery has revealed a significant decline in nitrogen dioxide emissions in Italy, coinciding with a reduction in traffic and industrial activities.

However, some commentators warn that a bounce-back in air travel, tax breaks for polluting industries and low oil prices that threaten to stifle a transition to clean energy may mean that Coronavirus leaves a negative ecological legacy. Some note that fossil-fuel dependent industries are being bailed-out and environmental protections are being rolled back under the cover of emergency responses to the crisis.

The environmental impacts of the downturn indicate that through regulatory resolve and enforced behaviour change, it is possible to achieve our climate goals. When governments understand a clear and present danger, they can mobilise radical, collective action. Social distancing and isolation have taught us how to work and collaborate remotely, connect with our neighbours through online networks, source food from local suppliers or produce our own, value our food and reduce waste,

savour slow quiet time with our families, discover secret green spaces and reduce our reliance on material goods. Many of these lifestyle choices are conducive to a slower-paced and environmentally sustainable way of life.

Our governments should take this opportunity to show the same resolve and regulatory muscle to address the climate and ecological crisis through sustained and systemic reform. This is an opportunity to reset, and choose green pathways to re-boot the economy in the post-COVID world, making it our only option but to adjust our lifestyles for a sustainable future.

We need a resilient and diverse food system

Cataclysmic events such as the Coronavirus pandemic reveal the very best of human nature – solidarity and resolve, kindness and courage. But such events also trigger fear responses such as panic-buying – an attempt to regain control in the face of uncertainty. Retailers have stepped up to meet our changing demands, adapting their international supply chains and collaborating with their competitors. Key workers maintaining our food supply chains from farm to checkout are finally earning the public respect that they always deserved. But panic buying has turned fears of food shortages in to self-fulfilling prophecies, and shelves of essential supplies often lay bare, affecting the most vulnerable in our communities.

Coronavirus has exposed the fragility at the heart of our global food system, defined by increased centralisation and reliance on a dwindling number of producers, crops and supply chain actors. Surging demand has highlighted our dependence on the small number of retailers dominating our food landscape. Retail giants that supply us with low-cost food are resilient to shocks in one location or affecting a single commodity. However, when systemic disruptions hit their complex, international supply chains and 'just in time' logistics networks, impacts can be seismic. As bars,

restaurants and hotels close, food is being discarded before it gets out of the farm gate as complex supply chains scramble to adapt. Diversifying and decentralising our food system by increasing the contribution of local food producers and suppliers would help to buffer supply and demand fluctuations whilst allowing independent businesses to flourish.

The crisis has underlined our reliance on a limited number of staple ingredients – ingredients now in short supply, that usually dominate our dinner tables and shape our agricultural landscapes. Our pursuit of low-cost staple ingredients has consolidated the farming industry, favouring a smaller number of large farms, intensive monocultures and integrated supply chains. It has squeezed family and mixed farms to the fringes of our food system. The monocultures that now dominate our agricultural landscapes in the name of ‘feeding a growing population’ inherently strip complexity and diversity from our soils, our landscapes and our food system. And they depend upon fossil fuel-derived fertilisers and increasingly frequent pesticide applications, which are associated with water pollution, insect population collapse and human cancer risk. The reductionist approach in more intensive forms of agriculture

stifles biodiversity at all trophic levels, and in doing so erodes the resilience of our food system.

Fruitful harvests for ourselves and for our children depend on soil fertility, pollination, effective conversion of solar energy, clean water supply, and many other services that are provided by healthy ecosystems. Coronavirus has given new impetus for us to transition to a healthy and vibrant food and agriculture system that produces a wide range of products whilst rebooting the functionality of an ecosystem, promoting biodiversity and supporting rural communities. Our farming landscapes could be increasingly characterised by land mosaics and locally-relevant practices yielding seasonal foods that diversify our landscapes as well as our diets. A transition to more diverse diets would help to alleviate our panic when staple ingredients are no longer on offer.

Opportunity follows crises. We can choose to emerge from this remarkable time in our history committed to renewing our place in the natural world, and building resilience through diversity at all levels in our food system from the soil microbes under our feet and the species occupying our landscapes, to the food on our plates and the people producing and supplying it.

SOLUTIONS

HOLISTIC SOLUTIONS FOR FOOD SYSTEMS

DR ASHLEIGH BRIGHT

Ashleigh has a PhD in Zoology from the University of Oxford and now works as an independent consultant from her native country, New Zealand. Ash is also an advisor to the Food & Global Security Network.

‘For the last 60 years our global food systems have been focused on yields and productivity – but globally we have not solved food security and at the same time we have created widespread ecological crises. We need a renewed focus on holistic solutions and metrics, which account for the multitude of benefits that crops and livestock provide in the long term. This holistic approach may require a different mind-set, skills, methodology and produce fewer black and white results than we are used to, but they are necessary if we are to truly value ecological, human, and animal well-being.’

A straight-forward solution to any challenge is appealing. Our food systems and the complex ecosystems on which they depend however are anything but simple. In this article, I will consider the necessity of taking holistic approaches to implementing solutions to global challenges such as climate change, biodiversity loss, rising food insecurity and zoonotic pandemics, and the importance of holistic metrics to monitor progress and limit unintended or unconsidered consequences.

Food security – the problem with a singular focus on yield

The Green Revolution is used to describe the large-scale transfer and adoption of new technologies in the agricultural sector in the 1950’s and 60’s, particularly in developing countries. These technologies included chemical inputs (such as fertilisers and pesticides), irrigation technologies, farm mechanisation (such as tractors), and high-yielding rice, wheat, and maize seed varieties,

which required fertilisers and pesticides to produce their high yields.

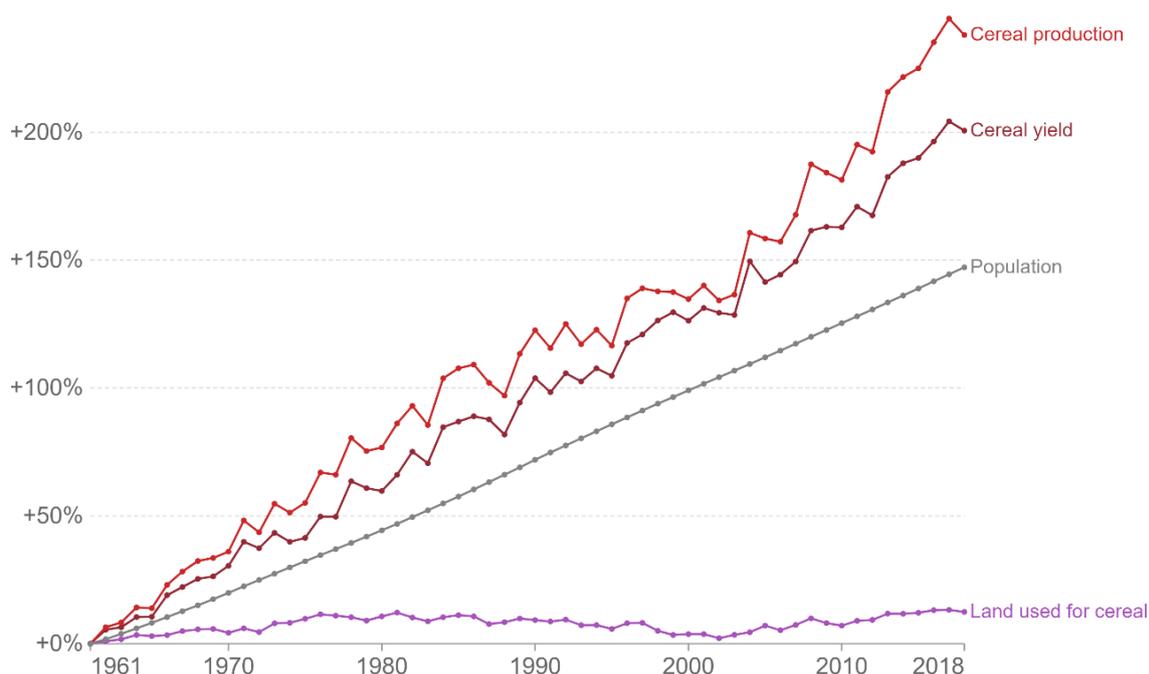
The focus of the research, innovations and policies of the Green Revolution was to address the problem of impending famine from a growing imbalance between population and food supply. Productivity was key and yield (amount of product harvested per unit of land) the predominant metric of success.

Since 1961, the average cereal yield has increased by 200 per cent, with a corresponding small increase in land expansion ([Figure 1, below](#)).

Alongside the high yield crop varieties came faster growing livestock breeds, supported by the availability of comparatively cheap animal feed crops, particularly pig, poultry and fed aquaculture, which could be reared in high numbers in a small area. The combination of population growth, rising per capita incomes, and urbanisation also created an unprecedented growth in demand for food animals. This growth has been termed a ‘Livestock Revolution’ by the FAO. Production of all major meat types has been increasing in absolute terms ([Figure 2](#)). In relative terms, the share of global meat types has changed significantly over the last

Change in cereal production, yield and land use, World, 1961 to 2018

Population and cereal production, yield and land use figures are indexed to the year 1961 (i.e. 1961 = 0).



Source: Our World in Data based on World Bank, Food and Agriculture Organization of the United Nations
OurWorldInData.org/crop-yields • CC BY

Figure 1. Change in cereal production, yield and land use, World, 1961 to 2018 (Ritchie, 2017).

50 years. In 1961, poultry meat accounted for only 12 per cent of global meat production; by 2013 its share has approximately tripled to around 35 per cent.

Like crops, the focus of food animal production is yield; ‘feed conversion ratio’ (FCR), is the weight of feed administered over the lifetime of an animal divided by weight gained and is a key metric for comparison and ‘efficiency’. Fed aquaculture and chicken have the lowest FCR’s, and ruminants such as sheep and cattle, the highest. More ‘efficient’ systems are often considered to have the lowest FCRs.

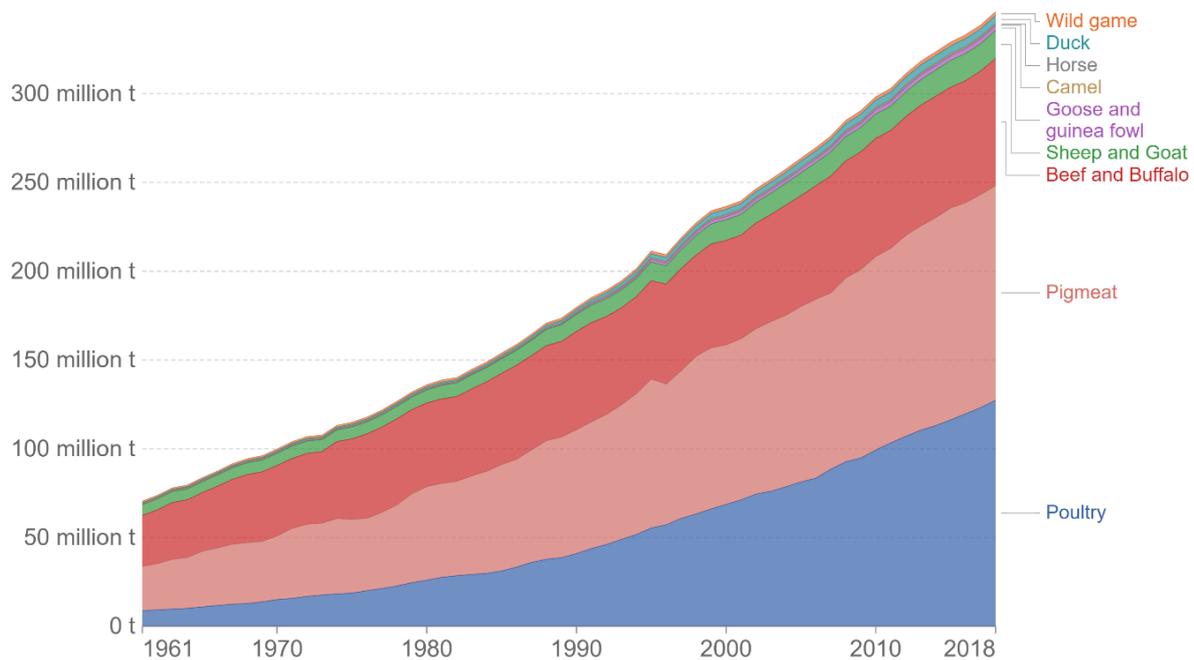
The end result of all this focus on yield is that globally, we produce more than enough food to sufficiently meet energy and nutrition requirements of the global population. But we have not solved food security issues. Food security is about more than there simply being enough food to go around: access (i.e. affordability, equitable trade and distribution networks) and utilisation (food waste)

is also critical. According to the latest SDG progress report, even before the COVID-19 pandemic, the number of people experiencing hunger globally and suffering from food insecurity had been rising gradually since 2014.

We have also created other problems. The spread of Green Revolution hybrids resulted in the cultivation of fewer varieties of crops, the large-scale loss of indigenous varieties (reduced agricultural biodiversity) and farmers who are often more susceptible to crop failure. The FAO’s 2019 report State of the World’s Biodiversity for Food and Agriculture concluded that while more than 6000 plant species have been cultivated for food, fewer than 200 make substantial contributions to global food output, with only nine accounting for 66 per cent of total crop production in 2014. The world’s livestock production is based on about 40 animal species, with only a handful providing most of the global output of meat, milk, and eggs.

Meat production by livestock type, World, 1961 to 2018

Our World
in Data



Source: UN Food and Agricultural Organization (FAO)

OurWorldInData.org/meat-production • CC BY

Note: Total meat production includes both commercial and farm slaughter. Data are given in terms of dressed carcass weight, excluding offal and slaughter fats.

Figure 2. Meat production by livestock type, World 1961 to 2018 (Ritchie & Roser, 2019)

Appropriate research and policies to incentivise judicious use of chemicals such as pesticides and inorganic fertilisers, which these new high yielding cultivars required, were largely lacking during the Green Revolution. Furthermore, techniques such as irrigation, mono-cropping and repetition of the crop cycle for increased crop production depletes the soil's nutrients and water table. The high concentration of livestock in a small area requires intensive energy and water use and creates large amounts of animal waste that need to be disposed of. Unintended consequences from soil degradation, pollution from chemical runoff, animal effluent, biodiversity loss and unprecedented rates of freshwater withdrawals have had serious environmental impacts and degraded the resource base on which our food production depends.

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Climate change – and the problem with a singular focus on carbon sequestration

In recent years, there has been increasing focus on the role of tree planting to address climate change through the removal of large amounts of carbon dioxide from the atmosphere. Some researchers argue that tree restoration is the most effective climate-change solution we have available and an expansion of plantation forestry – growing trees of a limited variety of ages and species (for example, in monoculture plantations) is taking place in certain parts of the world.

For example, a 2021 study in New Zealand by Orme et al., found that between 1 January 2017 and 31 December 2020, 92,118 ha of beef and sheep farmland were sold into exotic forestry plantation (2017 = 7,004 ha; 2018 = 27,567 ha; 2019 = 38,502 ha; 2020 = 19,045 ha). Of this 92,118 ha, it is estimated that approximately 34 per cent of these land sales were to carbon farming companies.

The researchers argue that this focus on carbon is likely to have knock-on effects on food production: 64 per cent of the proposed planting in the New

Zealand study is on low-erosion or moderate erosion land, which is often highly productive hill country. Beef & Lamb New Zealand (the industry organisation representing NZ beef and lamb farmers) estimate that the intended transitioning of productive land to exotic forestry over the last three years will result in a reduction of ~700,000 sheep, with downstream implications for processing companies and supplying services. There are other threats and risks from substantial increases in exotic plantation forest, such as physical and social impacts on local communities, biodiversity impacts from wilding species, exposure to fire risk and reduced water flows in drought areas.

There are also concerns that new forestry plantations are distracting from the need to rapidly phase out use of fossil fuels and protect existing intact ecosystems. Without limits on forestry offsets (i.e. how many carbon credits can be purchased to offset emissions), the more likely outcome according to Beef & Lamb NZ is an even faster increase in the sale of sheep and beef farms into forestry, with little or no change in fossil fuel emissions behaviour or commitment to real climate action from large emitters.

The way forward – holistic solutions and metrics

Nature Based Solutions – Defined by the International Union for the Conservation of Nature (IUCN), Nature-based Solutions (NbS) are 'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.' Through the work of organisations like the IUCN and The University of Oxford's Nature Based Solutions Initiative (Figure 3), NbS have gained popularity as an approach to address climate change and biodiversity loss while supporting a wide range of sustainable development goals.

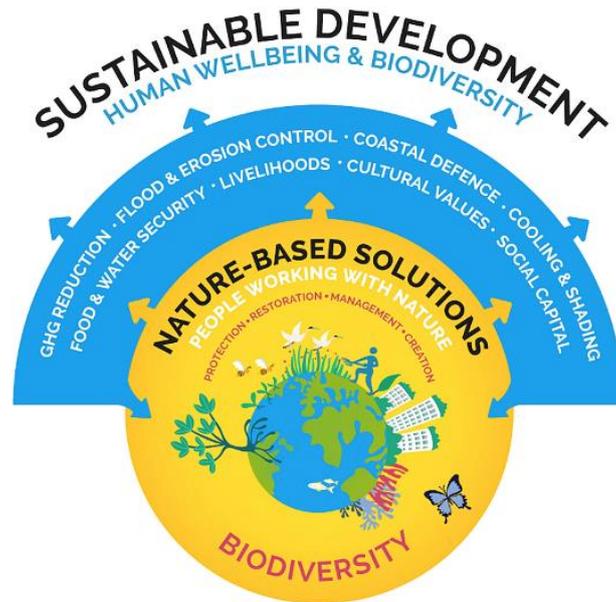


Figure 3. Conceptual diagram of nature-based solutions. People and nature, together (yellow circle), co-produce a variety of outcomes (ecosystem services or Nature's Contributions to People, blue band) which benefit society; these benefits can, in turn, support ecosystem health (blue arrows)(Seddon et al., 2021).

NbS have become prominent in international policy and business discussion on climate change. For example, they were highlighted in a recent landmark synthesis report in 2019 by The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). IPBES described NbS and 'nature-friendly' solutions as cost-effective ways of meeting the Sustainable Development Goals. The first draft of the post-2020 global biodiversity framework, as set out by the UN Convention on Biological Diversity (CBD), include NbS such as restoring peatlands and adopting regenerative agriculture contributing at least 10 GtCO₂e (gigatonnes of equivalent carbon dioxide) a year to global climate crisis mitigation efforts. This is around a third of the 32 GtCO₂e annual emission reductions needed according to UNEP, while ensuring there are no negative impacts on biodiversity.

A 2020 review by Chausson et al., mapped global evidence on the effectiveness of nature-based interventions for addressing the impacts of climate change and other extreme weather events, which was followed by the launch of an online evidenced-based platform: naturebasedsolutionsevidence.info

Much work has also been done to improve the understanding and conceptualisation of NbS, including development of a Global Standard for NbS by the International Union for the Conservation of Nature (IUCN) and work by a consortium of conservation and development organisations and research institutions led by The Nature Based Solutions Initiative to develop four high-level guidelines on how to develop successful NbS. (1) NbS are not a substitute for the rapid phase out of fossil fuels; (2) NbS involve a wide range of ecosystems on land and in the sea, not just forests; (3) NbS are implemented with the full engagement and consent of Indigenous Peoples and local communities in a way that respects their cultural and ecological rights; and (4) NbS should be explicitly designed to provide measurable benefits for biodiversity.

Alongside the planning and implementation of NbS are metrics. *NbS activities need to be evaluated and monitored with the right metrics, to account for the multitude of benefits they provide in the long term.*

Global Farm Metric - The Global Farm Metric (GFM) is a measure of on-farm sustainability developed by the Sustainable Food Trust that can be used by land-



Figure 4. The Global Farm Metric; 11 categories of sustainability and associated measures(Sustainable Food Trust, 2021)

managers to monitor their impacts (positive and negative) on the environment, economy, and society to inform sustainable decision making.

The GFM comprises eleven sustainability categories each with multiple measures which land managers carry out on their land and then input to produce a sustainability score for each category (Figure 4). This gives a clear and holistic indication of the areas where they are performing well and where they need to improve.

The GFM is designed to be adaptable to different climates, cultures and contexts, no matter the size, scale and income of the land. ‘A farmer in India can then have a conversation with a farmer in North America about how they’re doing on their soil indicators in a way which is genuinely comparable and meaningful to them both.’ While the GFM is still in the development phase, and further work is being undertaken on metric and digital development and trialling on-farm, such an adaptable and universally comparable tool is crucial if we are to make informed global decisions about sustainability actions.

Summary

There is an urgent need to shift our focus away from silver-bullet solutions such as monoculture forest

plantations to offset carbon emissions or ever-increasing crop yields to improve food security – they are unsuited to the stark *whole ecosystem* challenges we face.

Approaches such as NBs can inform the planning and implementation of sustainability actions and metric frameworks such as the GFM can evaluate the outcome of those actions through a holistic lens. They may require a different mind-set, skills, methodology and produce fewer black and white results than we are used to, but they are necessary if we are to truly value ecological, human, and animal well-being.

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A STRATEGY FOR AGROECOLOGY

SUE PRITCHARD

Sue is the chief executive of the UK Food, Farming & Countryside Commission.

‘It’s time to acknowledge that, at the same as working tirelessly for 1.5 degrees, we must risk-manage for 2.5 degrees. And, as we’ve started to see clearly in the last couple of years, more diverse and flexible systems are more resilient systems – from farms, to households, to communities, to businesses, to whole sectors.’

Here in the UK, the fragilities of the modern food system have never been more evident, as we navigate our way through a pandemic, and cope with the material reality of exiting the European Union and start to negotiate new trading relationships around the world. From supply chain logistics to staffing, in picking, processing and packing, the gaps on shop shelves bring home to us that those things we thought we could take for granted, in the affluent global north, are no longer so certain.

These are not the only crises we’re dealing with in food systems; the triple crisis of climate change, biodiversity loss and diet related ill health is prompting far reaching reflection on what we really need from a sustainable food system. It is now widely acknowledged that the increasing intensification of the global food system over the last sixty years has contributed to climate breakdown and damaged the natural resources on which all life depends. Whilst economic growth has improved millions of lives, it has also altered food and farming around the world, and led to huge costs to people and planet. And even the gains made in the richest countries are now stalling, in large part due to the foods we eat and the air we breathe.

Yet the IPCC Sixth Assessment report makes it clear we are failing to grasp how serious this crisis really is. Not only will we fail to meet the 1.5 degree target in the Paris Agreement, but, in their most likely

scenario, we will exceed 2 degrees of global warming and could reach 3.5 degrees by 2080. This will be catastrophic for Earth’s natural systems on which we all rely. We are already seeing the results of a changing climate in the rise of ‘unprecedented’ events around the world – storms and floods, heatwaves, fires, droughts and escalating extinctions.

In the face of this assessment, we need nothing less than a transformation of the whole food system, from the ground up. Literally.

As we approach COP26 in Glasgow, countries and businesses are setting out their plans to reduce their emissions and invest in a nature and climate positive future. A plethora of new initiatives has been announced – the Glasgow Financial Alliance for Net Zero, the Race to Zero, the Mission Possible Platform and more... The new energy, mobilising behind the climate challenge is encouraging (and overdue!) with investments in the technologies that will set a trajectory to net zero, and the plans and finance to back them.

But it is also essential to focus on the no-regrets and eminently deliverable nature-based actions that can be taken right now – and many of these are in the food and farming sector.

In the Food, Farming & Countryside Commission’s latest reports we set out how a UK transition to agroecology by 2030 is the most plausible and fair pathway to more sustainable land use, food and

farming. With the right enabling conditions in place, we find that:

- A transition to agroecology is feasible and achievable, keeping us fed, balancing trade without exporting production, and reducing diet-related ill-health.
- Emissions will be reduced by 66-77%, and this could be further improved if we account for the removal of imported deforestation via soya, reductions in food waste, and adopt the GWP* method of accounting for methane emissions.
- 1.8m hectares (10%) of current agricultural land would be released for ecosystem restoration.
- Biodiversity will be dramatically improved across all productive land by farming for more diversity in crops, grasslands and livestock and reducing synthetic fertilizers, pesticides and nutrient losses.
- A transition to agroecology works best at scale, allowing these interdependent benefits to develop in synergy across farms, communities and landscapes.

The right enabling conditions are fourfold.

Firstly, systemic problems require system-wide solutions. Aligning policies across government departments is essential, so that gains in one policy area are not undermined by actions in another. Specifically, a transition to agroecology requires: real and practical support for farmers through the new farm payment schemes, backed by knowledge and advice services; investment in diverse local food businesses and supply chains, using public procurement to start to rebalance the market; progressive trade deals which uphold high standards; frameworks for better land use decision making; and, in the UK, implementing the recommendations in the National Food Strategy, tackling the junk food cycle.

Secondly, we need aligned and co-ordinated actions by business. For too long, the food sector has worked on a price first model – cheap commodities, cheap labour, cheap hospitality, and cheap food baskets. This has externalised the true cost of food production, to be picked up by the public purse –

dealing with pollution, propping up low wages, and treating diet-related ill health, whilst the use of food banks is still spiralling. And it has locked farmers, producers and citizens into an increasingly dysfunctional system whose impacts now outweigh benefits. Healthy sustainably produced food has to be good business for everyone involved in it, with a serious commitment from food supply chains, backed by a rising regulatory baseline, to make fair and healthy, nature and climate positive food systems the norm, where the risks and rewards are more equitably shared between producers, shareholders, customers and communities.

Patient and innovative finance is the third critical component. At the moment, finance seems most attracted to the shiny new technologies that promise big results at a point in the future. Vertical farms have their place, but we can't live off basil and strawberries (though I do have a fabulous recipe for strawberry and basil soup). The finance community must start to look hard at both the serious and practical investment possibilities, and also at the potential stranded assets in the food system. For those big global agribusinesses who've cornered the markets in commodities and chemicals, the future must now become clear. Fund managers need to send unambiguous signals to businesses, and expect to see, in return, serious and workable plans for rapid transition away from these climate, nature and health damaging products.

Instead, the resources must flow to where the real work is needed; investing in a fair and resilient food system that makes sure that healthy, sustainably produced food is easily available to everyone everywhere; that provides a fair return and good work for all in the supply chain. This means investing in practices that improve soil health and increase soil carbon, avoiding bare soil and protecting soil structures, incorporating ruminants into rotations for natural fertility, introducing herbal leys instead of grassland monocultures, incorporating trees and hedges into farmed landscapes, for food, fuel, shelter, and nature, eliminating synthetic chemicals and allowing

natural processes to flourish – ‘when we farm in harmony with nature, nature comes to help us.’ These readily achievable and effective methods are available right now, to help sequester carbon, recover nature, increase farm profitability, and improve health and wellbeing. For the UK, or any country, it means taking responsibility for growing more of the healthy and sustainable foods we need, and are ecologically suited to grow in our landscapes, for a more resilient and secure food future.

Finally, it's time to acknowledge that, at the same as working tirelessly for 1.5 degrees, we must risk-manage for 2.5 degrees, by informing and resourcing communities to understand and adapt to the inevitable impacts that this scenario will bring. Working with communities to design-in resilience has to start now – space for nature, housing and

infrastructure, cleaner transport and energy, health and social care and of course food systems. It is through this real, practical, context and place-specific work that the realities and possibilities for tackling the climate crisis, the nature crisis, and the health crisis simultaneously really come to life.

To be clear, this isn't to give us reasons not to act now to meet the Paris targets; rather, when we acknowledge and start to work towards the implications of *not* meeting them, the incentives for taking meaningful actions *right now* are stronger. As we've started to see clearly in the last couple of years, more diverse and flexible systems are more resilient systems – from farms, to households, to communities, to businesses, to whole sectors.

And, to borrow a phrase adopted by a bold new innovator in farming, Andy Cato of Groove Armada, if we can fix food, we can fix the planet.

INDIGENOUS REGENERATION: DECOLONISING THE MIND

REGINALDO HASLETT-MARROQUIN

Regi began working on economic development projects with indigenous Guatemalan communities in 1988. He consulted for UNDP and advised the World Council of Indigenous Peoples. He's now president of the Regenerative Agriculture Alliance, based in the USA. His book, 'In the Shadow of the Green Man' is subtitled, 'My Journey from Poverty and Hunger to Food Security and Hope'. He is also an advisor to the Food & Global Security Network.

'Regenerating the planet means shifting from degenerative colonizing ways. Let's not confuse the scalability potential of regenerative agriculture with the lack of capacity to think collectively and transform our economies of extraction and exploitation into economies of regeneration at scale.'

Recodifying Agriculture: Indigenizing our Ways, to Regenerate the Planet

Some have said that 'the soil will save us' or that 'in soil we trust'; others have accurately described the rise and fall of civilizations based on how they have related to this thin layer of life-giving and energy-transforming infrastructure that we inherited from the past. We still have soil thanks to the evolution of the Earth and the living systems that have thrived on it. Our current population is possible because of the soil. What we do to the soil, we do unto ourselves. Soil, its health, or lack of it, its loss or regeneration, as in the past, is again at the center of global mass migrations, hunger, malnutrition, economic collapse, climate change... the list goes on.

This is a writing about soil, but not as matter or as a medium, rather about how it came to be, and how we can work with the Earth's ecosystems so we can regenerate it, and as a result restore in a significant way, the health of the planetary ecology, communities, and nations. I am writing this article in a language I am not native to, in a land I am not native to (Minnesota, US), and in a mindset I am

not native to. I write this seeking spiritual connection between my indigenous self, my indigenous intellect, my connection to the systems that have regenerated the Earth's living systems for millions of years, the systems that delivered us the diverse living systems which allowed us to evolve into our current human form, and the colonizing world that has now verifiably succeeded at creating the most effective structures for achieving global mass destruction.

I am also writing from my experience as a Guatemalan born in poverty, raised with a close symbiotic relationship with other living ecosystems, someone who experienced first-hand the wealth that healthy soil and living systems deliver, who experienced the original concept of indigenous regenerative ways. As a child I was taught to understand that we don't 'work with nature'; rather, we ARE nature. I am writing these words from an indigenous perspective on agriculture and food, a perspective recently 'discovered' and similar to other discoveries has been named 'regenerative', and like other colonizing processes is now under full scale appropriation and segregation from its

original expression, the one that holds the promise for large-scale planetary solutions to climate, hunger, malnutrition, poverty, and overall loss of the biodiversity on which we depend for our human survival.

I may not be native to this land I now call home, but I am not a colonizer or invader either. I know this because I have accepted, and fully embrace the fact that I, as any other living creature, am indigenous to this planet. We all came from it, because of it, and because of the evolutionary processes which gave us a magnificent and balanced design for all living systems to thrive. Systems that symbiotically feed on each other and have moved across time, an ebb and flow, a planetary level dance where ecosystems thrive and advance and make room for other living systems to emerge, thrive, evolve.

From this perspective, I offer some solutions to counteract the planetary disruption caused by our species, the largest the world has ever seen. I hope we will all see the need to collectively grasp the magnitude of the problem and build the indigenous intellect needed to move forward. We must be an intelligent species, but so far, the intelligent and rational part that is supposed to separate us from the behavior of other species has not fully kicked in. We insist on devouring the very planet that feeds us, and from that perspective, we cannot collectively claim to be better than a virus or bacteria that does the same till they consume the body that feeds them and their populations collapse. Yes, many of us are mobilizing in a way counter to our destructive and colonizing urges, and more in alignment with our indigenous sense of belonging to the Earth and of being part of its living systems, but at a large-scale we are still too few to tip the balance of destruction over to regeneration.

Understanding this divide is critical for a proper discussion of the issue of climate disruption. Too often, hearing that regenerative agriculture is not 'economical' or 'scalable' enough to be a solution. Embedded in those questions and remarks is the colonizing concept of extraction and exploitation. And yes, regenerating the planet means shifting

away from degenerative colonizing ways, and to do so we must radically change how we do things. That radical mental, economic, and structural shift from colonizer to an indigenous-centered stewardship of resources is what is not currently scalable, not the actual physical transition of the land. Let's not confuse the scalability potential of regenerative agriculture design with the lack of capacity to think collectively and transform our economies of extraction and exploitation into economies of regeneration at scale. The two may be connected at some point, but the truth is that there is still sufficient land outside of corporate control, in the hands of small farmers, native tribes, and community holdings to reach a tipping point. We can welcome the colonizers as they decide to shift, but we don't have to wait for the current system to decide to change at scale. We have sufficient scale. We just need better organization and to build infrastructure to harness the power that we already have.

Within its larger capacity to regenerate, the ecosphere evolved into thousands of macro and micro sub-ecosystems, from rainforests and their own micro-ecologies, to deserts, highlands, tundra, etc. Each of these ecosystems has developed its own regenerative blueprint over millions of years, and did so at a large scale with its own fully adapted soil profile. Such is the scale achieved, that they supported the emergence of life and food webs to support and sustain species over billions of years. Those are the regenerative processes that we owe our own existence to, and those are the processes that we have systematically disrupted and have pushed to the point of ecosphere-level imbalance. What we call climate change is simply the system responding and rebalancing to compensate for our disruption. The Earth's ecosystems have always done this, from giving birth to the age of the dinosaurs, to rebalancing after their demise; the Earth has a resilient and magnificent way of managing energy to support life and its regeneration. As a single ecosystem, everything on Earth is connected and life operates based on energy flows, its transformation, and constant

movement within this unique ecosphere-level, a system of organization that resembles every bit that of a fully functioning organism, which the Earth is from an indigenous perspective. That perspective is what can ultimately save us all if we start to collectively act as an intelligent species.

My experience as a farmer and farming systems professional has always been grounded in this indigenous understanding of the Earth's ecosystems. Yes, I obtained conventional monocropping, row-cropping, mechanized agricultural training, but after first having understood how the Earth's ecosystems operate, it was impossible to swallow all the theories and arguments being sold to us as students. It also took more than 25 years before those teachings would become relevant to my life's dedication to food and agriculture again. But here we are, and now more than ever, we will depend on this foundational systems-level understanding to regain our footing and give it our best at reversing the global calamities that colonizing systems have created.

From an indigenous perspective, the idea that farmers or companies 'produce' food is ridiculous. As farmers and food systems professionals our single most significant role is: 'the stewarding of energy transformation processes that turn inedible energy into physical forms that we call food.' These energy transformation systems developed over billions of years and were perfected by the Earth's evolutionary processes. Collectively they have the capacity to continually cycle energy at the largest scale the planet can support, and these energy transformation processes result in the diversity of life, the food systems that support this diversity, and the ebb and flow of the Earth's ecosystems, the evolution of us all.

So as stewards of energy transformation, rather than 'producers of food,' we must understand that the collapse of our systems is the result of how we have mismanaged this massive inheritance. And to solve our current riddle we must understand where the pivoting points are, so let me humbly submit to you that the Earth's energy transformation capacity

which ensures our food, the health of our bodies, our reproductive, mental, spiritual health, the very evolution of our species, all these basic and indispensable things are defined by; are governed by, how energy flows and balances out. Mess up these cycles, and we get the consequences we are living through. Address these root causes, and we stand a chance of a civilized society into the future. To apply these concepts to real life we must codify them according to indigenous ways of thinking – because if we apply colonizing extractive and exploitative codification processes, then we are bound to continue to consume the planet till we collapse as a species.

Focus on poultry

Focused on poultry, I want to show how completely capable we are of designing solutions that every farmer big or small (but especially small ones) can adapt immediately. I also want to expose that the problem we have is not one of know-how, but rather an insistence of trying to solve the problem while at the same time doing the same things that created it.

To codify this thinking into a regenerative model, we have sectioned out three globally critical energy transformation areas that every farm operation must engage: 1) Optimize the photosynthetic capacity of the native local species and those adapted sufficiently to independently thrive without invading the local space; 2) Optimize the management of animals' intestinal tracks, from earthworms to elephants, dolphins to eagles, animals have an ecosystem-level function of transforming complex energy structures – disrupt the role of animals in agriculture and the energy transformation stalls, and 3) Optimize the magnificent energy transformation capacity of the soil's microbiological systems.

Photosynthesis – Poultry is a jungle-fowl, so the photosynthetic infrastructure of a poultry farm can

be built from a multitude of economically viable and socially acceptable overstory and understory crops. In Minnesota we use sugar maple, oaks, basswood, hickory, and other species as overstory. For understory we use hazelnuts and elderberries among others. In Northern Guatemala the list of species is much larger. Perennial cover balances out soil temperature which optimizes biological activity, trees protect against predators but also provide highly valuable cash crops; chickens weed and fertilize, but also roam and peck supplementing their diets with nutrient dense forages. At the ground level we developed a series of agronomical practices intended to optimize forage production and sprouting grains. Photosynthetic processes, under this design are optimized to transform energy every minute the sun shines from the top of the trees to the sprouts in the ground. I hope these pointers help the readers' imagination do the rest. This process ensures that we optimize carbon and other greenhouse gasses draw down, we need those elements in the living systems of the Earth, not in the air choking our existence and degenerating our health and quality of life. It is not about sequestering anything; it is about restoring this energy to its rightful place in the cycles of life, but to do that, we must stop killing and destroying, we need to start regenerating the ecosystems and their functions.

Animal-based Energy Transformation – The optimization of photosynthesis generates the most flow of carbon into the plant systems, animals eat some of these plants (chickens in this case), while others grow as permanent aerial energy pumping systems, drawing more energy as they grow. Chickens are provided with ground-up feed supplements. Daily energy intake flows through the animals within a day or two and is then transferred to the ground as the chickens roam their ranging paddocks (designed and calculated to meet specific densities of bird population, blueprints are different for different species and ecological characteristics). As this raw energy intake is digested, it is broken

down further into molecular structure that can be available to the soil microbiology once it is passed and turned into manure. If we were to put a bag of grain or a bundle of forage into a regular compost pile and skip the animal intervention, it would take close to a year to achieve the level of breakdown that the chickens in this case can achieve in under three days, speeding the energy transformation cycles and draw-down (atmospheric carbon especially). The more the energy cycles through the landscape, the more of it we can harvest in the form of food. Remove the animals from an ecology and the system stalls to a crawl.

Soil-based Energy Transformation – As energy continues to flow through the animal-based digestion, some will be deposited as manure in the soil. In a healthy soil, this energy is rapidly taken up when there is a healthy soil macro and micro biota. The most important indicator of soil health can be accurately measured by the speed that it breaks down organic matter and makes it available as food to plants or to other microorganisms. Because of this endless process it becomes plant food, and later fruits, nuts, etc. There is no step in the energy transformation cycle where something is not food to something else, it is when we remove and place ourselves outside of the living systems of the Earth that we lose track of this ancestral blueprint that defines us, and we start acting against our own interest and that of all other living systems.

As humans, we have disrupted all three of these critical energy-transformation centers in the Earth's ecosystems. First, we insist on removing the multi-layers of perennial cover that already exist, effectively minimizing the photosynthetic capacity of each cleared acre. This disruption results in massive releases of greenhouse gasses into the atmosphere and the elimination of the photosynthetic infrastructure that feeds the animals and the soil and the very system that could recapture such emissions. Second, we have taken

animals out of the land and placed them under inhumane factory-like conditions, stalling all processes they are responsible for in nature, while we disrupt the established systems and reduce the landscape's capacity to deliver food.

Yes, an animal factory can fatten animals in a larger volume per square foot, but it costs over 40% (in the US Midwest) of the arable land, where a much larger number of the same livestock can be produced while also regenerating the very landscape where they are raised. The difference is that one requires stewardship and a symbiotic relationship with the ecosystems, and even though it produces more collective wealth, it is also more resistant to extraction. The sole goal of confining animals and deploying monocultures is to maximize extraction. Feeding the world is only the argument and mass communication agenda, not the actual end goal.

That is the reason we have supported one over the other against the will of the indigenous ways that delivered an efficient and time-tested design. Third, we systemically uncover and expose the soil particles when we disrupt it with equipment, which makes it easily erodible by wind and water. As the soil's nutrition decreases, soil poverty increases, and energy yield stalls. To 'correct' this artificial problem we have created, we recur to toxic and artificial inputs, this further increases the soil's biological and nutritional poverty and more of its inhabitants are killed or the soil is made inhospitable by nutrient deprivation, salinization, or is simply lost to erosion.

When we think of food and agriculture systems as they exist today, under the argument of feeding the world, what we are witnessing is a systemic process by which we have disrupted and brought under our manipulative control, the fundamental food-producing energy-centered mechanisms of the Earth. As we have taken command, we have applied our colonizing systems to them for the purpose of extraction and exploitation. It is no wonder hunger and poverty is increasing, civil conflict is exploding, and the planet is either on fire, flooded, or

constantly under plagues. We can do so much better.

Utilizing poultry, we have developed a blueprint for re-engaging the Earth's energy transformation centers, but this process is not intended for chickens alone. The laws of thermodynamics and the biological, physical, and chemical processes on which the Earth's energy transformation is based are universal.

Blueprint for chicken

We start by rebuilding the energy transformation infrastructure. This is a short story of the first year of a 75-acre farm where we systemically transitioned from conventional corn-soybean rotations to an agroforestry-centered regenerative poultry system.

During the 2021 growing season, we focused on the 45 tillable acres of land that had been used for corn and soybean rotations for as long as 30 years. Knowing that the land's energy systems were fully disrupted and hence its capacity to respond naturally, we focused on two central outcomes for this season. 1) Detoxification (let the toxic stuff in the soil get processed as life returns to it), 2) Recarbonization of the soil so that the biological systems can thrive and do their job again including the restoration of the natural hydrological pathways of the soil.

In the spring, while the previous year's corn stubble was still on the ground, we broadcasted an organic fertilizer, followed by a sheep pasture right on top of everything. Then we no-till drilled a barley nursing crop (a crop to help the smaller pasture seeds germinate and grow), the no-till drill small disturbance shook the pasture seed and fertilizer into contact with the soil.

A drought hit us right after but not before the pasture and barley had germinated. The crops had a slow start, but the newly undisturbed soil held sufficient water and the new green cover and roots kept the soil in place. Once we had some rain,

everything took off. To build the carbon further and to avoid harvesting toxic grains, we mowed the barley just above the height of the pasture. This step deposited a thicker layer of organic matter on the soil, as the dropped grain sprouted it further supported the biology build up. The perennial structure of roots and stems held the soil together once we received rain, which came heavy and in a short period of time as expected. We then planted 8,200 hazelnut bushes on 20 of the 45 tillable acres to start preparing this part of the farm for the introduction of chickens. In total, the farm is 75 acres, but the remaining landscape is already wooded, so we are using a separate management process for that section while the tilled ground regenerates. To track the changes, a team of four scientists are sampling the soil to measure its chemistry, structure, nutritional integrity, and the increase in biological activity by measuring organic matter decomposition rates and through lab analysis to establish a biological activity baseline. We have developed a process to systematically transition farm after farm into an agroforestry-based regenerative poultry system. In the spring of 2022, the first chickens will go into the area planted with hazelnuts and their manure will speed up the regeneration of that space. The manure from the night shelters will be utilized to inoculate and add nutrients and organic matter to the rest of the farm.

With this and other farm-level projects underway, we want to communicate an unequivocal message of the system-level transformation potential of regenerative thinking. For that to happen we need the land in the hands of those who know how to care for it, and the infrastructure that generates aggregated economic value under collective management. That is how we feed the world and regenerate the planet's ecosystems. We are happy to offer one blueprint for accomplishing rapid results without compromising the urgency of planning for 7 generations.

Poor soil leads to starvation & migration

From previous experiences in Mexico, Guatemala, and many other places where we have tested this model, we know that when the soil is poor, so are the plants that we try to grow, and the animals that feed on them. Any harvest will also be poor. Poor soil results in sicker chickens and less forage, a poor harvest results in poor farmers, which results in less food available for communities, which exacerbates food insecurity. Less excess output means less support for the local economies, a spiral that if unbroken lands whole communities unable to support themselves, from there, conflict and violence erupts, migration and family breakdown, further increasing the overall civil unrest plaguing the planet. Poor soil across Mexico, Guatemala, El Salvador, and Honduras is the single most important reason families are starving. Political instability and simply lack of jobs was not sufficient to have people leave their communities at the scale that is happening now. Starvation has now forced sometimes upward of 160,000 families in a single year from some of these specific regions where data has been collected. That's just one region; the world's population is migrating at accelerated, alarming, and unsustainable rates and food is at the center of most of this civil instability.

Through our work with Guatemalan organizations, we have been able to introduce this way of doing agriculture to multiple communities. These community-level prototype systems are delivering the same results as our work in the US Midwest. In Minnesota, immigrant farmers are optimizing their income by restoring the health of their soil, which reduces the cost of raising their chickens, increasing their net income, and creating the highest standards of animal welfare as well as working conditions for farmers and workers. In the Guatemalan communities, some of the families financed their poultry coops and the purchase of hens and feed with 'remesas' or money transfers from their relatives in the US. This new achieved stability is directly coming from the return to

ancestral ways of working with the soil and with each other.

Decolonising the mind

Too often, in our eagerness to impress and sound smart we create elaborate plans and long documents as we attempt to find solutions to today's food and agriculture problems.

But the truth is that for the most part, the answer is right under our feet, and the code for finding those answers is all around us, with the abuelos and abuelas, our healers and mentors. It has always been staring us in the face.

We can start by validating the elders in Native communities, their stories, and their wisdom, and their sacred instructions. The knowledge and tools may come from the universities of the world or the high towers, but the wisdom to use either for the common good will not. We have waited long enough, a few centuries in fact. We were promised progress and a civilized society, instead we are inheriting destruction and civil unrest.

It is time to be one with creation again.

We are at a time when the simplest solutions need more attention. Let's stop talking about how we 'scale' narrow and myopic ways of thinking. Instead let's talk about how we embrace the scale of how nature works and let it do it again. Accelerating the transition to agroecological agriculture, land use and production may look more like accelerating the decolonization of the mind, so we don't block the magnificent design we inherited from the Earth's evolution and from the indigenous peoples of the world. Those who despite suffering colonization, genocide, invalidation, and almost total annihilation, have managed to protect over 80% of the world's biodiversity on less than 20% of the total land-based surface of the Earth. They have also sustained a culture of sharing, inclusivity, and full understanding of how the Earth's ecosystems operate.

If we are sufficiently intelligent as a species, we will stop trying to colonize this knowledge by reducing it to specific practices so that our colonizing systems can continue to extract and exploit. We have a global opportunity to decolonize the mind and to validate and adopt ways that worked for tens of thousands of years before colonization spread across continents, the systems that hold the code for a civilized modern world are still available to us.

I wrote this article to touch the indigenous intellect in all of us, the intellectual capacity we will need to fix this broken food and agriculture system. This is a capacity that does not come from holding master's degrees or doctorates. Those deliver knowledge, but knowledge alone is dangerous. In fact, every single one of the over 80,000 registered agrochemicals, every weapon of mass destruction, every economic theory of extraction, every oil pipeline and the machinery that consumes its products – almost everything we associate with 'progress' has come out of the minds of 'knowledgeable and educated' people. Yet, that knowledge applied to the wrong end purpose is how we have come to threaten our own survival.

Knowledge without the wisdom to use it is effectively a weapon of mass destruction of the ultimate kind.

The decolonization of the mind, of science, methodology, of processes, of systems and structures can allow us to balance out the vast amount of accumulated knowledge with the wisdom to know how to use it for the greater good.

To achieve this, we will need to build the collective intelligence and courage to decolonize; to defend and recover the indigenized world we need to become a truly civilized society. The path forward is embarrassingly simple, and even though our colonizing system and global structures stand firmly in the way, every person on Earth must realize that the most promising and powerful answer to a very large part of our current troubles, is right under our feet.

DELIVERING REGENERATION

CAROLINE GRINDROD

Caroline is a regenerative agriculture expert and founder of rootsofnature.co.uk

‘In modern agriculture, we have made the mistake of thinking of a plant as something we can isolate from the soil food web and grow in a lifeless medium as long as we feed it a few key nutrients: nitrogen, phosphorus and potassium.’

The security threat to nations that hunger, inadequate access to water, and disease can create is well established.

There is a wide range of worthy humanitarian efforts and impressive initiatives across the planet seeking to prevent this melting pot of climate instability, biodiversity decline and rampant desertification from boiling over into a collapse of peace and security.

It is encouraging to see some international efforts seeking to address the root cause of issues rather than continuing to fire-fight the symptoms. There has been a distinct shift from directing resources to ‘avert hunger’ through the use of low-quality energy calories, to a wider view of food security and even ‘nutritional security’.

In their 2012 report, the Committee for World Food Security set the benchmark as ‘when all people, at all times, have physical, social and economic access to food which is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life’.

That is a huge step forward – but are we digging deep enough? I believe that the roots of true nutritional security starts in the soil.

Modern agriculture has a tendency to think of soil as a medium in which to grow a plant, but it is so much more.

Healthy soil is an entire ecosystem in its own right – alive with trillions of microscopic organisms working together as the soil food web.

In modern agriculture, we have also made the mistake of thinking of a plant as something we can isolate from the soil food web and grow in a lifeless medium as long as we feed it a few key nutrients: nitrogen, phosphorus and potassium.

What we have overlooked, to our detriment, is that a plant should be considered a holobiont. This is described, by Dr. Lynn Margulis in her 1991 book *Symbiosis as a Source of Evolutionary Innovation*, as an assemblage of a host and the many other species living in or around it, which together form a discrete ecological unit. The components of a holobiont are individual species or bionts, while the combined genome of all bionts is the hologenome.

Living soil is to a plant, what the gut is to a human.

Plant roots on their own are able to only take up a small percentage of the total nutrients stored in soil as they can only access nutrients in a plant-available form from the soluble pool. Plants have however developed a symbiotic way of achieving the dozens of nutrients they need to be healthy and grow optimally. Bacteria and fungi in the soil can access the inexhaustible pool of nutrients locked up in the

rock, sand, silt and clay of our soils. Through the use of enzymes and acids, they can solubilise minerals and take them into their biomass. Healthy, photosynthesising plants feed carbon-based exudates out through the tips of their roots to attract and feed these microorganisms and in turn their tiny predators. Through a combination of digestive secretions, death and decay, the previously unavailable range of nutrients held in the bodies of the organisms are delivered to the plant root in a form they can utilise.

Through a rapidly emerging world of plant research from a more holistic and biology focussed lens, we can understand that many of the diseases and vulnerabilities of our modern cropping systems stem from poor plant nutrition arising from dysfunctional soil health.

When a plant is unable to interact with a healthy soil food web it cannot optimally photosynthesise or synthesise nutrients into strong cell structures and waxy protective outer coatings. A plant's sap becomes highly attractive to pest insects with simple digestive systems and its physical structures are more easily attacked. Poorly plants are more easily affected by drought, flood, wind and frost - they lose their resilience. Only healthy plants with access to a wide spectrum of nutrients can make the phytochemicals that help them fight pests and diseases.

If plants are not able to take up the full spectrum of nutrients required for health and resilience, then the livestock that eat these plants, and the humans that eat the plants and animals, are subject to many of the same health vulnerabilities.

So what causes the loss of a functional soil food web and the resulting vulnerable and disease-prone plants and animals? Tillage, leaving soil bare and exposed, use of artificial fertilisers, use of pesticides, the use of antibiotics, a low diversity of species and overgrazing caused by badly managed livestock. Modern agriculture is at war with healthy soil.

The more we damage the soil food web, the more we must lean on energy-hungry and

environmentally damaging artificial fertilisers, pesticides and animal medications, to treat the symptoms of poorly plants and livestock caused by poorly soils - and so it goes on, the costs of production go up, and the nutrient quality of our food plummets.

But the threat of food insecurity from a loss of biodiversity and badly managed soils doesn't stop there. A damaged soil is no longer held together with the biotic glues and structures that come from a symbiotic relationship with functional plants. These dead soils release stored carbon into the atmosphere contributing to global warming. Some estimates suggest that 133bn tonnes of carbon, or 8% of total global soil carbon stocks, may have been lost from the top two metres of the world's soil since the dawn of agriculture 12,000 years ago. (Sanderman et al, Feb 2018)

What's more, with global warming, we are also concerned with feed-backs that contribute to heating over and beyond the impact of greenhouse gases themselves.

Bare and degraded soils lead to desertification which in turn leads to a series of ever-warming effects on our planetary systems such as:

- Increased soil surface and air temperatures due to loss of transpiring plants. The soil surface can be 40 degrees cooler under the protection of green or a tall sward of grass.
- The tiny dust particles from bare degraded soil cause warming heat hazes that create humidity droughts.
- Large areas of bare soil cause heat domes that repel clouds and prevent rainfall.
- Methane oxidation through the hydroxyl ion pathway is reduced by the lack of moisture provided by plant transpiration and dimmed sunlight levels caused by dust hazes.
- The effectiveness of cooling radiation windows is compromised by heat domes and heat hazes.
- For every 1% loss of soil carbon, the soil can retain approximately two buckets of water less per square metre in the soil structure leading

to floods and drought. Some agricultural soils across the world have lost up to 50% of their original carbon stocks.

The World Atlas of Desertification shows that globally we are turning an area approximately half the size of the European Union to desert every year. The warming effect this has on our planet through these complex mechanisms is surely vast.

So it is clear that soil health is the very foundation of food security – so what can we do to reverse the alarming decline?

Currently, the setup of government bodies and their policies are too siloed and specialised so the responses they generate are mostly a mirror of this rational and mechanistic world view. Nature is however complex, intertwined and self-organising. The whole is greater than the sum of its parts.

As tempting as it may be to try and find blanket global solutions as a response to these wicked global threats, responses must mimic nature itself in order to benefit from the power of whole system cooling and stability. This requires a mindset shift and the use of systems or holistic thinking to find effective and adaptive solutions.

As the soil microbiologist, Walter Jehne, has shown, agroecological and regenerative ways of producing food offer opportunities to leverage the multiple benefits of growing and rearing nutrient-dense food from low input, climate-resilient systems that also cool our planet.

Every environment across the world is unique and supports a different range of habitats and potential agricultural options. The rich diversity of our global cultures has emerged under the particular influences of what food and fibre can be locally and sustainably produced.

For example, pastoral systems emerged from places where it was hard to grow crops and easier to rear livestock, while arable plant food systems emerged from regions of deep flat soils and high fertility. Each region's recipes, fashions and culture are shaped by the foods people ate and the lifestyle that

was required to grow them. Epigenetics has meant that different people's health and nutritional requirements have co-evolved with their diet.

Agroecological regenerative systems use principles, not prescriptions. Below is an example of how we assess the health of the land and typical examples of guidelines we would use when designing a unique plan for the farm.

Water cycle – How effectively can you capture and retain your rainfall so that it is used by plants and animals for production?

Soil Health – How efficiently can plants and animals access nutrients, and how rapidly are these recycled so they can be made available again?

Photosynthesis – How optimal is the conversion of sunlight into food for the whole food web, including the livestock or plants you are directly managing?

Airflow – How can we better buffer the extremes of exposure to the elements to enhance plants and animals' production? How healthy are your soils' structures so that effective gas exchange can occur so plants can access the unlimited nitrogen and carbon available in our air?

Nature's dynamic networks – How complex and resilient are nature's interconnections in your landscape, so that pests are reduced, disease is minimised, and the growing season is long and stable?

Guidelines that help to achieve regenerative outcomes:

- Keep the soil covered with organic material
- Minimise repetitive soil disturbance
- Maximise diversity in crops, pasture plants and habitats
- Maintain a living plant in the soil all year round
- Integrate livestock or wild animals

With enough people working together we can start to impact local and even regional climate as well as reverse the collapse of biodiversity.

By teaching the principles of soil health and functional ecosystems, along with coaching in holistic thinking, we can support any farmer in the world develop their own way of producing a culturally appropriate healthy food on healthy soil in a way that builds community and cooperation.

This is the ultimate hopeful, proactive, simple and cost-effective approach to combating food instability and civil unrest.

TWO DIVERGING PATHWAYS FOR A FOOD SECURE FUTURE

CHANTAL CLÉMENT & NICK JACOBS

Chantal is Deputy Director, and Nick is Director of IPES-Food.

'Food and agriculture are in the eye of a perfect storm. Over the next quarter century, biodiversity loss, climate shocks, and land degradation will place unprecedented pressures on food and farming systems. Definitions of food security are likely to change and broaden, encompassing dimensions like access to healthy, nutrient-rich soils, and resilience to pandemic disruptions. Discussing soil health, food security, and national security in the same breath could become commonplace, as their interconnectedness becomes clear to all.'

The latest report from the Intergovernmental Panel on Climate Change (IPCC) told us what the news was already telling us: environmental breakdown is upon us. As of 2015, four of the nine planetary boundaries had been transgressed – climate change, biosphere integrity, land system change, and biogeochemical flows. We are already seeing an unprecedented rise in extreme weather conditions, from heat waves, storms, flash floods to ocean acidification. Parts of the Amazon, often referred to as the 'lungs of the Earth', are now emitting more carbon than they absorb largely as a result of agricultural expansion (IPES-Food & ETC Group, 2021). Climate 'tipping points' – irreversible changes to our environments with severe impacts for humanity – are on the horizon.

What does this mean for food security? Over the next quarter century, biodiversity loss, climate shocks, and land degradation will place unprecedented pressures on food and farming systems. Soil is particularly central. Soil health underpins productivity, biodiversity, crop and livestock health, and builds resilience to shocks like floods and droughts. But degraded soils are already affecting 3.2 billion people, with 33 per cent of farmland worldwide being moderately to highly

degraded. This equates to a 23 per cent drop in terrestrial productivity worldwide (Loconto, Jimenez & Vandecastelaere, 2018). In 2020, the first global report on soil biodiversity warned that after 12,000 years of harvests only 100 more may remain (FAO, 2021). Soil health becomes of paramount concern when 95 per cent of the food we consume is directly or indirectly produced in the soil (FAO, 2015).

These threats come in a context where food systems – and people's access to food – are already precarious. In a matter of weeks, the COVID-19 pandemic laid bare the underlying risks, fragilities, and inequities of the industrial food system (IPES-Food, 2020). While levels of world hunger and malnutrition had stabilized for 5 years, both increased dramatically over 2020, with 118 million more people facing hunger than in 2019 (FAO, 2021). Combined with armed conflict in countries including Yemen, the Democratic Republic of Congo, or South Sudan, the pandemic has left whole populations on the brink of starvation (UNICEF, 2020). In the US, the 2019 national food insecurity rate had reached its lowest point since it was first measured in the 1990s, but these improvements were turned upside down, with 1 in

7 Americans facing food insecurity in 2020 (Feeding America, 2020).

This may only be the tip of the iceberg. The climate crisis is driving the degradation of ecosystems, migration flows, new economic disparities, and disease spillovers. And when factoring in long, complex, and often opaque supply chains, sudden disruptions – such as COVID-19 or major weather disruptions – are a potential cause for significant economic and social disruptions over the coming quarter century.

In this context, food security will become an ever-greater political priority. As Alfred Henry Lewis famously wrote over 100 years ago, ‘there are only nine meals between mankind and anarchy,’ alluding to a global history clouded by moments of civil unrest driven by food insecurity. Treating food as a strategic asset – as China, Russia, and the US already do – will surely become the norm. Definitions of food security are also likely to change and broaden, encompassing dimensions like access to healthy, nutrient-rich soils, and resilience to pandemic disruptions. Discussing *soil health*, *food security*, and *national security* in the same breath could become commonplace, as their interconnectedness becomes clear to all.

But this new reality could lead to a variety of different approaches in the quest to deliver food security. Drawing on the findings of the ‘Long Food Movement’ project (IPES-Food & ETC Group, 2021), we lay out two contrasting visions of how governments and societies could respond to environmental breakdown, social upheaval, and new food security threats.

Scenario one

The first and perhaps most likely scenario is one in which powerful actors seek to appropriate and control productive resources through vast economic corridors. The need to ensure domestic food supply is already accelerating governments’ acquisition of foreign soils (and water) to produce food for their

populations. For example, Middle Eastern and North African countries are moving into Sudan (Schwartzstein, 2019). Across Southeast Asia and the African subcontinent, some 20 million hectares of farmland – equivalent to the size of Cambodia or the UK – have been transferred from rural communities to foreign corporations over the past decade (GRAIN, 2019; Goedde, Ooko-Ombaka & Pais, 2019).

Control of these production zones is being rapidly consolidated. Mass infrastructure schemes are being drawn up, based on automation and digitalization, to ensure the efficient handling of goods through global food supply chains. Large parts of Asia and Africa are being reconfigured into major production and distribution zones by China’s Belt and Road Initiative. In parallel, Western powers are reinvesting in their own global commodity infrastructures. Already, Cargill and ADM have formed Grainbridge as a joint venture to provide a common technology platform for North American grain farmers (Cargill, 2019). Over the coming decades, governments and flagbearer corporations are likely to continue developing these supply corridors into what they hope will be shock-proof agro-industrial complexes.

Furthermore, agribusinesses will be vying to use new technologies – from rapidly advancing AI to wholesale digitalization – to accelerate the rollout of ‘climate-smart’ precision production systems. On-farm robots, drones for spraying and surveillance, and self-driving tractors – all tied together in an ‘internet of farming things’ (Meola, 2021) – are already becoming part of food systems. Agribusiness giants are in fact pitching their digital agriculture platforms as the key to ‘regenerative’ farming since they can supposedly track (and therefore trade) carbon in the soil.

Meanwhile, AI is mapping every square kilometre on the planet (including every square centimetre of farmland), for soil, nutrients, moisture, and sunshine, and combining that with massive genomic data sets to suggest AI-designed ‘climate-smart’ agroecosystems building from DNA upwards

(Oak Ridge National Laboratory, 2019). Algorithms are also being primed to tailor either crop genetic mutations or transient gene-sprays to specific growing environments (Tencent, 2020). There could also be a push to engineer whole ecosystems, from gene drives – a technology that aims to rapidly spread genetically modified traits, transforming entire populations and ecosystems – to the engineering of microbes via alteration of the agricultural and human microbiome (ETC Group, 2018).

Although some governments are worried by the prospect of putting food security at the mercy of foreign-owned data systems, the ‘climate-resilient’ and ‘risk-free’ future on offer may ultimately be enough to convince low and middle-income countries to hand over their land, resources, and data. The pandemic has made this future more alluring still: the previously dystopian notion of a fully automated food chain without human workers is also being vaunted as a solution for food safety, hygiene, and resilience to social shocks.

In other words, this is a scenario where the keys of the food system are handed over to biodigital mega-corporations, data platforms, and private equity firms; where farmers and food-workers are disempowered; where resources are deployed in the service of keeping commodities flowing across vast supply corridors; where soil management is decided by algorithms; and where food security is placed at the mercy of increasingly centralized, opaque, and homogenous systems.

The risks of such a scenario are troubling. Already, just 1 per cent of the world’s 300 million farms account for 70 per cent of cropland, pastures, and orchards (Watts, 2020). Further erosion of diversity could remove critical firebreaks against climate shocks and disease transmission. These systems will also be increasingly vulnerable to supply chain disruptions. Pressure is already building at major trade ‘chokepoints’, where large volumes of staple commodities transit daily (e.g. maritime corridors, coastal infrastructure, inland transport infrastructure in crop-exporting areas).

Interruptions at these critical junctures could result in supply shortages and price hikes (Wellesley, Walsh & Tucci, 2017). Such consequences would be particularly dire for highly import-dependent nations such as the UK or Japan, regions such as the Middle East, or low-income countries with structural vulnerabilities. In tandem, the local subsistence network and territorial markets on which many countries currently rely are likely to become even more fragile and vulnerable to external shocks and influences.

Scenario two

However, the current cascade of threats could be used instead to set an entirely different course for food systems. Governments could instead look to the growing number of initiatives seeking to build the foundations for new, more sustainable food systems, and shift away from the short-sightedness of business-as-usual solutions that value individual (or national) gain over the wellbeing of all peoples and the planet.

This pathway, the ‘Long Food Movement’ described by IPES-Food and ETC Group, is rooted in agroecology and food sovereignty. Agroecology relies on natural synergies and diversity – not synthetic chemicals – to build resilience by combining different plants and animals to regenerate soils, fertilize crops, and fight pests. By ‘land sharing’ rather than destroying fragile ecosystems to make room for more uniform farming landscapes, agroecology allows for the production of diverse, healthy foods while protecting and preserving habitats and natural resources.

Agroecology’s capacity to meet the economic, environmental, and social dimensions of sustainability has now been recognized by major international institutions, including the FAO, IPCC, IPBES, and the World Bank and FAO-led global agriculture assessment (‘IAASTD’). Accelerating crises and stagnating productivity in industrial production systems could expedite this paradigm

shift. A growing premium will be placed on healthy soils, diverse crop varieties and livestock breeds, vibrant aquatic- and agro-ecosystems, and – with new farmland hard to come by – on management systems capable of regenerating arable land. Moreover, as tools for measuring soil health, carbon sequestration, and biodiversity are fine-tuned, it will be possible to identify which production systems are truly sustainable.

Indigenous peoples, peasants, and other small-scale food producers can also be expected to continue to build resilience through diversity: safeguarding landscapes and nurturing a wide range of crops and their wild relatives via proliferating community gene banks, living collections, and farmer-to-farmer and fisher exchanges across neighbouring ecosystems. The push to re-diversify diets in the face of growing micronutrient deficiencies will be key to reinforcing this transformation.

Farmers, fishers, and food movements will be the driving force behind this agroecological transformation, but it also requires government support to scale up and out. Substantial regional and national support programmes will be needed to ensure that farmers get the seeds they want, organic inputs, and agroecological advisory services. This pathway also relies on soil health, thriving ecosystems, and CO₂ sequestration finally being valued via some form of ‘true cost accounting’.

While not wholly immune to disruptions, territorial markets and short supply chains are also often a key component of agroecological systems that can enhance food security and reduce vulnerability to international markets. For net food-importing countries, ensuring dynamic local and regional food chains could become a priority alongside continued

international trade flows. However, countries would also have to seek to gradually shift away from trade-oriented agricultural policies that disadvantage small-scale producers or favour unsustainable food systems practices.

Barriers to diversity must also be reconsidered. Intellectual property arrangements governing agricultural genetic resources, such as crop and livestock, must not inhibit the full and free use and exchange of seeds and livestock breeds among farmers and breeders, or their communities. Over the longer term, land reform will also need to be considered to reduce major inequalities in access to land, particularly for the millions of small farmers cultivating less than two hectares across Southern Asia and Sub-Saharan Africa.

In other words, this second scenario is a pathway to sustainability *and* food security – which are ultimately two sides of the coin. This scenario is rooted in revaluing productive resources, not appropriating them. It builds resilience through diversity. It treats food as a strategic asset – but rather than stripping that asset from others, it invests in the people and the resources needed to sustain its value in perpetuity.

Which pathway is chosen will depend on the extent to which we are able to heed warnings. It should not take another global pandemic, or another natural disaster caused by climate change, to recognize the challenges we are facing. It is worth remembering that ‘the biggest shocks of recent years (e.g. mass extinctions of species, wildfires) were predictable and predicted – not in date and detail, but in parameters and probability’ (IPES-Food & ETC Group, 2021). The opportunity to move forward sustainably starts now.

LESSONS FROM COVID-19 & THE DASGUPTA REVIEW

GRAEME WILLIS

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'The pandemic has made us deeply aware of the importance of understanding microbiology. If we can better understand the complexity of our bodies and work cooperatively with it, that indeed will be key to unlocking greater health for us; but if can do the same for soils that will lead to a renewed relationship with the wider natural world that sustains us.'

The global pandemic has forced us to learn important lessons the hard way – at brutal cost to many individuals and those who care for them. Many of these will need no repetition but one point made by Richard Mabey, the great British nature writer, was that Covid-19 has taught us that a wholly benign view of nature – the oft mentioned value of engagement with nature as good for our health and well-being – is simplistic. This coronavirus reminds us that we are exposed to other organisms constantly as we eat and breathe for good or ill, that we are embedded in nature, and are and never have been separate from it. Whether we see it as threat or instrumentally as serving our needs or as something we are called upon to steward, our lives and fates are profoundly interwoven.

Notably this is also a central message and starting point of the recently published *Dasgupta Review* – the product of the leading economist commissioned by the UK Treasury. It makes clear that 'We are part of Nature, not separate from it,' and then goes on to draw lessons which inform understanding of our economic relationship to nature and the threat our current use of it poses: 'We have collectively failed to engage with Nature sustainably, to the extent that our demands far exceed its capacity to supply us with the goods and services we all rely on.'

Dasgupta frames this in the language of natural assets and natural capital which we have signally failed to manage well. But he also and absolutely connects this to our destruction of biodiversity and the role it plays in enabling 'Nature to be productive, resilient and adaptable'. There is current decline in biodiversity unparalleled in the human era and at '100 to 1,000 times higher than the baseline rate'. This increasing loss of our natural asset base means Nature's ability to produce the goods and services we need is diminishing fast but so too is its inherent diversity which enables it to remain resilient and responsive to change. This decline in turn is 'fuelling extreme risk and uncertainty for our economies and well-being'. So perversely, the way we are pursuing economic prosperity – and the putative well-being that derives from it – is a snake eating its own tail: we are all too successfully destroying the Nature which provides for us. We are getting nominally richer, not only because of Nature but at its expense.

The relevance of this analysis to the issue of food security is evident. Food (and drink) are perhaps the most tangible human benefits of natural systems and processes. But the productivity of these systems is under threat as Nature declines and so then is the secure supply of our food. Perversely production of food globally is the leading driver of

biodiversity loss through agriculture on land and, through overfishing, a similarly destructive force on the health, capacity and diversity of ocean ecosystems. Agriculture in the UK is, as part of the wider economic system, a perpetrator failing to properly value nature and its assets, but is also victim of it. The economic models and measures we use either at the macro level – Gross Domestic Product or Total Factor Productivity – or the micro level – such as in the balance sheet and profit and loss accounts of farm businesses – fail to reflect the value of farming’s prime capital asset: the soil and its health. At the most simple level at which farmers’ businesses operate of income and expenses – or the flow of cash coming in and going out – the price of wheat or of livestock or milk dominates, not the value of soils. In truth, farmers have rarely received the right economic signals to manage their soils in ways that conserve them. So while they may unwittingly (or in some cases heedlessly) degrade their land they are also victims of an economy which has failed to reflect Nature’s value to them and society at large.

Soil is perhaps symbolic in several important ways of our wider relationship to Nature. As Dasgupta says, part of the problem is that: ‘aspects of Nature are mobile; some are invisible, such as in the soils; and many are silent.’ Unlike much of what we think of in lay terms as biodiversity – mammals, insects, birds we can spot – soil presents mainly an impenetrable flat surface; and the life it supports – much of it at microscopic level – is largely invisible to the unaided human eye. As such soil can look lifeless, inert. Conceptually we downgrade it and degrade it – and vice versa. The impenetrability of its surface – though we can dig into it – also masks its shallowness and fragility: this living planetary skin is, compared to our own, around 10,000 times thinner yet we rely on it for some 95% of our food. Our other main source of food, the ocean, shares this impenetrability and invisibility of life – its life, large or small, is hidden. It can also look lifeless. Until recently we knew little of the vast biodiversity of the sea in its deeps; and for both soil and sea scientific understanding of their life at microbial

level is in its infancy. It is then relatively easy to understand how we have failed signally for centuries if not millennia to properly care for Nature and for soils. To this we should add as a contributing factor to our economic myopia the apparent boundlessness of nature – the sheer volume of the atmosphere or the expanses of ocean, forest and land. Where we have caused visible damage stripping forests, eroding hillsides or concreting watercourses, the assumption has crudely been that there is always more out there.

Dasgupta goes on to say that various aspects of nature – mobility, invisibility, silence – have enabled damaging human activities to continue as their effects are difficult to trace or account for. The costs are borne by the planetary ecosystem as ‘externalities’ and not reflected in our economies and our assessment of our wealth. For Dasgupta this means planetary costs are not well-reflected in market systems so these do not function properly, but tellingly this goes beyond market failure to ‘broader institutional failure too.’ Thus: ‘Many of our institutions have proved unfit to manage the externalities. Governments almost everywhere exacerbate the problem by paying people more to exploit Nature than to protect it, and to prioritise unsustainable economic activities.’

The question arises how we can achieve the transformation required to tackle the restoration of nature and in so doing also address the problems of climate change – at least those derived from our misuse of nature or where nature offers workable solutions. Dasgupta has three headline proposals: (i) Ensure that our demands on Nature do not exceed its supply, and that we increase Nature’s supply relative to its current level. (ii) Change our measures of economic success to guide us on a more sustainable path. And (iii) Transform our institutions and systems – in particular our finance and education systems – to enable these changes and sustain them for future generations.

The first touches very much on ‘the enormous problem of producing sufficient food in a sustainable manner’. This he says requires more

than technology alone but the restructuring of production and consumption systems. We will need to conserve nature and sustain the natural systems that feed us as less costly than degrading then restoring them. He argues for multifunctional land and seascapes to deliver ecosystem goods and services and proposes large-scale investment in Nature-based solutions to address biodiversity loss, contribute to climate change mitigation and adaptation, as well as deliver economic benefits, including job creation.

There is much to consider here and too little space to do Dasgupta justice. These are not merely economic solutions but wide ranging with implications for change, and which he describes as transformative to ensure we can choose the sustainable path. This in turn will need 'the sustained commitment of actors at all levels' The challenge for taking this forward is to make this relatable and plausible to all those actors from policy makers to farmers and other economic actors to the citizens in the general public. Here returning to the pandemic and what we have and are in the process of learning from it is useful.

As Covid has played out since early 2020 we have learnt much about the relationship between good science and public policy and decision making but also about behavioural science, culture and influencing what businesses and the public at large do. We know better as a society that we need rigorous science with equally rigorous collection and analysis of data. This work matters a great deal (as has sustained UK Investment in health and biosciences) and has proved vital from vaccine development to decoding viral genetics to epidemiological modelling. We also learnt that we need scientists we can trust to advise government and inform the public and to communicate well to both. Thirdly, we need well-informed and advised politicians who make the difficult political and policy decisions factoring in, we must hope, the costs, risks and benefits. Lastly, we have learnt, we need an engaged and informed public that understands the issues, is made aware of the risks,

costs and benefits and so acts to change its behaviour including patterns of demand and - importantly, to ensure there is a loop back to policy - giving politicians the space and support for resolute action. This has to include economic actors - from small businesses to corporate giants - altering their behaviour, processes and objectives in response.

It is not too fanciful to stretch this analogy to how we face the challenge of managing land in the future. The issues surrounding farming are as complex as those within public health and medicine - farming engages not only with climate and weather systems but also ecosystems including those of the soil. At base, how land is managed affects the health of those ecosystems and wider nature, and ultimately our own health through the nutritional quality of what we eat to the quality of the environment we all share. Yet, we have long devoted immense resources to understanding the human body and its systems - physical, chemical and biological. But, as Colin Tudge recently pointed out to me, we have yet to give due attention and resources to ecosystems and particularly the soil upon which we are so dependent.

In terms of addressing the challenges faced in how we manage the land and deploy it to restore biodiversity, help tackle climate change and contribute to human health and well-being - as well as sustained economic activity - we need similar resolve and commensurate resources but also, as said, engagement of all actors in this project. If we narrow this down further to what this might mean for soils, this suggests the following:

- We urgently need significant investment in the science of soils, including physics and chemistry but vitally also their biology and ecology, as well as the collection of representative national data ideally joined up with local in-field analysis and monitoring. We need to understand better the condition of UK soils and their potential but this must go beyond producing food, the principal focus of the agricultural quality maps we have from the

1960s onwards and the criteria which affect its grading (climate, soils, drainage, aspect, topography). We now need to understand the ability of healthy soils to perform multiple environmental services beyond food and fibre production to cover aspects such as water infiltration and storage, carbon storage, supporting biodiversity – and the thresholds when such services may fail as soils degrade.

- We need this science to inform policy makers and strengthen their commitment to putting soil health front and centre of agricultural and environmental policy-making. In the UK this means from the 25 year Environment Plan, when rebooted, to the Environment Bill and Net Zero Strategy. This includes sustained investment in the research: as the Sustainable Soils Alliance has shown government investment in soils compared to other natural elements – water, air – has been woefully small: taking the example of 2017-18 they show that of £68 million committed to research on air, water and soil just £240,000 or 0.41% was spent on soils.
- In terms of engaging the public Covid 19 has taught us that behaviour is not only shaped by financial support or regulation and enforcement – important though these are to set common standards – but also by well-communicated advice, by trusted authorities and social capital – people need to care about others as well as themselves or their immediate family. In short community relations and culture matter enormously too. The cultural shift required is for all of us to think about Nature too and realise that when we harm it we eventually harm ourselves and others, probably those less advantaged than we are.
- The combination of regulation, effective proportionate enforcement and financial incentives such as under the new environmental land management schemes are

entirely relevant to changing the behaviour of farmers and others in the land-based sector. But so too is culture. To manage soils well, to restore them to ecological health we need to recognise both the agri and the culture in agriculture. Farming must take account of the physical, chemical and biological properties of the fields it stewards but also the culture of those who manage the land. This means science and policy must consider the cultural traditions, beliefs, knowledge and applied skills of people who farm and their understanding of their land in shaping behaviour towards sustainable, nature-restoring, productive farming.

- The implications of this are significant: the science we have, insofar as it does guide policy making, is insufficient on its own to engineer the behaviour change we need in land management. Just as in the pandemic where research science and medical practitioners have collaborated to rapidly and radically alter practice to keep people alive, there needs to be a better collaboration between science – lab-based and field trials – with the practitioners, agroecological farmers, with their already vast body of accumulated knowledge of practices that work by taking into account the intricacies of their soils, and of wider nature and its many functions and interactions. Research science by definition advances by specialising in minutiae but practical land management requires more holistic, whole field understanding from the grass roots. We need more understanding of ecology and ecosystems – of the macro – in applying the micro of science to managing the land well.
- This means that top down technological solutions cannot be the sole answer, as Dasgupta makes clear. There needs, as he says, to be a fundamental restructuring of consumption and production patterns. Generally that means a systemic shift away

from damaging linear forms of resource use to re-use and recycling and sharing and a more circular economy. Nowhere perhaps better exemplifies this shift than forms of agroecological and regenerative farming. These harness the soil itself, an eternal combustion engine powered by the sun which drives birth, growth, death and rebirth in a cycle of life that produces food and cycles wastes to nutrients which again drive life.

- This to me then entails giving priority to incentivising, promoting and – where still needed, researching – regenerative and agroecological forms of farming which mobilise nature to restore life and health to soils as the underpinning for fertility, healthy crops and animals and thriving ecology. These in turn can maintain productivity but reduce costs to farmer, in resources and to the environment. This means applying widely a range of techniques already pioneered by farmers here and abroad and made to work for their context, for their land. These include approaches such as blending permanent crops with annual via trees and shrubs, diversity of crops within and between fields, low or no tillage and cover crops to protect bare soils and (re)integration of livestock. Dasgupta cites Nature-based solutions as one of the key tools to restore biodiversity and tackle climate change. We urgently need nature-based farming and it should feature strongly in the range of vital Nature-based solutions to rapidly deploy.

As with any programme for change, proposals and recommendations can merely drive the conversation. Much more needs to be done practically at multiple levels by multiple people. Most importantly, and left to last, is the need to move forward from the point with which we started

in recognising that we are of Nature as is our economy and our entire civilisation. This doesn't allow us to do anything in the name of Nature but to understand better how Nature functions within us and around us. In this we should know that, as David Montgomery and Anne Biklé point out in their book, *The Hidden Half of Nature*, 'the environmental systems on which we depend are founded on cooperation as much as competition'. They add that 'Diversity nested in cooperation creates dynamic systems that can stand the test of time.' Nature is of course the ultimate laboratory which has stress-tested its components over millennia. It behoves us to work out how we can cooperate with Nature in managing the land for our food rather than, as still is oft said, competing with it and seeing farming as replacing nature and its systems.

Lastly, bringing us right back to Covid-19, the pandemic has made us deeply aware of the importance of understanding microbiology. Human health depends on it as our own immune systems wage war on countless attacks of pathogens; yet, science is beginning to show us the critical role played by the microbiology in our own intestines – the rich flora of microbes in healthy human guts – in sustaining those same immune systems. There is perhaps no better way to illustrate our co-dependency on Nature in so many forms than its role in our personal health and its role within us and as part of us. If we can better understand the complex microbiology of our bodies and work cooperatively with it, that indeed will be key to unlocking greater health for us; but if can do the same for soils and their extraordinary diversity and harness their potential, that will lead to a renewed and better relationship with the wider natural world that sustains us.

FOCUS ON WARMING, NOT JUST EMISSIONS

FFINLO COSTAIN

ffinlo is the founder of the Food & Global Security Network, & chief executive of Farmwel.

'GWP-100 overstates the effect of constant methane emissions on global surface temperature by a factor of 3-4. This matters so enormously because when we accurately understand the impact of methane emissions from ruminants, our land use options change. We need a new consensus to emerge – one that focusses on warming from emissions rather than on the emissions themselves.'

In Chapter 7 of AR6, the IPCC's 2021 report into the physical basis of climate change, a small explosion occurs. On page 123, the report states that, 'Expressing methane emissions as CO₂ equivalent emissions using *GWP-100* overstates the effect of constant methane emissions on global surface temperature by a factor of 3-4 [...] while understating the effect of any new methane emission source by a factor of 4-5'.

This is revolutionary. And it matters so enormously because when we accurately understand the impact of methane emissions from ruminants, our land use options change. At a stroke the argument for land sparing, and the inevitable intensification of livestock agriculture that this leads to, is weakened. Immediately, the radical benefit of agroecological and regenerative agriculture becomes clear.

If we are to use land to address the multiple crises we face in nature, while producing enough high quality nutrition for all of the people on this planet, then accuracy is essential when assessing the global warming impact of agriculture.

The science referred to in AR6 is the product of research by Professor Myles Allen at the Oxford Martin School with Michelle Cain, Dave Frame, John Lynch, and Raymond Pierrehumbert. Professor Allen was a lead author on the IPCC's Special Report: Global Warming of 1.5 Degrees.

It shows categorically that methane from stable or slightly dwindling populations of cattle and sheep are not causing additional global warming. Although ruminant livestock produce methane almost constantly, the focus on their emissions is misleading – *it's the warming impact of those emissions that actually matters*. Far from being unsustainable as some people have argued (e.g. Poore and Nemecek), grass-based, low input cattle and sheep systems, such as agroecological systems, can become rapidly warming neutral, and they can help to restore biodiversity and soil health.

The Oxford Martin team has published several papers that explain both the science, and the use of a revised metric, GWP*, to measure the global warming potential of methane (Oxford Martin School, Climate metrics under ambitious mitigation). In a 2020 piece for Environmental Research Letters, John Lynch et al explain that: 'CO₂-equivalents have become a near-universal means of reporting greenhouse gas emissions, and in many cases are used to directly infer their climate impacts or role in mitigation strategies—even if such an expansive application was never intended. Given this, it is important to have a means of deriving CO₂-equivalents that provides a reliable link between reported emissions and their warming impacts. As demonstrated, in many cases

conventional use of GWP₁₀₀ does not achieve this, while GWP* does.’

GWP* accurately characterises the warming impact of methane for the first time. While carbon dioxide (CO₂) and nitrous oxide (N₂O) are active in our atmosphere for many generations, methane is broken down in about a decade. This means that the methane emissions of a herd of 100 cows today are simply replacing the emissions that were first produced when that herd was established by a previous generation of farmers. There was an initial pulse of warming when the herd was established, but there is no on-going warming from that herd.

As an example, under GWP*, total UK agricultural emissions fell from 45.6 million tonnes of CO₂ equivalent (MtCO₂e) in 2016 to just 9.5 MtCO₂e*. Of these emissions, warming from CO₂ and N₂O are the same as previously reported (5.6 + 14.3 = 19.9 MtCO₂e), but methane is recalculated as -10.6 MtCO₂e*. That’s a negative value because methane levels have fallen since the base year of 1996, the reference point for comparing 2016 emissions. (It should be noted that ruminant populations have also fallen in the USA and the European Union.)

Lynch et al continue: ‘Using GWP₁₀₀ to direct climate change mitigation strategy could be unfair, inefficient, and dangerous. Unfair, as it does not provide a clear link between emissions and climate change contribution, and could lead to an expectation that some actors (long-term methane emitters) have to undo their past warming, while others (CO₂ emitters) merely have to limit further temperature increases. Inefficient, as it would overstate the level of action needed to offset long-term sustained methane emissions, while simultaneously undervaluing the potential short-term benefits of reducing these methane emissions. Dangerous, as it can greatly understate the impacts of increasing methane emissions, and obscure the fundamental need for net-zero CO₂ emissions as soon as possible, regardless of what mitigations are made to shorter-lived climate pollutants.’

The science shows that enteric methane emissions must still fall – but to continue having a neutral impact, they only need to fall by 10 per cent by 2050. Stuart Roberts, deputy president of the UK National Farmers’ Union, put it simply when he wrote in Countryside Online, ‘If we continue gradually declining methane emissions it would make no further contribution to global warming.’

The use of GWP* also shows the danger of increasing ruminant numbers – while a continued shift towards more highly-stocked indoor ruminant systems would contribute additional CO₂ and N₂O emissions, for example from new building requirements, monoculture feed production, feed distribution, and slurry management.

By contrast, outdoor agroecological systems can produce significantly smaller CO₂ and N₂O footprints. By mainstreaming agroecology we would see first a national and global redistribution of ruminant livestock (as rotation is restored as a staple component for all farm systems) and a natural reduction in numbers (as farm business decisions become land-, rather than volume-oriented).

Lynch et al conclude, ‘There is an additional danger, which is to the perceived environmental integrity of climate policy. *Basing climate policies and emission trading systems on a metric that demonstrably fails to reflect the impact of different emissions on global temperature, while at the same time claiming these are designed to deliver a long-term temperature goal, risks undermining confidence in the entire strategy.* GWP* provides a straightforward means of dealing with these issues, calculating genuinely warming-equivalent emissions using information that is already being reported in the UNFCCC system.’

Soil regeneration and ruminant agriculture

In the UK, farmers own and manage more than 70 per cent of the land. Unfortunately, many of them

feel marginalised and threatened by the exaggerated focus on ruminant methane in causing global warming. This mis-characterisation runs the risk of alienating precisely the constituency we must inspire in the race to mitigate and adapt to climate change, to restore biodiversity, and increase our nutritional and soil security.

The Oxford Martin science shows us that cattle and sheep are not the enemy. GWP* is already being used by some farmers to footprint the warming impact of their farm businesses. The metric can be used to accurately inform farm business plans, and indicates the value of mitigating climate change by growing trees, hedges, and establishing ponds and diverse species-rich grasslands. These interventions should be integrated within whole farm systems to offer the greatest benefit, so that in addition to sequestering carbon they help to restore biodiversity, improve soil health, and restore and manage water flows. Renewable energy generation can be used to mitigate emissions even further. Additional flora for climate mitigation will also create the potential for greatly improved animal

health and welfare, with more shelter from extreme weather, more nutritional diversity in the sward, and better natural management of pests and diseases.

For clarity, GWP* is not a prescription for business as usual. As the population grows, humanity must also reduce its per capita meat and dairy consumption. But for enteric methane to continue having a neutral impact, emissions need only fall by 10 per cent by 2050.

Cattle and sheep have been part of the European landscape for generations and this research shows that they can be for many years to come. For this, we need a new consensus to emerge – one that focusses on warming from emissions rather than on the emissions themselves – and which mobilises more farmers to produce nutritious, affordable, quality food, while sequestering carbon, restoring nature, and helping to establish rural economic resilience.

REGENERATE OUR SOIL CARBON SPONGE

WALTER JEHNE

Walter Jehne is an internationally known Australian soil microbiologist and climate scientist and the founder of Healthy Soils Australia.

‘Just as the natural formation of the Earth’s soil carbon sponge 420m years ago created the terrestrial bio-systems we depend on; our regeneration of our soil carbon sponges is now the only option and agency we have to address the security threats before us.’

There are 8 billion people currently on this finite planet.

While 10 billion were projected by 2050, poorly recognized security threats challenge this.

Despite warnings these threats arise from dangerous hydrological climate extremes, including from:

- Intensified storms, hurricanes, floods, droughts, aridification and wildfires.
- Humid heat hazes whose health risks take large regions beyond human survival.
- Acute shortages of safe accessible fresh water to sustain urban and farm essentials.
- Food affordability crises given that 9 missed meals separate social stability from chaos.
- The impaired nutritional integrity of our food and its preventative health impacts.

We need solutions to avoid these threats and consequences, urgently, globally.

Fortunately nature has provided Earth and us with its solution: Water, which already:

- Covers 71% of Earth as oceans plus much of the land as snow, ice, lakes and rivers.
- Governs some 95% of the heat dynamics and thus climate of this blue planet.
- Governs some 80% of the natural and human enhanced greenhouse gas effect.
- Absorbs and for now retains 93% of the extra heat we trapped via this effect.

- Is fundamental to the creation and survival of all life and bio-systems on this planet.

Given that water already governs much of the Earth’s climate, ecology and balance, we need to understand the processes through which it does this, how we may have unbalanced them, and what we can and must do to restore these balances and address these threats.

To understand the why, what and how of each of these threats to our security, and what agency we may have through this understanding, to restore or rebalance these processes and thereby minimize their hydrological consequences both locally and globally and in time.

To do this we need to understand how nature created and regulates these hydrological processes, and thereby much of the Earth’s bio-geochemical cycles, soils, hydrology, life, bio-systems and the largely stable former climate we evolved in and depend on fundamentally.

How nature, via paedogenesis, formed soil sponges, by microbes solubilising rock and leaving behind organic detritus which enabled more water to be retained in the soil to accelerate their evolution and extension of their hydrology, plant and animal successions to help create the Earth’s hydrologically cooled and buffered climate.

Just as the natural formation of the Earth’s soil carbon sponge 420 million years ago created the

terrestrial bio-systems we depend on; our regeneration of our soil carbon sponges is now the only option and agency we have to address the security threats before us.

The regeneration of the Earth's soil carbon sponge

Despite 50 years of discussion, denial and delay focused on the abnormal rise in CO₂ levels few recognize it as largely a symptom of our oxidation of our current and fossil soil sponges. Even fewer have considered how this oxidation affected key climate drivers such as water.

This lack of attention was based largely on the assumption that because water was such a dominant driver of the Earth's climate, we could not possibly have changed it. Also as CO₂ is a minor greenhouse gas, its abnormal rise was the prime threat, not a symptom of a potentially much larger one.

This meant that we failed to recognize how the oxidation of these sponges and their hydrological consequences may be altering the Earth's heat dynamics, warming, and climate. Similarly how regeneration of these sponges may be able to re-balance this hydrology and climate.

Recognising this is critical – as slowing down the rise in the CO₂ symptom or reducing it can't now prevent the hydrological climate extreme that threatens our bio-systems and survival. That instead we need urgently to use this extra CO₂ as a resource to regenerate the sponge and the hydrological and climate processes we have unbalanced, in order to restore our safe climate.

So how can we bypass these assumptions and the inertia of business-as-usual to regenerate the Earth's soil carbon sponge, hydrology and safe climate, at scale, and in time?

Nature sustainably bio-sequesters from 0-300 tonnes of Carbon per hectare per annum via its various bio-systems. Leading farmers globally can

sequester up to 10tC/ha/an. Extended over 1 billion hectares, or 20% of farmed lands, this could take us a long way to achieving a zero net emissions target globally and to help regenerate and rehydrate those landscapes.

Industrial agriculture by contrast often loses 5-10tC/ha/an from its soil via its expensive oxidative practices and inputs while also degrading its long term draw down capacity.

Proposals by Regenerate Earth show that we can practically reduce Earth's current emissions of some 130 billion tC/an, and enhance the drawdown of 120btC/an, by the use of green bio-systems. Doing this could sustainably and profitably retain and return up to 20btC/an back into our soils, to achieve negative net Carbon emissions of up to 10btC/an by 2030, and rapidly rehydrate, buffer and cool the climate.

However rather than carbon accounting, the critical do or die issue if we are to avoid these dangerous hydrological climate threats, is that every gram of this retained or returned carbon is used to regenerate the Earth's soil carbon sponge, hydrology and cooling.

Similarly, that every gram helps to regenerate the bio-fertility, productivity, resilience, food output and the nutritional integrity of that food and the health of the resultant bio-systems.

As in nature, powerful positive feedback effects can help such regeneration:

- Each gram of carbon sequestered in the soil sponge can increase the water retention in the sponge by some 8 grams and up to 20 grams via improving soil structures.
- Each gram of carbon sequestered, by increasing the structure and exposure of mineral surfaces in that soil, can increase the availability of essential plant nutrients and thus the bio-fertility of that soil without the need for nutrient additions.
- This increase in soil structure will also aid the proliferation of roots and microbial symbionts in that soil to depth, thereby increasing the

plant's access to further soil volumes and nutrient resources while also increasing the resilience of the plants.

- This increase in root substrates and exudates will also aid the activity of beneficial microbes in these soils and their fixation, solubilisation, access, uptake and cycling of essential nutrients to aid growth and help control stress and disease agents.
- This regeneration of soil health can greatly enhance plant productivity and resilience even in degraded soils with minimal inputs by enhancing the longevity of green plant growth and thereby its protective hydrological buffering and cooling processes.

Extended globally, these soil health innovations can more than secure the essential food needs of the 10 billion via more autonomous, efficient, sustainable and equitable rural and urban farming systems that require lower external inputs. The food produced should have far higher nutritional integrity and preventative health values and benefits socially.

These soil health and hydrological innovations will enable large areas of former productive but now degraded wasteland to be regenerated back into productive rangeland, grain cropping and agro-forestry systems and address the identified food-related security threats.

Addressing the identified climate threats

In addition to addressing the security threats to global food and health values, regeneration of the Earth's soil carbon sponge, and its resultant soil health and hydrological outcomes, are now our only means and last chance to also address our existential climate threats.

As in nature this stems from the exceptional capacity of the Earth's regenerated soil carbon sponge to; infiltrate, retain and make available water to extend the longevity of green plant growth, its transpiration and its natural physical cooling or 'air conditioning' of the climate.

For water to transpire it must be converted from liquid into a gas, water vapour. This phase change requires some 590 calories of heat energy per gram of water transpired. As this heat comes from and leaves that surface it cools it. When the water vapour condenses this heat is released, with much of it radiating out to space thereby further cooling the planet.

On average 24% of the heat received by the Earth's surface, as incident solar radiation, is transferred from its surface into the air and back out to space via these processes. Locally this transfer of heat can cool transpiring areas significantly on hot summer days.

Theoretically we could offset the Earth's abnormal warming of 1.2C to date by increasing such heat fluxes by some 4-5% globally. This cooling could be induced safely within weeks, not the centuries estimated for reductions in CO₂ emissions to have any meaningful effect.

Regeneration of the Earth's soil carbon sponge and hydrology can also increase the soil area able to be protected by perennial plants as well as their longevity of cooling plant growth. These shaded moist soils with transpiring plants mostly absorb far less incident solar radiation compared to bare exposed dry soils and may stay far cooler; mostly at below 20C, compared with the 60C that the surface of exposed bare soils may reach nearby.

Consistent with the physics of 'black body radiators', this difference in the temperature of the surface vastly alters the amount of heat that is re-radiated from these soils, with the hotter bare exposed soil re-radiating vastly more heat than the shaded moist cooler soil.

As the greenhouse effect is driven largely by how much heat is being re-radiated from an area, and less so by the concentration of greenhouse gases in the air able to absorb that re-radiated heat, this directly and profoundly influences that local climate.

It means that we can turn down the local greenhouse warming effects from very high to low

simply by reducing the absorption and re-radiation of heat from our soils by keeping them protected and cool. We can do this rapidly within days, largely independent of the level of greenhouse gases in the air; as such gases can't absorb heat that has not been emitted.

As in nature, we can practically use either or both of these processes to safely and rapidly cool regions. However both need water. That is why regeneration of the Earth's soil carbon sponge and its capacity to infiltrate, retain and make available rainfalls is so critical.

Addressing water security threats

The quantity of heat being re-radiated from land surfaces not only influences the relative local strength of the greenhouse effect but it can also govern whether either high pressure heat domes or lower pressure zones form over landscapes. Whereas bare hot dry land with high re-radiation levels normally form high pressure heat domes, protected cool moist areas with far lower re-radiation generally form cooler low pressure zones.

These pressure differences greatly influence local air flows with air flowing from high to low pressure areas. They also influence where cool moist low pressure air can flow; given that such low pressure air cannot flow into or displace the hot air in high pressure regions.

As a consequence, hot dry areas with high pressure heat domes over them often block the inflow of cool low pressure air with high moisture levels. This can prevent rain reaching such high pressure regions intensifying their aridification. Conversely, protected green moist cooler regions with low pressure zones above them, often funnel in moist low pressure air flows to enhance local rainfalls.

It is also consistent with observations that rain often follows rain and that once dry, areas often miss out on intermittent regional rainfalls and further aridify.

These landscape-induced differences in pressure zones can also influence the reliability and spatial movement of monsoonal air flows and rainfalls. Former moist rangelands, if aridified due to overgrazing, soil degradation or wildfires, often have less reliable monsoonal rain and further aridify. Conversely nearby regenerated or reforested areas often receive more rain. This raises the question, can we restore the Australian and other former monsoons?

Catalysing action to address these security threats

Just as our degradation of our soils and their hydrology has contributed to these security threats; is our regeneration of the Earth's soil carbon sponge now our only option to avoid these threats in the limited time available?

As demonstrated in nature and by leading innovators, we have adequate knowledge of the ecological processes and balances that govern these threats and their avoidance, as well as the practical capability and imperative to address them urgently at scale and in time. While there will always be more to learn to tailor optimum solutions to specific needs, we will only learn this by doing it. Delaying further to learn more will often make us too late.

Given that nature and innovative leaders confirm there are safe solutions to address these imperatives we need to face our reality and just do it by:

- Empowering grass roots agency and action by farmers and youth everywhere to;
- Regenerate the Earth's soil carbon sponge, soil health and thus its hydrology to;
- Naturally rehydrate, reforest and cool and buffer the bio-systems they depend on.

However to effect these changes in time and at scale we must stop humanity deluding itself that business-as-usual can address these crises. We must demonstrate viable alternatives.

To do this we must demonstrate that business-as-usual, and its protection via many policies, subsidies and externalised consequences, are impediments that must be removed via the evidence of alternatives based on new metrics and values to catalyse the needed changes.

We must demonstrate that the wise ecological re-balancing of the Earth's fundamental soil and hydrological processes that govern our wellbeing and that we have impaired need to and can be restored. That we have and are standing on that solution: regenerating healthy soil.

Whether we can catalyse the needed changes in time or not, we can be confident that nature will again use these same soil, hydrological and plant processes to regenerate Earth.

Our only issue is will we help her in this and thus avoid our collapse within decades or let her do it without and after we have joined the many other 'civilizations' that also failed to respect the health of their soils, and are found in the dust of archaeology.

HOMAGE TO SOIL

PATRICK HOLDEN

Patrick is the founder of the Sustainable food Trust.

‘On my farm I have had the privilege of observing up to five seven-year rotation cycles and the impact on soil fertility outcomes, during all of which time I have not used any chemical fertilisers or pesticides. My observations have convinced me that this form of regenerative farming practice can not only build soil organic matter, but actually build soil.’

Perhaps surprisingly, given that I worked for more than 20 years for an organisation called the Soil Association, my striving to understand the full significance and importance of the soil is still an evolving process which continues to be inspired and illuminated by ongoing revelations derived from my farming, my reading, and my role in the Sustainable Food Trust. I thought it would be relevant to reflect on some of these recent milestones, particularly bearing in mind the various planetary emergencies which are now occupying the attention of citizens throughout the world in the run up to the COP26.

Everyone now knows that the soil is one of the world’s great carbon banks, actually second only to the oceans in its capacity, and arguably the only element of the Earth’s bank of natural capital where changes in farming practice could sequester significant amounts of CO₂ out of the atmosphere during the next 10 years. For that reason alone, it deserves to receive a huge amount of attention at the Glasgow summit. In writing this, I am mindful of the vision and leadership shown by the French minister Stéphane Le Foll at COP21 in Paris, launching as he did the so called ‘Quatre pour Mille’ (4 per 1000) initiative inviting all farmers to increase their soil carbon bank by 0.4 per cent per year. Many governments and organisations signed up to this initiative but, due to the lack of financial incentives and the absence of adequate record keeping, little progress has been made towards

achieving the French minister’s objectives, which is why the COP26 should be seen as a huge opportunity to implement the scheme.

Referring to the goal of increasing soil carbon places an emphasis on the physical, whereas in fact the soil is also a biological entity, containing as it does a multitude of micro-organisms and higher life forms. One way to understand this is to use the analogy of stomachs and to visualise the soil as the collective stomach of all plants on the planet; this is actually an accurate description because although plants don’t have an internalised stomach, 30% of the outcome of photosynthesis is exuded in the form of sugary saps into the root zones of plants, nourishing a symbiotic community of micro-organisms upon which the plant depends for its digestion. This example alone is illustrative of our evolving understanding of the world of soil which has been highlighted through the study of the human microbiome, in other words our digestive system, which can be understood in very similar ways – we eat food which feeds our stomach flora upon which we depend for our own digestion.

So the soil can be seen as an organism or an ecosystem, playing a central role in transforming the mineral matter of planet Earth into that thin biological film upon which all terrestrial life depends. It would be no overstatement to say that upon this thin layer of organic matter laid down over millennia, quite literally the future of

civilisation depends. As mentioned at the beginning of this article, there is nothing new in this observation, but it has taken me a lifetime of farming and advocacy for sustainable agriculture to understand its true significance.

There are so many wonderful examples of individuals who have understood and written about the true importance of soil. I'm thinking here of Sir Albert Howard who described the health of soil, plants, animals and people as forming one indivisible whole, or his wife Louise Howard who continued his work in a book entitled *The Earth's Green Carpet*. Much later John Seymour, the self-sufficiency guru of the 1960s and '70s, coined the phrase 'the fat of the land' in his book of the same name.

From my perspective, the soil is the fat of the land. It represents a resource laid down in times of abundance which acts as a reserve to nourish future generations of plants, animals and people.

Having now farmed for 48 years on the same piece of land, observing the impact of my actions on the soil, I have reached the conclusion that the future of humanity and its capacity to survive the triple threats of climate change, biodiversity loss and declining public health, hinges on the capacity of farmers not merely to maintain the fertility of our agricultural soils, but actually to rebuild them. Could this be possible? I think the answer is yes, once again derived from my own observations and the impact of my farming practices, both successes and failures, over time.

Here are a few observations about what needs to happen now about the potential to build soil and soil fertility based on this experience:

Farming must transition from the extractive to a regenerative phase. This can only be achieved through the introduction of crop rotations with a fertility-building phase which in the UK would normally be from three to five years of grasses, legumes and herbs normally grazed by cattle and sheep, thus producing food humans can eat from the fertility-building element of the rotation.

On my farm I have had the privilege of observing up to five seven-year rotation cycles and the impact on soil fertility outcomes, during all of which time I have not used any chemical fertilisers or pesticides. Despite not having kept consistent or comprehensive records of the impact of this system on soil fertility outcomes, the data I have recorded plus my observations on crop yields, convinced me that this form of regenerative farming practice can not only build soil organic matter, but actually build soil. This differentiation is absolutely crucial because whilst the current orthodoxy of the scientific community (as reflected in the Climate Change Committee's strategy for UK agriculture) fails to factor in any soil carbon sequestration, their justification for this exclusion is based on the failure of the scientific community not only to monitor the soil carbon impacts of regenerative agriculture, but also to factor in the potential of regenerative farming to actually build soil. As an example, my own farming practices might increase the soil organic matter, say from 5% to 7%, but if I was also building more soil this would not be captured through the existing measurement mechanisms.

This leads to a vital challenge of which farmers throughout the world are now acutely aware, namely the capacity of the scientific community to accurately measure soil carbon stocks.

As mentioned above, the tantalising prospect of paying farmers to act as soil carbon stewards was explored and promoted by the French Agriculture Minister, Stéphane Le Foll at the COP21 climate change conference in Paris, setting a target for all the world's farmers of raising their carbon stock by 0.4% per year. In the six years since the launch of this initiative, no single nation has yet claimed they have delivered this target. Yet if it was achieved globally, this would enable the world's agricultural soils to become the single biggest contribution towards climate change reversal by, over time, sequestering up to 100 parts per million of CO₂ back into the world's largest carbon bank after the oceans, the soil.

I've focused here on soil carbon, but in reality carbon should be seen as a proxy for soil fertility which is not merely carbon in both living, dying and dead forms, but also a remarkable, mysterious, even magnificent ecosystem, largely hidden from our eyes, upon which all above ground life depends.

Thankfully the soil science community is now shuffling towards a slightly embarrassing U-turn and realising in the process that it has been the obsession with physics and chemistry and the application of fertilisers and pesticides that has allowed farmers to largely destroy the biological element of soil fertility on which the future of life on Earth depends.

Homing in on UK politics, there are encouraging signs that governments and farming leaders alike have recognised the imperative of improving soil fertility and carbon stocks, as evidenced by Minette Batters of the NFU setting a net zero target by 2040, and currently in the discussions about the shape and incentive mix of the coming Environmental Land Management Scheme. I read in the farming press this week that a key conclusion of a survey was that farmers wanted to see stronger incentives at the heart of the ELMS scheme to help them move towards net zero, the principle factor of which of course should be incentivising building soil carbon stocks.

In completing this homage, it would be inappropriate not to make mention of the importance of composting. Farmers in general and livestock farmers in particular, of which I am one, have come very late to the composting party. Historically we have tended to stack our farmyard manures in anaerobic saturated heaps, relying solely on the chemical nutrients, nitrogen, phosphorus and potash to nourish subsequent crops. This despite a massive body of observations and evidence stretching back over a century of the incredible power of compost to accelerate soil fertility building.

Cynics often point out that people say they are going to do something and then don't actually do it, such as buying organic food, but they fail to acknowledge that with all of us the intention precedes the action. It is exactly the same with composting; I've been thinking of introducing it for years but have only finally got around to it very recently.

I first witnessed the transformative power of composting some 15 years ago when I visited the Sekem community in Egypt where Helmy Abouleish and his father have reclaimed lifeless desert soils and turned them into fertile fields producing an abundant range of nutritious crops solely by introducing large volumes of composted wastes from wherever they could find them including biomass and municipal waste from Cairo.

Eventually I was shamed into action and have recently covered and contained my composting area, as a result of which in 2021 we recently spread a field with the best compost we've ever made here in 48 years, covering a newly established herbal ley. Our 80 Ayrshire dairy cows have just finished grazing this field of around 9 acres which nourished them for eight days, a remarkable milk-stimulating phenomenon which has made me realise that in terms of my capacity to further build the soil fertility over which I have temporary stewardship, I am still only in the foothills of the potential which lies ahead.

I believe this situation is applicable to the majority of the world's farmers - in front of us is a monumental task, we need not only to maintain but to build soil fertility, which we must and can do by commencing a new relationship of the soils under our management, harvesting and growing the body of experience and evidence of the pioneers of soil building both historic and living. If we embrace this challenge at the scale which is necessary, namely globally, we might just be able to avoid the kind of collapse which Jared Diamond has so brilliantly chronicled in his book of that title.

I'd like to conclude on perhaps a mystical note, with a hymn written in 1867, which I used to sing as a child, substituting only three words, (apologies to Walter C Smith) -

1 Immortal, invisible, soil only wise,
In light inaccessible, hid from our eyes,
Most blessed, most glorious, the Ancient of Days,
Almighty, victorious, thy great name we praise.

2 Unresting, unhasting, and silent as light,
Nor wanting, nor wasting, thou rulest in might,
Thy justice like mountains high soaring above
Thy clouds, which are fountains of goodness and
love.

3 To all, life thou givest, to both great and small.
In all life thou livest, the true life of all.
We blossom and flourish as leaves on the tree,
And wither and perish, but naught changeth thee.

4 Great soil of all glory, great soil of all light,
Thine angels adore thee, all veiling their sight.
All praise we would render; O help us to see
'Tis only the splendor of light hideth thee.

A CALL TO ACTION

VICKI HIRD

Vicki Hird is Head of Farming at UK Sustain, and author of 'Rebugging the Planet'.

'We need 'nutritional' security not just 'food' security. There's a world of difference between what global and national food corporations provide and what we actually need. 'Food security' could include high fat content, sugar, oils, and feeds for industrial meat. 'Nutritional security' on the other hand considers the health value of food and the ways in which the food system determines an individual's ability to get essential nutrients, and not just calories.'

The last time global food prices reached the highs of this year was 10 years ago, when global instability and food riots contributed to the overthrow of governments in Libya and Egypt and many started to protect supplies. The causes of those peak prices a decade ago included the production of crops for fuel not food, oil and energy price rises, dietary shifts and hedge fund speculation in food commodities. All these same factors are here again now, and they are possibly at higher levels.

In addition, there is also fallout from the pandemic, more regional conflict, and growing climate breakdown. Droughts have been hitting Latin America, and agricultural top player Brazil is facing its worst drought in 91 years. A global food crisis is looking like a real possibility.

Such occurrences may become more frequent if the world's farms start to fail on a large scale – as depleted soils are not replenished, and fresh water sources are hit by drought, over-extraction and pollution. Our aid and trade policies also favour monoculture, so high input, export-led production has become the norm, rather than sustainable, resilient, and diverse food production for national and regional markets. Systemic failure is very possible.

And we need 'nutritional' security not just 'food' security. There's a world of difference between

what global and national food corporations provide (and encourage us to buy with extremely sophisticated advertising) and what we actually need. 'Food security' could include high fat content, sugar, oils, and feeds for industrial meat. 'Nutritional security' on the other hand considers the health value of food and the ways in which the food system determines an individual's ability to get essential nutrients, and not just calories.

Key tools we need to use if we are to deliver nutritional security for all would include:

1. Prioritising the protection of resources, including soil and water, using natural bio-controls and promoting the genetic diversity that underpins food production, with strong targets, well-enforced regulation, and fiscal measures.
2. Building agroecological farming systems (with incentives and penalties, advice, R&D) that provide food and more diverse products, whilst restoring and maintaining the natural systems in and around the farm and reducing global warming impacts. Less and better meat has to be part of this adjustment in affluent regions, given the unsustainable levels of pollution and land use, and public health risks (communicable as well as non-communicable) involved in industrial livestock systems, and the land clearances to accommodate their needs.

3. Driving dietary shifts and investing in new supply chains to match that supply.

4. Curbing the marketing and power of food corporations that squeeze producers everywhere and increasingly sell highly processed foods that rely on cheap raw materials. Some countries have made a start with supply chain binding codes of practice, sugar taxes and curbs on advertising to children. We need more to achieve nutritional security.

5. Addressing the impact of food commodity speculation – crops that pass through several hands before they are even grown – and harmful investments. This speculation can't help deliver stable farm incomes and fair consumer prices, nor can the remote unaccountable hedge funds that are acquiring control of the means of production, for example seeds, genetics, inputs and land.

6. Investing in strong early warning systems to avoid worst case scenarios.

These are big asks. And some would argue we've never had it so good. There is currently more choice from the global market place and the market seems to be providing. But this is not true for many of the world's malnourished eaters, and we are working on borrowed time with thinning soils, marine resources polluted or depleted, and climate change already making farming unstable, with land loss in many regions.

Fixing it through game changing tech like protein bug farms or algal fields may be options, but they are still a way off, and there are no guarantees that they will work. Nor will they fix the harm industrial farming causes in time, nor tackle underlying inequalities. Agroecology on the other hand is a win/win solution, and we should make the transition now.

Hungry people don't wait. Politicians shouldn't either.

FARMERS

MESSY FARMING

CLARE HILL

Clare is Director of Regenerative Agriculture at FAI Farms, which recently won the Compassion in World Farming Sustainable Food and Farming Award, for their regenerative grazing work with McDonald's UK & Ireland. Clare is also an advisor to the Food & Global Security Network.

'Becoming a regenerative farmer is about paradigm shift. In the old mechanistic paradigm, long, messy grass equalled wasted feed, but in the new paradigm – this is productivity. Now that we're able to hold onto so much more of the water from the winter and grow spring grass right through the summer, we've become more productive, finishing our animals on grass between 18 and 24 months, and we've used no additional inputs.'

'Messy,' is how most farmers would describe our farm now.

'Recovering beautifully,' is how I describe it.

Soil, water, natural nutrient cycling and sunlight have now become central to our decision making. And considering the fact that these things are all free, it seems strange to me now that this wasn't always the case.

I've worked on and around the farm at FAI in Oxfordshire for 18 years, managing it for the last four. We'd always worked to follow best practice, taking note of new research and driving our system to produce more from less. But despite farming having the opportunity to help in the fight against climate change and biodiversity loss, our emissions were increasing, and biodiversity loss was accelerating. Something wasn't working.

Becoming a regenerative farmer is about paradigm shift. The first time my brain moved up a gear was after working with a grazing consultant. After following his advice, we grew a lot more grass – so much so that he suggested we could increase the number of livestock, spreading our overhead and improving our profitability. That sounded like a

great idea, but when I delved a little deeper I realised we faced some problems.

First and foremost was that we would need to build a new shed to house the extra stock over the winter. This was going to be a sticking point. The farm is just one part of FAI's consultancy, so a full business case would be needed to demonstrate a return on investment – and on a tenanted farm with seven years left on the lease, and a landlord who was likely to write the value down to zero on any tenant investment, I felt that I had a pretty good sense of what the answer would be.

There was also a part of me that thought, 'Surely there needs to be a more sustainable solution than just laying more concrete.' But what was it?

I knew another farmer who out-wintered his cattle on bales, and while I was intrigued, I had a nagging demon in the back of my head reminding me of the words I'd heard repeated on the farm for the last 18 years: 'it'll never work here, our soil is too heavy to out-winter.'

But Humphrey, then the assistant farm manager, told a story about visiting the out-wintering farm and walking over the field towards the cows. There was soil and water squelching under foot and he

thought it must be drier at the other end of the field where the cows were. Instead it was wetter – but because of the abundance of biomass (grass and plants) above the ground, there was a ‘messy’ green carpet over the soil to prevent the cow’s hooves causing any damage.

That was it. I clapped my hands together and we decided to give it a go ourselves, but with a small number of animals so that we could bring them back inside if it didn’t work. This experiment served two purposes during the winter of 2019. Firstly, it gave us confidence, and secondly, it taught us a lot about water infrastructure and how our farm was not immediately set up for this type of grazing.

That meant we needed to invest in new fences and water infrastructure to feed more troughs, but somehow that felt a lot more progressive than investing in a new shed. The cattle needed to be moved on frequently – every two days – so that even in a really wet winter, with water standing on the soil surface, they’re not there long enough turn it all to mud. Outdoor in a field – this is where our cattle are at their happiest and healthiest, without the problems that are common in housed cattle sheds, such as respiratory disease or lice.

Redefining Productivity

The second gear shift in my brain was refining what I thought waste looked like.

In the old mechanistic paradigm, long, messy grass equalled wasted feed. When there were hay bales stored outside and rolled out onto the ground, the first question was always ‘how much utilisation are you getting?’ or ‘how much is wasted?’ But now I’ve learned to see the bales in a different way – it’s not waste, it’s carbon - and it’s getting trampled into the ground, feeding the microbes and keeping the soil warm so that it carries on growing throughout the winter. In the new paradigm – this is productivity.

We’ve now come to the end of our second summer of Adaptive Multi-Paddock grazing, and it’s working

so well that we recently won the Compassion in World Farming Sustainable Food and Farming Award, with our partner McDonald’s UK & Ireland.

There’s an easy experiment that anyone can do to see how well the system is working. If you put your hand under the grass and onto the soil it will feel cool and moist, even when the hot summer days are topping 28C in the shade. The soil is more resilient to hot summers as well as cold and wet winters – it’s alive, vibrant, and the grass is growing all year round.

The FAI farm land is on the River Thames flood plain. It’s always described as ‘wet in winter, burns off in the summer.’ But where does all that water go? Now that we’re able to hold onto so much more of the water from the winter and grow spring grass right through the summer, we’ve become more productive, finishing our animals on grass between 18 and 24 months, and we’ve used no additional inputs. This is our focus now. We work to improve soil health and its water holding capacity, to grow more grass to feed more animals, and to help reduce flood risk for the city of Oxford, nestled on our doorstep.

Biodiversity

All this change is also fantastic for biodiversity. When our grasses are going to seed, butterflies fly up with every step. There is more wildlife, and there are comments on local Facebook groups, from walkers who’ve used rights of way across our farm, that the fields are buzzing with insects the like of which people haven’t heard since their childhoods.

We have achieved this by learning that we are part of an ecosystem, rather than in charge of one. We’ve learned to read the feedback our ecosystem is providing.

We still produce organic cattle, but the way that we rear them has changed – in a nutshell, it’s a high density of animals, fed in smaller parcels of grazing land, moved on frequently, with the land left for a long rest period. The long rest period is what

differentiates AMP grazing from many other systems – that and the fact that our reliance on external inputs is minimal.

Importantly, it's not just us saying that we are regenerative. We're measuring our outcomes and monitoring our impact regularly. We're gathering data to assess whether the ecosystem processes of water cycle, nutrient cycle, air flow and photosynthesis are working effectively. We also dig holes and visually assess our soils, we measure our

infiltration rate and we count our worms. All of those measures are uploaded into our Soil Mentor app so that we can track our progress each time we assess. And finally we send soil samples to laboratories for analysis. On top of the usual nitrogen, phosphorous and potassium tests, we do soil carbon analysis, and look at soil biology, including organic matter and fungi/bacteria ratios. Like a jigsaw, each one of these tests pieces together a deeper understanding of our soil.

REGENERATING OUR 1350 HECTARES

JOHNNIE BALFOUR

Johnnie farms at Balbirnie Home Farms in Fife, Scotland.

‘The land, and our business, was addicted to a cocktail of mismanagement. Something had to be done. Our answer to these threats has been the implementation of holistic management with the adoption of regenerative agricultural principles.’

Balbirnie Home Farms is a large mixed farm in Fife, Scotland. We manage approximately 1350 hectares that ranges from heather hill ground at 250m to good quality arable ground at 50m. We grow cereal and vegetable crops as well as raising cattle and managing both native woodland and commercial plantation forestry.

Until 10 years ago we managed all of the land in what has often been described as a conventional management style: we ploughed all of the cultivated land; we had a short rotation of wheat, barley, oats and vegetables; we fed the cattle indoors on a barley-based mixed ration and sold them at 14-16 months as top quality beef; and we had plantations of spruce to sell for saw logs or wood chip.

Under this mainstream management system, we had seen the number of people working decrease over my lifetime, the number of hectares managed increase over the same time and the size of the tractors increase massively. Unfortunately, the farm was not profitable – and the race to the bottom was not producing good food, managing the environment or keeping as many people as possible living, working and thriving in the countryside. The land, and our business, was addicted to this cocktail of mismanagement.

Something had to be done. We had to address the haemorrhaging of cash, the loss of soil and the community becoming more urbanised and distant from its agricultural roots.

Our answer to these threats has been the implementation of holistic management with the adoption of regenerative agricultural principles.

The first key for us, to implement regenerative agricultural techniques, was to reduce both chemical and physical disturbance. While there is still work to be done, we have sold our plough, and we managed to grow our oat, barley and bean crops with no fungicides for the first time in 2021. While we have not eliminated mechanical or chemical disturbance from our farming, that is our target.

Keeping the soil covered reduces erosion and run-off and allowing life to flourish. We have sown crops in between our main crops to cover the soil over the winter and in 2020/2021 we only failed to sow anything in a handful of fields. We notice a reduction of run-off in bad winter weather.

Living roots in the soil help to keep nutrient exchanges working and allow life to flourish. At Balbirnie Home Farms we have permanent margins around most of our fields and are reinstating hedges. These permanent areas of the farm provide habitat for wildlife as well as predators of some of the pests that live in our crops. In addition we have under-sown crops into standing crops to reduce the time without living roots in our fields.

Biodiversity lies at the heart of regenerative agriculture. Diverse ecosystems are resilient particularly to fluctuations in temperature and moisture. By increasing the diversity not only around fields but also within them, we can make

our business more resilient to climate changes. Hedges, margins and agroforestry all provide diversity in our landscape. In addition, we sow polycultural crops rich in flowers and legumes to reinvigorate fields. We can pay for some of these by feeding them to livestock.

The glue that keeps all of these principles together is the integration of livestock. Livestock can convert plants into food for the soil. Livestock can harvest diverse polycultures that we are not able to harvest ourselves. Livestock can digest grasses and enhance our grassland ecosystems when managed in an environmentally sensitive way. The integration of a diverse range of livestock can enhance the ecosystem even further. In 2021 we used both cattle and sheep to manage our ecosystem. We expect to increase this in the future and farmers across the UK have options such as pigs, chickens, ducks, deer and many other species that can be used to help them.

By using human imagination and hard work, all of these principles can be brought to our landscapes and our local cultures can flourish. We are going to bring some allotments to our land along with educational programs in growing food in partnership with our local council. More people growing and eating more food grown in and around more villages will strengthen the cultural ties to the land and break down the walls between urban and rural life.

The principles of regenerative agriculture can heal a landscape and can build soil thereby becoming a critical element in developing our overall soil security. In addition, the food that is grown in soil that is diverse, rich and lively is in turn healthy, nutritious and tasty. By looking after our soils and the people that live, work and play on them we can lead happy, healthy and fruitful lives.

SOIL HEALTH MEANS RESILIENCE

MARTIN LINES

Martin is the chair of the Nature Friendly Farming Network & farms near St Neots, UK.

‘In England and Wales, over 2m hectares of soil are at risk of erosion and 4m hectares at risk of compaction. Intensive farming has caused arable soils to lose 40-60% of their organic carbon through relentless tilling and disturbance from vehicles. Ultimately, soil health equates to resilience. Governments must establish soil security as determining the health of our future and securing the foundations upon which all farming and food productions depends.’

When I took the reins of my family’s farm as a third-generation farmer, soil was traditionally given little consideration. It was something you had – not something that needed nurturing. It was ‘dirt’ after all – solid and reliable beneath our feet. But despite soil’s ubiquitous presence around the world, soil health is sadly often at its worst. In England and Wales, over 2 million hectares of soil are at risk of erosion and 4 million hectares at risk of compaction. Intensive farming has caused arable soils to lose 40-60% of their organic carbon through relentless tilling and disturbance from vehicles. In recent decades, farming’s collective awareness of soil’s value was diminished by a singular focus on the labour above ground. But now, with increasing climatic pressures, soil health is critical.

As a farmer who relies on the soil to grow nutritious food, healthy soil is my number one asset. If I improve the soil’s quality, then my farm business can be more profitable and viable in the long-term. Only healthy soil can sustain thriving biodiversity, and that consequently, sustains food production which directly delivers financial return.

I distinctly remember the turning point when I realised the impact our farm’s practices were having on the soil. It was nearly a decade ago and we were using heavy cultivation to prepare the soil

for crops. We were in the middle of ploughing when I noticed a tyre print from two years before in the bottom layer of soil. It was so heavily compacted from the weight of the tractor that the tyre print was sealed into the clay, ready to be revealed when we lifted the furrow once again. This was the beginning of a fundamental shift in my awareness of how our approaches were putting strain on the environment with lasting impacts. It quickly became my focus to develop practices that tread lightly on the soil, at the same time as restoring the ground’s natural biodiversity.

At Papley Grove Farm, we have transitioned to soil management that is regenerative. What is key to restoring our soils to a healthy, fertile condition is being able to read and assess it, to understand the properties and indicators for my soil type, including measuring how successful our regeneration techniques are. Through a ‘less is better’ approach, we have moved from a plough-based system to using a machine that moves the soil to a depth that doesn’t disrupt its biology, release carbon or cause compaction. Our machinery uses floatation tyres and track systems to distribute weight so we cause less harm. We grow a variety of cover crops selected for their benefits to soil health: buckwheat, phacelia, vetch, linseed, among others, all draw nutrients into the soil and enrich the organic

content of the Earth. We select different seed mixes according to area, so the more compacted and unhealthy zones are targeted with plants that will regenerate with the right desired outcome. This low soil disturbance has led to increased insect life in the fields, meaning that predators can manage our pest problems so we can reduce our input costs through the avoidance of insecticides. Another benefit of our cover crops and no-ploughing approach is in our topsoil. This was once routinely ploughed to the bottom of the furrow causing unnecessary disruption to natural processes, but it is now maintained without disturbance and the benefits to worm life are numerous.

Why should a farmer be concerned about earthworms? Worms, in many ways, are a crucial form of livestock for every farm, regardless of the system, as they fertilise the Earth by breaking down decaying matter, in turn providing nutrient-rich soil that will grow nutritious crops or feed livestock. Worms also improve the soil structure by loosening the composition and oxygenating the soil, leaving space for water to be drained from the surface.

But why is this necessary? In the context of climate mitigation and reducing threat from global warming, soil is the answer. Research has found that soil without earthworm activity can be 90%

less effective at draining water, which has a devastating knock-on effect for flood mitigation.

Soil is the largest store of carbon on Earth and we must do everything to protect and restore it if we have any chance of meeting ambitious net-zero targets. These actions will not only benefit the climate, but our business too. Our weather is becoming increasingly volatile as a result of the climate emergency, but the soil beneath our feet is key to building resilience in the midst of unpredictability. During times of drought, the regenerative practices we have adopted enable my crops to survive through their ability to hold on to water. In times of heavy rainfall, the opposite is true with a stable soil structure that can withstand flooding through faster drainage.

Ultimately, soil health equates to resilience. As we move towards a new era of public money for public goods in the UK, action to restore soil health will be vital as an underpinning asset of any successful farm business. But getting there takes time. Government must provide a clear roadmap and establish soil security as determining the health of our future and securing the foundations upon which all farming and food production depends. The answer to so many of our challenges lies right beneath our feet.

CARBON ACCOUNTING & PAYMENTS

THOMAS GENT

Thomas is the founder of Gentle Farming.

‘On my farm I’ve witnessed just how rapidly soil degradation can be reversed. By working with nature rather than against it we have been able to restore our soil health and soil function while continuing to produce fantastic, nutritious food. ‘The carbon offsetting market is well-established. Soil carbon certificates are simply a new product, and one of the most exciting because soil carbon sequestration can be delivered both rapidly and locally.’

I’m a fourth generation farmer living and working on our mixed family farm on the Lincolnshire/Cambridgeshire border. We produce free range eggs and arable combinable crops.

Around 12 years ago our family took a collective decision to focus on the soil – to farm regeneratively. This approach to agriculture has a key role to play for all farms and farming systems.

Soil is one of our planet’s most crucial ecosystems and supports almost all life on Earth. 95% of global food production comes either directly or indirectly from soil. Its degradation poses a major threat to global food security and to delivery of the Sustainable Development Goals (SDGs). A third of the Earth’s soils are already degraded, and according to the UN FAO this could reach 90% by 2050. Intensive farming practices are pushing humanity’s food producing capacity to the brink, with desertification becoming a huge problem around the world. We need to take decisive action today.

On my farm I’ve witnessed just how rapidly soil degradation can be reversed. By working with nature rather than against it we have been able to restore our soil health and soil function while continuing to produce fantastic, nutritious food.

Most farmers love their work, but our land is our livelihood, and wherever possible we need to get

paid for what we do. To ensure that we can continue farming for quality, rather than just volume, we need to find ways to monetise sustainability so that our efforts to restore nature and draw down carbon are rewarded. I founded Gentle Farming to do precisely this. I wanted to reward and recognise the work of farmers who are delivering sustainable farming practices, and in particular sequestering carbon back into our soils. Carbon farming is critical if society is to effectively combat climate change while also restoring biodiversity and improving water management.

The basics of soil carbon offsetting

Regenerative agriculture draws down and locks in carbon by using crop rotation, heavy impact from livestock, and long rest periods to ensure high levels of land recovery. For example, as pasture plants grow, they absorb CO₂ into their roots, stems and leaves. These grasses are eaten by livestock and turned into muscle or manure, the latter of which is trampled into the Earth, helping to stimulate growth and cycle nutrients. In the sward, a diversity of plants break up the soil as their roots grow, restructuring the Earth and creating channels for water, bugs and microbes – and then when the plants die, they decay, providing nutrients for the soil zoology. These various processes help to transfer carbon from above ground and into the

land – and as the organic matter grows, so does the amount of carbon stored in the soil.

Carbon offsets are an important tool in our global transition to net zero, but should be used by companies only as a last resort once they have reduced emissions as far as possible. Soil offsets from regenerative agriculture can be used to help reduce the direct impact of unavoidable carbon emissions, while financially supporting a farming transition to regenerative agriculture. Of course, what is unavoidable will change as experience, technology, and government policy change, and ideally companies will buy fewer soil carbon certificates each year as their carbon footprint reduces.

The carbon offsetting market is well-established and proven. Soil carbon certificates are simply a new product on the shelf, and one of the most exciting because soil carbon sequestration can be delivered both rapidly and locally.

Gentle Farming has now partnered with Agreeena, who help deliver accountability and straight-forward functionality. Agreeena's online assessment tool works on a field-by-field basis and takes account of everything that goes on in that field, one crop year at a time. We measure cover cropping, tillage rates, straw management as well as the use

of any synthetic fertilisers, diesel and chemicals. We award farmers with a number of certificates per hectare, depending on the mix of practices they use, as well as other factors, such as their underlying soil type.

Around forty UK farms are already using the Gentle Farming system, powered by Agreeena – and companies are already pre-ordering soil carbon certificates, which will be produced for the first time towards the end of 2021. Certificates will be awarded directly into each farmer's carbon wallet, creating a new asset class that the farmers can keep, sell, or use for trading. (We're now open for farmers to join up for the 2022 harvest.)

We anticipate that soil carbon payments will form a substantial part of a farm's income in the UK as we move towards a financial support system based on public goods.

I truly believe that this is the best time ever to be a farmer. There are so many opportunities coming, not just in terms of carbon, but in the whole sustainability world. Those farmers that take up the challenges and push ahead will be the winners in this new digital and sustainable world of food production.

HAPPIER AND HEALTHIER FARMING

NIKKI YOXALL

Nikki farms at Howe Mill Farm in Aberdeenshire, Scotland.

‘To help me manage my feelings of despondency around what I often perceive to be a lack of global action, I have taken to thinking small, considering what I can do in my corner of Scotland.’

The world we find ourselves in currently can be a scary place: climate change, health pandemics, conflict and biodiversity loss on a massive scale. It’s easy to become caught up in the fear and anxiety, and to be overcome by these issues; these threats.

To help me manage my feelings of despondency around what I often perceive to be a lack of global action, I have taken to thinking small, considering what I can do in my corner of Scotland, what changes I can make and the action I can pursue towards healing the Earth’s wounds and developing resilience for an uncertain future. My thoughts take me to the soil, to abundance and reciprocity, informed by ideas of indigeneity shared by Reginaldo Haslett-Marroquin, Rebecca Hosking and Robin Wall Kimmerer. *[Reginaldo Haslett-Marroquin has written elsewhere in this report.]*

Running a grazier business with my husband, we graze our livestock on land owned by other people, helping them to reach their ecological goals whilst producing 100% grass- and tree-fed beef. Our farming practice could be described as agroecological, a term the FAO define as ‘an holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems.’ This means we aim to optimise the interactions between plants and animals – integrating our herd of cattle into the ecosystems we have the privilege of becoming a part of as we graze them. For us, farming isn’t something that happens in a defined space, with

nature taking precedence elsewhere, instead our cattle nudge and enable ecological processes to happen; they become part of ‘nature’. We aim to think indigenously, considering not only now, but the future for the land we farm. We don’t own this land, we have no long term investment in it – but we are connected to it emotionally, we put time and energy into this place and we recognise that its value is priceless.

Underpinning the ideas of biomimicry and ecology, both literally and figuratively, is soil. Our grazing decisions are directed by managing soil impact, recognising the role that tall grass grazing has in providing soil with an armour that protects it from heavy rain and the sun’s heat, and, to some extent, the hooves of our cattle which enables us to keep them outside all year round. We see soil not as dirt, but as the thriving and highly complex ecosystem that it is, as Nicole Masters suggests, soil is made up of ‘dynamic and vibrant communities’. It is our job, as graziers and land managers to protect that soil, to create the conditions that allow those communities to flourish. Thinking from within the ecosystem, we want to see diversity and abundance. The soil below the permanent pasture, species rich grassland and woodlands we graze are packed full of seeds and tubers, rhizomes and roots that, given space and time between managed animal impact, can provide a huge range of diversity in plant species. When we have questions about what we or our animals need nutritionally, the soil has the answers.

As a result of the ‘Green Revolution’ we are presented with farming problems or issues, which we might not have known we had, being solved by bought in solutions or prescriptions. We seem to have lost our ability to put our faith in our local ecology to provide us with all we need, instead relying on mined minerals, fossil fuels and other extractive processes to supply answers. All of which come at a cost – not only to individual farm businesses financially, but environmentally and socially, having impacts in far off places that we will likely not be aware of. Instead, we could consider the words of the American novelist and farmer, Wendell Berry, who told us, ‘The soil is the great connector of lives, the source and destination of all. It is the healer and restorer and resurrector, by which disease passes into health, age into youth, death into life. Without proper care for it we can have no community, because without proper care for it we can have no life.’ By centring our focus under our feet, we suddenly realise how connected we are with everyone and everything else in our communities; we all stand on this common ground. We all have soil in common. In realising this, we are

suddenly no longer individuals working in isolation, instead like our friends in the soil, we are part of a web; a network, and we are connected.

In fast-paced times, where social media reigns and speed is king, where immediacy feeds our insatiable hunger for stimulation, taking a breath and thinking about our connection with and through the soil is a soothing balm. Our physical health is nourished by the foods that grow in and of the soil, but our emotional wellbeing is also nourished by this dark crumbling magic we can hold in our hands.

In a recent interview, botanist and author Robin Wall Kimmerer said, ‘This is our work as humans in this time. To build good soil in our gardens, to build good soil culturally and socially, and to create potential for the future. What will endure through almost any kind of change? The regenerative capacity of the Earth. We can help create conditions for renewal.’

Let us take the time to heed her words and rekindle our relationship with soil.

SOIL IS EVERYTHING

GEORGE YOUNG

George Young farms at Fobbing Farm in Essex, UK.

‘We can only grow properly nutritious food with healthy soil. It is no longer viable to just talk about food security – we must also focus on nutrition and soil security.’

Soil is the forgotten *everything* to humanity. It is the medium that feeds us, clothes us and (traditionally at least) houses us. Yet the past fifty or so years, post Green Revolution, have disregarded the importance of soil, treating it purely as a blotting paper into which plants can place their roots.

Finally, we are witnessing the error in this approach to agriculture. And some exemplars of agroecological farming are demonstrating that exceptional and exciting results can occur in a short period of time by understanding the true relationship between soil and humans.

The Green Revolution, which resulted in an abundance of food, leading to vast population growth, could only occur with the use of synthetic pesticides and fertilisers. These products go against nature, enabling poor quality farming to occur. They are hugely costly from a carbon standpoint to produce and transport, and also cause carbon losses from the soil when applied, as well as damaging all the microbes, fungi, bacteria and bugs & beasts which form the first trophic levels of our rich and biodiverse ecosystem.

Even disregarding the huge damage these synthetic agricultural products do to the life in our soils, there is a more worrying point to link the health of our soils to the health of humans. Crops grown in dead soils, pumped with fertiliser in order to produce a commodity crop, are likely to only have the key macro-nutrition, and significantly less micro-nutrition. The plants growing in a lifeless medium

have nothing apart from applied products to draw on.

However, there is another way: a way which restores soil health swiftly and holistically, which mimics nature, and which leads to significantly healthier food products to drive a healthier and thriving population of humans.

On my farm I am in the midst of this transition.

I returned to the family farm eight years ago. At the time we would be considered a conventional arable farm, growing three crops: wheat, oilseed rape and peas, in a rotation of wheat-wheat-rape-wheat-wheat-peas *repeat*. These were grown with the typical mix of synthetic agrochemicals and fertilisers. We did also have some store cattle (castrated males, bought young and sold older for someone else to fatten), however they were not integrated into the arable farm.

That was then – this is the transition we are making now...

Initially I added a more diverse mix of crops into my rotation. We now grow wheat, heritage cereals, beans, peas, lentils, buckwheat, hemp, diverse species grass/herb/legume leys. We are rotating our cows (now a breeding herd of Red Poll cattle, native to the South East of Britain) across our arable fields. We have planted 50 acres of agroforestry – around 7,000 trees in linear belts up one field, with the rest of the farm to follow. And I am dedicating a strip of land through the middle of my farm to be wild and host a plethora of wildlife,

never to be disturbed. We are also undergoing conversion to organic agriculture.

All of these changes are focussed around a central desire: to fix my tired and overworked soils and to ensure that the food products I grow are nutrient dense for the healthiest end products possible. This is a system based around building a soil ecosystem rather than applying products which destroy it.

Ruminants (e.g. cows and sheep) grazing diverse species leys for at least four years are the cornerstones to how I am rebuilding soil health. These are the key facets which allow me to grow crops for three or four years before rotating back into grazing leys.

My diverse leys feature upwards of 25 species and varieties of plants, all with varying rooting depths and profiles. These plants work synergistically together, forming fungal networks between the root systems, and sharing nutrition. This mixes soil nutrition in the entire soil profile. Some of these plants (e.g. clover) fix nitrogen from the air into the soil, adding natural fertility, whilst others will naturally mine phosphorus and potash, putting them in bioavailable forms for following crops to utilise.

These leys also happen to be exceptionally healthy for animals to graze: providing a fantastic varied diet, keeping the animals that eat them healthy – naturally free of worms and other parasites, circumventing the need for synthetic products to be used on the animals which would naturally then damage the soil life. The animals have two excellent additional properties: they tread the plants down into the soil, and defecate on the land. The treading of live plant material provides food for worms, and the dung provides food for a vast array of small creatures, which enhances the biodiversity present, enabling even more biodiversity further up the food chain. The dung also naturally fertilises the soil.

With the amazing remedial work performed by livestock and long-term resting of the land, it is now possible to utilise some of that enhanced soil health to grow some exceptional crops. I have moved towards growing heritage cereals alongside the more conventional modern wheat, even though they yield less and have better rooting systems. Yielding lower may initially sound like a bad thing, but the combination of that and their rooting means that these crops can access all the micronutrition in the soil, and bring that through to the harvested grains. Higher yielding modern crops on the other hand may yield more, but at the expense of micronutrition dilution and resilience to disease.

It has been said that the version of agriculture for which I am a proponent will not feed the world. However, reports such as FFCC/IDDRI *Farming For Change* report now contradict that. [See article by Sue Pritchard.] Mine is a type of farming which values all the creatures that get to call my farm their home, rather than just looking for mass food production.

It is true that people will need to eat a more diverse diet, and waste less, in this system. But is that a bad thing? We currently have a malnourished and obese population. Eating more nutritious food and fewer calories have strongly beneficial outcomes – leading to a healthier & happier population, and costing health services and the economy considerably less.

We can only grow properly nutritious food with healthy soil. To disregard that in favour of unproven technological fixes in the food system is asinine. Simple to implement, agroecological farming practices, some examples of which I have outlined, give rise to resilient farm businesses, and provide fantastic food alongside ecosystem services. It is no longer viable to just talk about food security – we must also focus on nutrition and soil security.

RECOMMENDATIONS

OUR RECOMMENDATIONS

To underpin the security of future generations, in the face of ecological breakdown, the regeneration of Earth's soils should become a foundational priority for all governments, food businesses, individual land managers and citizens.

Seven key recommendations

- 1. Governments should formally recognise healthy soil as a strategic asset, critical for maintaining food and societal security.**
- 2. Multi-outcome land use should be delivered by land managers as standard and holistic solutions and metrics should be widely adopted to inform policy and practice.**
- 3. Government financial support should be rapidly targeted towards agroecological solutions.**
- 4. To ensure accuracy when assessing the global warming impact of farm businesses, GWP* should be adopted as the standard metric.**
- 5. Businesses should step up and deliver soil sustainability in their supply chains.**
- 6. Governments should commission a threat assessment to better understand the security risks associated with soil degradation and ecological breakdown in their nation.**
- 7. Defence departments should work with departments for agriculture and the environment to jointly oversee delivery of increased food sovereignty and the regeneration of soil function.**

All recommendations

1. Governments should formally recognise healthy soil as a strategic asset, critical for maintaining food and societal security.
2. Governments should commission a threat assessment to better understand the security risks associated with soil degradation and ecological breakdown in their nation.
3. Strategic defence departments should work with departments for agriculture and the environment to jointly oversee delivery of increased food sovereignty and the regeneration of soil function and hydrology, in order to ensure food availability in times of need, and better drought resilience and flood protection.
4. Governments of all nations should develop a National Plan for Agricultural Land Use and Food Production.
5. This Plan should be multi-agency and aligned across government: food, agriculture, environment, health and strategic defence.
6. Planning should recognise the interconnected nature of ecological breakdown and seek solutions that restore ecological balance.
7. Governments should take action to boost national food sovereignty and increase national nutritional independence to at least 80%.
8. Multi-outcome land use should be delivered by land managers as standard – for example, a combination of food and fibre production,

global warming mitigation and adaptation, biodiversity regeneration, improved hydrology, better jobs, renewable energy production and improved amenity.

9. To assist a multi-outcome approach, holistic solutions and metrics should be widely adopted to inform policy and practice – the Global Farm Metric is particularly robust.
10. To ensure accuracy when assessing the global warming impact of farm businesses, GWP* should be adopted as the standard metric. As set out in this report, the IPCC has recognised that GWP100 overstates the warming impact of constant methane emissions by a factor of 3-4.
11. Where the State provides financial support for agriculture, carbon footprinting (with GWP*) should be a condition of eligibility.
12. Government financial support should be rapidly targeted towards agroecological solutions and the delivery of other ‘public goods’ that restore ‘natural capital’.
13. Government support for the production and use of fossil fuel-based farm inputs should be rapidly phased out.
14. Governments should ensure that each farmer and every hectare is supported in the transition to agroecological food production.
15. Governments should invest in, or otherwise financially facilitate, the development of infrastructure aimed at shortening supply chains and helping farmers process and retail their own products individually or co-operatively. This infrastructure may include local abattoirs, processing facilities and distribution and marketing capacity.
16. The Agroecology Development Bank, proposed by the Food, Farming & Countryside Commission, should be adopted in the UK and used as a model for other nations.
17. Governments should actively pursue strategies to support markets in fibre from livestock as well as food.
18. Governments, food businesses and civil society should invest in good agroecological knowledge-sharing and round-the-clock advice.
19. Agricultural colleges and universities should rapidly transition their programmes to focus on agroecology and regenerative practice.
20. To reduce the risk of zoonotic disease governments should ensure global protection of all remaining wild spaces, and prioritise the rapid restoration of key habitats and wildlife corridors.
21. Governments should take action to ensure that soil ecology is considered a shared asset of society rather than a profit centre.
22. Businesses should step up and deliver soil sustainability in their supply chains.
23. Natural capital costs that have been externalised, to taxpayers and the public, should be re-integrated with the costs of production.
24. Regeneration of soil health should become a board-level responsibility for all businesses engaged in any land management activity.
25. Dietary change is essential, but not to ultra-processed foods. Governments, food businesses and schools should promote increased food seasonality, whole foods, freshness and greater nutritional diversity.
26. Clear mandatory food labels should provide farm system information for citizens.

27. Food waste should be fundamentally eliminated, and major food businesses should be mandated to take greater responsibility.
28. International mechanisms to ensure the fair distribution of staple and commodity ingredients should be considered.
29. Society should invest in the science of soil, but also value the experience of farmers. Academic knowledge and practical experience are both helpful. We should move past a mindset that allows 'the perfect to be the enemy of the good'.
30. We should be braver – farmers should choose to focus on profitability rather than yield, and the era of simplification should be swiftly replaced by a new paradigm centred on ecological complexity and connectivity.

