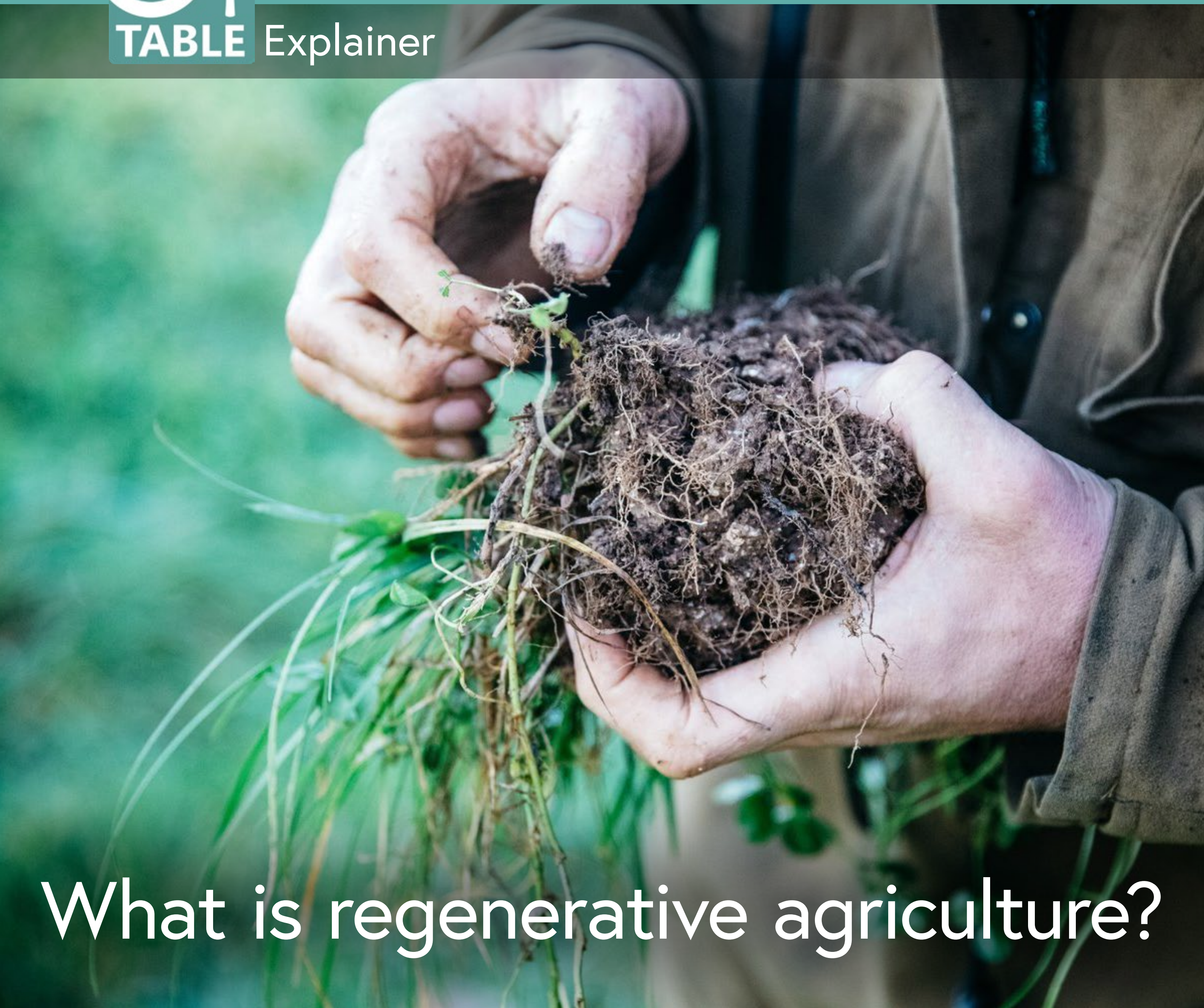
TABLE Explainer



What is regenerative agriculture?

June 2023

George Cusworth and Tara Garnett

TABLE

University of Oxford SLU Wageningen University & Research

Suggested citation

Cusworth G and Garnett, T. (2023). What is regenerative agriculture? TABLE Explainer. TABLE, University of Oxford, Swedish University of Agricultural Sciences and Wageningen University and Research.
doi.org/10.56661/2d7b8d1c

Written by

- George Cusworth, University of Oxford
- Tara Garnett, TABLE, University of Oxford

With input from Tamsin Blaxter and the wider TABLE team.

Reviews and contributions

Many thanks to the attendees of a TABLE workshop on regenerative agriculture, which was held at FarmEd in February 2023. The workshop participants reflected perspectives from civil society, Defra, the farming and food industry sector, and research. The comments and insights of these participants at the workshop have been invaluable in the creation of this explainer; some also provided extremely useful comments on a draft version, for which additional thanks. Please note that the contributions of participants do not imply endorsement.

A list of those who participated and who are happy to be named is as follows:

Jonathan Brunyee, FarmED; Rob Cooke, Natural England; ffinlo Costain, Chief Editor, 8point9.com and founder of the Food & Global Security Network; Dr Sasha Gennet, The Nature Conservancy; Bill Grayson, Morecambe Bay Conservation Grazing Company; Vicki Hird, Sustain; Professor Jamie Lorimer, University of Oxford; Nicola Randall, Harper Adams University; Matt Smee, The Organic Research Centre; Dr Taro Takashima, University of Bristol; Lucy Bjorck, RSBP; Sam Burford, Defra; Liz Genever, independent sheep and beef consultant; Martin Lines, Nature Friendly Farming Network; Sue Pritchard, Food, Farming and Countryside Commission; Joel Scott-Halkes, Wild Card; Kieron Stanley, Defra; Alison Warrington, NFU; Jonathan Woolley, Defra.

In addition to the input of workshop participants, the paper has benefitted from reviews by the following:

- Dr Lucie Buchie, Greenwich University
- Professor Ken Giller, Wageningen University
- Professor Charles Godfray, University of Oxford
- Dr Matthew Jordon, independent consultant
- Professor Tom Macmillan, Royal Agricultural University
- Dr Barbara Smith, Coventry University
- Professor Roger Sylvester-Bradley, ADAS

A special thanks also to Helen Breewood for organising the workshop and for her intellectual contributions.

Cover

Cover photo by Alexander Turner

To read more from the Explainer series, visit:
www.tabledebates.org/explainers

TABLE is a global platform for knowledge synthesis, for reflective, critical thinking and for inclusive dialogue on debates about the future of food.

TABLE is a collaboration between the University of Oxford, the Swedish University of Agricultural Sciences (SLU) and Wageningen University and Research (WUR)

For more information:

www.tabledebates.org/about

Contents

Go to contents

Introduction

"Regenerative agriculture" is a concept now commonly referred to in discussions about food system transformation. The concept is fluid and, because it is not associated with any formal definition, it is possible to discern among its practitioners and advocates many different perspectives as to what regenerative agriculture *is* or *ought* to be. That said, there is general agreement that regenerative agriculture is concerned not just with creating agricultural systems that 'do less harm', or that are merely 'sustainable', but that somehow 'restore' or 'regenerate' natural ecological functions.

Because of the relative newness of the term, regenerative agriculture has not yet crystallised into something with a clear and bounded meaning and as such, understandings differ. For some, regenerative agriculture is primarily an approach to farming that places great emphasis on the importance of fostering 'soil health', reintegrating livestock and arable farming, minimising tillage, and optimising the carbon sink potential of agricultural soils. For others, the goals of regenerative agriculture go beyond sets of practices that can be applied on the farm to encapsulate a fundamentally different way of thinking about humanity's relationship with the natural world, and producers' relations with consumers. The ultimate goal, for these actors, is to use the food system to close the rift between the human and natural, and to achieve a mutually symbiotic state of flourishing. Across these approaches, there is also some ambiguity about whether regenerative agriculture is primarily about the attainment of outcomes, or the adoption of specified practices.

Regenerative agriculture can trace its roots back to the crises of early 20th century agriculture including, in particular, the dustbowl of 1930s America that highlighted the intertwined fates of human life, soil health, and intensive agricultural management. Like supporters of the earlier 'conservation agriculture' movement, advocates like David Montgomery have sought to use this history to make the case for the adoption of regenerative practices (Montgomery, 2018). Some however note that regenerative agriculture has deeper and broader origins that this: that it might be a new phrase for a set of farming practices that were developed and have long been practiced by peasant and Indigenous practices.

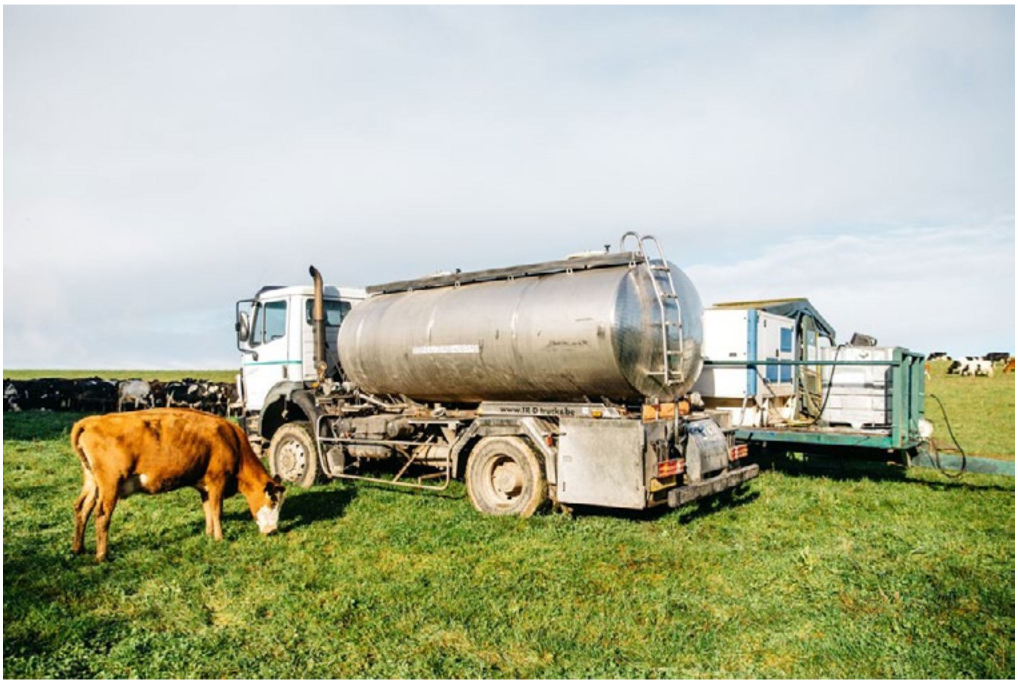
A farmer stands in a field of sudan grass in Baca County, Colorado, USA, during the Dust Bowl era. Photo by Russell Lee via Library of Congress (1939).

Although the term 'regenerative agriculture' has been in circulation since the 1980s, the last 10 years have seen an explosion in interest and usage (Giller *et al.*, 2021) and as such this spectrum of understandings reflect, in part, the diversity of actors interested in, supportive of, or doing regenerative agriculture. Along with the farmers and agronomists who have been contributing to the regenerative movement for some time, large multinational agri-businesses, politicians, and food marketeers are now also deploying its language. These actors are particularly interested in using regenerative practices to meet sustainability targets, to produce and sell soil carbon and biodiversity credits, and to leverage the language of regeneration in their marketing activities. Their arrival is potentially changing what it means to practise regenerative agriculture, with greater emphasis being placed on measurement, accreditation and marketing, and less on its credentials as a farmer-led movement organised around the redistribution of power in the food system. Whilst some welcome this 'broad church' approach, others are worried that regenerative agriculture will be co-opted by corporate interests, with its fundamental principles diluted.

Go to contents

In this explainer, we explore ways of thinking about regenerative agriculture in relation to its various definitions, the stakeholders using the term, its knowledge practices and knowledge base, and how it fits in with wider goals for food system change. Is regenerative farming just about adopting practices (like no-till, livestock integration etc.) understood to have restorative outcomes for the ecosystem? Or does *being* regenerative also entail a more emotional engagement with one's agroecosystem, and a more holistic sense of how agriculture, society and natural processes converge? What is the evidence in support of the claims made by advocates of regenerative agriculture, and how do different stakeholders think about what counts as evidence? Can regenerative agriculture be slotted into current systems of food provisioning or is it understood to form part of a much broader set of transformations that are necessary for the food system? There are different answers to these questions, depending on who you ask.

As with our other TABLE explainers, our aim is to provide clear and comprehensible descriptions of the actors, movements, and practices vying for attention in the debates around 'good' and 'bad' food. We pay particular attention to the values and norms at work in different propositions for food system transformation. Our aim, therefore, is not to close down the debate by explaining what regenerative agriculture *is*, but to open it up by reflecting on what it might be and how it is being used by different actors.



A cow grazes next to an open-air dairy operation in Dorset, UK.

Photo by Alexander Turner.

Go to contents

Regenerative agriculture: definitions and goals

Definitions of regenerative agriculture can be clustered into three (overlapping) kinds. Each is discussed in turn in the paragraphs that follow. There are those that place emphasis on a particular set of *practices*; those that focus on its desired or promised *outcomes*; and those that primarily see regenerative agriculture as a new way of relating to one another and to the natural world – as a *mindset*. For some the regenerative 'journey' – a metaphor that circulates in the regenerative world – can be understood as a development from **practices** to **outcomes** to **mindsets**.

Regenerative agriculture as a set of practices

What does regenerative agriculture look like as a set of farm management practices? For virtually anyone using the 'regenerative' term, it will involve some mix of the following: (1) limiting soil disturbance; (2) maintaining soil cover; (3) fostering agricultural diversity; (4) keeping living roots in the soil; and (5) integrating livestock and arable systems (Cherry, 2020). These are discussed in turn.

1. Limiting mechanical, and chemical disturbance of the soil

'Soil health' is an idea, or goal, that sits at the heart of regenerative agriculture. The idea of soil health is distinct from related concepts like soil fertility. Where fertility is about levels of specified nutrients like nitrogen or phosphorus, soil health relates to a more diffuse set of ideas around the importance of natural cycles, the presence of high levels of biodiversity, and its ability to deliver ecosystem services. As it lacks the precise ecological definitions of terms like friability or species richness, the term 'soil health' is subject to a certain amount of debate, speculation, and even scepticism (Cardoso *et al.*, 2013). Whilst we are mindful of these contentions, we nevertheless use the term to reflect the language used by regenerative practitioners and the worldview it hints at.

For regenerative agricultural advocates, an important means of achieving soil health is to reduce mechanical disturbance of the soil. This primarily relates to soil inversion via tillage, but can also include compaction from farm machinery. Mainstream agriculture frequently uses full inversion ploughing to turn the soil and bury existing residues, before one or more passes with a cultivator to create a fine 'tilth' or seedbed in which to sow the following crop. Regenerative practitioners, however, only lightly cultivate the top of the soil surface (known as 'min till' or reduced tillage) or sow seeds directly into uncultivated soil (also known as 'no till' or direct drilling). These practices can reduced soil erosion and improve soil structure and water drainage (Mondal & Chakraborty, 2022). By minimising soil disturbance in this way, farmers also reduce the rate at which microbes degrade carbon inputs to the soil. This can potentially increase soil organic content (Al-Kaisi & Lal, 2020) but, as we discuss in the **Science and Uncertainties** section, the relationship between tillage, and soil carbon content are heavily contested. There is good evidence to suggest that no-tillage simply redistributes carbon to different points in the soil depth profile, rather than leading to total gains in soil organic content (Luo *et al.*, 2010); that organic inputs (cover cropping, manure) are the key determinant in soil carbon gains rather than tillage practices *per se* (Mary *et al.*, 2020); and that tillage yields only temporary losses in carbon levels compared to no-tillage regimes with no discernible long-term effect on soil organic content (Campbell *et al.*, 2001). Downsides of reduced or no tillage can also include increases in soil nitrous oxide emissions in waterlogged conditions and weed build up.

In the regenerative model, soil health is also achieved by minimising chemical disturbance. The goal is to reduce applications of synthetic pesticides (including herbicides, fungicides, and insecticides), the rationale being that artificial inputs inhibit the soil microbial community, and reduce soil biodiversity in addition to having downstream environmental impacts like water pollution, biodiversity loss, and high greenhouse gas emissions. It is important to note, however, that since the reduced tillage regimes promoted by regenerative practitioners can lead to weed build up, they can therefore *increase* reliance on chemical applications as a means of addressing this problem. Whilst in conventional systems the land is tilled to prepare it for a successive cultivation, regenerative practitioners often end up using additional rounds of glyphosate (or other broad-spectrum herbicides) to kill off volunteer crops and weeds, and get the soil ready for the following crop (see Colbach & Cordeau, 2022 for discussion of these trade-offs). Some within the movement might argue that these farmers are not 'truly' regenerative, raising the question of who gets to define what RA is or ought to be, a point we return to below.

2. Maintaining soil cover

For RA practitioners, the restoration of soil ecosystems also relies on keeping soils covered with cover crops and plant residuals over the full calendar year.

In pasture systems, this involves avoiding overgrazing so that sufficient plant residuals remain to enable regrowth (Teague & Kreuter, 2020). Additionally, practitioners frequently adopt mob grazing approaches (related terms include adaptive multi-paddock grazing or Holistic Planned Grazing™) wherein grazing livestock are confined to small subdivisions of pasture (known as paddocks or cells) and frequently moved, thus resulting in short grazing periods and long rest periods for any given sub-unit of pasture. Rest periods can be varied in length to account for different rates of forage growth across the grazing season by removing or adding sub-units to the rotation. Such mob grazing approaches achieve temporarily high stocking densities, resulting in livestock trampling a proportion of forage biomass and thus creating a 'thatch' layer of decomposing plant residues at the soil surface (Wagner *et al*., 2023). The aim is to reduce fluctuations in soil temperature and moisture content to benefit the soil microbial community. Plant residue inputs to the soil are also increased, potentially building soil carbon although evidence for this is often context-dependent and contested.

In arable systems, farmers have various options for maintaining plant residue and cover. Firstly, crop residues can be retained on the soil surface, rather than removed as straw or incorporated by ploughing. Secondly, overwinter cover crops can be sown between the harvest of one primary crop in the autumn and sowing of the next the following spring. Alternatively, primary crops can be undersown or intercropped with a companion crop such as clover, a leguminous plant which fixes nitrogen and ensures the soil remains covered post-harvest. At least in the short term these options typically increase inputs of carbon into the soil (Jordon *et al*., 2022).

3. Promotion of diversity

A priority for regenerative advocates is to achieve a shift away from highly simplified monocultural systems. As such, they often seek to increase the number crops grown in an arable rotation, as well as the number of plant species and varieties included in cover crop or pasture seed mixes. These crop diversification practices are designed to create an environment in which pest suppression and soil fertility become emergent features of the farm agroecosystem, rather than variables which require management with chemical inputs (Prescott *et al*., 2021). This contrasts with intensive agricultural regimes, in which fertility and pest management goals are achieved via application of synthetic inputs. Legume crops, for example, are celebrated for the way they can draw nitrogen into the soil and reduce inputs of financially and environmentally expensive synthetic fertilisers (Cusworth *et al*., 2021) (although leaching can still be a problem). Note, in some contexts, adding fertilisers can 'kick start' plant growth, vegetation coverage and, in turn, soil organic content (Tittonell *et al*., 2008). Activities intended to promote biodiversity on land spared for non-agricultural purposes, such as sowing wild bird or pollinator mixes, agroforestry and hedgerow creation and preservation, also come under this diversification principle (Levin, 2022).

Go to contents

A shade-grown coffee plantation in Brazil.
Photo by Projecto Café Gato-Mourisco via Unsplash.

4. Keeping living roots in the soil

The main idea here is that plant roots 'leak' photosynthetic sugars into the soil, which feeds the soil microbial community. This is a key mechanism for increasing carbon inputs into the soil which is the key determinant in increasing levels of carbon sequestration (Jones *et al*., 2009). There are other benefits to maintaining living root and plant systems over the full year. These include increasing nutrient availability for uptake by future plant roots, and greater aeration, drainage, and water infiltration capacity of the soil (Kaspar & Singer, 2011). Options for keeping living roots in the soil include integrating overwinter cover crops into arable rotations, and resting pasture with sufficient residual heights rather than overgrazing, particularly during the winter.

5. Integration of animals and cropping systems

Livestock can be integrated into arable systems by grazing them on temporary grass-based leys, and by including forage crops such as brassicas in the rotation, as well as cover crops. Although measures that reduce crop yield (e.g., switching from autumn- to spring-sown crops to allow a forage crop) or totally eliminate crop production in a given year (e.g., a temporary grass ley) may result in compensatory cultivation elsewhere, this could in part be mitigated by reorientating livestock production to forage grown in mixed grass-arable systems rather than feed produced from exclusively arable systems. Measures such as temporary grass-based leys increase soil carbon stocks in arable rotations and there is some evidence that grazing livestock on these may achieve modest further increases in soil organic content compared to stock-free rotations (Teague & Kreuter, 2020). However, if arable systems are stocked using 'additional' livestock rather than simply animals redistributed from other areas, then the increase in emissions from ruminant enteric fermentation would likely far exceed any arising soil carbon sequestration benefits. Nevertheless, where the risks of compensatory cultivation or increases in livestock numbers can be mitigated, better integration of livestock and cropping systems is likely to result in environmental benefits compared to current conventional production which is typically spatially segregated (Jordon *et al*., 2022). Our piece on feed-food competition explores these debates in greater detail (Breewood & Garnett, 2020).

The role that livestock animals, particularly ruminants like sheep and cattle, should play in the food system has been a source of major contestation (Breewood & Garnett, 2023; Garnett *et al*., 2017) By attempting to re-cast livestock animals as part of a diverse, sustainable, natural and traditional way of farming (Cusworth *et al*., 2022), there are concerns that regenerative agriculture is problematically unengaged with now-mainstream concerns about the outsize impact meat and dairy products have on the warming footprint of our diets (Dutkiewicz, 2021). These disagreements can be understood in the terms provided by the discussions around *less and better* meat. Whilst regenerative agriculture majors on how and why livestock can be managed in a *better* way (livestock-arable integration, mixed species grazing, rotational grazing etc.) there are concerns that without an accompanying focus on *less* meat, the movement might detract from ongoing efforts to get consumers (particularly in the Global North) to reduce the amount of meat and dairy they eat. As we discuss below, it as an open question as to whether regenerative agriculture *does* or *must* engage with questions like this about downstream food system design, or whether it *can* or even *should* focus exclusively on the way farmers manage their land.

Regenerative agriculture as a set of outcomes

If the practices described above are designed to enable the restoration of agro-ecosystems, particularly soils (Schreefel *et al.*, 2020), then regenerative agriculture might equally be defined in terms of the *attainment* of that goal (Newton *et al.*, 2020). Whilst the precise list of environmental metrics that might be used as a proxy for ecosystem and soil health (at varying geographical scales) is somewhat open-ended, it is likely to include reference to soil carbon levels, invertebrate numbers, soil drainage, friability, moisture penetration, soil depth, soil nutrient content, fungal/bacteria ratios, greenhouse gas emissions, pollinator abundance, antibiotic usage, and biodiversity measures.

This understanding of regenerative agriculture – where a primacy is placed on improving ecological health – has several advantages that make it attractive for different food system actors. Particularly for commercial and political actors, the conflation of regenerative agriculture with a set of measured improvements in ecosystem health imbues it with an empirical and falsifiable footing. For example, the companies making claims about the 'regeneration' happening through their supply chains need to have a robust and legally defensible evidence-base to back up their claims.

This results-orientated version can also permit a higher degree of autonomy in how regenerative agriculture is practiced. Advocates of regenerative agriculture emphasise the importance of experimentation and context-specificity and given the variation in ecosystems underpinning agricultural production, each of the practices described above will likely yield different results in different places. By defining regenerative agriculture in terms of the outcomes it produces, farmers are empowered to adopt practices that lead to ecosystem gains in the particular landscapes they manage without being constrained by the need to observe a prescriptive set of practices. As such, they may opt to employ practices – like soil tillage – not usually encouraged in the regenerative model if doing so helps achieve a regenerative outcome. Phrases like *it's not the plough, it's the how* that circulate in the regenerative movement capture this pragmatism and adaptability.

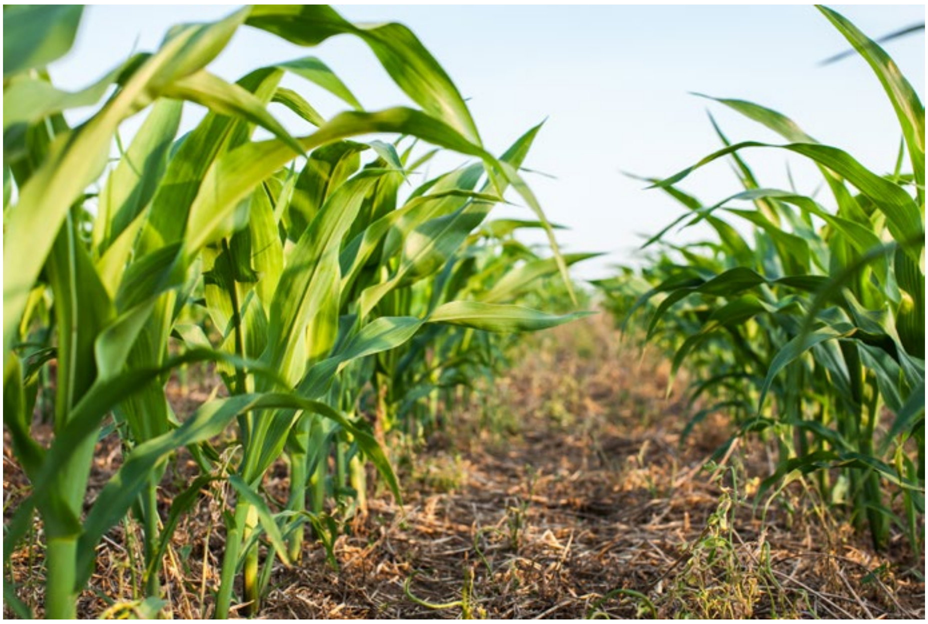
This articulation of regenerative agriculture raises some practical issues. Which metrics to use, and why? Metrics can never be more than proxies for reality, and there are always implications when electing to use one set over another. Whilst *more* environmental metrics can give a fuller picture of what is going on in an ecosystem, there are practical barriers involved in equating improvements in ecosystem health according to an increasingly large set of environmental metrics. This is because measurement costs time, money and requires technical expertise. Empirical tools like the Global Farm Metric and Soilmentor, along with peer-to-peer knowledge exchange networks, are emerging to help operationalise a version of regenerative agriculture that emphasises the importance of measured ecological improvements on the farm.

This results-oriented vision for regenerative agriculture might also include social outcomes such as better mental health for participating farmers, and better farm business profitability.

Go to contents

Regenerative agriculture as a mindset

There is a version of regenerative agriculture that has as much – maybe more – to do with attitudes as it does the adoption of specific farm management practices. These can be thought of as something like a regenerative mindset or *mindscape* (Gordon *et al.*, 2022) in which farm management is an ongoing process of experimentation taking place within nested, complex and intertwined ecological systems. These systems, which include water cycles, nutrient cycles, natural pollination, soil functioning and so on, achieve a level of self-perpetuation and resilience when their good health is achieved by the management practices applied on the farm. This approach is very much in keeping with the principles of those at the Rodale Institute who initially coined the term regenerative agriculture in the 1980s (Giller *et al.*, 2021).



Looking down a corn row in a no-till planted field.
Photo by Margaret Burlingham via Adobe Stock.

This emphasis on the possibility of co-vitality of humans and nature is connected with another idea: the idea of a *journey*. The idea, here, is that the job of regeneration is never finished, and that regenerative practice can always be improved. This holistic regenerative mindscape also stresses how Western scientific ways of knowing the world can be complemented by a more spiritual and emotional engagement with a farmed landscape. From this perspective, the benefits of relating to the natural world in this way are two-fold. Farmers will, in the first instance, develop a greater level of ethical commitment to the land if they engage with its living and vibrant qualities. And, as they grapple with the world in this way, they will be able to refine their regenerative practice by reflecting on the various ways, as they see it, an ecosystem makes its needs and desires known. This adaptive, generative, and open-ended sense of regeneration is arguably incompatible with, or irrelevant to the priorities of many of the purely commercial and political actors entering the regenerative space who need robust definitions to underpin their regenerative strategies.

This 'mindset' understanding is also more amenable to some of the more expansive social objectives in the regenerative movement. Regenerative agriculture, in this version, is about bringing farmers and consumers back into contact with one another, better mental health for farmers, the resilience of rural economies, the role of small-scale producers, processers and distributers, and a redistribution of power in the food system. Some worry that these social and political goals are, increasingly, losing footing in an economic and scientific climate more interested in using farm management practices to achieve specified ecological goals (Gordon *et al.*, 2022). Many farmers in the movement with a deep-seated commitment to these ideas are attempting to create allegiances with other 'regenerative movements' (in finance, development, planning), to ensure regenerative agriculture does not lose sight of these goals.

Defining regenerative agriculture: disagreements, consensus

These differing articulations are not necessarily incompatible but could rather be seen as constituting different *tiers* on the same regenerative framework (Soloviev & Landua, 2016). In some cases, these tiers might also encourage different actors who have begun their regenerative journey with a handful of easy-to-adopt farm management practices to go on to engage more with its psychological, ecological, and political ambitions.

The lack of clear definition of regenerative agriculture may be the very thing that has catalysed such a diversity of ideas as to how food production systems might be redesigned and involved such a wide variety of actors. If this is the case, then regenerative agriculture is made better, not worse, by its fuzzy contours. For this reason, there are some actors even from the more radical or alternative wings of the regenerative movement who are enthusiastic about the way big corporate actors are investing in strategies designed to help their suppliers become more regenerative. This 'broad church' approach to regenerative agriculture raises the possibility (for some) of doing away with definitions altogether. It also hints at the overlap with other alternative approaches to farming like permaculture, organics, and agroecology. The political, agronomic, and environmental aspirations of these movements overlap, diverge and flow through one another (Carlisle *et al.*, 2021).

One final point on the multiplicity of regenerative agriculture: particularly for the mindset and outcomes definitions, regenerative agriculture has the potential to be highly adaptative. In the right circumstances, and if done so for the right reasons, central planks of the regenerative project (like no-till management) can be removed from the farm without foregoing its claims to being considered regenerative. But if regenerative agriculture isn't no-till – or can be *not* no-till – what is it? One answer would be to invoke a sort of *family resemblance* theory notion of definitions: that there are a cluster of practices and principles that can be considered integral to regenerative agriculture, but none of which is, unto itself, a necessary condition.

Regenerative agriculture as a set of actors

From its inception in the 1980s, regenerative practices were developed by participating farmers and research stations, with information and experiences shared as a way of learning from one another's successes and failures (Giller *et al.*, 2021). Across the UK, the US, Continental Europe, New Zealand and Australia, there are now many regenerative conferences, shows, benchmarking groups and more, all dedicated to fostering a practitioner-focussed version of regenerative agriculture. This farmer-led incarnation of the movement emphasises the importance of small-scale farming, the merits of removing chemical inputs from the farm, the shortening of supply chains, and the need to reconnect farmer with consumers. Among other things, this implies a redistribution of power in the food system.

At the same time, against the backdrop of political and commercial imperatives to offset carbon, improve biodiversity, and deliver net-zero emissions targets, the idea of agricultural regeneration has begun to attract the attention of a much broader cohort of powerful actors from across the worlds of retail, finance, and politics. Over the last five years, companies including General Mills (General Mills, 2023), Danone (Danone, 2021), Nestlé (Nestlé, 2022), and many more have expressed interest in integrating regenerative principles into their procurement policies. These actors are working with research groups to understand which regenerative practices relate to the commodities they purchase, and what environmental outcomes might be secured through their adoption.

The arrival of large commercial actors in the regenerative space raises questions as to whether more politically radical goals, such as the revitalisation of relations between farmers and buyers, will remain part of the regenerative model into the future. Although their strategies are still being developed, it is likely that large corporate actors will use the regenerative model to make marginal (per-unit of food produced) reductions in the environmental footprint of their products, rather than to generate critique of their own privileged place in the food system.

Go to contents

With RA's growing political and social profile, accreditation schemes are beginning to emerge. Like the organics model before it, these initiatives seek to leverage regenerative agriculture in commercial settings. They do this to attract price premiums from consumers and to remunerate participating farmers for the adoption of regenerative practices and/or the attainment of regenerative outcomes. Regenerative agriculture accreditation schemes include Pasture For Life and A Greener World in the UK and the global Ecological Outcome Verification.

Some proponents of regenerative agriculture, particularly farmers, are suspicious about the utilisation of the regenerative term by large agri-businesses, and wary about what will happen to aspects of the regenerative model that are less amenable to corporate dilution, accreditation and greenwash. These aspects include the importance of farmer-led knowledge networks, attentiveness to context and site-specificity and the prioritising of processes and mindsets (building ecologically complex soils through iterative regenerative experimentation) rather than on more simple and measurable outcomes, such as tonnes of carbon stored in the soil.

Regenerative agriculture: knowledge practices

At work in these various articulations of regenerative agriculture are different ideas about science and knowledge, and the relationships between humans and the natural world. Like other alternative agricultural movements such as agroecology and organics, regenerative agriculture represents a critique of what it sees to be the reductivism of knowledge practices inherent in 'conventional' farm management. Functional agroecosystems contain such a complex set of ecological factors that they cannot, in the regenerative mindset, be fully *known* through a set of discrete metrics. Soil is a good example. While soil scientists have long recognised that soil quality – the ability to support plant growth – arises from a favourable chemical, physical and biological environment, quality in mainstream farm management is often understood to be mostly the function of levels of nitrogen (N) phosphorus (P), and potassium (K). In the regenerative model, by contrast, healthy and productive soils emerge through the interactions between mycelium networks, nutrients, water, carbon, worms, beetles, crop roots and so on. This list of things that might be included in the list is so large that, for some regenerative practitioners, it makes sense to treat soil as a living and complex *whole*.

Shifts in farm management practice flow from this more holistic understanding of the natural world. To stay with the above example, if soil health is more than just desirable levels of NPK, then regenerative soil management practices must grapple with health as something that is more diffuse and hard-to-quantify. Goals such as reducing soil tillage, and the preservation of living root systems throughout the entirety of the agricultural calendar have been developed with these principles in mind: providing soils the time and ecological complexity they need to build up their health, replenish their own nutrients, and shore-up their long-term agricultural viability, as opposed to just 'topping up' fertility in the form of synthetic inputs. These ideas have implications for the character of agronomic research needed for the development of regenerative practices. Instead of quantifying the yields of a specific crop under different fertiliser application regimes, a more holistic empirical approach would be to consider the water, biodiversity, nutrient and carbon cycle outcomes associated with multi-annual rotations.

The extent to which a regenerative approach to ecosystem complexity is distinct from the approach taken in so called 'conventional' farm settings is debateable (see Sumberg & Giller, 2022 for critical discussion on the term 'conventional agriculture'). As more mainstream farming actors start to engage with notions of soil health, approaches to sustainable soil usage orientated around biomimicry, complex agroecological systems, and resilience are no longer the sole preserve of those in the regenerative or other alternative farming movements (Pulleman *et al.*, 2022). The differences between regenerative and mainstream farming we are tracing out here lie not in whether the actors involved recognise that the system is complex or not, but rather what they do with that recognition, and specifically the degree to which they seek to reduce that complexity in ways that facilitate, or provide a template for, action.

Notwithstanding their emphasis on complexity, many regenerative practitioners are in fact proactive in the way they gather information about their farms' performance and the environmental outcomes of their regenerative practice. Also important is an emphasis on sharing knowledge and experiences through peer-to-peer networks.

The important point is that for some in the regenerative model, more metrics are better only insofar as they provide more insight into inherently complex systems; and that metrics need to be understood as an unavoidably partial proxy for the world. These recognitions lead many practitioners to seek to attune themselves to their farmed environments in more visceral, instinctive, and emotional ways. This way of relating to the farm can, for practitioners, help bridge the gap between the partial information that scientific measurements offer into the agroecosystems being managed and their holistic, even – for some – spiritual complexity. Tools such as the Global Farm Metric and Soilmentor referred to earlier may help farmers use their observations in a more rigorous and scientific way, but they cannot, from this vantage point, substitute for attentiveness and experience.

It is, however, the case that debates about holistic versus reductionist science and ecosystem complexity have muddied the empirical waters surrounding regenerative agriculture in some respects. If regenerative farm management aims to nurture the health of an agroecosystem as a whole, some advocates are doubtful whether scientific study can ever fully quantify its impacts. Whilst more metrics give a better proxy for the ecosystems being managed, there is no number that can act as a stand in for their full complexity, so this line of reasoning goes. These empirical and methodological challenges have been used to counter scientific research that does not find positive relationships between regenerative practices and good environmental outcomes. Where studies have failed to demonstrate the long-term carbon sequestration levels of regenerative grazing practices, for example, advocates have claimed the scientific study failed to properly represent the complex and adaptive way regenerative practitioners go about their livestock management.

Disputes about the execution and conclusions drawn by scientific research (dis)proving the environmental impacts of regenerative practice can be captured as different attitudes to the following two questions: *what counts as knowledge*, and *whose knowledge counts*? Trust is potentially an important factor here, and implies a need for greater engagement (as is starting to happen) between the scientific and practitioner communities by developing collaborative ways of seeking and sharing knowledge.

Go to contents

Regenerative agriculture and food system change

Some regenerative agriculture advocates are highly engaged in food system issues that extend well beyond the farm gate. A major focus is the idea of social regeneration (Soloviev & Landua, 2016). Many of the practices described above involve a more labour-intensive approach to farm management and the development of more diverse agricultural businesses deploying land in more diverse ways. This approach demands a broader range of skills on the farm and can help facilitate higher levels of employment on the farm and, if price premiums can be secured, improved wages. This particular articulation of the regenerative model also seeks to create local foodscapes characterised by higher levels of seasonality, greater local food specificity, the emergence of cottage industries for processing (independent flour mills, for example) and direct-to-market supply chains. Although the economics of these shortened value-chains are not always so simple (Aubry & Kebir, 2013), the argument goes that if farmers can sell more of their food to their local community, the value-added of the produce will flow to those actually working the land and doing the hard work that goes into agroecosystem regeneration. These changes also imply shifts in what people eat towards less processed, more local food and an assumed and intended redistribution of power within the food system: away from large corporate interests and shared among a diversity of smaller actors.

Vegetable box schemes offer one way to shorten value chains.
Photo by Freepik.

Large corporate interests are not necessarily uninterested in these social and political aspects of the regenerative project. Although in their nascency, the regenerative strategies these companies are developing engage with the importance of farmer-led innovation, peer-to-peer learning, and the need to employ context-relevant practices. In the main, though, corporate versions of regenerative agriculture tend to offer a relatively status quo political vision for the future of food, with the dynamics between consumer, producer, distributor and processor largely unchanged (e.g., Nestlé, 2022). Whilst farmers supplying to corporates may – possibly – be offered a premium for adherence to their regenerative procurement strategies, the value-added of their products will still flow to the large agri-businesses doing the processing and marketing, and they remain unconnected to the end consumers.

There are concerns about productivity that cut across these various practitioner-led and corporate articulations of regenerative agriculture. What level of yields might be achievable from the adoption of regenerative practices is the focus of ongoing research. Whilst some studies are beginning to reveal that there is a dip in food output per unit area of land being farmed (Rowntree *et al.*, 2020), others show how productivity can be maintained at high levels whilst agroecosystem regeneration is taking place (Khangura *et al.*, 2023). Owing to the current definitional ambiguities around what regenerative agriculture *is*, it is hard at this stage to make categorical statements about its impacts on yield.

Go to contents

Nevertheless, given that the conversion of more of the world's land to agriculture uses comes at immense environmental cost – particularly considering the opportunity cost of *not* using that land for more dedicated environmental purposes, be that biodiversity conservation or carbon sequestration purposes – it could reasonably be argued that the regenerative project *must* have a coherent vision for how consumption and production practices can be changed to accommodate shifts in the amount and types of food being produced. Without such a model of change, the regenerative project may risk incentivising the uptake of destructive and intensive farm management to make up for losses in productivity it is ushering in elsewhere in the world. This has potentially serious environmental and global justice implications given that such land use changes are likely to happen in poorer parts of the world in areas with fewer environmental protections. TABLE's *Land sparing and land sharing* explainer discusses these tensions in greater detail (Fraanje, 2019).

Livestock agriculture is an important point of contention in these regenerative agriculture and food system design debates. The livestock sector as a whole is implicated in a range of environmental concerns, including climate change via its contribution to greenhouse gas emissions and habitat destruction. That said, statements of this nature are often challenged by those within the regenerative movement for being too general and for not acknowledging that these environmental harms are unevenly distributed across different systems. These problems, they argue, are mainly the responsibility of industrial intensive livestock production; regenerative systems, by contrast, far from causing harm, actively benefit the environment. Others inevitably dispute these claims, arguing the reverse (Nordhaus, 2015).

Alongside debates as to which *systems* are to be preferred, there is now widespread political and scientific discussion around the role that meat and dairy products should play in our diets. A growing scientific consensus suggests that current global consumption trajectories are incompatible with climatic or biodiversity protection targets and as such efforts need to be made to reduce levels of consumption in affluent, high meat-consuming countries. Many NGOs are starting to promote the idea of 'less and better' or 'less but better' meat production and consumption (Resare Sahlin & Trewern, 2022). However, there is hesitancy within the regenerative movement with the idea of endorsing 'less.' The focus on 'less' risks stigmatising all animal source foods, including those products that come from the regenerative farming systems which, they argue, are part of the solution, rather than part of the problem. Closer probing of this hesitancy suggests that there is often an acceptance that in a regenerative world, so to speak, people will be eating less meat than the average British or American citizen does today. However, this dietary shift should be seen as an outcome of a transformed food system which operates within the capacity of the land to produce food rather than a specific goal in and of itself.

That said, given the current reality that regenerative farmers operate within a globalised market-dominated food system, it is not clear how an emphasis on 'better' farming without a parallel focus on achieving 'less' might give rise to this outcome, particularly given the risk of triggering land use change overseas. For farmers just wanting to 'do their bit' to restore the land they have to work on these questions are, arguably, beyond their responsibility; this is perhaps not the case for proponents of regenerative systems, such as civil society organisations, who work at levels of greater abstraction such as policy analysis and advocacy.

It is, in particular, far from clear how some of the agribusinesses developing their regenerative procurement strategies will approach the consumption issue. Many – like Danone, Nestlé, and Burger King – have product portfolios heavily dependent on meat and/or dairy, and although all are developing 'plant-based' products, their commitment to 'less and better' dietary strategies remains uncertain. For the versions of regenerative agriculture interested in changing farm management practices rather than broader social and consumption trends, these are tricky and unanswered questions. A more detailed discussion of debates about livestock can be found in the TABLE Explainer, 'Meat, metrics and mindsets: Exploring debates on the role of livestock and alternatives in diets and farming' (Breewood & Garnett, 2023)

The science and uncertainties

Many of the constituent practices in regenerative agriculture (cover cropping, crop diversification, no-tillage) have been analysed in terms of their impacts on yield, water retention, ecological impacts, and soil carbon stocks. The results of these studies should be treated with caution. The ecological and agronomic outcomes of different farm management practices vary according to the location in which the research was conducted, to the methods of analysis used, and with the inherent variability of research conducted in scientifically 'noisy' environments like farmed landscapes. Whilst this research does provide good insight into the environmental potential of regenerative practices, communicating the results of the research with headline figures can conceal a more complicated reality. The review of this work we offer here, it should also be noted, represents only a small fraction of the burgeoning research being published on the ecological mechanisms and outcomes of regenerative management. We would point readers towards dedicated review pieces to better understand the science on regenerative farming (e.g., Khangura *et al.*, 2023).

Cover cropping can improve soil microbial abundance, which helps improve fertility, nutrient content and soil organic content by 15-41% (Kim *et al.*, 2020). Crop diversification strategies, particularly via inclusion of a legume crop, can reduce reliance on fertilisers, improve pest control, improve biodiversity abundance and improve soil health (Beillouin *et al.*, 2021). No-tillage practices can improve soil aggregation and porosity relative to tillage, and decrease the contribution to global warming potential (Mondal & Chakraborty, 2022). Depending on the soil type, region, precipitation levels, and the crops being grown, no-tillage decreases global warming potential contributions by up to 19% relative to conventional tillage programmes. It can also *increase* it by up to 20% however, owing to emissions from old residues and soil carbon and nitrogen fluctuations (Oorts *et al.*, 2007). This variation averages out as a reduced global warming potential of 7.6% (Shakoor *et al.*, 2021).

In livestock systems, land managed under holistic regenerative grazing systems can store 13% more carbon compared to control groups using conventional grazing according to one study (Mosier *et al.*, 2021). As each of the farms in the experiment group had employed their regenerative practices for different lengths of time, this paper offers very little analysis on the time periods over which these gains were achieved. Per unit-area of land, multispecies rotational grazing systems had a 66% lower emissions footprint than conventional grazing (Rowntree *et al.*, 2020) but the study cited does not provide information on the emissions footprint per kg of food produced. Given the associated dip in productivity of these systems, it is important to note that if evaluated in terms of its per unit-food emissions these systems are unlikely to perform as well as so called efficient conventional systems (see Garnett *et al.*, 2015 for discussion on 'What is efficiency and is it sustainable?').

As above, whether these practices are able to make a helpful contribution to sustainable food system design depends somewhat on the extent to which they are accompanied by shifts in meat and dairy consumption practices. More generally, whilst some research identifies opportunities to increase soil carbon stocks whilst maintaining farm productivity (Mosier *et al.*, 2021), the relationship between the adoption of regenerative practices, the delivery of agroecological improvements, and the maintenance of productivity varies according to crop type, farm systems, soil type and bioregion, and is subject to significant debate (O'Donoghue *et al.*, 2022).

With regards to carbon, the scientific literature is cautious or even critical about claims made by regenerative practitioners about the offsetting potential of its practices (Garnett *et al.*, 2017; Hawkins *et al.*, 2022). Given how important soil carbon sequestration has been in attracting commercial and political interest, this contestation has dominated debates about the role regenerative agriculture should play in food system design (Moinet *et al.*, 2023).

There is particular confusion about the depth at which soil carbon gains should be assessed. Some evaluations show how no-tillage simply redistributes the carbon to higher up in the soil profile (i.e., where it is more readily measured) rather than increasing carbon in the soil overall (Blanco-Canqui & Lal, 2008). In their meta-analysis, Luo *et al.* (2010) conclude that the adoption of no-tillage management increases soil organic carbon content in the first 10cm, but reduces it from 10-40cm of depth, such that there is no overall change in carbon content.

These methodological and evidential uncertainties are related to the knowledge practices in the regenerative model described above. With its emphasis on context-specific practices, and its valorisation of holistic, and adaptive agricultural management, there is disagreement about *whether* and *how* regenerative agriculture can be legible to empirical inquiry. For example, there has been long-standing contestation about whether standardised scientific trials can fully capture the ecological benefits of regenerative rotational grazing systems that rely on practitioners' ability to adapt and respond to changing conditions in the animals' eating behaviours, the weather, and the grass (Briske *et al.*, 2011).

Cows graze in a field in Dorset, UK.
Photo by Alexander Turner.

Go to contents

Conclusion

Regenerative agriculture is an idea that resonates with many, attracting actors as diverse as small-scale farmers aligned with the alternative farming movement, to large corporates operating in markets across the world. As an idea that is relatively new and still evolving, it seems to mean very different things to different people. For some, regenerative agriculture constitutes a set of farming techniques that can help them operate within, and continue to benefit from, the current market context in ways that additionally help them meet their environmental obligations. For others regenerative agriculture connotes a whole new way of thinking and being – about food systems and what (and for whom) they are for, the power relations between different actors, the kinds of knowledge we value, and fundamentally our place in the natural world.

Without a formal definition as yet, the term allows for this diversity. Whether this is a strength or a problem is open for debate. For some the flexibility of the term allows different actors to try different things at different levels of ambition as they embark on their regenerative 'journey' – with the emphasis being on the journey, rather than the destination, since a regenerated *state* is necessarily unattainable. For others, this lack of an accepted definition risks weakening the radical heart of the idea and enabling unscrupulous actors to greenwash their unsustainable activities.

The aim here has not been to foreclose discussion on what regenerative agriculture is, what it ought to be or whether or not it should be defined more specifically. It has, instead, been written to explore the meanings of regenerative agriculture in relation to the different actors using the term and their visions of what a good future for the food system might look like.

It is also important to note that, notwithstanding their differences, there is also consensus in how the regenerative term is used. There is, for example, general acceptance of its broad principles (albeit to be applied with sensitivity to context) and a newfound respect for soil as a complex entity full of life, rather than just a collection of chemicals. This is potentially cause for optimism. On the other hand, the application of regenerative agricultural principles and the potentially lower yields that ensue, in a world where other aspects of the food system (as regards markets, consumption patterns, trade, biodiversity protection and so forth) remain unaltered, raise questions about the risks that environmental harms are simply exported overseas. Regeneration in the UK, mainland Europe or the US could potentially trigger further degeneration in already vulnerable regions of the Global South. As ever, the problem when it comes to addressing food system problems in an uncertain globalised context, is this: where does one start? Is it ever possible to do one thing without concurrently doing everything else if one is to avoid negative consequences? But since it is of course impossible to do everything, everywhere all at once, what else is there to do but to start with that one thing?

Go to contents

Bibliography

Al-Kaisi, M. M., & Lal, R. (2020). Aligning science and policy of regenerative agriculture. Soil Science Society of America Journal, 84(6), 1808-1820. https://doi.org/10.1002/saj2.20162

Aubry, C., & Kebir, L. (2013). Shortening food supply chains: A means for maintaining agriculture close to urban areas? The case of the French metropolitan area of Paris. Food Policy, 41, 85-93. https://doi.org/10.1016/j.foodpol.2013.04.006

Beillouin, D., Ben-Ari, T., Malézieux, E., Seufert, V., & Makowski, D. (2021). Positive but variable effects of crop diversification on biodiversity and ecosystem services. bioRxiv. https://doi.org/10.1101/2020.09.30.320309

Blanco-Canqui, H., & Lal, R. (2008). No-Tillage and Soil-Profile Carbon Sequestration: An On-Farm Assessment. Soil Science Society of America Journal, 72(3), 693-701. https://doi.org/10.2136/sssaj2007.0233

Breewood, H., & Garnett, T. (2020). What is feed-food competition? TABLE Debates. https://www.tabledebates.org/building-blocks/what-feed-food-competition

Breewood, H., & Garnett, T. (2023). Explainer Series: Meat, metrics and mindsets: Exploring debates on the role of livestock and alternatives in diets and farming. TABLE Debates. https://tabledebates.org/meat-metrics-mindsets

Briske, D. D., Sayre, N. F., Huntsinger, L., Fernandez-Gimenez, M., Budd, B., & Derner, J. D. (2011). Origin, Persistence, and Resolution of the Rotational Grazing Debate: Integrating Human Dimensions Into Rangeland Research. Rangeland Ecology & Management, 64(4), 325-334. https://doi.org/10.2111/REM-D-10-00084.1

Campbell, C. A., Selles, F., Lafond, G. P., & Zentner, R. P. (2001). Adopting zero tillage management: Impact on soil C and N under long-term crop rotations in a thin Black Chernozem. Canadian Journal of Soil Science, 81(2), 139-148. https://doi.org/10.4141/S00-035

Cardoso, E. J. B. N., Vasconcellos, R. L. F., Bini, D., Miyauchi, M. Y. H., Santos, C. A. d., Alves, P. R. L., Paula, A. M. d., Nakatani, A. S., Pereira, J. d. M., & Nogueira, M. A. (2013). Soil health: looking for suitable indicators. What should be considered to assess the effects of use and management on soil health? Scientia Agricola, 70, 274-289.

Carlisle, R., Cusworth, G., & Liang, E. (2021). Exploring the ebbs and flows of different agricultural movements. TABLE Debates. https://tabledebates.org/publication/regenerative-agriculture-organic-agroecology/visual

Cherry, J. (2020). 5 Principles of Regenerative Agriculture. Groundswell. https://groundswellag.com/principles-of-regenerative-agriculture/

Colbach, N., & Cordeau, S. (2022). Are No-Till Herbicide-Free Systems Possible? A Simulation Study. Frontiers in Agronomy, 4. https://doi.org/10.3389/fagro.2022.823069

Cusworth, G., Garnett, T., & Lorimer, J. (2021). Agroecological break out: Legumes, crop diversification and the regenerative futures of UK agriculture. Journal of Rural Studies, 88, 126-137. https://doi.org/10.1016/j.jrurstud.2021.10.005

Cusworth, G., Lorimer, J., Brice, J., & Garnett, T. (2022). Green rebranding: Regenerative agriculture, future-pasts, and the naturalisation of livestock. Trans Inst Br Geogr, 47(4), 1009-1027. https://doi.org/10.1111/tran.12555

Danone. (2021). For a regenerative future. Danone Website. https://www.danone.com/content/dam/danone-corp/danone-com/about-us-impact/policies-and-commitments/en/2021/Danone-regenerative-agriculture-2021.pdf

Dutkiewicz, J. R., G. (2021). The Myth of Regenerative Ranching. The New Republic. https://newrepublic.com/article/163735/myth-regenerative-ranching

Fraanje, W. (2019). What is the land sparing-sharing continuum? TABLE Debates. https://tabledebates.org/building-blocks/what-land-sparing-sharing-continuum

Garnett, T., Godde, C., Muller, A., Röös, E., Smith, P., de Boer, I., zu Ermgassen, E., Herrero, M., van Middelaar, C., Schader, C., & van Zantan, H. (2017). Grazed and confused? TABLE Debates. University of Oxford. https://tabledebates.org/sites/default/files/2020-10/fcrn_gnc_report.pdf

Garnett, T., Röös, E., & Little, D. (2015). Lean, green, mean, obscene…? What is efficiency? And is it sustainable? TABLE Debates. University of Oxford. https://www.tabledebates.org/publication/lean-green-mean-obscene-what-efficiency-and-it-sustainable

General Mills. (2023). Regenerative Agriculture: Keeping our planet healthy. https://www.generalmills.com/how-we-make-it/healthier-planet/environmental-impact/regenerative-agriculture

Giller, K. E., Hijbeek, R., Andersson, J. A., & Sumberg, J. (2021). Regenerative Agriculture: An agronomic perspective. Outlook on Agriculture, 50(1), 13-25. https://doi.org/10.1177/0030727021998063

Gordon, E., Davila, F., & Riedy, C. (2022). Transforming landscapes and mindscapes through regenerative agriculture. Agric Human Values, 39(2), 809-826. https://doi.org/10.1007/s10460-021-10276-0

Hawkins, H. J., Venter, Z. S., & Cramer, M. D. (2022). A holistic view of Holistic Management: What do farm-scale, carbon, and social studies tell us? Agriculture, Ecosystems & Environment, 323, 107702. https://doi.org/10.1016/j.agee.2021.107702

Jones, D. L., Nguyen, C., & Finlay, R. D. (2009). Carbon flow in the rhizosphere: carbon trading at the soil–root interface. Plant and Soil, 321(1), 5-33. https://doi.org/10.1007/s11104-009-9925-0

Jordon, M. W., Smith, P., Long, P. R., Bürkner, P.-C., Petrokofsky, G., & Willis, K. J. (2022). Can Regenerative Agriculture increase national soil carbon stocks? Simulated country-scale adoption of reduced tillage, cover cropping, and ley-arable integration using RothC. Science of The Total Environment, 825, 153955. https://doi.org/10.1016/j.scitotenv.2022.153955

Kaspar, T. C., & Singer, J. W. (2011). The Use of Cover Crops to Manage Soil. In Soil Management: Building a Stable Base for Agriculture (pp. 321-337). https://doi.org/10.2136/2011.soilmanagement.c21

Khangura, R., Ferris, D., Wagg, C., & Bowyer, J. (2023). Regenerative Agriculture-A Literature Review on the Practices and Mechanisms Used to Improve Soil Health. Sustainability, 15(3), 2338. https://www.mdpi.com/2071-1050/15/3/2338

Kim, N., Zabaloy, M. C., Guan, K., & Villamil, M. B. (2020). Do cover crops benefit soil microbiome? A meta-analysis of current research. Soil Biology and Biochemistry, 142, 107701. https://doi.org/10.1016/j.soilbio.2019.107701

Levin, B. (2022). Regenerative Agriculture as Biodiversity Islands. In F. Montagnini (Ed.), Biodiversity Islands: Strategies for Conservation in Human-Dominated Environments (pp. 61-88). Springer International Publishing. https://doi.org/10.1007/978-3-030-92234-4_3

Luo, Z., Wang, E., & Sun, O. J. (2010). Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments. Agriculture, Ecosystems & Environment, 139(1), 224-231. https://doi.org/https://doi.org/10.1016/j.agee.2010.08.006

Mary, B., Clivot, H., Blaszczyk, N., Labreuche, J., & Ferchaud, F. (2020). Soil carbon storage and mineralization rates are affected by carbon inputs rather than physical disturbance: Evidence from a 47-year tillage experiment. Agriculture, Ecosystems & Environment, 299, 106972. https://doi.org/https://doi.org/10.1016/j.agee.2020.106972

Moinet, G. Y. K., Hijbeek, R., van Vuuren, D. P., & Giller, K. E. (2023). Carbon for soils, not soils for carbon. Global Change Biology, 29(9), 2384-2398. https://doi.org/https://doi.org/10.1111/gcb.16570

Mondal, S., & Chakraborty, D. (2022). Global meta-analysis suggests that no-tillage favourably changes soil structure and porosity. Geoderma, 405, 115443. https://doi.org/https://doi.org/10.1016/j.geoderma.2021.115443

Montgomery, D. (2018). Growing a Revolution: Bringing Our Soil Back to Life. W. W. Norton & Company.

Mosier, S., Apfelbaum, S., Byck, P., Calderon, F., Teague, R., Thompson, R., & Cotrufo, M. F. (2021). Adaptive multi-paddock grazing enhances soil carbon and nitrogen stocks and stabilization through mineral association in southeastern U.S. grazing lands. Journal of Environmental Management, 288, 112409. https://doi.org/10.1016/j.jenvman.2021.112409

Nestlé. (2022). The Nestlé Agriculture Framework. Nestlé. https://www.nestle.com/sites/default/files/2022-07/nestle-agriculture-framework.pdf

Newton, P., Civita, N., Frankel-Goldwater, L., Bartel, K., & Johns, C. (2020). What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes. Frontiers in Sustainable Food Systems, 4. https://doi.org/10.3389/fsufs.2020.577723

Nordhaus, T. (2015). The Environmental Case for Industrial Agriculture: Small-scale Food System Enlarges Human Footprint. https://thebreakthrough.org/issues/food-agriculture-environment/the-environmental-case-for-industrial-agriculture

O'Donoghue, T., Minasny, B., & McBratney, A. (2022). Regenerative Agriculture and Its Potential to Improve Farmscape Function. Sustainability, 14(10), 5815. https://www.mdpi.com/2071-1050/14/10/5815

Oorts, K., Merckx, R., Gréhan, E., Labreuche, J., & Nicolardot, B. (2007). Determinants of annual fluxes of CO2 and N2O in long-term no-tillage and conventional tillage systems in northern France. Soil and Tillage Research, 95(1), 133-148. https://doi.org/10.1016/j.still.2006.12.002

Prescott, C., Rui, Y., Cotrufo, M., & Grayston, S. (2021). Managing plant surplus carbon to generate soil organic matter in regenerative agriculture. Journal of Soil and Water Conservation, 76(6), 99A. https://doi.org/10.2489/jswc.2021.0920A

Pulleman, M. M., de Boer, W., Giller, K. E., & Kuyper, T. W. (2022). Soil biodiversity and nature-mimicry in agriculture; the power of metaphor? Outlook on Agriculture, 51(1), 75-90. https://doi.org/10.1177/00307270221080180

Resare Sahlin, K., & Trewern, J. (2022). A systematic review of the definitions and interpretations in scientific literature of 'less but better' meat in high-income settings. Nature Food, 3(6), 454-460. https://doi.org/10.1038/s43016-022-00536-5

Rowntree, J. E., Stanley, P. L., Maciel, I. C. F., Thorbecke, M., Rosenzweig, S. T., Hancock, D. W., Guzman, A., & Raven, M. R. (2020). Ecosystem Impacts and Productive Capacity of a Multi-Species Pastured Livestock System. Frontiers in Sustainable Food Systems, 4. https://doi.org/10.3389/fsufs.2020.544984

Schreefel, L., Schulte, R. P. O., de Boer, I. J. M., Schrijver, A. P., & van Zanten, H. H. E. (2020). Regenerative agriculture – the soil is the base. Global Food Security, 26. https://doi.org/10.1016/j.gfs.2020.100404

Shakoor, A., Shahbaz, M., Farooq, T. H., Sahar, N. E., Shahzad, S. M., Altaf, M. M., & Ashraf, M. (2021). A global meta-analysis of greenhouse gases emission and crop yield under no-tillage as compared to conventional tillage. Science of The Total Environment, 750, 142299. https://doi.org/10.1016/j.scitotenv.2020.142299

Soloviev, E., & Landua, G. (2016). Levels of Regenerative Agriculture. Terra Genesis International. https://ethansoloviev.com/wp-content/uploads/2019/02/Levels-of-Regenerative-Agriculture.pdf

Sumberg, J., & Giller, K. E. (2022). What is 'conventional' agriculture? Global Food Security, 32, 100617. https://doi.org/10.1016/j.gfs.2022.100617

Teague, R., & Kreuter, U. (2020). Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services. Frontiers in Sustainable Food Systems, 4. https://doi.org/10.3389/fsufs.2020.534187

Tittonell, P., Corbeels, M., van Wijk, M. T., Vanlauwe, B., & Giller, K. E. (2008). Combining Organic and Mineral Fertilizers for Integrated Soil Fertility Management in Smallholder Farming Systems of Kenya: Explorations Using the Crop-Soil Model FIELD. Agronomy Journal, 100(5), 1511-1526. https://doi.org/10.2134/agronj2007.0355

Wagner, M., Waterton, C., & Norton, L. R. (2023). Mob grazing: A nature-based solution for British farms producing pasture-fed livestock. Nature-Based Solutions, 3, 100054. https://doi.org/10.1016/j.nbsj.2023.100054