Rethinking Sustainability

Life-centric agriculture in a techno-centric world

A review and gene-editing case study

A BIGGER CONVERSATION

Rethinking Sustainability
Life-centric Agriculture in a Techno-centric World
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Introduction

In 2022 a legislative framework for sustainable food systems in Europe was proposed.

Part of a new EU Green Deal, the idea was to integrate sustainability[1] into all food-related policies by adopting criteria for sustainability across the food chain.

This included adding a sustainability assessment to the proposed new legislation for gene editing, or new genomic techniques (NGTs, as they are called in the EU). The public consultation on the draft legislation sought opinions on the proposal and the rhetoric around the proposals even suggested that such a criteria could replace standard risk assessments, as part of the process for deciding which gene-edited organisms should be permitted.

Responses to the proposals were, predictably, mixed[2] raising interesting, even crucial, questions not just about genetic technologies but about how we define sustainability.

As the June 2024 EU elections drew near, the sustainability proposal was considered too difficult to implement before the change of government and was, therefore, withdrawn.

Nevertheless, the proposal was part of a reinvigorated interest in sustainability in general – what it is, how it is defined and how it can translate into policy.

In the face of escalating climate change, biodiversity loss and social discontent, governments around the world are grappling with how to incorporate sustainability concerns into policy and regulation.

Usually this focuses on corporate reporting rather than production processes and is more centred on creating 'green' markets and a 'green' economy rather than directly furthering ecosystem sustainability. The EU proposals triggered serious questions about the sustainability claims of gene-edited crops and foods[3]. Our intent at the time was to produce a response to the proposals focussing on these issues.

However, in trying to unpick these claims, it became clear that a consideration of editing could not be separated from a consideration of sustainability in agriculture. This, in turn, cannot be truly separated from looking at sustainability in a broader, more wholistic sense – and throughout this report we will use the term 'wholism' to signify the wholeness and interconnected nature of sustainability.

Agriculture is inextricably linked to many of the key environmental, social and economic challenges that fall under the umbrella of sustainability. Agricultural practices have major impacts on natural resource use, greenhouse gas emissions, biodiversity, soil health, water quality and the livelihoods of farmers and rural communities. Sustainable agricultural approaches must address these interconnected issues.

Whilst examining all this, we have become uncomfortably aware of how profoundly disconnected society and its leaders have become – in thought and endeavour – from the roots of wholistic sustainability

At the same time, sustainability in agriculture is influenced by, and should be aligned with, broader sustainability goals and strategies.

For example, tackling climate change, preserving natural ecosystems and supporting thriving local economies are all crucial for the long-term sustainability of agricultural systems.

Sustainability in agriculture is fundamentally about finding ways for food production to be environmentally responsible, socially equitable and economically appropriate – goals that are inherently tied to the wider sustainability agenda.

It quickly became clear, therefore, that while it is possible to examine specific sustainable agricultural practices these first needed to be situated within the larger context of an integrated, systems-level approach that recognises the interdependencies between different sectors and domains.

Sustainable agriculture – including interventions like gene editing – must be part of this broader vision and cannot be pursued in isolation.

Technology – the twist in the tale

At the same time, the rise of technology and the widespread emphasis on innovation in farming and the wider 'food system' provides a timely and unique context for revisiting and reaffirming fundamental principles around sustainability in general, and within that agriculture.

Many of these are decades old and while these principles have been discussed before, their application to current issues like the use of gene editing in agriculture, or indeed wider nature, brings fresh relevance. We spotted an opportunity for an updated and hopefully accessible perspective on how these enduring principles apply – or not – to so-called 'cutting-edge' technologies.

Gene editing – also known as precision-breeding (PBOs), bioengineering and new genetic technologies (NGTs) – is attracting increasing attention in the context of sustainable innovation.

Developers and lobbyists all over the world are actively promoting it as a way of fixing the system without the need for radical change and this is appealing to policymakers and politicians as well as corporate and philanthropic power brokers.

It is sold as an economic and environmental win-win, with the potential to "*increase yield, improve resilience to increasingly extreme weather conditions or reduce the need for inputs such as pesticides or fungicides*"[4], whilst at the same time driving new markets and new economies.

This win-win narrative has been adopted by many governments, including the UK which signed the Genetic Technology (Precision Breeding) Act into law in March 2023. The UK's Department for Environment, Food and Rural Affairs (Defra) claimed that gene editing would improve "*the sustainability, resilience and productivity of the UK's food system*"[5] and help to build a world-class biotechnology sector offering exciting new food products to the global marketplace.

The extent of these claims is breathtaking. The audacity of the aspiration is enough to justify scepticism, even before the paucity of evidence backing up the claim and the patchy track record of genetic engineering in farming and food is considered. Yet, leaving aside scepticism any serious look at the claims reveals some massive challenges to society and business which are being ignored or glossed over – often by green paint.

A 2019 UK government policy paper entitled *Regulation for the Fourth Industrial Revolution*, described "*a fusion of technologies – such as artificial intelligence, gene editing and advanced robotics – that is blurring the lines between the physical, digital and biological worlds*"[6].

This is a rather anodyne way of expressing a fundamental change in human intervention in the natural world, in ecosystems and the make-up of the building blocks of life.

Sustainability in agriculture is fundamentally about finding ways for food production to be environmentally responsible, socially equitable and economically appropriate – goals that are inherently tied to the wider sustainability agenda

Similarly, technology-focussed markets – research, innovation, intellectual property and capital generation – are being given priority status over the myriad and diverse needs of farming and food. This is more than a 'blurring of lines'. Whilst accepting that innovation can move us forward in positive ways, this view constitutes a profound challenge to farmers, conservationists, rural communities and the culture of growing food in a living ecosystem.

Thus, while the paper notes elsewhere that "*innovation increasingly blurs the lines between sectors and cuts across traditional regulatory boundaries*", in truth it doesn't so much blur the lines as obliterate them, along with all the protocols, procedures and regulations that flow from them.

It represents a fundamentally different approach to economies, markets, regulations, natural resources, business and political structures and democratic oversight. This has been labelled "technocapitalism" – which sounds like nothing more than an academic buzz word, but is more than that.

Technocapitalism, grounded in technology and science, is characterised by the convergence of advanced technology, capitalist market structures and an emphasis on technological innovation as the primary driver of economic and social change.

It seeks the disruption or deconstruction of natural, cultural, structural and regulatory boundaries, thereby challenging existing legal and ethical norms and frameworks. It operates through the commercialisation of knowledge by patents and monetised intellectual property and data capture. It smudges the boundaries between public and private spheres of interest and finance without transparency or oversight.

Whilst we are just on the cusp of such changes, the new reality being created by this new form of capitalism is likely to impact most aspects of human life and relationships including work, health, community and nature itself[7].

In search of clarity

There is no agreed definition of what constitutes sustainability, in the UK, EU or elsewhere in the world. Discourses on sustainability are many, varied and often conflicted. Sustainability criteria – proposed and existing – are contradictory, confusing about the levels and scope of application. They rarely (if ever) clearly link the point of application to a whole system let alone to a planetary context or timeline.

There is also no clarity or agreement as to what constitutes the food and farming system. There are few agreed or shared values, goals or protocols beyond aspirational statements that are themselves conflicting and/or hide conflicts behind heroic verbiage.

Whilst examining all this, we have become aware of how profoundly disconnected society and its leaders have become – in thought and endeavour – from the roots of wholistic sustainability.

This report attempts to address at least some of these things in a 'back to basics' way; starting with an overview of the various uses and definitions of the term 'sustainability'.

It considers the main barriers to change – or lock-ins – of the current industrial agricultural system and the emerging technocapitalist one and analyses the process of managing trade-offs in sustainability assessments – both of which are crucial factors when designing a sustainable agricultural system.

Finally, it proposes four key pillars for a 'life-centric' approach to sustainability and applies these foundational principles to help policymakers guide the assessment of the sustainability of gene-edited crops going forward and, crucially, to assist citizens in understanding and judging the policies and the policy-making.

Our aim is to open a discussion that is being increasingly side-lined and to address a widening gap in the discourse around sustainable agriculture and food systems, where technological solutions are often presented as 'sustainable' without sufficient consideration, or demonstration, of how they meet even the most basic principles of sustainability.

Key takeaways

This report covers a lot of ground and aims to provide food for thought about current approaches to sustainability, and in particular agricultural sustainability.

- It examines sustainability broadly and in relation to agriculture, noting that there has been a significant shift from a values-based "life-centric" to a market-based "techno-centric" approach to sustainability in recent decades.

- This is driven by a technocapitalist perspective which focuses narrowly on science, technology and innovation as means of increasing productivity, creating new markets and fuelling economic growth, leading to overwhelming corporate control.

- Despite widespread use since the late 1960s, "sustainable" and "sustainability" remain poorly defined and contested. Triple bottom line concepts like sustainable intensification, net zero, nature-based solutions, and climate-smart agriculture ignore fundamental differences that exist around the compatibility of economic growth, planetary boundaries and societal values.

- The failure to achieve the Sustainable Development Goals, alongside the increasing failure of the world to live within planetary boundaries, demonstrates how unsustainable and unfit for purpose a market/business/economy-centric approach (including "green growth") to sustainability is.

- We propose a shift to a life-centric approach to sustainability linked to a core philosophy that sustainability must first and foremost sustain life.

- We identify four key pillars that support this approach – Boundaries and limits; A duty of care; Sufficiency; and Equity and democracy.

- These pillars align with decades of sustainability thinking and provide a framework for: operating within clear ecological boundaries; addressing social and democratic aspects of sustainability; challenging existing power structures and economic models; promoting diversity in agricultural practices and decision-making and prioritising resilience and adaptability over narrow efficiency metrics.

- As it is fundamental to life and wellbeing, we have based much of our considerations of sustainability on the perspective of agriculture and the food system. We present several criteria and examples for how this might work including an appendix of positive actions which fit within these pillars.

- The path to sustainability can involve both 'end-state' goals and incremental processes. In recent years, we have increasingly adopted incremental and limited fixes as a means of transitioning to a sustainable end-state. But incremental sustainability efforts, which can seem like painless transitions, may end up becoming unhelpful lock-ins. The risks and benefits of incremental systems and processes, therefore, need to be carefully considered before deployment in the agriculture and the wider environment.

- As a case study exercise, we examined gene editing against our life-centric perspective and framework for sustainability and found it to be incompatible. We judge it to be a limited and incremental intervention, rather than a whole-system approach to agriculture, and one that doesn't align with a life-centric, whole-system approach to sustainability.

- Our framework doesn't categorically rule out a role for some applications of gene editing as part of a transition or incremental pathway to sustainability. However, we considered its sustainability claims and found that transparent, independent evidence for the contribution it might make to a transition to life-centric sustainability is lacking.

- Examples of life-centric approaches to sustainability in agriculture already exist, including aspects of organic agriculture, community-supported agriculture, the agroecological movement, and La Via Campesina.

- We recognise the practical implementation and development of these pillars will take much work and there will be resistance from vested interests. Crucially, consensus would require a commitment to a multi-faceted approach, combining policy measures, economic incentives, education and community engagement.

1 | A brief history of sustainability

The history of sustainability is long and frustrating. It's full of big thoughts, aspirational visions, wrong turns and broken promises. As the concept of 'sustainability' has inched up the political agenda, the way we define it has become distorted and compromised. Today many of our ideas about sustainability – sometimes even those espoused by environmentalists – are more about political expediency, corporate interests and market creation than rooted in sustaining life on Earth.

Because of this, and given a revived interest in concocting new narratives and creating new policies around sustainability, it's worth revisiting this history to better understand how we got to where we are today.

Following the 1962 publication of Rachel Carson's seminal work ***Silent Spring***[8]– widely credited with launching the modern environmental movement – there was an explosion of scholarly works shedding light on environmental breakdown and resource depletion and questioning the ideology of infinite growth on a finite planet.

As the concept of 'sustainability' has inched up the political agenda, the way we define it has become distorted and compromised

In 1971 Nicholas Georgescu-Roegen, a Romanian-American mathematician and economist, published ***The Entropy Law and the Economic Process***[9] introducing the concept of entropy to economics. It argued that continuous growth is unsustainable due to the finite nature of natural resources.

A year later, the pioneering report ***The Limits to Growth***[10] was published by the Club of Rome, an informal group of prominent businesspeople, state officials and scientists.

The report, a global phenomenon translated into 30 languages, describes the results of a groundbreaking 2-year research project by systems scientists at the Massachusetts Institute of Technology (MIT), which concluded that the biosphere has a limited ability to absorb human population growth, production, pollution and economic growth.

Soon after, in 1973, the economist E.F. Schumacher published the rather more lyrical ***Small is Beautiful***[11]. This, too, proposed that infinite growth in a world of limited resources is impossible and we should redesign our economy to focus on small-scale private enterprise and local sufficiency.

Around the same time, Edward Goldsmith's ***A Blueprint for Survival***[12] focussed attention on the urgency of environmental problems, including climate change and the sixth mass extinction and considered how humans and other organisms could adapt and survive. Chief amongst its recommendations was that people should live in small, decentralised and largely de-industrialised communities.

In essence all of these commentators, writers and researchers advocated that all human activity needed to stay within the finite natural resources of our planet and the natural functioning capacity of its biosphere.

This is the unalterable core of sustainability on our planet and yet all these works were controversial from the outset, often dismissed as doom-mongering by the mainstream. These publications coincided with the shock brought about by the end of the massive postwar growth in the global economy. A fact that contributed to the attention they were given.

But by the mid-1980s, the global economy had bounced back from its slump, oil prices had stabilised, free market capitalism (or neoliberalism) was expanding and serious discussions about limits to growth gave way to tokenistic rhetoric about 'green growth'.

Then, as now, advocates of green growth believed economic development could continue by separating – or decoupling – economic growth from increased resource use and its associated environmental damage or negative impact on human well-being. The concept of decoupling originated with the Organisation for Economic Co-operation and Development (OECD) in 2002[13], which described it as "*breaking the link between 'environmental bads' and 'economic goods'*".

Challenging this notion and reasserting the need to live within the planet's natural resources and its biosphere gained new sense of urgency when, in 2009, a group of scientists led by Johan Rockström from the Stockholm Resilience Centre and Will Steffen from the Australian National University pushed the growth discussion into new territory with the publication of their ***Planetary Boundaries Framework***[14].

This identified nine Earth-system processes and associated thresholds which, if crossed, could generate unacceptable environmental change: climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading.

The group defined these thresholds, or planetary boundaries, as "*the safe operating space for humanity with respect to the Earth system and are associated with the planet's biophysical subsystems or processes.*"

Once crossed, they said, "*important subsystems, such as a monsoon system, could shift into a new state, often with deleterious or potentially even disastrous consequences for humans.*"

At the time of their analysis, three of nine interlinked planetary boundaries had already been overstepped. As of 2023, all these boundaries have been further quantified and the scientists estimate that six of the nine have now been crossed[15].

Our relentless pursuit of growth is deeply problematic and, in the end, unachievable. Future economic growth will, as Richard Heinberg, senior fellow at the Post Carbon Institute, has observed, be impeded by the depletion of critical, natural resources, the increased costs of extraction and its associated negative environmental impacts, and ever-mounting debt[16].

The most obvious and, arguably, most powerful alternative is the modern movement for 'degrowth', defined in 2020 by economic anthropologist Jason Hickel, as "*a planned reduction of energy and resource use designed to bring the economy back into balance with the living world in a way that reduces inequality and improves human wellbeing*"[17].

In 2022, Intergovernmental Panel on Climate Change (IPCC) ***Sixth Assessment Report*** also acknowledged the idea of degrowth, suggesting that "*addressing the ecological crisis necessitates a shift away from business as usual and towards openly considering radical alternatives*"[18].

Contraction and convergence

In the mid-1990s, at the request of the Intergovernmental Panel on Climate Change, the Global Commons Institute (GCI), developed a framework called Contraction and Convergence[30], which set out a method for harmonising global greenhouse gas emissions to a safe and sustainable level within the next few decades.

This framework, based on the principles of equity and precaution[31], was seen as a rational response to the objectives and principles laid out in the UN Framework Convention on Climate Change (UNFCCC), which was agreed upon a year later at the Earth Summit in Rio and ratified into force in 1995.

In short, 'contraction' refers to the overall reduction of greenhouse gas emissions globally to a level that is considered safe for the climate. 'Convergence' involves ensuring that per capita emissions across all countries converge to a uniform level. It implies that wealthier, high-emission countries reduce their emissions significantly while allowing poorer, low-emission countries to increase theirs until they reach a common per capita level.

Although originally developed in response to climate change, its basic principles have been proposed as a way of "rebalancing", or assuring more equitable access to animal proteins throughout the world[32], and it offers valuable insights into agricultural sustainability, particularly in the face of growing environmental and social challenges[33].

Rockström *et al's* quantification of planetary boundaries came not long after the first International Degrowth Conference for Ecological Sustainability and Social Equity in 2008[19], which introduced the term "degrowth" into the international academic debate. Nine such conferences have taken place since then[20].

The central question of degrowth, as summed up by a Hickel *et al* in a 2022 commentary in the journal Nature is: "*how we enable societies to prosper without growth to ensure a just and ecological future*"[21].

Answers, in the form of policy suggestions, have included reducing production where possible, improving public services to provide strong social outcomes without resource use, introducing a green jobs guarantee to incentivise upskilling and provide a just transition for those in declining industries and reducing working time to lower carbon emissions and free people to engage in care and other welfare-engaging activities[22].

These kinds of ideas have been advocated by many degrowth advocates, including the late American economist Herman Daly[23], French economist and philosopher Serge Latouche[24], British economists David Flemming[25] and Kate Raworth[26] and British ecological economist Tim Jackson[27] as well as Catalan economist Joan Martínez-Alier[28] – amongst others – whose work and ideas return to and reinforce the essential core of sustainability.

In 2019 a report by a group of economists led by Timothée Parrique[29] examined the literature to assess the validity of the decoupling hypothesis. They concluded:

"*Not only is there no empirical evidence supporting the existence of a decoupling of economic growth from environmental pressures on anywhere near the scale needed to deal with environmental breakdown, but also, and perhaps more importantly, such decoupling appears unlikely to happen in the future.*"

Indeed, 'decoupling'– and certainly 'degrowth' – has yet to be fully embraced or actioned.

Some argue that there are indications it is happening incrementally in some areas, such as agriculture (which will be explored later). But, overwhelmingly, governments around the world continue to encourage us to produce, consume and sell more on the premise that future efficiencies driven by technology will result in 'green growth' and 'sustainable development'. This inexorable push is promoted and aided by policies that claim to promote business and corporate responsibility and thereby lead to sustainability.

The triple bottom line

This notion of 'sustainable development' has its roots in the 1987 ***Brundtland Report*** – also known as ***Our Common Future*** – which considered the question of how global aspirations for abundance

Timeline of sustainability thinking

- **1962** Rachel Carson publishes Silent Spring, raising awareness about environmental issues, particularly pesticide use
- **1970** The first Earth Day is celebrated, marking the birth of the modern environmental movement
- **1972** The Club of Rome publishes The Limits to Growth, modelling the consequences of economic and population growth with finite resources
- **1972** The United Nations Conference on the Human Environment in Stockholm leads to the creation of the UN Environment Programme
- **1972** A Blueprint for Survival is published in The Ecologist magazine, calling for a radically restructured society to prevent environmental breakdown
- **1973** E.F. Schumacher publishes Small Is Beautiful: A Study of Economics As If People Mattered, advocating for human-scale, decentralised technologies
- **1979** The First World Climate Conference is held, recognising climate change as a serious problem
- **1987** The Brundtland Report introduces the concept of sustainable development
- **1988** The Intergovernmental Panel on Climate Change (IPCC) is established
- **1990** The IPCC releases its First Assessment Report, confirming the scientific basis for climate change
- **1992** The Earth Summit in Rio de Janeiro produces Agenda 21, a comprehensive plan for global sustainability
- **1997** The Kyoto Protocol is adopted, setting binding targets for industrialised countries to reduce greenhouse gas emissions
- **2000** The UN adopts the Millennium Development Goals, including environmental sustainability as a key objective

continued on p11

and a better life for all could be reconciled with planetary boundaries.

Its answer was “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*”[34]. This perspective went on to form the basis of the ‘triple bottom line’, a view that defines sustainability as a balance between social, economic and environmental factors.

Although groundbreaking at the time, the Brundtland report has since been criticised for its vagueness, its unwillingness to face limits to growth and its lack of a clear theoretical base[35]. Nevertheless, it continues to exert a significant impact on approaches to sustainability.

A recent modelling exercise from the University of Exeter[36] found that “*the UK has been significantly influenced by its interpretation and implementation of the Brundtland report, which has primarily focussed upon the economic and social development aspects. This has resulted in the present-day very weak to weak sustainability occurring for Brundtland-based factors.*”

The triple bottom line of the ***Brundtland Report*** was, in the words of corporate sustainability guru John Elkington who coined the term, designed to “*resonate with business brains.*[37]”

Elkington first used the phrase in his 1994 book ***Cannibals with Forks: The Triple Bottom Line of 21st Century Business***[38]. He saw it as a way to align corporate objectives with the broader goals of sustainable development, including issues like climate change, resource depletion and social equity.

However, Elkington – a skilled communicator who is also credited with coining the terms ‘environmental excellence’, ‘green growth’, ‘green consumer’ and ‘people, planet & profit’ – has come in for criticism for failing to acknowledge trade-offs and for relying heavily on voluntary corporate adoption, rather than mandated policy changes. Critics claim that this approach has helped enable a business-more-or-less-as-usual perspective to prevail.

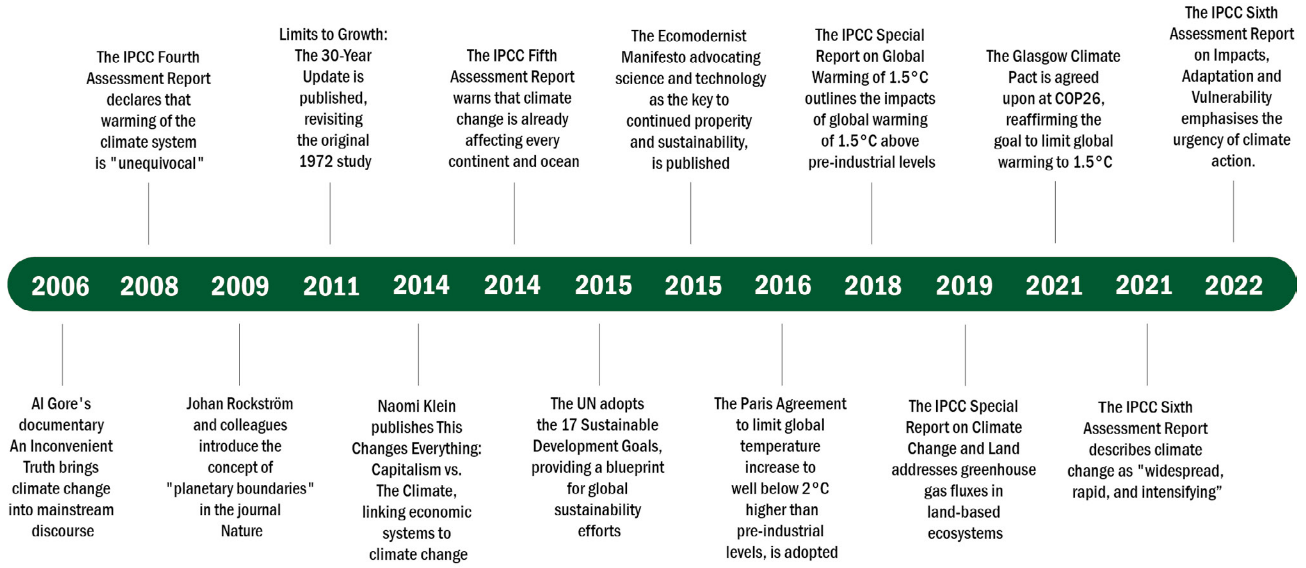
In between the milestones of ***Limits to Growth*** and the ***Brundtland Report*** have been a series of scientific reports and visionary books, international conferences and summits as well as global pacts, agreements and protocols (see timeline p10-11) suggesting that even as we continue to push the idea of having it all by pushing the triple bottom line, we are most decidedly, pushing in the wrong direction.

Even Elkington has suggested the need to recall and rethink a concept that he believes has been abused by business and so-called innovators, noting that “*the Triple Bottom Line has failed to bury the single bottom line paradigm*”[39].

Ecomodernism

The concept of Ecomodernism, first gained prominence in 2015 with the publication of the ***Ecomodernist Manifesto***, written by a group that described itself as “*scholars, scientists, campaigners, and citizens*”[40].

Timeline of sustainability thinking continued



The Manifesto, which is not a million miles away from the technofuture proposed by Stewart Brand in his 2009 book, ***Whole Earth Discipline – An Ecopragmatist Manifesto***[41], proposes deploying innovative technological solutions to global challenges while, at the same time, maintaining or increasing affluence. It emphasises ending material poverty and promoting modernism for improved well-being and resource productivity.

Ecomodernism advocates reducing human impact on the environment by concentrating activities on minimal land, prioritising nuclear energy over renewables, promoting urbanisation and intensifying agriculture, *e.g.* through biotechnology.

It rejects the idea of fixed physical boundaries to human consumption and proposes that by shrinking human impacts on the environment, we can make more room for nature. It also rejects the notion that human societies must harmonise with nature to avoid collapse.

Most recently the ecomodernist movement has morphed into WePlanet "*a professionally organised network of activists in multiple countries, dedicated to overtaking mainstream green thinking not just in impact but in ambition*"[42]. Amongst its more well-known supporters is the journalist and author George Monbiot[43].

Despite its ambitious goals, critics remain unconvinced. Author and small farmer Chris Smaje has entered into multiple public debates with Monbiot over competing visions of the future of agriculture. Smaje, author of ***Saying NO to a Farm-Free Future***[44], bluntly calls the ecomodernist movement "*an anti-agrarian, anti-rural, pro-urban, high-energy, techno-fix*"[45].

In their explainer ***What is Ecomodernism?***, Breewood and Garnett note how deeply entrenched disagreements about what ecomodernism is, and what it stands for, can become[46]. As a result, far from providing the answers to sustainability, it merely raises more questions, especially around land use and food production:

> "*Significant questions remain as to how ecomodernist approaches would play out in practice over the long-term. For example, what happens when ecomodernism encounters local preferences that go against its default assumption of land-sparing, for example in areas where extensive farming has significant social, economic, cultural, spiritual, or emotional benefits for people? And what role would belief systems other than 'Western' science, for example Indigenous frameworks for ecological management, play in shaping an ecomodernist food system?*"

While Ecomodernism has generated ample discussion and controversy, its real-world impact on sustainability remains to be seen.

Selling sustainability

Today, sustainability is more of an industry than a meaningful concept. It focuses on 'ecosystem services' and 'resource efficiency' and is very much aligned with whatever works for capital, business and the creation of new markets. It sits comfortably within current and emerging industrial and economic systems and across many sectors including agriculture.

Today, sustainability is more of an industry than a meaningful concept. It focuses on 'ecosystem services' and 'resource efficiency' and is very much aligned with whatever works for capital, business and the creation of new markets

Crucially, the corporate concept of sustainability is, sold[47] to the public and to policymakers and politicians using emotionally manipulative commercial marketing techniques – which, in this context, have earned the name "greenwashing" – and, increasingly, through the marketing of actual products including Walkers potato crisps[48], Patagonia clothing[49], IKEA homewares[50], Nissan cars[51] and Apple mobile phones[52].

In 2008 the WWF report, ***Weathercocks and Signposts: The Environmental Movement at a Crossroads*** [53], critically assessed market-based approaches to motivating environmentally-friendly behaviour change, concluding these were inadequate for solving these critical challenges.

While such approaches are favoured by political and business leaders as well as some NGOs, the report highlighted the limited success of behavioural change incentives, the fragmented and short-term focus of 'marketing-think' and its continual reinforcement of consumer culture.

It also highlighted the unwillingness to address underlying values and worldviews, which encourage

Sustainability – finite state or incremental process?

Rockström's work on planetary boundaries suggests that there are finite thresholds that, if crossed, could lead to irreversible and abrupt environmental changes. In this context, sustainability can be viewed as a finite state – a definitive, achievable end goal that requires all our efforts – *e.g.* closed loop manufacturing, local community energy generation from renewable sources – to be directed at maintaining human activities within these defined limits.

But sustainability is more commonly projected in a much less defined or determined way; a more fluid and, arguably, more slippery process of incremental improvement.

This perspective recognises that 'end state' sustainability is often difficult or impossible to achieve, but we can continually work – *e.g.* through gradually reducing a company's carbon footprint year over year or implementing increasingly efficient water conservation measures in agriculture – towards becoming more sustainable.

The reality is that sustainability often involves both end state goals and incremental aspects. There can be finite goals within an incremental process where organisations might set specific, achievable sustainability targets (end-states) as part of a longer-term, ongoing sustainability strategy (incremental process).

In some instances, a system might achieve sustainability in one aspect (*e.g.* energy use) while still working incrementally towards sustainability in others (*e.g.* waste reduction) – a recognition of multiple levels of sustainability progressing at different rates.

Even after achieving a seemingly finite end-state, there may be room for further improvements or adaptation to changing conditions, suggesting an incremental process of continual improvement.

Thus, this dual perspective allows for both targeted action and long-term, flexible thinking in addressing sustainability challenges. But there is a caution.

Incremental sustainability efforts, which can seem like painless transitions, may end up becoming unhelpful lock-ins (see also page 26). Natural gas, for example, is sometimes called a "bridge fuel" – a temporary solution that can help society transition away from fossil fuels and toward renewable energy sources. But the methane leakage associated with its extraction and transportation means its climate impact is similar to that of coal[54].

Bioenergy – burning trees and other biomass to create heat and electricity as part of an energy transition – undermines international climate and nature targets[55] and has led to a rise in 'clearcutting' where resilient natural forests are cut down and replaced with man-made tree plantations that do not replicate the ecosystem services of a healthy forest[56].

In the UK, after the use of some neonicotinoid insecticides was banned, the government has for the last four years created 'emergency' use exemptions for these chemicals for sugar beet growers, which have been shown to harm bees and other pollinators[57].

Globally, continual reliance on pesticides to protect crops and to maintain and increase yields, has created a disincentive to transition to integrated pest management and agroecological approaches[58].

Presenting actions that are – at best – steps on a pathway as sustainable ends is dishonest and misleading and potentially damaging.

The risks and benefits of incremental systems and processes, therefore, need to be carefully considered before deployment in the environment.

Where incremental actions are green-lighted, policy actions must be transparent about their transitional or incremental nature. There must be a clear requirement for honest reporting of the what, why and where we are at all times. In this way we can ensure that transitional sustainability measures don't become lock-ins.

tinkering at the edges rather than advocating for societal and structural change and a lack of critical reflection and dialogue.

It also suggested no substantial progress on climate-change goals could be secured without confronting the prevailing “extrinsic” values (acquisition of material goods, financial success, physical attractiveness, image and social recognition) by which society operates and replacing them with “intrinsic” values (personal growth, emotional intimacy, community involvement).

This, it said, implies no less than a wholesale reframing and redirecting of human development and a recognition that “*consumerism and sustainability are ultimately inimical*.”

The report called for a deeper, values-driven approach that engages with the root causes of unsustainable behaviour – something that would require the environment movement to shift from being ‘weathercocks’, which change direction with the prevailing winds, to ‘signposts’ that provide clear and consistent guidance toward sustainability. This process, it said, would require fostering open dialogue, building genuine alliances and developing strategies that are grounded in a deep understanding of social and ecological systems.

Who decides what’s ‘sustainable’?

Governments often claim to follow “science-based policy,” but this can be misleading. In reality, many policies are based on limited or skewed scientific views, or so called ‘normative science’[59]. This discrepancy between rhetoric and practice is a significant concern in sustainability governance.

Policymakers may selectively use scientific studies that align with their preexisting views or desired outcomes, ignoring contradictory evidence. They might also rely on a limited set of studies or disciplines, missing the broader scientific context. There’s frequently a failure to distinguish between factual scientific findings and ideological interpretations of how things ‘ought to be’.

When this happens the lines between objective facts and subjective values can become blurred, leading to policies that may not fully consider trade-offs or unintended consequences. It can also reinforce power imbalances, making it more difficult to challenge entrenched norms, mindsets, or lock-ins around economic growth and sustainability.

Examples of this phenomenon are widespread, from climate change policies prioritising certain economic interests to environmental regulations that misrepresent industry funded studies as independent science.

The ubiquity of triple bottom line thinking means that sustainability issues often involve competing interests and values, making them particularly susceptible to this kind of misuse of science.

Sustainability challenges, such as climate change, biodiversity loss and resource depletion are complex, interconnected and often global in scale. Policies implemented today can have cascading effects on ecosystems, economies and societies for generations to come[60]. Following a ‘science based policy’ influenced by narrow vested interests can result in missed opportunities for meaningful action, wasted resources and further damage to our planet’s life-support systems.

All of these challenges are well understood and have been deeply explored by advocates of what has been termed post-normal science (PNS), developed in the 1990s by philosophers of science Silvio Funtowicz and Jerome R. Ravetz[61].

PNS is a framework for decision-making in situations where there is high scientific uncertainty, high stakes and conflicting values and interests. It acknowledges that scientific knowledge is always provisional and subject to revision and that decision-making in such contexts requires the integration of diverse forms of knowledge and the involvement of diverse stakeholders in the process.

It’s crucial to maintain a critical perspective on claims of so-called ‘science-based policy’ and scrutinise the evidence and values that are actually informing policy decisions. This requires critical evaluation of policy claims, transparency in policymaking, robust peer review, clear communication of scientific uncertainty and diverse, interdisciplinary scientific input.

It also requires honesty on the part of researchers, universities and research institutions, when they are acting as advocates, not to present themselves as impartial observers or recorders of objective scientific ‘truths’ or ‘facts’.

2 | A sustainable agro-eco system

All of nature has been shaped by human activity to some extent, but agricultural ecosystems are distinct from those in wider nature because they are wholly created and managed by humans.

Through agricultural management we select which species to cultivate, alter soil composition, manage water resources and deliberately reduce biodiversity in order to focus on specific crops or livestock. In doing so we have often overlooked the intricate relationship between those landscapes that we cultivate and the wider natural world.

With the advent of the Green Revolution in the 1950s, and especially in recent decades, our efforts to feed a growing global population have turned this oversight into systemic neglect. Understanding this relationship is crucial for creating truly sustainable agricultural systems.

> **Far from being separate entities, agricultural landscapes and wider nature are deeply interconnected, forming complex ecosystems that sustain all living organisms on Earth**

The products of agricultural ecosystems are essential to our continued existence but they also have a high value in the marketplace. This has meant that, over the decades, agricultural practice has become more highly industrialised and its outputs much simpler to quantify in market terms. But the industrialisation of agriculture has a deep and lasting effect on wider nature.

The Wye Valley in the UK offers a stark example. Once celebrated for its pristine waters and diverse ecosystems, the River Wye and its surrounding landscape have faced mounting environmental pressures from agricultural intensification.

In recent years, the expansion of intensive poultry farming in the Wye catchment area has led to a surge in phosphate pollution. Chicken manure, rich in phosphates, is spread on fields as fertiliser. However, excess phosphates wash into the river during rainfall, causing algal blooms that deplete oxygen levels and harm aquatic life.

Similar stories play out across the globe, from the Doñana National Park in Spain where adjacent intensive strawberry farming threatens the park's unique wetland ecosystems and endangered species like the Iberian lynx, to the Baltic Sea where fertiliser runoff from intensive agriculture in surrounding countries, particularly in Denmark, Sweden and Poland, has caused eutrophication creating 'dead zones' that can no longer support marine life.

Further afield, nutrient runoff into the Mississippi River basin has created an even larger dead zone in the Gulf of Mexico, while in Australia over-allocation of water resources for irrigation has led to reduced river flows, increased salinity and degradation of wetland ecosystems in the Murray Darling Basin. Large scale deforestation in the Amazon rainforest and conversion of Brazil's wetlands and grasslands to agricultural land, threatens not only local ecosystems but also global climate patterns.

These are dramatic and visually obvious examples. Less obvious, but potentially more pernicious – and catastrophic – is the loss of a whole range of living organisms as a direct and indirect result of intensive farming practices, including crucial pollinators and micro-organisms from within and around the farmed environment.

Far from being separate entities, agricultural landscapes and wider nature are deeply interconnected, forming complex ecosystems that sustain all living organisms on Earth. To truly protect agricultural ecosystems, and lessen their global impact, our approach to agricultural sustainability must acknowledge and work within the same limits and boundaries as sustainability in the wider sense.

Signposts everywhere

If the Green Revolution, Brundtland and the SDGs have taken us away from a more holistic philosophy of sustainability, many other steps along the way have acted as signposts to guide us back. Many of these, mentioned in the previous chapter, had particular relevance for agricultural sustainability.

The Limits to Growth, ***A Blueprint for Survival*** and ***Small is Beautiful*** all, in their own ways, called for a radical transformation of society towards smaller, more decentralised models, including in agriculture. ***Rockström's planetary boundaries*** showed how exceeding the carrying capacity of the planet could trigger abrupt environmental change and sustainable agriculture was seen as crucial for staying within these boundaries.

The founding of the international organic movement in the mid-20th century promoted practices which focussed on soil health, biodiversity and reducing the use of synthetic inputs. These organic farming practices were explicitly linked the health of soil, plants, animals and humans to planetary health.

Agroecology sought the integration of local and indigenous knowledge, sustainable farming practices and ecological principles within agricultural systems, with the goal of creating more sustainable and resilient food production. La Via Campesina further evolved agroecological principles to food sovereignty, which includes the right of local communities to define their own agricultural and food policies, as an alternative to the industrialised global food system.

The ***Millennium Ecosystem Assessment*** analysed the consequences of ecosystem change for human well-being, from 2001 to 2005 [62]. The work of 1,360 experts worldwide, it highlighted the threats posed by unsustainable human activities, including industrial agriculture, to the world's ecosystems and the services they provide. It noted "*human actions are depleting Earth's natural capital, putting such strain on the environment that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted*".

The 2009 IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development) report, ***Agriculture at a Crossroads***[63], noted "*While industrial production systems yield large volumes of agricultural commodities with relatively small amounts of labor, they are often costly in terms of human health, have additional negative environmental impacts, and are frequently inefficient in terms of energy use*."

It called for a fundamental shift toward more sustainable, equitable and resilient agricultural practices to address the urgent challenges of food security, climate change and environmental degradation.

Connecting all of these works are concepts of whole systems thinking, awareness of the finite nature of the Earth's resources, the need to create sustainable human-environment interactions and to decentralise, localise and scale down. They respect food sovereignty and social and economic justice. They draw on a range of disciplines including ecology, economics, sociology and political science, to create frameworks for sustainability solutions.

Connecting all of these works are concepts of whole systems thinking, awareness for the finite nature of the Earth's resources, the need to create sustainable human-environment interactions and to decentralise, localise and scale down

Nevertheless, many of these concepts and frameworks – despite their robust theoretical, scientific and moral foundations – have faced significant resistance and rejection from mainstream global governance and policy and from power elites and investors.

The largest stumbling block, however, is the prevailing neoliberal industrial economic system and emerging technocapitalism which continue to prioritise growth and productivity and have contributed to the corruption of many concepts commonly seen as integral to sustainability.

A pivotal example of this is the long-standing notion of 'working with nature', which implies at least some understanding of humanity's place both as protectors of the natural world and also as part of it. However, in its increasingly prevalent and warped form it often means something very different now.

Today, working with nature is just as likely to mean exploiting natural resources for profit, externalisation of true environmental costs, short-termism and, where it is more convenient for business, undervaluing of key ecological functions such as pollination or privatising commons such as water resources, potentially limiting access and conservation efforts.

Ideas such as 'nature-based solutions' and 'ecosystem services' (see more in chapter 3), for example, reduce nature to quantifiable 'services', and the intrinsic value and complexity of ecosystems may be overlooked or diminished. The monetisation of ecosystem services can also create perverse incentives, where land managers or policymakers prioritise the provision of the most commercially valuable services over the holistic health and resilience of the ecosystem.

These concepts pay lip service to "working with nature" but they are based on nature as an entity separate from, subject to and at times, a hindrance to, human aspirations. They are all tradable with negotiable market and policy values – nothing is inviolable or priceless – and can be easily abandoned if they fail to take hold, or prove too complicated or expensive.

It doesn't have to be this way.

Sustaining life

One thing that unites generations of environmental thinkers is the need for human activities to be organised in a way that, in the broadest sense, sustains life.

We believe that the primary emphasis of all sustainability policies, practices and assessments should be on sustaining the Earth's 'life support systems' and explicitly acknowledging the intrinsic values and interconnectedness of those systems. This implies a long-term perspective, considering not just the present but ensuring the continuity of life for future generations.

This life-centric perspective on sustainability offers a profound and crucial counterpoint to business-more-or-less-as-usual environmentalism. It suggests that to truly understand sustainability, we need to be clear about our goals, about what we are aiming to sustain and to what end.

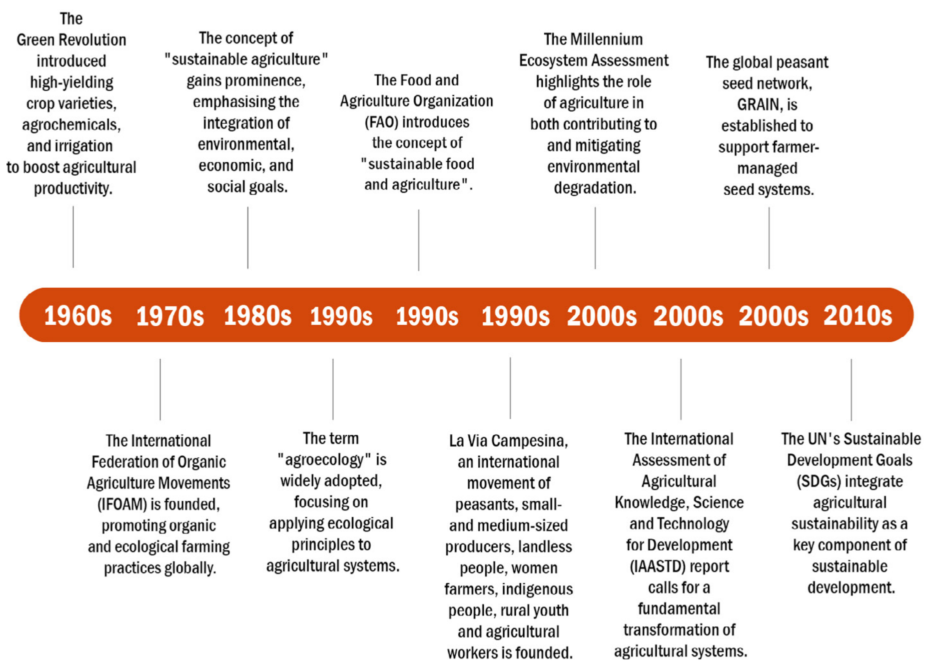
The idea of organising human activities to sustain life's interconnected support systems also suggests a need for fundamental changes in how we structure our societies, economies and relationship with nature.

Invoking the concept of 'intrinsic worth' brings an ethical dimension to environmental thought. It's not just about practicality, but about our moral obligations to others and other forms of life.

This view challenges many current approaches to sustainability that focus primarily on maintaining human economic systems with minimal environmental impact. Instead, it calls for:

A focus on living organisms centred on the integrity, well-being and survival of living organisms, including humans, animals, plants and microorganisms. This can lead to actions to protect

Agricultural sustainability timeline



and enhance the conditions necessary for life, such as clean air, water, food security and health.

Giving worth to living beings A life-centric approach incorporates ethical considerations regarding the value and rights of living beings, promoting actions that avoid harm and ensure the dignity and welfare of all forms of life. Examples of measures which might arise from this include stricter conservation areas and a focus on climate justice.

Healthy ecosystems By highlighting the inter-connectedness of all living organisms, the concept of life can reinforce the importance of biodiversity and healthy ecosystems. This approach can lead to policies and practices that support the resilience and adaptability of biological systems and the physical processes on which they depend.

A long-term perspective recognising that the health of the planet's natural systems is essential for future generations. It promotes the stewardship of natural resources, the conservation of landscapes and the mitigation of environmental degradation to ensure the planet's ongoing ability to support life.

A life-centric approach doesn't necessarily mean abandoning the notion of 'working with nature', which still has resonance for so many. But it does mean being aware of how it has become corrupted.

For instance, nature-centric approaches not tied to business-as-usual can be useful in encouraging comprehensive strategies that consider the entire ecosystem, including abiotic factors. They may provide a more balanced and integrated approach to sustainability, even though they could sometimes be less focused on the immediate needs of individual organisms.

Following on from these whole system considerations that support life, there is also a need to look at the way agricultural problems and solutions are framed.

Normative thinking, based on the predominant values of the status quo (see p14), particularly where sustainable solutions are concerned, narrows the questions we ask and the contexts we consider to the point where the answers are basically predetermined. As the old saying goes: "*when all you have is a hammer, everything looks like a nail*".

Whole systems thinking

Looking at the whole ecosystem, rather than separate parts, is crucial to sustainability because each part impacts others. Focusing on one aspect without considering others can lead to unforeseen negative effects.

Food system or ecosystem?

We all use phrases like 'the food system' or 'the farming and food system'. But what do these mean? In the context of this analysis, it means the interconnected food and farming 'ecosystem' which encompasses all actors involved in the production, aggregation, processing, distribution, transportation, consumption and disposal of food.

But to corporations, traders, researchers, politicians, writers, commentators and corporations, the notion of a food system is more mechanical in nature. Often this means a series of separate and discrete parts that can be managed or controlled or that can be tweaked, fixed or substituted like the spark plugs in a car.

The closest most corporations get to a whole system implementation is vertical integration, where they own, and therefore control, separate but connected parts of a supply chain.

This is common in livestock operations as well as within the GM crop set-up which ties farmers into a 'system' where they must buy seeds and compatible agrochemicals and other inputs from a single corporation.

The concentration of power and domination of resources in these areas is well documented. Just four firms control 62% of the agrochemical market, three companies control 100% of commercial poultry genetics and two companies control 40% of the commercial seeds market[64].

This kind of highly centralised system works for the benefit of large corporations but is the opposite of what we typically consider a healthy economic system.

Much like corporate approaches to sustainability, it reduces diversity, competition and the complex interactions that often drive innovation and efficiency in more open systems.

For example, farming practices affect soil health, water quality and biodiversity, which in turn influence food production capacity and nutritional value. Thus, simply focussing on productivity and increasing crop yields through intensive farming might seem beneficial in the short term, but could lead to soil degradation, unbalanced nutritional values and water pollution later down the line.

A whole system approach allows for identifying synergies and optimising resource use across the entire chain, reducing waste and improving overall sustainability.

It provides a framework for addressing social and economic aspects of sustainability, ensuring fair labour practices, access to nutritious food for all and the development of more robust and adaptable food networks that can withstand environmental, economic and social disruption.

Any shared concept of sustainability requires some level of agreement from all parts of the food system. This is challenging in a system where inequity and extreme concentrations of corporate power have become accepted as ‘normal’.

When it comes to the food and farming system, the impacts of different agricultural practices also vary based on geography, scale and frequency. What works in one area may not work in another and what works at one scale may not work at another.

This makes it impossible to prescribe a single set of sustainable agricultural practices that can be applied worldwide in a way which respects local ecosystems, cultures and equity.

The global food system is both responsible for and in a unique position to restore catastrophic biodiversity loss. By adopting a wholistic view and re-envisioning it as an ecosystem, we can begin to develop more effective strategies for long-term sustainability that balance all these factors. Where the system falls short is discussed in Chapter 3 and how it could be improved in Chapter 4.

3 | New narratives, old mistakes

The urgency and scale of current environmental challenges have pushed 'sustainability' into mainstream discourse. But the dominant narratives of sustainability and how we pursue them are still focussed on growth which does not recognise planetary limits. It might be called "green growth" but it is still a far cry from what is needed to sustain life or work with nature.

For instance, the UK's new Sustainability Disclosure Requirements (SDR)[65] and the EU's new Corporate Sustainability Reporting Directive (CSRD)[66], require companies and financial institutions to disclose their environmental and social impacts.

The EU has recently introduced the EU Taxonomy Regulation[67], which classifies economic activities based on their environmental sustainability. This regulation is designed to direct investments towards activities that contribute to the EU's goal of achieving net-zero emissions by 2050.

Additionally, the EU Deforestation Law targets global deforestation by imposing strict due diligence rules on companies dealing with commodities linked to deforestation. Plans for a UK Green Taxonomy[68], begun by the previous government are expected to advance with the new Labour government[69], also with an eye on strengthening a green economy.

SI incentivises relative improvements rather than adhering to absolute ecological limits. The high-tech systems it promotes are often resource-intensive, requiring significant energy and water inputs

All of these measures are business- or economy-focussed and are not the radical change demanded by a life-centric approach to sustainability. While there are touchpoints between the two concepts, a green economy is not the same as ecosystem sustainability.

Ecosystem sustainability is focused on the health and longevity of natural systems themselves. It is a life-centric approach that seeks to maintain the balance and functionality of natural environments, often irrespective of economic considerations.

The green economy, on the other hand, is primarily concerned with how human economic activities can be made more sustainable. It is a human-centred approach that focuses on narrowly defined reductions in environmental impacts while still pursuing economic growth. Examples of how this approach plays out in approaches to agriculture abound.

Sustainable intensification

In agriculture today the dominant narrative in political and industrial circles is that of sustainable intensification (SI).

As a concept, SI first arose in 1997[70] but gained significant traction following the 2007/8 food price crisis. It received particular attention in the UK with the publication of two influential reports: the Royal Society's 2009 ***Reaping the Benefits***[71] and the UK government's 2010 ***Foresight Report on the Future of Food and Farming***[72]. Both promoted SI as a method to increase productivity and sustainability simultaneously.

SI has since been endorsed by numerous international organisations, including the United Nations[73], the Consultative Group on International Agricultural Research[74], the Bill and Melinda Gates Foundation[75], the World Bank[76] and the World Economic Forum[77].

The Agricultural Biotechnology Council the umbrella group for the agricultural biotechnology industry in the UK, comprised of four member companies, Bayer, BASF, Corteva and Syngenta, has used the concept as a platform to promote a very specific agenda, stating "*agricultural technologies, such as GM, are among the tools which can help to deliver sustainable intensification*"[78].

Also in the UK, SI has received government funding and remains integral to agricultural policy and research. Defra and the Welsh Government funded a 3.5-year research project on SI, which ran to 2017[79]. Amongst its outputs were a set of tools to "*help individuals and groups identify SI opportunities which exist*".

As recently as 2022, ministers have confirmed that Defra "*directly funds innovative research on sustainable intensification*"[80] and its vision for the future of agriculture is rooted firmly in innovation and productivity.

The concept is also central to the business models of dominant agribusinesses. For example, Bayer states on its website[81]: "*We believe technology and innovation are key, like new biological or chemical crop protection solutions or robust varieties that help farmers grow enough. Sustainable agricultural intensification on existing arable land can also help protect biodiversity*."

SI is based on three fundamental assumptions:

1. The world needs to produce substantially more food in the coming decades to feed a growing and increasingly affluent population.
2. The area on which food is grown cannot be expanded significantly.
3. Agricultural production must become more resource-use efficient to preserve the natural capital on which agriculture relies[82].

Given these assumptions, SI proponents conclude that more food must be grown per hectare, primarily through enhancing the effectiveness of external inputs and optimising practices and technologies within crop production systems[83].

Land sparing

A key concept within SI is land sparing, which proposes concentrating agricultural activities on as little land as possible to allow more land for nature and biodiversity. This approach has gained dominance in scientific literature and policy circles and through ecomodernist thinking (see p11), though critics argue this may be due to its compatibility with existing paradigms rather than unequivocal proof of its effectiveness.

Although the term has been around in development literature since the 1990s, it was popularised by a group of British conservation biologists led by Andrew Balmford from the mid-2000s. Their seminal 2005 paper[84] compared the impacts of land sharing (or wildlife-friendly farming) and land sparing and concluded that the latter could be better for biodiversity.

Together with his colleague Rhys Green, Balmford has continued to research land sparing. His most recent decade-long research project concluded that "*while all species are 'losers' if mid-century food targets are met – more species 'fare least badly' under extreme land sparing: concentrated farming that allows for more natural habitat*"[85].

Compared with the ideas of land sharing, the land sparing narrative has achieved dominance in the scientific literature and been taken up in international policy, business and civil society circles. This is, say Loconto *et al*[86]:

> "*Not because the scientists have unequivocally proven that high-input industrial monocultures are more sustainable for biodiversity conservation, but because their models require inputs and provide outputs that are translated into simple metrics that are easily integrated into tools of the dominant paradigm*."

The land sparing-land sharing dichotomy is a good example of how choosing sides can become counterproductive. As Fraanje[87] writes:

> "*Higher crop yields and more cost-efficient production in a land sparing scenario may not actually deliver the intended sparing effect when land controls are absent or inadequate. Where higher yields lead to higher profits, farmers may simply be incentivised to further expand their farmed area*" and that "*both critics and proponents of land sparing agree that adequate governance and enforcement is necessary to ensure that land, particularly areas that are critical to biodiversity conservation, is being spared for nature*."

A high-tech vision

A key tenet of sustainable intensification is gains in efficiency through increasing outputs while reducing inputs – mainly achieved through technologies like:

- **Precision agriculture** Using technology for more precise application of inputs.
- **Robotics** For lower-cost, faster weeding, picking and packing of crops.

- **Mass data collection** To create accurate, worldwide soil and fertility maps.

- **Genetic technologies** To create high-yielding crops resilient to climate impacts and pests.

A prominent recent example of this high-tech vision is George Monbiot's concept of a "farmfree" food system based on microbial precision fermentation, as outlined in his 2022 book ***Regenesis: Feeding the World Without Devouring the Planet***[88].

This approach proposes that genetically engineered microbes are reproduced in vast bioreactors into protein-rich "*primordial soup*", which can then be turned into food[89]. The bacteria require hydrogen, so the main requirement for this technology is electricity to split water into hydrogen and oxygen through electrolysis. A constant supply of electricity is also necessary to run the bioreactors. Monbiot and his followers believe there is potential for precision fermentation to meet global food needs with less land, fewer emissions and less energy than the current system, though this is unproven and hotly debated.

The Good Food Institute (GFI) estimates that 10 million tons of alternative protein production annually (equal to 2.5% of expected global meat consumption by 2030) would require capital expenditures of between $10 and $18 billion (£7.6 to £13.7bn) for plant-based meat alone. But since 2022 capital funding of alt-proteins has fallen significantly due to the tightening of US monetary policy and slowing plant-based meat sales[90].

The problems of scale and investment have not blunted enthusiasm of media, commentators and governments. But the reality of the creation of new businesses and new markets is less sanguine. By the end of 2023 the GFI reported that globally there were 158 companies focussed exclusively or predominately on alternative proteins.

While the all-time investment in alt-proteins stands at a lowly $4.1bn (most of this in the preceding three years), just $515m – a 32% drop from the previous year – was invested in 2023[91].

Nonetheless, in February 2024, the UK government announced it was investing £12 million into the Microbial Food Hub, a research unit for fermentation-based foods at Imperial College, London[92].

Criticisms of sustainable intensification

With the word 'sustainable' in its name and endorsement by so many influential organisations, SI seems encouraging. Indeed, it does represent a major shift from the purely productivist narrative which dominated after the Second World War[94] and can be credited for helping bring environmental considerations into play in policymaking.

Even so, it remains firmly rooted in a productivist worldview. It does not challenge existing business or market structures, nor does it focus on reducing waste or shifting diets. Critics also argue that it fails to address planetary boundaries and lacks transparency about inevitable trade-offs. Key criticisms include:

No roadmap for operating within planetary boundaries

SI incentivises relative improvements rather than adhering to absolute ecological limits. The high-tech systems it promotes are often resource-intensive,

Productivism

Productivism is an economic and social philosophy that emphasises the importance of increasing the production of goods and services as a fundamental goal of economic and social policy. It views continuous economic growth as desirable and necessary for improving global living standards.

The roots of productivism can be traced back to the Industrial Revolution in the 18th and 19th centuries, when there was a significant shift from agrarian economies to industrialised production. The early 20th century saw the rise of Fordism, named after Henry Ford who revolutionised manufacturing with the assembly line and emphasised high production as a goal. After World War II, Western governments focussed on increasing productivity to rebuild economies.

Productivism, which values technological innovation and improvements in efficiency as a means to enhance productivity continues to be a significant force in modern economic thinking and policy-making. This is particularly true in agriculture, even as Green Revolution thinking and its detrimental impacts on environmental sustainability and human diets – and an over-reliance on the *deus ex machina* of big data and innovation[93] – attract ever stronger criticism.

requiring significant energy and water inputs. For example, the energy requirements for precision fermentation systems and the digitalisation of agriculture[95] are substantial. Chris Smaje, author of ***Say NO to a Farm Free Future***[96], has calculated that George Monbiot's precision fermentation system will require at least 65 kWh of energy per kilogram of bacterial protein – or twice the daily use of an average US household[97].

Water requirements for data centres needed to process agricultural data could compete with agriculture in water-stressed regions. According to Venkatesh Uddameri, professor and director of the Water Resources Center at Texas Tech University, the typical data centre "*uses about 3-5 million gallons of water per day – the same amount of water as a city of 30,000-50,000 people*[98]." Tech solutions will also place a great deal of stress on mineral resources around the world for feeding fermentation as well as powering new systems.

Finally, the sustainability claims of SI are premised on the assumption that it will free up land for conservation and biodiversity. There are very few real-world examples of this happening. As systems intensify, profits increase which provides an incentive for further expansion. Under the current neoliberal capitalist model, land sparing could easily become land grabbing unless strong governance is brought into play[99].

A limited perspective of sustainability

SI often neglects social and democratic factors such as equitable food distribution, access to land, food waste, concentration of power and malnutrition.

Research into SI has begun to consider social factors much more in recent years, with calls for the "*creation of novel social infrastructure*" to aid knowledge exchange, co-creation and trust building[100]. But its sustainability claims are still, typically, based on a limited number of easy to quantify environmental metrics, or controversial proxies such as carbon emissions trading and sequestration[101].

Other research suggests that SI practices may actually reduce the number of smallholders by inhibiting sovereignty over land use, decreasing livelihood flexibility and constricting resource access[102].

Assessment of trade-offs is complex and requires good data, accurate methodologies and engagement with all stakeholders, including farmers and consumers

Lack of transparency around trade-offs

Any discussion about sustainability must also include an assessment of trade-offs, defined as "*compromises between desirable but incompatible features*"[103].

Much has been written on how to manage trade-offs in sustainability assessments. One of the most influential has been Robert B. Gibson's contribution for the 2004 International Association for Impact Assessment (IAIA) conference. His paper, ***Sustainability Assessment: Basic Components of a Practical Approach***[104], offers advice on the development of an assessment process for formal decision-making about trade-offs, based around three main rules:

- The decision processes must serve the fundamental objective of net sustainability gain.
- These processes must ensure that all significant compromises and trade-offs are explicitly identified and that the most desirable option among the alternatives is chosen; and
- They must also ensure that all significant trade-offs are identified and addressed and that the decisions made are justified explicitly and openly.

It acknowledges that "*trade-off decisions are essentially and unavoidably value-laden*" and that whose values play a role is a crucial question. This issue leads to an inevitable conclusion that high levels of stakeholder engagement and buy-in from everyone, including civil society, will be needed to address trade-off issues[105].

SI often sidesteps complex trade-offs "*among different dimensions of efficiency (e.g., economics or use of biophysical resources), and values such as the right to food, wealth and (animal) welfare, environmental quality, social equity, nature conservation, biodiversity, dietary quality, poverty alleviation and food safety*"[106].

Harm can be caused by any sustainability strategy that does not recognise and acknowledge the complexity and normative choices involved in these trade-offs.

A failure to 'feed the world'

Simply producing more food does not necessarily feed more people[108].

The 2020 Global Nutrition report, ***Inequalities in the Global Burden of Malnutrition Global Nutrition Report*** found that "*malnutrition persists at unacceptably high levels on a global scale*", meaning that all diet-related non-communicable disease targets are off course "*with projected probabilities of meeting any of the targets being close to zero*"[109].

An estimated 2 billion people, or 26% of the global population experience food insecurity[110], while 39% of the world's population is now overweight or obese[111]. The latest estimates from UNEP show that 17% of global food production is wasted[112]. Some argue that productivity growth itself could be causing problems by increasing demand, reducing prices and increasing availability[113] beyond human metabolic limits, resulting in ill health and food waste[114].

Recently, some proponents of SI have attempted a more systemic view. In a 2019 paper, Benton and Bailey proposed "*re-focusing, away from yields per unit input, to the food system's overall productivity and efficiency – the number of people that can be fed healthily and sustainably per unit input*"[115].

To address both short and long-term food security concerns, there must be a focus on equitable distribution, individual empowerment as well as intergenerational justice, none of which are addressed in SI/productivist narratives[116].

Ultimately, sustainable intensification/land sparing rests on "*a neoliberal, technocratic assumption that investment in technological development will solve the issues*"[117]. By focussing too narrowly on production and failing to challenge economic systems or power structures, it enables current dominant political and corporate actors to continue operating without substantial change to their operations.

SI has gained dominance not because its approach is scientifically proven to work, but because its models, tools and language "*are easily integrated into tools of the dominant paradigm*"[118]. Although it does represent a shift from the purely productivist mindset, by focussing mainly on the environmental aspect of sustainability and largely ignoring social or democratic elements, it does not represent a truly sustainable option for food system reform.

Its popularity amongst policy-makers and corporations aside, as Garnett and Godfrey conclude, sustainable intensification is "*not a movement or a grand socio-political vision. It is not a strategy for the food system as a whole but just for one component within that strategy*"[119].

For example, it is conceivable sustainable intensification could promote a precision agriculture driven, gene editing-enabled increase in commodity crop production with lower inputs than today, even though there is increasing evidence that these commodity crops are contributing to a whole host of health problems[107].

Assessment of trade-offs is complex and requires good data, accurate methodologies and engagement with all stakeholders, including farmers and consumers. There is little evidence that SI is doing this at any meaningful level and little acknowledgement or transparency about the trade-off decisions being made.

Beyond sustainable intensification

Perhaps inevitably, after an initial flurry of excitement and support around the sustainable intensification concept, the term has become less commonly used in recent years. Instead, other terms have emerged that, while moving away from explicit SI language, still maintain its productivist, innovation-focused mindset.

Net zero

Put simply, net zero refers to the balance between the amount of greenhouse gas (GHG) we produce and the amount that we remove from the atmosphere. To reach 'net zero emissions' and become 'carbon neutral' polluting companies can continue to emit GHGs but pay for carbon credits that 'offset' the carbon they emit. These credits fund projects to, for instance, plant trees and protect forests.

Net zero is rapidly becoming one of the pillars of agricultural policy in the UK and the rest of the world. At first glance, it sounds like a reasonable proposition. But the path to net zero is littered with smoke and mirrors accounting and exaggerated claims[120, 121].

The concept of net zero greenhouse gas emissions gained prominence through the 2015 Paris Agreement, where nearly 200 countries agreed to limit global warming to 1.5 °C. In 2018, the IPCC reported that achieving this goal would require reaching net zero CO_2 emissions by 2050[122].

In response, the UK became the first major economy to pass a net zero emissions law in 2019, mandating all GHG emissions to reach net zero by 2050[123]. Since then, net zero has become commonplace in government literature, often paired with economic growth goals. For instance, the 2023 ***Net Zero Growth Plan*** aims to meet net zero commitments while supporting economic growth[124].

However, as little visible progress has been made and the UK government has made several policy U-turns, scepticism has grown. A 2021 article by climate scientists concluded that "*Current net zero policies will not keep warming to within 1.5 °C because they were never intended to. They were and still are driven by a need to protect business-as-usual, not the climate*"[125].

Truly 'nature-based solutions' such as organic agriculture, have not received the credit or investment they deserve for a long-standing commitment to working with nature and natural ecosystems

The net zero discourse has reinforced the SI framework in agriculture. Both Defra and the National Farmers Union advocate[126] producing "*more food on less land by using improved yet 'sustainable' agricultural methods*" as the preferred solution for reaching net zero emissions in agriculture.

The Climate Change Commission supports this view, encapsulated in its 2020 ***Land Use Policies Report***[127], which stated:

> "*Sustainable productivity growth is a key driver in our land use scenario: it allows more to be grown with less land and other inputs – and frees up land for other uses*".

Nature-based solutions

The concept of nature-based solutions (NBS) was introduced towards the end of the 2000s by the World Bank[128] and the International Union for Conservation of Nature (IUCN)[129].

In the purest sense, NBS work with and within ecosystem processes to address a range of socio-environmental issues climate change mitigation and adaptation and disaster risk reduction as well as human security issues such as water management and food security[130].

The idea is that more resilient ecosystems (whether natural, managed or newly created) provide solutions and co-benefits for human society and nature.

NBS have become popular in policy discourse; 84% of the most recent Nationally Determined Contributions (NDCs) – which countries are required to submit as evidence of their progress and intentions to meet the Paris Agreement – commit to restoring or protecting ecosystems or implementing agricultural systems such as agroforestry[131].

However, nature-based solutions have also faced opposition.

NBS tree-planting schemes have been heavily criticised for not accounting for the complexities in establishing healthy forests, for being too monoculture focussed and, in some cases, for causing more harm than good, for example by reducing local water supplies[132].

In addition,several high-emitting industries are now proposing to use NBS to offset their greenhouse gas emissions, including airports[133], airlines[134] and oil and gas companies[135]. This enables companies to claim carbon neutrality without cutting emissions production, selling customers a story that they can continue their high-emissions activities while the world achieves net zero[136].

The social aspect of sustainability has also been ignored in most NBS narratives. There are many reports of offsetting schemes enabling 'green land grabbing'[137] and harming local communities. For example, a 34,000-hectare restoration project in Cambodia results in a native forest being replaced by monocultures, leading to the dispossession of local communities[138].

There is also concern that truly 'nature-based solutions' such as organic agriculture, have not received the credit or investment they deserve for a long-standing commitment to working with nature and natural ecosystems.

As a result, NBS have been accused of enabling corporate greenwashing. This has led to growing scepticism among civil society. On the eve of the 2019 COP25, more than 250 civil society organisations signed a statement completely rejecting the term 'nature-based solutions'[139].

Climate-smart agriculture

Promoted by the likes of World Bank and FAO and climate-smart agriculture (CSA) aims to increase productivity and resilience and reduce emissions with modern agricultural technology and advances, such as inorganic fertilisers, pesticides, feed supplements, high-yield varieties, land management and irrigation techniques[140].

Despite its claims of being adaptive and considerate of trade-offs, CSA has been criticised for promoting a technology-focussed approach which is inaccessible to small-scale farmers[141], as well as being shaped by the interests of 'Big-Ag'[142].

Once again, it is based on a productivist mindset which focuses on the two most easily measurable outcomes – yield and carbon emissions. This ignores all other aspects of sustainability, for example the participatory democratic process which accounts for indigenous rights.

By focusing primarily on technological solutions and efficiency gains within the existing system, SI fails to address the fundamental issues of equity, power concentration and ecological limits that underpin our current food system challenges. It allows for the continuation of business-as-usual under a veneer of sustainability, potentially delaying or preventing more transformative changes.

To create a truly sustainable food system, we need approaches that:

- Operate within clear ecological boundaries
- Address social and democratic aspects of sustainability
- Challenge existing power structures and economic models
- Promote diversity in both agricultural practices and decision-making processes
- Prioritise resilience and adaptability over narrow efficiency metrics

There is a lot that stands in the way of achieving this. Only by addressing these deeper, systemic issues can we hope to create a food system that is truly sustainable for 'people and planet'.

Industrial food system 'lock-ins'

The dominant narratives around sustainable food systems often amount to minor adjustments to the current unsustainable system, lacking the radical approach needed for true sustainability. Recent literature has highlighted the forces that keep us locked into the industrial food system, which are so entrenched they can prevent us from imagining genuine sustainability. Understanding these insidious forces is crucial for future attempts to build a sustainable food system. Key interrelated lock-ins include:

Concentration of power A small number of large agribusiness corporations dominate the food supply chain, from seed production to distribution[143]. This self-reinforcing cycle[144] allows these dominant actors to take centre stage in framing the problems (*e.g.* the need to produce more to feed the world) and providing the solutions (*e.g.* new technologies) and to press these narratives onto policymakers[145].

Technological lock-ins The industrial model arose through the progressive adoption of agricultural technologies[146]. For example, specialisation led to monocropping, which required agrochemicals, leading to herbicide-resistant crops and weeds.

As a result farmers are trapped on an 'herbicide treadmill'[147], the most advanced examples of this are the commodity cropping of maize, soya and cotton where new genetically engineered herbicide-resistant varieties are used to compensate for failures in the previous hybrid technology. These technologies become social practices due to the learned skills, knowledge and cognitive routines[148], making alternatives difficult to adopt[149].

Subsidies and policies Trade and commodity market-focused policies and support have been significant drivers of also driven agricultural specialisation and industrialisation[150]. Historical decisions become embedded policies and have created institutions resistant to change. For instance, despite large subsidies in recent years, practices and policies favouring cereals over grain-legumes[151] have led to lock-ins in European cropping systems.

Infrastructure and supply chains The existing infrastructure, including transportation, storage, and processing facilities, is designed to support the industrial food system. This infrastructure is optimised for long-distance transportation, uniformity, and extended shelf life. Using this infrastructure for alternative systems incurs higher costs[152], and significant changes in running protocols and practices.

Attitudes and cultures Human factors can also come into play here. For example, a study in Brazil revealed how field-burning practices are still employed in some parts of Brazil despite their negative environmental consequences, as they have become part of the family history and farmers do not want to diverge from them[153].

There is also evidence to show that poorer farmers are less willing to take risks on change, especially if they have previously experienced a technology failure[154]. This demonstrates that farmers need to be supported to adopt different systems.

Agricultural research priorities Agricultural research and knowledge systems tend to support the status quo. Research is dominated by thinking that prioritises wide applicability over localised approaches, staple crop breeding over minor species and technological innovation over social innovation[155].

Increasingly, research has developed around 'production-innovation' and 'growth' narratives, which presents technology-driven economic growth as the way to feed the world. This narrative has gradually become systemically embedded, shaping monitoring and evaluation frameworks, investment and funding allocations and research agendas[156].

These lock-ins are interconnected and self-reinforcing. For example, the concentration of power influences research priorities and policy decisions, which in turn reinforces existing technological and infrastructure lock-ins. Similarly, attitudes and cultures can be shaped by dominant narratives promoted by powerful actors and research institutions.

It's worth noting also that this list is not static. New lock-ins can be created as new systems come on stream. Transitional systems and technologies aimed at incremental changes often require new infrastructures, institutions or practices. These can become entrenched, making it difficult to let go – even when they are clearly past their 'sell by' date.

New lock-ins can be created as new systems come on stream. Transitional systems and technologies aimed at incremental changes towards sustainability often require new infrastructures, institutions or practices

Being cautious about investing heavily in or committing to specific transitional technologies that might create path dependencies and encouraging diversity in technological solutions may be one way to maintain flexibility and a wider range of options for future transitions. Comprehensive assessment frameworks, to help to identify problems early on, would consider the full lifecycle and system-wide impacts of transitional technologies and processes, and include:

- **Clear criteria** Establishing clear, evidence-based criteria for what constitutes sustainability in a specific context.
- **Temporal boundaries** Setting time frames for transitional phases and regular review points.
- **Scale** Assessing, early on, the scalability and system-wide impacts of transitional solutions.
- **Equity and justice** Ensuring that transitions don't exacerbate existing inequalities or create new ones.
- **Reversibility** Considering the reversibility or adaptability of transitional measures.

There is no one-size-fits all solution to dismantling lock-ins. It will require a multi-faceted approach that addresses power imbalances, promotes diverse and localised solutions, reforms policies and subsidies, invests in alternative infrastructure, supports farmers in transition and redirects research priorities towards wholistic sustainability.

A desire to break free from the constraints of the current system and imagine truly sustainable alternatives challenges us to think beyond incremental changes and consider transformative approaches that can overcome these deeply entrenched barriers to sustainability.

4 | What sustainability could be

We propose a life-centric approach to sustainability that places the well-being of all living beings – humans, animals, plants and ecosystems – at the heart of all efforts to create a sustainable future. Unlike approaches that focus primarily on economic growth or technological solutions, a life-centric approach emphasises the intrinsic value of life and the interconnectedness of all living systems.

It has profound implications for agriculture, fundamentally reshaping how food is produced, distributed and consumed. Taking this approach emphasises the well-being of all life forms – humans, animals, plants and ecosystems – is one and indivisible and ensures that agricultural practices are aligned with the planet's ecological capacities while promoting social justice and equitable resource distribution.

This approach is built on four key pillars– boundaries and limits, a duty of care, sufficiency and equity and democracy – which provide the basis for policy and practice. These pillars are applicable to all aspects of economic and social activity, but we primarily present them here in relation to agriculture.

Boundaries and limits

The notion of boundaries and limits are foundational to the concept of sustainability. In modern sustainability discourse the two notions are often used interchangeably but while there is, of course, a significant degree of overlap in meaning, there are also important differences between them.

A boundary can be indicative of a limit – as in an area of land or a city – but it can also reflect personal and/or communal choice, which, through inclusion and exclusion, defines the identity and scope of a place, a person or a philosophy.

A limit can be seen more as a restriction – a rigid line that cannot be crossed. Limits can be, and indeed are, set by multiple intrinsic and extrinsic factors such as the availability of natural resources and policy and regulation, but also lack of knowledge, lack of investment and/or opportunity.

Both concepts, however, may evolve over time and with changing circumstances.

A major component of true sustainability which is missing from the Brundtland definition and the SDGs is the acknowledgement of limits and of the need for clear, quantified boundaries. These need to be the bedrock of any concept of true sustainability, as the Earth has a whole host of self-regulating natural systems which keep life viable and if these become disrupted, so does life.

The idea of boundaries as an integral part of human life on earth has been around since at least 1972, with the ***Limits to Growth*** report. Absolute planetary boundaries – in actual fact limits – were made clear in Rockström's work. The 2009 ***IAASTD Report*** – and a 2021 update[157] – also outlined the pathways towards a sustainable food and agricultural system that recognises ecological limits and planetary boundaries and embraces radical change.

Agriculture, by its very nature, relies on the careful management of natural resources, from the soil beneath our feet to the water that nourishes our crops. These resources are not limitless; they exist within defined boundaries, shaped by complex ecological processes and the laws of physics.

At the heart of sustainable agriculture lies the recognition that we must operate within these constraints. Pushing past the boundaries of what our land, water and climate can sustainably support leads to a cascade of negative consequences – soil degradation, water scarcity and the disruption of delicate natural cycles.

Consider the issue of soil fertility. Healthy, fertile soil is the foundation of any productive agricultural system. However, the nutrients and organic matter and biological functions that give soil its vitality have limits. Farming practices that extract and disrupt more than they replenish can deplete functionality and resilience, rendering the land unsuitable for continued cultivation.

Similarly, the water cycle that sustains our crops and livestock is not infinite. Groundwater aquifers and surface water bodies have thresholds beyond which their replenishment cannot keep pace with our demands. Exceeding these limits has far-reaching implications for both agricultural productivity and the health of surrounding ecosystems.

Biodiversity, too, plays a critical role in the sustainability of agriculture. Natural ecosystems possess a complex web of interdependencies, with each species occupying a specific niche. Producing food within a safe operating space may provide benefits in terms of resilience and the system's ability to withstand and recover from – and even adapt to and even improve in the face of environmental stresses, such as droughts or pest outbreaks. But when we disrupt this delicate balance, we risk compromising the resilience of the entire system.

Beyond the environmental considerations, the boundaries and limits of sustainability also extend to the social and economic realms. For agriculture to be truly sustainable, it must be economically viable for farmers, provide reliable livelihoods for agricultural workers and ensure food security for the communities it serves. Exceeding these boundaries can lead to the collapse of entire farming communities and the disruption of local and regional food systems.

As we strive to meet the growing global demand for food, fibre and fuel, the imperative to recognise and operate within the constraints of natural and human systems. Pushing past these limits leads to environmental degradation, economic instability and the collapse of agricultural systems.

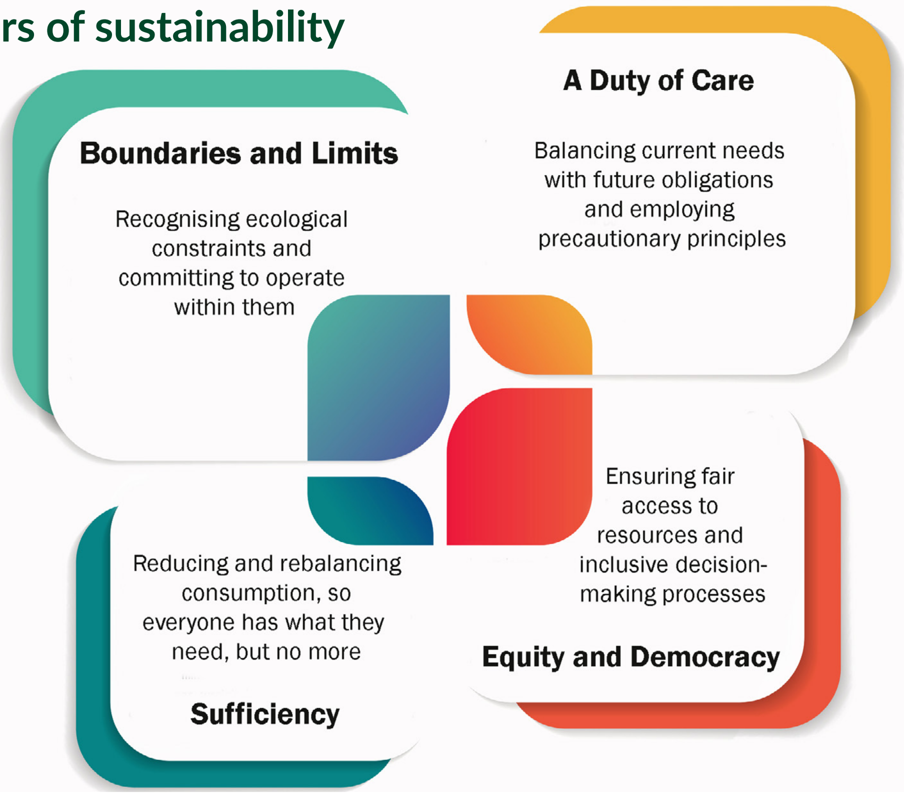
A duty of care

What do we owe to ourselves today and what do we owe to the future?

Balancing these obligations equitably is challenging because it involves a degree of foresight and weighing immediate, tangible needs against more abstract future concerns. Some argue that we have a stronger obligation to those currently suffering, while others contend that we have an overriding duty to ensure a liveable planet for future generations.

Ultimately, an equitable balance likely involves consideration of boundaries and limits and ideas of sufficiency (see below) as well as the idea of "option value" – preserving choices and possibilities for future generations rather than foreclosing them through irreversible changes to the environment or depletion of resources.

Our four pillars of sustainability



Attempts at finding this balance are an expression of care. The question of how much we should care is a topic of ongoing debate in ethics, economics and policy circles. There's no easy universal answer, but grappling with these questions is crucial for charting a sustainable path forward.

An important part of caring and foresight is precaution. The Precautionary Principle, which originated in Germany in the 1970s, in response to damage by acid rain in the beloved Black Forest.

The original German concept, 'Vorsorgeprinzip,' was developed to guide environmental planning. It translates best as 'the forecaring principle,' encompassing not merely precaution but foresight as a foundation for our relationships with the future.

Some approaches to agriculture already incorporate a duty of care. In organic agriculture, for example, the principle of care in conjunction with the principles of health, ecology and fairness are the philosophical bedrock, expressed through various practices such as:

- Using natural pest control methods instead of synthetic pesticides
- Implementing crop rotation to maintain soil health
- Choosing appropriate plant and animal species that are well-adapted to local conditions
- Providing animals with organic feed and access to outdoors
- Avoiding genetically modified organisms
- Minimising pollution and optimising the use of natural resources

In organic, the principle of care reflects a broader ethical stance that goes beyond mere technical standards. It embodies a commitment to act in a manner that protects the health and well-being of current and future generations and the environment.

Agriculture, by its very nature, relies on the careful management of natural resources, from the soil beneath our feet to the water that nourishes our crops. These resources are not limitless; they exist within defined boundaries, shaped by complex ecological processes and the laws of physics.

Opponents would argue that such principles can't be translated into real-world policy. But a duty to care and exercise precaution has also been adopted in many international treaties and conventions, such as the North Sea Declaration (1987)[158], the Ozone Layer Protocol (1987)[159], the Ministerial Declaration of the 2nd World Climate Conference (1990)[160], the Maastricht Treaty that created the European Union (1993)[161], the UN Fisheries Convention (1995)[162], the London Convention Protocol on Ocean Dumping (1996)[163] and the Cartagena Protocol on Biosafety (2000)[164].

The Precautionary Principle[165] is a foundational concept of European environmental law including regulations around environment, human, animal and plant health. It can be applied to a product, process or phenomenon and while it is not a risk analysis tool it can be invoked as part of a formal decision-making process. It acknowledges that we don't know everything and provides guidance for assessment in the face of scientific uncertainty, ambiguity or ignorance.

The European Commission's approach to the Precautionary Principle[165], which was laid down in 2000 and has not changed since, says that "*the precautionary principle is neither a politicisation of science or the acceptance of zero-risk but that it provides a basis for action when science is unable to give a clear answer*."

Criticisms that the precautionary principle is restrictive in the face of innovation, misrepresent the EU's stated approach to the Principle's application, which provides that: "*Measures should be periodically reviewed in the light of scientific progress, and amended as necessary*[166]."
As a signatory to the 1992 Rio Declaration the UK government is also bound to apply the Precautionary Principle. It was codified in the five environmental principles of the Environment Act 2021 and in the 2023 Environmental Principles policy statement of the Johnson government[167].

The latter document requires ministers to consider and integrate five key principles – integration, prevention, rectification at source, polluter pays and precaution – into policymaking. These are internationally recognised as practical benchmarks for environmental protection and enhancement.

Sufficiency

Sufficiency is a powerful yet neglected sustainability concept which recognises that planetary boundaries put limits on growth and consumption. It aims for a total reduction of resource consumption, with everyone having what they need but no more. It is based on the idea that prosperity and quality of life can be achieved through values other than consumption, such as social connections and cultural activities.

The Intergovernmental Panel on Climate Change (IPCC) has now recognised that sufficiency has a critical role to play in achieving the climate targets, with its 2022 report promoting the SER (Sufficiency, Efficiency, Renewables) Framework in relation to buildings[168]. This framework introduces a hierarchical layering, sufficiency first followed by efficiency and renewable.

A 2023 scoping report for the European Environment Agency (EEA) by EnergyVille/VITO and Germany's Oeko-Institut (The Institute for Applied Ecology) concluded, amongst its 8 key findings, that sufficiency is more than just behavioural change; it is in fact an enabler of that change and the key to reaching sustainability goals[169] .

The question of how much we should care is a topic of ongoing debate in ethics, economics and policy circles. There's no easy universal answer, but grappling with these questions is crucial for charting a sustainable path forward

Sufficiency has sometimes been described as the opposite of efficiency. The IPCC notes that "*sufficiency is about long-term actions driven by non-technological solutions, which consume less energy in absolute terms; efficiency, in contrast, is about continuous short-term marginal technological improvements*"[170] .

The difference in policy outcomes of adopting a sufficiency approach, as opposed to the dominant efficiency one, is significant. To take the private transport sector as an example, efficiency strategies are leading to technological innovations such as electric cars, which aim towards an increase in resource efficiency.

In contrast, sufficiency approaches in richer countries would contain an element of personal resource reduction, such as giving up the use of private cars. Sufficiency promotes shared utilisation of resources, such as car sharing schemes, as well as increased infrastructure for walking and cycling with the appropriate lifestyle changes to accommodate that. Implementation of sufficiency strategies would rely on infrastructure instruments and communication, as opposed to the economic/market-based instruments of efficiency approaches[171].

Sufficiency provides a framework for addressing issues of overconsumption and evasion of responsibility by companies and nations, particularly richer nations that import a lot of food and goods. It requires consideration of future generations. In the words of Thomas Princen[172], it compels decision-makers to:

> *"Ask when too much resource use or too little regeneration risks important values such as ecological integrity and social cohesion, when material gains now preclude material gains in the future, when consumer gratification or investor reward threatens economic security, when benefits internalised depend on costs externalised."*

Leaning further into sufficiency as a guiding principle for sustainable food systems could give rise to a diverse range of potential solutions, from business models focussing on circulatory and sufficiency[173], to a greater use of food from trees as a way to provide nutrient-rich foods and high biodiversity simultaneously[174].

Even though sufficiency is not yet politically mainstreamed, citizens do seem to be calling for more sufficiency policies. In the European Citizens' Panel on Climate Change, Environment and Health, about 50% of the total policy recommendations were related to sufficiency, mostly in the transport sector[175]. However, mainstream agriculture has yet to embed the concept, except in a distorted political form as 'self-sufficiency". Food sustainability narratives, under the SI umbrella, still focus on technologically-enabled efficiency.

Dietary changes in light of sufficiency

Diet and food consumption is a critical part of agriculture. Sufficiency is a useful lens through which to examine dietary change. Through it, we see that the challenge is not simply about producing more food, but about producing and distributing food in a more sustainable and equitable manner.

Studies have consistently shown that transitioning from high-meat, resource-intensive diets to predominantly plant-based ones has the greatest potential to reduce the environmental impact of agriculture[176, 177]. Moreover, modelling by the Food Farming and Countryside Commission and IDDRI suggests that with a substantial shift towards plant-based foods, it is possible to feed populations using organic (agroecological) farming methods that improve soil health and biodiversity, even in the face of climate change[178].

The EAT-Lancet Commission recommends doubling the consumption of healthy foods like fruits, vegetables and nuts, while reducing global consumption of less healthy items like red meat by over 50%[179] .

However, it has also been criticised for being top-down[180] and giving insufficient focus to the method of production[181], for being unaffordable for the world's poorest people[182] and for micronutrient shortfalls for adults and women of reproductive age[183]. In reality, a sustainable diet will vary from place to place, based on the capacity of the local ecosystem and cultural appropriateness.

Importantly, it is not necessary to eliminate meat for a sustainable diet. Ecologically sensitive grazing systems in appropriate landscapes can ensure complementary soil health and biodiversity while providing nutrient-dense food[184]. The focus of reducing meat production and consumption should be on shifting away from industrial meat production towards encouraging agroecological, landscape and culturally appropriate systems.

While there are signs of dietary change[185], the pace of transformation is slow. Widespread adoption will require a combination of individual behaviour change and policy interventions that facilitate and incentivise sustainable food choices.

Equity and democracy

Everyone has a right to safe, nutritious food that has been justly produced. A truly sustainable food system must deliver this while respecting planetary boundaries. This is difficult to imagine from where we are now – the food system is complex and intrinsically connected to a myriad of other social and environmental problems. Nobody has all the answers and there will be innumerable difficult decisions and weighing of trade-offs to be made as we design a sustainable system.

At the moment, there is a great deal of inequality in our national and global societies, with the gulf between rich and poor widening in most cases[186] – and set to worsen. The climate justice movement highlights the disproportionate effect on marginalised communities and developing countries, in terms of both the impacts of a changed climate and the required emissions reduction needed to curb it.

It is essential that sustainability measures mitigate this unfairness and seek to share the benefits and responsibilities of creating a food system fit for the future. Indeed, true sustainability is not possible without equity.

Far from being insubstantial or 'soft', in terms of policy thinking and implementation, these pillars cut across multiple areas of concern where deep change is needed

To ensure fairness, conversations about how to create a sustainable food system need to be broad and inclusive. Diversity is also of fundamental importance. We urgently need more diverse voices around the table and to embrace the multitude of different ways people value an ecosystem – for example sustaining livelihoods, providing health and spiritual benefits and the intrinsic rights of other living things to exist.

The focus on empowering local communities to take ownership of and act for sustainability is now widely accepted within sustainability discourse. This, too, falls under the heading of equity and democracy, while also touching on issues of sufficiency.

The current industrial food system is highly global, with commodity crops such as corn, soybeans and cotton grown for an international market and out-of-season foods available all year round in the supermarkets of the richest countries. Supporters of this system say that it is highly efficient, allowing specialisation best suited to local growing conditions[187], as well as increasing the availability and affordability of food and improving the stability of the food supply[188].

However, these arguments have come in for much criticism from those who point out that we already produce more than enough food to feed the global population[189]. The problem is it's not reaching those who most need it, either at all or at a price they can afford. Inasmuch as this is true, the industrial globalised food system is actually inefficient and inequitable.

Understanding this can galvanise more people to care for the world around them, as well as opening up more pathways to sustainability[190] .

One review of impact evaluation studies of protected areas show that when local values such as stewardship are integrated, decision-making delivers more just and sustainable outcomes, especially when these values have been traditionally marginalised[191].

As well as the IAASTD explored in Chapter 2, two recent European projects provide some further inspiration for a vision of a sustainable food system, both developed with equity and democracy in mind.

As part of the research and consultation into a legislative framework for sustainable food systems in the EU, an evidence review – *A Sustainable Food System for the European Union* – produced by the Science Advice for Policy by European Academies (SAPEA) consortium in 2020[192], focused on expected outcomes of a sustainable food system:

1. To provide safe, nutritious and healthy food for all current and future citizens in a given territory without compromising the availability of and access to safe, nutritious and healthy food for current and future people living outside that territory.

2. To provide food security without harming the environment.

3. To be robust and resilient in order to produce food, in a wider context that is itself not sustainable, but is challenged by environmental degradation, climate change, biodiversity losses and resource scarcity. Food systems also need to be sustainable in social and economic terms, resilient to price shocks and other crises and responsive to social inequalities and other forms of injustice.

The review advocated for a system-based, circular approach to the food system with an understanding of the interdependencies between key parts of the systems.

In 2022, a report from the European Commission's Joint Research Centre was the result of an EU participatory process also aimed at devising concepts for a sustainable EU food system.

It concluded that for the system to become sustainable there needs to be a paradigm shift away from the productivist view and towards the ultimate purpose of the EU food system, i.e. the long-term provision of food security in a broad sense for everyone in the EU, without the current threats to the environment and people[193].

Putting it into practice

These four 'back to basics' pillars provide a solid framework for a more coherent and wholistic approach to sustainability in general and agriculture in particular than the current piecemeal, opaque and inequitable ones.

The policies and practices which put them into practice must:

- Operate within clear ecological boundaries
- Address social and democratic aspects of sustainability
- Promote diversity in both agricultural practices and decision-making processes
- Prioritise resilience and adaptability over narrow efficiency metrics

There must be clarity about whether and how they:

- Apply to 'end state sustainability', incremental steps or transitional measures
- Are time-limited and/or time-dependent
- Serve the fundamental objective of net sustainability gain.
- Ensure significant compromises and trade-offs are explicitly identified and the most desirable option among the alternatives is chosen

A sustainable agriculture system built on these core pillars and implementation criteria offers a range of interconnected primary and secondary benefits.

Primarily, it promotes environmental sustainability by respecting ecological limits and boundaries, which helps preserve biodiversity, maintain soil health and mitigate climate change. Such a system also ensures food security by focusing on sufficiency, meeting global nutritional needs without overproduction or waste. By incorporating equity and democracy, it promotes social justice, ensuring fair access to resources and food for all populations.

This approach guarantees long-term viability by operating within planetary boundaries, sustaining both current and future generations. Moreover, the emphasis on sufficiency often leads to more balanced, nutritious diets, improving public health outcomes.

Potential secondary benefits of this system are equally impactful. It could, for example, foster economic resilience through diversified, sustainable farming practices that lead to more stable local economies. It may also play a role in cultural preservation by respecting local food traditions and farming practices, thus maintaining cultural diversity.

By operating within limits and with a duty of care, it can minimise resource-based conflicts, reducing environmental tensions. The focus on equity supports smallholder farmers and rural communities, enhancing rural livelihoods. Sustainable practices also often align with better treatment of livestock, improving animal welfare. Together, these primary and secondary benefits create a wholistic approach to agriculture that balances environmental, social and economic needs.

Our table in the Appendix gives a comprehensive overview of how these four pillars work with key actions and policies in agricultural sustainability. From this overview it is clear that, far from being insubstantial or 'soft', in terms of policy thinking and implementation, these pillars cut across multiple areas of concern where deep change is needed in order to foster more sustainable practices along the farming and food supply chain.

We, nevertheless, recognise that the practical implementation around these pillars is not straightforward. This is highlighted in the next chapter where we have sought to address their applicability to the issue of gene editing

There would be inevitable resistance from established agricultural industries, from economic pressures and global market forces. There would be initial lack of consensus on specific metrics and standards, as well as discussion about balancing short-term productivity with long-term sustainability. Crucially, consensus would require a commitment to a multi-faceted approach, combining policy measures, economic incentives, education and community engagement

Inevitably change will need to be responsive to the fact that there will be varying capacities and resources across different regions. Achieving widespread implementation would likely require strong policy frameworks at national and international levels; significant investment in research and education; economic incentives and support for transition periods; and a range of adaptive measures.

While full implementation around these pillars remains a challenge, the growing recognition of the need for sustainable agriculture puts pressure on those in power to act.

5 | Gene editing - a case study

In the preceding chapter we described an approach to sustainability that is life-centric and prioritises whole system thinking. This approach, we believe, can act as a framework for sustainability choices in a broad sense as well as in agricultural ecosystems.

But applying this whole system thinking to gene editing immediately raises a number of red flags, not least because, rather than being a whole system or even a distinct type of agriculture in the same way that the use of agrochemicals is. Instead, it is a limited and, at best, incremental intervention.

The term 'gene editing' describes a suite of laboratory-based technologies used to modify an organism's DNA. Using these techniques developers can add or remove specific genetic sequences and/or alter how they function within an organism's genome to create specific traits.

Conceptually and scientifically gene editing is a form of genetic modification and results in genetically modified organisms (GMOs)[194]. While the regulation of agricultural gene-edited organisms varies by country and is still evolving, no regulation requires, takes into account –or challenges – the sustainability claims of gene editing as an agricultural intervention.

As a technology – and taking account of all its aspects – gene editing does not align with our vision and "life-centric" perspective.

From development to application, gene editing is part and parcel of technocapitalism, which is heavily grounded in corporate power that seeks to commodify all aspects of our lives, to disrupt and control the intrinsic interconnectedness of all living things, to break biological and planetary boundaries and remove any barriers, regulation and transparent governance in the pursuit of innovation and global growth.

The structures, drivers, finance and owners of genetic technologies have no recognisable duty of care to anything outside of their own growth dynamic. Thus, while agriculture is one area of its operation, biotechnology businesses seek growth through integration with pharmaceuticals, nutriceuticals, energy production and food processing all wrapped up in monetised data and intellectual property rights (IPR) that generate profits but also create and maintain a web of technological lock-ins.

Irrespective of the possibility that some applications of the technology might have some benefits, the essence of our framework demands interventions be considered as a whole; in the same way that we should have assessed the use of agrochemicals before they became ubiquitous and before we more fully understood the bigger picture of the sustainability of life on this planet.

While there are a few specific applications emerging for the use of gene editing in conventional, industrial/intensive agriculture, these can be viewed as part of – or an extension of – sustainable intensification.

As with other SI tools, these could, in theory, be applied as incremental or transitional steps towards sustainability on a case-by-case basis. While our framework doesn't rule out incremental steps, it does require clarity on how they are chosen, assessed and monitored. This still leaves open the question of how to legitimately assess any potential incremental benefits of gene editing.

Sustainability claims for gene editing

As a prominent tool in the pursuit of sustainable intensification in agriculture, claims for gene editing's benefits tend to fall within the same tramlines as SI goals of increasing agricultural productivity and efficiency while minimising environmental impact.

The main advantages claimed by proponents of gene editing include:

Reduction of agricultural inputs Some gene editing applications claim the potential to produce crops that are more water-efficient, drought-tolerant and resistant to pests and diseases.

Carbon storage and climate change mitigation Developers speculate that future gene editing applications could help mitigate climate change by enabling crops to capture and store more carbon in the soil through deeper root systems. Plants may also be engineered to better withstand extreme or unpredictable weather conditions.

Enhanced nutritional content By changing the nutritional profile of crops, developers claim they can help produce food to improve human health and reduce malnutrition in developing regions.

Reduction of food waste It is claimed that some gene editing applications will make fruits and vegetables more resistant to bruising and browning thereby increasing shelf life and decreasing food waste, making a significant contribution to reducing greenhouse gas emissions.

Animal agriculture and welfare Developers speculate that some gene editing applications can enhance livestock production efficiency by creating disease-resistant animals with better growth rates and lower feed requirements. In theory, some applications could also contribute to animal welfare by, for example, producing hornless cattle (avoiding the need for painful dehorning procedures) or all-female chickens (avoiding the destruction of male chicks shortly after hatching).

Supporting biodiversity Proponents suggest that gene-edited crops adapted to diverse environmental conditions could reduce the need to convert natural ecosystems into agricultural land, thus preserving habitats and biodiversity.

Where's the proof?

While these claims are appealing, it's important to note that many of these applications are still in development and the claims for them are unproven. Their long-term impacts and the effectiveness of gene-edited crops in an agricultural system, remain to be fully understood, verified or tested against conventional breeding practices which claim to produce the same results.

Because gene editing is a limited intervention rather than a whole operational system, sustainability benefits can only reasonably be assessed on a case-by-case basis.

However, several things make the process of accurately assessing the sustainability of gene-edited crops and livestock challenging. For a start, few have been fully developed and fewer have reached the marketplace (see box p38).

Additionally, the removal of regulations around the trialling and commercialisation of gene-edited products in places like the US, Canada, Australia and Argentina and now the UK means there are no consistent or coherent standards to which gene-edited crops are currently held. Consequently, it is a challenge to clearly identify any real or consistent environmental/human health or economic benefits or adverse impact

> **While proof-of-concept is an important step in scientific discovery, it is not enough on its own to justify audacious claims for the sustainability of crops or food products that don't exist yet, or the abandonment of basic environmental, health and safety regulations**

It may be promoted as a revolutionary intervention that will revitalise industry, and make agribusinesses more sustainable. But gene-edited crops and livestock are produced under patents and closely guarded intellectual property rights making transparent and independent assessment almost impossible. Almost all the information on potential sustainability or otherwise of gene editing is from the developers themselves or from researchers funded by them.

This means that most claims for gene editing's sustainability benefits are based on little more than projection (see p37) and proof-of-concept studies performed in carefully controlled environments. While proof-of-concept is an important step in scientific discovery, it is not enough on its own to justify audacious claims for the sustainability of the crops, livestock or food products being made.

It should also be noted that the projected sustainability benefits of gene editing are focussed on existing market and production structures. Non-browning produce allows supermarkets to sell, and processors to use, produce that might otherwise be past its best; disease-resistant animals allow intensive livestock operations to continue. Altered or enhanced nutritional properties are sold as healthy foods but are more often aimed at the fast food[195] and biofuel[196] industries, as well as meeting the needs of the nutraceutical[197] and animal feed industries[198] for inexpensive 'natural' source nutrients. These claims, nevertheless, play well in the political and media arenas where 'weathercock' solutions are too often portrayed as 'signposts'.

Perhaps most importantly of all, sustainability is not the key driver of the development of agricultural genetic technologies. As Policante and Borg[199] note:

> "*As corporate science is directly in the service of private entities guided by a strict market rationality, while public research is increasingly pushed to prioritize immediate 'industrial applications' and the achievement of measurable 'socio-economic impact', genomic interventions are mostly geared towards expanding, accelerating and securing the accumulation of capital on a global scale.*"

Limitations and "unmet expectations"

The future-facing nature of gene editing PR means that claims for sustainability are often more prediction than proof. In the financial world, there are laws to warn investors about such promises – or 'forward-looking statements' – which have no basis in historical or current facts. An example of this can be found in the 2022 fourth-quarter financial statement from Calyxt[200], developer of a gene-edited high oleic acid soybean cooking oil (Calyno):

> "*This communication contains 'forward-looking statements' within the meaning of the safe harbor provisions of the U.S. Private Securities Litigation Reform Act of 1995. In some cases, you can identify these statements by forward-looking words such as "anticipates," "believes," "continue," "estimates," "expects," "intends," "may," "might," "plans," "predicts," "projects," "should," "targets," "will," or the negative of these terms and other similar terminology.*"

It goes on to warn that forward-looking statements framed in this way are "*predictions and projections*".

No such warnings are required for the framing of sustainability claims, though perhaps they should be. With gene editing, the forward-looking 'big front' of the PR machinery inevitably, perhaps even deliberately, casts into shadow the 'big behind' of limitations and scientific, ethical and environmental uncertainties.

On the 50th anniversary of the first laboratory demonstration of transgenesis, a large evidence review concluded that biotech was an industry "*dominated by high, unmet expectations, and underplayed damage and failure*" and that:

> "*Biotech's agricultural promises and hopes, as well as its few commercial products, raise questions of centralization and control, erosion of diversity, emergence of new dependencies, and more*"[201].

These unmet expectations are often blamed on burdensome regulations. In reality, agricultural genetic modification suffers from multiple limitations and these have not disappeared with the advent of gene editing techniques. These include:

Limited traits

Genetically modified herbicide-tolerant crops, a category that can include an herbicide-tolerant trait on its own or in combination with other traits, account for around 88% of the land area planted with GM crops worldwide[202].

A 2021 study by the EU's Joint Research Centre (JRC)[203], using data supplied by developers, demonstrated a similar trend for newer, gene-edited crops. Of the new plants that were classified as close to commercialisation, the largest trait group – 6 out of 16 plants – was herbicide-tolerance.

Like their predecessors, target crops include wheat, maize, rice, soybean, potato, oilseed rape (canola), flax, cassava, watermelon and tomato[204], engineered to withstand blanket spraying of different herbicides.

The experience with the older genetically modified herbicide-tolerant crops, which have been a component of the global agricultural system for nearly 40 years, is instructive[205].

The 'freedom' to blanket-spray entire fields with herbicides has had significant negative implications for all forms of biodiversity (plant, soil microbial life, insect and animal). Overuse of the most common herbicide, glyphosate, has led to a sharp increase in the herbicide-resistant weeds in recent years[206].

The problems with glyphosate have, bizarrely, prompted companies to turn to alternative, even more harmful chemicals, such as dicamba. US Department of Agriculture (USDA) data shows 79%

of soybean acres in Mississippi were planted with genetically modified dicamba-tolerant seeds[207].

Drift from dicamba spraying[208] can cause serious damage to neighbouring non-dicamba-tolerant soybeans and to other sensitive crops and non-crop plants. This effect can be seen up to half a mile away[209] from the original site of the spraying and can affect trees, vegetables, ornamental plants and commercial nurseries[210].

Insecticide-producing crops (developed by moving some of the genes from the bacterium *Bacillus thuringiensis* (Bt) into plants such as corn and cotton, likewise promised to reduce the amount of insecticide needed in conventional systems. Initially, this proved to be the case and BT crops have largely been regarded as a 'win' for genetic engineering. However, recent evidence has shown that insects are becoming increasingly resistant to Bt crops[211].

Limited diversity

Crop diversity underpins the productivity, resilience and adaptive capacity of agriculture. The FAO estimates that about 75% of genetic diversity in agricultural crops has been lost over the last century, with this trend accelerating in recent decades. FAO has warned that declining genetic diversity in food and agriculture makes food crops and livestock more susceptible to disease and farmers more vulnerable to crop failure[212].

While it is claimed that genetically engineering (including gene editing) new species will improve the diversity of both the types of foods we consume and the number of species in our ecosystems, the evidence points to the opposite effect.

The focus of gene editing remains on a handful of staple crops with high economic importance. Rice, tomatoes, maize, soybeans, wheat and oilseed rape represent around three-quarters of the crops currently in development[213].

Where genetic engineering is present in agriculture, crop diversity declines. Maize, a crop with huge diversity, is a case in point. In 2010 researchers calculated that in Mexico, where the spread of GM

Limited products

To date, very few gene-edited products have been commercialised. Proponents argue that this is due to over-burdensome regulation. But even in the US where regulation is minimal, there is little to show in the marketplace.

The product examples used by the UK government during the passage of the Genetic Technology Act are revealing this regard. In its media releases and briefs to parliamentarians Defra cited climate-resistant wheat, non-browning bananas and disease-resistant chickens[217]. It promoted sugar beet immune to virus yellow, wheat that is resilient to climate change and has lower levels of asparagine, tomatoes re-engineered to contain vitamin D and disease-resistant pigs[218].

The most recent House of Commons research briefing[219] says:

> "*Examples of current GE products include soybean oil with reduced saturated fat sold in the USA and a tomato sold in Japan that accumulates a chemical that lowers blood pressure. For the future, a range of wheat, chickpea, and peanut products with health benefits are in development, alongside products aimed at consumer convenience such as seedless fruits and corn that is higher in thickening starch*."

Most of these are nowhere near being commercialised and the sustainability benefits of low asparagine wheat, seedless fruit and corn high in thickening starch are debatable. Although several gene-edited crops and a few animals have been approved for commercialisation over the last decade, particularly in the US and Japan, few have made it to market and most have been abandoned, often without a single clear explanation as to why.

In some cases, as with the Calyxt's high oleic soybean cooking oil (Calyno) and Cibus herbicide-tolerant oilseed rape, a combination of lack of investment and lack of commercial interest has limited distribution[220]. In Japan a high GABA tomato developed by Developed by Sanatech Seed[221], a startup from the University of Tsukuba, has a limited distribution. But consumer enthusiasm for gene-edited produce is low. A survey of about 10,000 people by the University of Tokyo found that 40-50% did not want to eat genetically 'edited' crops or animal products, with just 10% showing interest in trying them[222].

crops has been resisted, small family farmers grew approximately 138 billion genetically distinct maize plants[214]. In contrast, in the US in 2015, just 33 varieties of GM corn had been approved, which together accounted for nearly 95% of the total area of corn planted in the USA[215].

There is no data at all to suggest that newer gene-edited crops will bring greater crop biodiversity gains than their predecessors and researchers suggest that, "*Further critical assessments of seed sector consolidation, varietal release procedures and intellectual property tools (i.e. UPOV and patents), and advanced breeding technologies (e.g. genetic modification and gene editing) are needed to develop and implement strategies to minimize negative impacts on modern cultivar diversity*"[216].

Limited access

Proponents of the technology – including governments – claim that due to its low costs in comparison to previous GM technologies, gene editing is providing more opportunity for small and medium-sized businesses (SMEs) to enter the market, thus making the development and use of the technology more accessible and democratic.

The 'impact assessment' accompanying the progression of the UK's Genetic Technologies (Precision Breeding) Act, specifically rejected the claim that gene editing would give big businesses more control over the food supply. However, it provided no data in support of this claim nor evidence that SMEs are lining up to invest[223].

In the US at least the technology has been widely adopted by start-up companies, but this has been limited to the early research phases which are relatively inexpensive to conduct. To get to market, there are a range of patents and licensing agreements which govern gene editing. In particular, the costs of the commercial licences – which allow companies to move products from the labs to markets – are prohibitively expensive and configured to allow large biotech companies to continue to secure a dominant market position[224].

The reality is that most of these start-ups will not have the resources to do this and will almost certainly be acquired by large biotech companies.

Information from the UK and the EU on SME engagement is less clear. In the UK, it appears that SMEs engaged in agricultural applications of gene editing are university or research institution-based spin-offs where staff have taken advantage of patents they are associated with and institutional support.

Small farmers, too, may be disadvantaged. Genetically engineered crops lock farmers into an industrial agricultural system where they are dependent on agritech companies for both their seeds and the chemicals with which the crops are designed to work. The experience of GM seeds has been that they cost more and therefore it's only the bigger farms that can afford them, something which has contributed to a trend towards fewer, larger farms in the USA adopting them[225].

Applying the four pillars

In a recent analysis[230], Heinemann and Hiscox question the narrowness of drivers of biotechnologies suggesting that a combination of technofix status quo and poorly or narrowly defined goals can lead to poor investment decisions:

> "*Awash in offers to painlessly ameliorate the effects of climate change, societies may struggle to find biotechnologies that deliver sustainable solutions while building social and ecological resilience in the face of climate and other shocks. This is because 'local actions that make sense to individuals may not produce sustainability at a system level'. How to choose a technology is therefore as important, and prerequisite to, what is chosen.*"

'Awash in offers to painlessly ameliorate the effects of climate change, societies may struggle to find biotechnologies that deliver sustainable solutions while building social and ecological resilience in the face of climate and other shocks'

This question of how to choose (and choosing wisely) is fundamental to sustainability. In the authors' view, it can only be answered by drawing on the understanding of a vast array of biophysical, economic, social and psychological research and creating and applying standards that reflect these. But this is not what is currently happening in the UK, the EU or elsewhere.

There is an urgent need to build into the process a balancing and weighing-up of the various aspects of true sustainability as well as considerations of those issues which are specific to gene editing.

Our vision of sustainability set out in chapter 4 supports this wholistic ambition and, as such, emphatically excludes gene editing and other genetic engineering as a whole technology.

However, our framework doesn't categorically rule out a role for some applications as part of a transition or incremental pathway to sustainability. In fact, it provides a structured approach for evaluating each application on its own merits, while keeping an eye on uncertainties and ethical considerations and a focus on long-term sustainability. Some considerations within each of our four pillars, include:

Boundaries/limits Gene editing has the potential to both respect and challenge natural boundaries. On one hand, it could develop crops that use resources more efficiently, potentially reducing pressure on land and water. For instance, drought-resistant varieties could help agriculture adapt to climate change within existing environmental limits. However, the ability to overcome natural genetic barriers also raises questions about where we draw the line in manipulating natural systems. Similarly, a gene-edited crop designed to require less water, may superficially align with this principle, but might also raise equity concerns if the technology is not accessible to all farmers.

A duty of care, precaution and stewardship prompt us to consider long-term impacts and unintended consequences. While gene editing might reduce the need for pesticides, benefiting ecosystem health, we must also consider potential risks to biodiversity and ecological balance. Our duty of care extends to future generations, necessitating thorough, long-term studies on environmental and health impacts.

Similarly, efforts to re-engineer plants or animals, control invasive species or revive extinct species through gene editing present a complex case for our duty of care – are we restoring ecosystems or further interfering with natural processes?

Wholism, integrity and sustainability

Proponents of genetic modification argue that the changes made to a plant's genetics in the laboratory could easily have occurred in nature. But this theoretical possibility is highly contested.

Of course, nature can theoretically throw up any number of organisms that are "freaks" as Dr Angelika Hilbeck, a participant in our 2024 webinar on sustainability suggests[226]. But the idea that natural mutations or spontaneous horizontal gene transfer (HGT – transferring genes across species) "*this doesn't mean it's acceptable, safe, or desirable to deliberately create them rapidly and on a large scale using gene editing*"[227].

Moreover, there is little evidence to suggest that these "freaks" survive, let alone thrive as part of either a wild or agricultural ecosystem.

In addition, as Robinson and Antoniou[229] point out,

> "*In conventional breeding and random mutagenesis, some regions in the genome undergo changes less frequently than others because these regions are protected by DNA repair mechanisms in the cell. In contrast, the gene-editing tool CRISPR/Cas can bypass these naturally occurring protections*[228]*, meaning it can access parts of the genome that are not accessible to change in conventional and random mutagenesis breeding*."

This intrinsic protective mechanism brings to mind arguments from organic and biodynamic agriculture, which suggest that genetic modification fundamentally interferes with the integrity of the living organism.

In these agricultures, an organism is viewed as more than the sum of its parts. There's a recognition that organisms have an innate ability to self-regulate and maintain balance. Interference with the organism's integrity and ability to self-regulate is one reason why genetic engineering is not allowed in organic and biodynamic systems.

But the notion of integrity within these systems goes beyond simply not allowing genetic modification, encompassing a wholistic view of the organism's nature, its natural rhythms and cycles and its relationships within the ecosystem and its inherent qualities.

Where genetic modification and, in many cases, gene editing involves deliberately inserting genes from one species into another, something that wouldn't generally occur naturally, this is seen as a fundamental violation of the organism's genetic integrity. From this wholisltic perspective, genetic modification is seen as inherently unsustainable.

Sufficiency Gene editing could contribute to sufficiency by enhancing nutritional content or extending shelf life, potentially reducing food waste and improving food security.

At the same time, the sufficiency principle prompts us to ask whether all applications serve genuine needs or if some primarily drive unnecessary consumption or profit-driven overproduction. Likewise, an application that significantly boosts yield could support sufficiency in food-insecure regions but might encourage overproduction in others, challenging the balance between sufficiency and limits

Equity/Democracy Gene editing technology raises significant questions about equity and democratic control. Who has access to these technologies? Who benefits from and controls this technology?

There's a genuine risk of further consolidating power in the hands of large agribusinesses, potentially exacerbating existing inequalities in the food system. Conversely, if developed and distributed equitably, gene editing could conceivably empower smaller farmers and address local agricultural challenges.

Trade-offs like these are inevitable, and can be desirable if they are transparent, equitable and encourage discourse and acceptable compromise. But the context(s) of these considerations is all important. For example, something acceptable in a research context might not be in an ecological landscape context; something acceptable as a short-term feed additive for livestock context might not be as an ongoing component.

Moreover, time and scale is all important when considering transition and incremental measures. Above all, none of these measures must compromise the goal of 'end state' sustainability.

Our proposed implementation criteria for the four pillars (see p33) provides clarity for these kinds of real-world considerations, ensuring they operate within clear ecological boundaries whilst addressing the diverse nature of sustainability.

Further thoughts on practical applications are summed up in the larger table in the Appendix, which looks at the kinds of actions and policies that might fall within, or evolve out of each of the four pillars.

While our framework doesn't provide a one-size-fits-all answer to the assessment of gene editing's sustainability claims, it does offer a structured approach for evaluating each application contextually. This kind of granular assessment is crucial because, like any powerful technology, the impact and effectiveness of gene editing depends on how it's developed, applied and governed.

Does gene editing 'fit' into existing sustainable systems?

Biotech developers have argued that traits such as increased disease-resistance could help support agroecological practices, such as Integrated Pest Management[231] and make organic agriculture "more sustainable"[232].

In truth, for many existing sustainable systems such as organic and agroecological systems gene editing is either not an option or not a good fit. Throughout the world, legally mandated organic standards simply do not allow genetically modified crops. Agroecological farmers are also sceptical of both the efficacy, the embedded values[233] and motives of gene editing [234]. As Clément and Ajena[235] observe:

"*While agroecology aims to serve local needs and livelihoods, the industrial logic behind the development of new genomic technologies like CRISPR/Cas remains profit-driven and reductionist in its understanding of food and food systems (i.e., geared primarily toward uniformization, productivity, and efficiency). It appears a challenge, therefore, to foresee how a tool designed under this logic could be reconciled with a holistic people- and nature-centered approach to food systems.*"

These and other criticisms were apparent in our own research into agroecologically appropriate technology. The agroecological farmers we interviewed for our ***Agroecological Intelligence*** project felt that gene editing was an over-hyped, technocentric approach to agricultural challenges that potentially overlooked more wholistic, agroecological solutions that could address root causes of unsustainability[236]. Uncertainty around the long-term impacts of the technology combined with this narrow productivist mindset meant gene editing was a poor fit for their systems.

A reckoning

Amongst the most frustrating aspects of the narrative that surrounds gene editing and other agricultural genetic engineering technologies is the widening gulf between a technology that may have potential to deliver some public benefit and the hype that surrounds it. This hype keeps genetic technologies from being grounded in anything real, meaningful or substantial.

In 2022, during the UK parliamentary debates over the proposed deregulation of gene-edited crops, a group of Labour MPs proposed an amendment to the draft bill that would require gene-edited organisms to be developed for, or in connection with, one or more of several sustainability criteria[237].

These included producing food in a way that protects or enhances the natural environment and supports the sustainable use of resources; growing and managing plants or animals in a way that mitigates or adapts to climate change; conserving the genetic resources of native animals and those of plants and their wild relatives; protecting or improving the quality of soil; and supporting or improving human health and well-being.

This was a recognition of the need for genetically modified gene-edited crops to be considered as part of a whole system.

Then shadow Environment Minister, Daniel Zeichner noted[238] the amendment reflected what was already in the UK Agriculture Act 2020, which lists the public goods that can be funded: "*We are simply applying the same approach to the development and use of gene editing technologies*."

Faced with government opposition that suggested that such requirements might "*place restrictions on research using these technologies*"[239], the amendment was withdrawn. And yet all of these requirements are things that gene editing promises to achieve.

The only conclusion that can be drawn is that the economics of the research and IPR industry are more important than ensuring it is used for the benefit of the taxpayers who are putting up a large part of the research funding.

There might also be an underlying fear that the technology can't actually deliver. For nearly 40 years, agricultural genetic engineering has promised to deliver big results, but always in some unspecified future, usually 5-10 years from now.

Campaigners, of course, have been saying this for years. But now the industry is approaching its own point of reckoning. A recent paper in the journal ***Nature***[240] called for biotech developers to stop "overselling" claims about increased yields which rarely materialise under real-world conditions. The authors said: "*Especially in the context of climate change and a growing human population, the growth of misleading claims around yields has become a cause of concern to us.*"

A recent paper in the journal Nature, called for biotech developers to stop "overselling" claims about increased yields which rarely materialise under real world conditions

They noted that no single gene affects yield and those that do work in conjunction with soil, fertiliser use and geography and that claims of yield increases of 10% to 68%, when tested in the field are more likely to be in the region of 1% to 5%.

As changes to gene-edited regulations in New Zealand have begun to be debated, eminent geneticist Prof Jack Heinemann – one of the authors of the 2009 ***IAASTD Report*** – put it more bluntly in a 2024 editorial[241]: "*Let's cut the crap on gene technology*".

In it, he challenged the ingrained myths that gene editing is different from genetic modification, that without deregulation countries would 'miss out' on lucrative markets and that deregulation posed no risks to the environment or human health.

Crucially he notes that for all the hype and promises of transformation the United States – the most biotech-friendly country in the world – has only commercialised 11 GM crops in 30 years[242].

Conclusions & recommendations

"We in this generation, must come to terms with nature, and I think we're challenged as mankind has never been challenged before to prove our maturity and our mastery, not of nature, but of ourselves."

When Rachel Carson spoke these words[243] shortly after the publication of ***Silent Spring,*** there was still hope that humans could learn to take care of, and "work with nature". Since that time, we have continued to wage a never-ending war on nature, seeing it as a problem to be solved, as a system to be gamed, as an organism to be manipulated and a marketplace from which to profit.

The growth agenda has become so quickly and deeply embedded in our day-to-day thinking and functioning that we have lost touch with the roots of truly sustainable thinking.

It is entirely possible that there are people advocating for sustainable solutions today who have no awareness of the great thinkers and the vast canon of literature, built up over decades, laying the foundations for a philosophy of wholism and a sustainable world.

innovation and technology are most effective when they are part of a larger mix of goals; when they are human scale, purposeful and developed within a meaningful and relevant social and cultural context.

Not even the great thinkers in the history of sustainability could have imagined how quickly the world would change and how far the notion of sustainability has moved from a life-centric to a technocentric position.

They might also be surprised by the shallowness and duplicity of our political leaders who seek to price everything, value little and put the market economy before the sustainability of the planet.

The EU may have abandoned its pursuit of sustainability criteria, but as we were finalising this report – and in an ironic twist – European Commission President Ursula von der Leyen made an impassioned speech at the Digital Life Design Nature Conference in Munich[243]:

"We can create a market for restoring our planet. It almost sounds too good to be true. But we know that, with the right standards, it can be done, because we did it before. Here in Europe, we already have an incredibly effective market for carbon. It has been working for almost 20 years [...] The same could apply to nature credits. We need to channel vital resources towards all those who are providing ecosystem services."

What von der Leyen didn't say was that carbon offsetting schemes often grossly exaggerate their ability to reduce carbon emissions[244]. A recent preprint study out of the public research university ETH Zurich estimated that just 12% of current carbon-offset projects "constitute real emissions reductions"[245]. Multiple studies and reports suggest serious integrity issues with the carbon offset market and a 2023 report by Survival International has linked carbon offset projects to indigenous people being forced from their land and other human rights abuses[246].

Irrespective of this, von der Leyen revealed that *"Work is already ongoing at the United Nations and in the European Commission, to define a global standard for nature credits."* In light of our analysis, an important question is: with whom – and for the benefit of whom – are such standards being developed?

The speed with which technocapitalism has overtaken the sustainability agenda is dizzying, and the aggression with which a handful of corporate elites, and the politicians in their thrall, defend that position is overwhelming. These changes are nothing less than a fiat, enacted without democratic, public or critical debate.

Of course, society can advance through industry and technology – but not only through these things. Society also advances through more sophisticated ethical frameworks and an expanded circle of moral consideration which can lead to social and political reforms and progress in areas like human rights, animal welfare and environmental stewardship.

It advances through education and access to information, which in turn empowers critical thinking and informed decision-making, and through individual and collective spiritual and philosophical growth, an increased understanding of human psychology and through cultural and artistic expression.

This multi-dimensionalism is the essence of a functional, sustainable and resilient society. It should drive and form the basis of our thinking around sustainability more broadly and sustainability in agriculture in particular.

The four pillars of our life-centric approach to sustainability are an attempt to encapsulate this – and to recognise that without true, wholistic sustainability society is unable to advance at all.

The world is changing. A narrow and relentless pursuit of GDP growth and ever-increasing productivity, without regard for these drivers, is fundamentally at odds with the goals of sustainability.

Instead, innovation and technology are most effective when they are part of a larger mix of goals; when they are human scale, purposeful and developed within a meaningful and relevant social and cultural context. In an increasingly technological age, the underlying message is that sustainability requires a careful alignment between technological progress and broader social, economic and environmental considerations.

The persistence of the growth imperative, despite decades of advocacy, highlights the need for continued efforts, innovative approaches and more radical systemic changes in the way we address sustainability challenges.

It also underscores the importance of the work of what feels like a perishingly small number of advocates, at keeping these values-based issues at the forefront and pushing for meaningful implementation of these long-standing principles.

Discussions about sustainability also often include references to 'resilience'. But the idea of resilience must go beyond the intention of recovering back to 'normal' – because the system as it currently operates is not sustainable. In recognition of this challenge, the concept of transformative resilience is gaining increasing traction in socio-economic thinking.

Defined as "*the deliberate pursuit of sustainability transitions in times of shocks, crises or stress*",[247] transformative resilience offers a framework for policies to adapt to, absorb and even anticipate shocks while retaining their transformative intent. This will require an agile government with a diverse range of possible approaches to shocks or crises which are designed to help a system recover quickly and better from future crises.

The framework set out in this report is our attempt to set out a wholistic, transformative values-based vision of sustainability. We recognise the challenges in the practical implementation of these ideas as well as the potential economic impacts and the need for widespread acceptance and adoption. But we also recognise that we are not starting from scratch. Examples of values-based sustainability exist right now.

While organic agriculture is not perfect and needs developing, it is a working example of sustainable agriculture in action. Organic is a values-based system rooted in principles of Health, Ecology, Fairness and Care[248] and proven throughout the world.

Community-supported agriculture (CSA), an increasingly popular model in many countries, embodies principles of equity and democracy by directly connecting consumers with local farmers.

The peasant and landworkers movements bring focus to social justice and equity in agriculture as well as to the many traditional agricultural practices, incorporated into indigenous farming systems, that inherently incorporate principles of care, sufficiency and respect for natural ecological boundaries. The growing regenerative agriculture movement emphasises soil health, biodiversity and ecosystem services, aligning with the duty of care principle.

Taken together these represent a large scale and global commitment to values-based sustainability in agriculture in principle and in viable practice. Nevertheless, challenges remain including:

- Resistance from established agricultural industries
- Economic pressures and global market forces
- Lack of consensus on specific metrics and standards
- Varying capacities and resources across different regions
- Balancing short-term productivity with long-term sustainability

We believe these challenges can be overcome with:

- Strong policy frameworks at national and international levels
- Significant investment in research of a variety of farming practices and education
- Economic incentives and support for transition periods
- Collaboration between farmers, scientists, policymakers and citizens
- Adaptive management approaches to refine strategies over time

Implementing our suggestions would require sustained effort and resources, but they offer pathways to overcome the inertia that has hindered the adoption of sustainability principles. The key is to create a multi-faceted approach that addresses the complex nature of sustainability challenges while building broad-based support for change.

Appendix – Policies and practices

In this report we suggest that sustainability in general, and agricultural sustainability in particular, should be oriented towards those things that sustain life.

The broad concept of "sustaining life" is not a common starting point in policymaking and you won't find this phrase used in any legislation or regulations that we know of.

Nevertheless, in some parts of the world, efforts have been made to incorporate ecological thinking and language into policy and the concept of sustaining life is implicit in many environmental and sustainable development policies.

In 2017, New Zealand's Te Awa Tupua Act[249] granted legal personhood to the Whanganui River, recognising it as "*an indivisible and living whole from the mountains to the sea, incorporating the Whanganui River and all of its physical and metaphysical elements*."

Bolivia's Mother Earth Law and Mother Earth Framework Law[250] was passed in 2010 and is based on indigenous concepts that view nature as a sacred home, or Pachamama (Mother Earth). The indigenous-derived concept of Living Well, which entails living in complementarity, harmony and equilibrium with Mother Earth, is embedded in the country's new constitution.

Sweden's Environmental Objectives system[251] comprises 16 environmental quality objectives that guide its environmental policy. These objectives use ecological language and concepts, such as "*Thriving Wetlands*" and "*A Rich Diversity of Plant and Animal Life*," "*A Balanced Marie Environment*" and "*Magnificent Mountains*" to set long-term goals for environmental protection.

Japan has incorporated the traditional concept of "Satoyama" (harmonious human-nature coexistence) into its national biodiversity strategy. This Satoyama Initiative[252] recognises water and food as "*blessings of nature*" and recognises the interdependence of human communities and surrounding ecosystems.

The Constitution of Kingdom of Bhutan, enacted in 2008, invokes a duty of care, stating that the protection of the environment is a duty of the individual: "*Every Bhutanese is a trustee of the Kingdom's natural resources and environment for the benefit of the present and future generations and it is a fundamental duty of every citizen to contribute to the protection of the natural environment*"[253].

These examples demonstrate various ways in which ecological concepts and language are slowly being integrated into policy frameworks around the world. They show a growing recognition of the need to consider ecosystems wholistically, recognise the intrinsic value of nature and think long-term about human-nature relationships.

It's worth noting that using the language of nature and ecological concepts to guide policy is not without its challenges. Many of these approaches are still evolving, and their long-term effectiveness and how they might conflict with long-held economic growth policies, is still being evaluated. But the fact they have been attempted at all – mostly in the last two decades – suggests a recognition of a need to change the way we make policy.

With this in mind, our work around our framework has led us to consider how and which policies and actions towards agricultural sustainability might be guided by our four principles of sustainability.

The language of nature and sustainability and the ways we describe the things that 'sustain life' is often considered 'abstract', 'soft' or 'impractical' in policy fora, and yet as the table below shows, many actions which are either being taken now or which are aspirational in order to protect agricultural ecosystems, clearly fall within the scope of each of these concepts.

The table on the following pages is not exhaustive, is not definitive and is certainly open to debate – indeed, we welcome and encourage debate. However, it gives an idea of the kinds of actions that can be taken, or would be appropriate, under each of our pillars of sustainability.

	Boundaries and Limits	A Duty of Care	Sufficiency	Equity and Democracy
Environmental impact and resource use	**Soil Health** ▪ Establish limits on tillage practices to prevent soil erosion and degradation ▪ Set guidelines for maintaining soil organic matter content ▪ Implement rotation requirements to prevent nutrient depletion **Water Use** ▪ Define watershed-specific water extraction limits ▪ Establish regulations on irrigation efficiency ▪ Set quality standards for agricultural runoff **Biodiversity** ▪ Mandate minimum areas for wildlife corridors and habitats ▪ Set limits on monoculture plot sizes to encourage diversity ▪ Establish no-go zones for agriculture in biodiversity hotspots	**Soil Care** ▪ Implement practices to maintain and improve soil health, such as cover cropping and minimal tillage ▪ Regular soil testing and remediation of degraded soils ▪ Promote soil biodiversity and microbial health **Water Management** ▪ Responsible irrigation practices to prevent water waste ▪ Protection of water sources from agricultural runoff ▪ Biodiversity Conservation ▪ Maintain and create habitats for local flora and fauna ▪ Protect pollinators through reduced pesticide use and creation of pollinator-friendly areas ▪ Preserve and promote native plant species **Wildlife Protection** ▪ Create wildlife corridors and protected areas within agricultural landscapes ▪ Implement measures to prevent conflicts between wildlife and farming activities ▪ Develop strategies to coexist with predators and other wildlife	**Water Efficiency** ▪ Implement water-saving irrigation techniques (e.g., drip irrigation, rainwater harvesting) ▪ Choose crops appropriate for local water availability ▪ Implementation of water recycling and rainwater harvesting systems **Energy Sufficiency** ▪ Implement energy-efficient farming practices and equipment ▪ Minimise reliance on fossil fuel-based inputs ▪ Aim for energy self-sufficiency through renewable sources (*e.g.* solar and wind) **Nutrient Cycling** ▪ Maximise on-farm nutrient cycling through composting and manure management ▪ Use cover crops and green manures to reduce reliance on external fertilisers ▪ Implement precision fertilisation techniques to avoid excess application	**Water Rights** ▪ Implement equitable water allocation systems ▪ Protect traditional water rights of indigenous communities ▪ Ensure fair access to irrigation infrastructure **Input Access** ▪ Develop programs to ensure equitable access to seeds, tools and other inputs ▪ Support development and distribution of open-source agricultural technologies ▪ Implement fair subsidy programs that benefit small-scale farmers **Environmental Impacts** ▪ Address disproportionate impacts of agricultural pollution on marginalised communities ▪ Ensure equitable access to clean water and unpolluted land for farming

		Insects ▪ Manage agriculture landscapes e.g. with IPM to reduce or eliminate insecticide use ▪ Establish landscape labs that enable farmers to use their their knowledge, expertise and concerns to co-design insect friendly farms ▪ Provide subsidies for ‘insect friendly’ agriculture		
Food production, distribution and access	**Use of Inputs** ▪ Establish a transition plan for moving away from synthetic chemical-based farming and to more sustainable alternatives. ▪ Set region-specific limits on nitrogen and phosphorus application including buffer zones near water bodies to prevent eutrophication ▪ Establish no-pesticide zones near sensitive ecosystems.	**Livestock Care** ▪ Ensure adequate space, nutrition, and veterinary care for farm animals ▪ Implement humane handling and transportation practices ▪ Provide environments that allow for natural behaviours	**Yield Optimisation** ▪ Focus on optimising rather than maximising yields ▪ Implement precision agriculture techniques to produce sufficient amounts with minimal inputs ▪ Encourage polyculture and integrated farming systems for diverse, stable yields **Crop Selection** ▪ Prioritise crops that provide essential nutrients and are well-suited to local conditions ▪ Promote diverse crop rotations to enhance soil health and reduce pest pressures ▪ Encourage cultivation of indigenous and traditional crop varieties	**Food Sovereignty** ▪ Empower communities to define their own food systems ▪ Support policies that prioritise local food production for local consumption ▪ Protect farmers’ rights to save and exchange seeds **Local Food Systems** ▪ Support development of local and regional food systems ▪ Implement policies that balance local food security with international trade **Cultural Appropriateness** ▪ Respect and promote culturally significant foods and farming practices ▪ Ensure that sufficiency measures account for diverse dietary preferences and needs

Local Food Systems

- Strengthen local food networks to reduce transportation needs and improve food security
- Encourage community-supported agriculture (CSA) and farmers' markets
- Develop food hubs to efficiently connect local producers with consumers

Post-Harvest Management

- Improve storage and preservation techniques to reduce food losses
- Instead of 'wonky' or 'imperfect' produce; expand the tolerance levels for size and quality of fresh produce on shop shelves
- Implement efficient processing techniques to utilise all parts of crops and animals

Nutrition-Focused Production

- Align agricultural production with nutritional needs rather than market demands
- Educate consumers about balanced, sufficient diets
- Promote diverse, plant-rich diets that are less resource-intensive

	Boundaries and Limits	A Duty of Care	Sufficiency	Equity and Democracy
Land use, access and ownership	**Expansion Limits** ▪ Implement strict zoning laws to prevent agricultural expansion into forests or wetlands ▪ Set national or regional caps on total agricultural land area **Intensification Boundaries** ▪ Establish limits on livestock density to prevent overgrazing ▪ Set guidelines for crop rotation and fallow periods	**Long-term Land Management** ▪ Implement practices that maintain or improve land quality for future generations ▪ Avoid practices that lead to long-term degradation of agricultural resources ▪ Invest in sustainable infrastructure and technology	**Multifunctional Landscapes** ▪ Design agricultural systems that provide multiple benefits (food, habitat, carbon sequestration) ▪ Implement agroforestry systems to increase overall land productivity **Efficient Land Allocation** ▪ Develop a land use framework which sets out priorities and strategies for sharing the land between multiple objectives. ▪ Prioritise land use for essential food production over cash crops or biofuels ▪ Implement vertical farming and urban agriculture to increase production in limited spaces ▪ Restore degraded lands to increase productive capacity	**Land Reform** ▪ Implement policies to redistribute land more equitably ▪ Support community land trusts and cooperative land ownership models ▪ Protect indigenous land rights and traditional territories. ▪ Increase access to land to enable the benefits of nature to be enjoyed by all. **Tenure Security** ▪ Strengthen land tenure rights for small-scale and tenant farmers and marginalised groups ▪ Implement transparent land registration systems ▪ Address gender disparities in land ownership
Local community and worker responsibility	**Farm Worker Welfare** ▪ Respect human limits - ensure safe working conditions and provide proper training and protective equipment for handling chemicals and machinery ▪ Address mental health issues in farming communities	**Local Economy** ▪ Support local businesses and create job opportunities in rural areas ▪ Participate in community events and educational programs ▪ Engage in fair business practices with local suppliers and customers		**Worker Protections** ▪ Strengthen labour laws in agriculture sector ▪ Ensure fair wages and safe working conditions for farm workers ▪ Address issues of forced labour and child labour in agriculture

Cultural Heritage

- Preserve traditional farming knowledge and practices
- Respect and protect culturally significant landscapes and species
- Engage with indigenous communities to incorporate their agricultural wisdom

Consumer Safety

- Implement rigorous food safety protocols
- Provide transparent information about farming practices and food origins
- Minimise the use of harmful chemicals in food production

Migrant Worker Rights

- Implement policies to protect and support migrant agricultural workers
- Ensure equal access to services and legal protections for migrant workers

Gender equity

- Support the leadership of women and minority genders in agricultural organisations and policy-making
- Ensure equal access to agricultural resources and services for farmers of all genders.
- Address cultural barriers that limit women and trans people's participation in agriculture
- Support research on gender dynamics in farming systems

Youth in Agriculture

- Develop programs to attract and support young farmers
- Integrate agricultural education into school curricula
- Create mentorship programs connecting experienced farmers with youth
- Implement policies to make rural areas attractive for young people

	Boundaries and Limits	A Duty of Care	Sufficiency	Equity and Democracy
Fair markets and livelihoods	**Resouce allocation** ▪ Incorporate the true environmental costs of goods and services, leading to changes in pricing mechanisms **Polluter pays** ▪ Extended producer responsibility laws require manufacturers to account for the entire lifecycle of their products **Job loss and creation** ▪ Policies setting caps on resource extraction may see transitions to new forms of employment **Trade restrictions** ▪ Changes in trade agreements, potentially including environmental standards or tariffs on high-emission goods **International treaties** ▪ Honour international treaties that limit environmental harms and/or unfair market practices	**Global awareness** ▪ Participate in fair trade practices that support farmers in developing countries	**Fair Livelihoods** ▪ Ensure farmers can earn a living wage from sufficient (rather than maximum) production ▪ Develop markets that value quality and sustainability over quantity ▪ Implement policies that protect small-scale farmers from market volatilities ▪ Develop fair trade agreements that respect sufficiency principles **Alternative Economic Models** ▪ Explore community wealth building models in agriculture ▪ Implement time banking or other alternative exchange systems for agricultural labour and products **Circular Economy** ▪ Develop systems to recycle and upcycle agricultural by-products ▪ Encourage use of agricultural waste for energy production/ as inputs for other industries	**Market Infrastructure** ▪ Develop inclusive market systems accessible to small-scale producers ▪ Support farmer cooperatives and collective marketing initiatives ▪ Implement policies to prevent monopolistic practices in agribusiness **Price Fairness** ▪ Establish fair price mechanisms for agricultural products ▪ Support direct marketing channels to increase farmer's share of final product value ▪ Implement policies to stabilise prices and protect farmers from extreme market fluctuations **Credit Access** ▪ Develop inclusive financial services for small-scale farmers ▪ Support alternative lending models like micro-finance and peer-to-peer lending ▪ Implement policies to reduce discrimination in agricultural lending

				Risk Management ▪ Develop equitable crop insurance programs ▪ Support community-based risk-sharing mechanisms **Fair trade** ▪ Support fair trade certification programs
Ownership/transfer of knowledge		**Knowledge Transfer** ▪ Mentor young farmers and facilitate intergenerational knowledge exchange ▪ Document and preserve traditional and innovative farming practices ▪ Support agricultural education and research for future advancements	**Farmer Training** ▪ Educate farmers on sufficiency-based production methods ▪ Provide training on diversified farming systems and risk management **Consumer Education** ▪ Raise awareness about the impacts of overconsumption ▪ Promote understanding of seasonal and local food systems	**Recognise Diverse Knowledge Systems** ▪ Recognise and value traditional and indigenous agricultural knowledge ▪ Integrate diverse knowledge systems in agricultural research and policy ▪ Protect farmers' rights to save, use, and exchange seeds **Open Access** ▪ Promote open-access agricultural research and data ▪ Support citizen science initiatives in agriculture ▪ Develop community-based participatory research programs
Climate impact	**Emissions Caps** ▪ Set sector-specific GHG emission limits ▪ Implement regulations on methane emissions from livestock	**Mitigation** ▪ Implement practices to reduce greenhouse gas emissions from agricultural activities		**Climate Justice** ▪ Implement policies to support small-scale farmers in adapting to climate change

	Boundaries and Limits	A Duty of Care	Sufficiency	Equity and Democracy
	Carbon Sequestration ▪ Establish minimum requirements for carbon sequestration practices	▪ Increase carbon sequestration through improved soil management and agroforestry ▪ Transition to renewable energy sources for farm operations **Adaptation** ▪ Develop resilient farming systems that can withstand climate variability ▪ Participate in climate change research and monitoring ▪ Share knowledge and resources to help other farmers adapt to changing conditions		▪ Ensure equitable distribution of resources for climate change mitigation and adaptation
Technology and innovation	**Automation Limits** ▪ Set guidelines on the use of AI and robotics to ensure job preservation ▪ Establish regulations on data collection, ownership and use in precision agriculture **Guidelines and Boundaries** ▪ Set clear guidelines on GM use and containment ▪ Establish buffer zones between GM and non-GM crops		**Appropriate Technology** ▪ Focus on technologies that enhance sufficiency rather than overproduction ▪ Develop low-tech, accessible innovations for small-scale farmers ▪ Implement open-source platforms for sharing agricultural innovations **Data and Monitoring** ▪ Use data analytics to match production with actual needs	**Digital Access** ▪ Ensure equitable access to digital agricultural technologies and information ▪ Implement programs to improve digital literacy among farmers ▪ Address the digital divide between rural and urban areas **Data Sovereignty** ▪ Develop policies to ensure farmers maintain control over their agricultural data

			▪ Implement real-time monitoring systems to prevent overuse of resources	▪ Support development of farmer-owned data cooperatives
Genetic modification (including gene editing)	**Limited Scope** ▪ Ensure GM addresses critical food security or nutritional needs, rather than being used for aesthetic traits or minor conveniences ▪ Using the least amount of genetic modification necessary to achieve the desired outcome. This might mean preferring cisgenic approaches (using genes from the same or closely related species) over transgenic ones when possible	**Genetic Responsibility** ▪ Ensure responsible use of genetic technologies in plant and animal breeding ▪ Preserve genetic diversity in crops and livestock ▪ Respect farmers' rights to save and exchange seeds **Monitoring** ▪ Ongoing monitoring and reivew of the performance and impact of GM crops and foods **Polluter Pays** ▪ Requiring GMO developers to establish funds for potential future remediation efforts ▪ Implementing strict liability for any ecological damage caused by GMO crops ▪ Mandating insurance coverage for potential environmental impacts ▪ Establishing clear guidelines for assessing and quantifying environmental damage from GMOs	**Ongoing Reassessment** ▪ Regular reviews would ensure that GM crops continue to meet genuine needs and that no better alternatives have emerged **Alternatives Assessment** ▪ Regulators to require a thorough exploration of alternatives, including organic, agroecologicla and traditional methods, Improved farming practices, changes in food distribution systems **Demonstrated Need** ▪ Existing crop varieties or farming methods are insufficient to meet local food security needs. ▪ The proposed GM crop provides significant benefits in terms of nutrition, yield stability, or resilience to climate change that cannot be achieved through conventional breeding or other agricultural practices	**Open Access** ▪ Open-source GM technologies, ensuring that the benefits are widely accessible rather than controlled by a few large corporations. **Local adaptation** ▪ Instead of developing universal GM crops, the emphasis would be on creating varieties tailored to specific local needs and conditions

Policy and governance	**Monitoring Systems** ▪ Develop comprehensive monitoring networks for soil health, water quality, and biodiversity ▪ Implement satellite monitoring for land use changes **Penalties and Incentives** ▪ Establish clear penalties for boundary violations ▪ Create incentive systems for staying well within established limits **Adaptive Management** ▪ Regularly review and adjust limits based on the latest scientific data ▪ Implement feedback mechanisms to allow for ▪ local adaptations within global limits	**Transparency** ▪ Provide clear information about farming practices, animal treatment, and environmental impacts ▪ Engage in open dialogue with consumers and stakeholders ▪ Participate in certification programs that verify sustainable and ethical practices	**Sufficiency-Oriented Policies** ▪ Implement policies that prioritise sufficient production over maximisation ▪ Develop indicators of agricultural success that go beyond yield and profit ▪ Create incentives for farmers who practice sufficiency-based agriculture	**Participatory Governance** ▪ Establish farmer-led advisory boards for agricultural policy development ▪ Implement participatory budgeting for agricultural programs ▪ Create platforms for community input on local agricultural development plans **Stakeholder Engagement** ▪ Ensure representation of diverse farmer groups in agricultural organisations ▪ Facilitate dialogue between farmers, consumers, policymakers, and researchers ▪ Support farmer-to-farmer knowledge exchange networks

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