FINAL REPORT

AI Agroecological Intelligence

Establishing criteria for agroecologically appropriate technology

A BIGGER CONVERSATION

Agroecological Intelligence
Establishing Criteria for Agroecological Appropriate Technology (Final Report)

Text Ayms Mason, Pat Thomas and Lawrence Woodward
Additional analysis Jane Ricketts Hein

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INTRODUCTION

Farmers have been innovating since before it was called innovation. For much of that time, innovation in agricultural systems and practices has been built around – and worked within – ecosystem boundaries. As the pace of technological development has sped up, the goals of innovation have become increasingly more controlling, disruptive and disconnected from these boundaries.

Today, the technological advancements of the Fourth Industrial Revolution are advancing ambitions to reconstruct our concepts of natural and nature.

A 2019 UK government policy paper, *Regulation for the Fourth Industrial Revolution*,[1] describes this revolution as:

> *"Characterised by 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."*

It further notes that, "*innovation increasingly blurs the lines between sectors and cuts across traditional regulatory boundaries*" as well.

The UK government's industrial and innovation policies sit at the heart of its economic vision for the UK – and heavily influence its approach to agriculture. But how do the ambitions of the Fourth Agricultural Revolution,[2] or Agriculture 4.0, shape the narrative of agriculture? Do they free us from or lock us into business-as-usual?

Change...but in what direction?

It is widely agreed that the dominant global agricultural system is a social and environmental failure and that the way we farm needs to change.[3]

In conventional farming, which is built on high inputs of fertilisers and pesticides and enhanced plant breeding and seed production, machines have helped to increase the output capacity of the land. But, for these gains, we have paid a high and unsustainable cost – soil degradation, air and water pollution, loss of biodiversity, loss of farmer autonomy, the demise of small diverse farms in favour of consolidation, commoditisation and industrialisation, the displacement of fresh foods with nutrient-poor ultra-processed foods and the disruption of local and regional food webs.

As a result, rhetoric about 'transforming' agriculture has become all too common. But there are competing versions of what this transformation will look like, who or what will drive it and what the endpoint will be.

At best what we know about agriculture and how it intersects with environment and society is partially understood and, too often, proffered solutions are filtered through gauzy and misleading concepts like "feed the world", "working with nature", "carbon farming", "protecting biodiversity", "sustainable intensification" and, most recently, the mantra of "public money for public goods".

In the search for a way forward, two main paradigms have emerged.[5]

Sustainable intensification envisions producing more crops and livestock while making more efficient use of inputs and a range of new technologies to optimise production on a minimised land base. This approach is often referred to as 'land sparing'.

In contrast, the agroecological approach aspires to work with ecological processes to manage agricultural systems and land use by replacing (as far as possible) synthetic inputs and minimising

external inputs. This approach is often referred to as 'land sharing'.

There are several variations on these perspectives, but all of them claim some focus on aspects of ecology, biodiversity and sustainability, and there is some overlap at the level of agronomic techniques and inputs. Even so, there are often opaque but significant differences about structures, goals and consequently, pathways – including technological ones – to achieving them.

Which way forward?

Of the two paradigms, sustainable intensification is the one receiving the most investment and the lion's share of the political and mass media attention.

It's difficult to overemphasise how deeply embedded the overarching, technology-focussed narrative of the Fourth Industrial Revolution has become across all aspects of policy, including farming and food. The UK government's Industrial Strategy (now the Build Back Better plan)[6] and its Innovation Strategy[7] are built around it. The NFU's Achieving Net Zero strategy[8] depends on it. The National Food Strategy[9] also had a strong focus on technology as a fundamental driver of sustainability.

Despite the enthusiasm of all these prominent organisations, it is uncertain whether farmers themselves, and agroecological farmers in particular, accept this narrative.

Agroecology – rooted in cyclical systems, functional biodiversity, resilience and ecological efficiency; and built on values of justice, equity, knowledge sharing and community-based governance – has traditionally been seen as low-tech with no or limited external inputs. As such, the values on which it is based are distant and disconnected from those of Agriculture 4.0.

In truth, the low-tech characterisation has not been wholly true for some time and in recent years, a range of new technologies claiming to fit within ecological and low-input systems approaches, have begun to emerge, posing several fundamental questions for agroecologists.

In his book, *English Pastoral – An Inheritance*,[10] farmer and author James Rebanks highlights how difficult it can be to find answers:

> *"There were profoundly important questions about the potential effects of each new technology which it was nobody's job to ask or answer. There was no mechanism for farmers or ecologists to judge whether a technology or new farming practice was on balance a 'good' thing or a 'bad' thing, and we didn't really know when we had crossed the invisible threshold from one to the other."*

What is "on balance a good thing or a bad thing" is a critical and difficult question for agroecology because it goes to the core of what agroecology is, what values is it built on and how these are expressed in practice and in different geographies. It begs consideration of how these technologies look through the varying lenses of agroecology's different strands and how, and if, these diverse visions and practices can be assessed and managed or regulated.

> *"Those who are heavily promoting technology take the view that it's an answer to everything. They completely fail to see that without a properly functioning environment, everything else falls apart — and we are getting close to the point where that actually starts happening. More technology for its own sake is not the answer. There is technology that can be of use, but it's very much about why you're using it, what you're using it for, and the context in which you operate it — that's what we need to focus on from here on"*
>
> **Pasture for Life Workshop**

About this project

The Agroecological Intelligence project brought together agroecological farmers and growers in the UK for a series of in-depth discussions about the role of technology in their farming systems and the main factors at play when making their decisions.

It evolved out of an increasing awareness of the tensions, conflicts and inequities between the competing versions of 'the way forward'. These tensions are apparent across the board, but are particularly stark when it comes to agricultural technology choices.

Key Takeaways

- Project participants were not inherently anti-technology nor anti-innovation. But they were suspicious of top-down, developer driven technology which they perceived as removed from their interests and challenges.

- They were critical of the narrative that technology is the primary way of addressing sustainability challenges. They felt this narrative distracted from the wider reforms needed for a more sustainable, fair and resilient food system.

- Many participants were already using 'new' technology – such as smartphone apps, virtual fencing and data analysis – effectively. Since one of the goals of agroecological farming is to lower inputs of all kinds, this translated into a questioning, 'techno-minimalist' attitude, towards more complex high technologies.

- There was a strong belief that improvement to existing technologies and lower tech alternatives that can be repaired, reused, shared and/or re-purposed was important and should be considered "innovative".

- Participants were divided on whether technology was "values neutral" – though most leaned toward believing it was not. For many it was important to understand embedded values in any technology and whether these aligned – or not – with agroecological values.

- Most thought that policies and investment in technology was not values-neutral and not aligned to the needs of farming communities in general and agroecological farmers in particular. There was a concern that think tanks, developers and entrepreneurs have a disproportionate influence in shaping notions of innovation with potentially adverse implications for land use, rural structures, environment, food quality, labour and employment and farming communities, as well as democratic governance and the quality of public benefits and services derived from agriculture.

- Most believed that agritech developers had a responsibility to embrace whole systems, consider the appropriateness and the consequences of their innovations – and that this should involve input from agroecological farmers and growers at the earliest possible opportunity, preferably at or before the development stage.

- Basic criteria to help guide agroecological practitioners in their assessment of agroecologically appropriate technologies emerged from our conversations. These included practical considerations – whether it is needed and its footprint; philosophical considerations – *e.g.* whether it supports diversity and farmer autonomy; and political considerations - who benefits and whether it was made collaboratively.

- While it's true that there are technologies that can enhance agroecology, it is equally true that there are technologies or applications of technologies that may be so far removed from agroecological principles that they should not be allowed within the system. The agroecological movement needs to take responsibility for establishing where those red lines and exceptions lie.

- Consideration of appropriate technology revealed a pressing need for a discussion about whether agroecology as a whole would benefit from a consistent set of standards – such as those that govern organic – or whether the principles which guide it, which are largely voluntary and variously applied, are enough, particularly in relation to the growth and scaling of the whole movement.

- The UK would substantially benefit from an independent, transdisciplinary knowledge hub for agroecologically appropriate technology, established and run in collaboration with the agroecology movement and sector and universities, institutions and other centres of agroecological excellence and expertise. It should have an ongoing mandate to understand and provide information about technology within robust, ethical and sustainable agroecological systems and to devise "best practice" protocols for the co-creative development, implementation and post-release monitoring on agroecological farms and communities.

- Agroecology's emphasis on whole systems, on an equitable balance between ecological, social and economic aspects of farming and the wider food system presents a challenge for policymakers and complicates policy formation. Nonetheless, allowing agroecological values to inform technological development is both innovative and transformative. Failure to recognise this narrows the range of innovations being considered at a time when we need more, rather than fewer, options

- The UK government's agritech innovation drive is an existential threat to agroecology and its underpinning values.

The project is UK-focussed, a relative rarity in agroecological discourse and its definition of 'agroecological' was broad, encompassing farmers and growers from 'strands' such as the Biodynamic Association, CSA Network, Food, Farming and Countryside Commission, Landworkers' Alliance, Nature Friendly Farmers Network, Organic Farmers & Growers, Organic Growers Alliance, Pasture for Life, Permaculture Network and Soil Association.

Our initial question seemed simple enough: Is it possible to create a criteria for technology use in agroecological systems?

We also began with a couple of assumptions. One was that choices around technology are not values-neutral (an idea we explore more in section 4). The other is that while the agroecological 'umbrella', made up of these different approaches, provides a narrative canopy made up of language and concepts – such as natural, holistic, food sovereignty, social justice, equity, health, small-scale, co-creation and indigenous knowledge – strict allegiance to these concepts likely varies between the different strands, which might make consensus over technology choices and implementation difficult.

"I have an app for everything! Some are about saving time, some are about saving input, some are about preventing a problem which allows more time to manage the farm"

Organic Farmers Workshop

Via survey and in the workshops participants were asked to rank which approaches to farming most aligned with their business and values. Most primarily identified with a specific strand (*e.g.* organic) but also aligned with agroecology.

We were, therefore, interested to see whether, given the diversity of approaches that sit under the agroecological umbrella, it was possible to produce criteria for technology choice that were acceptable to all. In particular, we were interested to see what nuances might arise in relation to these different identities and their approaches to technology choice (see sections 2 and 3).

Over the 18-month course of the project, however, the discussion grew much larger. The question of criteria within a values-based system of farming opened up other exchanges about the nature of agroecology in the UK and how participants saw themselves in relation to the wider movement, and how this influenced their approaches to technology.

It also demanded some consideration of the values underpinning agritech development and the places where these contrast or clash outright with agroecological values.

We sought to identify what trade-offs, if any, might need to be made for agroecology to accept certain new technologies and what structures and processes these require. Aligned to this, we wished to understand what UK agroecological farmers and growers wanted and needed from technology developers and from the government.

We did not find definitive answers to all these things, but we did find many shared values. We also identified some unresolved questions about differences – not just between the individual strands of agroecology but between 'UK agroecology' and agroecology as it is perceived and practiced elsewhere in the world.

What we did find was an eloquent antidote to the agritech hard sell based on deeply held values and an interest in technology that serves those values, but little to no interest in technology that doesn't.

All of these things were explored via a series of virtual and in-person workshops with a core group of 48 farmers and growers around the UK drawn from the various strands. We also conducted three open workshops – at the Organic Growers Alliance Organic Matters Conference 2022, Oxford Real Farming Conference 2023, and the Wales Real Food and Farming Conference 2023 (see Appendix 3).

In reporting on our findings we have used a mixture of direct quotes and precis of the thoughts, opinions and questions expressed during the workshops. Where we believe it is relevant and credible, we also provide context and analysis from other sources, including the existing literature.

These discussions and the opinions expressed by the participants during the workshops form the bedrock of this report and are the basis for the questions that underpin our proposed criteria for technology choices and our framework suggestions for policy and development.

1 WE NEED TO TALK ABOUT TECHNOLOGY

Debates about the place of technology in agriculture and the wider food system are not new. Farmers, scientists, scholars, civil society organisations, businesses and policymakers have been debating the applications and implications of technology use at the intersection of agriculture, environment and food for decades.

What has changed is the pace of technological development and the force of the 'hard sell'. The emergence of highly advanced agricultural technologies, or agritech, as a key driver of new markets has ramped up the level of conflict between the need for system change and the entrenched desire to maintain business more or less as usual for as long as possible.

The hard sell says that farming urgently needs more advanced technologies to become sustainable. In the UK, leaving the European Union (EU), from which it imports 30% of its food[11] and recruits most of its seasonal agricultural workers, has intensified rhetoric about agricultural 'self-sufficiency'. It has also brought to the fore claims that technical fixes can result in increased abundance, efficiency and sustainability and reduce the number of foreign workers needed in fields.

"We need technology. But we need it to help us be good managers, rather than allowing the technology to do the managing"

Future Farming Workshop

The definitions of 'efficient' and 'sustainable' are, perhaps conveniently, never fully articulated. Phrases like net zero, carbon neutral, energy efficient and land sparing often appear alongside descriptions of new agronomic approaches such as smart farming, sustainable intensification, precision farming and nature-based solutions.

These approaches, however, aim for limited change and accept – even reinforce – the existing social, economic, structural and cultural system of food and farming, built on an establishment and agribusiness view that the status quo, with its focus on increasing production and creating new global markets, can carry on indefinitely so long as it can be 'greened' through technology.

Farmers' reluctance to fully embrace the agritech agenda[12] is countered by claims that farming has always benefited from technological innovation and that the transition from the Green Revolution to the Fourth Industrial Revolution[13] – with its roots in what the Organisation for Economic Cooperation and Development (OECD) has termed the "innovation imperative",[14] is a kind of 'natural progression'.[15]

The innovation imperative was not aimed specifically at agriculture but has, nevertheless, been enthusiastically embraced as central to agricultural development and sustainability. As a result, farmers of all types across the world are being heavily lobbied to adopt various agritech 'solutions' that promise to make farming more productive, profitable and environmentally friendly.

These promised benefits are largely speculative and much of the agritech on offer has little to nothing to do with ecological farming practices at all. Even so, the notion that all farmers will adopt – and benefit from – these new technologies is portrayed as inevitable and the fervour around agritech innovation is such that to question it is seen as antagonistic and backward looking.

Seeding new markets, harvesting data

The UK government – much like those in other advanced economies – has adopted an

aggressively pro-innovation stance from which it has been promoting the agritech and associated R&D sectors for the last decade.[16] Much of the focus has been on the claimed potential of these sectors to support the growth of a 'knowledge-based' economy, trading largely in ideas and intellectual property and the collection and sale of data.

"I'm concerned that an awful lot of the tech that's being pushed towards us is essentially a product looking for a market and that it's of more benefit to the manufacturers and the retailers than it is to agriculture"

Pasture for Life Workshop

At the same time, it is widely acknowledged that the government lacks a joined-up and visionary strategy for food and farming.[17] Absent this key strategy, the government's vision for agriculture is, for the most part, linked to its innovation, intellectual property and knowledge-based economy aspirations.

As a result, the growth of technology-focussed markets – research, innovation, intellectual property and capital generation – has been given priority status over the myriad needs of farming and food. Initiatives which purport to improve agricultural, horticultural and forestry productivity in a 'sustainable' way, are often thinly veiled initiatives to support technology development.

The government's *Path to Sustainable Farming Plan*,[18] for example, launched in 2020, supports the purchase of equipment, technology and infrastructure, via initiatives such as the Farming Equipment and Technology Fund.[19]

Since 2021, as part of the Defra and UK Research and Innovation (UKRI) Farming Innovation Programme,[20] the government has announced over £120 million to fund industry-led research and development in agriculture and horticulture in England.[21] Much of this goes to "high growth" agritech businesses[22] – with outcomes measured solely in terms of economic metrics – and to developing new agritech such as robotics and automation.[23] Minister of State for Food, Farming and Fisheries, Mark Spencer noted:

> "*The government stands firmly behind agri-tech innovation as the cornerstone of modern farming practices. By providing opportunities, funding and a supportive ecosystem within the sector, we aim to empower farmers, drive innovation and create a sustainable and prosperous future for agriculture across the UK.*"[24]

To date, UKRI has not been focused on encouraging the development or scaling of agroecological farming, though the latest round of funding suggests a shift towards innovations that drive less tangible outcomes, such as 'sustainability', and encouragement of farmer-led projects. This is positive, but the underlying priority of agritech as the primary economic driver remains.

As agriculture is a devolved area, Defra's agritech focus is restricted to England. However Wales,[25] Scotland[26] and Northern Ireland[27] also have agritech strategies with similar goals.

A little further afield, in the EU, it is the same picture. The 2020 Farm to Fork Strategy – part of a proposed European New Deal that aims to make the EU climate neutral by 2050 – is predicated on the uptake of new technology throughout the farming sector. The strategy notes that:

> "*Research and innovation (R&I) are key drivers in accelerating the transition to sustainable, healthy and inclusive food systems from primary production to consumption. R&I can help develop and test solutions, overcome barriers and uncover new market opportunities.*"[28]

While it is true that the EU's New Green Deal declares an aspiration of 25% of agricultural land under organic farming by 2030,[29] progress toward this is uncertain as half of the Farm to Fork strategy has already been delayed or abandoned.[30]

"The benefits of technology should not be overestimated, and technology should not be relied upon to help reduce either the cost of food or climate emissions. It is a false solution to each and it is this sycophantic belief in technological solutions that has caused both these issues in the first place"

Community Supported Agriculture Workshop

No limits?

Unlike ecology, UK agritech ambitions recognise no limits or boundaries. While the idea of "no limits to growth" is not an articulated policy *per* se

The Agritech Landscape

Farm management software and apps
Farm management software can be accessed and run from a computer or a mobile app and can record, track and analyse a wide range of data related to the day-to-day planning and running of a farm. It can also be used to operate virtual fencing, control animal movement, manage grazing and monitor animal location and movement. It also gives access to market and weather information, peer-to-peer learning groups and financial services.

Data analytics
Data-driven tech enables farmers to uncover hidden patterns and connections in information relating to soil and crop health, irrigation, pricing systems and weather forecasts. Advanced sensor technologies can offer insights into ground nutrient levels and fertiliser needs and autonomously monitor livestock health and welfare in real time.

Digital food hubs
Although not strictly an agricultural technology, e-commerce technologies, which also use data analytics, are transforming how small and medium-scale farmers and food businesses source and distribute food, how consumers access local food and how market vendors negotiate sales. They can also facilitate a shift toward a re-localised food and farming system and farming pattern.

Farm-based hubs can be run by individual farm businesses from a barn or farm building selling direct to customers as well as sourcing other food items from neighbouring farms or nearby food producers such as local bakeries or micro-dairies. ***Off-farm hubs*** typically don't produce anything themselves and concentrate on running sales, packing and deliveries for local producers.

Drones
Several different types of these flying robots are being developed for agriculture. ***Scouting*** and ***crop health*** drones can provide a bird's eye view of fields and are often equipped with sensors to monitor weather, moisture, heat and crop growth. ***Spraying*** and ***spreading*** drones disperse pesticides, fertilisers, cover crops and seeds in calibrated doses. ***Security*** drones can identify pests, predators or invasive plants, contributing to farm biosecurity. Livestock farmers can use drones to locate straying animals.

Robots
Other kinds of robots can perform a range of tasks on farm including: ***Weeding robots*** use artificial intelligence and machine learning to differentiate between crops and weeds, thus pulling the weed without disturbing the crop. ***Harvesting robots*** that can pick soft fruit, top fruit and vegetables are currently in development. These can be programmed *e.g.* to detect and pick only the fruits that are ripe ***Feeding robots*** can be programmed to fill themselves with fresh food several times a day and to provide feed customised for individual animals. ***Milking robots***, or voluntary milking systems, replace all the manual labour involved in milking a herd of cows.

Agricultural biotechnology
In agriculture, biotechnology it is generally taken to mean a range of genetic engineering techniques that can be used to alter the traits and biology of crops, livestock and other organisms. Techniques such as gene editing ('precision breeding' in the UK) claim to produce new plant and animal varieties more quickly than through traditional breeding.

Emerging uses for genetic technologies include biopesticides and microbial inputs, RNAi sprays that switch gene function on and off and gene drives that drive genetic changes through open fields. Lab-grown meat, milk and egg products are also part of the biotechnology spectrum.

Indoor farming
Indoor farming incorporates a number of different technologies, and claims to be able to produce more food on the same amount of (or less) land.

Vertical farming grows vertically stacked layers of plants, such as salad crops, indoors (*e.g.* buildings, shipping containers, tunnels, and abandoned mine shafts) in a controlled environment.

Hydroponics is a method of growing plants indoors without soil, feeding them on mineral salts dissolved in water in a well aerated environment. Crops can be grown year-round. This method is most widely used to produce salad leaves, microgreens and greenhouse crops such as cucumbers, peppers and tomatoes.

Aquaponics integrates aquaculture with hydroponics in a closed loop system that reuses waste water from aquaculture as a natural source of fertiliser for the hydroponic plant system.

it underpins the thinking behind the economic policies of most governments, including in the UK.

This notion was debunked as far back as 1972 in the book *The Limits to Growth* which posited that even with advanced technology, the earth's interconnected resources couldn't support present rates of economic and population growth much beyond the year 2100.

Fifty years on, the conclusions of the report (which has been regularly updated) are as valid as ever.[31]

Despite this, an unquestioning confidence that technological innovation and market signals can benignly shape natural systems by pushing their limits – and ignoring the consequences of doing so – is deeply embedded in the agritech ethos.

For example, in the government- commissioned *National Food Strategy Report, Part 1*,[32] published in 2020, lead author and entrepreneur Henry Dimbleby, once described as the UK's 'food czar', set out his vision of 'food-topia':

> "*My ideal Food-topia would contain organic farms as well as solar-powered high-rise greenhouses growing fruit and vegetables in cities; rewilded landscapes, as well as traditional upland farms…I want weed-picking robots and blight-spotting drones to become as much a part of the landscape as cattle from local native breeds restored to their natural environment … [and] proteins fermented in vats fed by solar power. Instead of using pesticides, we will use photons of light of a specific frequency to switch on the immune systems of crops as a natural defence against harmful diseases.*"

He has since gone on to form a UK-based investment firm, Bramble Ventures,[33] which aims to champion "pioneering companies" that have the potential to "*grow into large profitable enterprises… maximising the beneficial impact on the global food system*" and helping "*UK entrepreneurs deliver what politicians have not yet been able to*".

Similarly, the think tank RethinkX – run by "*a team of technology, finance and market sector experts*"[34] – promotes the idea of food production without the limitations of land or farmers. In its report *Rethinking Food* and Agriculture 2020-2030[35] – ideas from which are woven throughout the National Food Strategy – it argues that:

> "*Modern production, however, has seen and will continue to see job creation for fermentation farmers, bioengineers, protein engineers, metabolic engineers, cell biologists, computer scientists, IT workers, food scientists and designers, nutritionists, and other similar professions…*"

This new agritech landscape is changing rapidly and while the options may seem varied, it is, at heart, a combination of digital technology and AI (artificial intelligence) generated analysis and/or advice. It encompasses a range of machines and technologies including sensors, robots, drones and other devices to monitor crops, livestock, soil, ground temperature, water levels and weather.

> *"A lot of technology is a distraction from an unfair economic system where labour is pushed to the periphery"*
> **Landworkers' Alliance Workshop**

These devices collect and transmit real-time data through mobile applications, network-linking edge devices or alternative channels. Most modern machinery is also connected to the internet and often remotely controlled.

At first glance, these visions of the future may seem intriguing. But sit with them long enough and uncomfortable connotations emerge, and the clash of aims and values in these mash-ups of the old and the new, the agroecological and the industrial, becomes more obvious. So does the question of whether an equitable coexistence between such deeply contrasting values systems and business models is possible or practical.

Transition pathway or Trojan horse?

A wider discussion of agritech's place in the future of agroecology (especially one led by farmers) has been slow to get started, but is now emerging.

A 2021 report, *AgroEcoTech: How Can Technology Accelerate a Transition to Agroecology?*[36] commissioned and published by the Soil Association, sought to identify technologies which "*represent the greatest potential opportunities for agroecology" and those which "demand tight governance to minimise risks*".

With the right governance, it noted, these "new" and "burgeoning" technologies could "*influence a transition to agroecological farming*".

It considered a range of technologies claiming to be climate smart and nature friendly, including:

- Production technologies; including Smart Agriculture, robotics, genome editing, novel biological controls and inoculants.

- Technologies for impact monitoring; *e.g.* remote sensing of environmental impact, big data, analysis and environmental footprint accounting.

- Supply chain technologies; including digital food hubs and dynamic food procurement, smart technology for food consumption

- Technology influencing agricultural demand; including cellular agriculture, controlled environment agriculture, bioenergy production

Coming from an organisation that promotes organic production and principles, the range of technologies considered in a favourable light may have seemed surprising. The concept of an "AgroEcoTech" – suggesting a seamless merger between agriculture, ecology and technology – also contained echoes of Henry Dimbleby's all-inclusive "food-topia".

Leading UK agroecology group the Landworkers' Alliance (LWA), which took part in the review process for the report, expressed "*serious misgivings*" at its "*lack of social and political analysis*".[37] At A Bigger Conversation we also had questions,[38] some of which informed this project.

All of these technologies fit comfortably and prominently in the sustainable intensification paradigm and the narratives of, for example, the EU's *Farm to Fork Strategy*[39] and the *FAO's Strategic Framework for 2022-31*.[40] This latter strategy is heavily focused on biodigital and biogenetic solutions (shorthand for genetic engineering, synthetic biology and related technologies). In highlighting the importance of these "*innovative technologies*", FAO was explicit in calling agroecology one of the "*entry doors*" to support the development of (these) emerging sectors and entry into "*the wider farming system*".

In response to the LWA's concerns, the authors of *AgroEcoTech*, Cumulus Consultants, said their aim was to "*review the technology and not the broader social context of agroecology*" the reason being that social concerns are "*not only related to technology but many larger issues such as economics, labour, land rights, and broader societal issues and policies*" which are "*intertwined with subjectivity*".[41] Several modelling studies of agroecological scenarios, such as IDDRI's *Ten Years for Agroecology*,[42] also do not include social movement aspects. This means that crucial aspects that determine technology choice and therefore investment, regulation and other structural issues – and which determine the scope, shape and speed of transition – are removed from the discussion.

These issues run deep. The values-based social context of agroecology is fundamental to its definition and to the radical change from business-as-usual farming that it represents.

How is it, then, that corporate-controlled artificial intelligence, energy gobbling data collection and storage, machinery that can't be repaired on farm, robots that replace human labour, disruptive technologies such as genetic engineering and the 'food without farmers' model of synthetic biology – can be seen as compatible with agroecology? How will we define the role of technology in agroecology – and who gets to define it? To what extent do these differing views of the future of farming reflect fundamental conflicts of world views and values? What is meant by "an agroecological transition"?

> *"I identify strongly with agroecology because of the social and political elements, such as food justice. I've always felt uneasy that organic is pushed into the niche, because I want to be part of a food system which grows for everyone"*
>
> **Landworkers' Alliance Workshop**

These are not academic questions. They are crucial to the justification for and shape of any policy, regulatory regime, consumer information and financial support for technologies in agroecology. There is a legitimate discussion to be had about technology in agroecology but, too often, the wrong people – the czars, gurus, think tanks, disrupters, developers and entrepreneurs – are leading it and the implications for land use, rural structures, environment, food quality, labour and farming communities are glossed over in the race to grow new technology markets.

The voices of farmers and other legitimate stakeholders, for now, are not carrying very far.

2 VOICES FROM THE FIELDS

The aim of this project was to listen to and report on what agroecological farmers and growers had to say – about themselves, about agroecology, about their values and choices. What we heard was a story of a strongly values-led movement, united in some places but divided and with differing practices and priorities in others. It was also evident that agroecology in the UK reflects the unique context of UK farming and farmers.

A strong thread that united the participants was the rejection of high-input, intensive industrial agriculture and a sense that they were working to create a different food system. There was a palpable sense of pride from farmers and growers about what they were doing and how that was contributing to an equitable and sustainable approach to farming, now and in the future.

Across the strands there was a clear desire to foster ***connectivity.*** Many participants said they valued agricultural systems that were more than merely systems of production.

These connections include the natural elements of the land, soil and wider nature; workers (including themselves); neighbours, customers and wider society; nutrition and nourishment; fairness in society, particularly regarding access to good food and nature; dignity and enjoyment in work; self-worth and good mental health; and spirituality.

"I feel very comfortable identifying as an agroecologist. I feel like it can encompass a whole range of practical farming techniques which a lot of us subscribe to. But I also feel like it is quite a loose term and probably needs refining and that there is a danger of being co-opted by Big Ag"

Community Supported Agriculture Workshop

The connection between nature and agriculture was also raised by some participants. While ***food production*** – the 'agro' part of agroecology – was the main aim of farm businesses, doing this with ***a minimum of harm to nature*** was vital. One respondent characterised this as "a beneficial manipulative relationship".

In addition to avoiding damage to, or preferably improving, the soil, air, water and the natural environment, it was felt that agroecological production should address ***social issues*** such as the provision of fulfilling work opportunities, sufficient remuneration, the production of nutritious food, consideration for future generations, and supporting other local businesses.

Some of these elements lead to further questions such as what a 'sufficient' income might mean, and recognition that this would vary according to individual lifestyles and situations. It would also affect what we leave to ***future generations*** in terms of a sound financial footing, biodiverse farmland and, ideally, a more stable climate.

Whether you call this 'holism' or 'wholism' (referring more to whole systems), for many, it is this all-encompassing, ***'wholistic' approach*** – rooted in whole system thinking and beliefs – that attracted them to agroecology in the first place. For others the attraction was that it was ***collegiate*** rather than competitive, with practitioners sharing information, teaching and encouraging others.

For others it was the combination of the ***political and scientific*** that attracted them to agroecology. As such, there was an interest in research and science coupled with a frustration that government and funding organisations, showed little interest or investment in whole systems agricultural research. Part of this whole systems approach involves

long-term thinking based on observations of nature and natural processes which many felt was important. Though, as the discussions progressed, we observed some tension between the concepts of what we owe to the future and what is necessary to maintain a viable business in the here and now.

Participants, for the most part, expressed ***satisfaction with the scale of their farms*** and businesses and were interested in ways of maintaining a viable business at their chosen scale.

Some expressed the view that the idea of scaling up to "feed the world" was largely an industrial or corporate concept and that their operations were not intended, nor designed, to feed the world. Instead, their goals were to improve their land and soil and the quality of their food, and therefore their service to the local community and the environment. Inasmuch as this is true, ***a sense of place and/or belonging*** is an important modifier to the notion of 'scaling' agroecology.

Inclusivity also emerged as a strong theme and the range of approaches within this broad movement was generally thought to be a strength.

Participants felt it offered room for farm businesses to find a way of working according to their priorities and with a community of people that suits them best. For example, an owner of a 2-acre vegetable plot may consider becoming a CSA or running a box scheme, which may be biodynamic, organic, permaculture-based or none of these.

However, there was also a recognition that, while autonomy was important, a lack of agreed principles across the different strands could lead to practices in one area that can cause difficulties for others.

For instance, the herbicide glyphosate – used by many regenerative farmers as part of the effort to reduce or avoid tillage – is problematic for many other strands of agroecology and, indeed, for some other regenerative farmers.

"If you look at the genuine definition of agroecology — which involves science, ecology and the social movement and people — then we're part of the agroecological movement. The danger is that it loses that definition"

Organic Farmers Workshop

The UK context

'Agroecology' is usually described as a scientific discipline, an agricultural practice and/or political and social movement.[43] Where that emphasis falls can change and take on different meanings in different geographies and cultures.[44, 45]

Since this was a UK focused project, we were keen to understand what agroecology meant in the UK context. Existing literature, for instance, highlights some notable differences between the UK and Latin American or African countries.

"I have a deep-seated affinity with nature, and that connection is an important part of why I farm"

Nature Friendly Farming Network Workshop

For one thing, the UK largely rejects the idea of a peasantry, which is at the heart of agroecology elsewhere in the world. There is also a much smaller rural population, with an increasing tendency towards bigger farms and a different balance of local and national food supply markets. This means that, for many in the UK, agroecology does not have the same deep emphasis on social justice that it does in some other regions and is, instead, more focused on the science and the practice.

As Lampkin *et al*[46] argue:

> *"[I]n regions where large farms are the norm, as in parts of the UK and Germany, it can be argued that an agroecological approach needs to engage with a farming structure that reflects the cultural and social characteristics and heritage of the region, rather than to attempt to re-impose a peasant farming system reflecting other human cultures."*

This was apparent in our discussions as well. In our first free-flowing workshops about technology development and choice, the issue of social justice and equity was rarely raised, although it was explored further later in the programme, through semi-structured discussions.

It should, nevertheless, be noted the Landworkers' Alliance in the UK does not recognise the concept of a "UK agroecology" and embraces the concept of a peasantry and adheres to the definition of agroecology which emerged from the global south in the 1960s and came to the fore when La Via Campesina formed in the 1990s.

It argues that the need for land reform and food sovereignty in the UK is just as great as elsewhere.

Some of our workshop participants suggested that the implementation of agroecological standards could be a way to provide clarity and unity around social justice. But this comes with its own challenges since the food sovereignty-focussed agroecological movement views standards as inherently undemocratic and top-down rather than grassroots based (see more on this in section 4).

"Biodynamic is about the whole – the plants, the animals, the whole connective tissue"

Biodynamic Workshop

The agroecological 'umbrella'

Despite the differences between the strands, agroecology has become an umbrella term. It can be and is being used interchangeably with words like organic, biodynamic, permaculture, nature friendly, pasture-fed and regenerative.

There are agreements and parallels between most of these approaches, and while this project uses the 'umbrella' terminology, we recognise that the metaphor can be problematic. It runs the risk of blurring important distinctions between each of the strands, may serve to de-emphasise the sociopolitical nature of agroecology.[47] This can open space for greenwashing and co-option within corporate culture, as well as the global policy and funding sphere.[48]

On the other hand, drawing the strands together demonstrates the growing momentum behind the need for agricultural transformation and the values that are driving this.

Most participants primarily identified with a specific strand (e.g. organic) but also aligned with agroecology and almost all acknowledged being part of a broader agroecological movement Whilst accepting the idea of the agroecological umbrella, some participants were keen to draw attention to the uniqueness of their own strands and were critical of the approaches of other strands.

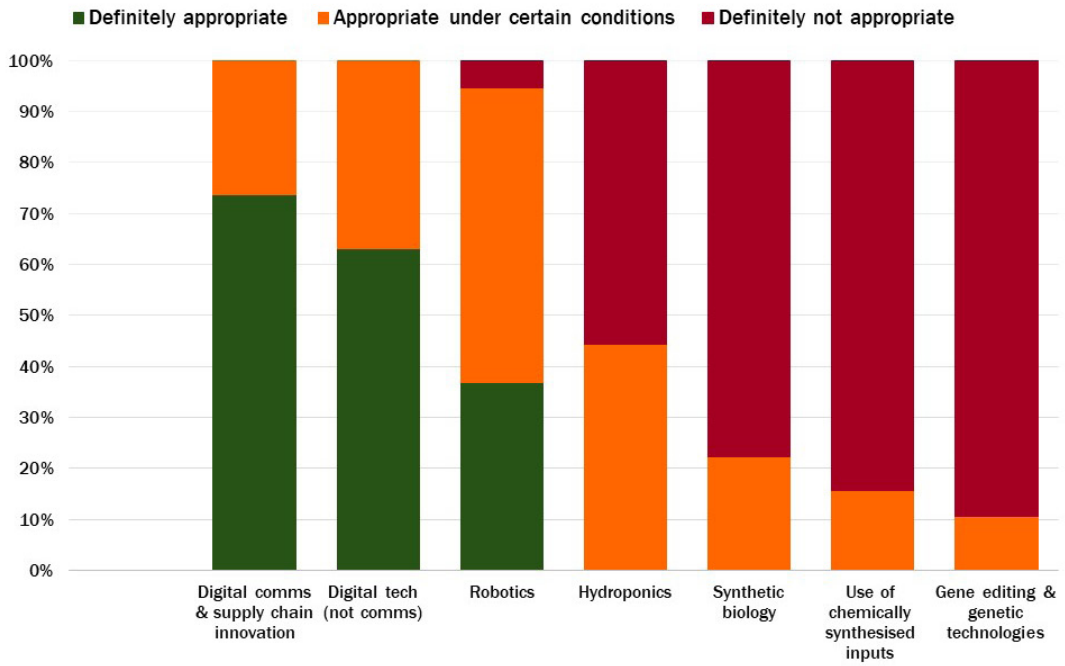
For example, there was a generally held view that regenerative farming – with its particularly vague definition – has already been co-opted by industry and corporations and has lost much of its meaning. Views varied about the extent to which this diluted or distorted the power of the movement.

On balance, there was more that united participants than divided them. This suggested a foundation upon which the movement can continue to refine and define itself and build its own narratives around how technology can support it.

How important is appropriate technology?

In exploring the idea of common criteria for technology, several themes emerged.

Chart 1 - Which Technologies are 'Agroecologically Appropriate'?



The agroecological practitioners we spoke to were critical of the narrative that technology is the primary way of addressing sustainability challenges. The majority felt it was top-down and developer-driven and existed to reinforce the institutional, technical and economic "lock-ins"[49] – larger farms, monocultures, the global marketplace and further intensification – of business as usual.

This is not to say they were inherently anti-technology. Many felt that technology could be helpful if it was designed with and for agroecological practitioners and could help them farm according to their values. But they also believed it should not be a distraction from the wider systemic challenge of reforming the food system.

"I'm always observing and think it is incredibly important. It's all about having a very long view – which is difficult when we feel that time is pressured and running out"

Organic Growers Workshop

Participants said they were aware of at least some, of the science and technology that has been put forward as supportive of agroecological farming approaches for example small robots,[50] data collection and modelling,[51] cooperative learning and mentorship[52] food network monitoring[53] knowledge diffusion[54] the solidarity economy[55] and citizen science.[56]

They nevertheless felt that technology was only one part of what was needed for a wider-scale transition to agroecological farming. In response to one of our surveys, for instance, one participant reflected:

> "*The movement towards agroecological farming does not exist solely in an economic vacuum where all that matters is profit margins and bottom lines. More often than not, there is a strong cultural community, developed over many generations, entwining a certain way of doing the work with the preservation of a language, culture and tradition. Newer entrants into agroecological landwork often have arrived at this occupation through a desire to be part of an ecological solution to the problems of climate change and biodiversity loss, as well as seeking better health, both physically and mentally, through the cultivation of better, healthier food. Equally there is a turning away from working in meaningless or climate damaging jobs to work that is fulfilling on an emotional and spiritual level and thus what outsiders might see as repetitive, boring jobs could well be experienced as meditative and grounding by the landworker and mechanisation might bring little benefit, as it is not solely profit which is sought.*"

There was a broad agreement that the creation of a more sustainable, fair and resilient food system requires reductions in on-farm inputs, an increase in biodiversity, the creation of alternative – more local – supply chains and food markets and a fundamental shift in our understanding of our relationship to each other and to the earth.[57]

Participants recognised that dietary shifts – e.g. less but better quality meat and dairy, more local procurement and greater emphasis of fresh as opposed to processed and ultra-processed foods – will be necessary[58] and that tackling inequality and food poverty[59] will be essential to secure an agroecological future.

But there was also a concern over the loss of individual knowledge, which may come with reliance on autonomous machines and computer analysis, and the loss of external knowledge resources.

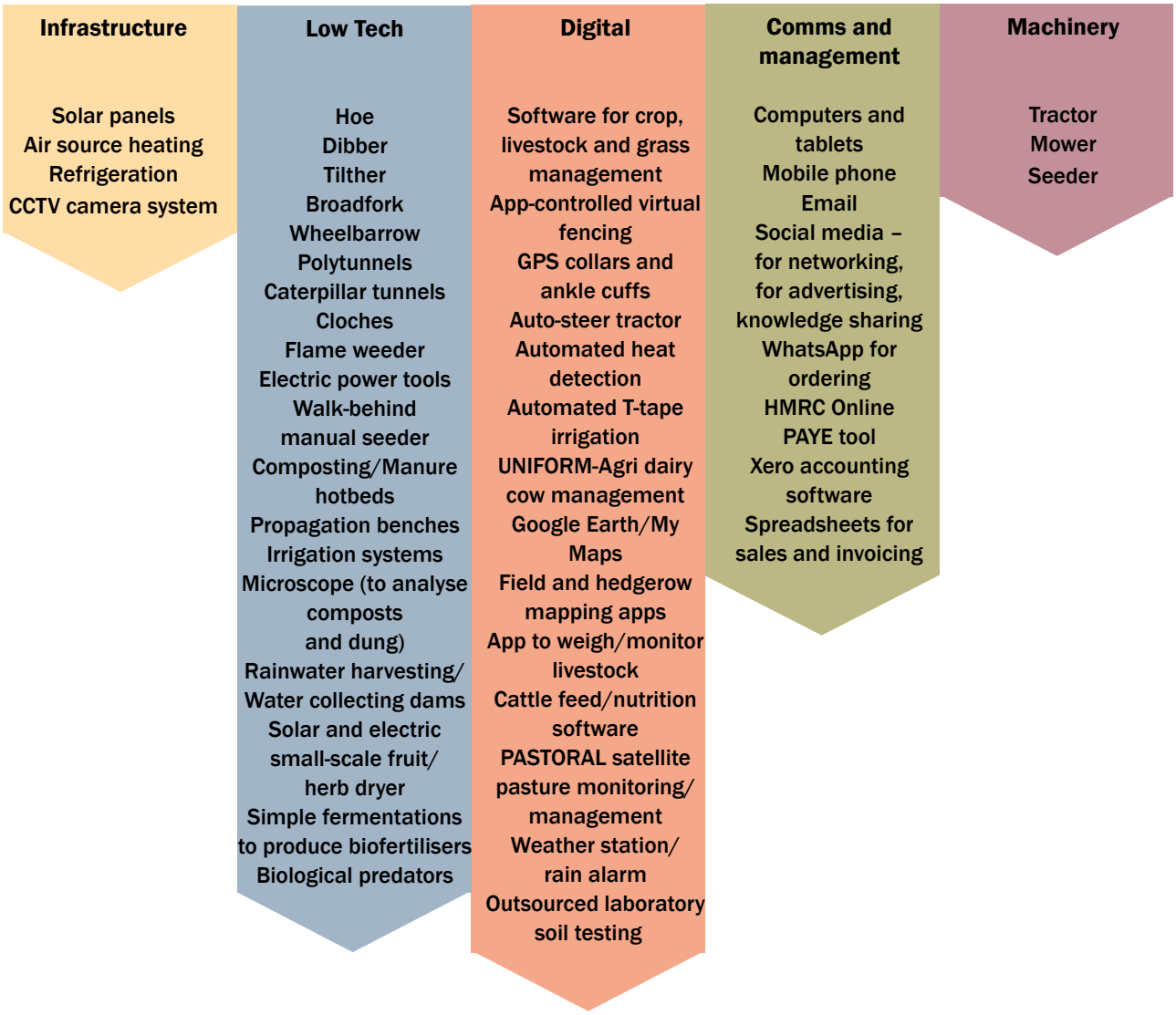
Several participants mentioned difficulty in finding information and resources on alternative or historical low-tech approaches to farming. Indeed, critics suggest that over-reliance on AI-generated information could lead to a kind of "knowledge collapse",[60] informally defined as "*the progressive narrowing over time of the set of information available to humans*".

"If the satellite technology to measure the biomass of grass in a field means you lose the skill to do this for yourself then I think that would be a retrograde step"

Organic Farmers Workshop

Both knowledge collapse and a narrowing of available information resources have implications for ownership of knowledge, which in turn relates to entrenched power structures within agriculture and agritech. We could not accommodate a detailed consideration of all these issues and, of course, the level of knowledge and interest varied, but these themes were a consistent backdrop.

Chart 2 - Which Technologies Were Participants Using?



Commonly used technologies

Many of the farmers and growers we spoke to were already using some forms of technology.

Every one used a smartphone (although some had reception issues on-farm), often with a variety of apps for measuring, monitoring and communication – ranging from software to manage fields and cropping, through to apps for turning electric fences on and off, to WhatsApp and social media for communicating with other workers and/or customers (see Chart 2, above).

Beyond that, the nature of the technology already in use varied considerably depending on the type of farm.

Smaller vegetable-growing operations tended to rely on lower-tech innovations such as hand tools, irrigation systems and polytunnels. Several of the livestock farmers we spoke to were using animal management technologies, such as GPS collars, satellite technology for measuring pasture and cow health ankle cuffs.

Use of machinery in some form was widespread – with a leaning towards older, and smaller, tractors and mowers, but also some use of auto-steer technology driven by satellite-based positioning systems and complex algorithms.

> *"Technology that takes away sovereignty of the human does not serve agroecology"*
> **Landworkers' Alliance Participant**

Older machines were valued because they were repairable on the farm or in the local garage, and thus can have a longer life, and the smaller size made them more suitable for some farms. However, it was recognised that age can also mean they are less fuel efficient and more polluting.

While participants were interested in emerging

technologies, one of the goals of agroecological farming is to lower inputs of all kinds and this generally translated into a cautious and questioning attitude to newer agritech.

Consequently, the farmers and growers we spoke to expressed a 'techno-minimalist' view, not dissimilar concept to that developed by Cal Newport, Associate Professor of Computer Science at Georgetown University, Washington DC.

In his book, *Digital Minimalism*,[61] Newport, a founding member of Georgetown's Center for Digital Ethics, defined the concept as a "s*elective and intentional reduction in digital technologies in everyday life*". He notes:[62]

> "*Digital minimalists see new technologies as tools to be used to support things they deeply value – not as sources of value themselves"; they reject the idea that "offering some small benefit is justification for allowing an attention-gobbling service into their lives, and are instead interested in applying new technology in highly selective and intentional ways that yield big wins*."

Of course, you don't have to be an agroecological farmer to buy into this; many other kinds of farmers will too – though what minimalist means in relation to "big wins" is likely to be context specific.

Capital asset rich and simplified output farms see value and benefits in a different light to asset poor and highly diverse output ones. Yet they all might be called "techno-minimalist". With this in mind, it was interesting to consider what technology participants wanted to use (see Chart 3, p.19).

"The nature of what we need to feed ourselves is right there before our eyes, there is no reason to mess with it"

Organic Growers Participant

Though, once again, many participants were keen to stress that they were interested in these tools only to the extent that they help them manage their land, not to replace their autonomy, skills or decision-making capacities.

Which technologies seemed appropriate?

During our second series of workshops we ran "quick fire" polls on the appropriateness of some of the broad categories of technological innovation currently being promoted.

The results (see Chart 1, p.15) show a strong preference for technologies that connect, especially those that connect producer to consumer. For instance, 70% of workshop participants thought that 'digital communications and supply chain innovations were definitely appropriate for agroecology, with the remainder believing they were appropriate under certain conditions.

Similarly, 60% of participants thought that other types of digital technology – for example crop management software, soil testing, remote sensing – were definitely appropriate.

"I like to feel like I'm part of an international community that's saving the planet"

Organic Growers Workshop

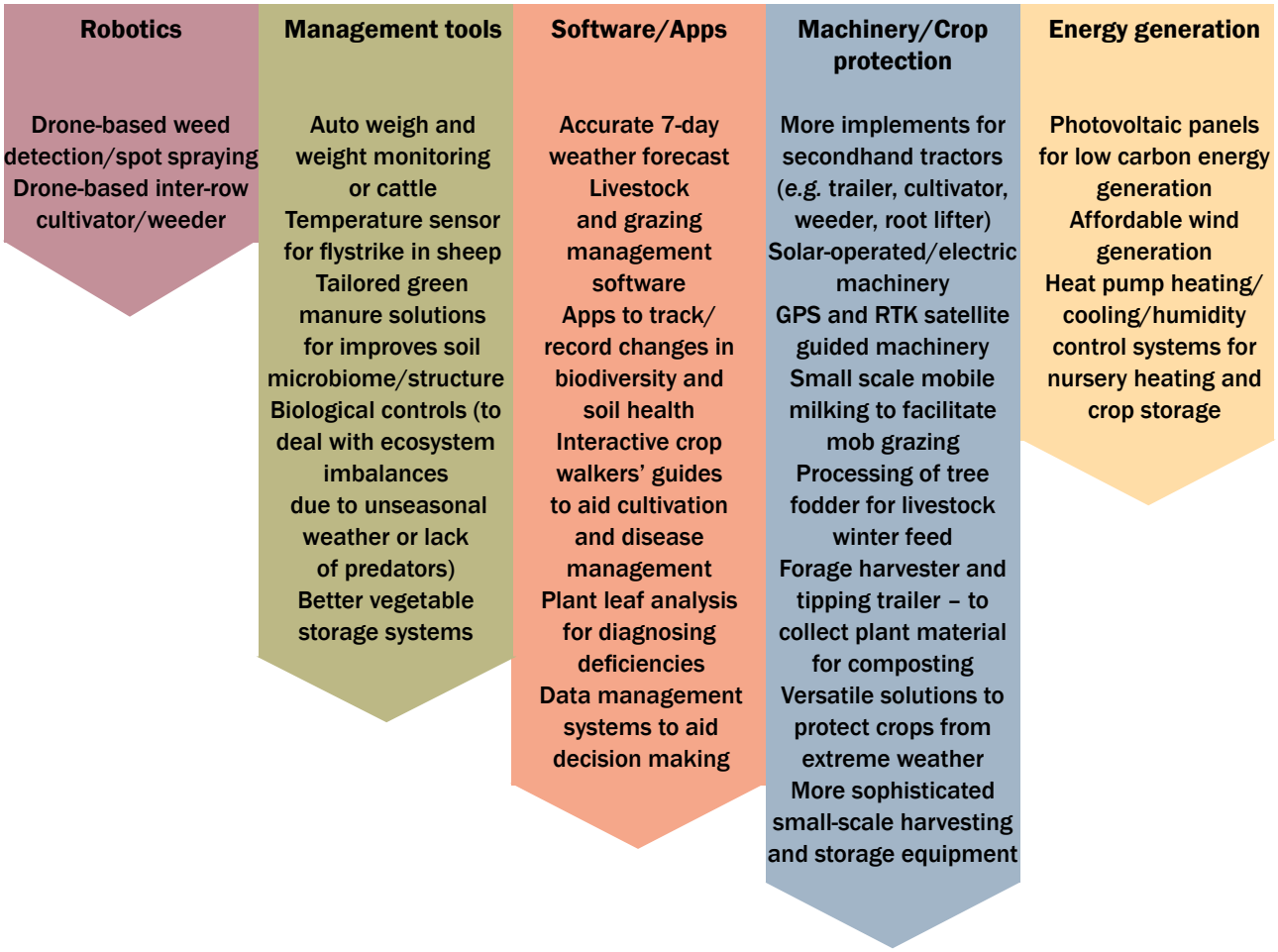
Robotics, participants felt, held a lot of promise – 90% believed they were either definitely appropriate or appropriate under certain conditions. Though in our workshops, CSAs and small market gardens seemed to have less real use for robotics and high-tech machinery than those working on larger farms.

This category provoked a great deal of discussion, particularly concerning weeding robots (most growers were interested if they were small and cheap enough, although there were wider concerns about the devaluing of agricultural labour in the current system) and robotic milking parlours (there were positive comments about the purported animal welfare benefits, but also concern about loss of jobs and loss of connection to the animal and these tended to correlate with the size of the operation).

Hydroponic systems also provoked discussion and debate, with slightly more participants thinking they were definitely inappropriate rather than appropriate under certain conditions. Those opposed generally cited concerns about inputs (including embodied energy and the non-renewable resources used for infrastructure), chemicals and, most commonly, the loss of the soil as critical to agroecological – and especially organic – systems.

Those with a more sympathetic view could potentially see a role for hydroponics for producing fresh produce in an urban environment – although the extent to which this could be thought of as agroecological was not fully considered.

Chart 3 - Which Technologies Did Participants Want to Use?



A similar view was held by a minority of participants in relation to synthetic biology, a broad category that includes engineered microbes to create meat and dairy and plant analogues or to act as soil improvers or biopesticides.

A few felt there could be a role for it in the food system so long as it posed no environmental or health threat. Nevertheless, 70% still felt that synthetic biology was definitely not agroecologically appropriate.

There was some conversation about whether there could be a case for using chemically synthesised inputs such as fertilisers or pesticides as a transition, or for a one-off case of a particularly troublesome weed outbreak, for example. However, 80% were opposed to it in every case.

Finally, the technology group with the least support was gene editing and genetic technologies, with 85% feeling that these were definitely inappropriate in an agroecological system. The main reason given was the high risk of unintended consequences – a sense that human understanding of genetics was too incomplete to predict the full implications of this technology.

Some expressed the view that intervening directly at the level of the genome is philosophically unacceptable. Others raised the issue of socio-economic impact and how a lack of affordability and accessibility could feed into power imbalances within the food system.

Despite some expressing the alternative view that gene editing could be appropriate in some circumstances – and one participant arguing strongly that gene editing could be helpful for harnessing the most useful traits of heritage plant and animal varieties – the majority felt that there was no need for this technology and instead more money should be put into supporting traditional and organic breeding programmes.

3 PRACTICAL, PHILOSOPHICAL AND POLITICAL

Over the course of the two sets of in-depth workshops, three conference sessions and two surveys, we collected a great deal of information on what farmers and growers think are the most important questions to ask when assessing whether a technology is appropriate to an agroecological system. The answers to these questions form the basic criteria for accepting or rejecting certain types of agritech.

The answers to these questions form the basic criteria for accepting or rejecting certain types of agritech.

When considering their criteria for appropriate technologies, participants' thought processes and questions fell into three broad categories: the practical (questions about the technology itself), the philosophical (how it fits with their values and ethical approach to farming) and the political (how it fits with wider concerns about the kind of food system they want).

We summarise this thinking below, and have used it to create a decision-making guide to aid other agroecological farmers and growers in the assessment of technologies in their systems. This can be found in Appendix 1.

We recognise, however, that there are issues which need further consideration. Notably, if agroecology is place-based and constantly evolving according to co-creation, how far can the development of all-encompassing criteria be taken?

"Appropriate isn't static – it's fluid according to the circumstances and the times"

Community Supported Agriculture Workshop

Reading through the criteria questions, it becomes clear that many of the priorities and concerns participants had around agritech – issues such as control, connection and collaboration – surface again and again, asking to be viewed through these different lenses.

Furthermore, the importance of respecting individual farms' differing environments, goals and autonomy came out strongly in our discussions. But how far does this go before the number of autonomous outliers disrupt the cohesion of the whole? In addition, there will inevitably be tensions and trade-offs between some of the themes and criteria we have uncovered as they play out in real-time, real-world situations. We explore these in section 4.

"I think there's a danger of using sophisticated technologies like genetic engineering to solve problems that aren't really problems"

Pasture for Life Workshop

Consequently, we have aimed at not being too prescriptive with these criteria. As they stand, they are intended to help foster thinking and individual decision-making. Whether they can be developed as overarching principles, codes of practice or even standards which can be applied at sector or movement levels or beyond remains to be seen.

The Practical

For most of our farmer and grower participants, the first questions they had about a technology were practical as they grappled with the question of how, if at all, it would fit on their farm. Many were keen to ascertain whether the technology would actually work for them, and whether it would make a tangible positive impact on their farms.

Is it needed?

The question of necessity is both broad and narrow.

There is no "one-size-fits-all" in farming. By connecting to the purpose and values behind the decision to farm agroecologically, an agroecological practitioner will be better able to work out whether or not a given technology will help move them towards these goals. Awareness of this may also help in managing trade-offs.

Another jumping-off point for several participants was whether the technology was solving a real problem, improving farmers' lives, improving the quality of their production system and its output, or bringing environmental and biodiversity benefits to the surrounding ecosystem.

Need and utility were seen as key. Many expressed the view that they had no interest in technology ideas that were, as one participant put it, "*just looking for a market*".

"If you're truly looking at the cost of the whole system, you need to look at every level. We need to have a proper LCA done on these technologies"

Pasture for Life Workshop

There was support for the view that to ensure technology is responding to an actual need developers should engage with farmers in co-design collaboration from the very beginning. The idea that procedures should be in place to ensure ongoing monitoring of the impact of the technology and a plan to withdraw it if needed, was also generally supported.

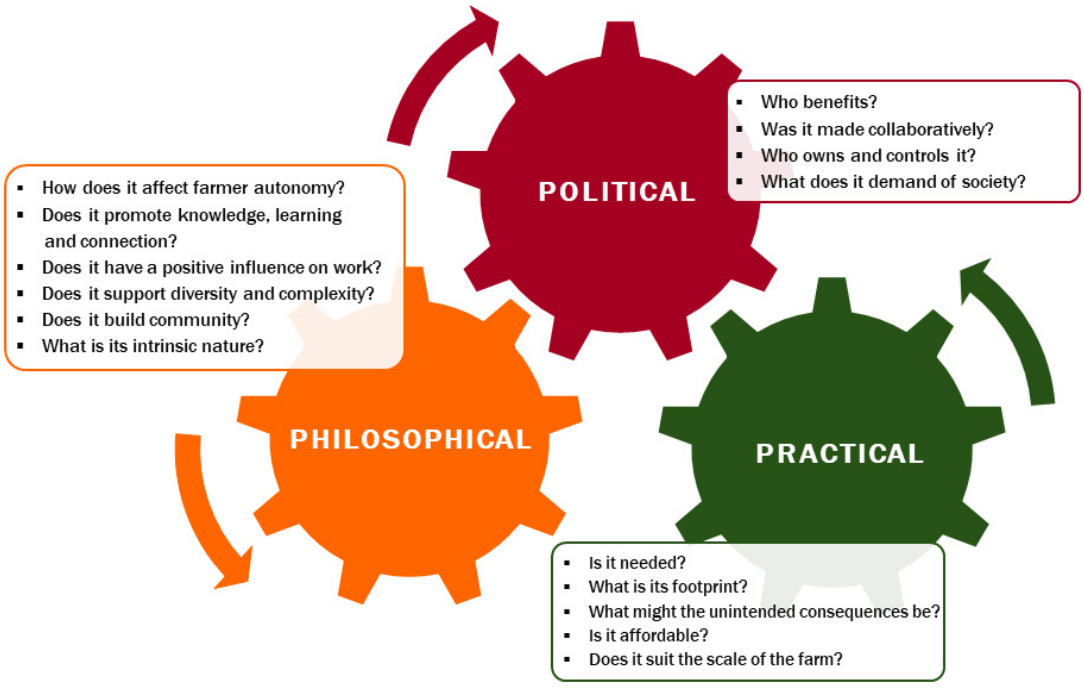
Several participants argued that plenty of appropriate technology already exists, but is not promoted as vigorously as new technologies coming from big businesses. They believed technologies they were already using could be improved and built on – for example more durable polytunnel covers – and this would help meet sustainability goals more quickly, without the need for high-tech alternatives (see Chart 2, p.17). Some expressed a desire to see more research to validate these traditional and low-tech alternatives.

Overall there was a feeling that the continuing emphasis on new technology and innovation can distract people (including scientists, funders, researchers, practitioners and advisers) from the real issues to do with resource use, food quality and accessibility.

As an example, several participants held the view that reducing food waste along the supply chain was fundamental to improving food security and reducing pressure on natural resources such as land and water.

Others felt that reducing or stopping altogether the burning of fossil fuels was the single most effective way to address climate change. As such, seeking to reduce methane emissions through gene editing

Criteria for Technology are Interconnected



cattle was seen as a distraction from taking more fundamental but necessary steps.

What is its footprint?
Most participants were aware that technological interventions come with environmental and social costs in addition to their development, production and distribution costs and that often society, in one way or another, picks up the tab for these. Environmental and social costs, therefore, must be considered against purported benefits.

"There is no such thing as precision pesticides, just as there are no 'smart' bombs. Collateral damage is inevitable, doing more damage in the long term"
Survey feedback

There was general understanding of this in relation to things like machinery and inputs but possibly less in relation to the extent of environmental costs of digital technologies (*e.g.* rare earth minerals and the energy use of data centres).

Several participants felt that the hard sell of agritech too often over-emphasised putative benefits and failed to make a realistic assessment of potential negative impacts and cost. It was seen as part of the precautionary ethos of agroecology that these costs and benefits should be transparent in order to allow potential customers to make informed decisions about technology development and use.

Life Cycle Assessment (LCA), a process by which these environmental impacts can be quantified, was highlighted as one way in which farmers could understand more about these factors.

A recently developed Social Life Cycle Assessment (S-LCA) which seeks to measure impacts on factors such as work and community was also mentioned. End-of-life and recycling concerns were also considered to be important. There was agreement that if these types of assessments were part of the development of all new agritech it would allow for an easier, more accurate assessment of their appropriateness.

What might the unintended consequences be?
Avoiding technologies that might do harm to the farm, to food quality and the ecosystem was a recurring theme throughout many of the group discussions. Elements and language consistent with the Precautionary Principle and the Organic Principle of Care could be discerned, though there were few direct references to either of them.

Whereas some aspects of risk assessment might be covered in Life Cycle Analysis, a transparent assessment of unintended consequences might not be since some of these might only become apparent after the technology has been in use for a while.

Many participants were aware of these issues – possibly in the wake of the ongoing controversies over the use of herbicides and insecticides and more recent changes in the regulation of genetic engineering technologies in the UK. The question of the extent of post-release monitoring and the costs involved was acknowledged but not addressed.

Several examples of potential unintended consequences came up in the discussions, including food safety, environmental, social, economic and societal as well as increased vulnerability on-farm.

One example of this vulnerability was the potential increase in land values if robotics were to make marginal land more productive, and therefore more appealing to corporations and large landowners. There are several potential twists to this – including the further development of carbon credit markets – all of which have potential adverse impacts for smaller agroecological producers seeking to access land.

"I feel like affordability is the elephant in the room for any scale other than thousands of hectares"
Organic Growers Workshop

It was proposed that information about risks and hazards, alongside meaningful information about post release environmental and social impacts – for instance, whether the potential social risks from a new robot were less than the actual harm to the business from not being able to find enough seasonal workers – would help farmers decide whether a technology was right for them.

Is it affordable?
While several participants stated that making money was not their main objective, ensuring economic viability was a key factor for all. Several

mentioned the responsibilities they had for family and employees. The need for fair pay but also, regarding technological investments, to get value for hard earned money was raised repeatedly.

"When we went digital with part of our farm shop it made our production much more accessible and has been an incredible experience"

Biodynamic Workshop

All participants found themselves, to a greater or lesser extent, in a balancing act between philosophy and practicalities. Financial considerations – including issues of access to technology and machinery but also seed and transplants – were the biggest barrier to them being able to farm in better alignment with their values.

Many participants felt that a great deal of modern technology was simply too expensive for smaller (and even many larger) agroecological farms to afford. Here discussions touched on issues of appropriateness for scale – including shape and size of fields, soil type and ecology.

But they also involved a degree of complexity (including the time and money needed to learn new skills and implement new systems) and infrastructure requirements such as improved connectivity to a wider network, new machinery, databases and computing services.

Invariably, and perhaps inevitably, concerns led to a wider-ranging discussion about many aspects of the food system, including affordability of food, the need for agroecologically produced food and farmers to compete with food produced in an industrial system that does not account for the true costs of production and the planning system that makes it difficult for farmers and growers to live on or close to the land they work.

Whilst these are issues that trouble the whole of the farming community, there is no doubt that, for many agroecological producers, these questions impact in relatively different and arguably more problematic ways due to structures, available finance and market factors. Hence, affordability has an additional aspect for the agroecological sector compared to the conventional farming sector.

Does it suit the scale of the farm?

For most participants, technology suited to human-scale businesses and smaller fields or plots was important. One grower spoke of the windy nature of their plot, where high hedges and big trees are very important for shelter. For them, appropriateness often boiled down to whether a particular piece of machinery could get through the gateway.

We also heard different views linked to the size of the business. One participant, for example, felt that robotic milking parlours were not cost effective for farms with only 50 or 60 cows, and that the technology "*incentivises scale and intensification*". Another expressed the view that this was not necessarily the case; there are different types of robotic systems and some are suited to small scale and at any scale can enhance the quality of life for livestock and livestock keepers.

However, scale is not simply a matter of size. Some producers who are small run diverse cropping which involves periods of intense sowing and harvesting activity and, consequently, relatively complex marketing and delivering. Many participants rely on some form of digital technologies for record keeping, data management and marketing. A good deal of appreciation was expressed for these technologies along with optimism about better systems being developed in the future.

There was lingering unease about being reliant on large and remote operations. In part, this overlaps with concerns over control and losing independence. Cooperatively run digital hubs that allow small producers to scale up/scale out through digital technology were discussed, but considerations of the relationship and potential imbalance of power between small businesses and large corporations were not resolved.

"For me, tech has to be human scale. I'm about humans being involved in the food system, humans being able to access the food system and humans being able to access land in order to grow food as a dignified means of making a living"

Landworkers' Alliance Participant

The Philosophical

For most agroecological farmers, growers and their supporters, agroecology is more than a set of agricultural practices. It is a values-based system, in which farmers and producers have made a

conscious decision to reject mainstream industrial agriculture in favour of a system that aspires to work in a harmonious and symbiotic way for them, their land, society and the wider environment.

"As soon as you put a complex machine onto the farm, the farm basically hands over an open cheque book to the company that supplies it"

Pasture for Life Workshop

Although participants came from different strands of agroecology, these values – what might be called a land and farm ethos – were shared by most, if not all, of those we spoke to. They were expressed directly and indirectly throughout our conversations, although with varying degrees of emphasis as individuals sought to understand and articulate the impact that technological choices can and do have on farming practices and beliefs.

From these discussions we have drawn the several philosophical questions which could be used to assess the appropriateness of technologies.

How does it affect farmer autonomy?

Agroecology evolved in the context of farmers' struggles to remain autonomous from agri-businesses and work towards food sovereignty.[63]

In an increasingly volatile world, the importance of maintaining sovereignty, agency and self-sufficiency was important for participants. When it comes to technology, this means questions such as: Does it empower or does it replace me? Can it be fixed? Does the data 'harvested' from my farm belong to me – or does it belong to an external company?

The farmers and growers we spoke to wanted to use technology as a tool to help them manage their land and their businesses, not as a replacement for human decision-making and control.

For example, many were sceptical about software that uses algorithms to generate a seeding plan with no transparency about how the calculations were made. On the other hand, there was much more enthusiasm for digital tech that helps them understand their land better, enabling them to make more informed decisions themselves.

There was an evident lack of trust that technology companies had the interests of farmers at heart. Much modern farm machinery running on proprietary software, for instance, can no longer be fixed by the farmers or a local mechanic. It is commonly sold with a maintenance contract, which is now an integral part of the manufacturer's business model. As one participant said, "*It's effectively farming by subscription*."

It's not just machinery that comes with these downsides. Digital technology is often also based on a subscription model. One farmer who used GPS collars for managing grazing noted that they were now totally reliant on a tech company – and should that company cease trading (a genuine risk with so many start-ups on the marketplace), they could potentially lose essential data.

Another, a large producer, said the introduction of pallet-stacking robots into their operation has replaced a "soul destroying job" and led to more consistency in everyday performance. At the same time, they felt the system had less resilience and back-up compared to when humans operated it. They had largely accepted this vulnerability due to the benefits the rest of the time, describing "*a mindset shift away from getting the product out at all costs.*"

"Once you start looking at farming differently, the only place you can really get advice is peer to peer. It's from other people that are doing it"

Pasture for Life Workshop

The impression we were left with was that the farmers and growers we spoke to would welcome technology that comes with a box of spare parts and training on how to maintain and fix it, as well as full ownership and control of their data.

Does it promote knowledge, learning and connection?

Throughout the workshops there was a great deal of positivity for digital communication platforms that connect with other agroecological farmers.

These were seen as one of the best ways of learning about and discussing new farming practices with peers. Many participants valued e-newsletters, forums and WhatsApp groups for this purpose. This learning translated into experimentation, either on their own farms, as part of funded schemes such as the Innovative Farmers network[64] or through reading recommended books and scientific papers and adjusting their practices accordingly.

Learning from the land was also a recurring theme. The idea that technology could bring increased understanding and knowledge of the land, to support human knowledge and decision-making, was, in general, received positively.

Some participants reported using GPS-based apps to assess their fields. Digital tools were viewed as a useful way to better understand what was going on in their soils and assess the impact of their interventions. However, others commented that there were few better technologies than welly boots to walk the fields and a spade to dig a hole and look at and smell the soil.

"Weeding is one of my favourite jobs. It's a time when my hands are busy, but my brain is free, and it's when I think about a lot of things. It's kind of meditative"

Community Supported Agriculture Workshop

More generally, acceptance of interconnectedness and complexity within ecosystems was seen as central to agroecological farming. Whilst technology has a tendency to simplify, there was speculation by some that AI might lead to tools which would help better understand the myriad of interactions and connections on their farm.

Inevitably, this discussion got bigger as it evolved, exploring, for instance, the distinction between information and knowledge. Drones, virtual reality, algorithms and apps that relay and predict what is going on in the field provide information but may not actually help embed knowledge or facilitate a deeper understanding of agricultural practice or the natural world. One participant asked if it could really replace "*sitting in the woods for six months*."

This isn't just a romantic notion. The value of farmer observation has also been noted in the research literature as well. As Thiemann et al suggest[65], an exaggerated belief in the precision of big data, over time "*leads to an erosion of checks and balances (analogue data, farmer observation etc) on farms*."

Does it have a positive influence on work?

Meaningful, satisfying and sufficiently remunerated work was seen as important, and technology that removes this was described as a social harm by some participants. Much of the current mainstream rhetoric around agritech describes robots that can replace human labour as an advantage for farmers. However, this idea was challenged by some and differences of opinion led to interesting and challenging discussions in most of the groups and sessions as participants discussed different scenarios and possibilities.

Many spoke about the joy of working the land, the physical and mental health benefits of getting hands in the soil, and the perceived increase in the number of people wanting to do meaningful, real-world work. Others spoke of the difficulty finding labour and of the toll that long hours and years of manual work took on their bodies and minds.

There are undoubtedly systemic issues here that are cultural as well as economic. Some current farm businesses are reliant on poorly-paid migrant labour. Others rely on family labour (which some might regard as indentured servitude but others saw as fulfilling fate). Still others use highly skilled but not necessarily highly paid local labour.

There was solid agreement that the value of skilled agricultural and horticultural work and experience, including that of livestock husbandry, should not be underestimated. Consequently, any technological addition to an agroecological farm should promote and increase the acquisition of skills and enhance the joy and pride that can come with this.

In one of the conference sessions the view was put forward, but not explored in depth, that digital tools could also help widen access to farming by replacing intergenerationally acquired knowledge of a farm – not available to new entrants or new owners/land managers – with digitally acquired information.

"I enjoy going to farmers' markets and I like a Slow Food approach with conversations about the food. Taking tech out of that slows the process down, and I enjoy that. Joy is part of what I want as a farmer, and I want people to have joy in relation to their food"

Food, Farming and Countryside Commission Participant

An interesting additional perspective was that many participants challenged the mainstream narrative that the "speed" that technology claims to bring was a positive thing. There was also some

challenge to the idea that enabling more to be done in less time, or faster increases in output was always beneficial.

"I think in agroecological systems, we should embrace complexity. And if technology is trying to make them less complex, the likelihood is they're not going to work"

Pasture for Life Workshop

This led to a consideration of slowness as an important – but usually unacknowledged – part of how several participants farmed. Working within seasons, cycles and land rhythms was important. One participant said they were still seeing things changing on the farm 25 years after they stopped applying fertilisers and pesticides.

There was no doubt among participants that the challenges we face are urgent. But prioritising speed over other considerations may mean losing sight of other values – including humility and respect for nature, acceptance of complexity and earning knowledge for one's self. In this respect some participants expressed an affinity with the ideas of the Slow Food Movement, with its emphasis on traditional food culture, connection to the land and craft and artisanal skills.

Does it support diversity and complexity?

Enhancing and supporting diversity in the farm's ecosystem are central tenets of agroecology and participants were generally critical of technology that promoted or required uniformity. Concern was expressed that much of the technology now available to farmers does not support the principle of biodiversity and cannot handle complex systems and that this situation is getting worse.

Our discussions provided no answer to the conundrum of what drives the desire for uniformity; was it, for instance, the available technology, the economics of the food system and/or the choices consumers make – or all of these things?

There was, however, general agreement that agroecological farmers are swimming against a powerful techno current which is getting stronger even as less affordable on-farm technology suitable for smaller scale and diverse comes on stream.

Several examples were discussed. One, which arose as feedback from a workshop, is especially illustrative. Many growers, including small and medium size ones, use transplants for certain crops (rather than growing directly for seed *in situ*).

When large numbers of plants are involved and labour is limited, transplanting machinery is used which requires the plant roots to be embedded in blocks or "cells" of compost. As the machinery has been developed for greater speed and planting precision, it has become less tolerant of variation in the quality of compost. Thus today, despite a strong desire amongst agroecological growers to end the (environmentally damaging) use of peat, it is very difficult to find peat-free compost that works well with transplant machinery.

Participants speculated that it ought to be possible to develop agritech that prioritises diverse production systems, whether cropping or livestock, through all phases of the cycle – including harvesting and storage. This highlighted the need for co-creation between producers and developers and a financial environment that encourages whole system, ecological innovation.

Does it build community?

Across all the various strands, many participants viewed themselves as part of a 'community' – either locally or in the non-local sense as in an organic community, grower community, agroecological community or citizen community – and were keen to understand how any technology under consideration would affect these communities.

One grower spoke of the stakeholders of the farm as being not only those working on the farm, but everyone who lives around it and the people who will eat the food. In other sessions nature was raised as an often ignored 'stakeholder'.

"People are more flexible than machines on the farm. We've got lots of different enterprises going on and I'd rather invest in people than machinery"

Biodynamic Participant

Participants generally supported the view that for a technology to be agroecologically appropriate, it should positively impact this network of relationships.

It was suggested that "shareability" between multiple producers was a desirable feature for

appropriate technology. This, in part, was a matter of organisation between individual producers, but design features enabling ease of assembly and transportability could make this easier.

"I think the application of genetic technology is a slippery slope down which the positives can be very quick to achieve but the negatives, in the longer term, can be quite damaging in terms of the sustainability of our food systems as they become more homogenised and less resilient, more fragile, and more technology-dependent"

Future Farming Workshop

Where technology has a software element to it, a multiple user profile facility for easy switching between farms and businesses would also be beneficial. Participants thought that these features might help address reservations about affordability, as well as concerns about natural resource use and negative environmental impacts.

Many participants felt that online platforms that link producers and customers were amongst the most promising technological developments. One explained that they did not have an easy market locally and communication through social media allowed them to tell their story and grow their customer base. This, along with facilitating a quick delivery service to any address in the UK, meant that they had been able to expand their business.

However, some concern was expressed about the potential loss of the in-person connections that are possible across and around the stalls of local markets. It is a question outside the scope of this report, but it does speak to the broad notion that there are trade-offs between various goals, activities and/or businesses grouped under the 'alternative' or 'agroecological' umbrella.

It was also interesting to note that the same concerns about ownership of data, corporate control versus open sourcing and environmental impact of energy, water and materials used – which were so apparent in discussions about digital technologies used in the field – did not surface when the same kind of technology was being used for communications or mobile phone controlled apps.

This was instructive in relation to trade-offs and the relative balance of risk/harm and benefit at different points.

What is its intrinsic nature?

The promise of agritech, indeed all technological innovation, is that it will transform our world. Indeed, throughout history we have used technology to change the world to better suit human needs and desires.

All technologies – being the results of human thinking and morality – come preloaded with their own set of values, which we use to define the 'world' as well as the 'change'. How these innate values can influence individual users and the wider community or environment of users can be difficult to predict.

Changing the world, after all, is not an exact science. It can come with unexpected benefits but also unexpected costs and risks. These benefits, costs and risks don't fall evenly across society but instead are experienced differently in different social groups and different geographies at different times.

Some of our discussions touched on, but did not explore in depth, whether certain technologies – such as AI and data 'harvesting' – can only function or even exist in a centralised context which is not conducive to transparency and oversight. If so, does this make them intrinsically incompatible with the values and aspirations of agroecology?

The intrinsic nature of certain technological tools presents a genuine challenge for agroecological transition. For instance, what are the circumstances (if any) in which the agroecological movement might consider forgoing short-term benefit at one level – *e.g.* on farm – to secure potential long-term system transformation? (see also, What does it demand of society, p.28)

"I ask myself the question, does it benefit the farm? Does it benefit the people who are gathering the data and handling the data? And is that an equitable and fair sharing of the benefits of it? And if it's not then it's not in the interests of the producer"

Pasture for Life Workshop

The Political

Examining and challenging dominant power structures is an inherent part of agroecology and was a theme that came through strongly in our workshops. For most participants, agroecologically appropriate technology was synonymous with democratic processes that support the creation of a food system based on fairness, justice and sustainability.

"I suppose the fundamental principles of what would be appropriate in my mind is that it is farmer controlled and sovereign – so not software or technology that has to be paid for to a company, but open source or transparent to the farmer, the landowner and the consumer"

Landworkers' Alliance Workshop

For many this implied technologies designed in a participatory manner, which give the farm and the farmer more ownership and control, and which seek to contribute to public benefit.

Who benefits?

Overall, participants expressed the view that technology was only of interest to them if it, first and foremost, benefits them and their community. They wanted transparency about the full costs, about what data is being collected and for whose or what purposes.

There was scepticism about the intentions underpinning claims about new technologies – and, therefore, reliable (as opposed to hyped) information about the company that developed the product was also seen as important.

Paired with this scepticism was an enthusiasm for technology that demonstrates genuine transparency and democratic values and which can help them become better agroecological farmers.

Was it made collaboratively?

Most of the farmers and growers we spoke to felt that technology development should encourage a culture of participatory learning and creativity, which can be very empowering.

An example that came up several times during our workshops was Farm Hack[66], a community of farmers who make and share their own tools, at online and in-person meet-ups. One participant gave an example of learning about an automated irrigation set-up using a microchip processor, which could be built for around £15. Sometimes this kind of 'frugal innovation'[67] is all that is required.

Who owns and controls it?

Questions of ownership, of both the product and the data, were common. Concerns were raised in most sessions about corporate control, patents and intellectual property rights (IPR) and the implications for farm businesses that wish to own their own data or repair or modify their own machinery.

There was support for community-ownership and a sense that through collective wisdom the community was in the best position to reflect, iterate, develop and adapt, in a way that meets its own needs.

Although it was also noted that data collection could be useful to help build the case for agroecology, there was a marked preference for open-source technology that allows for farmer or community ownership of data. However, the feasibility and steps to bring this about were beyond the scope of an already large and varied discussion.

What does it demand of society?

Technology does not exist in its own bubble. The adoption of a new technology often comes with or leads to profound changes that can ripple through other parts of society. These are often unforeseen and can be fundamental.

"I think there is a big danger that farmers will end up on leases for machines they don't own, with centrally controlled digital platforms. That could easily represent a massive concentration of power, ownership and control in the food system. But, equally, an open-source community might develop the technology and all be freely available open-source code, and then I might be able to weld up my own robot and download the free software"

Organic Growers Workshop

The internal combustion engine, for example, brought mass mobility and the rise of the global marketplace. But the societal trade-off has been significant – changes to our landscape and the environment through the building of countless roads and the way cities are designed and built to prioritise vehicles over pedestrians. It has contributed to global air pollution and the poor health associated with this, as well as increasing resource and energy consumption and the acceleration of climate change.

In farming, the development and utilisation of commodity crops like soya and maize has produced a plentiful supply of foods at reasonable prices, but it has also enabled industrialised production of livestock, vast soil-degrading monocultures requiring higher inputs of fertilisers and pesticides and the development of highly processed foods with all the environmental and health impacts and changes in food culture that have followed.

"The term agroecology has important social objectives, and that's the only basis on which we should use the term"

Organic Farmers Workshop

New technology also demands the adoption of new mindsets – for example, robots are better than farm workers or lab-cultivated meat is better than meat from animals – that have implications for how we think about work and about the environment, how we spend our money, what crops we grow and what food we eat.

Many participants were only beginning to grapple with how far-reaching the technological choices made by farmers in general and the agroecological movement in particular.

4 THE BALANCING ACT

Determining whether a specific technology is appropriate to agroecology is a complex and multifaceted process. During our workshops we sought participants' views on the use of specific technology applications – what they use and the appropriateness of what they might like to use. As the project came to a close it seemed evident that values and world views are a key part of the decision-making process for agroecological practitioners.

However, it also appeared that those values and worldviews can be specific to time and place and, therefore, flexibly applied according to circumstance.

This raises questions about just how elastic these values are and in which contexts and circumstances. For instnace; how much transparency is needed to ensure that the specific doesn't turn into a veneered generalisation and can there be such a thing as principled pragmatism?

This balancing act was recognised in a recent proposed 'Agroecology Assessment Framework'[68] drawn up by an international coalition of civil society organisations (CSOs) and non-governmental organisations (NGOs), farmer and research groups, philanthropists and development agencies known as the Agroecology Coalition. Using the UN's High Level Panel of Experts' 13 principles of agroecology (see Appendix 2), the framework seeks to assess projects and initiatives for their degree of agroecological integration – or their "agroecologicalness" – with a wide range of metrics that go beyond purely economic.

It evaluates the alignment of a project or initiative with each of the principles using two "value statements" – one describing a strong alignment with the principle, the other describing a lack of alignment, as well as a list of examples and indicators of what contributes to the implementation of the principle. It also includes an indication of the circumstances under which some principles may not be relevant, as well as red flags. In this way it allows for more general comparisons as well as local contextualisation of each principle.

We did not refer to this framework (or other attempts at basic criteria, such as the work by Clément and Ajena,[69] which also used the 13 agroecological principles as a foundation for decision-making) during the workshops. Yet we found a noticeable degree of similarity to that thinking emerged within our own discussions.

> *"What's appropriate for one environment may not be appropriate for another – each farm has different needs and it is not possible to create a blueprint."*
>
> **Food, Farming and Countryside Commission Workshop**

However, this project is rooted in UK conditions and the situation and perceptions of UK farmers and growers seeking to make a living. Our identification of core principles and criteria (in section 3) and the framework recommendations for agritech policy (in section 6), emerges from this context.

It may, therefore, align with that in other territories but, equally, it may differ from "agroecologicalness" in other locations and/or from the more global perspective of international or coalition based civil society organisations.

This especially may be the case when considering values, red lines, standards and regulation and the trade-offs between them.

Is technology values-neutral?

A great deal of narrative around modern agritech is predicated on the fact that technology is not inherently good or bad; rather, it is how it is used

that dictates its ethical value. However, this presumed neutrality of technology has always been questioned and the debate – which has a potent political edge – has never been resolved. Technologies of all kinds have become an intrinsic part of our daily lives and we rarely stop to think about the philosophies and worldviews underpinning their very existence.

The economist and philosopher EF Schumacher, credited with developing the idea of 'appropriate' or 'intermediate technology' (a middle path between high tech and low tech), dismissed the notion of values-neutral technology decades ago:

> "*People still say: it is not the technology: it is the 'system'. Maybe a particular 'system' gave birth to this technology: but now it stares us in the face that the system we have is the product, the inevitable product, of the technology.*"[70]

In his ground-breaking book *Small is Beautiful*, Schumacher, who later became President of the Soil Association, set out his ideas for a "technology with a human face" arguing that technology is far from neutral and values free and further that, unlike in nature:

> "*Technology recognises no self-limiting principle – in terms, for instance, of size, speed, or violence. It therefore does not possess the virtues of being self-balancing, self-adjusting, and self-cleansing... In the subtle system of nature, technology, and in particular the super-technology of the modern world, acts like a foreign body, and there are now numerous signs of rejection.*"[71]

Schumacher envisioned intermediate or appropriate technology as an alternative path for development for what were then called "undeveloped countries" But the concept is equally applicable for anyone seeking a more selective, values-based and mindful use of technology.

In the same way that technology developed in and for the minority of high-income countries might be inappropriate for the majority of low-income countries, technology developed in and for large industrial systems may well be inappropriate for smaller scale agroecological systems.

Part of our intention for this project was to highlight and challenge this values-neutral narrative as well as to understand if it reflected the views of UK agroecological farmers and growers.

What we found was a diverse set of opinions. Some did, indeed, feel that no technology was inherently bad and that how technology was used was the important thing. Taking a global view, for example, it was suggested that the use of a robot weeder is appropriate in Argentina with its low population and large, low labour input systems, but not in Bangladesh with its small-scale farms and few other opportunities for employment.

However, others rejected the idea of values-neutral technology, suggesting that even when these values are not obvious or made explicit, they nevertheless exist and often centred on recurring themes of power, control and ownership.

> *"Perhaps one of the key aspects of agroecology as far as I'm concerned is the human aspect of the people working in farming, or the relationships with those who are consuming food. The technologies we use need to reinforce that culture rather than the technology shaping the culture"*
>
> **Wales Real Food and Farming Conference Participant**

Participants expressed frustration at how difficult it was to find unbiased information about agritech. Some felt that the hard-sell, with its unyielding narrative of benefits and positivity can skew decision-making, or cause an individual to mistrust their own knowledge, observation and instincts. Measuring everything because technology allows, and even encourages it, was viewed as a trap akin to the old saying "knowing the price of everything and the value of nothing".

Farmer well-being also came through strongly in our discussions. It is widely presumed that the adoption of new technology will automatically improve well-being. But the measurement of farmer well-being is generally narrow – predicated on increased productivity and, therefore, income.[72]

Apart from the fact that neither productivity nor increased income can be guaranteed by the adoption of new technology, this presumption ignores important farmer and grower values, such

as happiness or joy, satisfaction in one's work and life, a sense of community and agency. Agricultural technology could have a mixed or even negative effect on these aspects of well-being, depending on the type of technology and its compatibility with farmers' worldviews and agricultural practices.

A re-definition of what constitutes success in farming, technology and food is perhaps required, with assessments made by a broader range of people, especially agroecological farmers themselves, as well as environmentalists, consumers and citizens' groups. The criteria questions in section 3 – which, in essence, are asking: Does this technology support the actions necessary to move forward in a fair, healthy, sustainable way? are a useful basis for this.

There are trade-offs, so should there be red lines?

Finding consensus, like almost every decision in life, involves some compromises and trade-offs. When the decision lies within a system as broad and complex as the food system, understanding and managing these trade-offs can be a daunting.

"I don't consciously think about what's good for the movement. Now, that may be something that I'm overlooking, and that may be a thought that I need to think about differently. But I'm very much focused on what's right for the farm, for the producer, for the community that farm is part of and for the environment that farm forms and is part of"

Future Farming Participant

Openness and transparency are a prerequisite, but the industrial farming and food system has rarely been transparent about its trade-offs. Since the Green Revolution, policies and innovations have traded social and environmental harms for yield and productivity. Research and metrics to assess the performance of newer farm-level interventions follow the same pattern,[73] leading to an innovation and funding landscape that is hard to change.

In recent years, as awareness of the hidden costs of farming and food has grown, there has been a recognition of the need for a methodology "*to systematically assess synergies and trade-offs*"[74] in agricultural interventions, including technology.

Our discussions highlighted several different categories of trade-offs that can arise when considering agroecologically appropriate technology:

- **Economic** How much financial burden would farmers be able/willing to accept for a new technology? How long will it take to pay back? Would there be financial risk to not adopting the technology?

- **Time/energy/quality of life** Many of our growers spoke of the burden of weeding – so would they reject the idea of a robot weeder if it is owned by a large corporation and ties them into a maintenance contract, rather than the community-owned, open-source ideal of agroecology?

- **Health** Would the answer to the above change if health was at risk? And where do questions of mental health fit in?

- **Food quality** Most participants valued growing nutritious food. Would they accept a technology that reduced workload or improved profit if it had a negative impact on this?

- **Environment** What level of harm to the environment is acceptable? Can it be mitigated by regeneration elsewhere? How can we balance different environmental harms against each other, especially when "facts" are contradictory, hard to measure or hard to find. For example, is the harm caused by glyphosate application greater than the harm caused by ploughing?

- **Animal welfare** Where is the level of tolerance for negative impacts on animal welfare? How can we assess risk *vs* benefit in this area? Many spoke of potential animal welfare risks of gene editing animals, for example, though a few perceived some benefits.

- **Societal/cultural** How does technology affect local food culture? Many spoke of negative impacts of more technology meaning less person-to-person interaction, as well as the loss of slowness. However, technology can also connect producers to customers, new and old.

Discussions also revealed that the needs of the agroecological movement can conflict with the needs of the farm.

For example, the movement may benefit from all the agroecological producers in one area signing up to a cooperatively owned online food hub to give customers the best experience possible and ensure cooperation, but it may not work for the farm to orient their production schedule in that way.

"Data is one trade-off I am happy to live with. But when it comes to animal welfare, it is difficult to accept any kind of trade-off"

Organic Farmers Workshop

For many, when push came to shove, the needs of the farm took precedence over the needs of the movement. Day-to-day practicalities, as well as exceptional circumstances affected the weight that personal values had on decision-making. A message we heard frequently was the importance of individual farms' goals and contexts. Therefore, individual farmers and growers may well draw lines and see trade-offs differently to others.

From this perspective, the decision about what trade-offs to accept is a very personal one. This does not mean that participants felt values were unimportant. Far from it. There was consistent recognition that when considering how values intersect with technology, it's not just end-users' values that count. The values that shape technology are also important.

This is why, rather than defining concrete criteria, we have sought instead to provide some clarity as to the different factors at play when weighing up the appropriateness of a technology within an agroecological system. Once the impacts are understood, individual farmers and growers can then decide what trade-offs are right for their particular context.

However, farmers do not exist within their own individual bubbles. All farmers operate in a market; and agroecological farmers identify, and seek to be identified, as adherents to a values-based production system. The nature of that system and its management are what people who buy agroecological food are buying-in to. An 'agroecological' potato – whether it is certified as part of an organic or biodynamic system or not – is not just a potato; it is an entire production and values system. This does, however, raise the question of "red lines" – that which is non-negotiable and non-tradable.

The use of genetically engineered seed or livestock, for instance, cannot be in the sole remit of an organic or biodynamic farmer because other farmers and customers perceive this to be a "red line" which is counter to their values and would not expect or countenance its use.

Historically, these "red lines" have been clear and barely worth mentioning because they have been part of the bedrock of beliefs espoused by those in the organic and agroecological movement.

But technology and, indeed, social relationships are becoming more complex and nuanced. Whereas, not so long ago agroecological and organic production out of soil would never have been contemplated, now new approaches, technologies and needs have emerged that challenge that certainty.

Social and economic structural changes are another challenge. In reality, there have always been some assumed and often unspoken red lines within organic, biodynamic and much of the agroecological movement.

A combination of the growth in these movements alongside technology and socio-economic change raises questions about whether these assumed and unspoken approaches should be questioned.

Should there be codes and standards?

In an innovation culture, which embraces concepts such as "fail fast, fail often" and where launch-first-ask-questions-later is the guiding principle, the development of standards is seen as petty and Luddite. Governments and many technology developers regard the application of standards and/or the acknowledgement of boundaries as stifling for innovation.

"Even some of the low-tech things have issues around standards"

Pasture for Life Workshop

In fact, standards are not simply constraining factors. They facilitate important feedback and insight into the shortcomings of any system and information on how to correct those shortcomings.

The presumption that innovation should never be inhibited is remarkably hubristic, especially when set alongside claims that a particular technology is transformative. In relation to this it is interesting to

observe the rise of groups positively embracing the name 'Luddite', so often intended as an insult, not because they reject technology but because they have questions about what technology displaces and whether it will actually make things better.

"The more you try to pin down exactly what you mean and put that in the standards, the more messy and complicated it gets. Whereas if you have a slightly, not necessarily vaguer, but more basic set of principles, you can always communicate to your customers or anyone else, how you are farming"

Organic Growers Workshop

Now, as historically, the goal isn't to indiscriminately 'smash the machine' but to target those technologies that deify progress at the expense of human dignity and autonomy. Thus modern Luddites, for example, are pressing developers to understand how AI might be used to replace human jobs, ingenuity and connection.[75]

There are no minimum scientific, environmental or ethical standards that agri-innovations must meet and there is no body set up to evaluate the appropriateness, effectiveness and impact of agritech. At the same time there is no consistent evidence to suggest that standards or regulations interfere with innovation.

A recurring theme in our discussions was that some technologies could be useful under certain conditions and in certain contexts. Agritech developers, however, are under no real obligation to consider conditions or contexts.

Yet, without minimum mandatory standards for things like data harvesting or AI, it could be argued we risk investing in and deploying technologies that could be "*unreliable, disproportionate, or simply unsuitable to the task at hand*".[76]

There is good reason to suggest that technology without boundaries or limits is irresponsible, even given the urgency of the challenges that society faces, because of the way it can divert attention and investment away from other simpler, cheaper and more immediately implementable solutions. Most of the farmers and growers we spoke to believed that tech developers had a responsibility to consider the appropriateness and consequences of their innovations – and that this should involve farmers and growers at the earliest possible opportunity, preferably at or before the development stage (see What Developers Should Do, p.39).

The diversity of approaches under the broader agroecological umbrella adds an interesting extra dynamic to the standards discussion.

Several of these do have production and processing standards. Certified organic and biodynamic are both guided by mandatory – and, in most parts of the world, legally based – standards. Failure to meet these can result in loss of certification. Both share similar aims and ideals, although biodynamic encompasses a metaphysical and spiritual dimension which is not explicit in organic concepts and not present in contemporary organic standards.

Similarly, Pasture for Life farmers must meet mandatory standards to gain certification, although these are subject to contractual agreement rather than mandated in law.

Attempts have also been made to create a basic set of principles for regenerative farming,[77] and some organisations in the US have established standards on the same contractual, non-legal basis as the Pasture For Life approach.

"Personally I've kind of bought into that idea as soon as I switch on my phone or my computer, somebody, somewhere is collecting data about me. For me, the positives of being able to create local markets, create better logistics, fill gaps where they're needed by someone that's got surplus, reduce food waste and food miles, get rid of food deserts and tell our story locally outweigh the risks."

Nature Friendly Farmers Network Participant

But for the most part, regenerative farming is not bound by any rules, there is no oversight or penalty if a regenerative farmer either ignores those principles or fails to live up to them.

Agroecology does not have mandatory standards but relies instead on variously declared and

published principles which can be unevenly interpreted and implemented in practice.

As an agrarian movement, agroecology is rooted in values shared by the organic and biodynamic movements. However, the food sovereignty aspects of agroecology go further and constitute an international social movement built on a values system that represents a major transformation of social, economic and political relationships concerning access and use of land and natural resources in the food system.

While organic and biodynamic certification describe categories of permissible and non-permissible inputs and have associated certification for some permitted products, these do not address technology use – other than genetic engineering technology – and they do not have any published criteria for assessing them. Nor do any of the other strands of agroecology, including the agroecological food sovereignty/social movement.

It was suggested in one workshop that it is difficult to see how the integrity of agroecology can be protected from inappropriate technology and the threat to its underlying values in the absence of codified consensus in the form of standards or robust codes of practice.

How to do this was raised but not resolved by our discussions beyond general acknowledgement and appreciation of its relevance to the process of identifying criteria around which consensus might be built.

5 FRAMEWORK AND RECOMENDATIONS

It can't be said often enough: to question the trajectory of technological development in agriculture is not 'anti-technology'. Instead, it is a frank acknowledgement of the realities of farming, the social, economic and environmental impacts of technology and an exploration of the aims and values that lie behind the development of new agritech.

Almost any enterprise can 'thrive' – at least for a while – in an unregulated environment with low standards, little or no foresight or regard for context or societal values. The participants in this project were, for the most part, looking for something with greater long-term potential.

A strong thread running through all the workshops was participants' sense of pride about what they were doing and how that contributes to equitable, sustainable farming practices now and in the future. This does not preclude the use of technology but it does suggest the need for a framework built around considerations of agroecology, politics and policies and the culture and practice of agritech development.

Our in-depth discussions revealed much about UK agroecological farmers' attitudes to agritech and showed a good deal of overlap and some areas of disagreement and strengths and weaknesses in knowledge and awareness. They also identified many questions and much that needs resolving. But within this there were hints of ways forward, ideas for action and a framework for the process of development, evaluation and implementation.

What the agroecology movement should do

While it's tempting to start with what the government and developers are getting wrong and what they need to do better, there are several good reasons to consider, first, what the agroecological movement in the UK can and should do to strengthen its position in relation to agritech.

We start here, primarily because, whilst agroecology is often affected by changes being made by others and by levers, structures and timescales controlled by others, there are some key steps that can be taken by the agroecological movement or sector, by and for itself. Indeed, we would argue that taking charge of the agenda is an essential prerequisite to bringing about meaningful change in politics, policy and technology development.

The building blocks already exist. The land and farming ethos of agroecology encompasses agriculture, relationship of production to land and ecosystem/environment and food (collectively a land and farming ethos). Fairness within the farming and food system domestically and internationally and intergenerational fairness and stewardship (collectively a fairness ethos) is also key. So too is social, ecological and environmental equity (an equitable sustainability ethos).

Our discussions uncovered a great deal of agreement between the different strands but also some lack of clarity and even disconnect, indirectly or by implication, in these values. This disconnect seemed less related to values than to differing priorities and dynamics in operation at farm, business, sector, supply chain and market levels.

Frequently, discussions about the acceptability of some techniques were qualified by the words "under some circumstances". We did not have the space to pursue what these circumstances might be, how long they might last or how widespread they have to be – i.e. farm, supply chain, market, policy, regulation – but it is likely they also differ considerably within and between these levels.

Given this, "under some circumstances" needs to have a consistent definition and application at movement, sector and market levels. Likewise, the

handy get-out clause, "on a case-by-case basis" – which is both valid and necessary – still needs a similar degree of clarity.

When these issues are raised, the phrase "*the need for good governance*" often crops up. It is usually used by organisations, think-tanks, policy-makers and politicians rather than individual practitioners (*e.g.* farmers and small businesses). Consequently, there is a great deal of literature about it.

The problem is that "good governance" varies according to context and circumstance. In the case of agroecological values, for example, good governance in respect of technology applied to agriculture and land domestically, might be far from "good" in terms of international or intergenerational fairness and wholly inappropriate for long term, equitable transformation.

We suggest it is critical for the agroecological movement and sector to work together in an agreed formal structure to address these issues and create a transparent framework and protocols for identifying agroecologically appropriate technology.

This involves identifying red lines and trade-offs, as well as resolving disconnects and conflicts between the different strands. It might well require standards or agreed codes of practice to achieve this.

The practical, philosophical and political questions gleaned from the workshops and our decision-making guide for individual farmers and growers could serve as a starting point for this.

What policymakers should do

The prevailing political and commercial drivers of the science, technology and innovation agenda set the direction and shape of agritech development. These are rooted in existing structures and leverage points which are often at odds with challenging values-based questions such as:

- Who is responsible for ensuring that new technologies are developed and deployed in a way that benefits the whole of society and how can this responsibility be enforced?
- How will the risks and benefits be distributed? How can they be defined and measured?
- How can we ensure that the policy framework for new technologies is flexible enough to accommodate rapidly evolving technological developments, while still providing appropriate safeguards to protect public safety and security?
- What role should the public play in influencing policy around new technologies, and how can we ensure that their voices and concerns are heard and accounted for?
- Who is in control, who is taking part and who will take responsibility if things go wrong?
- Are the motivations of developers transparent and in the public interest?

These questions are important because they can help ensure that the approach to new and disruptive technologies is effective, equitable and responsive to the needs and concerns of all stakeholders.

> *"When people talk about the vast possibilities of the digital future, I would like to sit them down and say so what? What problem are you trying to solve here? The test I'd like to apply is, how is this helping us to improve the world?"*
>
> **Organic Farmers Workshop**

They resonated with participants and were expressed in various ways – including when commercial and practical aspects of agriculture were being considered – throughout our discussions.

Consequently, we take the view that, all organisations, agencies and individuals who believe in a society- and citizen-first approach to innovation and technology, should take all possible steps to ensure that governments and technology developers embed these considerations and questions in the policy framework of all technology.

This would prevent society from being locked into a cycle governed by innovation for its own sake or for narrow economic gain. It would encourage an innovation culture which is responsive to public needs; one that recognises costs as well as opportunities, complexity as well as the unknowns and acknowledges boundaries, limits and trade-offs, and which can be comprehensively evaluated.

We recognise that a great deal of work has already been done on what a framework governing responsible innovation could look like.[78] This project aims to compliment, rather than override that work.

Through our workshops and surveys participants offered several thoughts about how the government and public sector could help ensure agroecologically appropriate technology. We have condensed these into five key asks aimed at ensuring that future innovation supports rather than supplants agroecology.

1) Produce a coherent plan and joined up policies for food, farming and land use that places agroecological systems on an equitable footing relative to conventional and high-tech farming.

We are certainly not the first to ask for this. However, without coordinated policies we lose the ability to create any meaningful long-term change in the face of emerging challenges. Through sheer inertia, conventional high-input industrial farming will simply carry on, whereas agroecological alternatives which support food security, resilience, social equity and better ecological management, will be deeply damaged.

"My personal feeling is that technology is an excuse not to have any vision for what society wants from its food system. There's no vision at a policy level and, therefore, it is driven by short term vested interests and sadly our five-year electoral system is the primary driver."
Future Farming Participant

Governments should, therefore, create an environment and culture that allows for technology that is appropriate for agroecological systems of all types and sizes to be developed and implemented in a consistent and coherent way.

2) The approach to technological innovation in agriculture should be based on a "whole system" approach, building on – not destroying or by-passing – farm ecosystem management.

A common and frequently expressed view in our discussions was that the government's agritech policies prioritised technofixes over a whole systems approach to understanding and solving agricultural challenges. Instead, policies should support a diversity of approaches and give credence – and, where needed, financial support – to those aspects of farm production that are already working ecologically and productively.

For many participants, the most useful technologies existed at the "lower" or "intermediate" end of the technology spectrum (including hand tools and simple mechanisation). These should be affordable, accessible and repairable on-farm or nearby.

Technologies at the intermediate to high end of the spectrum, should fit with the ecological parameters of the farm and production system and accord with human engagement and autonomy.

3) Funding for technology in agriculture should be primarily aimed at delivering public benefit. It should have a "farm to fork" perspective with the aim of increasing domestic supply of healthy, ecologically produced food using short supply chains.

Where taxpayer money is employed (through direct investment and direct or indirect grants to bodies like research centres and universities) the government should look for measures of success beyond productivity and narrow economic growth metrics. It should also employ a more wholistic assessment of public benefit innovation to support the equitable availability of healthy food.

Farmers and growers in our workshops, while welcoming more government investment in sustainable farming, were firmly of the opinion that UK governments should only pay for innovation that meets multidimensional and democratically agreed standards for projects that are for short and long-term public benefit.

4) Establish structures, protocols and a culture of transparency and review for technology development and implementation for all technologies – including agricultural technology.

There is currently a notable lack of data in the public domain which enables farmers, researchers, investors and citizens to separate substance from hype. In the agritech field it is also, often, unclear what technology is genuinely available (as opposed to what is promised) and what the uptake is of those technologies that are available (as opposed to marketing or PR claims).

What Developers Should Do

Through our workshop and analysis it became clear that very little agritech has been developed with agroecological principles or applications in mind.

However, an agroecological technology sector which is part of the agroecological movement – open source, not controlled by patents and intellectual property rights (IPR), values-based and equitably transformative – could make a meaningful contribution to meeting the agroecology aspirations of scaling up/scaling out and fundamentally changing the farming and food system.

Co-creation
Farmers are not just 'end users' who can provide 'customer feedback'. Involving farmers at the earliest possible point in agritech development is a 'bottom-up' process, essential for creating solutions that are responsive, relevant, and impactful.

For agroecology, a co-creative process aligns tech with values of social inclusivity and equity and may help prevent the marginalisation of smallholders, women farmers and other vulnerable groups.

Results from a 2022 Innovate UK workshop found that by "*getting the end users on board early (ideally at the design phase)*" developers will be "*able to think about the benefits of the end-product rather than just about its features*." Farmer-led development is also part of the Farming Innovation Programme for England, though it's not clear how this process is monitored or evaluated.

Crucially for developers, this co-creation process may also be more attractive to investors who may even be more inclined to invest in innovations that are 'farmer led' and based on real-world needs.

Think progress, not innovation
The terms "progress" and "innovation" are often used interchangeably. In truth, they are separate concepts and each plays a role in driving advancements within the agritech sector. In contrast to the "fail fast, fail often" credo of innovation, progress acknowledges the importance of building on established foundations, leveraging existing knowledge and adapting proven solutions.

Focussing on progress, the agritech sector can foster continuous learning and improvement, ensuring that advancements are practical, accessible and scalable for farmers across diverse contexts. Many of the farmers and growers we spoke to were in favour of this approach.

Embrace complexity
The many facets of agricultural systems, including crops, livestock, soil, water, pests, diseases, weather patterns, market dynamics, and socio-cultural factors are constantly interacting. Changing one thing in the system can have impacts throughout the system – for good but also for ill.

Participants in our workshops expressed a desire for agritech developers to consider the broader ethical and sustainability implications of their innovations – food security, environmental conservation, social equity, and economic development – to design more effective and sustainable solutions that address the nuanced challenges and opportunities inherent in agricultural production.

Who shoulders the risk?
Some farmers are willing to offer access to their land, facilities or sites to test out new innovations in a "real world" setting.

Doing so can yield valuable insights and foster collaboration, but it also poses certain risks including crop loss or damage if the intervention does not perform as planned and allied to this are unforeseen environmental impacts such as soil degradation, water pollution, or harm to beneficial wildlife. New tech may require new skills and practices. There may also be health and safety impacts to consider as well as ownership issues where sensitive data has been collected.

Developers must address these and other tricky 'co-creation' questions such as: Post-development are farmers simply expected to switch roles into paying customers – and at what price level?

Follow through and follow up
While it is true that all the farmers and growers we spoke to used mobile phones – for example, to support existing tech and communication – when technology goes wrong, a mobile phone in the field or a barn, hampered by potentially poor reception, rarely counts as support.

Most farmers are not engineers and are already overwhelmed with the day-to-day business of running their farms, so an app or a chatbot is not a substitute for in-person, boots on the ground customer support.

With much government funding and focus on the R&D side of innovation, follow-through is an aspect of tech deployment that some developers don't have the resources for, and some may even fail to understand the importance of.

There is rarely information about the environmental or social footprint of technology production and use. There is little or no monitoring or evaluation of post-release performance (whether positive or negative in relation outcomes for people, businesses, crops, livestock or the environment) – certainly none where the results are publicly available.

There is limited (if any) transparency around the use of data collected, or 'harvested', from farmers, growers and their customers during the purchase or use of technology – even when that technology has been developed using public funds.

This kind of transparency is vital, particularly when ecosystems, food systems and communities are involved, as is ensuring time is taken to consider long term impacts and the implications of technology interventions – along the lines of the ideas of "slow science" and "slow technology".

5) Establish an agroecologically appropriate technology knowledge hub similar to the transdisciplinary "centre without walls" model of the Danish International Centre for Research in Organic Food Systems (ICROFS).

Working in collaboration with the agroecology movement and sector, agroecological researchers and technology developers, the government should establish a hub to support the development and actions outlined above.

The ICROFS "centre without walls" concept[79] encourages and coordinates multidisciplinary research across universities, institutions and other centres of agroecological expertise.

A UK centre of this nature should have an ongoing mandate for understanding and providing information about technology within robust, ethical and sustainable agroecological systems and to devise "best practice" governance protocols for the development (including co-creation), implementation and post-release monitoring on agroecological farms and communities.

"I think for technology to be agroecologically appropriate, it needs to create some sort of public good around the data that it's generating"

Wales Real Food and Farming Conference Participant

A wealth of expertise in these areas exists throughout the UK agri-academic landscape with centres of excellence such as the Centre for Agroecology, Water and Resilience (CAWR) at Coventry University, the Crop and Soil Science team at the Scottish Rural College (SRUC), Organic Research Centre and some organic advisory teams.

The 'public goods' rhetoric

In addition to these, it is worth considering whether the current framework of "public money for public goods" helps or hinders the development of coherent plans for the UK's agricultural future and in particular the scaling of agroecology.

"I know a small dairy start-up locally – he is pasture fed, organic, all the good things. He's working out of totally inadequate premises and wants to borrow money to build a proper size dairy. But he can't raise the money because he is seen as being too high risk by the banks – and by the government. That the government feels it has to be risk-averse as well is bizarre because it should be taking the risk"

Future Farming Participant

Agricultural innovation currently receives government support in the region of 2% of the UK's £14.5 billion public sector R&D budget.[80] This spend is justified by the notion of "public money for public goods", as set out in the government's 2018 policy paper *Health and Harmony: the Future for Food, Farming and the Environment in a Green Brexit*[81] and codified in the Agriculture Act 2020.[82]

The definition of a 'public good' has been massaged by policy makers over the years. But at heart a genuine public good is a non-tradeable commodity available to all regardless of their ability to pay (and typically, a public good – a road, park, or school – is provided by a government and funded through taxes).

While there are some who believe that a public good may also be a basic need such as access to clean air and drinking water – things which agriculture could help deliver – availability of clean air and water quality may also be influenced by affluence and ability to pay in any given region.

Some of the poorest parts of the UK, for instance, also have the worst air[83] and water[84] quality and least access to other potential public goods such as green spaces.[85]

It is arguable whether the conservation of 'natural capital', as envisioned in *Health and Harmony,* and which forms the basis of the Environmental Land Management schemes (ELMs), is the same as the conservation of 'nature'.

For some, putting a monetary value on nature makes it more, not less, vulnerable to extraction and exploitation. But it is almost certain that food, land or patentable technologies will never be anything other than tradable commodities.

Unless the government is prepared to re-envisage food as a commons, stop all speculation and commodity trading of food and ban the patenting of living organisms, it should stop saying they are. Instead, it should focus on achieving a better alignment between innovation funding and how agriculture can deliver genuine public benefit or public value.

6 MOVING FORWARD

It is politically expedient, but not at all accurate, to say that technology is values-neutral. This deeply embedded narrative – often expressed as "it's not the tool it's the way you use it" – presupposes those systems designed with the values and goals of large, high input, industrial farms can be easily transposed onto agroecological farms. This project challenges that view.

One of the fundamentals of agroecology is the recognition of the interconnectedness of ecological, social and economic systems.

Central to this philosophy is the belief that farming practices should work, as far as possible, with nature, promoting biodiversity, soil health and long-term sustainability. The narrative that technology is values-neutral undermines this perspective by suggesting that technological innovations can be implemented without regard for their broader social and environmental implications.

It has long been understood, as discussed in section 4, that technologies are not created in a vacuum; they reflect the values, priorities, and interests of those who develop and control them, promoting the idea that technology is values neutral, obscures these inherent biases and power dynamics that shape the development and deployment of agricultural technologies.

In addition, an uncritical embrace of technology as inherently progressive and beneficial overlooks the complex interactions between technological interventions and agroecosystems. While some technologies may offer potential benefits in terms of more efficient farm management, increased productivity or reducing inputs, they can also have unintended consequences.

Throughout this project, the farmers and growers we spoke to emphasised the importance of a more critical and context-specific approach to technological innovation, one that involved creating and evaluating technologies based on their compatibility with agroecological principles.

In considering their criteria for appropriate technology, as summed up in section 3, they also questioned the potential impacts on environmental sustainability, social equity and food sovereignty.

Some went further suggesting that the assumption that technology is values-neutral can marginalise and devalue traditional and indigenous knowledge systems.

By prioritising technological solutions over locally adapted and culturally appropriate approaches, there is a risk of locking in power imbalances, eroding rather than strengthening the diversity of agricultural practices and diminishing the resilience of farming communities as well as narrowing the range of options available to address agricultural and environmental challenges.

> *"The technology that would help me is technology that would help me to better understand these natural systems and to better be able to facilitate them to help create long term system change. But I think that's a big ask"*
>
> **Future Farming Workshop**

Whilst curious about new technology, the mindset of the agroecological farmers and growers in this project could best be described as "techno minimalist".

They were reluctant to invest in technology for the sake of it, not particularly persuaded by notions of being "left behind" and sceptical of technologies

that replaced their autonomy, hard-earned skills or decision-making capabilities. They were interested in technology that is appropriate for the way they farm and in sync with deeply held values.

An increasingly large body of work suggests that agroecological farming – which emphasises local and regional food production, cyclical systems, functional biodiversity, ecological efficiency, and based on values of justice, equity, open knowledge sharing and community-based governance – is the system that can best ensure resilient and sustainable food production in the future.

Several of our participants questioned whether "scaling up" or "being left behind" were really the only two options for agroecology's development. Scaling up does not have to mean increasing farm size or output. In this respect the concept of 'scaling out'[88] – connecting existing practitioners of agroecological farming in a way that extends their reach, encourages replication and normalises the principles, practices and values that underpin them – may be more fruitful.

In section 1 we asked whether agritech was a transition pathway or a Trojan horse. At the present time it is impossible to answer that question since many possibilities and possible futures are in play.

However, it is clear that unless the issues of equity and social justice which are fundamental to the goals and rationale of agroecology are embedded in technology development, implementation and assessment it will be transitory modification rather than transitional change.

"The people who control and are able to manage these technologies don't do this for the good of society. There is a corporate agenda and the agenda is to make profits and through that you sell"

Future Farming Workshop

The rapid growth of certain technologies in agriculture does have the potential to accelerate an agroecological transition. However, it also poses many risks to agroecology, not the least of which is reducing a whole system approach to an à la carte menu of technology choices.

In the context of agricultural transition and the scaling of agroecology, how we innovate, how we develop, invest in and regulate agricultural technologies clearly needs to change.

The agroecological movements and associated sectors can and need to do a good deal for themselves (see section 5). Ultimately though, the context in which these exist and operate is largely set by outside forces.

Much is said and written by policy-makers, politicians, academics and business about the need to make radical change in the way we interact with natural resources and how we use and abuse them, as well as how we have to change our patterns of behaviour and consumption. Land management, food production and food systems – agriculture – is also recognised as pivotal. Yet it is questionable how much is changing, or even whether we have identified a pathway to real change.

The hoped-for agricultural transition is not possible unless the agroecological movement visibly and collectively works to challenge and influence political, regulatory and commercial institutions.

A need for joined-up action

A good first step would be to stop fetishising innovation and, instead, articulate a clear vision of the future of agriculture in the UK – and we make several recommendations in section 5 about the need for a whole system, transdisciplinary approach to the implementation, assessment and regulation of agritech solutions.

This is a complex area and current government policies are deeply entrenched and heavily defended. It can be hard to know where to begin. Technology choices in agroecology, however, may provide a jumping off point and a useful platform from which to begin challenging dominant structures and values systems.

Concepts like "post-normal science" which challenges the narrow, but dominant "science-based policy" model may also be useful. Post-normal science recognises that in situations where the stakes are high, the facts are uncertain, values are in dispute and decisions are urgent, a scientific approach on its own is inadequate to provide clarity.

Post-normal science encourages collaboration, inclusivity and engagement amongst diverse stakeholders to jointly explore potential solutions.

In so doing, it promotes transparency, accountability and public participation, enabling us to navigate complex landscapes coherently and with greater confidence.

This work – in the fields and in the halls of power – also needs to be properly resourced. The funding being poured into innovation by the government is not a free ride. It comes with values, narratives and expectations that shape the trajectory of technology.

"The ecological and social are often two very different strands. For example, you could have technology that helps improve the soil, but is owned by Microsoft. It doesn't score well on social measures but could be considered ecological. The question is: is it agroecological?"

Oxford Real Farming Conference Workshop Participant

As with the Food Farming & Countryside Commission's proposal for a development bank[89] it may, in the end, fall to private and philanthropic investors to help drive efforts to rebalance the ecology of the agroecological movement.

If so, philanthropic institutions – especially those that focus on agriculture, food and the environment, must prioritise investment in the nuts and bolts of change and not only narratives and solidarity networks – important as they are.

Joined up policies that take a whole systems approach to food, farming and land are essential. But these cannot be developed by a privileged few.

As the environmental, food system and economic challenges we face become more layered, more diverse and potentially more divisive, it requires more voices at the table taking an active role in developing policy, in planning, in implementation and in oversight.

Where innovation is developed with public money it is no longer appropriate to invest in technology that reflects the needs and values of limited, select interests (even if they are nominally public interest bodies such as universities and research centres) or to finance and generate profits for private companies.

Environment, land use, food production and food systems are inextricably linked together and the challenges of one are challenges for all. Dealing with them is not simply a matter of technology. It requires nothing less than the radical, wholesale social change envisaged within agroecological movements.

Appendix 1 | DECISION-MAKING GUIDE

Workshop participants asked several key questions that they believed were central to the assessment of technology in agroecological systems. From these, we have created a simple decision-making guide that provides prompts in the form of criteria questions and helps users to rate the strength of their answers.

To use (as in individual or as part of a group discussion), consider each question and circle the node you feel best represents the answer to the question. Your responses will give a broad overview of the appropriateness of this technology in agroecological practice. Consider which of these questions are most important for you and your farm's priorities, as well as with the bigger picture of the type of food system you want to see.

PRACTICAL

Yes ■----------■----------■----------■----------■ No

Is it needed?
Is it solving a problem I have? Could an existing option do the job?
Does it align with my aims and goals for the farm?

What's its footprint?
How is it made? What provisions are there for end of life?
Is there a lifecycle assessment?

Might there be unintended consequences?
What are the risks for the farm, food safety, environment and society?
Is there transparency about unintended consequences?

Is it affordable?
Is it financially accessible for your farm, without compromising your values?

Does it suit the scale of the farm?
Is it adaptable for the scale of your farm?

PHILOSOPHICAL

Yes ■----------■----------■----------■----------■ No

Does it positively impact farmer autonomy?
Is it a tool rather than a replacement? Can it be fixed?
Does it reduce dependency on external companies?

Does it promote knowledge, learning and connection?
Does it connect me to other agroecological practitioners to share knowledge? Does it encourage or enable the carrying out of autonomous research? Does it help me understand my land better?

Does it have a positive influence on work?
Does it help increase skills? Does it increase meaningful work? Does it respect my integrity and the dignity of work?

Does it support diversity and complexity?
Is it billed as a 'one-size fits all' solution, or is it adaptable? Can it handle polycultures? Does it increase biodiversity?

■----------■----------■----------■----------■

Does it build community?
Does it allow us to tell a story? Does it allow us to reach more people? Does it positively impact the neighbourhood? Is it shareable with other local producers?

■----------■----------■----------■----------■

What is its intrinsic nature?
Are the innate values transparent? Are they compatible with the values and aspirations of agroecology?

■----------■----------■----------■----------■

POLITICAL

Yes No

Does the farm and movement benefit?
Does it benefit the farm, farmers and community first and foremost? Is there transparency about the distribution of benefits?

■----------■----------■----------■----------■

Was it made collaboratively?
Was it designed with and rested by agroecological practitioners? Does it support participatory learning and creativity? Does it fully recognise farmers as co-creators of knowledge, rather than just sources of data?

■----------■----------■----------■----------■

Is it owned and controlled by agroecological practitioners?
Can it be owned by farmers or communities? What data is being collected and for what purpose? Is it open source?

■----------■----------■----------■----------■

What does it demand of society?
Does it require mindset shifts - and if so, are these compatible with your values and those of agroecology? Does it contribute to radical change?

■----------■----------■----------■----------■

Appendix 2 | THE 13 AGROECOLOGICAL PRINCIPLES

Agroecology means different things to different people and in different contexts. Although efforts have been made to define what it is and what it stands for through a set of 13 principles [90] or guidelines, these are not written in stone nor in legislation, and many are open to interpretation. Farmers and growers can choose to embrace some of these principles and reject others, whilst still calling themselves 'agroecological'.

1 Recycling Preferentially use local renewable resources and close as far as possible resource cycles of nutrients and biomass.

2 Input reduction Reduce or eliminate dependency on purchased inputs.

3 Soil heath. Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and by enhancing soil biological activity.

4 Animal health Ensure animal health and welfare.

5 Biodiversity Maintain and enhance diversity of species, functional diversity and genetic resources and maintain biodiversity in the agroecosystem over time and space at field, farm and landscape scales.

6 Synergy Enhance positive ecological interaction, synergy, integration, and complementarity amongst the elements of agroecosystems (plants, animals, trees, soil, water).

7 Economic diversification Diversify on-farm incomes by ensuring small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.

8 Co-creation of knowledge Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange.

9 Social values and diets Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diets.

10 Fairness Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fairtreatment of intellectual property rights.

11 Connectivity Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and re-embedding food systems into local economies.

12 Land and natural resource governance Recognise and support the needs and interests of family farmers, smallholders and peasant food producers as sustainable managers and guardians of natural and genetic resources.

13 Participation Encourage social organisation and greater participation in decision-making by food producers and consumers to support decentralised governance and local adaptive management of agricultural and food systems.

While they are a useful communication tool and represent a milestone in terms of expanding awareness of agroecology, these principles, defined in 2019 by the UN's High Level Panel of Experts (HLPE),[91] have become a kind of bullet-point rallying cry that drowns out the real radical, socially- and politically-oriented and transformative nature of agroecology.

This, arguably, is better represented in documents such as the 2015 Nyéléni Declaration of the International Forum on Agroecology.[92] a landmark agreement that defines agroecology as a key part of building food sovereignty, and establishes the six pillars of food sovereignty:

- The right to food
- The right to use and manage land and territory
- The rights to water and seeds
- The right to livestock and biodiversity
- Food sovereignty as a joint struggle for justice
- Agroecology as a form of resistance to an economic system that prioritizes profit over life

Appendix 3 | METHODS AND PARTICIPANTS

The Agroecological Intelligence project had several phases over an 18-month period.

In the first phase, which ran in the second half of 2022 and into 2023, we engaged with representatives from across the agroecological umbrella to begin to understand their priorities and approaches to technology choices. Their input also helped us to design a research programme that gives farmers a voice in the next phase of the process.

During this phase we spoke to the Biodynamic Association, the Soil Association, Organic Farmers & Growers, Organic Growers Alliance, the CSA Network, Landworkers' Alliance, Permaculture Network, Nature Friendly Farmers Network, Pasture for Life and the Food, Farming and Countryside Commission to capture their thoughts and priorities in the agritech discussion.

For the second phase, we identified approximately 62 farmers and growers willing to participate in a workshop designed to understand their thoughts and feelings about different agricultural technologies as well as the practical and philosophical underpinnings of the technology choices they are making. We recruited the farmers from across the UK through a combination of reaching out directly and with the help of the organisations we consulted in phase 1.

Farmers and growers who agreed to take part in the project came from most areas of the UK

The phase 2 workshops were semi-structured broadly covering why individual participants farmed in the way they did and their general views on technology. They were held online between March and May 2023. In total 48 farmers and growers participated in 11 workshops, of which 9 were separated into self-identified strands and the final two were mixed groups for those unable to make their original date.

Participants were given an initial written information briefing on the project that included links for further reading and asked to fill in an online survey about their farms. Response to the survey was high – 42 participants completed it. The recordings and notes of the sessions were made available to each group and we encouraged and received further feedback.

In phase 3, we conducted a second set of more structured and in-depth day-long workshops to follow up the issues raised in phases 1 and 2 and dig deeper into the issues surrounding technology choice.

These workshops took place between July and November 2023. Our intention was for all these workshops to be in-person, but due to geographical and scheduling considerations, three of them were on Zoom. Four in-person workshops were held in Oxford, Exeter, Lampeter and Manchester, and we also held three online ones for participants in Northern Ireland, Scotland and a mixed group who couldn't attend elsewhere. A total of 24 people attended these workshops. Again, further feedback was encouraged and received from these sessions.

In addition to our core workshops, we ran three very full workshops at the Organic Growers Alliance annual conference in October 2022 and the Oxford Real Farming Conference in January 2023, and the Wales Real Food and Farming Conference in November 2023. These were attended by 144 people (52, 42 and 50 respectively) and helped

us interact with and ask questions of a much wider group of farmers and growers to begin to understand their main thoughts and concerns, which are also integrated into this report.

From the 55 hours of in-depth, semi structured and structured discussions we have drawn the core of this report and have created a simple set of criteria questions for assessing the appropriateness of a technology for an agroecological system (see section 3 and Appendix 1).

Who we talked to

In addition to the workshops, we also asked participants to fill in a short survey to provide more information about themselves and their farms.

Forty-two participants filled in the survey, enabling us to get a better picture of who they were and how they farm.

Based on the survey data, participants were generally younger than the sector average. The most recent figures from Defra – from 2023 [93] – show that 35% of UK farmers are aged over 65, whereas amongst participants in our workshops only 19% fit into this age bracket. This corroborates research by the Landworkers' Alliance, which found that agroecology is generally attractive to younger people.[94]

Our initial survey included a question asking respondents to consider these various 'strands' of agroecology and rank them according to how closely they aligned with their own values and approaches to farming. Most primarily identified with a specific strand (*e.g.* organic) but also aligned with agroecology and almost all acknowledged being part of a broader agroecological movement.

Workshop participants come from diverse backgrounds. Many do not come from agricultural (or, at least, mainstream agricultural) backgrounds; some chose to take up farming as a second career, while others sought to find a practical outlet for their interests in conservation and the environment.

With land access and farm profitability continuing to be major issues, new entrants who do manage to establish businesses tend to be seeking different ways of farming and growing.

Other participants had taken on the family farm and either continued working in the way their families had always worked, or had changed direction through converting to organic or adopting new approaches.

Agroecological farms are generally diverse in either cropping, enterprise and/or non-farmed areas and most participants identified their farms as mixed (41%) or horticulture (27%). We only had one specialist cereal farmer and no pig or poultry specialists. Defra does not maintain data on UK agroecological farms so it is unclear how representative that is.

Participants' farms ranged in size from 0.2 hectares to 1550 hectares. One third of survey respondents (13 people) had farms under 20 hectares, which is similar to the Defra figures of 39% of farms in England less than 20 hectares.[95] Of our participants, 35% (14 people) had farms over 500 hectares, which is greater than the national average of 24%

We were keen to recruit participants from across the UK. We largely succeeded, although the East of England and Scotland are under-represented. Even so, there is no existing map of agroecological farmers in the UK, thus there is no reliable way of judging their true distribution in relation to our core group.[96]

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