Cyborg Agriculture

Transforming Our Relationship with Technology in a Way That Evolves Agricultural Systems

The Rockefeller Foundation

Smallholder Data Services

Terra Genesis

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Foreword

Smallholder Data Services (SDS), supported by a grant from The Rockefeller Foundation, is working to ensure that smallholders who are directly involved in defining, implementing, verifying and scaling regenerative agriculture have a stakeholder voice as each of these aspects are being shaped at a global level.

In support of this goal, SDS and one of its founding partners, Terra Genesis, are generating a series of reports, recommendations, best practices and guidelines that draw from early-stage regenerative farming by smallholders in various parts of the world.

This report explores the role that technology has to play in the process of scaling regenerative agriculture.

In the course of undertaking this Rockefeller Foundation-supported initiative, SDS has also been drawing on an additional partner, the Smallholder Farmers Alliance in Haiti.

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Smallholder Data Services (SDS) is a consulting and research firm exploring how big data and technology innovations are enabling a revolution in both sustainable supply chains and regenerative agriculture. We reimagine data as a new sustainability product that financially rewards farmers and others involved in sustainable production, including small-holders in the global south. We focus on how the combination of data products and emerging technology unlock solutions for those concerned with the environmental and social impact of the products and services they market and purchase.

More at
smallholderdataservices.com

Terra Genesis

Terra Genesis is an international regenerative design firm that convenes brands, farmers, developers, communities, investors, and NGOs to work at the intersection of agriculture, ecology and economy. Our work is to evolve the role of agriculture and business as drivers of social and ecological health. We work from the ground up to evolve stakeholder capacity and capability and to identify solutions, create processes and curate interventions for systemic regeneration.

More at
terra-genesis.com

The Smallholder Farmers Alliance (SFA) is social business non-profit working to feed and reforest a renewed Haiti using a new agroforestry model in which smallholders plant trees to earn credits they exchange for seed, tools, training and other agricultural and community services. The SFA's 6,000 farmer members use organic methodologies, and are now in the process of transitioning to become regenerative.

More at
http://www.haitifarmers.org/

CONTEXT

Introduction

All images in the report produced by the author using DreamStudio

This report is intended to be read not as a technical manual or an extensive review of the current landscape of technical solutions, but as an exploration of the role that technology has to play in the process of scaling regenerative agriculture.

This document should be read and considered as part of the larger body of work developed during the spring and summer of 2023, which outlines an **aim and purpose** for scaling regenerative agriculture in Southeast Asia, Sub-Saharan Africa, and South America in a way that works from the unique essence and potential of each region.

- **Regeneration and Regenerative Agriculture: Definitions, Principles and Practices** covers the **principles** that underlay the paradigmatic shift from extractive modes of production and exchange, towards a regenerative mode.

- **The Final Project Summary and Partner Briefing** elaborates on these principles to inform **a conceptual framework** for scaling regenerative agriculture.

- **Scaling Strategy for Smallholder Regenerative Agriculture 2023-24** outlines the **strategy,** region-by-region, to support scaling activities to go beyond replication to genuine place-making.

- **Secondary Crops for Agricultural Diversification: Crop Suitability and Market Opportunities** builds further detail by delving into the specific market **tactics** that can support scaling.

- This report and **Evolving New Market Opportunities with Regenerative Agriculture Systems: Market opportunities for secondary crops, data products, and environmental markets,** discuss the requirements for **implementing and scaling** regenerative agriculture technically.

- **Methods for Measurement of Regenerative Agriculture in Practice** briefly outlines the **requirements for monitoring and adaptively learning** from implemented regenerative agriculture projects.

- **Decolonizing community health, nutrition, and culture through secondary crops** addresses crucial social **outcomes and impacts** associated with the incorporation of secondary crops via agricultural regeneration.

What follows will begin with a framing of the central argument of the document. The thesis is that a fundamental misunderstanding about the central essence, purpose, and value of technology too often clouds our ability to accurately apply technology for the liberation and evolution of humanity. The corrective is to reconnect ourselves with that essence, purpose, and value in a way that enables us to view technology not as something which we either have to be enslaved by or to subject wholly to our own ends but, when viewed in its true light, can be seen as a central defining factor of what it means to be human. In the reclamation of that right view of technology, we can then approach the promise and role for technology in evolving our agricultural systems beyond their extractive, sustainable, or even circular modes of being towards a manner of existence that is truly regenerative.

Democratize, Decommodify, Decarbonize

"Democratise, because too few people have a genuine stake and say in how they work, what is produced, and for what purpose. Decommodify, as it is only by rethinking the provision of goods and services that we can overcome the endemic insecurity that many people endure. Decarbonisation, because reaching net zero is not just a technical challenge but an opportunity for collective reimagination."

(MATTHEW LAWRENCE)

The quote from Matthew Lawrence wonderfully summarizes the attitude and approach that is fundamental in transforming the perspective from which we view the potential of regenerative agriculture and the different lenses through which we can look by consciously shifting paradigms. To truly democratize our food and material systems, we must transform our modes of production, engagement, and exchange. To decommodify our food and material systems, we need to question the paradigm of agriculture we are currently working from. To decarbonize our food and material systems will require an examination of the network structure and modes of relating we use to share information, value, and story. Accomplishing this collective aim requires moving from extractive forms of production to regenerative forms of production that bring us into greater relations with each other and our place in the world, moving from panopticon-like network and governance structures that seek to surveil and control towards more rhizomatic networks that allow for evolution in how we understand ourselves, each other, and our places in the world. It also requires that we move from exclusive forms of decision-making towards inclusive, community-led practices that are enabling local agency without unreasonable external influence, wherever that may be in the world.

The Paradigms of Regenerative Agriculture Development (Tensen, 2021; see next page) framework helps to concretize three pillars of the democratization, decommodification, and decarbonization process: land stewardship, network structure, and project governance. One of the significant implications

	PARADIGMS OF AGRICULTURE	PARADIGMS OF NETWORKS	PARADIGMS OF ENGAGEMENT
REGENERATIVE EVOLVE VALUE	**REGENERATIVE AGRICULTURE** KINCENTRIC ECOLOGIES	**RHIZOMATIC NETWORK** EVOLUTION OF SYSTEM	**COMMUNITY LED** CULTIVATE DEMOCRATIC PARTICIPATION & EQUITY THROUGH COMMUNITY-DRIVEN DECISION-MAKING
CIRCULAR RESTORE VALUE	**NET POSITIVE AGRICULTURE** CARBON FARMING, AGROECOLOGY, RESTORATION AGRICULTURE, PERMACULTURE	**MARKET NETWORK** DEVELOPMENT OF SYSTEM	**COMMUNITY COLLABORATION** ENSURE COMMUNITY CAPACITY TO PLAY A LEADERSHIP ROLE IN DECISION-MAKING & IMPLEMENTATION
SUSTAINABLE SUSTAIN VALUE	**CONSERVATIVE AGRICULTURE** CLIMATE SMART, ORGANIC, SUSTAINABLE AGRICULTURE	**UTILITY NETWORK** REGULATION OF SYSTEM	**COMMUNITY CONSULTATION** GATHER INPUT FROM THE COMMUNITY & CONSIDER COMMUNITY NEEDS & ASSETS
DEGENERATIVE EXTRACT VALUE	**EXTRACTIVE AGRICULTURE** GREEN REVOLUTION	**PANOPTICON NETWORK** SURVEILLANCE OF SYSTEM	**COMMUNITY EXCLUSION** DENY ACCESS TO DECISION-MAKING PROCESSES & PROVIDE ACCESS TO RELEVANT INFORMATION

of this graphic is that, at our present stage of development and discussion about regenerative agriculture, we are strongly working from the Circularity paradigm. For example, agroecology is a movement of solidarity between farmers; however, in principle it is a movement reacting to dominant neoliberal oppression of labor. Historically speaking, nation-states are the prime perpetrators and/or enablers of violence and dispossession of indigenous peoples. Current evidence suggests that nation-states are inimical to indigenous rights or at best, government policies — whether they are explicit or conspiratorial — reinforce the belief that indigenous territorial sovereignty is subordinate to the interests of the state.

The implication for us is that nation-states are territorial entities that derive power from the governance of land and the resources contained therein such that, although there is overlap in interests with smallholder and peasant farmers, smallholder and peasant farmers often have protected rights under national jurisdiction that indigenous peoples do not share. This could become a failure point when pressure is exerted on solidarity movements like agroecology where, by law, certain adherents have rights while others do not. This painful contradiction then enables us to envision more clearly what the higher register of kincentric ecologies might feel like. Similarly, movements like agroecology that aspire to reform markets in favor of labor; carbon farming which aspires to compensate farmers for offsetting other economically extractive behaviors; permaculture which seeks to create an alternative outside of markets but in reaction to them nevertheless; or restoration agriculture which aspires to restore what has been extracted by market activities, stand in contrast to kincentric ecologies which exist without the need to reference something else. Such is also true when moving from market networks which seek economic development and vitality towards rhizomatic networks which characteristically leave room for other ways of relating outside of capital structures.

We can begin to feel into what this higher register might be like by moving away from a critique of modes of production to modes of exchange (Karatani, 2014). This enables us to avoid false binaries between formal and informal economies or between different theories of capital towards pluralistic economics which don't give in to the hegemony of any one form of exchange (Roelvink et al., 2015), but instead permit interdependent ecosystems of exchange to coexist. This means we need to question our urge to weed out informal economies, non-wage labor, reciprocity or gift economies, or reduce ourselves to anti-global nationalism. It also suggests that the current obstacle is not the existence of capitalism but the insistence of adhering to capitalist doctrine while rendering all other forms invisible. This enables us to image a positivist world where the wealth imbued in capitalist systems is reinvested in other modes of exchange that are fit for purpose without the negativist interpretation that requires the wholesale extermination of capitalist structures. Rhizomatic network structures, which include and exceed the lower registers are ever-evolving and seeking out resource exchanges like living roots or mycelial hyphae (Deleuze & Guattari, 1987), require engagement strategies that challenge our notions of how governance can operate at scale.

Community-led engagement loses its true meaning if we reduce it to a feel-good aphorism or non-profit mission; it is an imperative across the board in order to achieve effective governance at scale. Collaborating with communities is valuable, but it often means many structural decisions have already been made outside of the community by grantors and project developers. Community-led governance fosters conditions of agency at the local level which has implications not only for the immediate transaction or grant program but for what becomes possible in long-term change. To exceed work at the level of circular restoration of value within these three pillars, requires we hold in our minds the promise beyond our current abilities of a deeply regenerative world.

Understanding how to do this well — to democratize, decommodify, and decarbonize — is therefore tricky and requires a delicate touch in order to trace the contours of something which is emerging with this promise beyond our ability, while guessing as to what it is exactly that will emerge. How does one do this with skill? Consider the example of a baby inside a mother's womb. The mother has the best sense about who is becoming inside her. It requires technical advancements for others, other than the mother, to scan and map the qualities and characteristics of who is taking form. These technical objects are the remnants of this outer revealing of the inner and may be our best entry point into the thicket through the means we all agree will enable scaling of collective action: technology. In so many words, technology is the ongoing process of making the invisible visible.

> **"Technology is therefore no mere means. Technology is a way of revealing. If we give heed to this, then another whole realm for the essence of technology will open itself up to us. It is the realm of revealing, i.e., of truth."**
>
> (HEIDEGGER, 1977)

A technical object by definition has no agency, other than the specific purpose for which it has been designed. A technical object is, taking off of Heidegger, a result of enframing *(Gestell)*, or revealing: a thing which has been separated.

> **"Enframing means that way of revealing which holds sway in the essence of modern technology and which is itself nothing technological. On the other hand, all those things that are so familiar to us and are standard parts of an assembly, such as rods, pistons, and chassis, belong to the technological."**

Non-technical objects — the continuum out of which technical objects are enframed and ordered — however, are alive, they have agency and importantly, interiority; meaning things can issue forth from the interior that bear no markings of the exterior: an idea from the mind, a baby from the mother, a flower from the stalk. To judge the works of a technical object, you can judge by the exterior alone, by the fruits of its actions: the wrench by its wrenching, the knife by its cut, the computer by its program. However, with non-technical objects, this is not a sufficient criterion. For the non-technical object, we have to withhold that judgment and consider judgment on the idea and the mind it is in, baby and the mother she is within, the flower and the stalk that contains it. In this action, we find one thing connected to the next, and the next, in an infinite regression. With a technical object, we can judge the thing in itself.

> **The visceral fear of technology that is a common experience, stems from this fear of being ourselves rendered a technical object, something cut off from its animating life force, something which can be judged wholly upon itself without any connections or relations.**

Just as the monarch declares himself sovereign, so too can his subjects declare themselves emancipated sovereigns. This kind of overthrow of the non-technical by the technical, or the becoming of the monarch by the subjected is far from something to be repressed, it is the act of creation that we must run towards. The act of balancing the technical and the non-technical is the act of creation at issue in this report.

The echoes of this rhythm of creation can be felt in the discussion regarding advancing technologies today, key among them artificial intelligence. We must allow, at historical moments, for the technical object to give birth to the non-technical and vice-versa. This is Haraway's cyborg. Donna Haraway's cyborg theory emerges from her background as a feminist scholar and historian of science. She was influenced by ideas from Marxism, feminism, and science and technology studies. In the 1960s and 70s, second-wave feminists criticized biological essentialism and determinism. At the same time, scholars were grappling with how science and technology shape society and culture. Cyborg theory challenges essentialist notions of what it means to be human or female.

The cyborg is a hybrid figure that blurs boundaries between human and machine, physical and non-physical, nature and culture. We are all cyborgs now, enhanced by and immersed in technologies that extend our capabilities. The cyborg metaphor allows us to imagine new freedoms and new forms of social relations outside the usual constraints of gender, race, and class. Cyborg theory informs critical analyses in fields like science studies, technology studies, digital media studies, and the environmental humanities. It prompts us to critically examine how technologies shape who we are and how we experience the world.

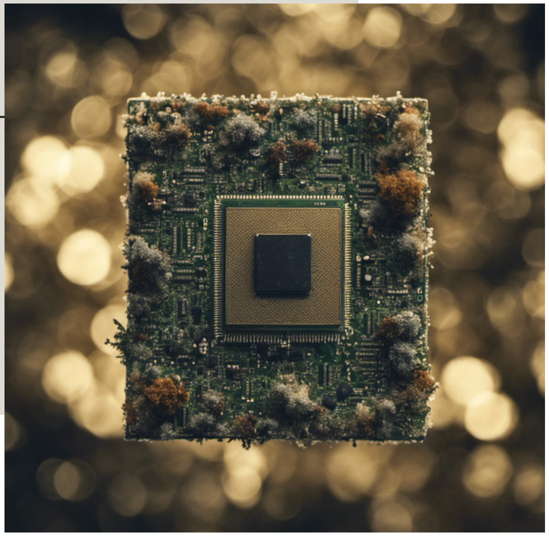
The task of this report is to demonstrate that, far from needing to subjugate technology to the will of humanity, or humanity being subject to the will of our technology, we need to find the imbrications where we become one; where our technology is essential to ourselves. Maybe, even, such that we are both able and willing to see our innermost selves in technology and vice versa. This radical perspective also borrows from a quantum understanding of

the world, and implies that there is no absolute center which issues commands like monarch to subject, or server to local client, but the technology enables the command from within to be heard, not the command from without to be obeyed. This is the urge followed by the pioneering internet developers, by the early personal computer innovators, by today's open-source technology developers: to enable democratic engagement with our collective posterity, technology.

Now, this point is of crucial importance: the act of scaling in social systems will be perceived, when taken as a strictly technical object, to be an external activity conveyed from some central authority according to writ and implemented by mimesis, an urge we must resist. The alternative is instead to queer our conception of it, see scaling in cyborg terms, with both a technical and a non-technical nature. In this sense, then, scaling has this inner dimension — one that is intimate, sensitive, and personal — which, if we deny it, will guarantee that technical scaling will be defined by subjugation, a mutual enslavement of technology to humanity and humanity to technology. This need not be the case. However, our governance systems, globally speaking, too often fail to live up to our hopes in their ability to adequately and humanely govern either social or technical systems at the level of national administration or international cooperation. So, in order for us to rise to the occasion, we must concern ourselves not only with the technical question, but with the intersections of our technical, legal, and business systems.

This is the challenge: How do we bring this democratization of technology to bear in the pursuit of our aims in advancing a more just, a more equitable, a more cyborg form of agriculture? Rather than seeing our technology as like a slave to our desires, and thus the threat of us always being potentially subject wholly to the desires of another, we see technology as emancipatory. The luddites were not defined solely by their ability to produce textiles. The luddites were specific men and women, with specific families, and relations. The threat lay not in the technology itself but in the wielding of the ability of one to render another human a mere technical object, and thus obsolete and unworthy of the life that animates them. The threat we perceive lies not in the technology itself but in the being who would wield technology to subjugate another. Let us not repeat the mistake, of taking ourselves for technical objects, or of mistaking our fellow beings for technical objects in our pursuit of this more perfect union.

The Role of Technology



We understand, from above, that technology is a reflection of our current understanding of the world and how it works. Heidegger offers us a means to deepen our grasp of how exactly technology also reflects our current understanding of technology and how it works. In *The Question Concerning Technology,* he states:

> ”The essence of technology is by no means anything technological. Thus we shall never experience our relationship to the essence of technology so long as we merely conceive and push forward the technological, put up with it, or evade it. Everywhere we remain unfree and chained to technology, whether we passionately affirm or deny it. But we are delivered over to it in the worst possible way when we regard it as something neutral; for this conception of it, to which today we particularly like to do homage, makes us utterly blind to the essence of technology.
>
> According to ancient doctrine, the essence of a thing is considered to be what the thing is. We ask the question concerning technology when we ask what it is. Everyone knows the two statements that answer our question. One says: Technology is a means to an end. The other says: Technology is a human activity. The two definitions of technology belong together. For, to posit ends and procure and utilize the means to them is a human activity. The manufacture and utilization of equipment, tools, and machines, the manufactured and used things themselves, and the needs and ends that they serve, all belong to what technology. The whole complex of these contrivances is technology.”

(HEIDEGGER)

There are a few important points here for us to use in our inquiry. First, to affirm or deny technology or even to believe it a neutral force blinds us to the true nature or essence of what technology is and does — our judgment of technological artifacts is a type of blindness that results in our own disenfranchisement. Therefore, striving at a true understanding of what technology is and does liberates us from the potential to be chained to our use of technology. In a day and age when social media is seen as an addiction, algorithms tuning to capture more and more of our thoughtless attention, words like these can serve as a balm and a call to action. As a second point, technology must be considered not as either a means to an end or an end in itself but the resolution of both as a single essence. Technology is the concatenation of a means and an ends as a unique whole. This gives us a strong indication of how we can elucidate a theory of technology and apply that to an understanding of the challenges facing humanity in scaling regenerative forms of land management.

Technology is the application of knowledge to achieve efficient means for practical purposes (ends) in a reproducible way. It is critical to understand the utility and limitations of technology generally before testing its application for scaling a movement like regenerative agriculture. There are 7 key characteristics to technology, modeled on the work of Jacques Ellul (Ellul, 1954), which elucidate how technology works. Technology utilizes an **artificial, engineered process** that follows a **discrete logic** according to a **standardized system** in a way that is **automated, self-augmenting and adaptable**, and **universally scalable** in order to generate **specific value.**

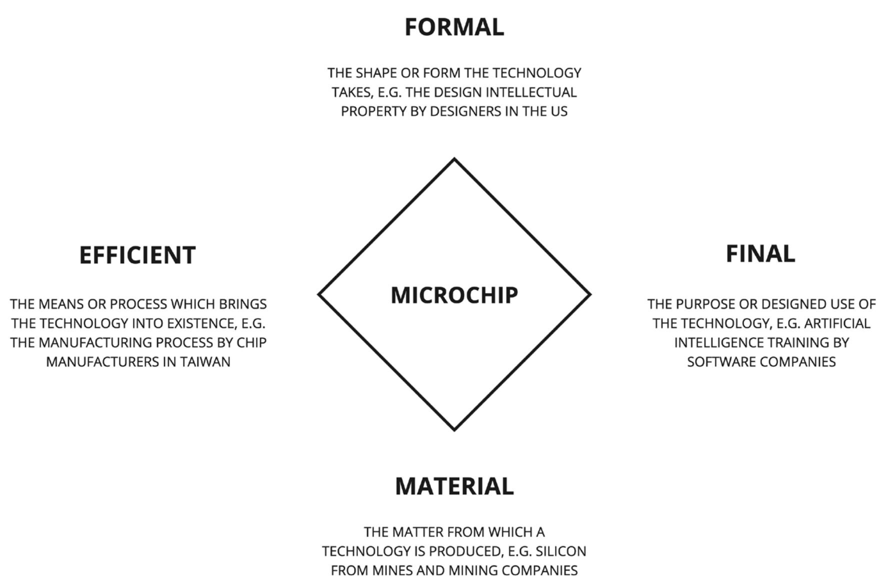
1. **Technology relies on a standardized system,** meaning it is the result of the process of systematizing and standardization according to a rational order.
2. **Technology is an artificial, engineered process,** meaning it intends to subordinate–and often destroy–the natural world and its inherent processes.
3. **Technology follows a discrete logic,** meaning it is a closed system with a reality and laws unto itself.
4. **Technology creates specific value,** meaning it reduces actions to the single most efficient means.
5. **Technology is automated,** meaning technical means are replicable and achieved according to mathematical standards of efficiency.
6. **Technology is self-augmenting and adaptable,** meaning it grows and builds on itself as the number of technical users increases.
7. **Technology is universally scalable,** meaning that it performs the same way everywhere it is employed.

Both Google Sheets and Microsoft Excel, for example, exemplify technology as the application of knowledge to achieve efficient means for practical purposes in a reproducible way. These spreadsheet software tools embody the characteristics of technology outlined by Jacques Ellul. They utilize artificial, engineered processes following a standardized system that operates with discrete logic. Through automation and adaptability, they enable users to create, analyze, and manipulate data efficiently. Moreover, these applications are universally scalable, catering to various needs, industries, and scales, generating specific value by facilitating data management, analysis, and decision-making in a reproducible manner.

We can see from this characterization that technology is neither an end nor a means in itself. It would be more apt to describe technology as the solidification of a particular form of means to accomplish a specific end. From this perspective, we can then begin to formulate questions such as: What reproducible means will enable the scaling of regenerative agriculture? What kind of standardization is necessary in order to scale without serving the means of the standard over the ends of regeneration? What engineered process can be applied to augment natural processes without destroying them?

Technology can also be understood, in its essence and broadest sense, through the four Aristotelian causes. Below is an example analyzing microchip technology from that perspective.

The significance of this framework in our understanding of the role of technology must not be underestimated. For non-linear or discontinuous evolution in the technological capability of human civilization is only possible through the alignment of these four terms: efficient, final, material, and formal. Taking, for example, AI: it was not until TSMC in Taiwan innovated some of the most efficient and precise manufacturing procedures that artificial intelligence has been able to achieve the ubiquity of today. However, the formal procedures for AI itself were mapped out in many cases 70 years ago, with huge leaps in formal understanding of AI at various periods over that 70 years. However, it took decades of materials innovation progressing before the manufacturing efficiencies of TSMC could be refined enough to enable the use of silicon wafers that truly unlocked the manufacturing innovations that then enabled the unlocking of the formal understanding of AI. In many cases the final uses of artificial intelligence, through science fiction and philosophy, far outpaced the other three causes.



Technology in Agriculture

> "The field that the peasant formerly cultivated and set in order appears differently than it did when to set in order still meant to take care of and to maintain. The work of the peasant does not challenge the soil of the field. In the sowing of the grain it places the seed in the keeping of the forces of growth and watches over its increase. But meanwhile even the cultivation of the field has come under the grip of another kind of setting-in-order, which sets upon nature. It sets upon it in the sense of challenging it. Agriculture is now the mechanized food industry.
>
> This setting-upon that challenges forth the energies of nature is an expediting, and in two ways. It expedites in that it unlocks and exposes. Yet that expediting is always itself directed from the beginning toward furthering something else, i.e., toward driving on to the maximum yield at the minimum expense."
>
> (HEIDEGGER)

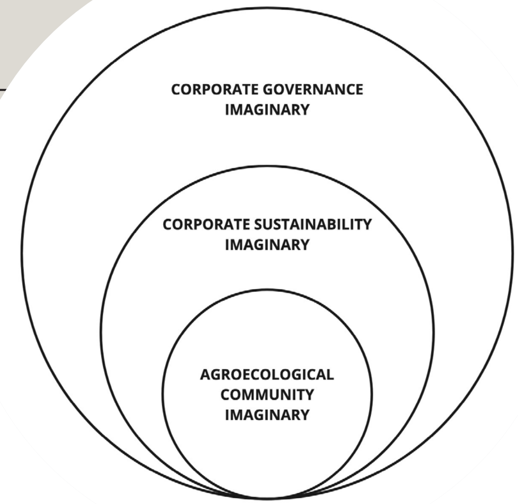
Technology has enabled the growth of industrial forms of agricultural production. Key among these technologies have been fossil-fuel powered tractors, petroleum-derived plastics, agrichemical inputs, and global positioning systems (GPS). None of these technologies are in and of themselves necessarily harmful, no more than the fire is harmful to the hand. But if we hold our hand to the promethean fire too long, it will burn.

Over-reliance of our agricultural system on fossil fuel and synthesized inputs, be they fertilizers or biocides, is a fire we have held our hands over for too long. I stress, however, that restraint is necessary to not criminalize these technologies.

As mentioned earlier, it was not the machinery that the luddites feared; it was who controlled them, or rather the lack of control over their own destinies, that they feared the most. We must be courageous here and avoid running headlong in the opposite direction of the thing we mistrust, and instead be skillful and intentional in moving towards the thing we desire, and let technology take shape around that process, however that needs to take place. This can help us avoid the common pitfall with technology of the means determining the ends.

Technology development is *literally* building the bike as you ride it. How else can you know what qualities or characteristics determine a good bicycle, airplane, or re-usable space shuttle? If we knew what those characteristics were in advance, it wouldn't be technological development: it would be technological infertility. So, we must apply a design science approach to true technological development to, as Buckminster Fuller would say, "Make the world work, for 100% of humanity, in the shortest possible time, through spontaneous cooperation, without ecological offense or the disadvantage of anyone."

Three Imaginaries



An imaginary is a valuable sociological tool for examining a set of shared values, norms, aspirations, and dreams that bind a group together. It is particularly useful for us in unpacking the confluence of stakeholder groups that are driving both the growing interest in regenerative agriculture as well as the concomitant eddies, frictions, and froth that arise from their differences. Each of these groups has an invaluable role to play in successfully scaling regenerative agriculture, and there are notable similarities between their approaches. However, it is equally important to identify differences, and be prepared to intercept the impacts of those differences, so that we can work with them productively. The first of the three groups are the local actors, the agroecological communities themselves, encompassing the land, waters, wildlife, and human communities that make places what they are. The second group is corporate sustainability, which encompasses the individuals, companies, industry groups, and other sustainability professionals that are committed to reforming business practices to better align the climate ambitions. The final group is international governance, which encompasses multinational organizations and government actors that have a global influence including the UN, EU, US, and other multilateral national partnerships.

Based on each of their unique perspectives — which are in many cases an evolving set of consensus perspectives laid out in reports, policy, speeches, and essays — we can begin to disambiguate what it is that each of them might see as the role of technology in scaling regenerative agriculture, and how that perspective will then set the tone for what is possible with that technology. We will now lay out some candidates for what each of these groups may see as the promise of technology and use that to explore how, based on those assumptions, scaling would unfold if we followed each imaginary to its logical conclusion. From there, we can use the fruits of our exploration to evaluate some of the potential themes and technologies that are prominent in technological discourse today.

Below is a table outlining the stakeholder role, the desired end-state that they seek from technology, and the purpose of that technology in action as they might see it. These preliminary conclusions are based on our experience working closely with these three stakeholder groups and will require further testing and upgrading as the movement progresses.

Stakeholder	Desired End-State	Technology Purpose
International Governance	Transparent, Stable, Trusted and Secure International Infrastructure	Technology that enables monitoring at a global scale in a way that is compliant with regulatory mechanisms so that we know our progress against global metrics.
Corporate Sustainability	Third-Party Compliance Reporting Framework	Technology that supports corporate risk reduction and strategic decision making in a way that holistically accounts for corporate impacts so that brands can hold themselves increasingly accountable and self-regulatory.
Agroecological Community	Community resources are owned and controlled locally	Technology that enables place-appropriate decision-making in a way that supports localized data ownership so that the value farmers create through stewardship activities is represented.

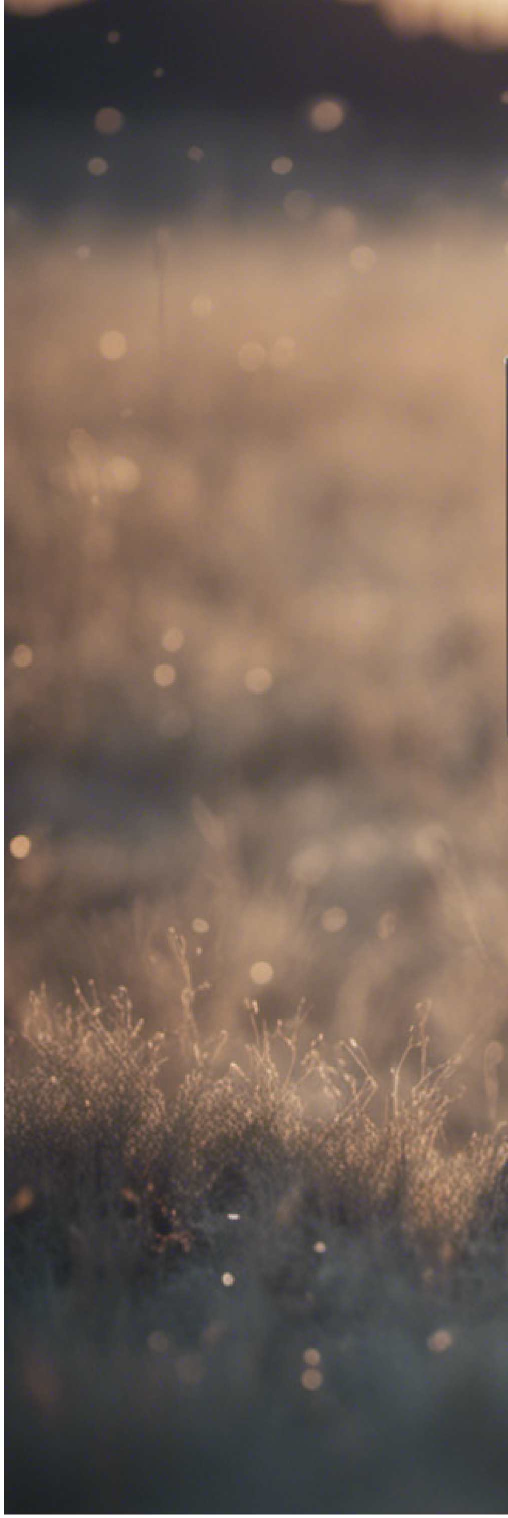
If we take these as our starting point, we can also identify some key differences in how each group might envision how projects scale regenerative agriculture and implement technologies.

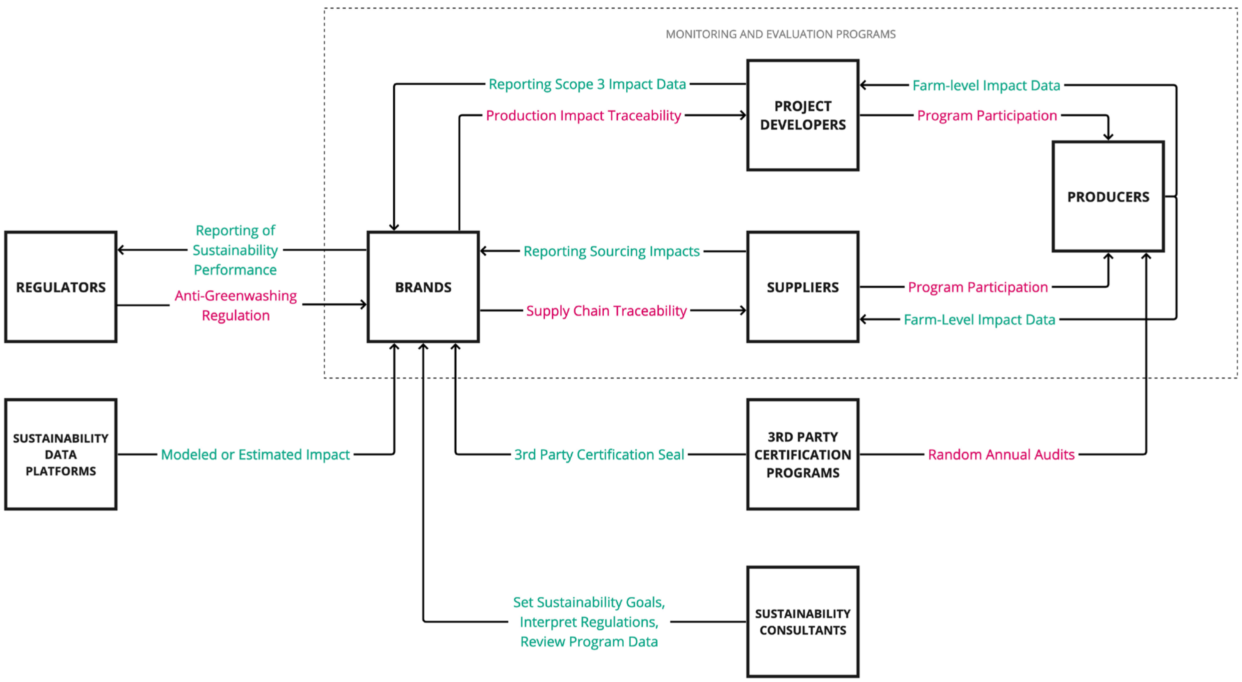
Stakeholder	Lead	Implementing Partner	User Base	Funding Source
International Governance	Nation-state representatives	Largest tech firms and civil society organizations	Governments and NGOs	Taxpayer Dollars
Corporate Sustainability	Sustainability Department Heads	Sustainability and climate consultants, project developers	Primarily company Sustainability departments but useful across different company divisions (legal, procurement, marketing)	VC, impact investment, customer-led software development, in-house funding
Agroecological Community	Community Leaders	NGOs, project developers, and other service providers	Land stewards	Grant funding

Further, we can extrapolate, based on the seven characteristics of technology outlined above, the characteristics each stakeholder might value and seek to accentuate in the technology.

Standardized System	Artificial Process	Discrete Logic	Specific Value	Automated	Adaptable	Scalable
National Application	Monitor and report on global climate and sustainability metrics.	Auditable	Compares global data from varied public and proprietary sources.	Compliance with current and emerging global regulations on interoperability, cyber security and privacy.	Global Working Groups.	saves time/money
Industry Application	Monitor and report on supply system sustainability metrics.	Interoperable	Compares sustainability program data from varied public and proprietary sources.	Data management, storage, and analysis.	Communities of Practice.	saves company resources/employ ee time
Local Application	Monitor information about a place and/or persons.	Customizable	Collects, stores, and analyzes data.	Data ownership and sharing protections.	Local Communities .	create jobs and/or not make farmers lives more expensive/difficult

Some of the key similarities between each of the groups is the need for high quality data, for secure data management, and for reporting activities across different scales. It is also important to note that in many cases the data producers are the communities on the ground, the immediate recipients are the industry actors who they are commercially or otherwise engaged with, who report to the international governance players. A flow diagram of relevant actors might look something like this (see next page):





Now there are some critical differences between each of these stakeholder types that are worth exploring initially through imaging the world as it would be if only one were successful in 2050.

Agroecological communities will have sovereignty and autonomy over their lands, their economic fortunes, and their data. There are successful corporate and multi-national oversight and controls to prevent rent-seeking and extractive behaviors to their detriment and the enrichment of others but not so much that it overly infringes on their self-determination. Communities are places where young people experience economic opportunity, have good educational options, where appropriate healthcare is available, and where land tenure is secure. Productive landscapes are a blend of local food, medicine, fodder, and fiber production as well as producing a surplus that is available for global market export. One of the greatest risks and an urge that is a conceptual location of active contestation is that of the reduction of phenomena to the technical object of local taboo and tradition. Those same values which can be liberatory can also constrain, disempower, and exclude. This process leads to factionalism, a type of neo-tribalism, and at slightly larger scales nationalism. It is the attempted subduction of other world views, perspectives or histories under others.

Corporate sustainability images a world of net-zero business that has strong, dedicated consumer bases who feel that the brands represent their values in their business practices without excessive and costly oversight and regulation. Sustainability has moved from a cost-center to a profit-center as nature and society are on the balance sheet, and business activities are demonstrably contributing to an increase in the net value of those assets. As a result, sustainability is not just an appendage to reduce risks for the overall business but has become central to good business operations and strategic decision-making. Corporates are celebrated for their ability to partner with the communities who produce their raw materials, to have transparent and equitable supply system relationships throughout the value chain, and are able to both reduce risks associated with climate change and other social disruptions as well as be more aspirational in doing good. One of the greatest risks in this imaginary is the reduction of phenomena to the realm of technical objects governed by capital.

This manifests as the financialization of industries, communities, and even government to the subordination under the rules of capital growth.

International governance organizations are successfully creating a stable and prosperous world, where the economic activity that is the lifeblood of global interactions is free from forced labor, free from deforestation and other harmful environmental damages, and decisions for extractive activities are made with full transparency and adequate oversight. As a result, there is a strong sense of a planetary identity emerging as hope is built that it is possible to generate economic vitality without leaving countries or cultures behind. One of the greatest risks posed in this imaginary is the reduction of phenomena to the realm of legal technical objects. This is visible in the grotesque and often contorted logic, band-aid solutions, and over bureaucratization of society.

Though we have clearly articulated some of the fundamental distinctions and relations between them, it is in their application, technically, commercially, and legally of specific technologies that we can clarify what is essential to each stakeholder type and image how we might see them interact with each other, both in conflict and in harmony. To resolve these three imaginaries with one another in practice in applying modern technologies, it is helpful to establish a shared vocabulary and reservoir of ideas. This will provide a working foundation for us then to test the unfolding of these imaginaries and their aims.

A Common Language For Bridging Worlds in the Integrated Circuit

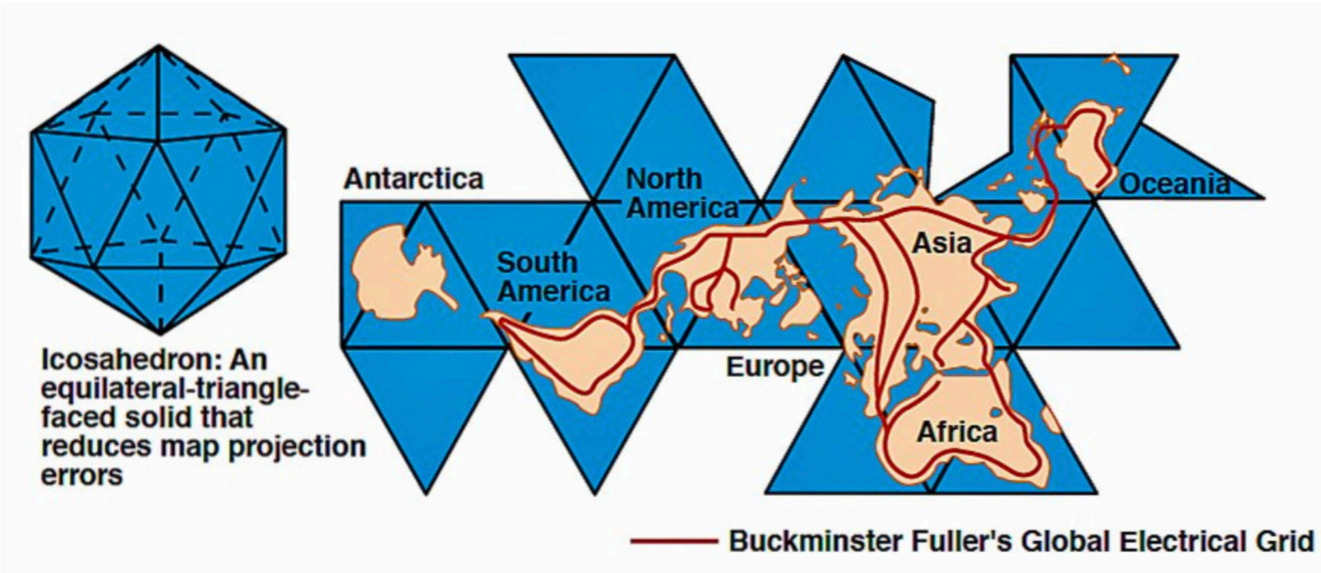
THEMES

ENERGY SYSTEMS

Energy systems constitute the totality of the means by which we generate, store, exchange, transmit, or consume energy. This is inclusive of the infrastructural, technical, business, legal, and social components as a co-constituted whole. Energy systems underlie our entire civilization: without fire, we would not have had the ability to keep warm on cold nights, cook food that enable the brain development that makes us who we are; without whale oil, generations would have lived in darkness; without coal, natural gas, and other fossilized sources of energy we would, for good or ill, have none of the development that brought us to today.

We are in the midst of a historic energy transition, from non-renewable fossil sources of energy to renewable forms of energy generation. However, these come with a cost. Many of the critical minerals needed for the energy transition are being extracted with potentially devastating ecological consequences. The locations of many of these minerals lay under indigenous territories, primary forests, and conserved lands. Extraction will come at a cost.

R. Buckminster Fuller proposed, through a World Game Workshop exercise, the world grid. The belief was that this grid would arise not through centralized planning but through spontaneous cooperation between nations based on need. Today, we are seeing most scholarship on this topic and the requirements of such a grid coming out of China, which is worth considering but highlights the need to develop research initiatives in other countries for a balanced approach to validate findings, like we are seeing in unprecedented international energy cooperation between European nations, Southeast Asian nations, and East African countries.



It is critical to understand the energy implications of the technology solutions proposed: data storage centers consume enormous quantities of energy, the computational power to produce insights from large datasets using artificial intelligence are even more energy intensive. For us to be able to usefully and resiliently manage data across international boundaries, we will need to consider the energy costs not just in establishment but over the lifespan of the technology.

A critical component of the World Grid, as proposed by Fuller, included localized micro-grids interconnected but modular in their relationship with larger regional or national grids. At present, there are no examples of international energy cooperation that would provide a precedent for the international governance imaginary, though one could imagine a federating model of local micro-grids with representation at regional or national level, and national level representatives at the international level.

MEASURING, MONITORING, REPORTING, AND VERIFICATION (MMRV)

MMRV systems comprise means and technical methods for data production, structuring those data for the purposes of monitoring system state over time, reporting in a credible manner based on those observations and retaining a trusted verification methodology to ensure soundness of data, observed changes or lack thereof, and the resultant statements that can be claimed about the observed system.

MMRV is the foundation of the programs that link international governance organizations, corporate actors, and communities. Much has been written in these reports on MMRV, especially in Report 2, Methods for Measurement of Regenerative Agriculture in Practice.

Case Study: Ethos, Regen Score, Regen10, and Textile Exchange Outcome Methodologies

DATA ECONOMICS

Data economics is the study of the production, storage, distribution, and consumption of data. As a disciplinary field, it implies a transdisciplinary lens incorporating elements of social science, computer science, and physics in order to understand the value of data. Getting data economics right is fundamental to the right working of all downstream processes. Data requires thermodynamic energy to be produced, to be stored, to be distributed, replicated, and consumed. This has energy cost significant implications for the physics and economics of valuing data in a way that is only beginning to be explored. It also requires other critical resources like network bandwidth (which is limited) as well as minerals for the devices that produce, store, distribute, and consume the data, and it relies on the labor to both produce the methods and tools for the above as well as for the ongoing collection and maintenance of the systems.

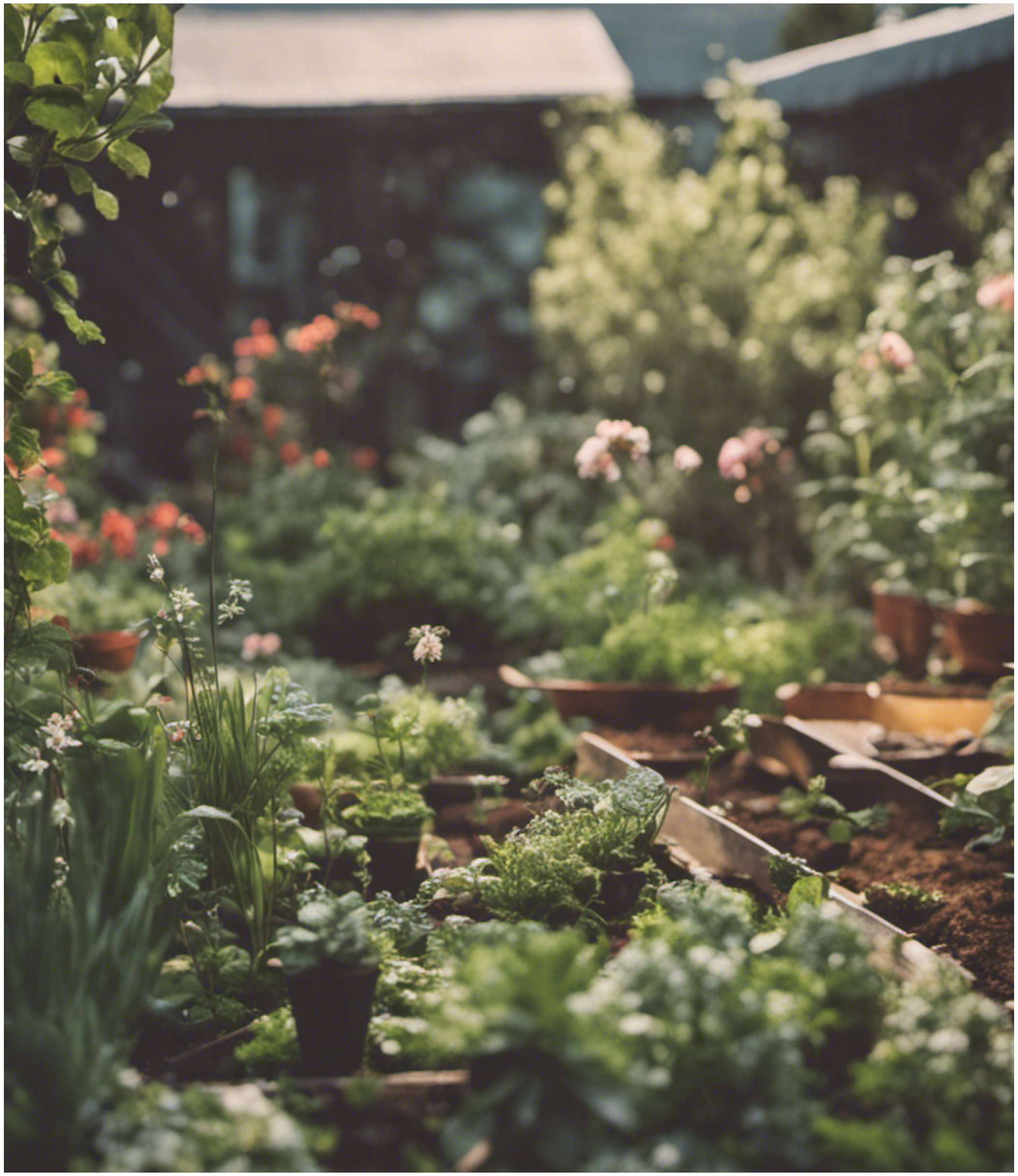
Different approaches to data economics reveal different foundational assumptions about what the field represents, what it could do, and how it should go about doing what it does. Here, we are first of all interested in identifying promising currents of thinking about and engaging with data economics, in novel ways that seek to ground, evolve, and clarify the appropriate role that bringing data to markets might play in a broader effort to regenerate landscapes alongside honoring knowledge and practice tied to particular places. This includes a journey into country-centered, CARE principles — examined in greater detail below — and other approaches developed by indigenous peoples. These are perspectives that are uniquely placed to speak to a pluralistic worldview and deep connection to particular territories at a time when the dominant tendency toward the monoculturization of landscapes, knowledge, and lifeways is demonstrating its detrimental effects to all life on our planet. They are also perspectives that are particularly sensitive to dominant power dynamics and how territory and culture are really two sides of the same coin of *place*.

The big challenge of data economics follows a similar trajectory: to operate with enough coordination at scale so that value exchanges can take place in significant ways, but to also operate in ways that do not assume that the purpose of data economics is to *empower* people, or to engage in similar notions of *helping* by

introducing technologies from the outside. Whilst not necessarily intentionally so, these are all expressions of neo-colonial ways of engaging with people and places, of generic and predetermined approaches that will only serve to further the monoculturization of all life. Credits related to tree planting schemes are a case in point, with numerous examples of displacement of people and existing ecologies with large-scale planting of mostly one or a very small number of species, with little attention paid to the actual characteristics and inherent potential of specific places and the people who inhabit them.

How, then, can we ensure that people and landscapes are not mere data points, not subjects for outsiders to help, not *tabulae rasa* for overly simplified landscape interventions, but active creators of the systems where data is traded? This is our current challenge.

Case Study: Regen Farmers Mutual Data Cooperative



TRUE COST ACCOUNTING

True cost accounting is a proposed expansion of traditional accounting practices that seeks to incorporate not only the direct costs associated with a product or service but also direct and indirect ecological and social costs. The externalization of these costs is enabled by the extraction of a public good, which is often justified legally through the belief that economic growth is a creator of a greater public good. There is a lot of effort at the moment to establish voluntary crediting schemes for natural resources, however, due to the complexity of converting the analog continua of nature into digital quantities, these programs are brittle and prone to damaging errors. It is possible that the epistemological foundations of quantizing nature into units are fundamentally flawed. One alternative to overly reductive and mechanistic approaches to comprehending nature is true cost accounting.

This methodology, like financial accounting, allows for a much more flexible and realistic approach to valuing ecosystem and social services. It is approachable for communities, governments, and companies. While there may be differences of opinion as to appropriate valuation measures, it creates a framework for negotiating those differences and enabling regular accountability, taking data from simply providing statements of outcome and impact, to being priced into market products and services.

International governance organizations have a crucial role to play in leading the formulation of minimum accounting standards for TCA and the integration of TCA methods with national balance sheets. Some forward-thinking brands are already looking at different approaches to TCA — as an example, we might mention Kering's Environmental Profit and Loss tool. However, for strong accountability, international standards will have to be established and certified by a standards body for trust to be maintained across sectors and actors.

It is worth mentioning that TCA is an important commercial accounting methodology but should not be seen as a replacement for the Rights of Nature and the legal frameworks that are being developed to invest inalienable rights in the biosphere itself.

Case Study: Global Alliance for the Future of Food and True Cost Accounting

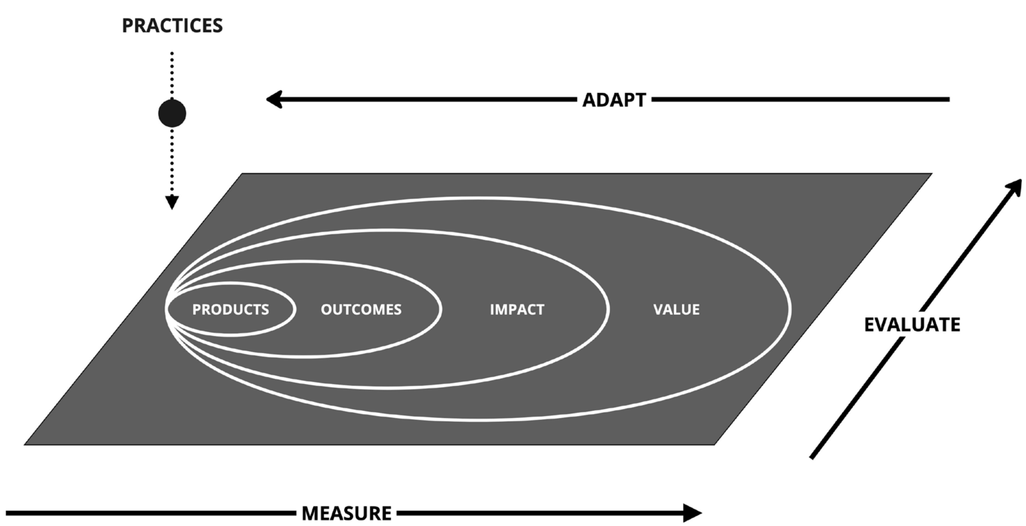
PRACTICES ARE THE INPUTS, RESOURCES, AND BUSINESS ACTIVITIES.
E.G. KILOGRAMS OF RUBBER

PRODUCTS ARE THE DIRECT RESULTS OR OUTPUTS OF THOSE PRACTICES.
E.G. ON-FARM BIODIVERSITY

OUTCOMES ARE THE OBSERVABLE CHANGE RESULTING FROM THE PRACTICES.
E.G. INCREASED FOOD SECURITY AND HABITAT

IMPACT IS THE TRANSFORMATION IN THE SYSTEM, PLANET, INDUSTRY, OR SOCIETY AS A RESULT OF THE PRACTICES.
E.G. ENHANCED COMMUNITY AND WILDLIFE RESILIENCE

VALUE IS HOW WE ASSIGN MONETARY OR MONETARY EQUIVALENT VALUE TO THE IMPACTS.
E.G. AVOIDED COSTS OR NET ADDITIONAL VALUE IN USD

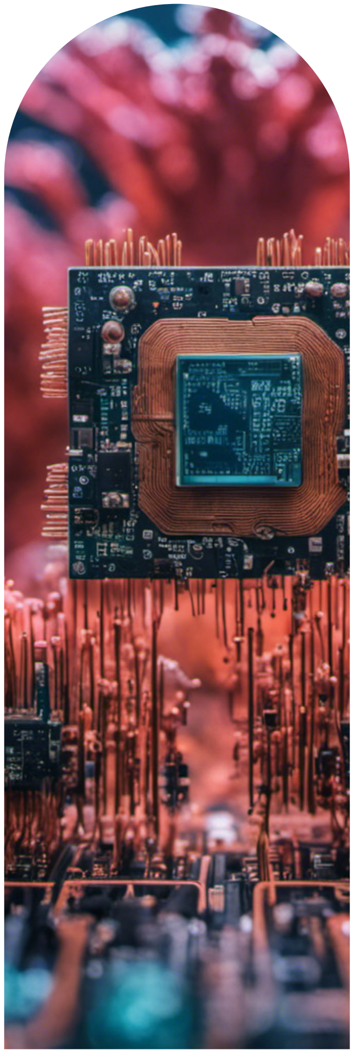


ALIGNMENT

Alignment is a new field of study intending to better understand how to align artificial intelligence with the desired needs of humans. AI alignment is a critical challenge facing humanity today. More organizations are being created to study and advise on how to better understand the biases and hallucinations in AI systems. One of the basic challenges facing alignment researchers is available data for the training of artificial intelligence algorithms. Many of the issues that arise are due to gaps in data that accurately represent the diversity of humanity. Programs that center communities and compensate them for usage of their data in models can both assist in better aligning AI algorithms with human desires while also creating new revenue streams for data producers like on-the-ground communities. Corporations are widely implementing AI without appropriate safeguards and regulators are struggling to keep up with the advances in the technology.

NETWORKED GOVERNANCE

Networked governance, as opposed to territorially derived authority, is the means of governance of a networked system of people. This includes more recent and novel forms of networked governance like blockchain-based DAOs and platform cooperatives in addition to more traditional forms of centralized network governance.



One of the greatest contributions the Internet has made to society is its ability to connect like-minded individuals regardless of location. With the advent of widely available social platforms and blockchain technology, communities have been able to move beyond message boards, forums, and social media to platforms and technologies that enable distributed and participatory decision making. These types of advances can enable community ownership, whether it be of businesses, interest groups, physical places, or natural assets. They, in some form, will play a notable role as regenerative agriculture programs scale.

Case Study: Regen Foundation, Community-Owned Blockchain and DAOs

GAMING

Gaming, for our purposes, can include any form of play that includes technical and social participation. Play is foundational to how humans interact, learn, grow, and build relationships. As gaming has increasingly moved online and now into mobile devices, there are opportunities to gamify experiences in a way that builds new ways of forming relationships across distances. Whether it be collaborative storytelling, mission-driven digital and real world actions, or simply using gaming as the basis for education, understanding the role of gaming in empowering communities will be worth evaluating as we progress.

DIGITAL ID

Digital IDs are a diverse set of tools which specifically identify an individual. This can include elements such as email credentials or biometric proofs. Identification is nearly invisible until you lack appropriate papers or documentation: email, borders, bars, and workplaces are among the critical uses for proper identification. As our lives hybridize between the digital and real worlds, digital IDs will become fundamental to human interaction.

CYBERSECURITY

Cybersecurity is the practice of protecting technical, often networked, infrastructure from unauthorized or malicious threats to either the infrastructure itself or the users. The need for robust cybersecurity will only increase in importance as we increasingly digitize and live our lives online. More and more critical infrastructure and personal information lives on networks that are vulnerable to malicious intrusions. We will need to seriously consider the safety and security of vulnerable populations as they become potentially more vulnerable to government oppression, fraud, and other issues that arise from insecure digital infrastructure.

Cybersecurity will increase in its relevance as we expand the availability of Internet access to Internet-poor geographies of the world and extend the process of data collection and valorization that is advanced in the global north into the global south. Corporates will likely see rapidly developed and varied governmental responses to the management, storage, and control of sensitive data: this could include restrictions on how personal data of citizens of one country is stored in country, how it is accessed by actors outside of that country, and conceivably even adding tariffs or levies on the trading and export of data products. ■

BLOCKCHAIN

Blockchain technologies are a type of digital database that differs from conventional databases through its use of a decentralized ledger of transactions amongst the participating nodes. There has been a lot of hype and inordinate investment in these technologies, especially cryptocurrencies, over the last decade since Bitcoin was launched in 2008. Following the so-called crypto winter of 2022, many blockchain companies, cryptocurrency exchanges, and blockchain miners have failed to find true value generating activities. The challenge for utilizing potential blockchain applications in scaling regenerative agriculture will be to avoid hype and to discern where it truly adds non-displaceable value to the efforts of communities, companies, and governments.

Some of the noted advantages of blockchain technologies over traditional database technologies are the former's transparency to network participants, the immutability such that database records cannot be altered, and the auditability; since transactions are recorded immutably, you can audit past transactions. Blockchains can also be public, semi-private, and private, enabling a variety of applications. Some notable disadvantages include the fact that past records cannot be edited, that the transparency can be a double-edged sword so private data is usually best not stored on public blockchains, energy intensive proof of work protocols, and the fact that the majority of blockchain methods are extremely energy-intensive and costly to implement.

ARTIFICIAL INTELLIGENCE

Artificial intelligence is a broad field of study which aims to apply our understanding of human intelligence and technical systems to synthesize a fundamentally non-organic intelligence that rivals or exceeds that of humans. Artificial intelligence, particularly large language models, have been the recent subject of overhype in the media. Artificial intelligence has many fields ranging from computer vision to natural language processing and more. Increasingly, the cutting edge will not only be in the optimization of a single form or model but of multi-modal AI which combines image, video, audio, text, and more into a single fluid interface.

Artificial intelligence, despite its name, is not as intelligent as media hype often portrays it to be (Baron, 2023) (Schaeffer et al., 2023). There are numerous biases, hallucinations, and other harmful behaviors. However, for rote tasks, it can greatly increase efficiency. It can detect patterns in datasets that no human expert would be capable of detecting, and it is dramatically upgrading our ability to make actionable sense of large amounts of information.

Active Inference is an emerging field that combines advances in our scientific understanding of Bayesian statistics and cognitive neuroscience to describe "a normative framework to characterize Bayes-optimal behavior and cognition in living organisms" (Parr et al., 2022). The theory describes the way biological organisms utilize sensory input and perception processing to minimize surprise in the organism's sensory observations. Applied computationally, researchers are working to use theoretical science to improve the predictive capacity of machine learning.

INTERNET OF THINGS

> **“The internet, as a mediator of human interactions, is not a place, it is a time. It is the past. I mean this in a literal sense. The layers of artifice that mediate our online interactions mean that everything that comes to us online comes to us from the past — sometimes the very recent past, but the past nonetheless.”**
>
> (L.M. SACASAS)

The Internet of Things is the networking of devices to enable the exchange of data. Internet of Things enables edge devices such as mobile phones, sensors, and other electronic devices to exchange data packets, upgrade software remotely, and collect data in remote areas. It does, however, come with considerable risk: as more and more devices go online, the surface area of risk increases dramatically threatening privacy and security.

We can also move beyond thinking of distinct sensors and consider moving into environmental computing. In *Program Earth,* Jennifer Gabrys examines instances where researchers are experimenting with large-scale landscape monitoring using local area networks, algorithms to analyze and process data in edge devices, and transmit valuable data packets to central servers for deeper engagement. She explores further how this isn’t simply infusing the environment with sensors but actually creating new ecologies inclusive of the technical and computational components: producing computational ecologies, a type of cyborg ecosystem. One can easily imagine these experimental stations expanding globally as costs decrease and applications clarify, in line with John Seely Brown’s proposal in his 2001 essay Ecological Computing (Seely-Brown & Rejeski, 2000).

Case Study: Ecoacoustics and eDNA for Biodiversity Monitoring

SPATIAL COMPUTING AND EXTENDED REALITY

Extended reality technologies include virtual reality, augmented reality, and mixed reality and have been frequently bundled into the term Metaverse. Extended reality technologies enable engagement with fully virtual environments, or overlaying digital objects in the real world. Increasingly hybrid experiences are available with different degrees of digital and physical world interactions.

Advantages include giving people immersive experiences, learning opportunities, and communication abilities that are not possible with traditional digital technologies. Challenges include that extended periods wearing virtual reality headsets can cause physical sickness. They are also expensive, and are not yet at the point of having dependable value for many different applications.

Extended reality technologies will play an important role in expanding access to education and training in regenerative agriculture, in plant disease diagnostics, and potentially even in machine repair. It is conceivable that in the future MMRV surveys can be conducted remotely by auditors and producers using extended reality technologies.

3D PRINTING

3D printing technologies, also called additive manufacturing, enable the construction of objects from 3D digital models. 3D printing is used to fabricate all sorts of household and other tools that were never possible before, including manufacturing parts, architectural models, buildings, and even spaceships. Potential 3D printing applications could be used to develop or print open source agricultural tools, to test feasibility of agricultural structures prior to full construction, and for educational purposes.

AUTONOMOUS VEHICLES

Autonomous vehicles, or self-driving vehicles, do not require a human to operate. Autonomous vehicles are still very early in their development, with most real-world applications taking place in major US cities. These pilot programs are not without their issues, whether it be Waymo, Tesla, or General Motors. Potential benefits of autonomous vehicles could include improving the reliability and lowering the cost of logistics; however, the current costs and risks make it infeasible in the near future.

ROBOTICS

Robotics technologies enable humans to augment, automate, or otherwise streamline tasks. Potential robotics benefits could be easing some of the strain that comes with more labor-intensive demands of farming, helping with more mundane or repetitive tasks, or even extending human appendages. However, we must be careful to avoid over-designing agricultural systems to fit our robotic technology and instead see how robotics technologies can improve the ability to manage regenerative agriculture systems.

Many images of robotics in agriculture today feature monoculture systems with robotic weeders to lower labor costs, robotic pesticide applicators to avoid human exposure to harmful toxins, and robotic fertilization based on precision agriculture insights. However, we can evolve beyond this unimaginative rendering of the future and instead consider how robotics can be integrated into agroforestry systems to support in robotic harvesting of chestnuts or automated transportation of apple bins from field to storage. We also often think about how robotics extend the human ability to do tasks but we could also thread the line of science fiction and ask how we can extend the agency of the trees, shrubs, and plants to care for themselves; extending cyborg agriculture beyond just human-machine interaction towards biological organism-machine interactions.

BREEDING AND GENETIC ENGINEERING

Breeding is a natural process that has evolved into the technical field of genetic engineering with the advancement of human understanding of genetics. Potential genetic engineering benefits could be enabling new varieties of historically annual species that perennialize, as is demonstrated in the breeding efforts of the Land Institute in Kansas or the genetic modification of the American chestnut in SUNY's American Chestnut Research and Restoration project. This approach can also be used in other efforts such as supporting species to adapt to climate change and diversifying genetics for the sake of natural resiliency. Some notable issues with genetic engineering have specifically arisen when the technology is employed to increase farmers' ability to apply agrichemicals and to protect corporate intellectual property through patent enforcement efforts that further jeopardize farmers' livelihoods and unmodified genetics.

There are a lot of opportunities to explore the edges of human imagination with genetic engineering moving into the space of biological computing (Gent, 2023), where instead of using silicon-based processors, we are using biological-based processors. This technology is at a very early stage but is worth watching as cyborg realities continue to blend the machine with the biological in new and surprising ways.

5G NETWORKS

5G networks are critical for expanding access to many of the aforementioned technologies by enabling increasing bandwidth and data transfer speeds. They will support the proliferation of edge computing and IoT, autonomous vehicles and robotics, and enable more equitable access to the Internet. Some of the challenges posed relate to the necessary proximity of transmission towers which increases costs of implementation and the ongoing risk posed by the different spectrum allocations established in the western world and countries utilizing Chinese infrastructure. Satellite and Low Earth Orbit (LEO) technologies like starlink, alongside 5G internet connection, will continue to play a critical if controversial role in interconnecting humanity, especially in Internet and data poor geographies.

Spectrum and electromagnetic spectrum allocation is a critical and yet often overlooked aspect of our infrastructure. To make way for 5G, spectrum reallocations occurred by the federal government and were then auctioned off. Different nations have different spectrum allocations and different bandwidth or frequencies of spectrum have different value for particular uses. One major discussion point has been the fact that China allocated for lower spectrum and is constructing infrastructure for 5G based on that, while the US allocated a higher frequency leading to the potential for non-interoperability that would be extended to countries which choose to partner with telecommunications firms from either the US or China. One example of the implication is that, due to the lower frequency spectrum allocation, Chinese repeaters can be placed at further distances than US infrastructure, potentially lowering the overall cost.

This esoteric aspect of our natural world, though, should be considered as indigenous space (Jean & Cocullo, 2022). Similar to other natural resources, in post-colonial national administration, once the electromagnetic spectrum became valuable with the advent of radio communications technologies, nation-states were quick to claim ownership and displace any notion of indigenous rights over it. There is a particularly striking example in New Zealand where Maori leadership successfully sued the government for access to spectrum, arguing that the colonization of spectrum was a breach of the Treaty of Waitangi (Taylor & Middleton, 2020). This successful suit didn't result in complete accession of spectrum, but did lead to the establishment of the first indigenous radio station on tribal frequencies.

CRYPTOGRAPHY

Cryptography today is expanding beyond early applications of security and later ones for decentralized consensus, such as blockchains and cryptocurrencies, into new frontier areas of computing, through technologies such as cryptographic data sharing. Cryptographic data sharing technologies are a set of techniques that allow organizations to share data securely and privately by encrypting the data so that it cannot be read or stored by unauthorized parties while still allowing for its utilization in both one-to-one and multiparty scenarios. The techniques of cryptographic data sharing include public-key encryption, homomorphic encryption, secure multiparty computation, zero-knowledge proof, and differential privacy. Among them, the techniques provide security, ownership, privacy, compliance, and efficiency in the sharing of data between parties.

PATHWAYS

Technical, Business, Legal

In order to appropriately characterize where we are and the current ways in which technology is being implemented or proposed for implementation to scale regenerative agriculture, what is needed is a technical, business, and legal analysis framework. We need to understand the technical requirements in order to ensure feasibility and technological readiness and the business context to ensure there are both appropriate incentive structures for implementation and maintenance as well as viable business models for iteration and improvement. Lastly, the legal aspect helps us consider the needs to regulatory and policy guardrails, potential harms — existing or novel — that could be aggravated by the technology, and agreements that need to be in place between parties to ensure equitable and fair use of technologies in practice.

Today we live in a world where, in most cases, business and government are out of step with one another. Either through failures for policy to catch up to technology — as is the case with artificial intelligence and social media, businesses circumventing laws in one jurisdiction by moving certain operations to other jurisdictions as is the case with many cryptocurrencies, or through enabling self-regulation within industry without appropriate government oversight — there will be many more technical, legal, and business challenges posed along the way.

Technical Requirements: How It Is Done

Technical Imperative: *data storage structures and infrastructure that enable global interoperability*

The technical requirements of achieving regenerative agriculture at scale will be great, but we have already come a long way. There are three primary aspects of the technical infrastructure that will need to be developed: infrastructure and hardware, systems and software, and protocols and processes.

INFRASTRUCTURE AND HARDWARE

Infrastructure and hardware is where some of the most expensive investments will be required. This is the aspect of technical development that will require a diversity of minerals to construct it, energy to power it, governments and companies to invest and de-risk it, and lots of labor and time for its establishment and maintenance. This is also the portion that can have the greatest negative impact on the environment and communities through the extraction of natural resources to construct the infrastructure, the energy systems to utilize both resources and land that could be put to other purposes, and the greatest potential for waste if materials reuse is not factored in on the front end.

Many thinkers have highlighted these concerns including Greg Watson, Fellow of the Schumacher Center for New Economics, Vaclav Smil, Professor Emeritus of the University of Manitoba, and Olivia Lazard, a Fellow of Carnegie Europe. The International Energy Agency has indicated that there will be significant challenges in both extracting and recycling critical minerals for the renewable energy transition *(Executive Summary – The Role of Critical Minerals in Clean Energy Transitions – Analysis - IEA,* n.d.). Further details have been added to the conversation through reporting by the MIT Technology Review which indicates that although the minerals for the renewable energy transition exist for extraction, there are challenges and trade-offs as mining activities may have non-trivial impacts through further emissions, poor labor practices, and negative ecological impacts (Crownhart, *2023).*

The International governance imaginary has to date disproportionately prioritized the acceleration of renewable energy development and corporate regulatory measures over protections for local community sovereignty in locations of greatest natural resource extraction. These geographies often are not only rich in biodiversity and culture but in minerals and fossil energy, leading to a classical economic opportunity cost paradox. Given the incentives are much stronger in enforcing renewable energy development and corporate governance oversight, privilege is given not to the needs or priorities of the community but to those of international governing bodies. This itself is a classic case of law being wielded as a force for negating the non-technical nature of these communities and geographies in favor of viewing them singularly from the technical object perspective. Specifically, viewing them as legal technical objects.

Succeeding in creating the more just and equitable promise of the regenerative paradigm requires not only assessing the risks posed to local and global security from the perspective of technical analysis, but also from the non-technical perspective of the way of life that is drained from one location to preserve a way of life in another. In most cases this means draining the life-preserving ability of geographies in the global south in favor of the way of life in the global north. We see this most often perpetuated by the trade-off made for avoiding deforestation or carbon crediting at the expense of local access to natural resources.

These minerals will be necessary not only for energy infrastructure, but also for other components of our technical infrastructure, including:

Data Production

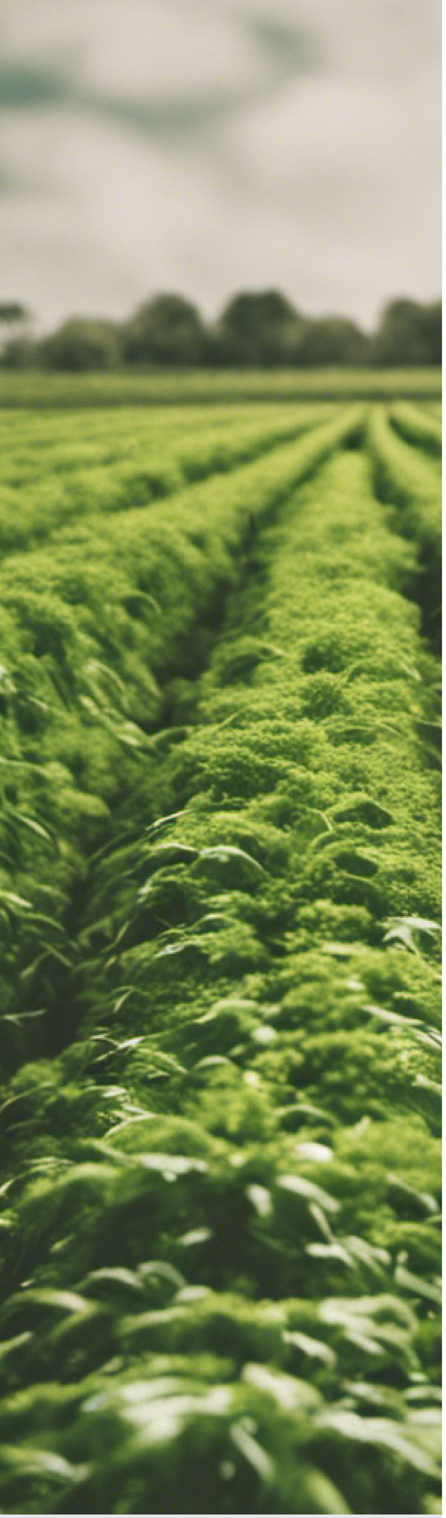
- In-field sensors for monitoring biogeochemical processes
- Mobile devices for handheld data collection

Data Transmission

- Undersea fiber optic cables
- Satellite constellations for GPS, hyperspectral imaging, and communications
- 5G transmission infrastructure
- Low-carbon and renewable energy infrastructure

Data Storage and Consumption

- Data centers and cloud storage
- Private servers and computer clusters for on-site data processing



SYSTEMS AND SOFTWARE

Systems and software include the operating systems, programs, platforms and software that can be both open-source or proprietary and that enable network users to interact with the data and each other. There are many challenges to confront with regard to systems and software from cybersecurity, ownership and usage restrictions on the underlying intellectual property, and the software architecture and its assumptions and biases.

There are many existing efforts to address and proactively design the schemas for appropriate systems and software architecture including FAIR and CARE principles that have implications for software architecture and systems design such that data be Findable, Accessible, Interoperable, and Reusable. Similarly, Lou Downe has done a tremendous job of articulating 15 design principles for good services. These principles explore many of the key considerations for what designers and developers must be considerate of when ensuring not only accordance with principles of universal design and FAIR principles, but how we can minimize time spent on simply navigating interfaces or making sense of software navigation and spend more time on purposes we are trying to utilize the technology to achieve.

Key elements of systems and software include:

Data Production

- Survey software
- Digital IDs

Data Transmission

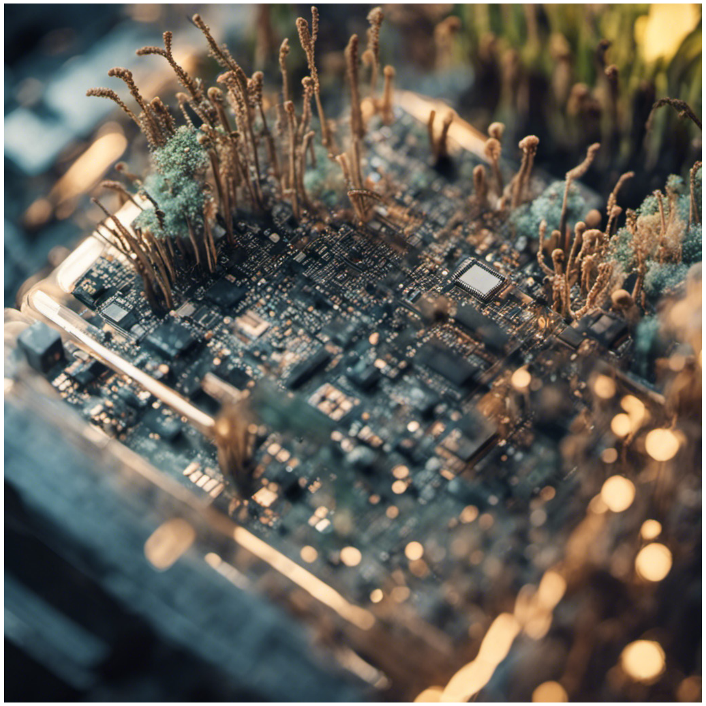
- Database technology, including blockchain
- Cryptography
- Data valuation and exchange

Data Storage and Consumption

- Data lockers and digital wallets
- True cost accounting software
- Sustainability impact platforms
- Farm management platforms
- Digital marketplaces
- Finance and insurance platforms

PROCESSES AND PROTOCOLS

Processes and protocols include the pre-processing algorithms, the methodologies for data collection, the claims structuring out of data whether for ecosystem service markets or regulatory compliance reporting, as well as the standardized methods for dashboarding and ultimate sense-making from the data. There are important considerations that arise from a technical and governance perspective related to who owns the rights to the data, the algorithms, and the methodologies. Similarly, it is necessary to question the peer review and standardization procedures to ensure that those aforementioned protocols are valid and trustworthy within their domain of application.



Great examples of these from above include the accessible database and AI analytical tools provided by Rainforest Connection. Even though we may experience a future where our datasets are vast enough to enable low-cost in-field sampling for genetic diversity, Nature Metrics provides access, in effect, to communities for scientifically valid laboratory analysis.

Key elements of processes and protocols include:

Data Production

- Artificial intelligence algorithms for sorting signal from noise in data streams
- Survey question-sets
- Sampling methodologies

Data Transmission

- Auditing and verification procedures
- Zero knowledge proofs
- Multiparty computation

Data Storage and Consumption

- Credit retirement on blockchain ledgers
- Claims retirement for insetting programs
- Data analysis and dashboarding

Legal Requirements: How It Is Done

Legal Imperative: *strong local governance structures to interface with national and international organizations*

This may be the most difficult of the three aspects to get right. It requires a level of collaboration, shared agreements, and empathy that we have not seen before. From aligning stakeholders from the local up to the global levels with an appropriate and dynamic exchange of powers and information to balancing the needs of privacy with transparency, there are many novel approaches that will need to be explored and iterated on in the coming years. As discussed in a previous section, new local or bioregional governance structures will include features like:

- DAOs and Platform Cooperatives to enable networked decision-making
- Producer cooperatives like Farmer Producer Organizations (FPOs) in India and Community Forestry User Groups (CFUGs) in Nepal include cooperative data governance infrastructure
- Localized cooperatives federate to enhance their negotiating power and benefit from economies of scale for larger infrastructure investments or similar initiatives
- Establish templated data usage agreements like those below, developed by the OpenTEAM community

PUBLIC AND PRIVATE

Managing to protect personal privacy while generating publicly available datasets that are widely Findable, Accessible, Interoperable, and Reusable will not always be a clear-cut decision. It will take time to develop shared frameworks for differentiating and valuing data as public, semi-public, or private.

Examples of public, semi-public, and private data types and infrastructure include:

- Private: Farmer-controlled data using DIDs, data lockers, and digital wallets

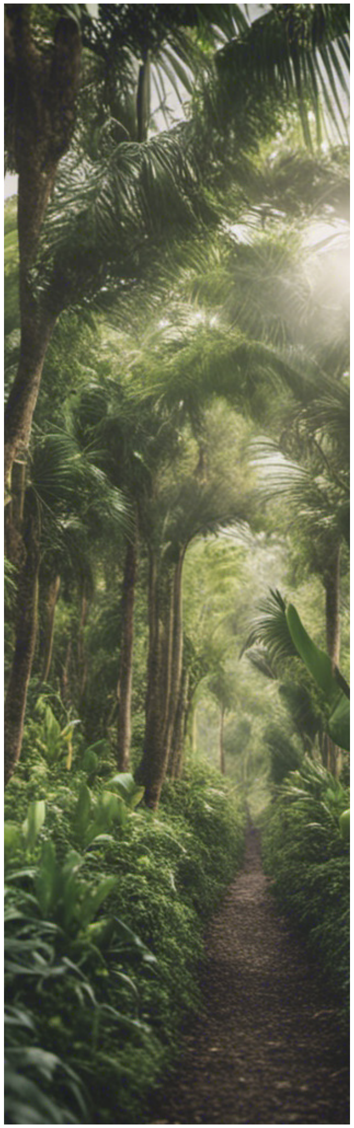
- Public: Calibration datasets taking the example of the Multi-Resolution Land Use Characteristics Consortium. These could include nutrient density databases, crop suitability maps, and soil carbon stocks.

EXAMPLE DOCUMENTS FROM OPENTEAM

Principles that can help us better understand data management and governance have been developed into FAIR — so that data is Findable, Accessible, Interoperable, and Reusable — and CARE — so that data stewardship is for the Collective Benefit, provisions Authority of Control for data producers, and data is Responsible and Ethically governed. Some examples of guardrails and documentation based on these principles developed by the OpenTEAM community include:

Agricultural Data Glossary
"Establishes a foundation for a shared language and understanding of agricultural data use concepts. Each definition is linked to an icon and additional context. This is a public and searchable resource with definitions of common terms and acronyms for agricultural data use concepts."

Agricultural Data Oath of Care
"Serves as a trust-building document between individuals in advisory roles with producers. It is meant to establish adherence to other OpenTEAM ag data artifacts, as well as good faith activity when it comes to advising and data collection practices."



Bill of Data Rights
"A set of rights that are ensured to producers in regard to their data within the OpenTEAM technology ecosystem. It is the responsibility of community members within the ecosystem to uphold these rights on behalf of producers, as well as to implement mechanisms for producer control. This document shapes all other OpenTEAM data artifacts, which are meant to maintain producers' data rights."

Storage and Hosting Agreement
"Defines the standard for hosting, storing, and securing producer data as a means of upholding the data privacy and security standard expected by the OpenTEAM community. This will maintain many of the rights defined in the Agriculturalists' Bill of Data Rights, such as the right to privacy and security, erasure, access and use, portability, etc. We expect all partners who host or store agricultural data to adopt this agreement, and to provide feedback within the versioning process."

Business Requirements: How Incentives Work

Business Imperative: *trusted business incentives to enable ongoing investments in and valuing of regenerative agriculture*

Business requirements are different from purely legal considerations like legal structures of the business, contractual terms and conditions, or intellectual property ownership, though they mutually inform one another. Business considerations relate to how we structure incentives for risk-taking towards innovation in the development of public and private infrastructure. It is also important to ensure that there are adequate incentives and profit potential to support not only initial implementation but also the ongoing ability to maintain, upgrade, and respond to alterations in the market environment such that the optimal products and services evolve to fit customer needs. Ten years from now, regenerative agriculture will be more mature after missteps and iterations; however, technology will be dramatically different. To think about how to develop strong market structures to support scaling regenerative agriculture we must look beyond simple acceptance of technology as it is today and consider how to utilize natural and artificial incentives to move us in the right direction.

There is a difference between natural and artificial incentives, and both have a crucial role but can be misused. Natural incentives are an organic pull for materials, products, services, or resources such as the demand for increasingly convenient and affordable access to healthy food, clean water, and secure shelter. Artificial incentives are structured against the natural state of market demands by restricting or incentivizing behaviors, which can include government tariffs (sticks) or subsidies (carrots), as well as emissions restrictions that generate cap-and-trade or offset credit markets or land use restrictions that generate land banking activities.

The underlying assumption we will begin with is that we want to enable a world where people can freely engage with markets if and how they so choose based on their prevailing circumstances, skills, and resources. Incentives that exist naturally can become perverted, however, when market demands are catered to exclusively without condition or consideration for other values which we see exemplified in the drive for ever more addictive social media experiences. Similarly, artificial incentives can become self-reinforcing and perverted, leading to increasingly negative externalities. One example we have encountered in our work is the use of the farm bill to subsidize production of US commodities for foreign aid to Haiti. In theory, there is altruistic intention, but we must heed Gregory Bateson here when he says, "He who would do good to another must do it in minute particulars. General good is the plea of the scoundrel, hypocrite and flatterer." The net result is that natural incentives for local production for export crops, food sovereignty, or even food security have been suppressed completely. This apparently altruistic idea of food aid has undercut not only Haiti's ability to meet its basic food needs domestically, but also the natural incentive to develop economically to engage in export market relationships.

A key consideration in better understanding activities that technology can play a role in incentivizing is the rapidly approaching generational farmer transition. There aren't sufficient natural or artificial incentives to encourage the generational transition of farming lands. The immediate leap many make is to then simplify and mechanize our production systems and remove human labor from the equation. Although automation and robotics absolutely have a role to play in agricultural systems of the future, we also risk losing incredible tacit knowledge that these farmers have accrued over the course of their careers and inherited from their forebears.

Rural communities around the world, Global North and Global South, have been systemically disinvested in. The claim that urbanization is a foregone conclusion may be one of the most damaging assumptions we have convinced ourselves of over the last 20 years. Rural communities struggle to access quality healthcare, competitive education and livelihoods, and basic services like reliable internet access and public transportation. Further, three quarters of the estimated 828 million people experiencing hunger worldwide live in rural areas with most of them being smallholder farmers in the Global South. Farms and rural communities of the future can utilize the applications of technology to regenerative agricultural transition to apply high-value skills for young farmers including apprenticing with more experienced farmers and learning how to productize digitally some of the approaches specific to their geographies, collecting data for data marketplaces, and managing shared farm robotics like we see with equipment cooperatives today. Efforts such as these examples do double work of both providing natural incentives for younger farmers to head back to rural communities and insuring us against the dramatic knowledge loss that would otherwise occur.

INCENTIVES FOR BUSINESS

It is critical that the important incentives including capital from venture capital, institutional investment, government stimulus, and market conditions like market size, educated consumers, and demand exist to support the development of the technology needed to scale regenerative agriculture. Some examples of emerging business incentives include:

- Corporate sustainability departments and impact investors integrating true cost accounting into balance sheets
- Regulators support with development of minimum acceptable accounting frameworks for TCA and demonstrating efficacy through managing national balances of social and ecological assets
- Government de-risking of key investments at the earliest and riskiest moments of transition through tools like Development Impact Bonds (DIB)
- Exploration of more networked alternative currencies like the Global Carbon Reward and Tree Currency as community-managed local currencies

There is also a critical role for consumers and the general population to play in driving natural incentives as well as responding to the market environment. Increasingly, opportunities to utilize extended reality technologies including QR codes and other scannable technologies can enable access to data dashboards, virtual or augmented reality experiences, and interaction with other media. These so-called phygital — a portmanteau of physical and digital — technologies enable deeper co-creative lifestyle engagement between brands and their consumers. These technologies can also further extend the sustainability aspect by enabling brands to offer incentives for consumers to provide end-of-life data on their products, exchanging products for rebates on future purchases, or data on product durability to improve future product performance. All of these ways engage consumers directly in regenerating supply chains downstream of retailers.

REGEN FARMERS MUTUAL AND DATA COOPERATIVES

Who are they:

"Regen Farmers Mutual is a farmer-owned company that helps farmers create regenerative agricultural landscapes. We are wholly aligned to maximising value to our members — those farmers who deliver environmental outcomes through their farm management practices."

What do they do:

"As a farmer-owned business, the mutual is focussed on creating the digital infrastructure, transaction processes and governance structures that enable farmers to optimise environmental outcomes. It is partnering with existing farmer and member organisations to deliver distributed services such as farmer support, training and network development. The margin structure of transactions will provide for these services, and underpin a sustainable revenue stream for its partner farmer networks. In this way, the mutual can maximise returns to its farmer members, while leveraging the networks that they belong to."

Why does it matter:

The significance of Regen Farmers Mutual is not only that they are a cooperatively-owned enterprise — for farmers, by farmers — but that they are taking this to the point of building the shared infrastructure to collect, store, and manage data for their members. Just as pooling of resources to support equipment purchases or larger physical infrastructure projects for storing, processing, or transporting of agricultural goods, they are applying that same approach to digital infrastructure. Their focus on partnering with technology developers like the OpenTEAM community will not only enable their cooperative members to own and exchange their claims of positive social and ecological impact for increased revenues, but also for the same infrastructure to then be available to other cooperatives to develop based on their specific contextual needs.

REGEN FOUNDATION AND COMMUNITY BLOCKCHAIN AND DAOS

REGEN FOUNDATION

Who are they:

"As the non-profit arm of Regen Network, we pilot implementation level research in community ownership and governance in regenerative finance."

What do they do:

"We build the Regen Commons. A global network of grassroots DAOs to ensure climate finance ultimately supports sovereign regenerative bioregional economies."

Why does it matter:

If we are to successfully democratize, decommodify and decarbonize we need not only locally networked farmers but the technologies to federate local data cooperatives — or in the world of blockchain, Decentralized Autonomous Organizations (DAOs) — into global networks of locally-owned and managed natural and digital assets. Regen Foundation, as the non-profit arm of Regen Network — a platform for investing in high quality ecological assets — is focused on supporting the commoning and governance frameworks for communities engaging with digital platform governance. Inclusive of this effort is exploring and educating communities about emerging economics and the role of decentralized scientific research utilizing high quality data assets and community participation. Efforts like these go beyond Regen Farmers Mutual in seeing the need for more explicit forms of networked governance that transcend the local and bridge cultures, geographies, and national boundaries. ■

GLOBAL ALLIANCE FOR THE FUTURE OF FOOD AND TCA

Who are they:

“We are a strategic alliance of philanthropic foundations collaborating on bold action across the planet to transform food systems and their impacts on climate change and food security. Seven principles shape our vision for the future, express our values, and encompass the change we want to make in the world: renewability, resilience, equity, diversity, healthfulness, inclusion, and interconnectedness.”

What do they do:

“We develop research and tools based on systems perspectives and built on diverse knowledge and evidence. This approach helps us work as a global community to understand and assess interrelationships, dependencies, priorities, risks, and trade-offs. We craft meaningful solutions by highlighting what’s wrong with the current system and pointing to changes needed to bring about a more desirable future.

We facilitate authentic, meaningful, and actionable dialogue amongst diverse agents of change — the scientific community, grassroots movements, policymakers, farmers, the private sector, Indigenous Peoples, and others. We are all committed to food systems transformation, so, together, we can better understand current realities, co-create the solutions we need, and inform action within our respective constituencies.

We connect global and local perspectives, knowledge, and understandings across geographies. We aim to collectively accelerate effective action on the ground with the recognition that change must be sensitive to context.”

Why does it matter:

The Global Alliance for the Future of Food has been building a body of knowledge demonstrating the value and impact of True Cost Accounting. In their 2021 report, True Value: demonstrating the positive impacts of food systems transformation they use six case studies to elucidate how accounting for the positive impacts of regenerative agriculture systems and clarifying the negative impacts of extractive modes of production can shift our perspective. Specifically, it highlights the dangers of limited quantitative approaches to valuing regenerative agriculture especially as it relates to social and community impacts, the value that comes from seeing the relationships between social and ecological systems and how they are impacted by production decisions, and underlining the importance of philanthropic organizations accounting for these typically externalized and unmeasured factors.

ETHOS, REGEN SCORE, REGEN10, AND TEXTILE EXCHANGE OUTCOME METHODOLOGIES

Who they are and what they do:

ETHOS

"EthosTM monitors and tracks farm-level impacts while generating farmer-owned data assets. It enables farmers to monitor and report on the impacts of their production systems, offer verified products to buyers, and receive revenue from data assets. It enables brands to monitor and report on the impacts of their sourcing, source ingredients verified as regeneratively grown, make credible product claims, and communicate regenerative sourcing stories to consumers. It does this in a way that is relational, place-sourced, and holds brands and farmers as equal stakeholders, in order to promote equity and regeneration within sourcing relationships."

REGEN SCORE

"RegenScore is a unified, adaptive framework that recognizes and integrates all approaches to regenerative transition, monitoring and verification; assigning a numerical value to farms and ranches and translating detailed information into an accessible, engaging format for purchasers and consumers."

REGEN10

"Frameworks will develop, through a highly consultative process, the principles, metrics and framework needed for building a truly inclusive regenerative food system."

TEXTILE EXCHANGE

"The Regenerative Agriculture Outcome Framework aims to help the fashion, textile, and apparel industry develop outcome-based methods for assessing the holistic impacts of regenerative agriculture. The framework provides a flexible, context-adaptable way to assess regenerative impacts, laying out the key indicators that make for a regenerative system — while also allowing those in different regions and at different stages of their journey to select indicators that work for them."

Why does it matter:

Taken as a whole, these four outcome-based methodology frameworks demonstrate a profound shift in the way farmers, corporates, philanthropies, and the academy view regenerative systems as fundamentally different than their predecessors. They share the perspective that for all stakeholders to truly understand and fully benefit from the regenerative transition it is not sufficient for a third-party expert to "certify" that certain boxes have been checked. Rather, what is required is a deep commitment to a universal framework that is adapted to localized contexts and reflective of the needs of key stakeholders beyond government and corporates alone. Though each may be at a different stage of development and implementation and tested in different geographies, they collectively demonstrate a paradigm shift that is still in its early days of full realization.

ECOACOUSTICS AND EDNA FOR BIODIVERSITY MONITORING

Who they are and what they do:

NATURE METRICS AND EDNA

NatureMetrics is a company based out of the UK that uses eDNA, qPCR and metabarcoding to make biodiversity surveys possible at scale by putting the tools to collect samples in the hands of communities or project developers on the ground. Samples of water and soil are submitted to their labs for analysis, assessing for biodiversity.

- eDNA enables the detection of birds, humans, insects, amphibians, and reptiles
- qPCR enables single species identification for a variety of aquatic species
- Metabarcoding utilizes high-throughput sequencing to detect multiple taxa for example from malaise traps for insects or fungal diversity from a soil sample

RAINFOREST CONNECTION AND ECO-ACOUSTICS

Rainforest Connection is a US-based company that develops acoustic monitoring hardware and artificial intelligence tools to detect illegal logging, animal poaching and biodiversity monitoring. They also manage a database of ecoacoustic and bioacoustic recordings that users can submit their field recordings to for analysis and detection of threats to the environment or presence of key species.

Why does it matter:

Technologies like those developed and employed by Nature Metrics and Rainforest Connection are pushing the boundaries on how in-field monitoring can be deployed at scale. HIstorically, biodiversity surveys are costly endeavors, requiring local subject-matter experts conducting longitudinal studies with costly and specialized equipment. We are entering a period where ecoacoustic datasets from all over the world are available for analysis online and where high-resolution biodiversity sampling can be conducted for a couple hundred dollars with limited sample collection training. This portends a future where subject matter experts are increasingly supporting community science initiatives rather than the sole scientific contributors and where communities are empowered to be directing the topics and focus of research based on local concerns and interests. These types of approaches are then amplified in their impact by storing and transacting with their data through local data cooperatives on decentralized governance infrastructure.

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