Algorithmic Food Justice: Co-Designing More-than-Human Blockchain Futures for the Food Commons

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The relationships that constitute the global industrial food system tend towards two dominant values that are creating unsustainable social and environmental inequalities. The first is a human-centered perspective on food that privileges humans over all other species. The second is a view of food as a commodity to be traded for maximum economic value, rewarding a small number of shareholders. We present work that explores the unique algorithmic affordances of blockchain to create new types of value exchange and governance in the food system. We describe a project that used roleplay with urban agricultural communities to co-design blockchain-based food futures and explore the conditions for creating a thriving multispecies food commons. We discuss how the project helped rethink algorithmic food justice by *reconfiguring more-than-human values* and *reconfiguring food as more-than-human commons*. We also discuss some of the challenges and tensions arising from these explorations.

Additional Keywords and Phrases: Food justice, Commons, Blockchain, More-than-human design, Sustainability, Algorithmic governance, posthuman

ACM Reference Format:

Sara Heitlinger, Lara Houston, Alex Taylor, and Ruth Catlow. 2021. Algorithmic Food Justice: co-designing more-than-human blockchain futures for the food commons. In CHI '2021: ACM Conference on ACM CHI Conference on Human Factors in Computing Systems, 2021, Yokohama, Japan. ACM, New York, NY, USA, 10 pages. NOTE: This block will be automatically generated when manuscripts are processed after acceptance.

1 INTRODUCTION

The global industrial food system is made up of a complex network of relationships between producers, processors, shippers, intermediaries and consumers, operating across all continents at a range of scales. This system encloses and extracts value from our planet's resources, concentrating benefits in the hands of a few major players. In the process, industrial agriculture is driving unsustainable human and ecological inequalities, causing mass species loss, degradation of soils, and the disempowerment of small-scale farmers, ultimately threatening food security for all life on Earth [3,69].

In recent decades, computation has played a significant role in transforming farming at scale into a data-driven business. But if we fail to examine the values that underpin the unsustainable practices involved in this social and environmental crisis, then technology risks intensifying the crisis and its accompanying inequalities. Two value systems are stoking the interlinked crises of climate breakdown, species loss and food insecurity. HCI, with its increasing interest in the role of technology within food systems [14], is well placed to grapple with and challenge both of these value systems.

The first value system rests on a human-exceptionalism, where humans are believed to have a privileged status when set against other "non-human" actors. From this perspective, humans are perceived to be living in a sovereign body, distinct from nature and "effectively independent of the web of life" [43]. Yet sustaining human life on Earth depends not only on the sustainable management of the planet's natural ecosystems, but also on the *more-than-human*: a term that accounts for the entangled roles and contributions of humans and non-human actors such as plants, animals, and insects, as well as soil and water. This web of life incorporates the "food web" – interlinked food chains that are critical to the flourishing of ecosystems [48]. The Anthropocene is the consequence of this human-exceptionalism and neglect of the interdependencies between human and nonhuman actors. Referring to a new geological era in which human activity is transforming earth systems [35], it reveals a human-centred perspective that is untenable, accelerating climate change and causing mass extinctions [43]. Drawing on fields such as Science and Technology Studies and environmental humanities, HCI has started to explore posthuman or more-than-human design to consider the entanglements between human and non-human worlds [10,21,24,30,33,60,66] in order to overcome problematic narratives of human privilege and exceptionalism.

The second value system that is driving the social and ecological crisis within the global industrial food system perceives food as a commodity to be traded for maximum profit. This has created perverse incentives that have depleted the natural resources of our planet and created monopoly concentrations at the expense of farmers' livelihoods. We have lost over 75% of all cultivated crop diversity [3]. Four seed companies control more than 60% of the global seed market. The idea of "food justice" calls into question these predominantly market-driven relations. As a concept, it asks what other modes of organisation and governance would ensure growth and abundance is distributed evenly, amongst humans and non-human others? To explore the idea of food justice, and its related concepts of food sovereignty and security [34] we will turn in the following to the older idea of "the commons". The small-scale agricultural communities that we have worked with in the past [30,31] tend to utilise commons-based, co-operative structures, and regenerative growing methods, where food is not commodified, but managed sustainably for collective benefit [30,64,65]. *Commons* as we use it, then, refers to commonly held property, use, stewardship and management of the available and produced resources [47] by a community; and *commoning* refers to the social process that creates and reproduces the commons [2]. HCI has long been interested in digital technologies to help communities organise their social practices and manage resources, both material and digital, "for collective benefit in fair, inclusive, sustainable and accountable ways" [8], and thereby contribute to strategies for creating viable commons arrangements.

This paper reports on a project that undertook a critical engagement with these two value systems, drawing on alternative governance models from commoning and exploring possibilities for more-than-human values in food systems. Because information systems are social systems, we approach technology as a means to explore existing conditions and reflect on alternatives. The paper considers, in particular, how blockchain, the technology underpinning cryptocurrencies such as Bitcoin and Ethereum, might offer ways to disrupt the prevailing paradigms and open up possibilities for more sustainable systems of value in the context of food.

We focus on blockchain for its particular affordances that enable explorations in both commons-based governance, and more-than-human design. Blockchain is a general purpose technology that offers the potential to create

decentralised organisations that allow for new types of decentralised non-extractive value exchange. While blockchain systems might also be used for runaway accelerationist extraction, blockchain facets such as tokenisation and smart-contracts provide affordances to help manage resources more fairly and transparently. For example, they allow for contributions of diverse actors to be identfied and tracked within an economic system, without the need for a central authority. For these reasons there has been increasing interest within HCI in the potential for blockchain to help manage self-governing commons-based enterprises that distribute benefits for the collective good of a community [49,57]. They also offer the potential for embedding the interests of non-humans into such systems and infrastructures [16] and provide the mechanisms for non-human entitites to become agents within food governance systems.

This paper aims to contribute to these emerging areas of HCI research within the civic blockchain, justice, the commons and posthumanist design by answering the following questions: How might we use blockchain to reimagine the food system as a more-than human commons in which human and non-human actors can govern themselves in ways that are sustainable and fair? What conditions does technoscience make possible for flourishing ecologies and just multi-species relations? How might we use the co-design of blockchain-based systems to envisage new governance and economic structures so that interspecies flourishing is at the heart of our food systems? And what methods might be appropriate to engage diverse more-than-human members of food systems whilst ensuring that we don't intensify existing inequalities?

We attempt to answer these questions by framing, presenting and discussing a project called *Algorithmic Food Justice* that used co-design research in 3 workshops with urban agricultural communities in London, U.K. to prototype blockchain-based futures for a thriving more-than-human food commons.

In this paper, we make the following contributions. We begin with a discussion of related work around the more-than-human, the commons and blockchains within HCI to provide a critical lens through which to challenge the dominant values within food systems and surface the potential for blockchain to open up a space for alternative values within food systems. We present the Algorithmic Food Justice project, reporting on the co-design workshops and how they generated different modes of knowledge production through inclusive speculative design activities. Finally, we reflect on the project in terms of how algorithmic food justice can be understood through a reconfiguring of more-than-human values and the food commons, and the tensions and challenges that arose.

While blockchain might be optimistically touted as the solution to many complex problems, including sustainable food systems, there are significant doubts as to whether the technology is appropriate, sustainable, or feasible to use in real world settings. Worse, we know that it is already being used in neoliberal models of agriculture, potentially accelerating extraction and exploitation [67]. In this project we resisted a techno-optimistic approach to blockchain as a fix or solution. Rather we used the technology as a tool to critically engage with value systems and think in generative and creative ways about alternatives. Put another way, we approached blockchain as a design material for developing future socio-technical systems, to open up conversations about values and governance, and to attempt to understand whether its affordances would lend themselves to a more just system. Building on emerging interest in HCI around blockchain to both sustain the food commons and create new value systems for more-than-human actors, our work is intended as a still early foray for HCI community into understanding the technoscientific conditions that make possible flourishing ecologies and just multispecies relations for food sovereignty and security.

2 RELATED WORK

2.1 Blockchain and food systems

The global blockchain market is predicted to rise from USD 3.0 billion in 2020 to USD 39.7 billion by 2025 [41]. It has expanded from a technology used primarily in financial systems to one that has entered many different industries and application areas. This includes food systems, where it is being used to increase food traceability, safety and provenance, and in inventory management in supply chains [18]. The promise of blockchain within food systems is to allow for a specific product to be traced immediately. This can help reduce food waste and track contaminated food easily and quickly, while data-sharing between actors in the supply chain is designed to prevent the sale of fraudulent food products. One example, BeefLedger [25] is a blockchain product being developed for traceability of beef products from Australia to China, where there are consumer doubts over the product's authenticity. Another, is a UK company called Provenance that has created a blockchain-based platform for both producers and consumers for increasing transparency, traceability and certifiability within supply chains, especially within food systems and for sustainable and ethical brands, and products such as organic and slavery-free food [51]. New applications such as AgriBlockIoT [5] are being developed and studied for their combined use of Internet of Things, AI and Blockchain to automate data recording, verification and execution of processes within industrial agricultural systems [40]. The techno-optimistic view is that these systems will allow everyone along the supply chain to be paid more quickly, through readily available and verifiable market data, with the potential to eliminate middlemen, lower transaction fees and lead to fairer pricing [7] and transparency.

However, without examining the values driving the development of blockchain technologies in food systems, they have the potential to intensify inequalities and ecosystem depletion. As Xiaowei Wang has written in their book on the use of high tech in rural China, "Blockchain Chicken Farm"[67], big business in China has been using technologies such as AI, sensors and blockchain to optimise and centralise agricultural production, as well as provide wealthy urban consumers data about food provenance and safety at a price beyond the reach of most people. In these ways the technology does little to address government and societal problems around access and food security. The benefits remain in the hands of an elite few and, rather than technology providing a solution to the problems of governments or communities, the inequalities are amplified.

While blockchain has the potential to intensify inequalities and injustices and contribute to accellerationist ecological destruction, it is also being developed for restorative and regenerative agriculture and more sustainable economies. For example, Regen Network [70], Nori [71] and GainForest [12] are three blockchain-based platforms that are being developed to incentivise regenerative land use, carbon capture in soil, and the reversal of destructive land use practices that contribute to CO^2 emissions such as clearing forests for monocultural crop production. Investors can pledge money to farmers, indigenous communities, and enterprises around the world to help regenerate the land. The regeneration practices are measured, monitored and verified using data from satellite images and AI, with smart contracts paying out rewards to those farmers and enterprises who meet the predetermined conditions over a set amount of time. These are examples of blockchain systems based on more ecological and socially just value systems that account for a wider range of stakeholders.

And yet while these regenerative blockchain applications contrast to those developed for industrial global agricultural systems (such as BeefLedger and AgriBlockIoT), they still tend towards a deterministic or techno-optimistic view of the ecological and social problems that we face within food systems, one in which the technology provides the solution; complexities and possible negative impacts of such solutions remain unexamined. They are still relying on technologically-mediated digital marketplaces as a solution where the power lies in the hands of investors. In contrast,

policy level interventions implemented without the use of technology are trying to redress the unsustainability in agriculture. For example, subsidies and incentive schemes such as the European Green Deal aim to make the continent carbon neutral by 2050, through "green payments" for farmers to regenerate soil and increase biodiversity for benefiting soil and biodiversity [17].

2.1 Blockchain and the Commons

The main business model within the global industrial agricultural system, however, remains firmly neoliberal, where resources are extracted from particular localities for their exchange value rather than their use value, and profit, prioritised over all other rights and claims, is concentrated in the hands of a minority of shareholders rather than distributed more evenly for the collective good. In contrast, the commons refers to a set of practices for sustainably managing all the available, produced and owned resources in a system by a collective. Nobel laureate in economics, Elinor Ostrom, studied the collective management of natural resources such as fisheries, forests and farmland and showed how the commons can be sustainably managed by a community without intervention by the state or market economics. She showed how the "tragedy of the commons", which refers to the depletion of the pool of resources through short-term overuse and by free-riders, at the expense of long-term viability [28], can be avoided easily under certain conditions [47]. Drawing on extensive field research, Ostrom outlined 8 "design principles" that characterise the successful user-organised systems that she studied [46]:

1. Clearly Defined Boundaries: who is in the collective and has access and rights to the resources
2. Congruence between Rules and Local Conditions: the rules of resource use and their required labour are matched to those who use them and the local conditions
3. Collective Choice Arrangements: members who are in a collective and are affected by the rules of the community are able to participate in modifying the rules
4. Monitoring: monitoring of members' behavior is carried out by the community members
5. Graduated Sanctions: Violations of rules are dealt with by graduated sanctions
6. Conflict-Resolution Mechanisms: Conflict resolution is dealt with by users in low-cost, local means
7. Minimal Recognition of Rights to Organize: External government authorities do not interfere with the rights of users to manage their own institutions
8. Nested Enterprises: Governance is organised in multiple layers of nested enterprises

Although these principles were originally applied to the natural commons, they have also been used to help collectively manage digital resources [57] and the urban commons [23,59].

2.1.1 How blockchains are being used to address the commons

Blockchains are a way of reconfiguring and redistributing forms of *value* (including currency, but also non-financial values) without the need for a central authority such as a bank, and therefore are being explored in multiple contexts where "radical regulation" [16] could help redistribute power and address issues of justice and equality. In particular, a new strand of research is emerging around the "Civic Blockchain" (ibid) where systems play an important role in the fields of justice and governance [8]. Blockchains "are well placed to play a fundamental role in registering resource production, usage, and transactions; keeping track of account balances; and managing identities and rights" [8].

The promise of algorithmic governance for commons management comes about through the use of blockchains to create new organisational structures called *decentralised autonomous organisations* (DAOs) and *decentralised autonomous corporations* (DACs). DAOs and DACs are, in turn, made possible through 'smart contracts' — rules encoded in

blockchain-based software that can automatically enforce a contract without human intermediaries [58]. Blockchain affordances such as tokenisation and smart contracts provide not only new possibilities for community currencies, but also multiple types of non-monetary interactions such as sharing, voting, and reputation-tracking [57], potentially providing new mechanisms for a community to govern itself in ways that are fair, transparent and sustainable without the need for a central authority. Blockchain affordances such as tokenisation promise to help manage resources and recognise contributions of diverse actors within an economic system, in ways that distribute benefits for the collective good of a community [57]. This makes blockchain fertile territory for exploring commons management and indeed recent work has explored how Ostrom's design principles for managing the commons might be operationalised using blockchain technology [8,49,57].

Experimental platforms such as Backfeed [49] - a blockchain-based platform supporting decentralised cooperation – and Commonfare [62] – a blockchain-based platform for a new model of welfare – illustrate how tokens can be used as a means of value exchange, for example through local currencies, as well as providing a mechanism for a social protocol to help achieve consensus about the value produced by community members' contributions to a collective effort and its appropriate reward. This happens via the awarding of non-exchangeable tokens called *reputation*. The reputation system "allocates influence according to the value contributed and the alignment with the overall perception of value of the community [and] … constitutes a proxy for social value of the individual actions in the commons ecosystem" [8]. Ostensibly, blockchain thus offers the potential for the creation of new non-extractive value creation systems that aim to be more supportive of social and environmental values, in response to the human and environmental cost attributed to predatory and extractive neoliberal activities. While such value systems are limited in their economic means of exchange, in contrast to traditional capitalist and fiat systems, they can emphasise other values that are not purely financial, such as trust, fairness, equality, social relations, community, and solidarity [39,68].

Numerous tensions and concerns are raised in the literature around using blockchains for managing the commons. One key concern is that blockchain-based systems will encourage a technocentric approach to the social dynamics of sharing [49,57]. For example, when blockchain applications attempt to monetise and formalise interactions that are typically based on informal social relations and motivated by intrinsic rewards, there is a risk of de-incentivisation, as in the case of Backfeed [8,49,57]. Another key issue revolves around the exchange of currencies leading to conflicting incentives, as illustrated in the case of Commonfare. While a non-exchangeable community currency incentivises contributions to the community values, an exchangeable currency may lead to simple accumulation instead of circulation inside the community [62]. This then leads to tensions between sovereignty and scalability: a completely independent currency, while allowing for greater control by those who support and use it, "has issues of scalability, as its adoption can be limited only to the ones who control it" [ibid].

Finally, a core critique of automated governance is that algorithms, once unleashed, run automatically according to predetermined rules without stopping, obscuring the need for changes to respond to unforeseen occurrences along the way. This is pertinent to Ostrom's third design principle, "collective choice arrangements", in which people who are affected by the rules should be able to participate in their modification [47]. While there have been attempts to bring human agency back into algorithmically governed systems, such as upgrades and "hard forks" (a kind of reset of the system), these are far from straightforward and often have high costs.

2.2 More-than-human Values and Blockchains

Blockchain opens up interesting opportunities for managing the commons. However, this newly evolving field of research has thus far taken a solely human-centred view of the commons. Our work seeks to draw on posthuman design

[22] to incorporate a more-than-human perspective on food production and on the commons. The posthuman has been theorised in a number of scholarly fields, to offer critical readings of human exceptionalism and the privileged status of humans vis-à-vis non-human others. Proposals for decentering or radical re-distributions of agency across humans and nonhumans have emerged from threads of scholarship in STS (e.g. Latour [36], Law [37], and Mol [42]) and Feminist Technoscience authors (e.g. Haraway [27], Puig de la Bellacasa [55] and Tsing [63]), as well as concepts like the "hyper object" [44]. These scholars consider feminist ethics of care and more-than-human relations in the context of a damaged planet, challenging human exceptionalism and privilege, and recognising that our human survival is interwoven with that of non-human others. The analysis of indigenous epistemologies and ontologies in [38] challenges technological reductionism with a commitment to "human flourishing", asserting the status of all things on the earth as beings in a network of kinship relationships, and refusing their reduction to subjects of or vehicles for exploitation, extraction and depletion. What becomes an especially powerful rhetorical device in thinking with the more-than-human perspective is how authority, agency, and values are distributed across actors and emerge through unfolding relations.

We draw on these posthumanist perspectives in design, and in particular the feminist and speculative ethics of care to settle on the notion of the "more-than-human" in our work. For our purposes we use this term as a generative concept that offers a means to further unravel the extractive logic and value system that dominates the global neoliberal food production system, and a way to shift from a human-centred perspective of food systems to a recognition of the interdependencies and interconnections of all life on earth. Critically, the distribution of agency in the concept of the more-than-human is not to suggest heterogeneous actors cease to be distinct or cease to exhibit distinguishing characteristics. Instead it is to invite an examination of how what is material, what comes to matter and be valued, is continually enacted through always unfolding relations. Once we imagine a variety of authorities, agencies, and values at play, we can begin to think about why particular actors come to authority and power, and how that power is sustained.

The more-than-human offers, then, a fundamental basis from which to reconsider value in the food web. This has to do with more than redistributing value more evenly amongst the actors, and instead invites the question how other, neglected things and processes might come to be valued in different ways. Typically, alternative pro-environmental schemes, such as the ecosystems services perspective, aims to account for the economic value that non-humans afford to humans [20,50]. This, however, continues to centre on a transactional value system where everything is treated in monetary terms. A more-than-human value system moves beyond human benefit to acknowledge the needs and contributions of non-humans, and recognises the entanglements between them in the web of life [43]. A more-than-human value system therefore aims to decenter the human from its place of privilege, and redistribute power, benefit, agency and flourishing more evenly across human and non-human actors.

Within HCI, researchers are starting to acknowledge such varied and heterogeneous relations between humans, other species and technology within food systems, as documented in recent work in the field of Human-Food Interaction [1,15] and explored in a recent workshop at DIS on "Designing with More-than-Human Food Practices for Climate-Resilience" [14]. Emerging research in this field advocates for a shift within human-food interactions to support creative, equitable, and sustainable more-than-human food practices, by leveraging "more-than-human perspectives to support environmentally sustainable food-tech innovation" [15]. For, as Clarke et. al. have written, we can no longer deny that, "from the billions of bacteria within us to the multitude of species on which our food supply depends, our lives are completely entangled with the well-being of non-human others" [11].

2.2.1 More-than-human Blockchains

While blockchain-based initiatives such as GainForest, Regen Network, and Nori aim to incentivise regenerative farming, these mostly operate around an endpoint where the benefit is centred on the human and measured in monetary terms (as in an ecosystem services approach). However, in some more radical projects, blockchains intervene in an understanding of value flows and relations between human and non-human actors. These offer transformational possibilities for more-than-humans (e.g. trees, plants, animals, lakes or soil) to participate in economic and governance systems. Distributed autonomous organisations (DAOs) and Decentralized Autonomous Corporations (DACs) can manage capital through digital programmable wallets. Assets can be tokenised and broken into smaller ownership stakes. This software then becomes the arbiter that tallies votes and carries out the will of the organisation's (or corporation's) members. "Once an (artificially) intelligent agent operating on decentralized infrastructure is granted control over an amount of capital, the agent in question is not merely an AI controlling capital, but a decentralized autonomous organization." ([58] discussing Vitalik Buterin, co-founder of cyptocurrency platform Ethereum). This opens up a vast landscape of possibilities in which to explore new value flows and governance systems that shift the balance away from humans to create a more level playing field amongst more-than-human actors, raising questions such as: "What kind of rights could parking spaces, playgrounds, garages, or trees be afforded within a blockchain network? And, as a designer, what would it mean to design civic technologies and interventions that embed the interests of our environment and non-human actors?" [16].

One example that defines itself as 'ground-zero' for using DACs as proxies for natural-ecosystems is terra0, the blockchain-augmented forest that owns and utilizes itself [58]. terra0, created by a small team of artists and developers also called terra0, is a prototype of a self-owned forest based on the idea that "DACs can be proxies for natural systems, and enable them to better manage their technical and ecological resources. In this framework a forest is able to sell licenses to log its own trees through automated processes underpinned by blockchain technologies, and in doing so to accumulate capital" [58]. A shift from reliance on third parties to self-administration enables the forest to maximize and sustain its marketable resources. "With this capital, via the DAC, control of this process is devolved over time to the forest as it buys itself from the project initiators, eventually owning itself. The forest is no longer a source of material to be utilized by third parties, but instead interacts with them as a peer. Therefore, terra0 can be seen as a prototype for an autonomous economic unit in a post-human system of relations." This is one version of possible alternate value systems on the blockchain: commons management that prioritises the health of a natural resource that is set up and maintained by humans but ultimately tries to minimise the degree to which they can extract value. Unlike the start-up blockchain initiatives mentioned previously, the project looks to automation not to deliver efficiencies but to craft some form of autonomy for more-than-humans on the blockchain—which attempt to free the forest from (at least some) aspects of human-centred value extraction. The code affords the forest sovereignty and security, and opens up new possibilities for thinking of non-human agency and power.

Other possibilities present themselves in Plantoid, by artist collective O'khaos, which claims to be the first evolutionary blockchain-based life-form that can reproduce itself [19]. These mechanical flower sculptures are also algorithmic entities that harness the forces of automated governance to propagate Plantoid offspring through collective decision-making. Plantoids move and glow when they are tipped with Bitcoins or Ether. Viewers send money to any of the sculptures they find beautiful. Once adequate funds have been acquired, Plantoid's software triggers a commissioning process to create a new Plantoid sculpture that lives, feeds and reproduces on the same blockchain. Co-creator de Felipi, writes: "It is a hybrid creature that lives both in the physical world (as a mechanical contraption made up of recycled steel and electronics) and the digital world (as a software deployed on top of a blockchain-based network)" (ibid).

By finding new ways that use, but do not prioritise, money to articulate the relations, exchanges and agencies at work in complex more-than-human systems we reach beyond our own anthropocentric views and vested interests. As co-author Catlow writes in the introduction to the book Artists Rethinking the Blockchain, with terra0 and Plantoids the otherness of technology and smart contracts, works with that of plant-based systems to form a more-than-human assemblage, testing the edge where a decolonising-nature rhetoric meets technosolutionist reality. This potent line of speculation has to be tempered by an acknowledgement of lessons of the industrial and digital revolutions. Technology is never neutral, it always carries the imprint of its (human and corporate) creators. Whether this be the humans writing the code, the humans or human institutions commissioning the code to be written, investing in infrastructure, or influencing voting using systems outside of the DAO or DAC [6].

Big questions remain to be answered including: How do we involve non-human voices into our designs of such systems and "make the experiences of non-human others palpable?" [11]. How do we involve diverse non-technical, marginalised stakeholders in the design of new blockchain based systems for the food commons, in ways that don't intensify existing inequalities or create new ones? In the next sections we describe our attempt to answer these questions.

3 THE ALGORITHMIC FOOD JUSTICE PROJECT

The project consisted of three workshops that took place in late 2019 at Spitalfields City Farm, an urban agricultural community in east London with whom we have been conducting long term participatory design research [29,31,32]. We involved diverse participants from our established networks that included community growers and organisers, activists, artists, and technologists, who we understood to be already engaging in post-humanist design. We used playful and creative activities to experiment with alternative configurations of value and to open up a space where humans and non-humans such as plants, animals and soil, as well as technologies and their infrastructures, can play a part in a thriving food commons of the future.

3.1 Our approach

Technological innovations have an important role to play in shaping access, control, participation and benefit with the potential to amplify social and environmental inequalities. Interest in blockchains is growing, including in food systems [25], and yet there are significant barriers to access and participation with these complex technologies [16] that inhibit work on widening civic blockchain initiatives.

Drawing on well documented examples within HCI that use creative arts-based methods to both decentre the human in design [9,13] as well as engage diverse non-technical citizens in complex futures with technologies such as blockchain [45,52,56], we used fiction, roleplay and games to understand the affordances and implications of emerging technologies that are not yet widespread, explore technology futures beyond participants' lived experience, and ensure that the speculative futuring was grounded in the values, needs and challenges of the real communities with which we were working. These narrative techniques were used to help people understand the implications of the technology and how they might play out in specific situations, interrogating use cases for blockchain that are possible but not yet real and address questions of ethics, values, social interactions and their consequences [8]. In addition, our collaborator and co-author, Ruth Catlow, from London-based arts organisation Furtherfield, had previous experience of developing an award-winning programme engaging non-technical participants in blockchain futures around the arts [72] using LARP, on which we were able to draw.

Our approach used both participation and speculation as an attempt to elicit and understand what a structure of society and values might be. Speculation and participation were also used to bring different people's experiences and

forms of knowledge together in inclusive ways, to create a fictional community managing a food commons on the blockchain. We used roleplay and gameplay as a way of opening up a space in which we could take seriously the possibility of humans and non-humans having a voice and a stake in a value system as a way of addressing the inequalities and power imbalances within industrial food systems.

In the workshops we considered Spitalfields City Farm as a test case for prototyping sustainable food futures, but also drew on participants' experiences of other community gardens. Although we had around 5 participants who were actively involved in building blockchain systems, others had not heard of the technology before. For this reason, in our recruitment flyers we did not mention blockchains, and instead "invited growers to jump into the driving seat and shape how future technologies can best serve living beings and urban ecosystems to create a food commons". We carefully planned the activities so that participants did not feel excluded and were able to participate with their own level of experience.

We chose to work with urban agricultural communities as these are tied up in food justice. Spitalfields City Farm is in the inner east London borough of Tower Hamlets, one of the most economically deprived boroughs in the UK. It is characterised by high population density, large-scale immigration, ethnic diversity, poverty and huge divides between rich and poor. It suffers from a range of food-related illnesses, which are further compounded due to the availability of unhealthy eating options. As documented in our prior work, the challenges of volunteer labour, limited access to land, diminishing funding, and diverse users of urban agricultural communities offer opportunities to study the possibilities for digital technologies to support more-than-human entanglements and the food commons [30].

3.2 Workshop 1: Mapping the Future Farm

The first workshop brought together diverse urban community growers to explore the agencies of other beings and the more-than-human interrelationships on which thriving community growing spaces depend. Many of the participants came from migrant backgrounds, who are typically marginalised in industrial food systems, and were able to draw on their expert knowledge of regenerative agricultural techniques to map human and non-human stakeholders of the city farm, now and in the future, as well as the needs and contributions of these stakeholders, and the resource flows between them. By privileging the perspectives of urban community growers these activities allowed for a mode of knowledge production beyond a human-centered perspective of value in food systems.

Activities involved: brainstorming different stakeholders in 4 categories including: Human, Creature, Natural Environment, and Infrastructure & Organisation now and in the future (see Figure 3 for a sample) with a focus on breadth; a consideration of the specific costs and contributions of individual stakeholders from different categories, now and in the future (Figure 2); a mapping of the interrelations between stakeholders in terms of their costs and contributions and resource flows between human and non-human stakeholders of the farm in the year 2030. Participants were asked to consider resources beyond those with a financial value, such as volunteer labour, oxygen, time, and care, and to think about who manages those resources.

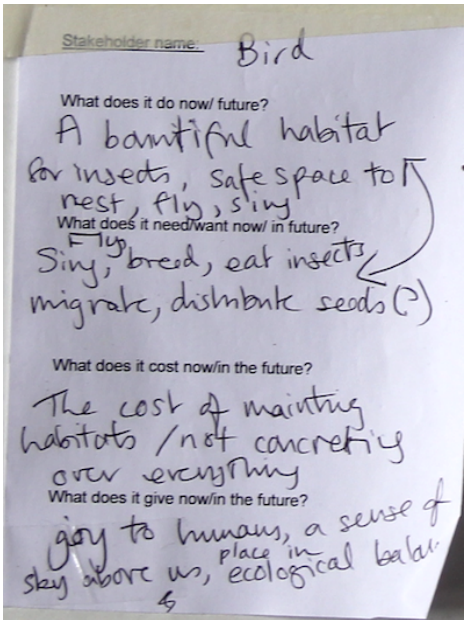

Figure 1 (left): Participants in workshop 1 mapping more-than-human stakeholders in the city farm

Figure 2 (right): Stakeholder sheet for "bird"

Creature	Human	Natural Environment	Infrastructure
birds	local residents	wildlife area	unions
Stag beetles	Local schools	Green roof gardens	permaculture
pollinators	Ethical funders	parks	Composting infrastructure
Worms and waste recyclers	volunteers	Waste ecologies	Board of trustees
frogs	Future commons landowners		Commons governance system
aphids	Extinction rebellion		constitution

Figure 3: Sample of stakeholders mapped in workshop 1.

These open-ended activities facilitated a space for experienced growers to draw on their knowledge to make visible the myriad more-than-human entities involved in small-scale regenerative agriculture, including their needs and contributions, and resource flows, as a way of surfacing new value propositions. Discussions revolved around the often invisible but important labour of care work that happens in community gardens, which is not adequately recognised or compensated for example in funding schemes, and is completely elided in industrial agricultural systems. This mode of

knowledge production from the grower's perspectives produced rich materials to ground the scenarios we developed in the second workshop.

3.3 Workshop 2: Now London is a City Farm

While the focus of the first workshop was mapping the more-than-human actors in our food systems, in the second workshop we used a type of roleplaying game called a Live Action Role Play (LARP) as a research tool to open up a playful space to imagine and critically examine possibilities for more-than-human actors to take part in governing a future food commons.

Set in 2025, in the aftermath of a "Great Food Emergency", the aim of the game was to transform London from an extractive financial centre into a global city farm in which all of London's available spaces and infrastructures are turned over to creating a thriving food commons for its biodiverse inhabitants. Participants were given different roles to play within fictional scenarios and played out multispecies relationships, new economies, and radical decision-making processes for sustaining a city-wide commons. Players' actions were informed by scenarios based on what we learned in the first workshop as well as real-world events, and current facts about food and environmental injustices, as we tried to establish new decision-making systems and urban infrastructures.

Participants came from a mix of growers, organisers, researchers, and also technologists including people familiar with blockchain concepts. They were split into 2 groups, representing 2 different decision-making bodies: one roleplayed within the Greater London City Farm Assembly (representing the city-wide perspective); the other roleplayed within E1 City Farm Assembly (representing a local community farm like Spitalfields City Farm). In each assembly, participants took on representative roles from committees that included: Coordination, Health, Agriculture, Security, Culture, Justice, Resources and Waste management, Education, Energy, Infrastructure, and Liaison.

At the start of the game, each person filled in an official looking Identity Certificate from which they chose both a human character and a "companion species" (drawing on [26]) to represent. Companion species included: birds, insects, farm animals, honey bees, soil, plants, trees, sensors, water, air, weather. The cast of human and non-human characters were drawn from the list of stakeholders generated in Workshop 1. The players wore a badge with a picture of their chosen companion species to remind them to account for the interests of both their human and companion species. The game began with a ritual. Participants were asked to close their eyes, imagine their human character in one hand, their companion species in the other hand, rub their hands together until they felt heat, and then to clap (Figure 4). They were told that after the clap they would speak (for the duration of the game) for both their chosen human character and for their companion species.

The LARP took place during the 2 assembly meetings in which players sat around a table discussing the items on an agenda (Figure 5). Agenda items were based on Ostrom's design principles for the commons. For each item on the agenda, the Chair of the meeting facilitated the discussion by introducing a scenario to discuss. While the agenda items were researcher-led (based on Ostrom's design principles), the scenarios were developed from "matters of care" [55] that arose in discussions in the first workshop. To illustrate with an example, in workshop 1 discussions arose around changes that could be made to the land to help pollinating insects, including lower impact agriculture, organic measures, the creation of new habitats, and banning pesticides. This "matter of care" was used as a basis for a script for the second agenda point: *Review of the sharing policy* (based on Ostrom's design principle 2). The Chair (one of the authors) introduced the agenda item with the following script: "*The next item on the agenda is a review of how we're managing resources, and ensuring that everyone's contributions are rewarded. … An issue that's come up recently in the sharing policy: so the bees, as you know…have been on strike now for six months. They've stopped working.*" The Chair continued: "*How was the Justice*

Committee proposing to resolve the dispute between the bees and the gardeners?" The representative from the committee called on responded, representing both their human's and companion species' interests at the same time. In this example, the justice representative replied, "*We are piloting various multispecies assemblies, which have representatives of all sorts of actors on the farm, to give equal voice to them all. But also working closely with infrastructure to meet the bees' demands. Which on the whole don't seem too wild and quite fair.*" Other members from other committees would then be called on to join in the discussion, and the speculative roleplay of more-than-human governance issues unfolded from there. Developing scenarios out of the previous workshop was important as it enabled participants to see their knowledge and experience put to work in the development of a future system. These scenarios helped us to imagine our emerging food commons, and work out a system of governance that would produce and distribute food for the benefit of all species.

We concluded the workshop with a risk matrix of the city farms to assess the likelihood and impact of different possible outcomes, in light of the different decisions that were taken in discussions by participants during the assembly meetings. The outcomes (which were pre-determined by the researchers) to be assessed were: 1) People going hungry 2) Crop species declining 3) Interspecies relations declining 4) Wealth and power concentrated within one group and 5) Depletion of resources by free-riders.

The LARP worked to bring together participants with different backgrounds and experiences of governance, from the community level to a technical systems perspective. The LARP scaffolded and patched together these different types of knowledge and experience of governance, and created a space for inclusive participation without requiring equivalent expertise.

Figure 4 (left): Participants preparing to clap in the ritual. Figure 5 (right): Participants in the EC1 Assembly

3.4 Workshop 3: Prototyping the Food Commons

The aims of the final workshop were to 1) co-design blockchain-based conceptual prototypes for governing more-than-human food commons and 2) critically stress-test these prototypes to better understand the implications for algorithmic food justice including what could go wrong. The workshop was split into two sessions, a morning and afternoon, which allowed for different experiences and understanding of governance to contribute to the creation and critical examination of blockchain prototypes for algorithmic food justice.

In the morning session we brought together participants with experience of blockchain governance and local currencies to create conceptual prototypes for new types of organisations to manage the more-than-human food commons through DAOs and smart contracts. Participants were given a selection of 8 scenarios, developed out of the

previous workshop materials, on which to base their DAOs. Each scenario highlighted conflicted and entangled relations between humans, other species and planetary systems. Each explored a different challenge for commons management, pertaining to membership, local rule-making and conflict resolution. Each included a direct quote from the LARP, was assigned a speaker/role, an assembly, a companion species, and a keyword relating to one of Ostrom's corresponding design principles. We illustrate with an example:

————————————————

Scenario 5: How can we re-value the contributions of each species, to produce balanced ecosystems?
Speaker / Role: Coordination
Assembly: Greater London City Farm Assembly
Companion Species: Soil
Quote from LARP:
"Multispecies sharing obviously isn't quite working right now. People still, or people - as in bees and plants - are not thinking there's a fair exchange. And so, I think that's just a wider question about how to learn more about how to do that better. And probably might be looking at existing models like soil ecosystem and how sharing happens within those systems."
Keyword: contribution, fair share

————————————————————————

In the example above, scenario 5, the quote came directly from a discussion in the LARP, the scenario related to Ostrom's design principle 2 around matching the rules of governing use of common goods to local needs and conditions, making sure the sharing is fair. The companion species and human role involved in the discussions in workshop 2 were soil and coordination, and the discussion took place in the Greater London City Farm Assembly.

Participants used these scenarios for context, and worked with paper-based prompts as design materials to define their DAOs, including how members make new proposals, and how voting works. They then produced a series of "smart contracts" for managing their DAOs as a food commons, paying attention to the multispecies relations, value flows and fair distribution of resources. Syntax cards were provided to help scaffold the smart contracts: each with a single word based on conditional programming e.g. IF, THEN, ELSE, and variable words such as TOKENS, ACTOR, ASSET, DURATION, LOCATION, and EVENT (Figures 6 & 7). These were based on the "IF THIS THEN ELSE" paper prototypes used in the GeoCoin project to plan out rules for smart contracts [45,61].

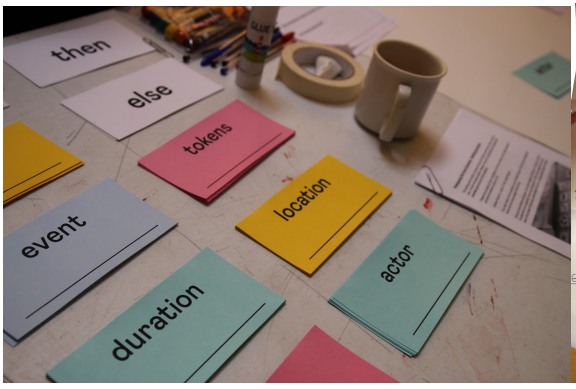

Figure 6 & 7: Syntax cards for prototyping smart contracts

The groups produced three different conceptual prototypes, which we present briefly here and discuss in further detail in the discussion section below.

1) *DAO-n to Earth* is a currency exchange for community currencies. The exchange rate is set automatically according to the soil health data of each community, as measured by networked sensors and AI, and calibrated over time. The better the quality of the soil, the higher the value of that local currency. In blockchain terms, soil health data over time is used as 'reputation' to determine the worth of each community's tokens. As a participant from this group explained, "*The aim of the DAO platform was to create a common incentive for people to create healthy soil and transmute that into a positive market value for their community*". This is an umbrella DAO that "*helps coordinate the smaller micro DAOs within the London Food Network.*"

2) The *Fellowshit of Dark Matter* consists of an app that lists unwanted materials in a commons, which other multispecies members can claim. The giver and the recipient are rewarded with tokens for this exchange and the transmutation of materials (e.g. manure is claimed and used as fertiliser).

3) The *Corn Council* is a system for repairing the disconnect and alienation that many humans experience from other species. It rewards humans with tokens for spending time with plants, as well as for caring for them, kindling new care-taking relationships. Non-exchangeable reputation tokens are used to make new proposals for managing the commons. Each crop has its own council and comes together through an umbrella council.

In the afternoon session we invited community growers and organisers to join in with their expertise of multispecies relations, food-growing, and community governance to try and fuse these forms of knowledge in critically examining how these DAOs might serve local and wider multispecies interests, as well as all the awful things they might do by accident. Knowledgeable growers helped reconfigure tech-focussed imaginings and added important depth and nuance to multi-species relationships and ecosystems by 'stress testing' the DAOs. This was achieved through discussions around where each DAO sits on a matrix with axes of dystopian/utopian, and discrete/federated (as pre-determined by the researchers).

By bringing together people with different experience of governance the workshops opened up different valences for people to engage with algorithmic governance and consider new perspectives. For example, the growers' knowledge forced the technologists to consider the implications of their prototypes on multispecies communities. At the same time growers were brought into a conversation about technology that they wouldn't have had before. In these ways the workshop activities created an inclusive space in which a plurality of human and non-human actors (including soil, animals, computation, and sensors) and their different forms of knowledge were brought to bear on a more-than-human value system represented through algorithmic governance.

4 DISCUSSION

The Algorithmic Food Justice project aimed to open up a space for rethinking the two value paradigms that are driving ecological and social injustices within global industrial food systems: a human-centred perspective of food and a perspective of food as commodity to be traded for maximum profit for the benefit of a few shareholders. In this section we discuss how the co-design activities and their outputs surfaced alternative configurations of value that allowed for benefit and power to be distributed more equitably between more-than-human actors.

We reflect with illustrations and perspectives from participants how the project and its speculative methods allowed us to triangulate the dicussion between the commons, the more-than-human and blockchain, and start to conceptually

reposition value within food systems beyond human-centeredness and food as commodity, through an articulation of *reconfiguring more-than-human values* and *reconfiguring food as a more-than-human commons*. We conclude with a discussion of some of the challenges and tensions in this work.

4.1 Reconfiguring more-than-human values

The speculative workshop methods created a space in which human exceptionalism and privilege within food systems were challenged, allowing alternative values and perspectives to surface. In the first workshop we attuned participants to the more-than-human by asking them to consider the breadth of human and non-human stakeholders in the city farm and the networks of relations between them. We asked participants to consider, *what are your needs from and contributions to the community enterprise?* from the pespective of these different stakeholders. This enabled participants to imagine themselves as other, and to collectively speculate on the conditions for thriving interspecies communities, raising issues of ethics, responsibility, and care labour in urban space. For example, one participant reflected on pigeons who had been displaced from nearby railway arches. "*They were a bit of a horror - guano all along the way. But this was a place that they belonged, had been there forever, since the railway was built. For months the pigeons would be trying to fly in. The waste could have been a resource - productive for gardening.*" Others discussed the unrecognised amount of collective care and unpaid labour that goes into maintaining community gardens and farms, which contribute to the overall health of humans and non-humans in the city. In the second workshop we used creative props such as companion species badges, identity certificates and the hand-rubbing ritual to set up the roleplay, which allowed humans to speak on behalf of non-human stakeholders. Like the masked performative walks used in the Ministry of Multispecies Communication [9], these methods worked to decentre the human and "facilitate imaginative reflection and embodied play on future urban relations between species, data and communication technologies" (ibid), and spaces for interspecies negotiations and value exchange. For example, discussions around security, stealing and overuse in the gardens brought up issues of monitoring and membership of both human and non-human members, which were dealt with in often surprising and humourous ways, and led to exploration of dubious outcomes. Ideas proposed included loyalty cards, apps, data from social media use, and, in a prescient vision of COVID-19's impact on air travel, body scanners from the now-defunct airports were to be reused as a means to detect those trying to steal pumpkins. As the Security representative said, "*What we felt from internal discussions so far is that we don't have enough information, both about our own members and…in particular about the broader community, so that we can feed that in to our data sets model accordingly.*" The Culture representative brought up the membership of pollinating companion species, "*because I hear there was a problem with people using pesticides. Which is a bit of a heavy-handed way of dealing with that membership question.*" By the time we got to the last workshop a more-than-human perspective had taken root with participants and was firmly embedded into the activities and planed outcomes. Prompted only by the scenarios and an accompanying companion species, each of the three teams worked to design blockchain prototypes that took the interconnections and interdepencies of human and non-human actors seriously, and were committed to moving beyond human exceptionalism towards a fairer distribution of value within food systems across human and non-human actors.

These techniques of decentering the human created possibilities to think differently about agency, needs and contributions from a more-than-human perspective within a thriving food commons. The creative workshop methods worked as "performative material" [9] allowing participants to play with transcending human experience and scaffolding "alternative embodied…imaginaries to take place that suggest future alternative possibilities [with data] that… decentre human privilege, even if momentarily, and support more relational perspectives to be encountered and negotiated" (ibid).

As a result, new possibilities for attributing and exchange of value emerged. For example, in the case of The Fellowshit of Dark Matter DAO, faeces and other organic waste was reconfigured from something to dispose of, to a valuable asset. "*As a human, I might not know that my bean plant cuttings are going to be useful to another species such as birds or soil microorganisms. And it's only when people empathising with/as birds or soil microorganisms see the alert [from the app] that they can reframe waste as matter in the wrong place. So, the system helps identify and surface actors in the community saying actually that's not waste.*" Similarly, in the Corn Council DAO, a recognition of plants as stakeholders allowed for their needs to be recognised and met. From the plant's perspective, human time and care became valuable assets, contributions to the multispecies community, and therefore recognised as such. Drawing on a feminist ethics of care [53], we can see how the workshop techniques helped to reveal the hidden actors, practices and labours that are generally neglected in industrial food systems, and help us reconfigure values in ways that recognise the interdependencies and interconnections of human and non-humans in the food web.

Possibilities also emerged for value to be bestowed not only on individuals, but on relations between more-than-human actors. One of the participants explained the Fellowshit of Dark Matter DAO: "*One of the things that we really wanted to prioritise were the relations - that waste in itself as an object maybe wasn't the centre, it was the relations between entities, actors, objects, etc.*" A more-than-human value system here considers not only resource flows between individual actors, but also their contributions towards increasing and strengthening these interrelations, on which a thriving food web relies. As a participant explained: "*We sensitise ourselves to multispecies relations, that we're always thinking along the chain if you like, we're always thinking, well if we start to reduce waste and some kind, and enter into this system how might it feed into other systems, and transmogrify into a manifold set of relations and relationships.*" Here, too, there are echoes in Puig de la Bellacasa's ethics of care, in its "feminist approach that engages with care as a way to draw attention to the significance of practices and experiences made invisible or marginalized by dominant, 'successful', forms of technoscientific mobilization.... In this sense, focusing on care draws attention to glimpses of alternative, liveable relationalities, and hopefully contributes to other possible worlds in the making" [54].

In the imaginaries produced in the workshops, blockchain provides the mechanisms to facilitate ecological repair and regeneration by incentivising the expansion and increasing the abundance of mutually beneficial relations. For example, in the Fellowshit of Dark Matter DAO: "*People are incentivized to move matter from the wrong place to the place where it can have its value realised....And so the whole system is about furthering the abundance of relations and rewarding people who are trying to expand the network of relations between entities all the time.*" Through its "proof of healthy soil" protocol in which the value of a community's currency is determined by the health of its soil over time, the DAO'n to Earth prototype uses blockchain to incentivise regenerative soil practices. The value of a single community's currency is regulated by its soil health, while the exchange between different community currencies is regulated by the overall health of the soil in all the community members in a federated umbrella DAO. Collective responsibility for the overall health of the system is incentivised: within the DAO 'n to Earth prototype, when there is a market crash, all DAOs on the exchange are alerted, kickstarting emergency response. Blockchain, here, is used as a way of "*imagining [the system] as a collective organism and not as these individual parts that are always competing with one another"* (as one participant explained).

While terra0 and Plantoid can be seen as "ground zero" for using DAOs as "proxies for natural-systems" [58], they are limited in their possibilities for ecological regeneration, because they consider the more-than-human as reduced to discrete entities in a system of financial exchange. The opportunities surfaced in our project are a departure from these previous examples in that they present possibilities for using blockchain to rethink value from a more-than-human perspective beyond the merely financial. They also present propositions for "radical regulation" to force us to consider,

not only non-humans as individual actors, but also the interdependencies between multitude more-than-human actors in an ecological web and in which ecological balance is incentivised. Future work that investigates the potential for blockchain to support these more-than-human interdependent interrelations is where we see the greatest potential for rethinking more-than-human values for more sustainable and inclusive food systems.

4.2 Reconfiguring food as a more-than-human commons

The dominant food systems extract value from the planet's resources, concentrating benefit in the hands of a few. Through the different workshop methods we speculated on food governance for a heterogenous set of more-than-human actors in accounting systems, as a way of addressing the inequalities and power imbalances within the current industrial food systems. In the three workshops, we used notions of the commons to think with blockchain from a position of diverse multispecies stakeholders: commoning, collective governance and in particular Ostrom's 8 Design Principles were threaded throughout the workshops. Here, we discuss how the workshop methods allowed us to play with governance and envision a more-than-human food commons with blockchain, thereby transforming the conditions of the commons to meet the needs of more-than-human communities.

4.2.1 Workshop 1: grounding a more-than-human commons in lived experiences

In the first workshop we structured activities around resource use, assets, contributions, and scarcity to think about the urban farm as a collectively managed ecosystem. We further explored resource flows and value exchanges between humans, other species, ecosystems, and infrastructure to rethink how the needs of more-than-human stakeholders might be met in the future farm without jeopardising its sustainable management of its resources through overuse. Participants, many of whom came from community growing spaces and organising backgrounds, were well versed in and had strong opinions about the myriad governance issues that typically arise in these kinds of places, including the interdependencies and sometimes competing needs between (human and non-human) members. These workshop methods generated rich discussions that directly related to Ostrom's design principles. For example, discussions arose about the challenges of membership and defining boundaries of community growing spaces, that are compounded when land use is temporary and insecure, and populations are transient (design principle 1). Other discussions revolved around the unpaid volunteer care labour that goes into maintaining community growing spaces (design principle 2). As one participant highlighted, the invisibility of this care labour is "*built into the assumptions of funding schemes that there's so much volunteer work already…and an unwillingness to acknowledge and properly value and finance the care work that's put into keeping these things going*". Discussions around how to address the needs and contributions of non-human members such as pollinators, through lower-impact growing and banning pesticides, highlighted the challenges of commons governance with other species. Issues around monitoring, sanctions and conflict resolution (design principles 4, 5 & 6) were raised to address the "free-rider" problem. For example, one group discussed the problem of theft of crops, raising further discussions around wider food justice issues, "*Why are people taking food? Are they taking it because they need it? Because we don't have a fair food system? We need to change that food system.*" Thinking through issues of abuses of common resources by other species, the issue of urban foxes damaging the gardens prompted possibilities for inclusive conflict resolution and re-valuing their contributions: "*Are they seed carriers? How will they evolve in the next 10 years? Will they remain pests or could they be encouraged to do something different?*" Conversations about governance issues with outside entities also arose (design principles 7 & 8), for example by replicating small scale farms across the city, and by local authorities mandating that urban planning permission applications include wildlife areas. By asking participants to consider both the human and non-human actors in collective governance, the often invisble practices, labours and

players in food systems were made visible and helped shape the development in the subsequent workshops. Their lived experiences provided the foundations for exploring how the interwoven relations between different actor's stakes, food justice issues, and emerging technologies might come together in new and more just ways.

4.2.2 Workshop 2: Roleplaying a future more-than-human food commons

In the second workshop, the LARP allowed us to roleplay how commons governance might play out in the future. Governance issues within a more-than-human commons unfolded in assembly meetings in which agenda items were structured more explicitly around Ostrom's design principle for the commons, while the characters and scenarios were grounded in the lived experiences of participants. This elicited rich and detailed discussions about how governance might work, or not work, to both avoid the Tragedy of the Commons, and ensure that any system was fair for a more-than-human collective. Contributions that are marginalised in industrialised food systems were brought to the fore, demanding recognition and allowing for a re-evaluation of values. As the Justice representative, speaking on behalf of her 10-year old human character, Pip, on the bee strike, said, "*It's also a question of evaluation of work and what kind of work we value most.*" Pip asked the assembly to consider the undervalued and often invisible labour of the hand pollinators and bees. This labour, performed by marginalised communities and species, is overlooked within neoliberal food systems. Therefore, revaluing them can lead to restructuring of power relations. Like in workshop 1, in workshop 2 issues around needs and contributions in relation to the "free-rider problem" were challenged, again by the Justice representative. "*[I have] issues with sanctions... and chucking anyone out, and would rather like to rethink a membership based on capacity and need.... It's about not thinking about every interaction as one of necessarily equal exchange, but rather existing within the greater system of things and interaction.... Often exchanges aren't 50/50 and can still be worthwhile.*" Here, commons governance is not about everyone making an equal contribution, or a transactional exchange of value, but rather about recognising everyone's different contributions and needs, as in a more relational economy [68]. Relationality is seen not in terms of immediate exchange value, but wider systems of exchange that sustain and extend the relations. The challenge of how these kinds of longer-term relations can be accounted for and made visible began to be addressed in workshop 3.

4.2.3 Workshop 3: Governing a more-than-human commons on the blockchain

In the third workshop, we created speculative prototypes using blockchain to begin to imagine new types of commons governance through the help of smart contracts and tokens. While we didn't explicitly bring Ostrom's design principles into the final workshop, we took conversations around commons management from the LARP and turned them into scenarios that formed the basis for the DAO prototypes. Participants were tasked with creating smart contracts to sustainably and fairly govern the DAOs for the benefit of multispecies members based on the scenarios. The DAOs addressed the different design principles, revealing opportunities for managing thriving more-than-human food commons on the blockchain. As in examples such as Backfeed [49] and Commonfare [62], exchangeable tokens in the form of a currency, and non-exchangeable tokens in the form of reputation, were used in all three DAO prototypes to manage the rules in ways that are fair for multispecies communities. New rules could be proposed and voted on by those who participate and are affected by the rules (design principle 3), with the help of reputation tokens and smart contracts, allowing the DAOs to evolve over time. For example, in the Corn Council DAO, caring for crops is incentivised with reputation tokens, which a member can then use to help the DAO evolve by proposing and voting on new proposals.

Votes are weighted according to how many reputation tokens you have. The system recognises the value of caring for crops and rewards this activity that supports the commons (design principle 2). Invisible values such as spiritual

connections between humans and non-humans that are viewed as contributing to the commons are recognised and rewarded, for example by awarding reputation tokens for time spent participating in human-plant rituals (design principle 2). In the Fellowshit of Dark Matter DAO, relations between species are recognised as necessary for a thriving commons, and therefore the rules based on these local conditions are used to recognise and reward their abundance. This is done through a ceremony in which the collective value of these relations are collectively assessed and appropriate rewards are distributed. Likewise, in DAO'n to Earth, reputation is allocated to individual farms according to the health of their soil over time, through a "Proof of Healthy Soil" protocol and as measured through AI-based sensor networks called "Soil Sentinels". Reputation can be used to change the algorithms of the overall DOA. The rules recognise and incentivise the work for increasing, and repairing the commons, contributing to its overall health and abundance.

The free rider problem and subsequent Tragedy of the Commons are addressed in the DAO prototypes through the blockchain incentivisation mechanisms, and supported by AI and Internet of Things. For example, in the DAO 'n to Earth example, if you don't look after your soil well, then the value of your tokens decrease. Monitoring happens through the Soil Sentinels, AI enabled sensors and their data sets, which replaces social sanctions in more traditional commons management.

Design principle 7 observes that local communities should have jurisdiction for local rules which are recognised by higher authorities. This is interrelated to principle 8 which addresses the ways in which multiple layers of organisations can address issues that affect issues of resource management at local and broader levels. All three DAOs consider their relations with other enterprises of varying scale, allowing communities to address issues that affect managing them differently. The vision explored in the Corn Council DAO is for different DAOs to help manage different crops, with an umbrella DAO to manage the different crop councils within the whole farm, and allow for voting on general proposals for the farm. The DAO 'n to Earth DAO is essentially an umbrella DAO that helps manage different DAOs to produce balanced ecosystems. Nested enterprises are managed by understanding balanced ecosystems in relation to each other. Each farm DAO in the London farming community has its own currency on the exchange. And each farm's tokens go up and down in value according to the health of that farm's soil over time. Looking after the soil of your farm increases the reputation of your DAO against the other DAOs. This allows for scaling of the commons and its values. Furthermore, the ecological repair for the whole system is incentivised by the exchange: if you start off with badly polluted soil, the value of your tokens is weighted according to how much it improves over time. Communities are incentivised to take on soils that might be in bad health and to improve them. This DAO goes one step further: if a soil is accidently damaged or depleted the whole system is affected, all actors are alerted and this triggers a response (for example, a vote to offer experts to go help out and remediate the soil). This is to help the overall health of the system because you don't want one farm's token to crash because it might destabilise the whole exchange.

These examples illustrate how within a more-than-human food commons, values are reconfigured and different types of contributions and labours that are invisible in the dominant food systems might be surfaced, acknowledged and rewarded by the community. In contrast to examples such as BeefLedger, Provenance and AgriBlockIoT, which use blockchain to solve the problems of traceability in food systems, the blockchain prototypes developed here help to reconfigure value within food systems and contribute to regenerative food systems that benefit the Earth, similar to Nori, Regen Network and GainForest. Where our project departs from these examples is the use of blockchain facets such as tokenisation, reputation and smart contracts to not only reconfigure these values but also to operationalise Ostrom's design principles, as in [8,49,57]. Going futher, the DAOs in our project look to automation not to deliver efficiencies within commons governance but, as with terra0 and Plantoid, to craft some form of autonomy for more-than-humans on the blockchain—which attempt to free food systems from human-centred value extraction. Here, code

affords the food commons a type of autonomy and agency beyond the human and beyond the individual. As with the examples of terra0 and Plantoid the DAOs surface new possibilities for blockchain facets to offer the basis for creating new value systems that not only allow for the interests of non-humans such as seeds, water and soil to have a stake in food systems, leading to radical regulation and redistribution of power, but indeed the possibility for the food commons itself to function as an autonomous self-organising multispecies agent. Here we move beyond a human-centred perspective of the commons, and also beyond a discrete, individualist understanding of capital and value, to consider how the health and wellbeing of individual actors both human and non-human are inseparable from the collective wellbeing of their ecosystems. It is the combination of both commons-based and more-than-human values that we see essential for algorithmic food justice.

4.3 Tensions and challenges

While we encouraged speculation around more desirable futures, we also encouraged critical examination of the blockchain-based futures generated in the workshops. In particular, in the final afternoon session of the last workshop we stress-tested the DAOs to better understand what dystopia or food injustices the prototypes might unintentionally create. We reflect on these here, paying attention to the limitations of our investigations addressing the twin challenges of a more-than-human value system and food as commons.

Many issues are unresolved around how to involve more-than-human entities as stakeholders in blockchain-based food systems. It is still humans speaking on behalf of other actors and making decisions on behalf of non-humans, and it will be humans, subject to prevailing economic and social pressures and incentives, who write the code (as it is in the examples of terra0 and Plantoid). We attempted to overcome this epistemological challenge by engaging expert growers with their experience of regenerative agriculture, using decentering techniques such as roleplay to speak on behalf of other species, and a consideration of non-human actors such as sensors, AI and blockchain in our accounting systems. We conclude that, at best, these could work, as in terra0, as proxies for non-humans. More worringly, growers brought up power imbalances and the potential for blockchain-based systems to intensify inequalities, depending on whose stories were being told. For example, in the DAO'n to Earth DAO, the currency on the exchange is affected by soil health as determined by sensors. As one grower argued, "*If you're focusing on PH or the chemistry of the soil, then that's telling us a story about the soil. A chemical story rather than a microbiological one.*" AI and Big data in agriculture have the potential to intensify power asymmetries between farmers and large agribusiness [4], as well as between humans and non-humans. As highlighted in Wang's Blockchain Chicken Farm [67] when blockchain is coupled with these technologies, rather than solving problems, these technologies have the potential to contribute to accelerationist control and amplify inequalities in food systems. Whose stories would the sensors be telling, and into whose hands will they be playing? There are ethical implications around these systems for, as the grower participant said, different stories around data "*produce different types of truth… it could be corrupted in lots of different ways*". This is very important to what we see as the critical question of value systems provoked by our use of the more-than-human. Importantly, critical race studies shows us that while the more-than-human may make room for multiple subjectivities, it may not serve those who have historically been excluded from the category of human in the first place, such as people of colour. "As such, it is important to ask how emergent design practices, including those that might de-center the human, might simultaneously support equality and justice for humans and nonhumans alike" [22]. A feminist ethics of care shows how we might pay attention to neglected humans and nonhumans, their relations, and their practices in order to re-configure value in ways that contribute to a more sustainable and just food system.

Tensions arose around using blockchain to create formal accounting systems of value and introducing external rewards in what was previously informal and intrinsically motivated [8,49], as in the examples of Backfeed and Commonfare. Firstly, the possibility for accumulation may lead to perverse incentives resulting in stinky piles of waste, useful things being turned into waste, short-termism, and overproduction created by their incentivisation mechanisms as revealed by the stress-test of Fellowshit of Dark Matter prototype. As highlighted in [67], the danger here is the assetisation of nature, in which DAOs as "proxies for natural-systems" [58] consider the more-than-human as reduced to discrete entities in a system of financial exchange (as with terra0). Secondly, while blockchains promise to facilitate more equal distribution of benefits, if the system is not set up correctly, bad actors will find a way to corrupt the system and work it to their own ends. For example, in the DAO'n to Earth DAO, people might have land with poor soil, and dump some healthy soil only where the sensors are, effectively hacking the sensors. In the example of the Corn Council DAO, humans are rewarded for being present and aware in nature with tokens that allow you to make proposals and vote on proposals. But concerns were raised about bad actors abusing this by sitting and looking at their mobile phone instead of "authentic consciousness raising", thereby earning too much power without a proper contribution. Conversely, those who can't get out into nature for whatever reason are disempowered. Finally, the practical challenges of constant maintenance in these accounting systems was raised: how to identify and log so many microtransactions? What are the energy and time costs of managing the connection and exchange, storage, and the process, and how can this be resourced? Echoing [8] "Such systems would require constant monitoring of everyone's actions in order to constantly update the reallocation of tokens and reputation according to the perceived value of offers and contributions. Here, questions regarding whether every action needs to be assessed and how to deal with the cumbersomeness of a constant assessment arise". And of course, rather than a solution itself, any blockchain system will need to exist within larger sociotechnical systems, as illustrated within the DAO prototypes from workshop 3 (for example, an app and ceremonies are part of the Fellowshit of Dark Matter prototype). The HCI community is well placed to explore these tensions in future work involving the social sciences and humanities perspectives to better understand sociotechnical concerns in blockchain-based solutions for the commons.

These tensions and challenges highlight the urgency of including the insights of heterogenous, marginalised actors and voices (e.g. small scale farmers, migrant communities, other species) in the design of algorithmic systems, in order to avoid intensifying inequalities. Without a variety of stakeholders working on these technologies, accelerationist tendencies and injustices will be exacerbated. We can't afford to leave the development of this very powerful technology to financiers, engineers and corporations.

5 CONCLUSION

In this paper, we presented new work that aimed to open up possibilities for algorithmic justice to address both social and environmental injustices within the dominant global food systems. Within HCI we are starting to see posthuman perspectives to design, as well as ways for decentralised technologies such as blockchains to help communities to govern themselves and their resources in ways that are fair and sustainable. We drew on these emerging research angles within HCI to discuss possibilities for using blockchain to create new mechanisms for value creation and exchange within food systems, by decentering the human in design and considering food beyond a commodity to be traded for maximum profit. We presented a research project called Algorithmic Food Justice that used blockchain as a design material, together with creative techniques such as roleplay and fiction, to co-designed algorithmic possibilities for managing food systems as a commons, where non-human stakeholders play a part. We reported on the workshop activities, which engaged diverse participants in the creation of speculative futures that explored using blockchain as a way to recognise

and support the interrelations and interdependencies of multispecies actors that are required to maintain a thriving food commons. We concluded with reflections on how the project elicited new configurations of value, humans, non-humans such as other species, as well as technologies such as blockchains, AI and sensors within food systems, that suggest more sustainable and fair futures. We also discussed some of the limitations and tensions that arose, and suggested directions for future work in this area.

We offer these findings and reflections as first steps towards creating a more-than-human food commons through blockchain. Algorithmic justice is a promising area of research for HCI and the potential for blockchain to intervene in this space is ripe for exploration. We urge HCI design researchers interested in blockchain for the commons to build on these first steps in designing for the commons in the domain of food, but also other domains such as the urban commons and the digital commons, to consider how the ways in which membership within a commons might be extended to other species as a way of creating more fair and sustainable futures. Incorporating Ostrom's design principles through blockchain mechanisms is a fruitful way forward for HCI to engage in designing for the commons, and requires further work. We urge researchers to question the values driving the research, and argue that a human-centred perspective of value is no longer tenable. Our current agricultural model is untenable, and we urgently need to prototype new paradigms for more sustainable futures. Our speculative research explores how post-human designs might work in giving value to the contributions made by more-than-human species that are externalised and marginalised under other value systems. Experiments in paradigm change towards more-than-human design are necessarily speculative because they seek to imagine system change at scale. We also urge design researchers working in this area to continue with our speculative and inclusive experiments as a way of imagining systems change for redistributing value and benefit more evenly in order to create more socially inclusive and environmentally sustainable food futures.

ACKNOWLEDGMENTS

We wish to thank all the participants in the workshops. We especially want to thank Spitalfields City Farm for showing us what a thriving multispecies food commons looks like. This project was funded through an EPSRC NotEqual Network+ grant.

REFERENCES

[1] Ferran Altarriba Bertran, Samvid Jhaveri, Rosa Lutz, Katherine Isbister, and Danielle Wilde. 2019. Making Sense of Human-Food Interaction. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (CHI '19), 1–13. DOI:https://doi.org/10.1145/3290605.3300908

[2] Corelia Baibarac and Doina Petrescu. 2017. Co-design and urban resilience: visioning tools for commoning resilience practices. *CoDesign* 0882, December (2017), 1–19. DOI:https://doi.org/10.1080/15710882.2017.1399145

[3] J Bélanger and D Pilling. 2019. *The State of the World's Biodiversity for Food and Agriculture*. Retrieved from http://www.fao.org/state-of-biodiversity-for-food-agriculture/en/

[4] Isabelle M Carbonell. 2016. The ethics of big data in big agriculture. 5, 1 (2016), 1–13. DOI:https://doi.org/10.14763/2016.1.405

[5] Miguel Pincheira Caro, Muhammad Salek Ali† Ali, Massimo Vecchio, and Raffaele Giaffreda. 2018. Blockchain-based traceability in Agri-Food supply chain management: A practical implementation. In *2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany)*, 1–4. DOI:https://doi.org/10.1109/IOT-TUSCANY.2018.8373021

[6] Ruth Catlow. 2017. Artists Re:Thinking the Blockchain Introduction. In *Artists Re:thinking the Blockchain*, Ruth Catlow, Marc Garrett, Nathan Jones and Sam Skinner (eds.). Torque editions.

[7] Sylvain Charlebois. 2017. How blockchain technology could transform the food industry. *The Conversation*. Retrieved December 20, 2020 from https://theconversation.com/how-blockchain-technology-could-transform-the-food-industry-89348

[8] Nazli Cila, Gabriele Ferri, Martijn De Waal, Inte Gloerich, and Tara Karpinski. 2020. The Blockchain and the Commons: Dilemmas in the Design of Local Platforms. In *Conference on Human Factors in Computing Systems - Proceedings*, 1–14. DOI:https://doi.org/10.1145/3313831.3376660

[9] Rachel E Clarke. 2020. Ministry of multispecies communications. In *DIS 2020 Companion - Companion Publication of the 2020 ACM Designing Interactive Systems Conference*, 441–444. DOI:https://doi.org/10.1145/3393914.3395845

[10] Rachel Clarke, Sara Heitlinger, Marcus Foth, Carl Disalvo, Ann Light, and Laura Forlano. 2018. More-than-human urban futures: Speculative participatory design to avoid ecocidal smart cities. In *ACM International Conference Proceeding Series*, 18–21. DOI:https://doi.org/10.1145/3210604.3210641

[11] Rachel Clarke, Sara Heitlinger, Ann Light, Laura Forlano, Marcus Foth, and Carl DiSalvo. 2019. More-than-human Participation: Design for

Sustainable Smart City Futures. *Interactions* 26, 3 (April 2019), 60–63. DOI:https://doi.org/10.1145/3319075

[12] David Dao, Catherine Cang, Clement Fung, Ming Zhang, Reuven Gonzales, Nick Beglinger, and Ce Zhang. 2019. GainForest : Scaling Climate Finance for Forest Conservation using Interpretable Machine Learning on Satellite Imagery. *ICML Clim. Chang. Work. 36th Int. Conf. Mach. Learn.* (2019), 5–7.

[13] Carl DiSalvo and Jonathan Lukens. 2011. Nonanthropocentrism and the nonhuman in design: possibilities for designing new forms of engagement with and through technology. In *From social butterfly to engaged citizen: urban informatics, social media, ubiquitous computing, and mobile technology to support citizen engagement*, Marcus Foth, Laura Forlano, Christine Satchell and Martin Gibbs (eds.). MIT Press, Cambridge, MA, 440–460.

[14] Markéta Dolejšová, Sjef van Gaalen, Danielle Wilde, Paul Graham Raven, Sara Heitlinger, and Ann Light. 2020. Designing with More-than-Human Food Practices for Climate-Resilience. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference* (DIS' 20 Companion), 381–384. DOI:https://doi.org/10.1145/3393914.3395909

[15] Markéta Dolejšová, Danielle Wilde, Ferran Altarriba Bertran, and Hilary Davis. 2020. Disrupting (More-than-) Human-Food Interaction: Experimental Design, Tangibles and Food-Tech Futures. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (DIS '20), 993–1004. DOI:https://doi.org/10.1145/3357236.3395437

[16] Chris Elsden, Inte Gloerich, Anne Spaa, John Vines, and Martijn de Waal. 2019. Making the blockchain civic. *interactions* 26, 2 (2019), 60–65.

[17] European Commision. 2017. *CAP explained: Direct payments for farmers 2015-2020.*

[18] Feng Tian. 2016. An agri-food supply chain traceability system for China based on RFID blockchain technology. In *2016 13th International Conference on Service Systems and Service Management (ICSSSM)*, 1–6. DOI:https://doi.org/10.1109/ICSSSM.2016.7538424

[19] Primavera De Filippi. 2017. Plantoid – The Birth of a Blockchain- Based Lifeform. In *Artists Re:thinking the Blockchain*, Ruth Catlow, Marc Garrett, Nathan Jones and Sam Skinner (eds.).

[20] Brendan Fisher, Kerry Turner, Matthew Zylstra, Roy Brouwer, Rudolf De Groot, Stephen Farber, Paul Ferraro, Rhys Green, David Hadley, Julian Harlow, and others. 2008. Ecosystem services and economic theory: integration for policy-relevant research. *Ecol. Appl.* 18, 8 (2008), 2050–2067.

[21] Laura Forlano. 2016. Decentering the Human in the Design of Collaborative Cities. 32, 3 (2016). DOI:https://doi.org/10.1162/DESI

[22] Laura Forlano. 2017. Posthumanism and Design. *She Ji J. Des. Econ. Innov.* 3, 1 (2017), 16–29. DOI:https://doi.org/https://doi.org/10.1016/j.sheji.2017.08.001

[23] Sheila Foster and Christian Iaione. 2017. Ostrom in the City: Design Principles for the Urban Common. (2017), 1–24. Retrieved from https://www.thenatureofcities.com/2017/08/20/ostrom-city-design-principles-urban-commons/

[24] Marcus Foth. 2017. The Next Urban Paradigm : Cohabitation in the Smart City Proposal for ' Building a New Economy for Australia ' Conference. 59, September (2017), 259–262.

[25] Marcus Foth. 2017. The promise of blockchain technology for interaction design. In *Proceedings of the 29th Australian Conference on Computer-Human Interaction - OZCHI '17*, 513–517. DOI:https://doi.org/10.1145/3152771.3156168

[26] Donna Haraway. 2008. Companion species, mis-recognition, and queer worlding. *Queering the non/human* (2008).

[27] Donna J Haraway. 2016. *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press.

[28] Garrett Hardin. 1968. The Tragedy of the Commons. *Science (80-.).* 162, 3859 (1968), 1243–1248. DOI:https://doi.org/10.1126/science.162.3859.1243

[29] Sara Heitlinger, Nick Bryan-Kinns, and Rob Comber. 2018. Connected Seeds and Sensors: Co-designing Internet of Things for Sustainable Smart Cities with urban food-growing communities. *Particip. Des. Conf.* (2018). DOI:https://doi.org/10.1145/3210604.3210620

[30] Sara Heitlinger, Nick Bryan-Kinns, and Rob Comber. 2019. The right to the sustainable smart city. In *Conference on Human Factors in Computing Systems - Proceedings*, 1–13. DOI:https://doi.org/10.1145/3290605.3300517

[31] Sara Heitlinger, Nick Bryan-Kinns, and Janis Jefferies. 2013. Sustainable HCI for grassroots urban food-growing communities. In *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, 255–264.

[32] Sara Heitlinger, Nick Bryan-Kinns, and Janis Jefferies. 2013. UbiComp for grassroots urban food-growing communities. In *Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication*, 589–594.

[33] Sara Heitlinger, Marcus Foth, Rachel Clarke, Carl DiSalvo, Ann Light, and Laura Forlano. 2018. Avoiding Ecocidal Smart Cities: Participatory Design for More-than-human Futures. In *Proceedings of the 15th Participatory Design Conference: Short Papers, Situated Actions, Workshops and Tutorial - Volume 2* (PDC '18), 51:1--51:3. DOI:https://doi.org/10.1145/3210604.3210619

[34] Eric Holt-Giménez. 2010. Food Security, Food Justice, or Food Sovereignt? *Food First Backgrounder, Inst. Food Dev. Policy* (2010).

[35] Donna Houston, Diana Maccallum, Wendy Steele, and Jason Byrne. 2017. Make kin , not cities ! Multispecies entanglements and ' becoming-world ' in planning theory. (2017). DOI:https://doi.org/10.1177/1473095216688042

[36] Bruno Latour. 1999. *Pandora's Hope: Essays on the Reality of Science Studies*. Harvard University Press.

[37] John Law. 2004. *After Method: Mess in Social Science Research*. Routledge.

[38] Jason Edward Lewis, Noelani Arista, Archer Pechawis, and Suzanne Kite. 2018. Making Kin with the Machines. *J. Des. Sci.* (2018). DOI:https://doi.org/10.21428/bfafd97b

[39] Ann Light and Clodagh Miskelly. 2015. Sharing economy vs sharing cultures? Designing for social, economic and environmental good. *Interact. Des. Archit.* 24, 1 (2015), 49–62.

[40] Jun Lin, Zhiqi Shen, Anting Zhang, and Yueting Chai. 2018. Blockchain and IoT Based Food Traceability for Smart Agriculture. In *Proceedings of the 3rd International Conference on Crowd Science and Engineering* (ICCSE'18). DOI:https://doi.org/10.1145/3265689.3265692

[41] Markets and Markets. Blockchain Market by Component (Platform and Services), Provider (Application, Middleware, and Infrastructure), Type (Private, Public, and Hybrid), Organization Size, Application Area (BFSI, Government, IT & Telecom), and Region - Global Forecast to 2025. Retrieved December 19, 2020 from https://www.marketsandmarkets.com/Market-Reports/blockchain-technology-market-90100890.html

[42] Annemarie Mol. 2002. *The Body Multiple: Ontology in Medical Practice*. Duke University Press.

[43] Jason W Moore. 2017. The Capitalocene, Part I: on the nature and origins of our ecological crisis. *J. Peasant Stud.* 44, 3 (2017), 594–630. DOI:https://doi.org/10.1080/03066150.2016.1235036

[44] Timothy Morten. 2013. *Hyperobjects: Philosophy and Ecology after the End of the World*. Minneapolis: University of Minnesota.

[45] Bettina Nissen, Larissa Pschetz, Dave Murray-Rust, Hadi Mehrpouya, Shaune Oosthuizen, and Chris Speed. 2018. GeoCoin: Supporting ideation and collaborative design with smart contracts. In *Conference on Human Factors in Computing Systems - Proceedings*. DOI:https://doi.org/10.1145/3173574.3173737

[46] Elinor Ostrom. 1999. Design Principles and Threats to Sustainable Organizations That Manage Commons. *Work. Polit. Theory Policy Anal. Cent. Study Institutions, Popul. Environ. Chang. Indiana Univ. Bloom.* 812 (1999), 1–16.

[47] Elinor Ostrom. 2015. *Governing the commons*. Cambridge university press.
[48] Robert T Paine. 1966. Food web complexity and species diversity. *Am. Nat.* 100, 910 (1966), 65–75.
[49] Alex Pazaitis, Primavera De Filippi, and Vasilis Kostakis. 2017. Blockchain and value systems in the sharing economy: The illustrative case of Backfeed. *Technol. Forecast. Soc. Change* 125, July 2016 (2017), 105–115. DOI:https://doi.org/10.1016/j.techfore.2017.05.025
[50] Garry D Peterson, Zuzana V Harmá, Megan Meacham, Cibele Queiroz, Amanda Jiménez-aceituno, and Jan J Kuiper. 2018. Welcoming different perspectives in IPBES : " Nature ' s contributions to people " and " Ecosystem services ." 23, 1 (2018).
[51] Provenance. 2015. *Blockchain: the solution for transparency in product supply chains*. Retrieved from https://www.provenance.org/whitepaper
[52] Larissa Pschetz, Kruakae Pothong, and Chris Speed. 2019. Autonomous Distributed Energy Systems: Problematising the Invisible through Design, Drama and Deliberation. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (CHI '19), 1–14. DOI:https://doi.org/10.1145/3290605.3300617
[53] Maria Puig de la Bellacasa. 2011. Matters of care in technoscience: Assembling neglected things. *Soc. Stud. Sci.* 41, 1 (2011), 85–106. DOI:https://doi.org/10.1177/0306312710380301
[54] Maria Puig de la Bellacasa. 2015. Making time for soil: Technoscientific futurity and the pace of care. *Soc. Stud. Sci.* 45, 5 (2015), 691–716. DOI:https://doi.org/10.1177/0306312715599851
[55] Maria Puig de la Bellacasa. 2017. *Matters of Care: Speculative Ethics in More Than Human Worlds*. University of Minnesota Press, Minneapolis.
[56] Jonathan Rankin, Chris Elsden, Ian Sibbald, Alan Stevenson, John Vines, and Chris Speed. 2020. PizzaBlock: Designing artefacts and roleplay to understand decentralised identity management systems. In *DIS 2020 - Proceedings of the 2020 ACM Designing Interactive Systems Conference*, 1593–1606. DOI:https://doi.org/10.1145/3357236.3395568
[57] David Rozas, Antonio Tenorio-Fornés, Silvia D\'\iaz-Molina, and Samer Hassan. 2018. When ostrom meets blockchain: Exploring the potentials of blockchain for commons governance. *Available SSRN 3272329* (2018).
[58] Paul Seidler, Paul Kolling, and Max Hampshire. 2017. terra 0 – Can an Augmented Forest Own and Utilize Itself? In *Artists Re:thinking the Blockchain*, Ruth Catlow, Marc Garrett, Nathan Jones and Sam Skinner (eds.).
[59] Anna Seravalli. 2018. Infrastructuring urban commons over time. In *PDC '18*, 1–11. DOI:https://doi.org/10.1145/3210586.3210593
[60] Nancy Smith, Shaowen Bardzell, and Jeffrey Bardzell. 2017. Designing for Cohabitation: Naturecultures, Hybrids, and Decentering the Human in Design. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (CHI '17), 1714–1725. DOI:https://doi.org/10.1145/3025453.3025948
[61] Chris Speed. 2018. New Economic Imaginaries. Retrieved September 17, 2020 from https://chrisspeed.net/?p=2025
[62] Maurizio Teli, Peter Lyle, and Mariacristina Sciannamblo. 2018. Institutioning the Common: The Case of Commonfare. In *Proceedings of the 15th Participatory Design Conference: Full Papers - Volume 1* (PDC '18). DOI:https://doi.org/10.1145/3210586.3210590
[63] Anna Lowenhaupt Tsing. 2015. *The Mushroom at the End of the World*. Princeton University Press.
[64] José Luis Vivero-Pol. 2017. Food as commons or commodity? Exploring the links between normative valuations and agency in food transition. *Sustainability* 9, 3 (2017), 442.
[65] Jose Luis Vivero-Pol, Tomaso Ferrando, Olivier De Schutter, and Ugo Mattei. 2018. *Routledge handbook of food as a commons*. Routledge.
[66] Ron Wakkary. 2020. *Things We Could Design For More Than Human-Centered Worlds*. MIT Press.
[67] Xiaowei Wang. 2020. *Blockchain Chicken Farm: And Other Stories of Tech in China's Countryside*. FSG Originals x Logic.
[68] John Wood. 2018. Relational Money. 1–7.
[69] WWF. 2020. *Living Planet Report 2020 - Bending the curve of biodiversity loss*. Retrieved from https://f.hubspotusercontent20.net/hubfs/4783129/LPR/PDFs/ENGLISH-FULL.pdf
[70] Regen Network. Retrieved December 20, 2020 from https://www.regen.network/
[71] Nori. Retrieved December 20, 2020 from https://nori.com/
[72] DAOWO blockchain laboratory and debate series for reinventing the arts. Retrieved December 28, 2020 from https://www.furtherfield.org/daowo-blockchain-laboratory-and-debate-series-for-reinventing-the-arts/