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Farming Within Limits

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> *Here's the tragedy of agriculture in our time.... The politicians, the agricultural bureaucracies, the colleges of agriculture, and the agri-business corporations went all out to industrialize agriculture and to get first the people and then the animals off the land and into the factories. This was a mistake, involving colossal offenses against both land and people. The costs have not been fully reckoned, let alone fully paid.* —Wendell Berry [1]

Many still associate farming with bucolic landscapes of attentively tended plants and roaming animals. But modern farms have become carefully designed, high-tech industrial operations, and the consequences are dire. Some consider the adoption of agriculture about 11,000 years ago the soft start of the Anthropocene: the beginning of ecosystem domination and the first step toward planetary domination [2]. Now humans produce food on two-fifths of all ice-free land on earth. Catalyzed by industrialization, agriculture has replaced wildly diverse ecological communities with standardized crops and livestock the world over, contributing to staggering rates of biodiversity loss. Farming introduces more nitrogen and phosphorous into ecosystems than scientists' best guess at critical thresholds of planetary sustainability and directly releases about 15 percent of humanity's carbon emissions [3]. While not all people practice agriculture in destructive ways, agricultural systems use more resources than the environment can supply and generate more waste than ecosystems can integrate. Global agricultural production is alarmingly unsustainable.

Critically Situating Agriculture as Technology and Technology in Agriculture

Farming is technology. Manipulating living beings, their genetics, and entire ecosystems to produce food has always been a technological feat. Tools made humans more effective at it. Machines even more so. From the domestication of the first grains to terraced rice paddies, the Haber-Bosch process, Holsteins that produce 72,000 pounds of milk per year, and drones for precision vegetation monitoring, as farming technology has become more powerful, its scale has grown too—*by design*. With the ability to produce more food more reliably, human populations have grown, requiring even more food. Substituting human agricultural labor with technology has permitted people to produce ever-greater quantities of other goods. While many technological advances decrease environmental damage per unit of food produced, whether new technologies make individual farms more or less resource efficient matters little compared to the macro-scale economic growth that increasing agricultural productivity enables. That using resources more efficiently leads to more resource use overall, not less, is a pervasive phenomenon often called the Jevons paradox [4]. Advancements in farming technology have made it possible to surpass planetary boundaries [3], and information and communications technologies (ICT) have intensified human control over agroecosystems [5].

Agricultural technology has not evolved spontaneously to spark growth and the consequent environmental catastrophe. People in power force society to adopt technologies that facilitate and perpetuate their domination. Technological change in agriculture generates tension between those who benefit and those who bear the costs. Automation is an apt example. The mechanization of farming during the Industrial Revolution benefited property owners, pushed peasants off the land,

and made food cheap, which kept wages low. When threshing machines were introduced in 1830s England, agricultural workers rioted, destroying hundreds of the machines that had replaced them. This contentious history has continued with the rise of global institutions such as the World Intellectual Property Organization (WIPO), which gave agri-business exclusive ownership over technologies, forcing farmers out [5]. Since the 1960s, high-yielding seed varieties have displaced traditional ways of farming, especially where colonial injustices are strongest. Companies sell farmers patented hybrid seeds that require a conventional farming technology package of chemical fertilizer, pesticides, and substantially more water than traditional seeds—as well as an annual repurchase of seeds. Today a few global actors control food production [6]. The megacorporations that sell farmers' inputs and buy their outputs squeeze them at both ends. This precarious context constrains farmers' choices about how to farm and what technologies to use.

From monitoring soils to enabling the entrenchment of corporate power, agricultural technology is not neutral. On a global scale, technologies feed data into increasingly pervasive information systems, distancing the knowledge being gathered from the people, land, and context from which it is gathered. On the land, technology mediates between humans and their environment, and can distance people from culturally important agricultural practices. Of course, humanity is not an undifferentiated mass, and neither is technology. While some farmers appreciate interacting with some technology, technology can also supplant human experience on the land, a shift from tactile feel and experiential expertise to machine-mediated farming dictated by algorithms [1]. This distancing might undermine a deeper caring for the land, as high-tech systems replace people and traditional local knowledge.

What Is the Role of Agricultural Technology in Answering Socio-Environmental Challenges?

Farming is for feeding people. Agriculturalists have leveraged increasingly sophisticated machines and computers mainly to boost production, yet in ways that have arguably inhibited progress toward sustainable food security for all [6,7]. World cereal production has tripled and the global livestock population has quadrupled since the 1960s, but today more than 800 million humans suffer from chronic food deprivation. At least a billion more experience hunger in ways that official statistics do not capture, for instance through seasonal food shortages or micronutrient deficiencies. Agriculture produces more than enough to feed the world's human population, but the global economy allocates food inequitably among people and redirects food to industrial feedlots, biofuel refineries, and the waste stream. All parts of the food system need to be considered, with many important opportunities for HCI design and research to help further sustainability efforts [6]. Technology does matter, but technical solutions alone cannot fix the underlying socioeconomic systems that produce unjust and unsustainable food systems.

This leaves us with urgent considerations: *What* is needed to truly address these socio-environmental challenges in agriculture? *Who* is present and who is absent when envisioning sustainable agriculture and considering the role of technology in creating it? *How* can we increase the diversity of perspectives and values while supporting agricultural sustainability?

Assessing Agricultural Technology for Sustainability and Equity

The same systems of domination create both unsustainability and injustice. Addressing them separately is not enough. And as Norton et al. eloquently noted, even those technologies designed to support sustainability often perpetuate unsustainability and injustice [6]. Given the powerful role that technology plays, the recent focus on design justice, sustainable interaction design (defined as "an act of choosing among or informing choices of future ways of being" [8]) and sustainable human-computer interaction (SHCI) is encouraging. The HCI community has set research agendas for sustainable food systems [6] and created comprehensive criteria to evaluate technology in terms of promoting quality and equality [8]. We offer contributions to this discourse—starting with three questions for technology assessment within agricultural production.

Does agricultural technology enable:

- *Effective conservation of resources? Or further exploitative resource use*? When technologies maximize efficiency in an economy designed to grow, they risk enabling unsustainable and inequitable practices. Global agriculture relies heavily on off-farm inputs for nutrient and pest management. Precision agriculture combines ground-based monitoring and satellite or aircraft observations to apply fertilizer, pesticides, and water at the right time and in the right quantity to maximize crop yields. While important, these precision technologies maintain reliance on those inputs, and the singular focus on maximizing efficiency can crowd out other solutions. In addition to applying external resources in ever more precise ways, technologies should support closed-loop integration of agricultural production within its environment. Examples include farming practices often associated with agroecology, permaculture, or other biodiversity-based strategies that replace off-farm inputs with on-farm products or with human knowledge and labor. These technologies tend to promote smaller-scale "eyes to acres" production [1].

- *Increasing access, participation, and democratization in information generation and technology use? Or deepening inequities in resource access, control, and decision making?* When technologies concentrate power and resources in the hands of those who already have technological skills and access, they risk enabling inequitable and unsustainable practices. The development of data-oriented technologies within the agricultural sector takes place within socio-ecological-technological systems that are already defined by deep inequities in resource access, control, and decision making. Emerging agricultural information systems may therefore be as likely to exacerbate oppression and inequality as they are to increase access and participation. In recognition of these patterns, the Design Justice Network has offered 10 design principles (http://designjusticenetwork.org/network-principles) that we propose can inform the design of agricultural technology, including accountable processes, community-controlled outcomes, and non-exploitative solutions.

- *Action-oriented agricultural practices? Or agri-surveillance?* When technologies are envisioned and developed that only monitor a problem instead of help to solve the problem, they risk enabling unsustainable and inequitable practices. Bringing agricultural processes into monitoring, reporting, and verification regimes, often used to measure environmental impacts, can result in technology primarily designed for gathering data for agri-surveillance instead of enabling action. However, information and technology sharing enables communities such as Farm Hack (https://farmhack.org/tools) to develop and share tools in support of addressing agricultural challenges. Offering alternate open-source paradigms from within the field of ICT can undermine the centralization of power and enable more direct development and application of technologies by those who use them.

Beyond Assessment: Changing the System

> *If you are feeding people by destroying the land, and the rural communities, and polluting the water systems—and if you consider that damage to be a sustainable cost—you're crazy. This turns us toward the need for a better general criticism than we have of the economy and the culture.... To have good farming or good land use of any kind, you have got to have limits. Capitalism doesn't acknowledge limits. That is why we have supposedly limitless economic growth in a finite world.* —Wendell Berry [1]

Economic systems that operate on ideals of limitless growth will always be fundamentally at odds with sustainability. Technology helps the economy grow and further dominate. Even when precision agriculture does improve yields and reduce inputs, this frees up land and resources to produce more overall. Efficiency begets growth. The Jevons paradox is ubiquitous. Agricultural technologies must therefore be assessed based on their sustainability and equity impacts at all levels, starting with their relationship to the logic of growth and domination that got us here—from subverting to reinforcing these systems.

Recent work by the computing within limits (LIMITS) and SHCI communities recognizes that broader, co-evolving social and technical systems need to fundamentally change. LIMITS researchers have called for a "transformative shift in computing research and practice," informed by ecological economics (EE) and degrowth, guided by three principles: 1) questioning growth, 2) considering models of scarcity, and 3) reducing energy and material consumption [9]. SHCI researchers have offered an agenda for food systems and sustainability that emphasizes trust and accountability, food sovereignty, and sustainable food policies [6]. Together the LIMITS, SHCI, EE, and degrowth communities comprise a rich body of research and action; the cross-pollination of ideas between them should be strengthened. In particular "a comprehensive analysis of how agriculture and the food system should change to meet the call for degrowth has not yet been produced" [7] and food-system sustainability has been situated as a grand challenge for HCI [6]. There is much need for continued applied work at this intersection.

Technologies that make agricultural systems ostensibly more sustainable and equitable might entrench rather than transform the underlying unsustainable, inequitable paradigm. We advocate for interrogating the socioeconomic systems that underpin agricultural technology and highlight the need for cross-cutting and transdisciplinary collaboration. Drawing from design and system transitions movements, it is possible to chart a course for the role of technology in sustainable agriculture to begin to answer: How can technology serve system change? And how can farming transform the unjust systems it literally feeds?

Farming within LIMITS should:

- *Be critical.* Interrogate the power structures behind institutions, knowledge systems, technologies, and ideas. Ask critical questions of the role and responsibilities of agricultural technology, and of the underpinning narratives within which these technologies are designed: sustainability and development of, for, by, and according to whom? Question why and how agricultural technologies have eroded vibrant, diverse food systems in service of global markets, displaced traditional knowledge and skills, and denied people agency. Cultivate a deeper critique of technology as unable to fully address systemic unsustainability and inequities. Practice reflexive self-criticism; the changes we propose in this article are still ultimately elite, academic ideas about how to improve the world.

- *Redefine success.* Change expectations regarding agricultural production. Forget maximizing any single variable. Center human nourishment and ecological flourishing. Listen to those who grow food. Consider any action's effects on loosely comparable, often conflicting values such as food production, biodiversity, cultural diversity, social equity, landscape aesthetics, and dignified livelihoods. Let people decide on goals and make decisions collectively.

- *Embrace inefficiency.* Recognize that the more efficiently humans have turned nature into food, the more nature our species has consumed and transformed overall. Question increasing labor productivity in particular, since dedicating more of society's labor to food production could facilitate a transition to degrowth. Focus on farming practices and technologies that support healthy agroecosystems. Make farm work dignified. Acknowledge that repetitive, strenuous, and dangerous agricultural labor has been—and continues to be—forced on enslaved and marginalized peoples around the world. At the same time, celebrate freely chosen connections to land. Empower people to do what they find meaningful.

- *Change the system.* Promote agricultural technologies and practices that subvert or shift the current socioeconomic paradigm. Work together with people sustaining or creating alternative systems. Rebel against technology that denies people agency and displaces sustainable and culturally important practices, knowledge, relationships, and skills. Support ongoing efforts to increase transparency and participation in the design, development, manufacturing, use, and governance of technology by farming communities.

- *Think together.* Bring agricultural, design, degrowth, and computing communities together to address the interactions of agriculture and technology. Assess agricultural technology through and alongside the weighty critique of Western colonial capitalist anthropocentric growth-minded values and objectives. Collaborate for agricultural—and planetary—sustainability.

Given the fundamental need to produce food to feed humanity, it is difficult to imagine a more challenging or important stage on which to envision and enact the principles of degrowth and computing within limits than in the soils and pastures, barnyards and orchards of nearly half of all land on earth. Agricultural technology needs to be designed and held accountable in support of sustainability, justice, and the needed transformations in these deep-rooted and life-sustaining systems.

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Insights

- Agricultural production is globally unsustainable, and agricultural technology co-evolves with agricultural growth.
- Assessing agricultural technology for contributing to (un)sustainable and (in)equitable practices needs to be done together *(and better).*
- There is an urgent need to change underlying socioeconomic systems that propagate unsustainability and inequity, requiring reflection, design, collaboration, and action.