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Communication

Hello Technology, Hello Innovation! Do You Have a Mind?

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Abstract

Technology and innovation are two favorite words for the development sector, and recently, they have entered the realms of food systems sustainability discourses and transitions. However, our past experience demonstrates that technology and innovations are not neutral in social-ecological systems, and the negative impacts tend to outweigh social welfare. Employing various examples including recently fledged genome-edited rice, I show their ill effects on food systems and discuss the conflicts in light of recent technological triumphs and policy changes.

Keywords: genome-edited rice; HT rice; community seed bank; natural farming; sustainable food system

Introduction

Tools and technology have been closely entwined with agriculture and co-evolved with its expansion, diversification, specialization, and intensification. In this century, a seminal change in the usage of tools and technology in agriculture has happened, ranging from farm machinery to factory-produced fertilizers and lab-derived seeds, which are not autochthonous to a farm but rather mostly outsourced from elsewhere. The rapid progress of scientific knowledge, its application, and dissemination with the Industrial Revolution, social mobilization in the background, and regulatory and geopolitical inertia kindled its integration and evolution (Stone 2022).

In the last hundred years, technological innovations have metamorphosed the agrifood sector, beginning from the early Green Revolution to recent developments in genetically modified crops. The Green Revolution has mitigated the food crisis, eradicated impending hunger, and led to economic growth (Johnson et al. 2024). On the other hand, it brought in several concomitant changes in public health, the ‘triple burden’ of malnutrition, or the co-existence of hunger and micronutrient deficiency. Furthermore, ecological costs are also on the rise, including groundwater depletion, nutrient imbalance in ecosystems, soil and water degradation, and finally their severe cumulative impact on human health and social welfare (Shah et al, 2021). So, the broader long-term impacts of technological innovations are not all good but a mixed bag of positive and negative outcomes. In popular development-inclined discourse, the brighter positive side tends to downplay the darker shades; whether the positive outperforms the negative is a matter of continued conjecture, and it also depends on scale, geography, culture, the temporal span of observation, and through which lens you are examining the problem.

Recently, there has been a lot of furor over the technological innovations in agri-food sectors, which are often touted as game-changers and could enable intensified production, alleviate hunger and poverty, promote healthy diets (Barrett et al. 2020; Herrero et al 2020). Drawing on a suite of examples of biotechnology and industrial production of farm inputs, I argue whether innovations drive positive change toward ecological, social, and economic sustainability.

Technological Innovations for Sustainable Agrifood Systems: The Putative Origin of the Problem

The growing global population, its calorific and nutritional needs, often occupy the center stage of hunger and food insecurity discourses. So are the themes of policy landscapes that hinge on various techno-fixes, ignoring the uncertain socio-ecological sides. They are variously named as nature-based solutions, smart-farming, sustainable, people-centric, pro-environmental, etc, to imply a positive orientation to ecology and the environment and present a win-win situation (Bennett et al 2013; Ronald 2011). The strategy culminates in the narrative of intensified production from limited resources, which could only save the burgeoning global population from the fangs of impending hunger (Fróna et al. 2019). Technological innovations are at the forefront to pioneer change and act as the savior to rescue from this crisis, e.g., high-yielding seeds, herbicide-tolerant crop varieties, seeds with other value-added traits like biofortified grains or higher yields, pest-resistance, etc, Bt seeds, or other transgenic seeds (Qaim 2009; Raymond et al 2011). Although the increasing global population is a serious concern that may underlie intensified production, hunger, and malnutrition are multi-dimensional problems, and production deficit does not linearly relate to the cause (Collins et al. 1986; Glover & Poole, 2019).

Many of the technological innovations are not socially, ecologically, or economically neutral, but rather double-edged swords; sometimes the flipside outweighs the benefits. Although developed in a scientific milieu to co-create knowledge and its wider application, technology is neutral as long as it stays in the scientific pursuit of knowledge production, implementation and is delimited within pedagogy. Beyond this, they operate in socio-economic, ecological, and cultural spheres where various actors in differential power hierarchies influence their dissemination and adoption, and the transformative power of a technology depends on the socio-economic and political conditions as well as on the needs of the society (Hall & Dijkman, 2019). The actors also determine and control their usage. The cost-benefits ushered from technology are multi-faceted and are not always for the greater social good.

The Flip Side of Techno-Innovation

The technological innovations span the entire food system, from food production and processing to consumption and beyond. It has been emphasized that the diverse innovations in global agri-food systems are indispensable in meeting sustainable food system challenges (Herrero et al. 2020; Barrett et al 2020). The narratives around technological innovations mostly employ a narrow view of intensified production and economic development (Qaim 2009, Bennett et al. 2020; Herring and Paarlberg 2016), either undermining or entirely overruling impending socio-ecological or economic costs and hence their sustainability concerns. The underlying assumption is fairly straightforward: newer technologies, lower cost, more production, fewer hungry and malnourished people.

So, a few key questions pop out: their scale-neutrality, their greater role in general social welfare than serving only smaller segments (Azadi et al, 2015; Agrawal, 2024), the question of economic or ecological sustainability in the long run, and minimizing collateral damage to the environment or societal fabric? For example, technological triumphs like biotechnology-driven development of improved seeds for better abiotic stress or pest resistance, genetically modified organisms or GM seeds, or manipulated seeds for value-added traits (e.g., nutrient-delivering biofortified seeds) are often promoted and applied for their specific objectives. These technology-derived seeds are frequently useful in a limited sense of their specified objectives, despite being repeatedly endorsed for the greater public good (Van Der Straeten et al, 2017). Going half a century back, the semi-dwarf high-yielding rice and wheat varieties, the precursors of modern-day biotech seeds, were instrumental in raising the productivity of the two staples but with vast amounts of nitrogenous fertilizers and excess groundwater. Its successors, the miracle rice (IR8) or other IR varieties (IR36, IR64), were a seminal triumph of agricultural plant breeding, reached a new height in yield, and drew much public attention (Mackill and Khush 2018). Despite their role in selective economic growth

(Boyce 1987), they caused serious, long-lasting, irreversible socio-ecological harm (Alauddin M, Tisdell 1991; Ray 2022; Shah et al. 2020). On the other hand, the dissemination and adoption of HYV seeds were instrumental in the dwindling of agricultural biodiversity (Ray 2022) and the creation of technological lock-in with far-reaching implications. The biotechnology-derived new improved seeds, either public-funded or private-funded, made enough room in the agricultural sector, were widely embraced, and pushed traditional varieties to the brink of extinction (Ray 2023). Although their role in food security or nutritional security is undeniable, improved and biotech seeds are the impediments to agrobiodiverse farming, seed and food sovereignty, and self-reliance (Clapp 2021). Similarly, biofortified cereals, one specialized group, aimed to alleviate micronutrient malnutrition or hidden hunger detrimental to agrobiodiversity and cause alienation of traditional seed networks still existing in the country (Ray 2021). Short-sighted intervention may not yield to meet the complex nutritional challenge of hidden hunger (Prasad 2024), let alone culturally appropriate food (Huey et al 2024).

On the other hand, easy access and availability to technological innovation can lead to behavioral changes in consumption, often a spurt in usage (FAOSTAT Statistical Database. 2024). The examples include the rapid rise of the rampant application of weedkillers or herbicides. Glyphosate, promoted as a safer alternative to its predecessors, dicamba, atrazine, or neonicotinoids, the forerunners in this group, has undergone a rapid rise in sale and continues to cause ecological devastation and public health crises (Maggi et al. 2020). So, when 'environment-friendly' herbicide-tolerant technology (HT rice or cotton or maize) is promoted in the name of carbon sequestration, improved soils and weed control, and labor-saving, and legitimizes the ill-effects of herbicides, it appears to be an anthropogenic crisis (Bonny 2016). It continues to plague various agroecological systems of the country (Kaundinya 2023). Recent surge in digital agriculture armed with AI, IT-enabled services, and 'smart-technologies', it is becoming a norm; new inventions and newer technologies keep emerging and getting absorbed. Digital agriculture, climate-smart agriculture, and precision farming have become buzzwords, gathering pace in different forms, and leading to large-scale agrarian change, often disguised in the name of equity, social justice, and sustainability (Agrawal 2024). For example, using drones as technology becomes cheaper and widespread, while reducing labor costs simultaneously endangers natural resource bases, and compromises public health and biodiversity (Kuruganthi 2025). Moreover, drones are capital intensive investments which are not affordable to Indian smallholders. The exercises of digital agriculture, highly lucrative they seem, highlight transformation of the Indian agrarian landscape towards uncertain technological lock-in and away from sovereignty disempowering the key-decision makers, the farmers.

Technological Logjams or Conflict of Interest?

Lastly, I would situate the debate amidst a couple of recent developments which seem like technological logjams. One is the official release of two genome-edited rice varieties, DRR Dhan 100 (Kamala) and Pusa DST Rice 1, developed by ICAR on 5th of May 2025 (Shagun 2025). They claim to offer solutions to climate change challenges and boost rice yields by up to 30 per cent. While they may all look clean and clear superficially, genome-edited varieties are a threat to the rice genetic diversity already embedded in the agroecosystems of India. A major fraction of the diversity has disappeared, thanks to the Green Revolution (Ray 2022). The other concerns relate to its biosafety measures, whether that is properly followed or not. Similar developments are taking place in the agrifood landscape of the country. For example, the clearance of two herbicide-tolerant basmati rice, or HT basmati has shortly been approved for commercial cultivation (Huq 2024). Here is the problem! Basmati is a cash crop that not only fetches a high price in the national market but also acts as a source of revenue through global trade. It is already a source of trouble in northwestern India, the epicenter of basmati cultivation to the heavy use of groundwater, pesticides, and fertilizers. By introducing herbicide-tolerant cultivars, doesn't it invite more troubles of enhanced application of herbicides in the agroecological systems, let alone further erode agricultural biodiversity? Rampant application of the famous weedkiller to eradicate weeds, or to clean courtyards, gardens, and fallow

land, are also used to ease harvest of several key crops as these are labor-saving, but they are larger problems in disguise, whatever convenience they may offer, be it labor-saving, one-shot, cost-effective, etc. They do greater harm to agroecosystems and human health than can be perceived (Maggi et al. 2020). Short-sighted, top-down approaches undermining social, ecological, and economic sustainability can not bring long-term solutions rather foster injustice and inequality (Fairbairn et al, 2025).

Yet another crucial step is setting up the second National Genbank for the preservation of crop genetic diversity, as announced by the finance minister. While this might look like a welcome addition when the Natural Farming [<https://nfcoalition.in/>] endeavor is gradually proliferating its roots in South Asia and capitalizes on our country's traditional or indigenous seed biodiversity (Saini et al. 2024). Indigenous or traditional seeds are often promoted as a resilient, cost-saving, and ecologically viable option (Varshney and Chauhan 2025). The prime minister announced full-scale economic support to haul this venture. On the other hand, the same Government is vouching for genetically modified seeds. Furthermore, improved seeds, high-yielding, biotech-derived seeds, the spawns of the Green Revolution and plant biotechnology, have already amassed in the seed sector and Indian agriculture. Do they not come into direct conflict (of interest) with the spirit and ethos of natural farming or sustainable agriculture in general and community seed banks or traditional seed savers in specific? Or do we adhere to the alternative innovation pathways for addressing sustainability challenges (Arora et al. 2024)?

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