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Digital technologies and food security during crisis: COVID-19 experiences from smallholder farmers in Odisha, India

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This research explores the significance of digital agricultural technology concerning food security for smallholder farmers and their communities in Odisha, India, amidst the COVID-19 pandemic. The study is a collaborative effort between academic researchers based in Canada, 15 small-scale farmers from Odisha, and the India-based social enterprise, eKutir. The farmers' experiences utilizing eKutir's technology are examined to understand how it aids them in meeting their food security requirements, sustaining their livelihoods and participating in local food systems before and during the pandemic. eKutir shares transactional data that illustrate how their platform facilitates food movement through local food systems during the pandemic while exploring its potential to enhance food security and food system resilience further. The primary goal of this research is to strengthen the adaptive capacity of smallholder farmers and the food systems dependent on them, particularly during non-conflict crises like the COVID pandemic, that affect economic, physical, and social aspects of life. This research is also intended to contribute to the continued development of digital technology in a way that supports smallholder farmer interests. Our findings reveal that access to eKutir's platform enabled farmers to remain connected to essential markets, continue earning income, and support local food systems during the COVID pandemic. While potential negative consequences associated with data-focused agricultural technologies can accrue, when technology design is guided by and tailored to the needs of resource-constrained farmers, it can substantially contribute to their resilience in the face of contemporary challenges and risks.

KEYWORDS

food security, digital agriculture, small-scale farming, eKutir, Odisha, COVID-19

1 Introduction

In recent decades, the widespread and rapid adoption of digital technologies in agriculture, often called the 'digital revolution,' has sparked optimism and concerns regarding their potential impacts on farmers, socially and environmentally sustainable farming, and food and nutrition security. 'Digital agriculture' encompasses various activities, including automated farming, remote sensing equipment, and e-finance for agricultural products (Mooney and ETC Group, 2018). These digital technologies are hailed as potential solutions to global hunger and malnutrition, promising increased food production with fewer resources (Newell and Taylor, 2017; Robert Townsend et al., 2019; Basso and Antle, 2020; Prause et al., 2021; World Bank,

2021). Moreover, they are viewed as tools to enhance food safety through traceability functions (Robert Townsend et al., 2019; World Bank, 2021) and a means to develop agribusiness, thereby improving farmer livelihoods and contributing to broad-based development (Fabregas et al., 2019; Pingali et al. 2020).

However, alongside these claims, there are concerns about digital agriculture's significant drawbacks, particularly related to data ownership, inaccessibility or inequity, lock-in features, and more (Rotz et al., 2019; Carolan, 2020; Prause et al., 2021). Digitization is typically promoted in the name of efficiency and productivity. While the efficient use of resources can contribute to more sustainable agricultural production, the market logic of efficiency and productivity have also long underpinned the dispossession of people from the land they use, inhabit, or own, mainly small-scale producers, racialized, and Indigenous peoples (Bhandar, 2018). The commodification of farm data and 'data grabbing', through which farmers are dispossessed "of the value of the data they produce" can also support land grabbing efforts (Fraser 2019, p. 906). When considering the merits of digital agriculture or specific technologies, we must consider how they relate to these issues.

Since the onset of the COVID-19 pandemic, it is estimated that an additional 150 million people are experiencing hunger, resulting in a total of 702 to 828 million people experiencing hunger in 2021 (Food and Agriculture Organization of the United Nations et al., 2022, p. 5). Moreover, it is projected that by 2030, about 670 million people will still face hunger, indicating that existing policies and practices are insufficient in addressing the challenges faced by small-scale food producers (Food and Agriculture Organization of the United Nations et al., 2021, 2022). Given these circumstances, digital technologies have garnered significant attention as they offer promising solutions and are increasingly deemed crucial for 'recovery' plans (Kumar et al., 2020; Bahn et al., 2021; Food and Agriculture Organization of the United Nations, 2021). The linkages between the global hunger crisis and digital technologies make them particularly appealing to many, as they hold the potential to address the pre-existing and emerging challenges faced by food producers.

Digital platforms can offer users valuable insights regarding growing and market conditions specific to their geography, climate, environment, and economic situation. These platforms can also guide sustainable food production while taking into account individual farm risk factors and market conditions. The pandemic has intensified the uncertainty in food production, emphasizing the pre-existing vulnerabilities in our food systems and the likelihood of future crises. Unfortunately, only a limited number of digital platforms currently cater to the needs of smallholder farmers worldwide. eKutir created one such digital platform in India (known as Bloom at the time this research was conducted), which has supported farmers within local and regional supply chains in Odisha and neighboring states during the COVID-19 pandemic.

This study focuses on understanding the contribution of digital technology, particularly eKutir, in addressing food security during crises. The primary objective of this research is to study and analyze the roles of eKutir in enabling farmers to cope with the impacts and challenges brought about by the COVID pandemic crisis. Additionally, the study examines whether eKutir's digital services have enhanced household and community food security. Specifically, the research seeks to understand how adopting eKutir's digital technology impacts

farmer livelihoods, household food security, and local and regional food systems before and during the COVID-19 pandemic. By exploring these aspects, the study aims to shed light on the effectiveness of digital platforms like eKutir in supporting farmers during times of crisis and promoting overall food security.

2 A brief description of eKutir

In India, the for-profit social enterprise, eKutir (refer to Figure 1), operates as a digital-human platform that tackles critical challenges small-scale farmers face, resulting in a two-fold impact: Through its network of micro-entrepreneurs, eKutir provides free access to essential information for farmers, which supports their livelihood generation and, ultimately enables them to address local and regional food demands. Right from its inception, eKutir has centered its development around the needs of low-resource farmers. The social enterprise actively sought feedback from small-scale and low-resource farming communities, which it now serves, to shape the pre- and post-harvest technology. With its primary focus on empowering low-resource farmers, eKutir aims to create job opportunities and strengthen livelihoods. Additionally, it endeavors to maximize the benefits for farmers while mitigating the risks typically associated with larger data-driven platforms and agricultural digitization.

eKutir has a clear and explicit goal of promoting democratization in agriculture by providing access to digital technology and markets for farmers operating with low resources. The platform provides farmers with access to essential information and tools typically enjoyed by more extensive and competitive operations. By connecting farmers to buyers and input distributors and facilitating interactions among small-scale farmers, eKutir establishes a strong network within the region. Through the post-harvest functions, farmers can list their yields on the platform, and these harvests are aggregated with those of other farmers. Buyers are given a short window of 30 min to make purchasing decisions. This feature empowers farmers in their transactions, as it counters the typical scenario in other marketplaces where buyers may shop around and drive down farmgate prices. In such situations, farmers often find themselves in a 'buyer's market,' leading to unequal power dynamics where sellers may undervalue their goods while waiting for buyers' decisions. To address the challenges faced by small-scale farmers with low bargaining power and limited economies of scale, eKutir's aggregation model effectively reduces transaction costs when accessing urban food supply chains. By facilitating transactional functions, the platform aids in distributing food within Odisha and to neighboring states, contributing to the region's food security. Overall, eKutir's approach of democratizing access to technology and markets for low-resource farmers is vital in equipping them and fostering food security in the state and its surrounding regions (eKutir, 2020). Figure 2 provides an overview of eKutir's integrated digital platform.

3 Methods

This paper presents the outcomes of a collaborative research effort involving small-scale farmers from Odisha, the India-based social enterprise eKutir, and scholars from Canada. We document the firsthand experiences of farmers utilizing a pre- and

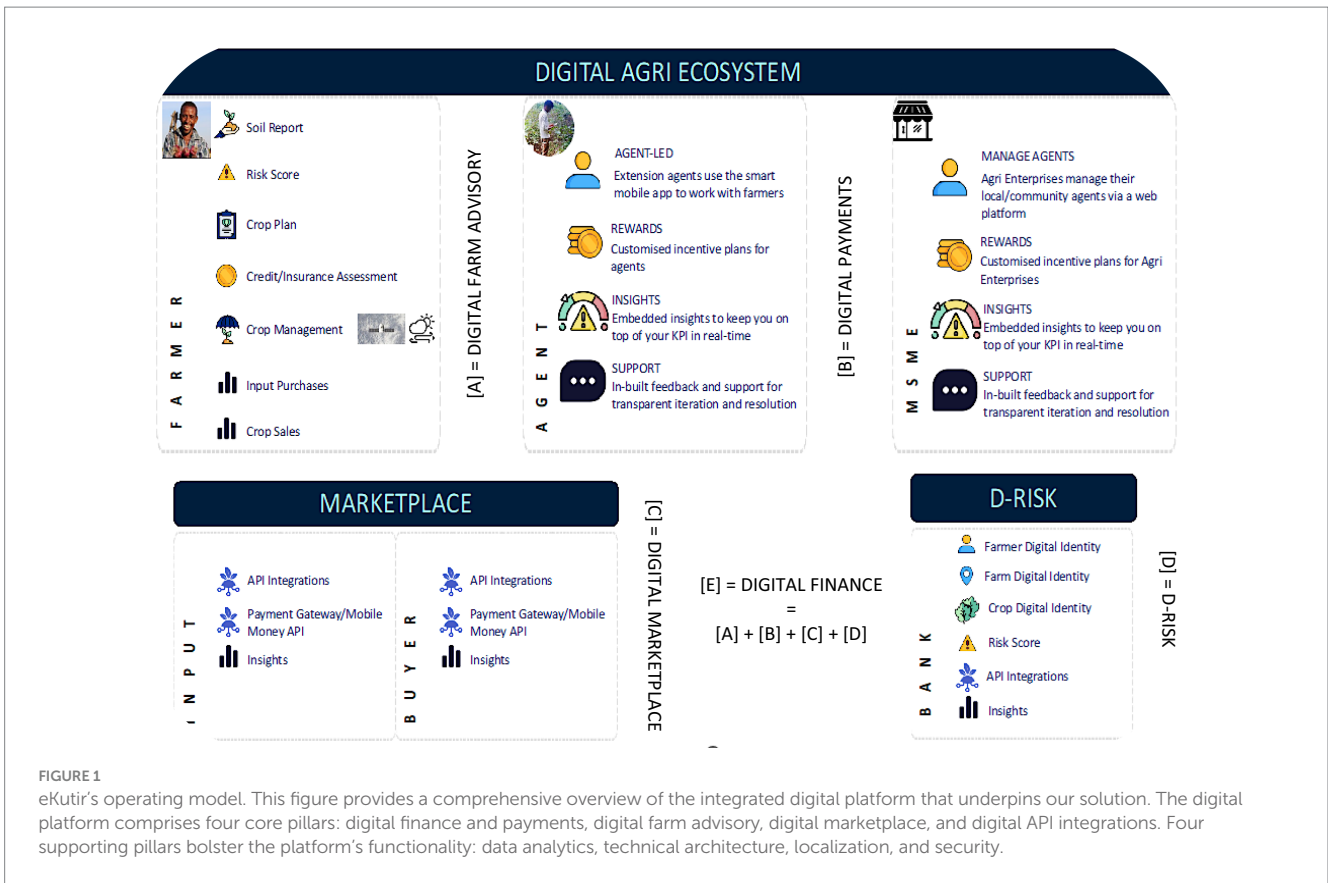


FIGURE 1 eKutir’s operating model. This figure provides a comprehensive overview of the integrated digital platform that underpins our solution. The digital platform comprises four core pillars: digital finance and payments, digital farm advisory, digital marketplace, and digital API integrations. Four supporting pillars bolster the platform’s functionality: data analytics, technical architecture, localization, and security.

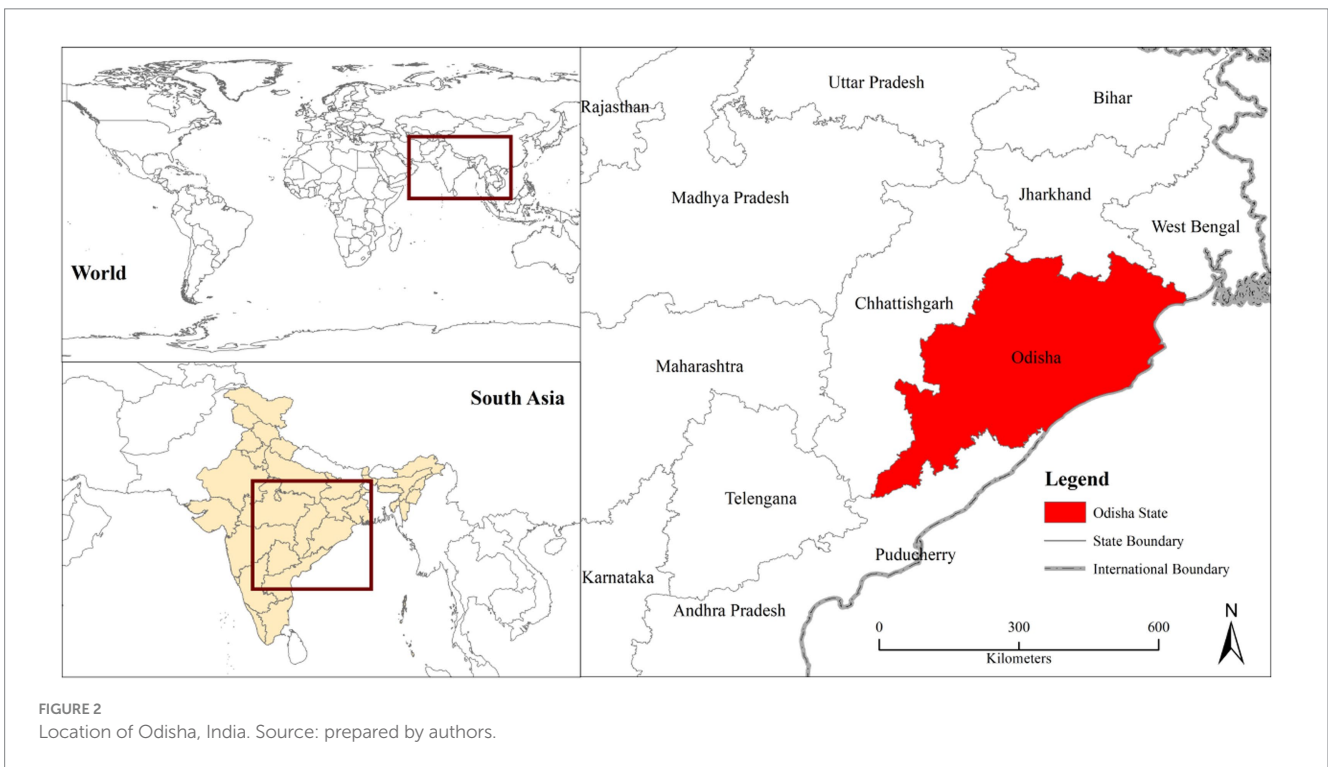


FIGURE 2 Location of Odisha, India. Source: prepared by authors.

post-harvest platform designed to contribute to the democratization of digital agricultural technologies. The data collection phases of this project involved close cooperation between scholars from Canada, eKutir employees, and farmers who have adopted eKutir’s

technology. Participants are located in three distinct regions of Odisha, India.

The research methodology consists of three key components: (i) narrative literature review to gather existing insights and provide

context for small-scale farming in Odisha; (ii) Qualitative data collection through interviews for an in-depth understanding of farmers' experiences, and (iii) Secondary quantitative data analysis for a comprehensive view of eKutir's impact. These approaches provide valuable insights into the democratizing effects of eKutir's technology for small-scale farmers in Odisha.

3.1 Literature review

The research team conducted a narrative literature review by searching scholarly journals, library resources, and Google Scholar to contextualize their research questions within existing knowledge and frameworks. Initially, they compiled a bibliography to support their research questions and seek funding for the study. To frame the overarching issues, the team conducted an extensive review using broad search terms such as “digital agriculture,” “food security in India,” “food security in India COVID-19,” “India food systems COVID-19,” “digital agriculture and nutrition,” “equity and access to digital technology for agriculture,” “digitization and the global South,” and “food systems and health policy.”

Additionally, they searched for localized food security and food systems knowledge, focusing on “Odisha food systems,” “small-scale agriculture and COVID-19 and Odisha,” “smallholder agriculture and COVID-19 and Odisha,” and “eKutir.” This secondary literature search yielded a smaller number of relevant articles, particularly in terms of developments during the pandemic. The team targeted specific journals related to food security and organizational websites such as the Food and Agriculture Organization of the United Nations and the International Food Policy Research Institute. They also referred to Indian governmental resources, including the Indian Agricultural Census, to access timely and pertinent research and data.

3.1.1 Description of small-scale farming in Odisha, India

Small-scale farmers in Odisha, India (Figure 2) hold a central position within the local and regional food systems and play a crucial role in ensuring food security at various levels—household, community, state, and national. However, Odisha remains one of India's most food insecure food-insecure states, with over 35% of the rural population unable to afford two full meals a day (Behera and Chandra Penthoi, 2017, p. 42). As per the National Bank for Agriculture and Rural Development (NABARD), for most producers in Odisha, agriculture serves as their primary source of income, and they often operate with limited resources on small land areas to produce food for both consumption and contribution to local food systems (NABARD, 2018). According to the most recent survey carried out by NABARD, about 87% of farming families work landholdings that are smaller than 2 hectares (the most widely used upper limit to define small farms), 67% less than 1 ha, and 37% less than 0.4 ha (NABARD, 2018). Comparison with previous censuses shows a trend toward farmers losing land and resorting to wage labour or dividing their land between children. Both tendencies have severe implications: They widen an already sizeable income gap between rural and urban populations, with almost 30% of rural Indians living below the national poverty line (NABARD, 2018).

Our research takes place in Odisha not only because the collaborating social enterprise, eKutir, operates in the state but the

socio-economic, agricultural, and food security issues present make it an important site to understand how access to digital agriculture technologies can impact livelihoods and food security (Rahman, 2016; Mohapatra, 2018). Over 82% of the population in Odisha resides in rural areas (Government of India, 2011). The majority of the rural population works in agriculture, either as casual labourers (18%) or self employed (35%) (Government of Odisha 2020, p. 20). These statistics also highlight smallholders' important contribution to food supplies in the country, which might be strengthened through access to digital tools (Altieri et al., 2012; CWFS, 2022). Even before COVID-19, farmers faced multiple risks (including risks related to climate, markets, and soil health), hindering food cultivation, security, and livelihood sustainability. Odisha's location in a sub-tropical coastal region of the country presents particular climatic and weather risks that have historically had significant negative impacts on agricultural production (Government of Odisha 2020, p.21)

While internet coverage is relatively broad in India, including coverage over the majority of cropland, approximately 69% of Indian farming households do not have internet access - infrastructure, cost, and digital literacy limitations function as barriers to accessing basic internet and information communication technologies, including digital technologies for farming (Mehrabi et al., 2021; Rajkhowa and Qaim, 2021). Inequitable access to digital farming technologies, and particularly market data, between small and large farms, women and men farmers, and the Global South and North broadly, reflect the growing 'digital divide' between these groups, with livelihood consequences affecting small-scale, women farmers in the Global South disproportionately (Upadhyaya et al., 2019; Mehrabi et al., 2021; Dickinson and Koo, 2022). For example, women farmers tend to face additional barriers in accessing the internet and agricultural market information when compared to men, and this has been found to contribute to the comparatively lower prices women receive for the same crops sold by men, even in the same place (Dickinson and Koo, 2022).

The COVID-19 pandemic and its cascading effects have significantly impacted small-scale farmers' ability to grow, harvest, and sell their products. Beyond the direct experience with the virus, mobility constraints arising from lockdowns affect food accessibility and availability within food systems. Additionally, the COVID-19 pandemic has overlapped with multiple other crises, compounding the effects on food security (World Food Program, 2022). These consequences have disproportionately affected people with low incomes and limited resources, including numerous small-scale food producers and women, further exacerbating the challenges they experience (World Food Program, 2021).

3.1.2 Impacts of the COVID-19 pandemic on food producers in Odisha

At the time of writing, Odisha reported nearly 39 million COVID-19 cases (Johns Hopkins University & Medicine, 2021). The pandemic's impact extends beyond health status, with governments implementing restrictions disrupting mobility. Interviews revealed that some farmers faced healthcare access challenges, primarily related to treatment delays due to pandemic circumstances.

COVID-19 health policies, such as national lockdowns and state-level restrictions, significantly impacted the agricultural sector. Market closures, limited transportation, and scarcity of inputs increased their

costs and availability, leading to disruptions throughout the supply chains (Ceballos et al., 2020; Chowdhury 2020). Farmers in Odisha, who rely heavily on manual labour due to limited access to machinery, faced challenges in hiring seasonal workers, and agricultural equipment deliveries were delayed due to compulsory border checks. Returning seasonal and migrant laborers to their homes in different states resulted in a loss of essential income for farmers and labourers (Gunia 2020; Ceballos et al., 2020). This situation further exacerbated difficulties in making a living from small-scale farming during the pandemic, and farmers noted increased food waste, as perishable goods spoiled before being harvested and sold. The global economic downturn also impacted smallholder farmers, particularly those close to the poverty line, as changing consumer demands resulted in fewer buyers for perishable foods. This can be confirmed in media reports. For instance, India's mango farmers report losses and waste due to canceled celebrations that traditionally involve mango consumption (Parkin and Rodrigues, 2020).

The pandemic's effects on the agricultural sector have thus led to multifaceted challenges for smallholder farmers disproportionately affected by food insecurity amidst economic, social, and mobility changes. Supporting farmers in generating their income, accessing markets, and contributing to local food supply chains is essential to preventing severe food deprivation where a significant portion of the population relies on small-scale agriculture for sustenance and livelihoods.

3.2 Qualitative data collection

During the qualitative research phase, intensive semi-structured online interviews were conducted with 15 smallholder farmer partners in Odisha who were actively using eKutir's platform (at the time called Bloom). Farmers chosen for the interviews were members of the broader Farmer Producer Organisation, which included 1,426 farmers. These 15 farmers were among the early adopters of the eKutir's technology and, as such, were understood as having taken on farming and technical risks. The interviewed farmers are nearly all smallholders (farming on less than 2 hectares of land), representing the region's and state's farming populations.

Due to the constraints imposed by COVID-19, traveling to India for an intensive questionnaire survey was not feasible. Moreover, gathering many farmers for online interviews was challenging due to the pandemic. Consequently, the interviews were conducted via Zoom from Canada. eKutir's field representatives carried out the selection of farmers for the interviews. Scholars, the partnering social enterprise eKutir, and farmers collaboratively developed the initial interview questions to ensure culturally appropriate language and focus on relevant issues and insights. These questions were prepared by scholars, translated, and modified as needed. Throughout the conversations, the questions were adapted to address the specific concerns raised by the farmers. All interview questions and responses were translated from Urdu or Odia to English. The interviewed farmers provided their definitions of food security and self-reported their household food security status. They also shared how food security had changed since gaining access to eKutir's platform. Additionally, the farmers were asked to describe their role within the local food system and how they contribute to their community's food security. The priorities identified by the farmers during the interviews

played a significant role in shaping the approach to the subsequent quantitative analyses.

3.3 Analysis of secondary quantitative data

eKutir provided the research team with quantitative transactional data, revealing how the platform, aimed at democratizing digital technology for small-scale, low-resource farmers, facilitated the movement of agricultural inputs and food through local and regional food systems. To gain insights into the volume, variety, and value of food transactions facilitated by eKutir's aggregation function, we analyzed the transaction data and mapped the flow of these transactions. The data also reinforced the farmers' statements, affirming that the platform enabled them to maintain vital connections with key markets for inputs and the sale of their produce.

Additionally, wherever possible, we contextualized the findings by considering data on food security in Odisha, particularly in rural areas and the communities where the food sold through eKutir ultimately reaches. This integration of transactional data and food security information provides a comprehensive understanding of the platform's impact on the local food systems and its potential contribution to enhancing food security in the region.

4 Data analysis and results

The data analysis and the results of the paper are presented below:

4.1 Farmer perceptions of the impact of eKutir during COVID-19

eKutir's technology users' experiences highlighted their intensified challenges during the pandemic, particularly concerning their livelihoods, food, and nutrition security, and the local food system. Access to the platform played a significant role in shaping their responses to these challenges.

4.1.1 Impact on livelihoods

In this study, many farmers relied on manual labour and hired seasonal workers for crucial planting and harvesting periods. For the study period over the pandemic period, many farmers expressed how mobility restrictions resulted in a shortage of farm labour, making it challenging to harvest crops fully. As noted above, this meant that surplus items remained unharvested or could not reach markets in time. One farmer explained how this impacted their second pandemic season planning as well: "Labour and other things are totally affected [...] due to the unavailability of labour, I also grew less because I wasn't able to manage" (translated). Another farmer noted that some farmers work on farms other than their own for additional income; their farm is "not their only income. So, whenever they are free, they engage themselves as [an] agriculture labourer also" (translated). Therefore, mobility restrictions also impact their ability to obtain this secondary income.

Farmers highlighted the significant impact of temporary market closures in two regards. First, it was difficult for them to sell items during lockdowns. As one farmer explains:

Basically, the market was shut down in lockdown, the; the market was shut [...] Nobody was allowed to go outside [...] In the village area generally [...] the market is very, very small [...]. So, if they want to go to an urban market, they must go 50 to 100 km away from their location (translated).

Farmers also noted how their access to essential farm inputs changed during the pandemic. All 15 interviewed farmers stated that local supply chains for seeds, fertilizers, and pesticides were disrupted, making these crucial items unavailable during critical growing seasons. Limited access to farm inputs emerged as one of the most significant challenges faced by most farmers interviewed for their pre-harvest tasks. The disruption also affected international supply chains, leading to shortages and price increases for various items. Although India-based companies produced some inputs, local restrictions still influenced access issues.

Farmers mentioned that eKutir's technology helped them manage with lower quantities of inputs like fertilizers and pesticides, indicating its potential to support more sustainable practices. Still, quantitative data revealed that many farms had poor-quality soil with low nutrients and faced high-risk factors related to the environment and climate, therefore, farm inputs remained crucial for ensuring short-term production continuity and livelihood generation.

All (15) farmers stated that they engaged with the app more since the onset of the pandemic. Farmers noted how eKutir's pre-harvest functions allowed them to connect with suppliers and arrange transactions. They listed seeds, fertilizers, and pesticides as items purchased through the app, even when conventional markets were closed. A farmer explains that "after COVID-19, the interaction with the application increased [...] because the market was closed, and he was able to get his input of pre-harvest requirement[s] from the application [...]. He was also getting help making decisions for his agriculture practices because he was also unable to communicate to the government agencies from where they generally get [advice]."

Farmers suggested that the app gave them more control over the price at which they sell their products. One farmer states that the app helped them "to get a better return because [...] during [the] morning, the price changes, so whenever the price will increase, they will sell.

Whenever the price will be high, I will then sell. [...] There is no storage or warehouse," which would allow them more flexibility regarding the timeframe they had to sell the food. The connectivity provided by this digital technology played a significant role in sustaining their livelihoods during the pandemic.

4.2 Risks and investment in Land

The farmers using eKutir's technology encounter various weather, ecosystem, and soil-related risks that pose additional challenges to small-scale farming. By analyzing individual farmers' financial inputs and investments, provided in the quantitative data by eKutir, we plotted total financial investment values against corresponding composite risk, weather risk, ecosystem risk, and overall composite risk values. This analysis helps us understand how farmers facing higher risks utilize the platform, how they allocate resources to tackle challenges, and whether they use more or fewer inputs for food production, which can impact soil health and the environment.

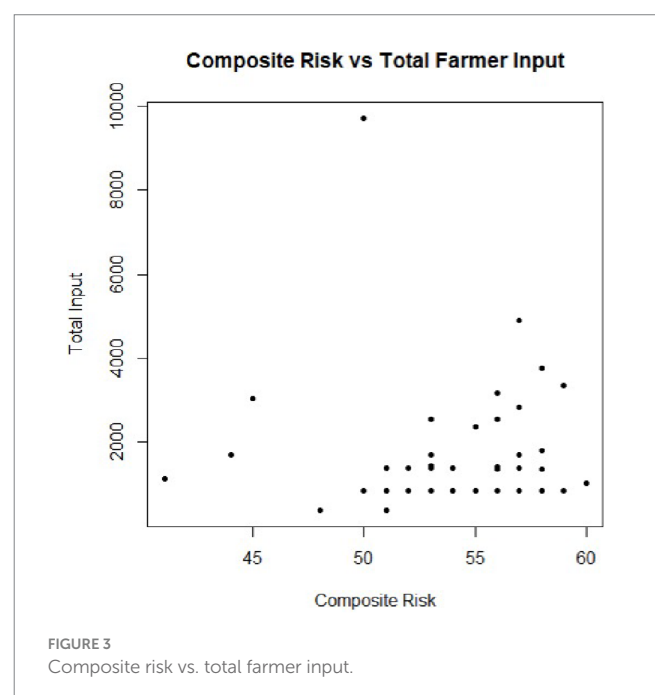
Through scatterplots, we identified trends and correlations within the observed data, indicating how certain variables and farming conditions are related. We also plotted risk scores against financial inputs to determine if specific risk levels were associated with higher or lower inputs. Our findings are as follows.

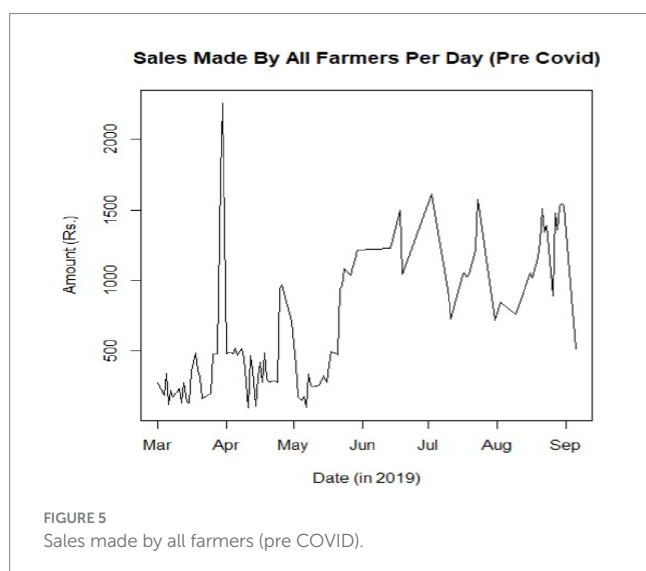
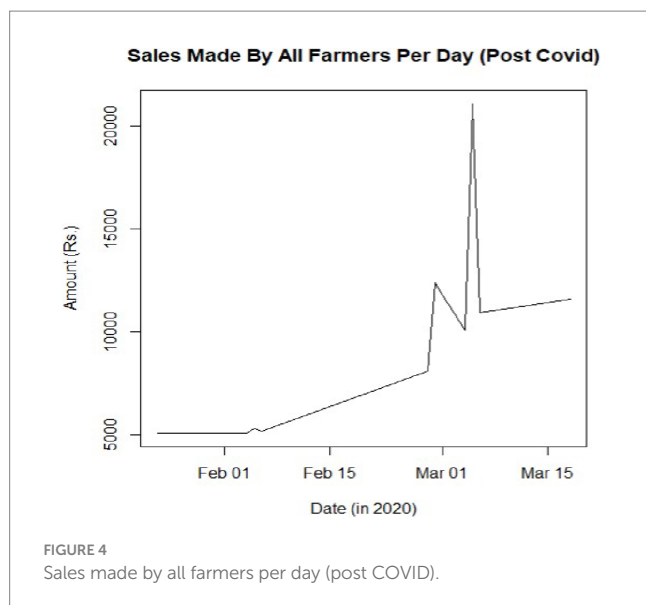
4.2.1 Total financial input and composite risk

In [Figure 3](#), most data points reveal that lower financial inputs are associated with higher composite risk scores. Composite risk scores are calculated based on synthesizing identified risks related to: skillset, assets, weather, ecosystem, marketing, financial, and risk reduction behaviour. This trend suggests that farmers with limited investments in their agricultural activities face higher risks to their farming output. It implies that those operating on riskier land areas may lack the financial resources to implement safeguards against risks. The data showing a mid-range composite risk with high input could be due to certain risks that cannot be fully mitigated financially. Instances of low-risk and low inputs may arise from farmers with naturally less vulnerable land (e.g. consistent weather patterns), reducing the need for significant financial input ([Figure 3](#)).

4.3 Total sales before and during the COVID-19 pandemic

An essential aspect of small-scale farmers' livelihoods, critical for overall food security, is their profit from selling their harvests. We investigated how the adoption of eKutir impacted farmers' profits during the COVID-19 pandemic using the data available, which offered a brief period of overlapping timeframes between the early days of the pandemic and the previous year ([Figures 4, 5](#)). This comparison offered some initial insights into their resilience during this challenging time. To analyze this, we examined the collective total profit of all farmers in the dataset, calculating daily profits and plotting them over





time. Before the pandemic, income levels were generally lower from March to May compared to June to September, with one notable exception in April, where the highest profit was recorded across the entire dataset. This analysis aimed to observe the sales performance in the farming community during different seasons and months of the year and compare them to the sales made during the pandemic and subsequent lockdowns. After the pandemic's emergence and the implementation of lockdowns, there was a wide variation in profits, but a rough upward trend was evident. This trend aligns with the experiences shared by the interviewed farmers during this period.

4.4 Impacts on food and nutrition security and health

During the interviews, farmers provided their definitions of food security. While some reports included aspects of nutritious

foods, all agreed that food security means either that “nobody should stay hungry” or that people “have enough to eat” (translated). Some farmers considered health in their definitions. For example, one farmer stated that food security means people “maintain good health” (translated). Overall, they emphasized the importance of ensuring that everyone in their household or community should have sufficient food security. This understanding aligns with a Senian entitlements-based or rights-based approach, emphasizing basic entitlements and people’s ability to access food as a household or community (Sen, 2003). India recognizes the human right to adequate food through bill provisions that explicitly guarantee the right to food and related entitlements. Notably, the local definitions of food security differ somewhat from the definition presented by the FAO (1996), which asserts that “Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.” While both definitions share common themes related to ensuring an ample food supply and promoting good health, they diverge in terms of their scope, comprehensiveness, and the emphasis placed on rights and entitlements. The local definitions often lean towards a more community-centered perspective, whereas the FAO definition takes a broader, global approach, encompassing factors such as economic access and dietary preferences.

All farmers acknowledged past experiences with food insecurity, primarily due to the high cost of food and low wages, making food too expensive for them, indicating an issue of economic access (translated). In line with definitions of food security, such as those promoted by the Committee on Economic, Social, and Cultural Rights, the farmers acknowledged that enjoying the right to food entails ensuring other needs are not overlooked to obtain sufficient nourishment. During the interviews, 14 farmers estimated spending 50–75% of their income on food, but they highlighted improvements in food security since adopting eKutir’s technology. Approximately half of the farmers interviewed (eight) mentioned foregoing medical care, including access to medicines, due to food costs before adopting eKutir’s technology. Three others noted that their previous food insecurity forced them to reallocate funds away from other items they deemed essential to access food. Nine farmers highlighted that food expenses impacted their ability to meet housing costs. At the same time, six mentioned transportation challenges, especially critical for farmers needing to transport food to markets for their livelihoods. Three farmers, two identified as women, shared how their previous food insecurity affected their ability to afford childcare and education.

With access to eKutir’s platform and greater reach into local and regional markets to sell their produce, farmers noted some relief from the threat of reallocating funds or adjusting household budgets to ensure adequate meals. This improvement is attributed to higher yields, input advice, and increased opportunities to sell their produce. One farmer stated, “Currently [my] yield is higher, so my family requirements are fulfilled and [...] I can sell in the local market where the community people are buying. So, they see me as a cultivator who feeds the community” (translated). Overall, farmers emphasized the importance of being able to sell the food they produce in order to secure their livelihoods during the pandemic.

4.5 Impacts on local food systems

The participating farmers using eKutir's technology played a crucial role as cultivators within their food systems, supplying food to their families and communities. Many farmers described themselves as 'cultivators' and explained that they were "feeding [their] families as well as the people in the community" (translated). They contributed to local food security by selling surplus food within the community and, in some cases, to direct food distribution and nutrition programs.

During the pandemic, mobility constraints affected food movement within local food systems, potentially impacting access to locally produced food for consumers and other eaters. However, farmers using eKutir's platform avoided some of these challenges and continued to sell similar amounts of food in the early months of the pandemic as before the pandemic.

The buyers' profile changed after the onset of the pandemic, with larger businesses or food distribution stores purchasing more significant volumes of aggregated foods. Crop decisions shifted during the pandemic, with a reduction in the variety of crops being sold. The data suggests greater crop diversity before the pandemic, while cabbage and cauliflower were more commonly planted during the pandemic. The challenges of the pandemic, including lockdowns that limited access to seeds, equipment, labor, and markets, contributed to decreased crop diversity, which may ultimately affect dietary diversity and nutrition within local food systems.

5 Discussion

The results and data analysis reveal the significant impacts of the COVID-19 pandemic on food producers in Odisha and emphasize the vital role of smallholders in the region's food supplies. The pandemic's challenges affected farmers' food security and livelihoods, particularly those engaged in subsistence and small-scale agriculture. Market closures, limited transportation, scarcity of inputs, and disruptions in supply chains increased costs. They affected farmers' ability to sell their produce, as seen in the literature and confirmed by interviewed farmers. As a result, some farmers faced food wastage and reduced profits, which impacted their dietary diversity and nutrition.

eKutir's technology is intended to support farmers in understanding the risks associated with their unique farming operation and to assist them in mitigating the risks where possible (e.g., through soil amendments tailored to the land farmed). Some risks cannot be attenuated through individual behaviour changes, such as weather-related ones. However, data collected over time could be used to support policy change related to climate change targets or environmental protection. The available data shows that eKutir's platform assisted farmers in mitigating market-related risks by securing buyers for products during the pandemic, even when consumer needs and habits changed. More data from the overlapping periods (i.e., same months in pre-, during, and post-COVID years) would be needed to draw more robust conclusions about how farmers using eKutir's platform can cope with market volatility.

We centre farmers' definitions and assessments of food security in this research in order to situate the findings within the context of local

knowledge and perspectives. The farmers' definitions of food security were generally more minimalist when compared to the widely employed definition by scholars, activists, and organizations by the Food and Agriculture Organization of the United Nations, which describes food security as "existing when all people at all times have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2006, p. 1). Popular understandings of food security tend to focus on ongoing food accessibility in the present and the future. Farmers did not use the conventional metrics and indicators commonly employed to assess food security in self-assessments. Instead, they focused on subjective satisfaction with food accessibility and availability, suggesting some improvement in household food security.

Most farmers did not include a procurement method in their definitions of food security; whether through purchase, cultivation, sharing, charity, or other forms of public distribution, the ability to access food determined food security. Participation in direct food provision programs did not appear to diminish food security self-assessments. The farmer's perspective raises important questions about how food obtained through alternative channels, like public distribution schemes, might align with definitions of food security. Unlike approaches that emphasize individual or household purchasing power for food accessibility, the farmers' understandings leave open the potential for alternative models involving community-based initiatives beyond charity to achieve food security goals. We might consider how food insecurity that arises from market failures can be better mitigated through improved government support, including but not limited to food provision programs. However, the farmers found governmental distribution schemes sporadic and unreliable, underscoring the significance of their ability to sell their produce to have food security, especially during the pandemic. Farmers considered their food security improved due to higher yields, advice on inputs, and increased opportunities to sell their produce. The pandemic affected farmers' access to medical care, housing, and transportation. For some, food expenses impacted their ability to afford essential items like childcare and education, even before the pandemic. eKutir's technology was thought to provide relief by improving market access and supporting income generation.

The study also highlights farmers' contributions to local food systems. Farmers played a crucial role as cultivators, supplying food to their families and communities. The available data shows that despite mobility constraints, farmers using eKutir's platform sold similar amounts of food, which entered local food systems. Crop decisions shifted during the pandemic, reducing crop diversity and potentially impacting dietary diversity and nutrition. The authors note that diet diversity is crucial for nutritional outcomes (Heywood, 2013; Koppmair et al., 2017), and economic downturns are associated with reduced dietary variety and poorer nutrition (Brinkman et al., 2010). However, existing research finds that access to digital technologies has the potential to promote the consumption of healthy and diverse foods (Dubé et al., 2020).

Regarding respect and protection of local knowledge, eKutir has expressed its commitment to respecting local knowledge. At the same time, it acknowledges the challenges faced by farmers, particularly in regions like coastal Odisha, where unpredictable climate variations pose significant threats. Over time, eKutir has observed that traditional

practices lack the resources needed for preservation. In response, eKutir has undertaken a digital initiative wherein each crop and its seed variety are cataloged and agronomic knowledge is digitized and validated by a community of farmers and certified agronomic experts. This data is the foundation for an approach that connects crops to predefined activities, optimizing yield potential. Each activity is linked to the products and services essential for farmers during the cropping cycle, complete with cost assessments. At this juncture, users can harmonize culturally relevant practices with commercial, market-based strategies. The outcome is a holistic farmer portfolio that balances local traditions and commercial efficiency. Importantly, it also furnishes a transparent ledger, which is critical for accessing financing that may be otherwise elusive from formal sources. The ultimate goal is to enhance farmers' financial standing, ensuring that local cultural practices remain significant even during turbulent times.

The COVID-19 pandemic presented multifaceted challenges for smallholder farmers in Odisha, affecting their food security, livelihoods, and local food systems. eKutir's technology played a significant role in supporting farmers by enabling connections with suppliers, thereby enhancing access to inputs, arranging transactions when markets were closed, and facilitating food movement within food systems. However, addressing farmers' vulnerability to risks and improving their food security and nutrition requires continued attention and targeted interventions. For example, analyses that revealed that farmers with limited investments faced higher risks and may lack adequate resources to adapt to environmental risks may require additional support. Overall, we put forth that efforts to provide small-scale farmers with appropriate digital technologies can bolster their resilience and contribute to the sustainability of local food systems in Odisha and elsewhere when they are designed with equity and farmers' needs in mind. Observing the platform's various benefits, it becomes evident that it has the potential to bolster the sustainability of local food systems in Odisha and beyond, even in the face of climate change.

6 Conclusions and recommendations

The COVID-19 pandemic has heightened the vulnerability of smallholder farmers, necessitating research into digital solutions like eKutir to enhance their resilience. However, digital technology for food security raises concerns regarding data commodification and potential exploitation of farmers and the environment. While these challenges must be addressed, digitization can improve small-scale farmers' income, market access, and food security, with a focus on democratizing digital technology in low-resource settings.

Access to digital technology tailored to the needs of small-scale farmers can strengthen local food systems and resilience. During the pandemic, eKutir's technology provided connectivity and market access when transportation was disrupted. It facilitated resource-sharing and microfinancing, enabling farmers to access machinery and financial support. However, careful consideration is required to avoid potential lock-in features associated with digitized microfinancing (Carolan, 2020; Prause et al., 2021).

While our study primarily addresses the impacts of the COVID-19 pandemic on food producers in Odisha and the role played by eKutir's technology in supporting them during this specific crisis, we are keenly aware of the pressing necessity to assess the platform's

adaptability to a range of other challenges and potential crises. Investigating the versatility of this system in diverse contexts, such as coping with flood events, droughts, pest infestations, and more, holds great promise for future research endeavors. Furthermore, there is an opportunity to integrate eKutir's technology and analogous solutions into the broader framework of India's ongoing transition and the global food systems transformation. Subsequent research efforts can delve deeper into these dimensions, offering a more comprehensive understanding of the digital transition's role in the future of agriculture and food systems.

The following considerations and recommendations are based on the priorities expressed by farmers, data analyses, organizational knowledge, and a review of existing literature.

1. **Platforms as Iterative Technologies:** eKutir designed its platform with user needs in mind, soliciting feedback from users during various stages of development and use and enabling research involving users and outside researchers (including this study). While eKutir's commitment to small-scale farmers' needs has been evident during the pandemic, farmers expressed a desire for more crop and post-harvest advisory support, including transitioning to new crops. Integrating feedback into platform evolution is crucial to maintaining alignment with farmers' evolving priorities.
2. **Respecting and Protecting Local Knowledge:** As noted above, eKutir is committed to respecting local knowledge while acknowledging that traditional practices can be supported by digital initiatives that optimise yield potential. A stated goal is to enhance farmers' financial standing and, therefore, resilience, which can ensure that local cultural practices retain their significance even during turbulent times. The interviewed farmers did not raise the issue of local knowledge protection within the platform. However, it is clear from the literature that relevant laws and policies on data protection generally (in India and beyond) have not kept pace with advancements in data-driven farming. Farmer-to-farmer interfaces within platforms are one example of how knowledge-sharing can occur within communities and enhance farming community resilience while limiting data exploitation.
3. **Sustainable and Agroecological Food Production:** eKutir's pre-harvest advice efficiently utilizes fertilizers and pesticides based on farmers' risk profiles. The platform can further support agroecological practices by advising on soil quality and amendments, diverse crop options, and pest control without synthetic chemicals. Some farmers expressed interest in transitioning to organic farming, highlighting the platform's potential to assist in such transitions.
4. **Health and Sustainable Food Systems:** Innovative technologies should contribute to sustainable food systems by diversifying food supplies for better nutrition. eKutir's data demonstrates how it encourages agrobiodiversity and diet diversity by facilitating the movement of various foods within local food systems. Digital technologies can focus on supporting farmers in producing and selling diverse and culturally relevant foods.
5. **Data Accessibility and Affordability:** Given the data-centric nature of the platform, it is imperative to continuously

implement measures that ensure both data accessibility and affordability for smallholder farmers.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Office of Research Ethics at York University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

SM was employed by the social enterprise eKutir.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2023.1150197/full#supplementary-material>

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