Empowering Farming Communities Through Information Tracking: A Design Approach to Crop Planning and Management

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Abstract

Agriculture is a key sector in the U.S. economy, supporting not only farmers but also industries like food processing and transportation. Due to labor shortages and an aging population, immigrant farmers have become essential to the workforce. However, they face challenges such as outdated tools, reliance on family labor, and uncertain land leases, contributing to economic insecurity. Additionally, their low literacy levels often result in ineffective tracking of crucial information, leading to missed opportunities in crop disease management and budget planning. Through interviews with 7 immigrant farmers and prototyping, we explored their everyday farming practices and identified opportunities for improved recordkeeping. Our findings suggest that improved information tracking could facilitate learning, crop management, and community support. This research informs the design of self-tracking technologies tailored to farmers, offering insights into culturally relevant solutions. Based on these findings, the team will develop and deploy a high-fidelity prototype on local farms.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**; **Empirical studies in interaction design**.

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Agriculture, farming, immigrant, community, information management, self-tracking, design

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1 Introduction

Agriculture is fundamental to the U.S. economy and food supply, contributing more than $1.5 trillion and 22 million jobs in 2023 [19]. However, recent demographic changes present profound challenges, particularly for aging farmers, with the average age of farmers rising to 58.1 years in 2023 — an increase of 0.6 years since 2017 [38]. This trend has led to a growing labor shortage, which is often mitigated by an increasing number of immigrant farmers [39]. Although they are considered an important part of the workforce, immigrant farmers face significant barriers, including financial insecurity, unstable land access, and sociocultural challenges [5]. Among these challenges, low digital literacy stands out as a major obstacle, limiting their ability to access essential agricultural information, such as seed selection [7] and weather forecasting [17]. Additionally, low digital literacy prevents immigrant farmers from effectively using information-tracking technologies to manage their information practices [31].

To support immigrant farmers, traditional interventions include financial aid programs and policies aimed at improving resource distribution and equality [27]. Recently, digital solutions have emerged to help farmers overcome infrastructure and literacy barriers. Studies have explored mobile applications, Internet of Things (IoT) monitoring, and AI-driven tools to enhance decision-making and productivity [1]. While these technologies have proven effective for large-scale farms, small-scale and immigrant farmers often face barriers, such as affordability, digital literacy, and language constraints [9], highlighting the need for accessible and culturally tailored technological interventions.

Self-tracking has been widely studied across various HCI domains, including everyday health management [3], workplace productivity [16], and chronic illness care [10]. It enables users to collect and communicate personal data to make informed decisions. Large-scale farms have leveraged advanced tracking systems to improve their agricultural performance. However, small-scale farmers, particularly immigrants, often lack access to such systems due to high costs and usability challenges [22]. While self-tracking has shown promise for other underserved populations, its potential for small-scale immigrant farmers remains underexplored.

In this study, we explore the potential of self-tracking technologies to support immigrant farmers by improving record-keeping and expanding access to opportunities. Examining the farming practices of an immigrant community provides valuable insights into similar small-scale farming groups, including women-run gardening collectives and indigenous farmer organizations. This study is part of a multi-phase project that combines ethnographic fieldwork with iterative design to create technologies for farmers from socially marginalized groups. Specifically, this phase reports on users' perceptions of an initial low-fidelity prototype and identifies implications for future iterations.

We conducted semi-structured interviews with 7 immigrant farmers to understand their experiences, challenges, and strategies. Based on findings from Hmong farmers' practices in tracking information for growth, adaptation, and collaboration, we designed a mobile application prototype using iterative design methods. The prototype includes three key features to support Hmong farmers' record-keeping: voice-assisted input, map-based visualization, and community collaboration. Preliminary user tests were conducted with 3 participants to gather feedback. The findings from this phase will inform the next step: developing a high-fidelity working prototype of self-tracking technologies for immigrant farming communities, followed by a field deployment study. Our contributions are twofold:

- We translate insights from immigrant farmers' experiences with information management into design implications that can enhance their agricultural practices.
- We present the front-end design process of a self-tracking tool aimed at improving the daily farming practices of small-scale immigrant farmers.

2 Related Work

2.1 Technologies to Support Farming

Advancements in digital and automated technologies have significantly transformed agricultural practices, integrating innovations such as IoT, autonomous robots, and artificial intelligence (AI) [1]. These technologies have been applied across various agricultural activities, including livestock management [23], food safety monitoring [15], and climate adaptation strategies [2]. While previous studies have prioritized large-scale farms, more recent studies have examined accessible, cost-effective technological solutions for small-scale farmers. For example, satellite-based field mapping in a developing country has enabled small-scale farmers to optimize land use through automated boundary detection and resource allocation [41]. Similarly, mobile applications designed for African farmers have provided access to real-time agricultural information, market prices, and weather forecasts, facilitating informed decision-making [40].

In addition, studies have explored how technologies can address infrastructure limitations and challenges associated with digital literacy among small-scale farmers. For example, a study examined how easy-to-use digital tools, combined with farmers' existing practices on small farms, can help them adopt new technologies [13]. Similarly, Raghunath et al. showed the potential of Android apps to improve access to information among farmers in rural areas [29].

Notably, within small-scale farming communities, immigrant farmers in the Global North face distinct sociocultural barriers (e.g., limited training and funding opportunities due to language barriers) that require community-specific approaches in designing technologies [9], which can support the unique practices and constraints of immigrant farming populations.

2.2 Self-tracking technologies in HCI

Self-tracking tools have been studied in various HCI domains [11], including everyday health management [3, 37], chronic illness care [10, 35, 36], mental wellness support [20], mood tracking [34], and productivity enhancement in the workplace [16]. These studies have explored ways to process user-generated data, facilitating data management, visualization, and collaborative decision-making. For example, Schroeder et al. showed that using visualizations of data tracked by patients with irritable bowel syndrome can facilitate patient-provider collaboration and improve patients' healthcare outcomes [33]. Similarly, another study investigated how freelance workers integrated self-tracking technologies to balance personal responsibilities, entrepreneurial goals, and workload expectations [16].

Researchers have also explored the application of self-tracking in agriculture. For instance, large-scale farms primarily use advanced data-tracking technologies to monitor soil conditions, assess crop health, and track yield and production [28]. These technologies include sensors, big data analytics, and data-driven decision-making. On the other hand, small-scale farmers often lack access to many available resources, including the budget for advanced agricultural technologies. Many of these farmers, including those from immigrant communities, face systemic barriers to adopting and accessing these innovations, which are crucial for improving their farming practices [22].

While self-tracking applications have shown promise in various contexts, it remains unclear whether these tools can benefit small-scale farmers. Our study aims to extend the application of self-tracking technologies to small-scale immigrant farmers by identifying the barriers to adoption and exploring design opportunities that can enhance agricultural efficiency and sustainability.

3 Design Process

3.1 Study Context

In this study, we collaborated with a local immigrant farming community—Hmong-American farmers with unique historical and socioeconomic backgrounds. Originally from Southeast Asia, many Hmong people were recruited by the U.S. military during the Vietnam War. Afterward, a significant number sought refuge in the U.S. By 2023, an estimated 360,000 Hmong individuals were living in the country [14]. Many Hmong individuals have continued farming in the U.S., building on their agricultural heritage and traditional farming practices from their home countries. However, they still face economic instability and struggle to sustain their small-scale farming operations. High land costs and short-term lease agreements limit their access to land [24], while the high cost of agricultural technologies restricts their ability to adopt digital tools for information management [28]. This makes it difficult to track production, manage budgets, apply for financial assistance, and optimize farm operations. Additionally, many have limited English proficiency, which further restricts their ability to navigate regulatory requirements and participate in training programs [21]. Our study focuses on Hmong farmers in Minneapolis, Minnesota, a U.S. metropolitan area where they primarily operate small-scale, diversified farms specializing in fresh-market vegetables and flowers. Understanding the farming practices of this immigrant community can offer valuable insights into similar small-scale farming communities, including women-run gardening groups and indigenous farmer collectives.

3.2 Semi-structured Interviews

3.2.1 Data collection and participants. In October 2024, we conducted interviews with 7 Hmong farmers (see Table 1) who were affiliated with a local non-profit agricultural organization (NPO). All participants were NPO members with at least one year of farming experience. The interviews focused on three main topics: daily routines and tasks, challenges in farming, and the use of agricultural tools and technologies. To recruit participants, we collaborated with an NPO staff member who introduced us to farmers and provided translation support as needed. Each interview lasted approximately 45 minutes and was audio-recorded for transcription and analysis. We continued recruitment until no significant new information emerged from the participants. All participants identified as Hmong community members. The mean age of the participants was 58 years (range: 35–71 years), most of them had between 10 and 20 years of farming experience (4/7). The study received ethical approval from our university's Institutional Review Board.

3.2.2 Data Analysis. We applied a constructivist grounded theory approach [6] and performed a thematic analysis [4] to identify emerging findings from the interviews. Using NVivo, the first and second authors independently conducted open coding, generating approximately 500 low-level codes (e.g., "The community helps farmers establish external connections so they can overcome language barriers," and "Participants did not track the crops and forgot where they planted certain crops last year"). We engaged in an iterative review process, meeting regularly to refine the coding results, discuss emerging patterns, and address any interesting aspects. Through this process, we consolidated the codes and established

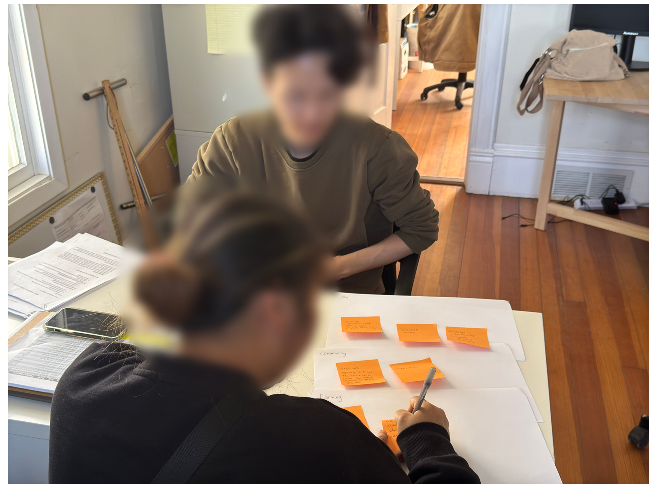

Figure 1: The researcher is conducting an interview with one of the participants.

a hierarchy based on their level of detail. We created three levels of codes: higher-level codes were more general, while lower-level codes provided more contextual details. Next, we performed affinity clustering to synthesize the high-level codes into broader themes. Given that the primary objective of this study was to develop a technology-mediated solution to enhance farmers' information tracking through effective record-keeping, we focused on identifying themes related to their current practices, successful strategies, and areas for improvement. From this analysis, we derived three high-level themes, which are presented in the Findings.

3.2.3 Findings. **Tracking information for growth: supporting continuous learning and business.** Self-tracking emerged as an important but challenging aspect of Hmong farmers' agricultural practices. Participants tracked key information about their activities, including crop planting schedules and locations, equipment and material expenses (e.g., seeds and fertilizers), and income from produce sales. By tracking and reflecting on their plans, farmers could continuously refine their strategies, ultimately improving their farming operations. However, for many farmers, including P1, information tracking was often inconsistent and fragmented: *"It is not just, 'I'm going to plan.' That's how you learn over time. It's like, 'Oh, I see this, and I see that. I need to correct this course of action, and then I need to go these directions, and I need to take notes now, and I need to track data.'" (P1)* Many farmers preferred to keep plans in memory, while others used physical notebooks and calendars to document their strategies. Younger farmers (i.e., P1 and P2) reported using digital tools like Microsoft Excel and Google Maps for tracking information. However, limitations such as the inability to track details, difficulty retrieving information, and the risk of misplacing paper records were identified as major downsides of current practices.

Tracking information for adaptation: managing crop portfolios and rotation. All participants indicated that they leased small-scale farmland (i.e., five to ten acres) through a local NPO. In

Table 1: Demographic information of participants

Participants	Occupation	Age	Gender	Years in Farming	Contribution
P1	Farmer	49	M	12 years	Interview, User Test
P2	Farmer	35	F	10 years	Interview
P3	Farmer	63	F	14 years	Interview
P4	Farmer	64	M	10 years	Interview
P5	Farmer	61	F	10 years	Interview
P6	Farmer	71	M	25 years	Interview
P7	Farmer	63	F	30 years	Interview
P8	Farmer	39	M	3 years	User Test
P9	Farmer Advocator	28	F	N/A	Prototyping, User Test

Note: F=Female, M=Male

contrast to large-scale farming, which often spans over 100 acres, small-scale farming requires meticulous planning. Hmong farmers frequently cultivate a diverse range of crops within relatively short growing seasons, making simultaneous management particularly challenging. Despite limited land and the threat of crop diseases (e.g., bacterial infections and pests), they lack effective methods for precisely managing crop types and locations—methods that could optimize yields, control disease spread, and maintain soil fertility. Farmers agreed that tracking is crucial for managing diverse crop portfolios and rotational strategies. As one farmer noted: *"The other problem is because we don't necessarily track what we plant, where we plant. I don't know. I think it was right about here, right about there. We have no idea. And then the next year, well, we got to plant the crop again. I think it's about over here, let's stick over here." (P1)* The lack of tracking often led to delays in sowing dates and produce deliveries. While participants acknowledged the importance of proper documentation, they frequently lost track of previous crop locations, which made rotation more difficult. Without clear planning and consistent tracking, they often faced confusion about crop placement and progress.

Tracking information for collaboration: knowledge sharing through tailored modalities. The participants valued the critical role of their farming community in knowledge sharing and skill development. The community served as a central resource, supporting farmers by providing training programs, educational materials, and essential information. For example, farmers relied on the community for visual educational materials, in-person farming training in Hmong, and assistance with grant applications—resources that were especially helpful given their limited English proficiency. Verbal and visually oriented methods of instruction were particularly beneficial for them. One participant described their learning style, which was rooted in direct, experiential farming knowledge passed down from their parents: *"(My parents' teaching process) is just like, 'Here's the tool, dig a hole, this is how much seed you put in it, and let's bury it,' and they're like, 'Okay, now the weed's going, here's the tools, go take out the weed.'" (P5)* They found information delivery tailored to the Hmong community (i.e., verbal and visual approaches) particularly effective. Some participants emphasized the importance of sharing planting plans to avoid market oversaturation and secure better prices at farmers' markets, where many sell their produce to local customers. One participant explained: *"I am thinking about connecting with other farmers and knowing what they are planting so that we don't end up planting a lot of the same stuff." (P3)* As this quote shows, Hmong farmers value knowledge sharing with fellow farmers for mutual benefit.

3.3 Iterative Prototyping

3.3.1 Brainstorming and Prototyping by an Interdisciplinary Design Team. Our team consisted of 7 researchers, including 6 graduate students specializing in design and computer science. The iterative design process spanned two months, with team members meeting once or twice a week to refine concepts and prototypes. We held a 45-minute silent brainstorming session to create a safe, open forum for idea generation. During the session, each team member independently wrote down potential solutions, resulting in a total of 100 concepts. These ideas included both physical and digital platforms, such as a notepad with embedded marks to convert handwritten memos into digital records and a digital whiteboard to visualize real-time crop status. After the brainstorming session, the team collaboratively reviewed and evaluated each concept based on the community's technological needs and cultural preferences [8]. After multiple rounds of discussion, we selected a voice-assisted record-tracking system as the primary design concept. During our interviews with farmers, record-keeping emerged as a central theme for successful farming, as it facilitates business growth and crop management. Therefore, we prioritized self-tracking as the core concept. Additionally, given the farmers' low digital literacy and preference for oral communication over written forms, a voice-based system was considered the most intuitive and accessible solution.

Based on these insights, the team created initial ideation sketches, focusing on three key implications identified from the interviews. We refined these sketches through heuristic evaluations guided by UI design principles [25]. Throughout the process, we presented the low-fidelity prototype to a staff member at the NPO (P9) and gathered feedback for further refinement, such as adding Hmong translations to the interfaces. After this iterative process, we used Figma [12] to finalize the low-fi prototype and conduct preliminary user tests (see Figure 2). On the technological side, the team implemented two core features: voice recognition and map visualization. The key enabler of audio-to-map visualization is large language models (LLMs). While our system is not tied to any specific LLM, we

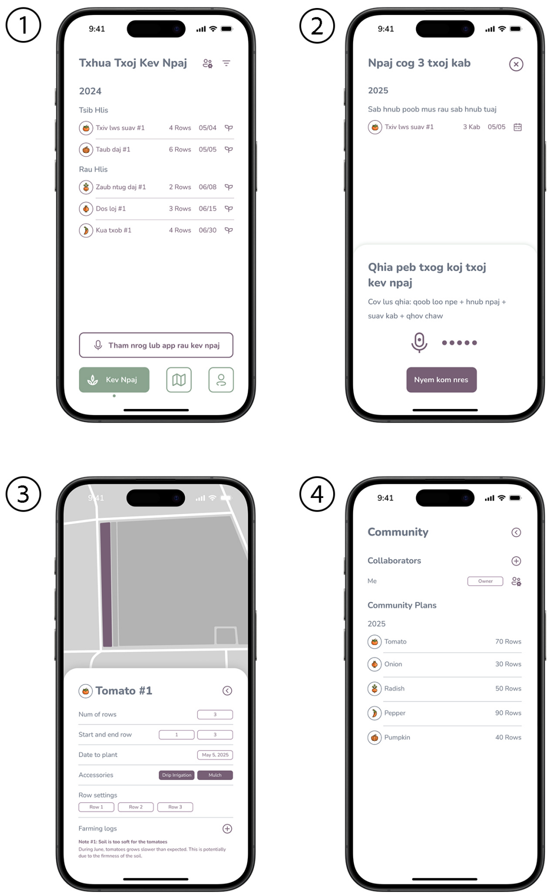

Figure 2: Low-fidelity Prototype. List view (1), voice input (2), map view (3), and collaboration (4). The first two screenshots are in Hmong.

leveraged the OpenAI API service [26] for computational efficiency in this study. When farmers provide voice commands, the LLM processes the input and updates the relevant farmland attributes accordingly. Updates may include new plantings, modifications to existing plans, or deletions, ensuring an accurate digital record of ongoing agricultural activities.

3.3.2 Key Design Features. Our prototype includes three key features (see Figure 2 and Table 2) that align with Hmong farmers' daily farming needs, particularly in relation to self-tracking essential information. These features support intuitive and efficient planning, as well as the tracking of crucial farming data.

Supporting self-tracking through voice input. Users primarily interact through voice input, with text input available as a supplementary option. This design choice was informed by farmers' preference for verbal communication, which facilitates easy information tracking, particularly for those with limited literacy. Farmers can verbally record crop types, assign them to specific areas in the field, and add details about relevant farming tools. For example, a user might say, *"I want to plant three rows of tomatoes in the western part of my field on May 5, using mulch as the main tool."* The system then schedules the plans and sends reminders on the specified date. Additionally, the prototype allows users to document key observations, challenges, and lessons throughout the growing season. To accommodate varying levels of English proficiency, the interface supports both Hmong and English.

Visualizing farming plans and history on a map. After processing the voice input, the system generates an interactive map that visualizes the user's upcoming farming plans. The visualization provides an overview of the location of each crop, the planned activities, the tools needed, and relevant past records. This simplified approach to visualizing information aligns with our farmers' preferences, offering an alternative to text-heavy record-keeping practices that have led to lower engagement with information management for many farmers. Also, by reviewing their planting history, farmers can strategically plan crop rotations to maintain soil health and sustainability.

Enabling collaboration through collective planning and knowledge sharing. Recognizing Hmong farmers' strong community ties and their values of collaboration, as emphasized during the interviews, our prototype incorporates features that support shared planning and information exchange. Users can invite family members or fellow farmers to collaborate on farming plans, assigning designated roles (e.g., editor or viewer), ensuring coordinated decision-making on aspects such as crop schedules, planting quantities, and tool usage. Additionally, the prototype provides an overview of the crops grown by all farmers within the community and the total quantity of each crop. This feature helps farmers coordinate crop production, minimizing oversupply and maximizing market efficiency by diversifying the produce available at local farmers' markets.

4 Preliminary User Tests and Insights from Farmers and Staff

We conducted 3 initial user tests with two farmers affiliated with the NPO and one staff member (P1, P8, and P9) (see Table 1). One session was conducted in person at the participant's home, while the other two were conducted online . Each session lasted approximately one hour. The goal of these tests was to gather insights into the prototype and explore how the system could be used in real-world scenarios. Each session was structured in two main parts. In the first part, participants interacted with the prototype on their mobile phones through Figma, completing key tasks such as adding and editing crop entries using voice input, accessing the map visualization feature, and sharing their farm plans with collaborators. Participants were encouraged to navigate the prototype independently, while the researcher provided guidance when necessary. In the second part, follow-up interviews were conducted to learn about their experiences with the prototype, particularly focusing on usability issues, potential use cases, and design recommendations. Detailed information on the usability and feasibility of the prototype will be provided in a separate publication once the large-scale deployment study is completed.

Table 2: Key design features and functions of the low-fidelity prototype

Key Design Features	Functions of the Prototype
Feature 1. Supporting self-tracking through voice input	• Users primarily interact through voice input, with text input available as a supplementary option. • The system can schedule plans and send reminders on the specified dates. • The system allows users to document key observations, challenges, and lessons learned throughout the growing season. • The interface supports both Hmong and English languages.
Feature 2. Visualizing farming plans and history on a map	• The system generates an interactive map that visualizes the user's upcoming farming plans. • The visualization provides an overview of the location of each crop, the planned activities, the tools needed, and relevant past records, helping farmers strategically plan crop rotations.
Feature 3. Enabling collaboration through collective planning and knowledge sharing	• Users can invite family members or fellow farmers to collaborate on farming plans, with designated roles (e.g., editor or viewer). • The system provides an overview of the crops grown by all farmers within the community, along with the total quantity of each crop.

4.1 Benefits of the Prototype

Participants shared positive experiences with the prototype, highlighting its effectiveness in supporting their information tracking—both for upcoming tasks and past activities. They found the overall design intuitive and user-friendly, particularly appreciating the voice-assisted input feature, which simplified the process of creating and managing information, especially for older farmers. As P8 excitedly stated, *"Instead of them (farmers) having to do the paperwork and put on their notes every day, every time they plant, now they're just doing an app, and it's so much easier. So that when it's time to report to USDA (U.S. Department of Agriculture), FSA (Farm Service Agency), you just send in this report. I like it".* Participants valued the prototype as a practical tool for planning and reflecting on farming data, which can improve decision-making. They also highlighted the convenience of having their farming records accessible on their mobile phones, reducing the need to rely on memory.

4.2 Areas for Improvement

Despite the notable benefits, participants also provided insights for further refining the prototype. They expressed a desire for actionable, practical recommendations based on the information they entered. These suggestions included optimal crop numbers per row, suitable fertilizers, and farming techniques tailored to weather conditions. Participants viewed these features as especially valuable for overcoming barriers posed by limited digital literacy, as they would enable farmers to make more informed decisions. Additionally, participants expressed a need for greater flexibility in recording and managing farm-related data. They suggested that the system should allow for more detailed tracking of crop varieties, such as distinguishing between different types of tomatoes. As P9 mentioned, *"When they (farmers) plant a crop, they do have a variety inside the crop, like for tomatoes. They might have like cherry tomatoes, black tomatoes."* Additionally, participants emphasized the importance of integrating financial tracking features to monitor farm-related expenses, yields, and income, as this would further support the sustainability of their farming businesses.

5 Discussion and Conclusion

Our findings align with previous studies on technologies for self-tracking in socially marginalized communities, reinforcing the importance of approaches tailored to the cultural practices and community characteristics of end-users [13, 18]. We found that Hmong farmers use workaround strategies for planning and tracking, such as relying on physical notebooks to sketch plans and preferring verbal communication and visual materials. Our findings also reflect broader patterns of collective data management observed in other marginalized communities (e.g., low SES families [32]). The collaborative features of our prototype were seen as effective in strengthening community ties and supporting shared agricultural goal management. Beyond these commonalities, our results highlighted unique characteristics of Hmong farmers, such as the use of non-standard measurement units like pallets and rows, and a strong demand for detailed agricultural data to manage diverse crop portfolios on small-scale farms. These insights extend beyond our specific study population and can inform the design of self-tracking technologies for other immigrant and socially marginalized farming communities.

Building on these findings, we developed an initial self-tracking prototype through an iterative design process. The three key design features aligned well with Hmong farmers' preferences for verbal communication, visual materials, and collective knowledge-sharing. Participants found these features valuable in enhancing their planning and fostering collaboration within their community. The prototype was generally well-received, and key design features, particularly voice input and collaborative planning, have the potential to be integrated into existing information-tracking technologies to better support immigrant farmers' record-keeping practices. However, further refinements are needed to better address farmers' needs. Specifically, participants emphasized the importance of incorporating more detailed data to support precise and sustainable farming practices, such as tracking different varieties of the same crop. Additionally, improving support for Hmong-language voice input would enhance accessibility, especially for older farmers with limited English proficiency. These refinements are crucial for strengthening the prototype's usability and effectiveness, particularly for immigrant farming communities.

Future work should explore the perspectives of NPO staff and other stakeholders, including those involved in the supply chain, to gain a more comprehensive understanding of their experiences with farmers. Also, while we observed generational differences in technology adoption and acceptance within the farming community, the limited number of participants was insufficient to explore participants' experiences with the prototype in depth. Evaluating the prototype with a more diverse group of farmers (e.g., individuals across different age groups) would provide valuable insights into usability challenges and potential areas for improvement. Additionally, given the limited English proficiency among immigrant farming communities, future research could investigate the impacts of accents and dialects when designing voice input systems for agricultural applications [30]. As a next step following the preliminary user test, we will refine the low-fidelity prototype and conduct a field deployment with Hmong farmers and NPO staff.

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