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A Regional Digital Transformation System for Enhancing Local Vegetable Supply in School Lunches

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Abstract

This paper introduces the development and implementation of a digital transformation (Agri-DX) system aimed at enhancing the use of locally produced vegetables in school lunches in a Japanese regional city. Initiated in 2021 through a university-municipality collaboration, the system facilitates six-month menu-based planning, integrates cultivation and shipment scheduling, and enables real-time data sharing among producers, agricultural cooperatives (JA), and school lunch centers. The system's cloud-based architecture improves transparency, optimizes supply chains, and enhances food education and sustainability. Results show a significant improvement in local sourcing rates, aiming from 16.3% in FY2022 to 44.6% by FY2029. This study demonstrates how structured information systems can address food security, economic stability, and regional revitalization

Keywords: Agri-DX, local food systems, school lunches, supply chain, regional revitalization, food traceability.

1 Introduction

The Japanese school lunch program is internationally recognized not only for its nutritional balance but also for its integration of cultural and social learning objectives. School lunches in Japan are considered an extension of education, where children not only receive nutritionally balanced meals but also gain awareness of food origins, dietary habits, and environmental considerations. However, despite the strong institutional foundations of the system, many municipalities face growing difficulties in sourcing locally produced vegetables. These challenges are rooted in several socio-economic trends, including the aging farming population, fragmented supply chains, delayed procurement cycles, and a lack of digital coordination across stakeholders.

In recent years, the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF) has promoted various smart agriculture initiatives to address rural sustainability and food security. These efforts include the adoption of IoT and AI in precision farming, and policy support for local food consumption under the "chisan-chisho" (local production for local consumption) banner. However, most of these approaches focus primarily on optimizing production at the farm level, without sufficient integration with demand-side data, such as institutional food service schedules or nutritional targets in schools.

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To address this gap, several academic and municipal pilot projects have attempted to align production with public consumption, particularly in educational institutions. Prior work by Matsumoto et al. (2021) and Hasuike et al. (2022) explored information system models that connect school menus with planting plans. Nevertheless, these systems often remained conceptual or suffered from limited scalability due to data fragmentation and low usability among older producers.

Against this backdrop, the city where the experiment was conducted launched a multi-year Agri-DX initiative in collaboration with Kindai University to develop a digital platform that enables synchronized planning between school lunch demand and agricultural supply. This paper introduces the resulting system—designed to visualize six-month menu plans, support coordinated crop planning, and ensure timely delivery through centralized data sharing—and examines its operational structure, implementation process, and early-stage impacts. The case illustrates how municipalities can utilize digital platforms not only to improve local sourcing but also to strengthen regional food ecosystems and educational value through institutional meals.

2 Related Work and Policy Context

Efforts to increase local food consumption in Japan have a long policy history, particularly under the banner of "chisan-chisho" (local production for local consumption). These initiatives were designed to revitalize regional economies, reduce food mileage, and promote food education. However, they have often been implemented through loosely coordinated activities such as farmers' markets, school events, or procurement guidelines that lacked technological integration. As a result, their impact has been constrained by fragmented supply chains, inconsistent data exchange among stakeholders, and limited scalability.

In parallel, Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF) has actively supported smart agriculture policies that promote digital technologies including IoT, AI, and data management platforms in the farming sector. These policies have enabled precision farming, autonomous machinery, and weather-responsive irrigation systems. While these innovations improve on-farm productivity, they tend to focus on the production side and rarely address integration with downstream food services such as school lunches. Thus, the potential for smart agriculture to contribute to food security, public health, and education remains underutilized.

Recent academic research has begun to explore the intersection between digital transformation and public food procurement. For instance, research by Hasuike et al. (2022) proposed an optimization model to align menu requirements with procurement costs in school lunches. Matsumoto et al. (2021) developed prototype systems for school menu visualization and information sharing with local producers. However, these studies often assumed idealized communication flows or required high ICT literacy among farmers, which limited real-world implementation.

Moreover, few systems have been able to operationalize data from both the demand (school menus) and supply (crop production) sides in a continuous and scalable manner. The lack of a dynamic, data-driven feedback loop between producers and school meal centers hinders systematic improvement in procurement efficiency, food education, and producer sustainability.

In this context, the system proposed in this study addresses several unresolved issues in the existing literature and policy landscape. By combining real-time visualization of school menu plans with crop scheduling and shipment coordination, the system provides a practical, scalable approach to realizing integrated regional food systems. It contributes not only to food logistics but also to digital governance and agricultural sustainability at the municipal level.

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3 System Development and Timeline

The development of the local vegetable supply system began in 2021 as a collaborative research initiative between the municipal government and us. Recognizing the inefficiencies in matching local agricultural production with institutional demand, particularly in school lunches, the partners launched a multi-phase project to explore how digital transformation (DX) technologies could enable a coordinated and data-driven supply system.

Table 1: Development Timeline of the Local Vegetable Supply System

Fiscal Year	Activities and Milestones
FY2021	Launched university joint research project on Agri-DX; initial field surveys and needs assessment
FY2022	System design with six-month menu input planning; stakeholder interviews and UI prototype evaluation
FY2023	System requirement definition; full development; test deployments with selected producers and centers
FY2024	Official launch in October; operational deployment in all school lunch centers; system training sessions for JA and producers

To illustrate this multi-stakeholder collaboration, Figure 1 presents a schematic overview of the development process, showing the flow of planning, design, implementation, and stakeholder engagement.

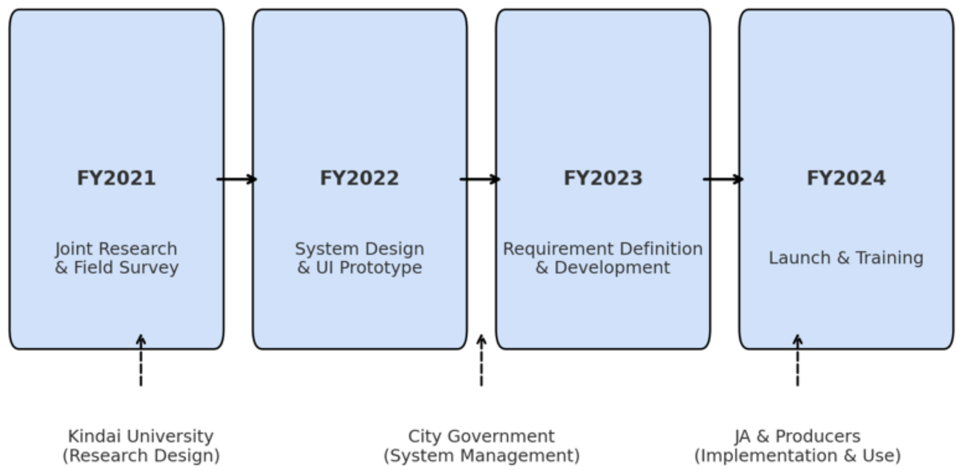

Figure 1: System Development Framework

This phased approach allowed the project team to address operational issues iteratively while adapting to the ICT literacy of participating farmers and institutional users. Each phase was informed by feedback loops between field trials and development, ensuring that the final system met practical requirements in terms of usability, accessibility, and functional value.

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4 Operational Flow and Stakeholder Roles

The operational flow of the system is designed to create a seamless connection between institutional food demand and local agricultural production, involving five core stakeholders: school lunch centers, schools (children), JA (agricultural cooperatives), producers (farmers), and the market distribution center.

The process begins with the school lunch centers, which finalize six-month meal plans based on nutritional and operational requirements. These menu data, including vegetable types and required quantities, are input into the system. The platform automatically processes the data and calculates the projected demand for each vegetable type on a weekly and monthly basis.

This demand forecast is shared through the system with JA, which coordinates with registered producers to confirm planting intentions and assign cultivation roles. Producers use this information to plan and adjust their planting schedules in advance, often revising previously uncoordinated production cycles to better align with demand. The market center manages quality assurance, aggregation, and final shipment based on the producers' supply.

Schools receive the locally produced vegetables via the lunch centers, ensuring fresher meals with educational value. The entire flow reinforces the educational message of food traceability and local sustainability for children.

5 Features, Evaluation, and Impact

The developed system operates on a cloud-based architecture and is accessible from various devices including PCs, tablets, and smartphones. Its user interface was designed with simplicity in mind to ensure accessibility for users with varying ICT literacy, including elderly farmers and administrative staff. The interface enables stakeholders to input, visualize, and extract information relevant to school lunch planning and local vegetable procurement.

Key system features include:

- Visualization of six-month school lunch menu plans and their associated vegetable demand
- Real-time dashboards showing supply versus demand by crop type
- Scheduling tools for cultivation and shipment, linked to each producer's capacity
- Exportable planning sheets and automated alerts for mismatches between expected and actual supply

The system was also developed with future adaptability in mind. All operational data are stored and structured in a way that allows for future integration with AI-based predictive tools, such as yield forecasting, market pricing trends, and adaptive delivery planning.

The impact of the system was evaluated both quantitatively and qualitatively. Quantitatively, the local vegetable self-sufficiency rate improved from 16.3% in FY2022 to over 25% by the start of FY2024, despite partial implementation. The goal is to reach 44.6% by FY2029, with an average annual increase of 4.6%. These figures are significant in the context of regional agricultural revitalization.

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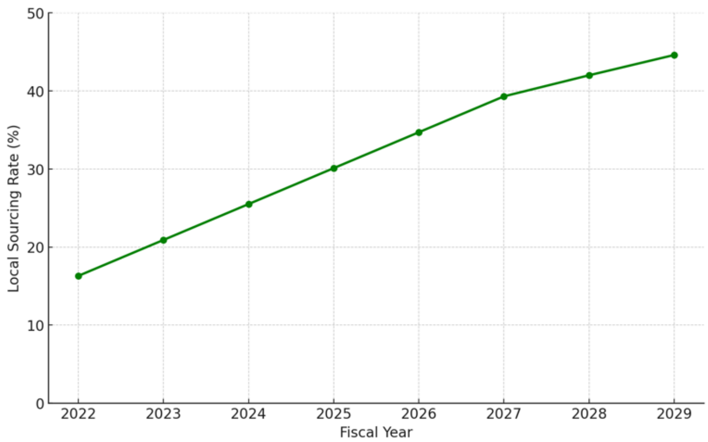

Figure 2: Local Vegetable Sourcing Rate

Qualitatively, interviews and feedback from stakeholders highlighted the following effects:

- School Lunch Centers: Improved menu planning and procurement stability; reduced price fluctuations
- JA Hiroshima: Better coordination with producers; streamlined assignment of delivery responsibilities
- Producers: Greater clarity in cultivation targets; income stabilization due to predictable demand
- Students: Access to fresher vegetables; enhanced food education experiences

The system not only improves operational efficiency and food quality but also contributes to strengthening the trust and engagement among all stakeholders in the school lunch ecosystem.

This case offers a replicable model for other municipalities. Future enhancements include:

- AI-based predictive yield planning
- Integration with local retailers and healthcare institutions
- Public dashboards for transparency and food education

The research team also received a Satake Foundation grant to explore machine learning optimization and regional food ecosystem design.

6 Results: Effects of System Implementation

The implementation of the Agri-DX system has produced tangible operational and behavioral improvements among key stakeholders. One major outcome is the transformation of JA's role in production planning. With access to six-month forecasted demand data, JA began using the system to proactively coordinate crop assignments with producers, moving away from reactive procurement practices. JA's agri-centers, in particular, actively downloaded allocation data from the system to support field-level planting discussions and schedule alignment.

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The system also enabled visibility into user behavior and workflow activity. System access logs and screen operation histories were analyzed to monitor usage patterns across different authority levels. This made it possible to track how frequently agri-centers revised planned shipments, contributing to a better understanding of real-time field adjustments.

Furthermore, the system allowed for more flexible ingredient allocation adjustments. Whereas allocations were previously fixed far in advance, the digital platform enabled revisions even one month before delivery, significantly improving adaptability in procurement planning.

These outcomes demonstrate that the system not only improves data transparency and efficiency but also facilitates more structured and predictive behavior among intermediaries, thereby enhancing supply chain stability.

7 Conclusion

This study shows that municipal-led Agri-DX initiatives can enhance regional food autonomy, education, and economic resilience. By aligning school lunch menu planning with crop cycles through shared digital platforms, local governments can transform school meal systems into engines of sustainability, regional revitalization, and food education.

The implementation of the system demonstrated that clear data sharing among municipalities, agricultural cooperatives, and producers can lead to measurable improvements in local sourcing rates, supply chain stability, and community engagement. The system's ability to visualize six-month menu-based demand and support cultivation scheduling played a key role in reducing mismatches and enhancing production planning.

Beyond operational improvements, the system has contributed to educational outcomes by reinforcing students' awareness of where their food comes from and the importance of local agriculture. This form of institutionalized traceability strengthens both dietary habits and civic awareness among future generations.

However, several challenges remain. Some older producers faced barriers in digital literacy, which necessitated continued training and system interface refinement. Moreover, while the platform has succeeded in increasing participation among core stakeholders, further efforts are needed to integrate it with broader retail and institutional networks to enhance scalability.

However, some issues remain to be addressed. Currently, the system does not collect structured data on the reasons behind allocation or cultivation changes, such as price fluctuations or weather-related disruptions. Implementing a selectable reason input mechanism could improve future demand-supply simulations. Additionally, direct system usage by producers remains limited. Although some graphs and planning views are available to them, usage logs suggest indirect access through JA rather than active individual use. Enhancing usability and feedback mechanisms for producers is an area of ongoing improvement.

Future research and development should explore:

- Integration of AI-based yield and demand forecasting to optimize planning cycles.
- Development of open data interfaces for retail stores, hospitals, and disaster response food logistics.
- Long-term impact evaluation on producer income, food waste reduction, and local government cost efficiency.

In conclusion, this case offers a replicable model that addresses both agricultural and

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educational policy goals through the power of digital transformation. Continued innovation and inter-sectoral collaboration will be essential to fully realize its potential. By aligning menu planning with crop cycles through shared digital tools, local governments can transform school lunches into engines of sustainability.

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