From Soil to Market: Enhancing Hill Farmer Incomes Through Digital Platforms

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ABSTRACT

This study investigates the role of digital platforms in transforming agribusiness linkages and improving farmer incomes in the Himalayan hill districts of Uttarakhand, India. Implemented as part of the World Bank–supported Uttarakhand Decentralized Watershed Development Project Phase II (UDWDP-II), also known as *GRAMYA-II*, the initiative integrated mobile applications, e-commerce tools, and centralized data systems within a decentralized institutional framework comprising Farmer Interest Groups (FIGs), Farmer Federations (FFs), and Agribusiness Growth Centres (ABGCs). Using a mixed-methods approach that combined project documents, digital platform analytics, sales data, and stakeholder interviews, the study evaluated digital platform adoption, marketing performance, and institutional synergies. The *Gramyashree* platform functioned as both a digital marketplace and a management tool, facilitating direct producer–buyer engagement, real-time inventory tracking, yield forecasting, and coordinated marketing. Findings indicate that digital interventions improved market transparency, reduced transaction costs, and expanded access to urban and institutional buyers, particularly benefiting smallholders in remote areas. However, adoption varied due to connectivity limitations, uneven digital literacy, and product quality challenges. The study concludes that digital platforms can significantly enhance agribusiness outcomes in mountainous contexts when embedded within federated governance structures and supported by investments in capacity building, branding, quality assurance, and last mile logistics.

Keywords: Agribusiness Growth Centres, Digital platform, e-commerce, Farmer federations, Farmer Interest group, Smallholder farmers,Value chains.

INTRODUCTION

The agricultural sector in developing countries is undergoing a structural transformation, increasingly driven by the integration of digital technologies. These innovations not only enhance productivity but also offer new pathways for market access, financial inclusion, and value chain integration. In geographically disadvantaged regions such as the Indian Himalayas, where market access remains constrained by terrain, poor infrastructure, and fragmented supply chains, digital platforms have emerged as viable solutions to bridge gaps between producers and markets.

India's agriculture, employing nearly 54% of the population and contributing about 17–18% to national GDP, remains largely smallholder based (Department of Agriculture and Farmers Welfare, 2025). Despite this significance, farmers in hilly states like Uttarakhand face challenges in accessing organized markets. Traditional mandi systems involve multiple intermediaries, high transaction costs, and delayed price discovery, reducing farmers' income share.

In this context, the *Uttarakhand Decentralized Watershed Development Project* Phase II (*Gramya-II*), implemented by the Watershed Management Directorate (WMD) with World Bank support (2014–2022), introduced interventions to enhance watershed management, climate-resilient agriculture, and market-driven agribusiness (Watershed Management Directorate, 2023). Central to this effort was the deployment of digital tools to improve value chains and create sustainable market linkages.

The project established the *Gramya Shree* brand and the *Gramyashree* digital platform (mobile app and e-commerce portal) to enable real-time listing of produce, connect farmers directly to buyers, and provide transparent information on price and availability. By reducing dependence on middle men and expanding digital reach, the platform empowered farmers to access broader markets, while offering buyers traceable, fresh, and often organic produce. Embedded within a larger ecosystem of FIGs, FFs, and ABGCs, the digital component amplified transparency and outreach key for inclusive agribusiness in hilly terrains.

LITERATURE REVIEW

Over the past two decades, digital innovation has significantly transformed agribusiness, evolving from basic information dissemination systems to integrated digital ecosystems leveraging advanced technologies such as artificial intelligence (AI), Internet of Things (IoT), and blockchain. Early digital agriculture interventions in the 2000s primarily focused on the delivery of agricultural advisories and market price information through SMS and radio-based platforms. These initiatives laid the foundation for Information and Communication Technology for Agriculture (ICT4Ag), with emphasis on localized and context-specific content delivery (Glendenning and Ficarelli, 2012).

By the mid-2010s, digital technologies began to play a more central role in agricultural market integration and value chain efficiency. Studies have demonstrated that digital tools contribute to reduced price dispersion, improved market transparency, and enhanced efficiency in agricultural markets (Nakasone and Minten, 2013; Shalendra et al., 2019). Market Information Systems (MIS), such as Kenya's KACE, enabled real-time access to price data, thereby strengthening farmers' bargaining power and reducing information asymmetry (Mukhebi et al., 2008). More recent studies highlight the role of digital platforms and e-commerce in enhancing smallholder incomes, improving traceability, and building consumer trust (Ju and Lou, 2024; Ningsih et al., 2024; Chiwaridzo et al., 2024; Sermuksnyte-Alesiuniene and Melnikiene, 2024).

Beyond economic benefits, digital platforms have been widely associated with improved price realization, reduced transaction costs, and minimization of post-harvest losses (Barton, 2003; Clasen and Mueller, 2006; Landreth, 2022). Integrated digital solutions such as DigiFarm have further expanded access to inputs, credit, and advisory services, thereby strengthening agricultural ecosystems (Sam and Grobbelaar, 2021). However, the benefits of digitalization are not uniformly distributed. Persistent challenges related to digital inequality, including limited connectivity, affordability constraints, and gender-based disparities, continue to hinder widespread adoption (Hackfort, 2021; Saha et al., 2024).

Several theoretical frameworks have been developed to explain technology adoption, among which the Technology Acceptance Model (TAM) (Davis, 1989) is widely recognized. TAM identifies perceived usefulness and perceived ease of use as the primary determinants influencing users' attitudes, behavioral intentions, and actual technology usage. Subsequent extensions, including TAM2, TAM3, and the Unified Theory of Acceptance and Use of Technology (UTAUT), incorporate additional factors such as social influence, facilitating conditions, and user characteristics, thereby enhancing the model's explanatory power across diverse contexts (Xue et al , 2024).. These frameworks are particularly relevant in agricultural and rural settings, where technology adoption is shaped not only by perceived benefits but also by infrastructural limitations, social dynamics, and institutional support mechanisms.

Environmental and institutional dimensions of digital agriculture have also gained increasing attention. Technologies such as blockchain and IoT enable enhanced traceability and support climate-smart agricultural practices, contributing to sustainability and low-emission systems (Deshmukh and Patil, 2022; Pavesi et al., 2024). Nevertheless, there remains a significant gap in the literature regarding the long-term sustainability,

scalability, and institutional integration of digital platforms, particularly in low-bandwidth and resource-constrained environments.

METHODOLOGY

This study adopts a mixed methods research design to assess the role of digital platforms in strengthening agribusiness linkages within the Gramya-II project, implemented in Uttarakhand, India. The methodology combines quantitative data analysis with qualitative insights, drawing on field-level observations, institutional records and stakeholders interviews

Study Area: The Gramya-II project was implemented between 2014 and 2022 across 527 Gram Panchayats (GPs) situated in 82 micro-watersheds of Uttarakhand (fig.1), characterized by rugged Himalayan terrain and limited market accessibility.

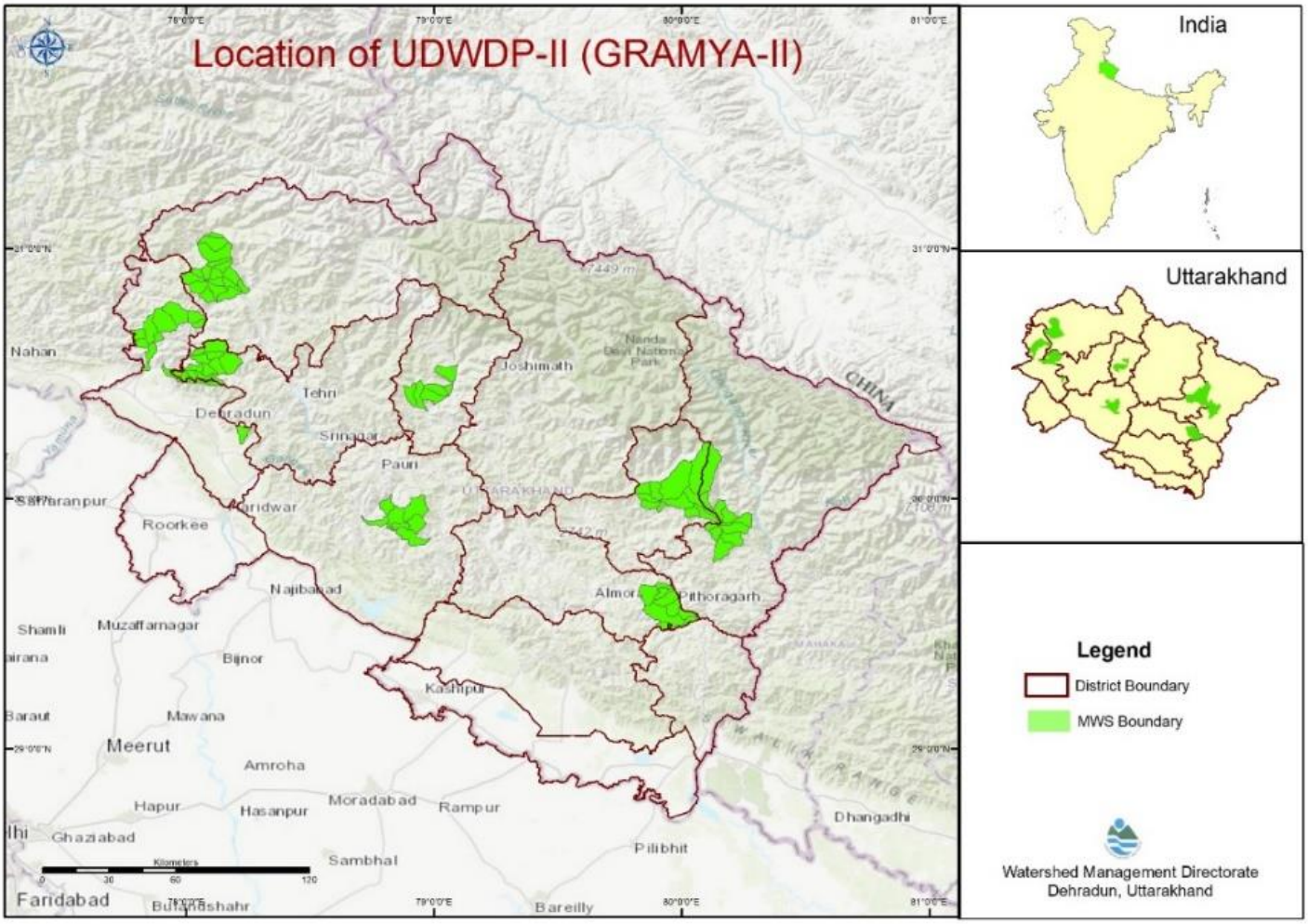

Fig. 1: Project location of UDWDP-II(GRAMYA-II)

The project aimed to enhance rural livelihoods through watershed management, climate-resilient agriculture, and digitally enabled agribusiness promotion. These interventions were particularly focused on remote and ecologically fragile hill regions where conventional market systems are often inaccessible or inefficient

Agribusiness Model and Digital Integration: The agribusiness strategy under Gramya-II was centered around the formation of Farmer Interest Groups (FIGs) voluntary associations of 5–15 farmers within a GP. These groups were consolidated into Farmer Federations (FFs) and supported through the establishment of Agribusiness Growth Centres (ABGCs). The ABGCs functioned as local hubs for aggregation, post-harvest management, value addition, and product marketing.

To enable digital integration, a digital platform *(www.gramyashree.in*) (fig-2) including mobile application "Gramyashree" was developed by the Project Management Unit (PMU), using the ODK platform (ODK Inc., n.d.). The customised app allowed farmers to enter crop production and sales data, receive advisories, and engage directly with registered vendors and buyers (fig 3). This information was synchronized with a centralized Project Management Information System (PMIS), which provided real-time inventory tracking, yield forecasting, and financial monitoring (Semwal, Vatsa and Rana, 2025). Additional data on seasonal availability was collected using Google Forms. Digital outreach was further expanded through active social media marketing on platforms such as Instagram and Facebook. These tools collectively created a digitally supported agribusiness value chain that linked smallholder production with consumer demand, both locally and in urban markets.

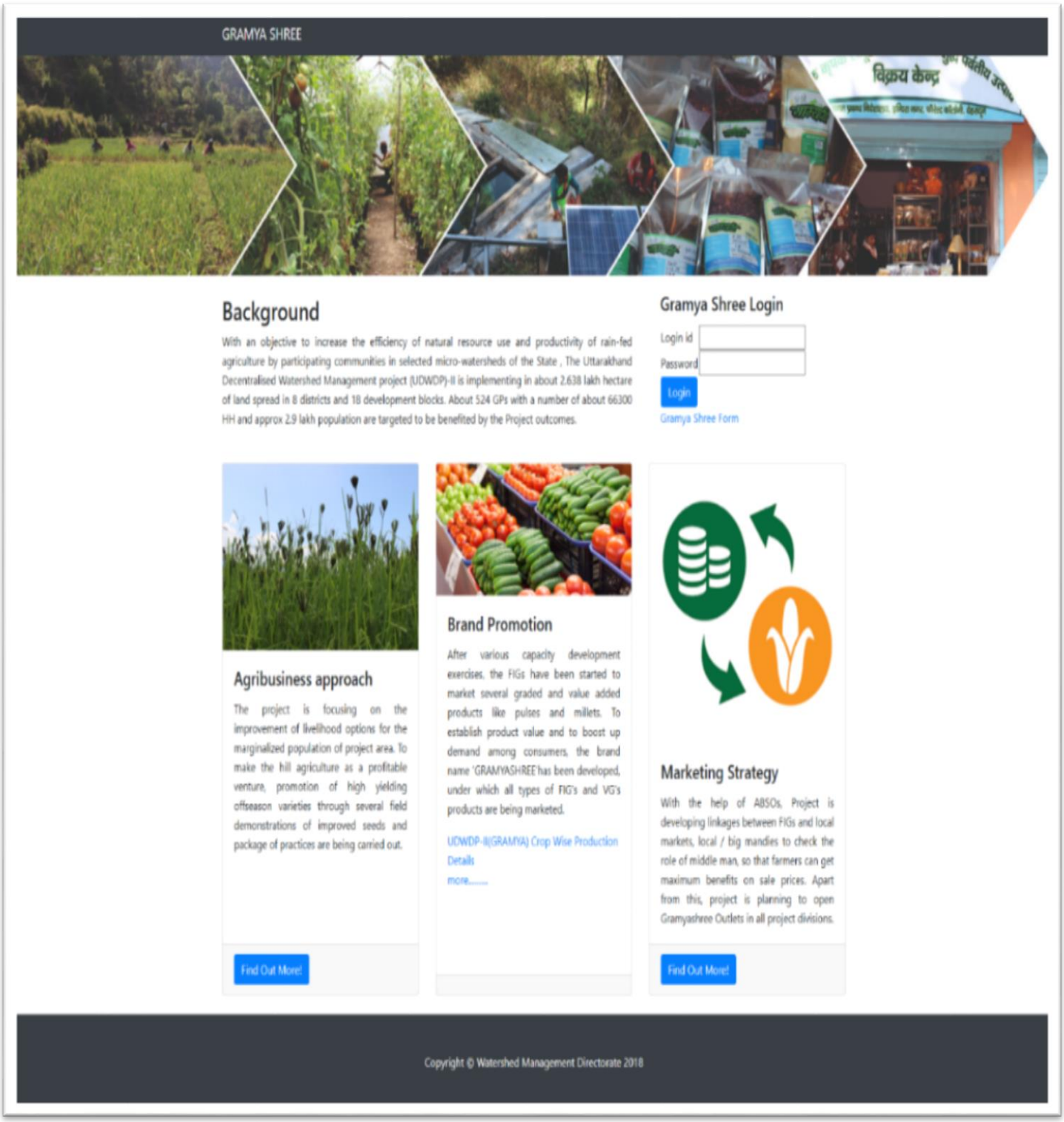

Fig. 2: Screenshot of Gramyashree digital platform

Data Collection: Primary data sources included app based analytics from the Gramyashree platform, covering metrics such as vendor registration, crop-wise production, and transaction volumes. Additional data was obtained from PMIS dashboards, internal sales registers of ABGCs, and periodic reports generated at the district and state levels. Supplementary information was drawn from project evaluation documents and official Gramya-II completion reports. Where necessary, qualitative insights were gathered through interviews with federation members, digital facilitators, and field coordinators.

Analytical Framework: The analysis was organized across three dimensions-

Descriptive Statistics: Aggregated data was used to analysed the usage of digital tools, including the number of registered farmers and vendors, the volume of produce marketed through the app, and the distribution of sales across different marketing channels.

Comparative Assessment: Digital platform performance was evaluated by comparing sales volume and income generation across Gramyashree app users, physical Gramyashree outlets, and other sales channels.

Platform Evaluation: Qualitative feedback from farmers and consumers was analyzed to assess user satisfaction across online and offline marketing platforms. The review also examined the PMU's initiatives to streamline and enhance sales channels, ensuring balanced promotion and accessibility of both digital and physical marketing pathways.

Fig.3: Step by Step data entry in Gramyashree App

Variables Considered: Key variables analyzed included--

- Volume of produce marketed via the digital platform versus traditional mandis
- Number of digital transactions per FIG or Federation
- Income realized from digital sales compared to offline counterparts
- Crop-wise price differentials linked to digital access
- Vendor and farmer engagement levels with the platform

Limitations: The effectiveness of digital adoption varied across districts due to differences in internet connectivity, digital literacy, and institutional support. While centralized sales outlets showed higher adoption rates, app-based participation was more prominent in areas with better digital infrastructure. Consequently, the findings are contextualized within the specific geographical and infrastructural conditions of Uttarakhand's hill districts.

RESULTS AND DISCUSSION

The GRAMYA-II project underscores the transformative potential of integrating digital tools within decentralized agribusiness models in hill geographies. The introduction of the Gramyashree digital platform, in combination with physical infrastructure through Agribusiness Growth Centres (ABGCs), demonstrated a replicable model for improving market access and income diversification among smallholder farmers in Uttarakhand.

The digital platform registered 7,729 farmers and 309 buyers/vendors, facilitating structured engagement through its mobile application and web interface. Over the project duration, digital sales totaled ₹20.88 million, with ₹107.47 million transacted through physical Gramyashree outlets and an additional ₹42.92 million through external markets (Table1). These figures highlight the importance of hybrid digital-physical market pathways.

Table1: Sales Performance by Channel (GRAMYA-II)

Sales Channel	Amount (₹ million)	% Contribution
Gramyashree Outlets	107.47	62.78%
Other External Markets	42.92	25.07%
Digital Sales (App-based)	20.88	12.20%
Total Sales	**171.27**	**100%**

Furthermore, analysis of the potential marketable surplus from project-supported crops. suggests an untapped value exceeding ₹8,128 million (Table 2), if full-scale digital integration and cluster-based market mobilization are achieved. These findings reinforce the scalability of the model and the economic potential of digitally integrated agribusiness in hill states.

Table2: Adoption and Participation Metrics

Metric	Value
Registered Farmers (App)	7,729
Registered Vendors/Buyers (App)	309
Functional Agribusiness Growth Centers (ABGCs)	10
Functional Farmer Federations	21
Potential Marketable Value (Full-scale)	**₹8,128 million**

The Gramyashree app's operational design was particularly suited to low-bandwidth environments, ensuring its usability in remote terrain. It facilitated real-time product listing, vendor matching, and inventory tracking, which proved critical in synchronizing production with demand especially for perishable and value-added goods.

The Farmer Federations (FFs) and Agribusiness Growth Centres (ABGCs) played an essential intermediary role, linking digital tools with physical service delivery. The ABGCs offered packaging, grading, and primary processing facilities, while also serving as collection and distribution hubs for FIGs (Farmer Interest Groups). These centers ensured product quality and brand consistency under the single-brand "Gramyashree", which gained visibility both in local and urban markets, as well as tourist routes.

The integration of the Project Management Information System (PMIS) enabled granular tracking of income, stock movement, seasonal forecasting, and federation level analytics (fig 4). Simultaneously, use of social media (e.g., Facebook, Instagram) expanded brand reach, while the centralized portal (gramyashree.in) enabled direct-to-consumer sales.

Compared to traditional mandi systems, which are prone to logistical inefficiencies and price volatility, the digital platform introduced transparency in price discovery and reduced farmers' dependency on intermediaries. Farmers could negotiate prices directly and retain a greater share of consumer-end value.

Importantly, GRAMYA-II illustrates that digital tools are not standalone solutions; their effectiveness is maximized when embedded within supportive institutional ecosystems such as federations, ABGCs, local governance bodies, and market-oriented clusters.

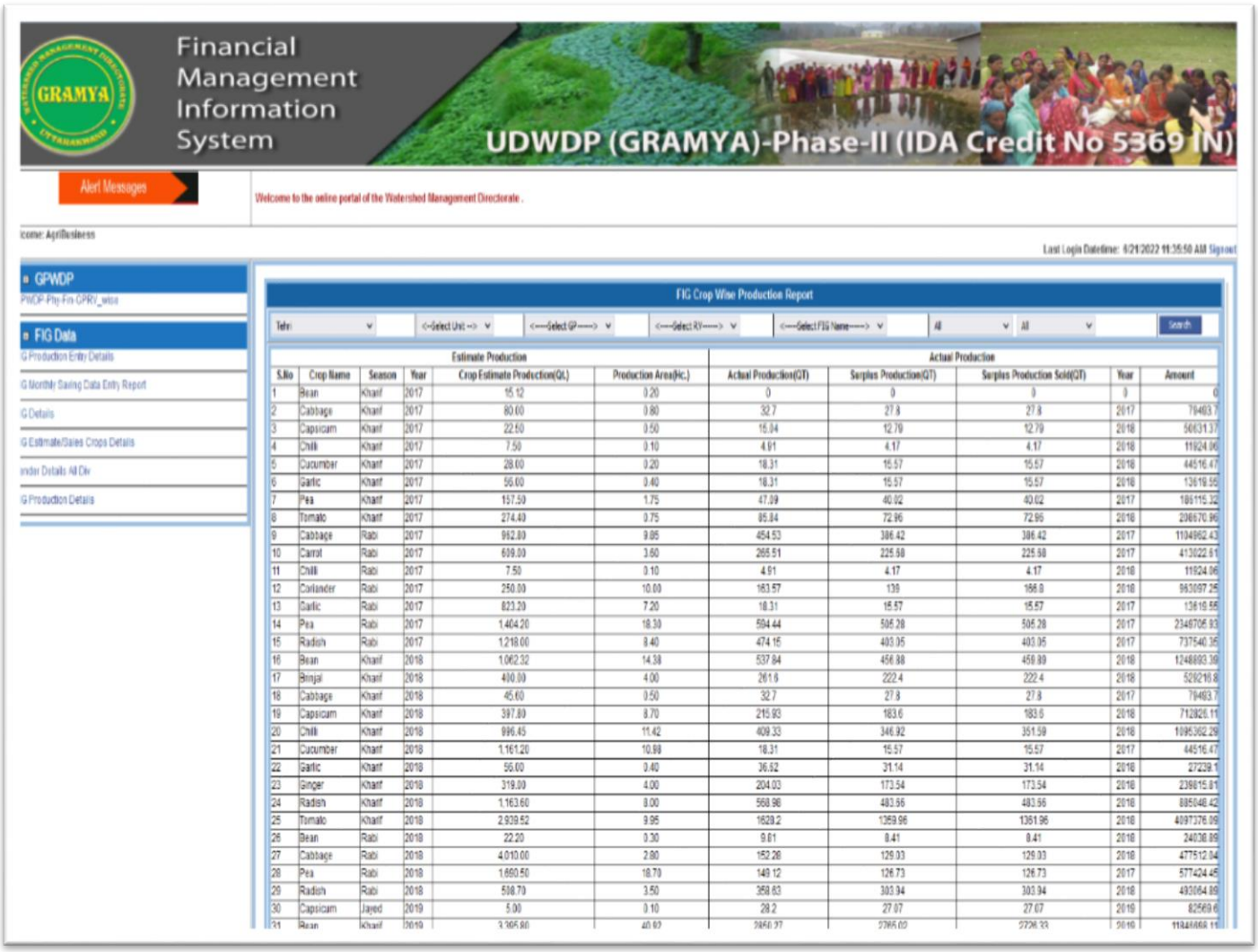

Fig. 4.: Aggregation of Agribusiness data in PMIS GRAMYA-II

CONCLUSION

The agribusiness strategy implemented under the GRAMYA-II project reflects a successful convergence of digital innovation, community-based aggregation, and decentralized value chain development in the context of

Himalayan agriculture. By integrating the Gramyashree platform with a robust institutional framework comprising Farmer Interest Groups (FIGs), Federations, and Agribusiness Growth Centres farmers transitioned from isolated, subsistence-oriented production to a more organized and digitally enabled agribusiness ecosystem.

The platform significantly improved market access by connecting farmers directly to vendor networks and institutional buyers. Transparent digital transactions enhanced price realization, while value addition through processing and packaging at growth centres contributed to brand visibility and higher consumer trust. These advancements were further reinforced by the scalability of the model, made possible through federated structures and mobile-based connectivity, even in low-infrastructure environments.

The digital transformation promoted wider developmental outcomes in addition to transactional efficiency. These included a measurable rise in farmer incomes, a reduction in post-harvest losses, and an increase in formalized trade through federated systems. However, sustaining and scaling these gains requires strategic attention to several areas. Strengthening quality assurance systems will be essential for maintaining consistency across decentralized production clusters. Equally important is the implementation of unified branding strategies to ensure coherence and recognition across diverse product lines Building digital literacy among farmers and enhancing last-mile infrastructure will further improve adoption.

Despite these achievements, several challenges remain. The pace of digital adoption varies significantly across locations, often influenced by connectivity, literacy, and institutional capacity. Inconsistencies in product quality and the lack of standardized branding also pose limitations to market expansion. Addressing these gaps will be crucial for adapting and replicating it in other hill and rainfed contexts, where climate-resilient, digitally integrated agribusiness models are increasingly needed.

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Competing Interests

The Authors have declared that no competing interests exist.

Authors Contributions

Vikas Vatsa conceptualized the study, designed the research framework, and prepared the initial draft of the manuscript. Manoj Semwal and Vijaypal Singh Rana developed the digital platforms, managed data collection and analysis, and contributed to the interpretation of results. All authors reviewed, refined, and approved the final version of the manuscript.

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