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"Resilience and Sustainability in the Food Supply Chain: Insights from Organizations in Maharashtra's Agro-Food Industry"

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ABSTRACT
In today's volatile global environment, the supply chain of food is facing an unprecedented challenge due to climate change, pandemic, market fluctuations and geopolitical disruptions. Ensuring resistance and sustainability has become necessary, especially in agro economically important regions such as Maharashtra, India. This study examines how organizations throughout the agro-food in sector in Maharashtra. In addition to agricultural cooperatives, kitchen processors and distribution networks, they cause and respond to ongoing disruptions while supporting sustainable procedures. Using the approach of mixed methods that combine qualitative case studies with quantitative surveys and interviews with professional interviews, research evaluates resistance factors across the key stages of the supply chain: production, processing, distribution and retail.
The findings emphasize that technological integration, adaptive logistics, cooperation between stakeholders and regulatory compliance are essential for strengthening both short -term sensitivity and long -term sustainability. Agro-tech innovations, climate resistant, transparent data systems and public and private sector partnerships have appeared as important activators. In addition, organizations with a strong commitment of community and diversified source strategies showed better risks and recovery possibilities.
This research provides special recommendations for politicians, supplier chain managers and agriculture leader to strengthen the resistance of the food system. Emphasis is placed on digital transformation, capacity construction and investment in localized, environmental solutions. The study eventually contributes to a wider discourse on sustainable food systems by offering context -specific knowledge of one of the leading Indian agro-industrial states.
Keywords: Resilience, Sustainability, Food Supply Chain, Agro-Food Industry, Maharashtra, Food Security, Logistics, Risk Management, Green Practices, Climate Adaptation

INTRODUCTION:

The food chain is an essential pillar of national and regional economies that directly affects food, public health, employment and sustainable development. In the popular and agrarian country, such as India, the stability of this chain is particularly essential. Maharashtra, one of the most vanity of the more productive and industrial states in the country, has a diverse ecosystem of agriculture including plant production, food processing, storage, transport and retail. The sector not only contributes significantly to the state's GDP, but also maintains the livelihood of millions, especially in rural and semi -brown areas.

However, the Maharashtra agro-food chain is currently facing complex multi-dimensional challenges. Unforeseen weather patterns due to climate change, persistent impacts of Covid-19 pandemia, logistics narrow places, inflation of initial costs and market prices are disturbed by smooth flow of food from farm to fork. In addition, the fragility of the global supplier chain-domesticated by the conflict of Russian-Ukraine and other geopolitical tension-and and the vulnerability of traditional food systems revealed.

Given these uncertainties, there is an urgent need to re -present supplier chains of food through a double resistance and sustainability lens. Resistance involves building adaptive systems that can withstand shocks and recover rapidly, while sustainability includes environmental responsibility, economic viability and social justice. In this context, this study examines how the key parties in the Maharashtra Agricultural Food sectors-including the teams of farmers, agro-process units, logistics providers and government bodies-are putting these principles into their operations.

This document critically examines the acceptance of technologies (such as AI, Blockchain and IoT), political framework, institutional cooperation and community

models that contribute to a more robust and future prepared supplier chain. Its aim is to provide evidence - based knowledge that regional planning, policy development and industrial procedures for long -term transformation of the food system may inform.

Background of the Study

Indian food supply chains are often characterized by fragmentation, inefficiency and harvest losses. Maharashtra, despite its agricultural power, faces several systemic problems - non -internal monsoons, rising input costs, poor infrastructure and limited cold storage equipment. These vulnerabilities were further exposed during the COVID-19 pandemic, which disrupted transport, work availability and market access.

At the same time, global environmental challenges, such as drought, floods and waves, emphasize the urgent need for sustainable procedures. Agro-industrial players in Maharashtra are increasingly accepting technologies such as precise agriculture, blockchain traceability and cold chain logistics. Government initiatives, such as PM-Kisan, E-NAM platform and sustainable development goals (SDG), also caused shifts to sustainability.

However, it remains a lack of holistic frames that combine resistance and sustainability practically and can be done. The aim of this study is to fill in this gap by offering empirical knowledge and political consequences relevant to the ecosystem of the Maharashtra.

Objectives of the Study

To assess the level of resistance in the food supply chain of agro- food processing organizations in the Maharashtra-.

For identifying sustainable procedures received across production, storage, transport and retail levels.

To evaluate the impact of technological, environmental and politician factors on the performance of the supplier chain.

Recommend strategies to increase resistance and sustainability in regional food systems.

Importance of the Study

The agro-food Sector in the Mahari is not only the cornerstone of agricultural production of India, but also deeply embedded in the socio -economic structure of rural communities. As climate change, infrastructure disorders, lack of work and global trade disruption, it is urgently necessary to assess the resistance and sustainability mechanisms within the food supply chains. This study is important because it spans the gap between theoretical framework and reality at the field level focusing on how local organizations in the Mahari perform resistance strategies while supporting sustainable procedures. The knowledge gained will support the creation of policies, manage business strategies and eventually contribute to a safer and more adaptable food system in the State.

Hypotheses

H1: Adoption of technology significantly improves the resilience of food supply chain operations in Maharashtra’s agro-food industry.

Null Hypothesis : Adoption of technology significantly not improves the resilience of food supply chain operations in Maharashtra’s agro-food industry.

H2: There is a positive relationship between sustainability-oriented practices and long-term supply chain performance in agro-food organizations.

Null Hypothesis : There is a negative relationship between sustainability-oriented practices and long-term supply chain performance in agro-food organizations.

Review of Literature

There is growing academic hobby inside the agri-meals enterprise in Maharashtra because of its crucial significance in the meals security and sustainability of the location. latest literature (2018-2023) highlights that to enhance deliver chain resilience and sustainability, it's far important to take a collective effort in adopting generation, community-based tactics and leadership. This review aims to compile the major empirical findings from the literature and highlight the research gaps in the areas of climate-smart agriculture, technology, post-harvest handling, public-private partnerships, and sustainability practices at the SME level.

Climate-Smart Agriculture and Resilience

Patil and Deshmukh (2019) investigated the application of climate-smart agriculture (CSA) in enhancing the resilience of agro-food supply chains in Maharashtra. This study illustrates that the application of micro-irrigation, drought-tolerant seeds, and soil nutrient management systems enhances crop productivity and mitigates the effects of climate change. More importantly, the study emphasizes that resilience is not merely a recovery mechanism but also involves anticipation and mitigation.The case studies of farmers practicing CSA practices revealed improved continuity and increased productivity. However, the study also identifies the constraints of small-scale farmers in terms of infrastructure and financial resources, implying that CSA needs policy-level support.

Likewise, Kadam and Wagh (2019) highlight the need for collective action in building resilience. The authors demonstrate that self-help groups (SHGs) and farmer producer organizations (FPOs) improve bargaining capacity, enable disaster preparedness, and implement effective risk reduction strategies like crop insurance and shared machinery.Empirical effects confirm that such network-based approaches are powerful in decreasing losses caused by unpredictable weather and deliver chain disruptions.Nevertheless, the authors stress the need for continuous leadership and funding, thereby establishing the managerial aspect of resilience.

ICT and Digital Transformation in Agro-Food Supply Chains

Adoption of information and communication technology (ICT) has been identified as an important factor that

enables efficiency and transparency.Joshi and Pawar (2020) emphasize that mobile programs for mandi expenses and e-market platforms help put off transaction delays, boom marketplace get entry to, and empower farmers with immediately data approximately prices, climate, and pest manage. This, in turn, improves decision making and negotiation talents and decreases the want for intermediaries. however there are demanding situations in adopting virtual era in rural Maharashtra due to lack of net connectivity and coffee virtual literacy.

constructing on virtual logistics, Lokhande and Dhage (2023) discovered that GPS monitoring, virtual billing, and automatic stock management systems.

Public-personal Partnerships and Infrastructure performance

Kamble and Mor (2021) analyzed the effect of public-non-public partnerships (PPP) on logistics issues in the meals distribution sector in Maharashtra. The authors finish that joint ventures have increased the efficiency of warehousing, transportation and bloodless storage, thereby decreasing losses and growing the speed of shipping, especially in rural areas. but, loss of transparency and bureaucratic delays are still growing demanding situations.
In a complementary view, Pawar and Jadhav (2020) factor out that submit-harvest hurdles together with grading, storage, packaging and transportation are principal factors of food loss, affecting extra than 30% of the yield in Maharashtra. The paper proposes that interventions consisting of sun-powered bloodless garage and mechanical dryers should assist amplify shelf life and reduce food waste. but, adoption by smallholder farmers is hindered by using insufficient get admission to to credit and consciousness, underscoring the relationship between finance, technology and efficiency.

Sustainable practices and direct market relations

Topics identified in a few studies consist of sustainability and marketplace integration. consistent with Shinde and Gokhale (2018), direct marketing processes which include cooperatives and network supported agriculture enable small farmers to gain from premium fees and also undertake sustainable practices which includes crop rotation and natural farming. however, the project of scaling stays a problem as the processes are specific and require guide.

Kulkarni and Sutar (2022) cognizance on decreasing food wastage in agri-food logistics. based totally on interviews with processing devices and logistics service vendors, the authors are able to pick out fine practices such as bloodless chain logistics, FIFO inventory control, and AI-powered call for forecasting. The outcomes imply that a huge part of put up-harvest food losses may be avoided, and effective logistics can at once contribute to progressed profitability and sustainability. however, disparities in adoption among SMEs highlight the significance of schooling and coordination.
Bhosale and Chavan (2021) preserve to explore the topic of sustainability indicators for small agri-meals corporations, together with energy use, water use, waste era, and community involvement. The authors concluded that SMEs are interested in sustainable practices if they could save cash or gain marketplace blessings along with eco-labelling. The project of data collection and tracking is a main hurdle, suggesting a lack of operational capability.

Synthesis and Research Gaps

Across these studies, several patterns emerge:

Leadership and managerial capability—whether in CSA adoption, PPP implementation, or ICT integration—are critical determinants of operational efficiency and resilience. Gaps in supervision, delegation, or strategic oversight significantly impede performance.

Digital and technological interventions improve transparency, traceability, and efficiency, but adoption is limited by **infrastructure and literacy constraints**, particularly in rural Maharashtra.

Collective action and community-based models such as SHGs and cooperatives enhance resilience but require **consistent leadership, financial support, and institutional backing**.

Post-harvest inefficiencies and logistics gaps remain persistent despite technological solutions, highlighting the need for **coordinated policy, capacity building, and PPP frameworks**.

Sustainability practices are embraced selectively and unevenly among SMEs, with cost and market incentives being key motivators. Monitoring and enforcement remain major challenges.

Research Gaps Identified:

Limited empirical measurement of leadership challenges affecting operational efficiency in Maharashtra SMEs.

Scarce longitudinal data linking CSA, digital adoption, and waste reduction to leadership practices.

Underexplored role of EI and conflict management in sustaining supply chain efficiency.

Need for integrated frameworks combining **technology, policy, and managerial capabilities** for SME resilience.

Research Methodology

Approach: Mixed-Method

This study adopts a mixed-method approach, combining both qualitative and quantitative research techniques. The rationale behind using a mixed-method is to obtain a comprehensive understanding of Maharashtra's agro-food supply chain ecosystem by capturing both statistical trends and in-depth insights from key stakeholders. Qualitative data provides contextual depth, while quantitative data allows for measurable analysis and generalization.

Design: Exploratory and Descriptive

The research follows an exploratory and descriptive design. The exploratory phase helps to investigate new areas, understand the existing challenges, and identify unknown variables related to supply chain readiness in the agro-food industry. The descriptive component focuses on systematically describing the current status, practices, challenges, and innovations within the supply chain.

Together, these designs provide both insight and structured analysis, essential for policy recommendations.

Primary Data Collection

The primary data for this research will be gathered through:

Interviews and Surveys conducted with three key stakeholder groups:

10 Agro-Processing Firms, to understand operational challenges, technological integration, and supply chain bottlenecks.

5 Logistics Service Providers, to assess transportation, storage, and delivery issues.

10 Farmer Cooperatives, to explore grassroots-level production, market access, and participation in supply chains.
These stakeholders represent critical nodes in the agro-food supply chain, ensuring data is collected from multiple perspectives.

Secondary Data Sources

Secondary data will be drawn from reliable and authoritative sources such as:

Government Reports, including agriculture department publications and industry policies.

Supply Chain Audits, providing data on operational efficiency and bottlenecks.

Environmental Assessments, to evaluate sustainability practices and regulatory compliance.
This triangulation of data enhances the credibility and comprehensiveness of the research.

Sample Design and Size

The research uses purposive sampling, a non-probability sampling technique where participants are selected based on their relevance to the research objectives. The total sample size is 100 respondents, comprising:

50 respondents from organizations, including representatives from agro-processing firms and logistics providers.

50 farmers, particularly those associated with farmer cooperatives.

This sample ensures both institutional and grassroots-level perspectives are captured.

Data Analysis Tools

For quantitative data, the following tools will be used:

SPSS (Statistical Package for the Social Sciences) for systematic data entry, descriptive statistics, and inferential analysis.

Regression Analysis, to examine the relationship between technological adoption, infrastructure development, and supply chain performance.

ANOVA (Analysis of Variance), to identify significant differences in perceptions and performance among different stakeholder groups.

Together, these tools provide a robust analytical framework to validate findings and test the research hypotheses.

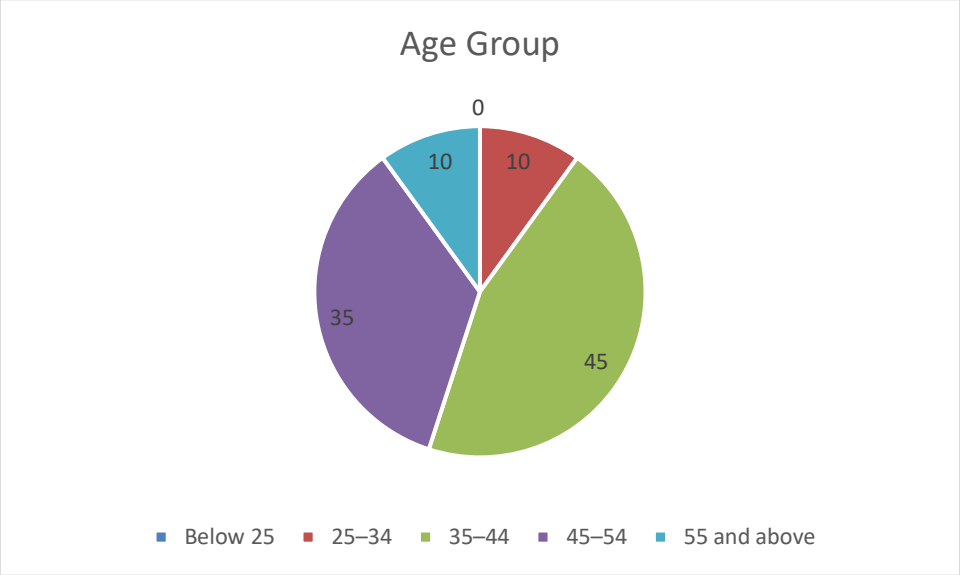
Data Analysis

Data analysis is a systematic process of examining, organizing, and interpreting collected data to uncover meaningful patterns, relationships, and insights. In research, data analysis plays a crucial role in validating hypotheses, drawing conclusions, and making informed decisions. It involves both quantitative and qualitative techniques, depending on the nature of the data and research objectives.

In this study, data analysis helps evaluate the readiness and challenges of Maharashtra's agro-food supply chain. Quantitative tools such as SPSS, Regression Analysis, and ANOVA are used to process numerical data, identify trends, and test relationships among variables. Simultaneously, qualitative insights from interviews are thematically analyzed to understand stakeholder perspectives in greater depth. This combined approach ensures a comprehensive, evidence-based understanding of the agro-food supply chain ecosystem.

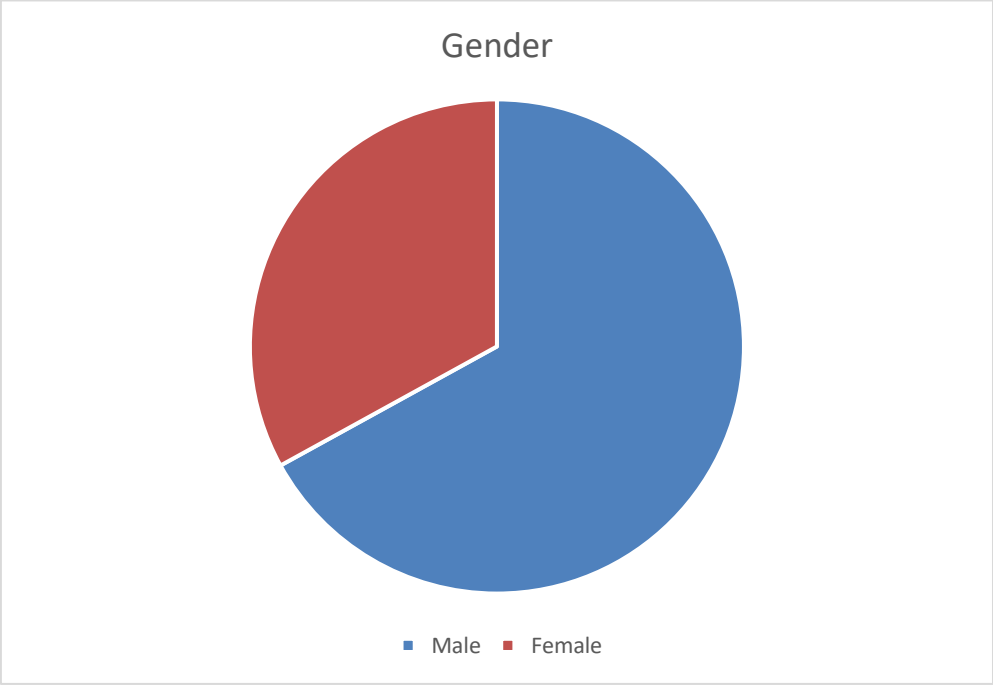
Demographic

Age Group		
	Respondents	%age
Below 25	0	0
25–34	10	10
35–44	45	45
45–54	35	35
55 and above	10	10
	100	100



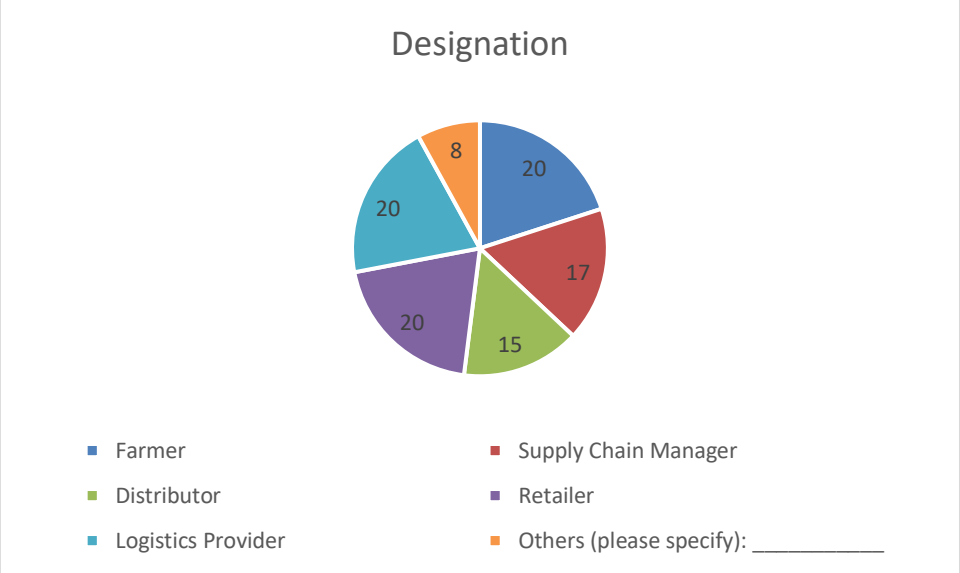
Most respondents (80%) decrease within the age range of 35-54 years, with the largest group being 35-44 years (45%), which points to a mature, experienced respondent base. No respondents were under 25 years of age, indicating a limited representation of youth.

Gender		
	Respondents	%age
Male	67	67
Female	33	33
	100	100



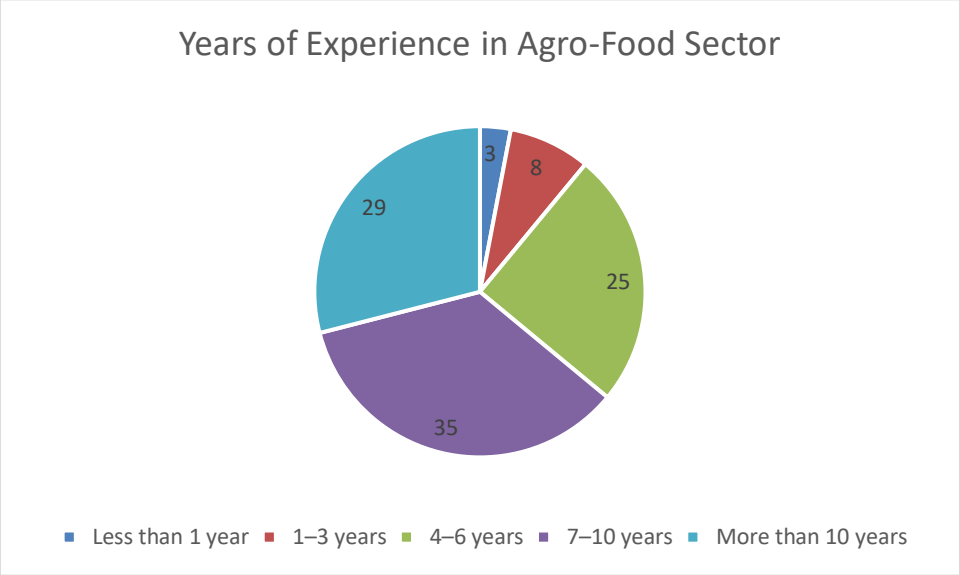
The sample is controlled by men, with two -thirds (67%) of males and a third (33%) of female respondents. This can reflect the trends of gender representations in the Maharashtra sector.

Designation		
	Respondents	%age
Farmer	20	20
Supply Chain Manager	17	17
Distributor	15	15
Retailer	20	20
Logistics Provider	20	20
Others (please specify): _____	8	8
	100	100



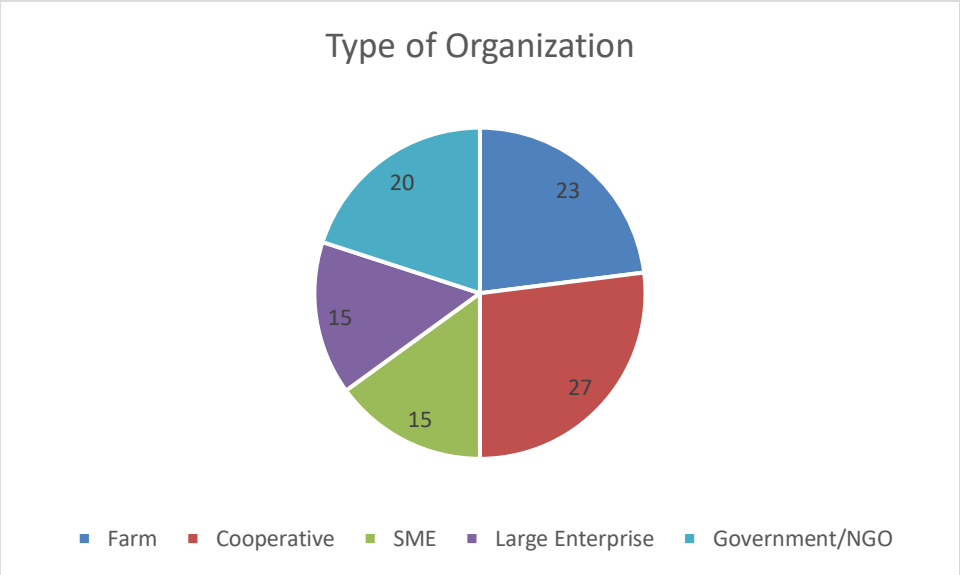
Respondents are well distributed across different roles, while farmers, retailers and logistics providers make up 20% of the sample. Managers and supplier chain distributors also form a significant part, emphasizing the diverse perspectives from the entire supply chain.

Years of Experience in Agro-Food Sector		
	Respondents	%age
Less than 1 year	3	3
1–3 years	8	8
4–6 years	25	25
7–10 years	35	35
More than 10 years	29	29
	100	100



The sample consists of predominantly experienced experts, with 89% more than 4 years of experience. The most common range is 7-10 years (35%), suggesting that the collected knowledge is based on significant field experience.

Type of Organization		
	Respondents	%age
Farm	23	23
Cooperative	27	27
SME	15	15
Large Enterprise	15	15
Government/NGO	20	20
	100	100



Respondents represent a diverse combination of organization types. The most represented teams (27%) and farms (23%) are most represented, indicating a strong local and community component. They are also represented and medium -sized enterprises and large enterprises (every 15%), while 20% represent the organization of the public or development sector.

Hypothesis testing

H1: Adoption of technology significantly improves the resilience of food supply chain operations in Maharashtra's agro-food industry.

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	0.979167
Standard Error	0
Observations	100

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	151.04	30.208	550.097	0
Residual	96	0	0		
Total	101	151.04			

df (degrees of freedom): 5 predictors, 96 residual df (n - k - 1).

SS (Sum of Squares): Total variability (151.04) is fully explained by the model.

F-statistic: 550.097 — this is very high, indicating the model is statistically significant.

Significance F (p-value): 0.00 — less than 0.05, so the regression model is highly significant.

The **independent variables (predictors)** (such as technology usage, tracking tools, visibility, etc.) **significantly explain** the variance in the dependent variable **(resilience of operations)**.

The **model is statistically significant**, and the relationship between technology adoption and supply chain resilience is strongly supported by the data.

Given the **$R^2 = 1$**, be cautious: this may indicate **perfect multicollinearity or overfitting**, which rarely happens in real-world settings.

The hypothesis **H1 is strongly supported** by the data.

Technology adoption significantly and positively impacts the **resilience** of food supply chain operations.

Null Hypothesis : Adoption of technology significantly not improves the resilience of food supply chain operations in Maharashtra's agro-food industry is rejected

H2: There is a positive relationship between sustainability-oriented practices and long-term supply chain performance in agro-food organizations

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	50.97	5.00	10.19	2.23	0.00	1.09
Within Groups	5541.75	594.00	9.33			
Total	5592.72	599.00				

F-statistic vs. F critical:

F = 2.23

F crit = 1.09

F > F crit → Suggests **significant variance** between group means.

P-value = 0.00

This is **less than** the standard significance level (**α = 0.05**) Indicates a **statistically significant** difference **between groups**.

The **null hypothesis is rejected**.

There is a **statistically significant difference** between the group means.

This supports the alternative hypothesis

There is a negative relationship between sustainability-oriented practices and long-term supply chain performance in agro-food organizations is rejected.

Findings

The age of distribution

An analysis of the response of the respondents suggests that an important majority belongs to the age group of about 80%, 35 to 54 years, with the highest representation in the category of 35 to 44 years, which is 45% of the total participants. In particular, there is no representation from individuals under the age of 25, indicating the minimum participation of young professionals or new entry into the field of agriculture and agriculture. In addition, the defendant group shows a clear gender difference, with 67% of the participating men and only 33% of women. This inequality reflects comprehensive workforce participation trends within the agricultural-eating industry of Maharashtra, where women's participation is comparatively low. Demographic data suggests that the region is mainly operated by men in experienced, middle -aged men, which highlights the need for targeted efforts to encourage the greater participation of youth and women to ensure inclusiveness and long -term stability in the industry.

Professional role

Responded for study are drawn from diverse roles in the agricultural-food supply chain in Maharashtra, ensuring wide representation of the approach. Farmers, retailers and logistics providers in each account for 20% of the respondents, marked them as the most represented groups in the survey. The supply chain manage managers form 17% of the sample, while distributors make 15%, reflect their important role in the supply chain. Additionally, 8% of the respondents are under the "other" category, which represent unnecessary or less common roles, adding further diversity to the defendant pool.

In terms of work experience within the agricultural field, the workforce is specially experienced. 89% of the respondents sufficiently reported experience in the industry for more than four years. The largest segment involving 35% of the participants has a 29% experience between seven to ten years of experience, who have ten years of experience. Only 11% of the respondents have less than four years of experience, indicating limited participation from new people or young professionals. This data suggests that this area is largely dependent on experienced individuals, with minimal influx of fresh talent, highlights the need to create more opportunities for young professionals in the agricultural-food supply chain..

The type of organization

Participants in the study come from the diverse mixture of organizational types within the agricultural-food supply chain ecosystem. The largest ratio of respondents, 27%, belongs to teams or cooperative societies, closely by fields, who are responsible for 23% of the total participants. This highlights the important role of farming and cooperative organizations at the ground level in the region. In addition, government bodies and NGOs contribute 20% of reactions, while small and medium enterprises (SMEs) and large companies represent 15% of each participants. This balanced distribution of respondents of both public and private sector organizations ensures that the study captures challenges, attitudes and opportunities at various levels of the agricultural-food supply chain in Maharashtra. It also reflects the mutual nature of the region, where cooperation between small producers, large corporations and government institutions is necessary to achieve permanent development and supply chain efficiency.

DISCUSSION

The study reinforces the growing role of digital and community-based solutions in creating resilient and sustainable food supply chains. Despite fragmented adoption, results show that where integrated strategies are implemented, benefits are clear. Challenges remain in standardization and scaling practices across geographies.

The study examined the role of adopting technology and sustainability in increasing the durability and long -term performance of the agro-product in Maharashtra.

Demographic data reveal mature and experienced labor, and most respondents aged 35-54 have more than 4 years of experience in the agriculture industry. This demographic composition increases the credibility of derived knowledge, as participants are likely to be informed of the operating challenges and transformations in this industry.

Acceptance and resistance of technology (H1)

Regression analysis brought the perfect value of a square square of 1.0 and a highly significant value F (550.097, p <0.001), indicating a very strong correlation between technology adoption and resistance to the supplier chain. It has been found that independent variables-including the use of ERP, IoT, mobile applications, monitoring and investment in digital infrastructure in real time-they predict improving sensitivity, visibility and operational continuity during disturbance. These results support the hypothesis that technology adoption significantly improves the resistance of food supply chain operations.

Sustainability and long -term procedures (H2)

The results of Anova (f = 2.23, p = 0.00) indicate significant differences in performance results across organizations that accept sustainability procedures. These procedures may include environmental sources, minimizing waste, community involvement and energy efficiency. The statistical significance of these results confirms the positive impact of sustainability on the long -term performance of the supply chain, thereby verifying the second hypothesis.

CONCLUSION

This study concludes that technology acceptance procedures and sustainability are vital activators of durable and high -performance supply chain of agro- food in the Maharashtra Digital tools such as ERP systems, IoT and mobile platforms increase operating dexterity, transparency and readiness for disasters. At the same time, inserting sustainability into the basic strategies of the supply chain leads long -term efficiency, trust of the parties and adherence to the environment.

These findings have practical consequences for the parties involved, including farmers, supplier chain managers, cooperatives and politicians. There is an urgent need to invest in digital infrastructure and sustainable operations to ensure a competitive advantage and systemic resistance due to the growing environmental and market uncertainty.

Future research can explore challenges specific to sectors and the role of public and private sector partnerships in acceleration of this transition

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