



## Research Article

# CHALLENGES AND OPPORTUNITIES FOR AGRI-TECH STARTUPS IN DEVELOPING ECONOMIES

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**Abstract:** The agrarian sector in developing economies is at the cusp of a technological revolution facilitated by agri-tech startups. This paper delves into the challenges and opportunities these startups encounter, elucidated through a detailed examination of the Indian agri-tech ecosystem. Key challenges identified include technology adoption barriers, funding constraints, regulatory hurdles, infrastructural deficits, skill and capacity building needs, and issues in market access and supply chain integration. On the flip side, the agri-tech domain is ripe with opportunities for innovation, public-private partnerships, access to new markets, promoting sustainable agriculture, and enhancing education and awareness among the farming community.

Several Indian agri-tech startups are navigating these challenges while capitalizing on the opportunities, as demonstrated through case studies. A comparative analysis underscores the transformative potential of agri-tech startups in revamping the agricultural landscape of developing economies, whilst highlighting the requisite supportive frameworks to foster their growth. The findings of this review are poised to inform policy, investment, and entrepreneurial initiatives, paving the way for a sustainable and technologically advanced agricultural sector in developing economies. Through a blend of policy support, innovation, and stakeholder collaboration, agri-tech startups can significantly contribute towards achieving food security, economic resilience, and environmental sustainability in the agricultural domain.

**Keywords:** *Agri-tech Startups, Developing Economies, Opportunities, Challenges, Innovations*

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## Introduction

The intersection of agriculture and technology through startups is evolving as a decisive force in advancing agricultural productivity and sustainability, particularly in developing economies. With a global investment summing to \$10.6 billion in 2022, agri-tech startups continue to attract substantial financial backing despite a 13% decrease from 2011. This sector has witnessed a remarkable 20-fold growth in venture capital investments over the last decade [1], signifying its escalating importance in addressing food security [2] amid a growing global population and climate adversities [3].

The trend towards investing in agri-tech startups is particularly notable in emerging markets. For instance, the Middle East saw a growth from 1% to 4% in agri-tech deals from 2021 to mid-2022, while Africa experienced a rise from less than 1% to around 6% over the same period. Such trends underline the burgeoning recognition of agri-tech as a catalyst for overcoming traditional agricultural challenges, whilst unlocking new potentials for economic growth and sustainability in developing regions. Furthermore, amidst the increasing investments and deal flows, exemplars of successful agri-tech enterprises are emerging. A case in point is the Abu Dhabi-based Pure Harvest Smart Farms, which, with \$272 million in funding, became the second-most-funded startup in the Middle East and North Africa in 2022 [4]. This venture operates three greenhouses in the UAE and has additional projects underway in Kuwait and Saudi Arabia. Such success stories herald the potential of agri-tech startups in transforming the agricultural landscape of developing economies, making an exploration of the associated challenges and opportunities both timely and pertinent [5]. This review aims to dissect the challenges and opportunities faced by agri-tech startups in developing economies, providing a comprehensive understanding that could guide stakeholders in fostering a conducive ecosystem for agri-tech innovations.

## Background on agriculture in developing economies

Agriculture is pivotal for nutrition, income, and combating hunger, significantly impacting economic and social spheres. Over recent decades, global crop production has escalated due to expanded agricultural land and enhanced crop yields. The variety in diets has broadened globally, transitioning from staple crops to a diverse range including legumes and fruits. Historically localized, agricultural production now has a pronounced international presence, with substantial food trading internationally, especially benefiting lower-income nations through revenue from 'cash crops

In developing economies, agriculture remains a crucial sector, employing a large segment of the population and significantly contributing to the Gross Domestic Product (GDP). However, these economies often grapple with challenges such as inadequate infrastructure, limited access to markets, and climate change adversities [6]. Despite these hurdles, the fusion of technology with agriculture, spearheaded by agri-tech startups, presents an avenue for addressing longstanding challenges and propelling these economies towards enhanced agricultural productivity and sustainability. The following sections will delve deeper into the specific challenges and opportunities encapsulated in this burgeoning nexus of agriculture and technology in developing economies.

Moreover, the ongoing investments and innovation in agri-tech startups reflect a broader global recognition of the transformative potential inherent in modernizing agricultural practices in developing economies. By dissecting the challenges and opportunities within this domain, this review aims to contribute a nuanced understanding that may guide policy, investment, and entrepreneurial initiatives, thereby nurturing a conducive ecosystem for agri-tech innovations and their broader adoption across developing economies.

Significance of agri-tech startups in enhancing agricultural productivity and sustainability

## Challenges and Opportunities for Agri-Tech Startups in Developing Economies

*Table-1 Opportunities available and challenges faced by Agri Tech Startups*

Aspect	Opportunities	Challenges	Examples (India)
Innovation and Technology	Development of precision agriculture technologies for optimized resource use	High upfront costs of new technologies may be prohibitive for smallholder farmers.	Agastya AgriTech: Working on microbial solutions to enhance soil fertility and crop yield.
	Implementation of smart irrigation systems for water conservation	Resistance to technology adoption due to lack of awareness or trust in new systems.	
	Automation in farming operations to save labor and increase efficiency.	Lack of technical support and maintenance services for modern agricultural technologies.	
	Advancements in biotechnology for developing disease-resistant and high-yield crops.		
Public-Private Partnerships	Policy support for agri-tech innovations through collaborative frameworks. - Resource mobilization from both public and private sectors to support agri-tech startups.	Policy uncertainty may deter investment and innovation in the agri-tech sector.	Government of Karnataka's collaboration with various agri-tech startups for developing economical viable solutions.
	Leveraging public infrastructure for better market accessibility for agri-tech products and services.	Compliance costs with varying regulations can be burdensome for startups.	
Access to New Markets	Online marketplaces connecting farmers to a wider range of buyers.	Challenges in establishing market linkages for new agri-tech products.	Over 500 active agri-tech startups working on various market access solutions including digital platforms for market linkages.
	Mobile applications providing real-time market information and aiding decision-making.	Meeting quality standards and certifications can be challenging, impacting market access.	
	Blockchain technology enhancing traceability and building consumer trust in agricultural supply chains.	Integrating with existing agricultural supply chains can be complex and requires collaboration with various stakeholders.	
Sustainable Agriculture	Technologies enabling resource optimization and waste reduction.	Weather uncertainties affecting agricultural output and adoption of sustainable practices.	Several startups working on smart irrigation and organic farming practices to promote sustainability.
	Development of climate-resilient agricultural practices.	Challenges in adopting sustainable farming practices due to lack of awareness or financial constraints.	
	Tech-enabled organic farming practices for soil and water conservation.		
Education and Awareness	Digital platforms offering educational resources and training to farmers.	Lack of awareness about the benefits of new technologies and sustainable practices.	Digital platforms and mobile applications providing real-time market information, training, and community forums for knowledge sharing among farmers.
	Virtual Reality (VR) simulating agricultural scenarios for practical learning.	Insufficient education on how to use new technologies effectively.	
	Mobile applications and online forums for knowledge sharing among farmers and stakeholders.		

The ascent of agri-tech startups is pivotal in bridging technological gaps, thereby elevating agricultural productivity and sustainability. Investments soared to \$10.6 billion in 2022, underscoring global confidence in agri-tech's potential. These startups usher in innovations like precision farming and smart irrigation, optimizing resource use, and minimizing environmental impact. Furthermore, agri-tech facilitates data-driven decisions, enhancing yield and profitability. The global venture capital in agri-tech and food technology burgeoned 20-fold over a decade, reflecting the sector's escalating significance in ensuring food security amid climate adversities and a burgeoning global populace.

Moreover, agri-tech startups are instrumental in catalyzing the shift towards more sustainable agricultural practices by promoting the adoption of technologies that reduce greenhouse gas emissions, conserve water, and minimize the use of harmful pesticides. They also play a vital role in enhancing market access and supply chain efficiencies for farmers in developing economies, thereby fostering economic resilience and livelihood improvements [7,8]. This review seeks to elucidate the multifaceted challenges and opportunities encountered by agri-tech startups in developing economies, with an aim to foster a conducive ecosystem for their growth and the broader adoption of sustainable agricultural practices.

Through a comprehensive examination of recent literature and case studies, this review aspires to provide insights that could inform policy frameworks, encourage informed investments, and stimulate entrepreneurial initiatives in the agri-tech sector. The subsequent sections will delve into a detailed analysis of the prevailing challenges and opportunities, aiming to contribute to the broader discourse on fostering a sustainable and technologically advanced agricultural sector in developing economies.

### Challenges

#### Technology Adoption

Technology adoption is perceived as a cornerstone for propelling agricultural productivity and sustainability, especially through the lens of agri-tech startups. However, the pathway towards extensive adoption of new technologies by farmers in developing economies is often obstructed by several factors. A predominant barrier is the lack of awareness and education regarding the benefits of new

technologies. Farmers, especially those with limited educational backgrounds, may find it challenging to understand the utility and operation of modern agricultural technologies, thereby deterring adoption [8,9].

Moreover, the financial aspect of technology adoption cannot be overlooked. The high upfront costs associated with new technologies pose a significant hurdle, particularly for smallholder farmers operating on tight budgets. Their financial constraints exacerbate the challenge of accessing modern technologies, a situation further aggravated in remote or rural areas where the availability of such technologies is scarce.

The cultural fabric of traditional farming communities also plays a substantial role in technology adoption. The deep-rooted adherence to traditional farming practices often breeds a resistance to change, hindering the adoption of modern technological solutions. This resistance is sometimes fuelled by a lack of adequate technical support and maintenance services for modern agricultural technologies, which leaves farmers apprehensive about embracing new methods. The fear of venturing into unfamiliar technological territories is further intensified by the perceived risks associated with new technologies, especially in the absence of demonstrable success stories within their communities.

All these factors amalgamate to decelerate the pace of technology adoption in the agricultural sector of developing economies. Hence, there's a pronounced need for targeted interventions to dismantle these barriers. Such interventions could include comprehensive awareness campaigns, educational programs, financial support mechanisms, and the provision of robust technical support and maintenance services. By addressing these challenges, a conducive environment can be created, fostering a more rapid uptake of agri-tech innovations, which in turn, has the potential to significantly advance agricultural productivity and sustainability.

#### Funding and Investment

Access to capital stands as a crucial pillar for agri-tech startups, fueling their ability to innovate, scale, and engender a meaningful impact within the agricultural sector. However, the journey towards attracting investment often presents a bumpy road, riddled with various challenges.

A significant deterrent stem from the high-risk perception associated with agri-tech ventures. Investors often find the agricultural sector to be riddled with uncertainties, primarily due to fluctuating market conditions and the unpredictable nature of weather patterns, which directly impact agricultural outputs.

Furthermore, the agricultural sector inherently encompasses a long-term horizon for return on investments, a facet that could be unappealing for investors in pursuit of quicker financial returns. This long-term nature of agriculture often clashes with the short-term financial outlook of potential investors, thereby creating a disconnect. Moreover, a lack of understanding or familiarity with the agricultural sector can instill a sense of hesitancy among investors. The agricultural domain, with its unique challenges and operational nuances, may appear as an enigmatic arena for investors accustomed to other sectors.

Additionally, the scenario is further complicated by the issue of insufficient collateral. Smallholder farmers and emerging agri-tech startups often find themselves in a tight spot when it comes to providing the necessary collateral to secure loans, thereby stifling their access to essential capital resources [10,11].

Addressing these multifaceted challenges necessitates a collaborative approach from various stakeholders. Creating a favorable investment climate for agri-tech startups involves dispelling the clouds of risk perception, bridging the understanding gap among investors, and establishing supportive financial mechanisms that can accommodate the collateral limitations of smallholder farmers and budding agri-tech ventures. Through concerted efforts, the financial landscape can be reshaped to become more conducive for the infusion of capital into agri-tech startups, thereby unlocking their potential to revolutionize agricultural practices and contribute meaningfully to food security and economic growth in developing economies.

### Regulatory Environment

The regulatory environment is a pivotal aspect that profoundly impacts the trajectory of agri-tech startups. At the helm of regulatory challenges is policy uncertainty. Unclear or frequently changing policies can cast a shadow of ambiguity over the agri-tech sector, often deterring investment and stifling innovation. Investors and innovators alike seek a stable and predictable policy landscape to confidently navigate their ventures.

Moreover, the burden of compliance costs cannot be understated. Startups, especially in their nascent stages, may find the high costs of complying with various regulatory stipulations to be onerous. These costs can divert crucial resources away from core activities such as research, development, and market expansion, thereby hindering the growth of these startups.

Furthermore, the market access is often dictated by the regulatory frameworks in place. Restrictive policies can act as barriers to market entry and cross-border collaborations, limiting the scope and scale at which agri-tech startups can operate. This restriction not only stifles the growth of individual startups but can also impede the collective evolution of the agri-tech sector [12].

Intellectual Property Rights (IPR) protection emerges as another critical facet of the regulatory environment. Adequate IPR protection is instrumental in fostering innovation and attracting investment, as it provides a safety net for innovators and investors to protect their inventions and investments respectively.

The culmination of these challenges underscores the urgent need for efforts to harmonize regulatory frameworks and streamline compliance processes. Such efforts are fundamental in creating a conducive environment for agri-tech startups to flourish. A harmonized and supportive regulatory environment can significantly alleviate the hurdles faced by agri-tech startups, paving the way for enhanced innovation, investment attraction, and market access [13]. This, in turn, can significantly contribute to the growth and sustainability of the agri-tech sector in developing economies.

### Infrastructure

Infrastructure stands as a bedrock for the adoption and effective deployment of agri-tech solutions, bridging the gap between innovative technologies and their practical application in the agricultural domain. A prime aspect of this infrastructure is internet connectivity, which is the lifeline for digital agri-tech solutions. However, the stark reality is that internet connectivity often dwindles in

remote and rural areas [14], the very locales where much of agriculture thrives. This digital divide hampers the accessibility and effectiveness of digital agri-tech solutions, thereby stymying the potential benefits they harbor.

Electricity, another fundamental pillar of infrastructure, is indispensable for operating modern agricultural technologies. The reliability of electricity supply can significantly impact the functionality and efficiency of agri-tech solutions, ranging from automated irrigation systems to data monitoring and analysis tools. Yet, consistent electricity supply remains elusive in many agricultural regions, posing a significant barrier to technology adoption. The essence of efficient transport and logistical support cannot be overstated, especially when it comes to facilitating market access and supply chain integration. Efficient transport systems ensure that agricultural produce can reach markets in a timely and cost-effective manner, while robust logistical support is pivotal for navigating the complex supply chains that often characterize the agricultural sector.

Moreover, a consistent water supply is at the heart of agriculture, serving as a vital resource for irrigation and other agricultural activities. The availability and management of water resources directly influence the success and sustainability of agricultural endeavors. In light of these infrastructural challenges, it becomes unequivocally clear that improving infrastructure is a prerequisite for fostering a conducive ecosystem for agri-tech startups in developing economies. An upgraded and reliable infrastructure can significantly enhance the adoption and impact of agri-tech solutions, thereby contributing to the advancement of agricultural productivity and sustainability.

### Skill and Capacity Building

Skill and capacity building emerge as crucial facets in the narrative of technology adoption within the agricultural sector. The trajectory of agri-tech startups is significantly influenced by the level of technical and business acumen harbored by both farmers and the entrepreneurs steering these startups. On one end, farmers require a solid grasp of technical skills to effectively utilize the agri-tech solutions at their disposal. This technical prowess not only enables them to operate modern agricultural technologies but also empowers them to troubleshoot minor issues, thereby reducing downtime and enhancing productivity.

On the flip side, agri-tech entrepreneurs necessitate a blend of technical and business skills to navigate the multifaceted landscape of running a startup. Technical skills are indispensable for developing and refining agri-tech solutions, while business acumen is paramount for managing operations, orchestrating finances, and marketing their innovations in a competitive marketplace. The synergy of these skills significantly influences the sustainability and growth trajectory of agri-tech startups.

Central to the endeavor of skill and capacity building are training programs. Tailored training initiatives can bridge the existing knowledge gaps, providing farmers and entrepreneurs with the requisite skills and knowledge to thrive in the agri-tech domain. These training programs can range from hands-on technical training to business management workshops, each designed to address the unique challenges and needs of the agricultural sector.

Investing in skill and capacity building is not merely a measure to enhance the competencies of individuals but a strategic step towards accelerating the growth and impact of agri-tech startups in developing economies. By nurturing a skilled and knowledgeable workforce, the foundation is laid for a vibrant agri-tech ecosystem, poised to drive innovation, enhance agricultural productivity, and contribute towards a sustainable and economically resilient agricultural sector.

### Market Access and Supply Chain Integration

Market access and supply chain integration are cardinal elements underpinning the success of agri-tech startups. The realm of market integration is often fraught with hurdles for many agri-tech startups, with establishing robust market linkages standing as a notable challenge. The quest to connect with markets, entrench a foothold, and sustain a presence is an uphill battle for many, especially amidst competitive and sometimes saturated market landscapes. Adding another layer of complexity is the endeavor to integrate with existing agricultural supply chains. This integration is not a straightforward venture but a complex undertaking that necessitates collaboration with various stakeholders.

It requires a fine-tuned orchestration of activities, ensuring that agri-tech solutions dovetail seamlessly with established supply chains, thereby facilitating a symbiotic co-existence that enhances the value proposition for all involved.

Moreover, the journey towards market access is often punctuated by the need to adhere to quality standards and attain requisite certifications. These quality thresholds, while essential for maintaining product integrity and consumer trust, pose a significant challenge for many agri-tech startups. The endeavor to meet, and possibly exceed, these standards demand a meticulous attention to quality control, often requiring investments in both time and resources.

Addressing these market integration challenges transcends mere operational tweaks; it demands the forging of strong linkages with market actors and a concerted effort to streamline supply chain processes. By cultivating relationships with key market actors and investing in processes that enhance supply chain efficiency, agri-tech startups can significantly ameliorate the challenges of market access and supply chain integration [15]. Such strategic actions are not merely instrumental for market success but are crucial for actualizing the potential impact of agri-tech innovations in developing economies. Through well-nurtured market relationships and streamlined supply chain processes, agri-tech startups are better positioned to navigate the market dynamics, contribute to agricultural value chains, and ultimately, foster a more sustainable and economically viable agricultural sector.

### Opportunities Innovation and Technology

The agri-tech sector burgeons as a crucible of innovation, presenting a plethora of opportunities to infuse technological advancements into traditional agricultural practices. Among the front runners of this innovative wave is precision agriculture, a paradigm that leverages data analytics to judiciously allocate resources and bolster crop yields. By distilling actionable insights from a myriad of data points, farmers can transcend the one-size-fits-all approach, tailoring interventions to the unique needs of each plot of land. Moreover, the dawn of smart irrigation heralds a significant stride towards water conservation—a critical need in an era grappling with water scarcity. Technology-driven irrigation systems empower farmers to meticulously manage water resources, ensuring each drop is optimally utilized to nurture crops. On another frontier, the advent of automated machinery is redefining operational efficiency within agricultural realms. Automation unveils a pathway to significant labor-saving and enhanced efficiency, allowing farmers to execute routine tasks with unprecedented precision and speed.

Biotechnology too, holds a promising torch of innovation, with its ability to engineer genetic modifications that birth disease-resistant and high-yield crops. Through the lens of biotechnology, the battle against persistent agricultural foes such as pests and diseases gains a formidable ally, significantly enhancing the resilience and productivity of agricultural systems.

Furthermore, blockchain technology is carving a niche within the agri-tech innovation landscape by instilling a level of traceability and transparency in supply chains that was hitherto unattainable. Through blockchain, every stakeholder along the supply chain can ascertain the journey of agricultural produce, fostering an environment of trust and accountability [16–18].

Collectively, these innovations accentuate the transformative potential harbored within the agri-tech sector. They unfold new horizons for sustainable and productive agricultural practices, embodying the potential to significantly alter the agricultural narrative in a positive light. As these technological advancements continue to permeate the agricultural sector, they lay the foundation for a more sustainable, efficient, and productive agricultural paradigm, thus heralding a promising trajectory for the agri-tech sector in the foreseeable future.

### Public-Private Partnerships

Public-Private Partnerships (PPPs) emerge as a potent vehicle to propel the momentum of agri-tech into higher realms of impact and sustainability. The confluence of public sector, private sector, and agile agri-tech startups offers a fertile ground for collaborative endeavors that can significantly augment the growth trajectory of agri-tech innovations. One of the cardinal facets of this collaboration is resource mobilization, where the pooling of resources from both

public and private sectors can provide the much-needed financial and infrastructural support to nurture and scale agri-tech innovations.

Moreover, policy support stands as a critical pillar in creating a conducive environment for the proliferation of agri-tech ventures. Through PPPs, there's an avenue for the collective shaping of policies that are tailored to foster the growth of agri-tech, addressing the unique challenges and opportunities inherent in this sector. Market access, a critical determinant of agri-tech success, can be significantly enhanced through leveraging public infrastructure. The public sector, with its expansive infrastructure and networks, can provide a robust platform for agri-tech startups to access markets, expand their reach, and integrate seamlessly with existing agricultural supply chains.

Furthermore, technology transfer is a crucial aspect that can be facilitated through PPPs. The private sector often harbors a wealth of technological innovations that, when transferred and adapted to the public sector, can significantly elevate the technological landscape of agriculture. This transfer not only enhances the technological capacity of the public sector but also fosters a climate of innovation and knowledge sharing that is vital for the continual growth of the agri-tech sector. In essence, PPPs can act as catalysts, significantly accelerating the pace of innovation and adoption of agri-tech solutions. By bridging the chasm between traditional agricultural practices and modern technology-driven farming, PPPs have the potential to usher in a new era of agriculture. An era characterized by enhanced productivity, sustainability, and a harmonized collaboration between public, private, and entrepreneurial stakeholders, setting a promising precedent for the future of agriculture in developing economies.

### Access to New Markets

In the contemporary era, digital platforms and technologies are unveiling new market avenues, serving as conduits that connect the agricultural realm to a broader market spectrum. At the forefront of this digital expedition are online marketplaces, which act as virtual rendezvous points, bridging farmers and buyers. These platforms expand the market reach of farmers, transcending geographical confines and enabling them to access a wider customer base [15].

Complementing the capabilities of online marketplaces are mobile applications, which emerge as invaluable companions for farmers. By providing real-time market information, these applications empower farmers with timely insights, aiding their decision-making processes. Whether it's determining the optimal time to sell or identifying the most lucrative markets, mobile applications serve as a window to market dynamics, facilitating informed and strategic decisions.

On another frontier, blockchain technology is carving a significant niche by enhancing traceability within agricultural supply chains. Through blockchain, every transit point of agricultural produce is logged in a transparent and immutable ledger, fostering a level of traceability that builds consumer trust. Consumers, equipped with the knowledge of the journey of produce from farm to table, are more likely to trust and prefer products with clear traceability [17].

Moreover, the advent of e-commerce is a boon for agri-tech startups and farmers, opening the doors to international markets. The digital storefronts facilitate an unprecedented level of market access, offering a platform for farmers and agri-tech startups to showcase their products to an international audience, thus increasing sales opportunities manifold.

Collectively, these digital innovations are not merely technological advancements; they are enablers of market access. By bridging the geographical and informational chasms, they empower agri-tech startups and farmers to tap into new and broader markets. The ripple effect of this enhanced market access extends beyond individual stakeholders to the larger economy, driving economic growth and setting a precedent for the transformative potential of digital innovations in agriculture.

### Sustainable Agriculture

Agri-tech emerges as a linchpin in the quest for sustainable agriculture, embodying a myriad of solutions that echo the ethos of sustainability and climate resilience. One of the cardinal tenets of sustainable agriculture is resource optimization, a realm where agri-tech shines brightly [19]. By leveraging technologies that reduce waste and ensure the efficient use of resources,

agri-tech paves the way for a more sustainable agricultural landscape, where every resource is judiciously utilized to its fullest potential.

Furthermore, as the specter of climate change looms large, agri-tech steps in as a potent ally for climate resilience. Technologies equipped to monitor and adapt to the vagaries of climate changes arm farmers with the ability to respond proactively to environmental shifts. Whether it's developing drought-resistant crops or deploying weather monitoring systems to predict and prepare for adverse conditions, agri-tech holds the promise of fostering a climate-resilient agricultural ecosystem.

In addition, the marriage of agri-tech with organic farming practices unfolds as a harmonious union for soil and water conservation. Tech-enabled organic farming practices not only enhance soil fertility and water retention but also mitigate the deleterious impacts of synthetic chemicals on the environment. Through precision farming, for instance, farmers can optimize the use of natural fertilizers and pesticides, ensuring both soil health and crop productivity.

Beyond the soil, agri-tech ventures into the realm of renewable energy, unlocking avenues for utilizing renewable energy sources in agricultural operations. Whether it's solar-powered irrigation systems or bioenergy from agricultural waste, agri-tech innovations are at the forefront of integrating renewable energy solutions into the agricultural fabric.

Collectively, agri-tech is not merely a conduit for modernizing agriculture; it is a catalyst for a transition towards sustainable and climate-resilient agricultural practices. By fostering this transition, agri-tech significantly contributes to environmental conservation while concurrently ensuring food security. The blend of sustainability and technological innovation heralds a promising narrative for agriculture, one that resonates with the global agenda of environmental sustainability and food security, thereby spotlighting agri-tech as a critical player in the sustainable agriculture narrative.

### Education and Awareness

Technology unfurls a rich tapestry of opportunities for bolstering agricultural education and awareness, creating avenues for continuous learning and community engagement [20]. Central to this educational odyssey are digital platforms, which serve as repositories of knowledge, offering a plethora of educational resources and training modules to farmers. Through these platforms, farmers can access a wealth of information at their fingertips, delving into new farming techniques, pest management strategies, and market trends, among others.

Furthermore, the immersive realm of Virtual Reality (VR) propels agricultural education into a new dimension. By simulating a diverse array of agricultural scenarios, VR provides a practical, hands-on learning experience. Farmers can navigate through virtual farms, interact with digital crops and livestock, and experiment with different farming techniques in a risk-free, virtual environment. This practical learning experience significantly enhances the understanding and retention of agricultural knowledge.

Moreover, mobile applications emerge as vital conduits for disseminating real-time information and best practices. With a smartphone in hand, farmers can receive timely updates on weather forecasts, market prices, and agricultural advisories, aiding them in making informed decisions. Additionally, mobile applications can serve as platforms for accessing agricultural tutorials, videos, and expert advice, further enriching the learning experience.

Beyond individual learning, technology also fosters a sense of community through online forums. These forums burgeon as virtual gathering spots, enabling knowledge sharing among farmers. The exchange of experiences, solutions, and ideas within these forums cultivates a collaborative learning environment, empowering farmers to learn from each other's successes and challenges.

In essence, technology-driven education and awareness initiatives are not merely tools for information dissemination; they are catalysts for empowerment. By equipping individuals with the requisite knowledge and skills, these technological avenues significantly uplift the agricultural sector. They foster an environment of informed, skilled, and community-driven agriculture, laying the foundation for a modern, sustainable farming landscape. The infusion of technology into agricultural education heralds a promising avenue for enhancing the human

capital within the agricultural sector, thereby contributing to its long-term sustainability and growth.

### Policy Implications

The derived insights from this review significantly inform policy directives that could foster a conducive ecosystem for agri-tech startups in developing economies. A harmonization of policies that encourage innovation and investment in the agri-tech sector is paramount. This includes creating clear regulatory frameworks that are supportive of agri-tech advancements. Additionally, the establishment of diversified funding mechanisms is crucial to propel the growth of agri-tech startups. This could encompass grants, low-interest loans, and incentives for venture capital investments in the agri-tech sector.

Furthermore, embarking on educational initiatives is essential to bridge the knowledge gap that hampers technology adoption. Comprehensive training and educational programs tailored for both farmers and agri-tech entrepreneurs can significantly enhance the uptake and effective utilization of agri-tech solutions. Infrastructure development, especially in rural and remote areas, is another critical area of focus. Investments in robust infrastructure, including internet connectivity and electricity, are fundamental to ensure the effectiveness and accessibility of agri-tech solutions.

Promoting public-private partnerships can also play a significant role in leveraging the collective resources, expertise, and market access necessary for the success of agri-tech startups. Such collaborations can foster a symbiotic relationship where both the public and private sectors benefit from the growth of the agri-tech sector. Lastly, the creation of digital platforms to facilitate market access and streamline supply chain integration is pivotal. These platforms can act as conduits that connect farmers, agri-tech startups, and markets, thereby enhancing the market reach and operational efficiency of agri-tech startups in developing economies.

### Conclusion

The landscape of agriculture, especially in developing economies, is at a pivotal juncture, marked by an urgent need for transformation to meet the growing food demands, ensure environmental sustainability, and improve economic livelihoods. Agri-tech startups emerge as a beacon of innovation, offering a gamut of solutions to address the entrenched challenges and unlock new opportunities within the agricultural sector. This review elucidated the myriad challenges and opportunities that agri-tech startups encounter, spanning from technology adoption, funding, regulatory frameworks, to market access and supply chain integration. The discourse also shed light on the transformative potential of various technological innovations and the significant role of Public-Private Partnerships in fostering a conducive ecosystem for agri-tech growth.

The transition towards a more sustainable, efficient, and productive agricultural paradigm necessitates a harmonized effort from all stakeholders. Policymakers, private sector entities, academia, and agri-tech entrepreneurs must engage in collaborative dialogues and actions to overcome the barriers and harness the potential of agri-tech for sustainable agricultural development.

Moreover, the need for fostering an environment conducive to continuous learning, skill development, and community engagement is paramount. Technology-driven education and awareness initiatives are vital for empowering farmers and agri-tech entrepreneurs with the requisite knowledge and skills for modern, sustainable farming. The digital platforms, VR, mobile applications, and community forums highlighted in the discourse are instrumental in achieving this objective.

In summation, the journey of agri-tech startups is both exhilarating and fraught with challenges. However, with the right blend of policy support, technological innovation, collaborative partnerships, and education, the agri-tech sector holds a promising potential to revolutionize agriculture in developing economies.

**Application of research:** To contribute to the broader understanding and dialogue concerning the agri-tech ecosystem and its pivotal role in propelling the agricultural sector towards a more sustainable and prosperous future.

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## References

- [1] Klingler-Vidra R. (2016) *Socioecon Rev*, 14, 691.
- [2] Sharma K., Mathur H.P. (2018) *International Journal of Business*, 12, 26.
- [3] Usupbaev I. (2023) Cornell University Graduate School of Global Development. <https://phys.org/news/2023-07-korean-team-room-temperature-ambient-pressure-superconductor.html>
- [4] Kumaraswamy P. R., Quamar M., Hameed S. (2020) *Palgrave Macmillan, Singapore*, 249-293.
- [5] Deshmukh S., Patil S. (2021) *International Journal of Agriculture Sciences*, 13, 10928.
- [6] Kuckertz A., Berger E.S.C., Gaudig A. (2019) *J Clean Prod*, 230, 1138.
- [7] Deshmukh S. S., Yasodagayathri A., Jalal P. (2023) *Impact analysis of Agripreneurial initiatives of Ministry of Agriculture and Farmer's Welfare, Government of India on Employment generation, National Institute of Agricultural Extension Management, Telangana State, India.*
- [8] Shah D., Sharoff S. (2017) *Agricultural Economics Research Review*, 2, 282.
- [9] Singh A. K., Dubey S. K., Sah U., & Singh L. (2016) *Current Science*, 110(7), 1169-1177.
- [10] Asia, D. (2021) Colombo, Sri Lanka: Commission on Sustainable Agriculture Intensification. 57.
- [11] David D., Gopalan S., Ramachandran S. (2021) *Investment in Startups and Small Business Financing*, 193.
- [12] Wright B. D., Pardey P. G. (2006) *International Journal of Technology and Globalisation*, 2, 12.
- [13] Srinivas K., Gerard M., Singh V., Gupta M., Soam, S.K., Arunachalam A., Datt S., Saxena S. and Srinivasa Rao Ch. (2018) *AgRIM Agri-Startups: Reflection of ICAR Technologies in Market Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare, Krishi Bhavan, New Delhi*, 121.
- [14] Kumar S. K. A., Ihita G. V., Chaudhari S., Arumugam P. (2022) In 2022 14<sup>th</sup> *International Conference on COMMunication Systems & NETWORKS (COMSNETS)*, IEEE, 911-916.
- [15] Deshmukh S., Patil S. (2021) *International Journal of Agriculture Sciences*, 13, 10928.
- [16] Yadav V.S., Singh A.R., Raut R.D., Cheikhrouhou N. (2021) *Asian*

- Journal of Agricultural Extension, Economics & Sociology*, 41, 855.
- [17] Deshmukh S., Patil S. (2022) *Journal of Agricultural Extension Management*, 23, 159.
- [18] Demestichas K., Peppes N. Alexakis T., Adamopoulou E. (2020) *Applied Sciences (Switzerland)*, 10, 1.
- [19] Phand S., Deshmukh S., Muhammed S.T. (2023) *Journal of Agricultural Extension Management*, 24, 24, 23.
- [20] Deshmukh S., Jadhav K. (2023) *Asian Journal of Agricultural Extension, Economics & Sociology*, 41, 855.