HARNESSING TECHNOLOGY FOR AGRICULTURAL ADVANCEMENT: A COMPREHENSIVE REVIEW ON ADOPTION AND SELF-SUFFICIENCY IN AFGHAN AGRICULTURE

Abdurrahman Salihu Abubakar[1] *
[1]Physical Planning Unit, Federal University Gusau, Zamfara State Nigeria
abdulss06@gmail.com

ABSTRACT
Agriculture is a vital sector in Afghanistan, contributing significantly to the country's growth and development. However, the sector faces several challenges that have hindered its growth and development, including inadequate infrastructure, limited market access, and low productivity. This review paper critically examines the transformative potential of technology adoption in advancing Afghan agriculture towards self-sufficiency. The review delves into the current state of technology adoption, emphasizing precision agriculture, digital platforms, and innovative research as key components of the modernization process by providing a holistic understanding of technology's impact on Afghan agriculture. The paper evaluates the tangible impact of technology on agricultural productivity, shedding light on increased yields, resource efficiency, and improved farm management practices. Despite these advancements, challenges in widespread adoption are identified, including limited access to resources and infrastructural constraints. The review emphasizes the importance of precision agriculture and digital platforms, showcasing their role in optimizing resource use and facilitating data-driven decision-making. The review also highlights the need for investment in research and development to improve crop yields and quality and adopt modern farming techniques and technologies. The paper also identifies the need for infrastructure development to support the sector, including road construction, provision of storage facilities, and processing plants. By synthesizing these elements, the paper contributes valuable insights to policymakers, researchers, and stakeholders aiming to propel Afghanistan toward a self-sufficient and technologically advanced agricultural sector. Furthermore, with the right mix of policies and investments, the country's agricultural sector can become self-sufficient and contribute to the country's overall economic growth. Thus, recommendations are proposed to navigate these complexities effectively.

KEYWORDS: Afghanistan, Agriculture, Technology Adoption, Infrastructure

Corresponding emails: abdulss06@gmail.com

1. Introduction:

1.1 Background:

Afghanistan's agricultural sector plays a pivotal role in its economy, employing a significant portion of the population and contributing substantially to the nation's GDP. However, the sector has been hampered by various impediments, and one of the most pressing issues is the lack of adequate infrastructure. This article delves into the necessity of robust infrastructure as a foundation for agricultural development, analyzing the multifaceted challenges and potential solutions. Public-sector programs have attempted to overcome information-related barriers to technological adoption by providing agricultural

extension services. The potential mechanisms through which ICT could facilitate agricultural adoption and the provision of extension services in developing countries are necessary (Aker, 2011). The application of these technologies in some developing countries in Africa and Asia is limited by factors such as technology compatibility with the environment, availability of resources to facilitate the technology adoption, cost of technology purchase, government policies, adequacy of technology, and appropriateness in addressing the population's needs. This has led to low productivity and high cost of production, among other things.

There has been an attempt to evaluate the application of present-day technology and its limitations in advancing large-scale mechanization in developing countries (Onwude et al., 2016). The increasing rate of technological advancement across various disciplines, particularly the agricultural sector, has increased efficiency and productivity. For instance, Ugochukwu et al. (2018) examine returns on investment in technological research and development. Fundamental advancements in the agricultural industry have been made by adopting labour-saving technologies in agriculture. This research intends to review several economic theories that form the basis of the economics of labour-saving technologies, including the theory of induced innovation (Gallardo et al., 2018). Thus, to increase crop yields and sustain yield gains, recent case studies of technology adoption unanimously recommend adopting integrated farm management systems. Agriculture has been a major review subject in developing nations, prompting the growing need for technology adoption and its impact on the agricultural sector (Takahashi et al., 2020). Understanding technology adoption attributes is needed to assist extension practitioners in promoting adoption and better understanding the innovation adoption phenomena.

These studies are necessary for agricultural extension specialists to motivate farmers on technology adoption and precision agriculture (PA) to understand the different perspectives of agricultural experts and to determine the future areas of contributions, particularly those related to complexity (Lee et al., 2021). Better ways of acquiring agricultural knowledge, together with improved methods of transmission of the same knowledge, are primary in the advancement of agriculture within a group of people. Numerous cutting-edge initiatives that use information and communication technology to provide agricultural knowledge to farmers have been researched (Kountios et al., 2023). Other influential work includes (Muzari et al., 2012).

1.2 Objectives:

The primary objectives of this review are to:

a. Assess the historical trends of agriculture in Afghanistan.

b. Analyze the current state of technology adoption in the agricultural sector.

c. Evaluate the impacts of infrastructure on enhancing agricultural productivity.

d. Explore the challenges and opportunities for agricultural infrastructural development.

e. Propose strategies for achieving self-sufficient agriculture through infrastructural development and technology adoption.

2. Historical Context:

Afghanistan has a long history of agriculture, dating back to ancient times. The country's agricultural sector has been a primary source of income and employment for its people. Afghanistan is an agricultural country where more than 80% of the population depends on agriculture for their livelihoods (FAO, 2023). Livestock farming largely contributes to the livelihoods of the rural population and is also a major source of income and food. The agriculture sector contributes over 25.5% of Afghanistan's gross domestic product (GDP) (NSIA,2020), employs about 45% of the national workforce (MAIL, 2019), including more than half the rural workforce, is a source of income for 44% of households (and is the primary source of income for 28%) (CSO, 2018), dominates Afghanistan's exports, accounting for 85% of total exports in 2019 (NSIA, 2020), provides livelihoods for nearly 80% of the population directly or indirectly (CSO, 2018), and is likely to remain the largest employer of rural people in Afghanistan for the foreseeable future (MAIL and FAO, 2020). Figure 1 illustrates the GDP per capita from 2002-2020.

Figure 1. GDP per capita from 2002-2020.

According to the Food and Agriculture Organization of the United Nations (FAO), agriculture accounts for about a quarter of Afghanistan's GDP and employs about 60% of the country's population (FAO, 2024). During the Soviet occupation of Afghanistan, the government invested heavily in the country's agriculture sector, which led to significant growth and development. However, after the Soviet withdrawal, the sector suffered from a lack of investment, which resulted in a decline in productivity and quality of produce (Cordesman & Mausner, 2010). Furthermore, the sector has faced numerous challenges throughout history. One of the earliest challenges was the lack of water resources, which made it difficult for farmers to irrigate their crops (Cordesman & Mausner, 2010). This was

addressed by constructing irrigation systems such as the Karez system, which is still used today. Another challenge is a lack of investment and infrastructure deficits, i.e., damaged roads, inadequate storage facilities, and outdated technology that hinders productivity in the agricultural sector. Despite these challenges, the country's agricultural sector has shown resilience and has continued to grow. In recent years, the government and international organizations have invested in the sector, significantly improving productivity and quality of produce. Adopting modern farming techniques and technologies has also helped increase crop yields and improve the quality of produce (FAO, 2023). The history of agricultural development suggests the adoption of innovative technologies as a key critical factor in improving sustainable livelihoods. Decisions by farmers to adopt new technologies are multifaceted. Thus, Afghanistan's agricultural sector has a rich history and has faced numerous challenges. However, with the right mix of policies and investments, the sector has the potential to become self-sufficient, contributing to the country's overall economic growth and set the stage for technology integration.

3. Current State of Agriculture in Afghanistan:

The history of agricultural development shows that adopting innovative technologies has been one of the essential factors in the growth of agricultural production systems (Basso et al., 2018; Gallardo & Sauer, 2018; Zambon et al., 2019). According to a report by the Food and Agricultural Organization (FAO), Afghanistan's agricultural sector is facing a dire situation. The country's farmers and herders need seed, food, and cash, with many facing "catastrophic and famine-like conditions" (United Nations, 2021). The report also states that 18.8 million Afghans are unable to feed themselves every day, and this number is set to rise to nearly 23 million by the end of the year. The widespread drought that has hit the country has exacerbated the situation, leaving families with nothing to eat during the current lean season. The FAO warns that unless immediate large-scale support arrives soon, there is a very high risk of famine in 2022 (United Nations, 2021). A joint report by the Government of Afghanistan and the World Bank Group highlights the sector's role in explaining the dynamics of rural employment and its potential for growth and development (World Bank, 2018). Figure 2 illustrates the percentage dominance of the agricultural sector when compared with other sectors.

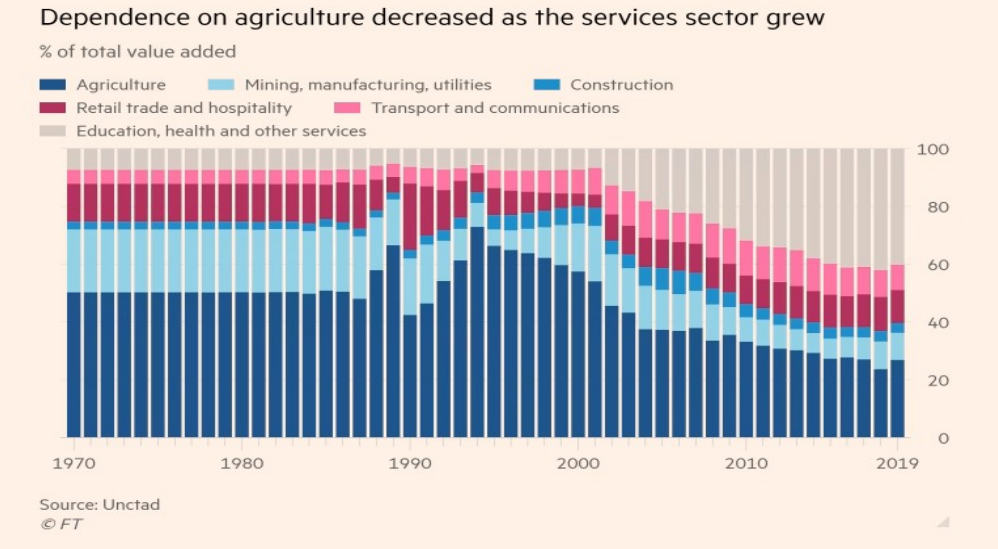

Figure 2. Percentage dependence based on sectors.

The report identifies several enhancements that can be made to improve the sector, including adopting modern farming techniques and technologies, investing in research and development, and developing infrastructure to support the sector (World Bank, 2018).

On the other hand, since the 2010s, there have been increasing studies on social networks or farmer-to-farmer technology extension. These studies explore the need to harness technology for agricultural advancement for self-sufficient Agriculture. Other studies assess the adoption/use of mobile Internet technology (MIT) to improve accessibility to financial and agricultural services for smallholder farmers (Khan et al., 2022). At the same time, others emphasize the need to leverage on artificial intelligence (AI) in agriculture to highlight the challenges and opportunities in agricultural systems and processes (Sood et al., 2022). Others have advocated adopting Precision Agriculture (PA) (David & Ebel, 2016). PA adoption processes are complicated and low (Bramley, 2009; Fountas et al., 2004), and the intricacies exist in diverse elements and interactions (Pathak et al., 2019). Thus, the adoption of precision agriculture technology is attracting more attention as a solution in food production to feed a growing population (Godfray et al., 2010). Assessing how these technologies can be harnessed and integrated into Afghan agriculture is vital to attaining self-sufficiency in agricultural production. Figure 3 illustrates the estimated cereal production of wheat, rice, maize, and others from 2018 to 2023.

Afghanistan

Cereal Production

	2018-2022 average	2022	2023 forecast	change 2023/2022
		000 tonnes		percent
Wheat	4 280	3 810	4 000	5.0
Rice (paddy)	593	592	550	-7.1
Maize	187	190	190	0.0
Others	112	110	110	0.0
Total	5 171	4 702	4 850	3.1

Note: percentage change calculated from unrounded data.

Figure 3. Estimated cereal production from 2018-2023.

3.1 Impact on Agricultural Productivity:

The impact of agricultural productivity in Afghanistan is a multifaceted and critical aspect of the country's socio-economic development. Agriculture plays a pivotal role in the livelihoods of the majority of Afghans, with a significant portion of the population relying on farming for income and sustenance. Improvements in agricultural productivity can have far-reaching effects on Afghanistan's economy and the well-being of its citizens. Enhanced productivity can lead to increased food security, reducing dependency on imports and mitigating the risk of hunger in vulnerable communities. Moreover, a more productive agricultural sector can contribute to poverty reduction by generating employment opportunities, especially in rural areas where the majority of the population resides.

Addressing the issues of water management and introducing modern farming techniques can significantly boost yields and efficiency in Afghan agriculture. Additionally, advancements in agricultural productivity can serve as a catalyst for economic diversification, promoting agribusinesses and creating value-added products for both domestic consumption and export. The impact of improved agricultural productivity in Afghanistan extends beyond the fields, influencing food security, poverty alleviation, and overall economic development. Sustainable interventions and strategic investments in the agricultural sector are crucial for fostering resilience and prosperity in the country. Tangible benefits can be derived from technology adoption, such as increased yields, resource efficiency, and improved farm management practices, leading to increased agricultural productivity.

3.2 Water Management:

The impacts of water scarcity and inefficient water management practices are limiting agricultural productivity, necessitating the need for potential solutions and sustainable irrigation practices. Water management in Afghanistan is a vital aspect of the country's development, given its arid climate and dependence on agriculture. The nation faces challenges such as water scarcity, inefficient irrigation systems, and the impacts of climate

change. The availability and distribution of water resources have direct implications on food security, livelihoods, and the overall well-being of the population.

Efforts to improve water management in Afghanistan involve a combination of infrastructure development, policy formulation, and community engagement. Investment in modern irrigation techniques, reservoirs, and water storage facilities can enhance agricultural productivity and mitigate the risks associated with erratic rainfall patterns. Furthermore, the implementation of effective water management policies is crucial for equitable distribution and sustainable use of water resources. Community involvement and awareness are vital components of successful water management strategies. Localized initiatives that empower communities to participate in decision-making, adopt water-saving practices, and address water-related challenges contribute to the overall resilience of the water sector. Thus, to effectively address the water management issues, Afghanistan requires a comprehensive approach that integrates infrastructure development, policy reforms, and community engagement. Sustainable solutions are essential for ensuring water security, supporting agriculture, and fostering the socio-economic development of the nation.

3.3 Land Use and Soil Health:

An analysis of land use patterns, soil degradation, and the importance of soil health for sustainable agriculture is necessary for soil conservation and restoration. Land use and soil health in Afghanistan are critical factors influencing the nation's agricultural productivity and overall sustainable development. A significant portion of the population relies on agriculture for their livelihoods, making the efficient and responsible use of land essential. Challenges such as deforestation, overgrazing, and improper land management practices have led to soil degradation in various regions of Afghanistan. This degradation poses a threat to agricultural productivity, water resources, and biodiversity. Addressing these issues requires a comprehensive approach that includes sustainable land use practices, afforestation initiatives, and soil conservation measures. Efforts to improve land use and soil health involve promoting agroecological practices, reforestation projects, and the adoption of conservation agriculture techniques. Integrating these approaches not only helps in preserving soil fertility but also contributes to mitigating the impacts of climate change, such as soil erosion and desertification. Community involvement is crucial in implementing successful land use and soil health initiatives. Educating farmers about sustainable practices, providing access to technology, and incentivizing environmentally friendly agricultural methods can enhance the resilience of the agricultural sector and promote long-term soil health. Therefore, sustainable land use and soil health management in Afghanistan are imperative for ensuring food security, supporting rural livelihoods, and fostering environmental sustainability. Implementing practices that balance agricultural needs with ecological preservation is essential for the country's future prosperity.

4. Challenges in Technology Adoption:

The challenges to widespread technology adoption include limited resource access, lack of awareness, and infrastructural constraints. Afghanistan faces significant challenges in the adoption of technology, hindering the nation's progress towards economic development and modernization. One of the primary obstacles is the country's fragile infrastructure, with

limited access to reliable electricity and internet connectivity in many regions. This lack of basic infrastructure inhibits the widespread use of technology and impedes digital access for a substantial portion of the population. Moreover, issues related to education and digital literacy contribute to the slow pace of technology adoption. A considerable segment of the population lacks the necessary skills to effectively use and leverage technology, limiting its potential impact on various sectors, including education, healthcare, and business.

The ongoing security situation in Afghanistan poses another significant challenge, creating an environment that is not conducive to sustained technology adoption. Instability and conflict disrupt the establishment of a robust technological ecosystem, hampering investment and inhibiting the growth of the digital economy. Addressing these challenges requires a concerted effort involving government initiatives, international partnerships, and targeted investments in infrastructure and education. Developing policies that promote digital inclusion, expanding reliable internet access, and implementing programs to enhance digital literacy are essential steps towards overcoming the barriers to technology adoption in Afghanistan. Despite the obstacles, addressing these challenges is crucial for unlocking the full potential of technology to contribute to the country's socio-economic development.

4.1 Environmental Challenges:

The agricultural sector in Afghanistan confronts formidable environmental challenges that impact both productivity and sustainability. Climate change, water scarcity, and natural disasters negatively impact the Afghan agricultural sector, which is exacerbated by irregular rainfall patterns and over-extraction of groundwater, which poses a significant threat to crop cultivation. Inefficient irrigation practices further compound this issue, leading to soil erosion and degradation. Deforestation and land degradation also plague Afghan agriculture, diminishing arable land and exacerbating the vulnerability of ecosystems. Unregulated grazing practices contribute to soil erosion, limiting the capacity of the land to support crops.

Additionally, the agricultural sector contends with the consequences of climate change, including extreme weather events and shifts in temperature and precipitation patterns. These environmental challenges not only jeopardize food security but also exacerbate poverty and hinder rural development. Sustainable solutions are imperative, encompassing the promotion of water-efficient irrigation techniques, afforestation initiatives, and the adoption of climateresilient crops. Implementing sound land management practices, regulating grazing activities, and investing in climate-smart agricultural technologies are vital steps to mitigate the environmental pressures faced by the Afghan agricultural sector. A holistic approach involving government policies, international collaborations, and community engagement is essential to build resilience and ensure the long-term sustainability of agriculture in Afghanistan.

4.2 Socio-Economic Challenges:

The Afghanistan agricultural sector grapples with profound socio-economic challenges that impede its development and hinder the well-being of rural communities. Widespread poverty, exacerbated by decades of conflict, limits farmers' access to essential resources such as quality seeds, fertilizers, and modern farming equipment. This economic hardship

restricts their ability to invest in sustainable agricultural practices and impedes overall productivity. The graph below shows Afghanistan's ranking in terms of socio-economic measures. Figure 4 illustrates the socio-economic status of Afghanistan Compared to other developing nations, ranging from education to social capital on a scale of 1- 100 when compared with the developed nations.

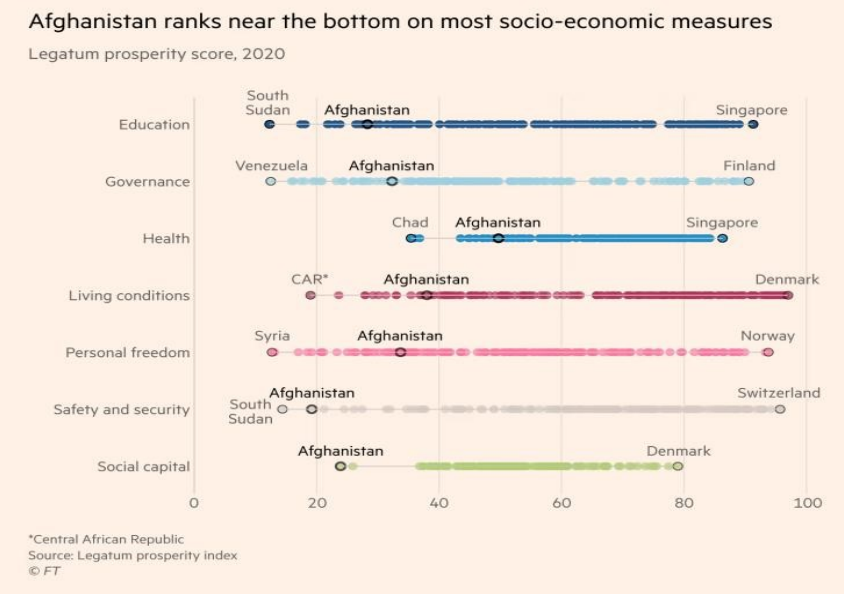

Figure 4. Socio-economic status of Afghanistan Compared to other developing nations.

Lack of education and vocational training further exacerbates these challenges, hindering the adoption of modern farming techniques and reducing the sector's efficiency. The absence of diversified economic opportunities in rural areas leads to a heavy reliance on agriculture, making communities vulnerable to fluctuations in crop yields and market prices. There are several other socio-economic challenges, such as land tenure, access to credit, and market infrastructure, that hinder the economic viability of Afghan farmers.
Addressing these socio-economic challenges necessitates a comprehensive approach, including targeted investments in education and vocational training, rural infrastructure development, and the creation of alternative income-generating opportunities. Moreover, land disputes and a lack of transparent land tenure systems undermine agricultural productivity and hinder long-term planning for rural development. By fostering economic diversification and enhancing the resilience of rural communities, Afghanistan can work towards sustainable socio-economic development within its vital agricultural sector. Furthermore, proactive measures need to be taken to address the issues in order to attain self-sufficiency.

4.3 Security Concerns:

The Afghanistan agricultural sector grapples with severe security concerns, most especially in the past that significantly impede its functioning and long-term viability. Prolonged conflict and insecurity have led to the disruption of farming activities, displacement of rural populations, and damage to critical agricultural infrastructure. A fragile political

environment contributes to the difficulties faced by the agricultural sector. Ongoing conflict disrupts farming activities, hampers infrastructure development, and deters investments. Farmers face threats to personal safety, making it challenging to tend to their fields and hindering the adoption of modern agricultural practices. The instability also exacerbates issues related to land tenure and management, as ongoing conflicts contribute to land disputes and make it challenging to establish secure farming environments. The overall security situation in Afghanistan discourages both domestic and foreign investments in the agricultural sector. Limited access to credit, coupled with the risk of property damage and loss, stifles economic growth and modernization efforts in the agricultural domain. Addressing security concerns is paramount for the sector's revitalization, necessitating a multifaceted approach that involves conflict resolution, community engagement, and the establishment of secure environments for farmers to cultivate their land. A stable and secure environment is foundational for the sustainable development of Afghanistan's agricultural sector. Continued investments in rural roads and local infrastructure, information and communication technology, and reliable and affordable access to energy are fundamental to enabling local producers to access markets and increase agricultural productivity.

5. Enhancing Agricultural Productivity:

Enhancing agricultural productivity is pivotal for achieving self-sufficient agriculture in Afghanistan, addressing food security concerns and fostering economic resilience. The promotion of sustainable farming practices is crucial for long-term productivity gains. It involves the adoption of efficient irrigation techniques, organic farming methods, and integrated pest management strategies. Additionally, providing farmers with access to modern technologies, including farm machinery and precision agriculture tools, can significantly boost efficiency and output. Additionally, there is the need to introduce and disseminate improved crop varieties that are well-suited to local conditions, ensuring higher yields and resistance to environmental stresses. Thus, investments in technology adoption, research and innovation, precision agriculture, digital platforms, policies, and strategies are essential for achieving selfsufficient agriculture in Afghanistan.

5.1 Technology Adoption:

The role of technology adoption is vital to the attainment of food security and self-sufficiency. These technologies involve adopting precision agriculture, drones, and digital platforms to improve efficiency and productivity. It includes using high-yielding crop varieties, improved irrigation systems, and better pest management practices. These technologies can help increase crop yields and improve the quality of produce, which can help farmers compete in local and international markets. Harnessing the potential of technology in agricultural processes is vital for improving labour productivity, efficiency, and food security. Adopting a new approach (innovation) should have an observable advantage over previous techniques to allow trialability and fit into the local culture and resource availability (Lee et al., 2021).

5.2 Research and Innovation:

The importance of research and innovation in the Afghanistan agricultural sector cannot be overstated, as these factors are instrumental in driving sustainable development and

addressing the myriad challenges faced by the industry. Research provides valuable insights into climateresilient crops, efficient irrigation techniques, and sustainable farming practices tailored to the Afghan context. Innovations arising from research efforts empower farmers to enhance productivity, adapt to changing environmental conditions, and improve the overall resilience of the agricultural sector. In a country with diverse agro-climatic zones, targeted research can lead to the development of crop varieties that thrive in specific regions, bolstering food security and income generation. Innovation in water management technologies is crucial for mitigating water scarcity, a pressing concern in many parts of Afghanistan. Additionally, research facilitates the identification and implementation of environmentally friendly practices, fostering long-term sustainability.

Investments in research and innovation attract new technologies and methodologies that can revolutionize traditional farming systems. Moreover, they contribute to capacity building, enabling farmers to adopt modern techniques and improve their socio-economic status. A commitment to research and innovation is thus essential for steering Afghanistan's agricultural sector towards a more resilient, productive, and sustainable future. Research and innovation are necessary to develop technology solutions tailored to the specific needs of Afghan agriculture.

5.3 Precision Agriculture and Digital Platforms:

Precision agriculture (PA) is a sustainable, innovative systems approach that assists farmers in production management. Precision farming is a holistic, innovative systems approach that assists farmers in managing crop and soil variability to decrease costs, improve yield quality and quantity, and enhance farm income (Paustian & Theuvsen, 2017). PA applies traditional farming practices with new technology, practices, and economic drivers to enhance sustainability in a dynamic balance (Balafoutis et al., 2017). Studies have reported positive outcomes from PA adoption, including economic savings in productivity factors (Loures et al., 2020), increasing yield and environmental sustainability (Ullah et al., 2021), and improving food security and community economic vitality in developing regions (Yue et al., 2016). Adopting PA could improve sustainable food security and community economic sustainability (Lee et al., 2021). The transformative potential of precision agriculture and digital platforms cannot be overstated in optimizing resource use and facilitating data-driven decision-making. Figure 5 illustrates the combined internal and external interactions of farming operations, offering digital information on all farm sectors and processes. Farming operations become smarter, more efficient, safer, and more environmentally sustainable due to the combination and integration of production technologies and devices, information and communication systems, data and services infrastructures.

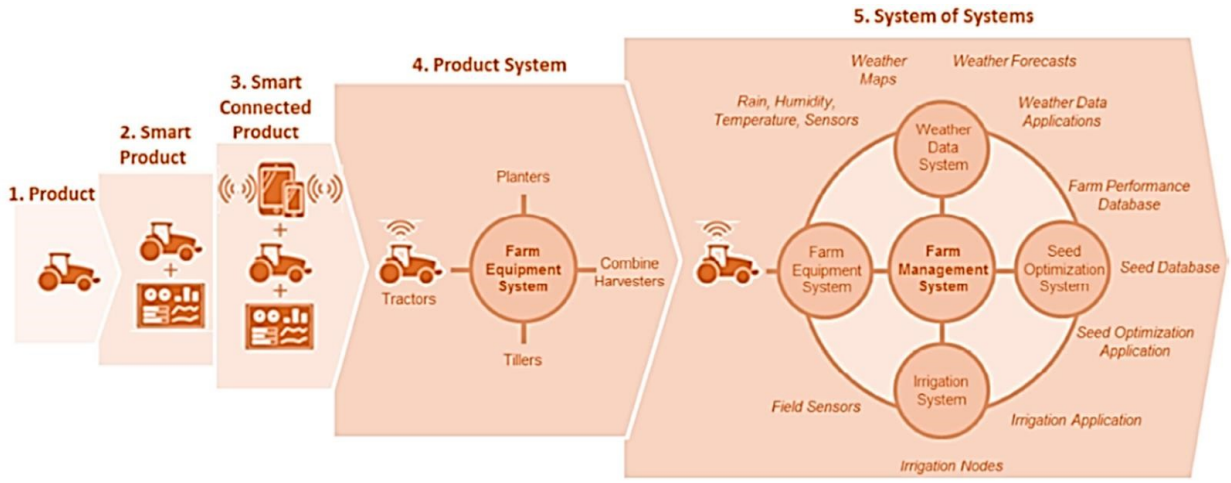

Figure 5. Combination and integration of production technologies (Zambon et al., 2019)

5.4 Policy Implications:

The influence of government policies in promoting and regulating technology adoption in the agricultural sector is vital to attaining self-sufficiency. Policy implications play a pivotal role in shaping the trajectory of the Afghanistan agricultural sector, influencing everything from productivity and sustainability to economic growth and rural development. Well-crafted agricultural policies can provide a roadmap for addressing challenges, promoting innovation, and ensuring the equitable distribution of resources. Effective policies can encourage investments in critical areas such as infrastructure development, water management, and education. Clear regulations and support mechanisms for farmers can stimulate economic growth, enhance food security, and alleviate poverty in rural communities. Moreover, policies that promote sustainable agricultural practices contribute to environmental conservation and resilience in the face of climate change.

Land tenure policies are vital for resolving disputes and establishing a secure foundation for agricultural activities. Additionally, policies fostering market access, fair pricing, and value chain development can bolster farmers' incomes, encouraging their participation in modernized and diversified agricultural practices. Given the security challenges in Afghanistan, policies that address conflict resolution and provide a secure environment for farming activities are imperative. Policy frameworks that consider the unique socio-economic landscape of Afghanistan are crucial for achieving lasting positive impacts in the agricultural sector, supporting the livelihoods of millions and contributing to the overall stability and development of the nation.

5.5 Strategies for Self-Sufficient Agriculture:

The study proposes some actionable strategies, including policy recommendations, investment priorities, and community-based initiatives, to leverage technology for achieving selfsufficiency in Afghan agriculture. Furthermore, achieving self-sufficient agriculture in Afghanistan requires a multifaceted approach encompassing strategic interventions and sustainable practices. These strategies are as follows:

a. Investing in modernizing agricultural techniques is crucial. It includes promoting the use of efficient irrigation systems, resilient crop varieties, and precision farming methods tailored to Afghanistan's diverse agro-climatic conditions.

b. Water management is a cornerstone for self-sufficiency, necessitating the construction and maintenance of water infrastructure such as dams and reservoirs. Implementing effective water conservation strategies and promoting judicious water use through education and outreach programs are also essential components.

c. Encouraging diversification in crop production can enhance food security and mitigate risks associated with mono-cropping. It involves promoting the cultivation of a variety of crops suited to different regions, reducing vulnerability to pests, diseases, and market fluctuations.

d. Investments in rural infrastructure, such as roads and storage facilities, are pivotal for connecting farmers to markets and reducing post-harvest losses. Furthermore, fostering agribusiness and value chain development can create additional income streams, encouraging farmers to adopt modern technologies and practices.

e. Community engagement and capacity-building initiatives are essential in educating and training farmers so as to empower them to make informed decisions about their agricultural practices.

f. A stable and secure environment, supported by effective governance and conflict resolution mechanisms, is fundamental for implementing and sustaining these strategies towards achieving self-sufficiency in Afghanistan's agricultural sector.

6. Conclusion:

In conclusion, synthesizing historical perspectives, current trends, and future possibilities, this review provides insights for policymakers, researchers, and stakeholders seeking to navigate the intricate path toward a technologically advanced and self-sufficient agricultural sector in Afghanistan. It also highlights the need to invest in infrastructure and future possibilities of technology adoption in Afghan agriculture. Furthermore, the paper explores the nexus between research, innovation, infrastructure, and technology, underscoring the need for tailored solutions to address the unique challenges of Afghan agriculture. Therefore, a holistic approach is required to address the infrastructure gaps, promote sustainable agricultural practices, and empower the farmers to achieve self-sufficient agriculture in Afghanistan. The nation can move closer to food security and economic stability by implementing good government policies and community engagement strategies that promote technology adoption. This review also contributes to the general body of knowledge by providing a comprehensive overview of the historical context, current status, and proposed recommendations that will help navigate effectively the complexities towards attaining self-sufficient agriculture in Afghanistan.

7. References

Aker, J. C. (2011). Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics*, *42*(6), 631–647. https://doi.org/10.1111/j.1574-0862.2011.00545.x

Balafoutis, A., Beck, B., Fountas, S., Vangeyte, J., Van Der Wal, T., Soto, I., Gómez-Barbero, M., Barnes, A., & Eory, V. (2017). Precision agriculture technologies positively contributing to GHG emissions mitigation, farm productivity and economics. *Sustainability (Switzerland)*, *9*(8), 1–28. https://doi.org/10.3390/su9081339

Basso, B., Dobrowolski, J., & Mckay, C. (2018). From the Dust Bowl to Drones to Big Data: The

Next Revolution in Agriculture. *Georgetown Journal of International Affairs*, *18*(3), 158–165. https://doi.org/DOI: https://doi.org/10.1353/gia.2017.0048

Bramley, R. G. V. (2009). Lessons from nearly 20 years of Precision Agriculture research, development, and adoption as a guide to its appropriate application. *Crop and Pasture Science*, *60*(3), 197–217. https://doi.org/10.1071/CP08304

Cordesman, A. H., & Mausner, A. (2010). Agriculture, Food, and Poverty in Afghanistan. *Center of Strategic and International Studies*, 1–9. http://csis.org/publication/agriculture-food-andpoverty-afghanistan

David, S., & Ebel, R. (2016). Sequential Adoption and Cost Savings from Precision Agriculture. *Journal of Agricultural and Resource Economics*, *41*(1), 97–115.

Fountas, S., Pedersen, S. M., & Blackmore, B. S. (2004). *ICT in Precision Agriculture – diffusion of technology*. *6*, 1–15. http://departments.agri.huji.ac.il/economics/gelb-pedersen5.pdf%5Cnhttp://departments.agri.huji.ac.il/economics/gelb-table.html

Gallardo, R. K., & Sauer, J. (2018). Adoption of Labor-Saving Technologies in Agriculture. *Annual Review of Resource Economics*, *10*, 185–206. https://doi.org/10.1146/annurevresource-100517-023018

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C. (2010). Food Security: The Challenge of The Challenge of Feeding 9 Billion People. *Science*, *327*(5967), 812–819. https://doi.org/DOI: 10.1126/science.

Khan, N., Ray, R. L., Kassem, H. S., & Zhang, S. (2022). Mobile Internet Technology Adoption for Sustainable Agriculture: Evidence from Wheat Farmers. *Applied Sciences (Switzerland)*, *12*(10). https://doi.org/10.3390/app12104902

Kountios, G., Konstantinidis, C., & Antoniadis, I. (2023). Can the Adoption of ICT and Advisory Services Be Considered as a Tool of Competitive Advantage in Agricultural Holdings? A Literature Review. *Agronomy*, *13*(2). https://doi.org/10.3390/agronomy13020530

Lee, C. L., Strong, R., & Dooley, K. E. (2021). Analyzing precision agriculture adoption across the globe: A systematic review of scholarship from 1999–2020. *Sustainability (Switzerland)*, *13*(18), 1–15. https://doi.org/10.3390/su131810295

Loures, L., Chamizo, A., Ferreira, P., Loures, A., Castanho, R., & Panagopoulos, T. (2020). Assessing the effectiveness of precision agriculture management systems in Mediterranean small farms. *Sustainability (Switzerland)*, *12*(9), 1–15. https://doi.org/10.3390/su12093765

Muzari, W., Gatsi, W., & Muvhunzi, S. (2012). The Impacts of Technology Adoption on Smallholder Agricultural Productivity in Sub-Saharan Africa: A Review. *Journal of Sustainable Development*, *5*(8), 69–77. https://doi.org/10.5539/jsd.v5n8p69

Onwude, D. I., Abdulstter, R., Gomes, C., & Hashim, N. (2016). Mechanization of large-scale agricultural fields in developing countries - a review. *Journal of the Science of Food and Agriculture*, *96*(12), 3969–3976. https://doi.org/10.1002/jsfa.7699

Pathak, H. S., Brown, P., & Best, T. (2019). A systematic literature review of the factors affecting the precision agriculture adoption process. *Precision Agriculture*, *20*(6), 1292–1316. https://doi.org/10.1007/s11119-019-09653-x

Paustian, M., & Theuvsen, L. (2017). Adoption of precision agriculture technologies by German crop farmers. *Precision Agriculture*, *18*(5), 701–716. https://doi.org/10.1007/s11119-0169482-5

Sood, A., Sharma, R. K., & Bhardwaj, A. K. (2022). Artificial intelligence research in agriculture: a review. *Online Information Review*, *46*(6), 1054–1075. https://doi.org/10.1108/OIR-102020-0448

Takahashi, K., Muraoka, R., & Otsuka, K. (2020). Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature. *Agricultural Economics (United Kingdom)*, *51*(1), 31–45. https://doi.org/10.1111/agec.12539

Ugochukwu, A. I., & Phillips, P. W. B. (2018). Technology Adoption by Agricultural Producers: A Review of the Literature. *Innovation, Technology and Knowledge Management*, 361–377. https://doi.org/10.1007/978-3-319-67958-7_17

Ullah, A., Nawaz, A., Farooq, M., & Siddique, K. H. M. (2021). Agricultural innovation and sustainable development: A case study of rice–wheat cropping systems in South Asia. *Sustainability (Switzerland)*, *13*(4), 1–15. https://doi.org/10.3390/su13041965

United Nations. (2021). Afghanistan's farmers, herders desperate for seed, food and cash. *United Nations News*, 1. https://news.un.org/en/story/2021/11/1106212

World Bank. (2018). *Unlocking the Potential of Agriculture for Afghanistan's Growth*. 1–6.

Yue, Y., Zhou, Y., Wang, J., & Ye, X. (2016). Assessing wheat frost risk with the support of gis: An approach coupling a growing season meteorological index and a hybrid fuzzy neural network model. *Sustainability (Switzerland)*, *8*(12), 1–21. https://doi.org/10.3390/su8121308

Zambon, I., Cecchini, M., Egidi, G., Saporito, M. G., & Colantoni, A. (2019). Revolution 4.0: Industry vs. agriculture in a future development for SMEs. *Processes*, *7*(1). https://doi.org/10.3390/pr7010036.