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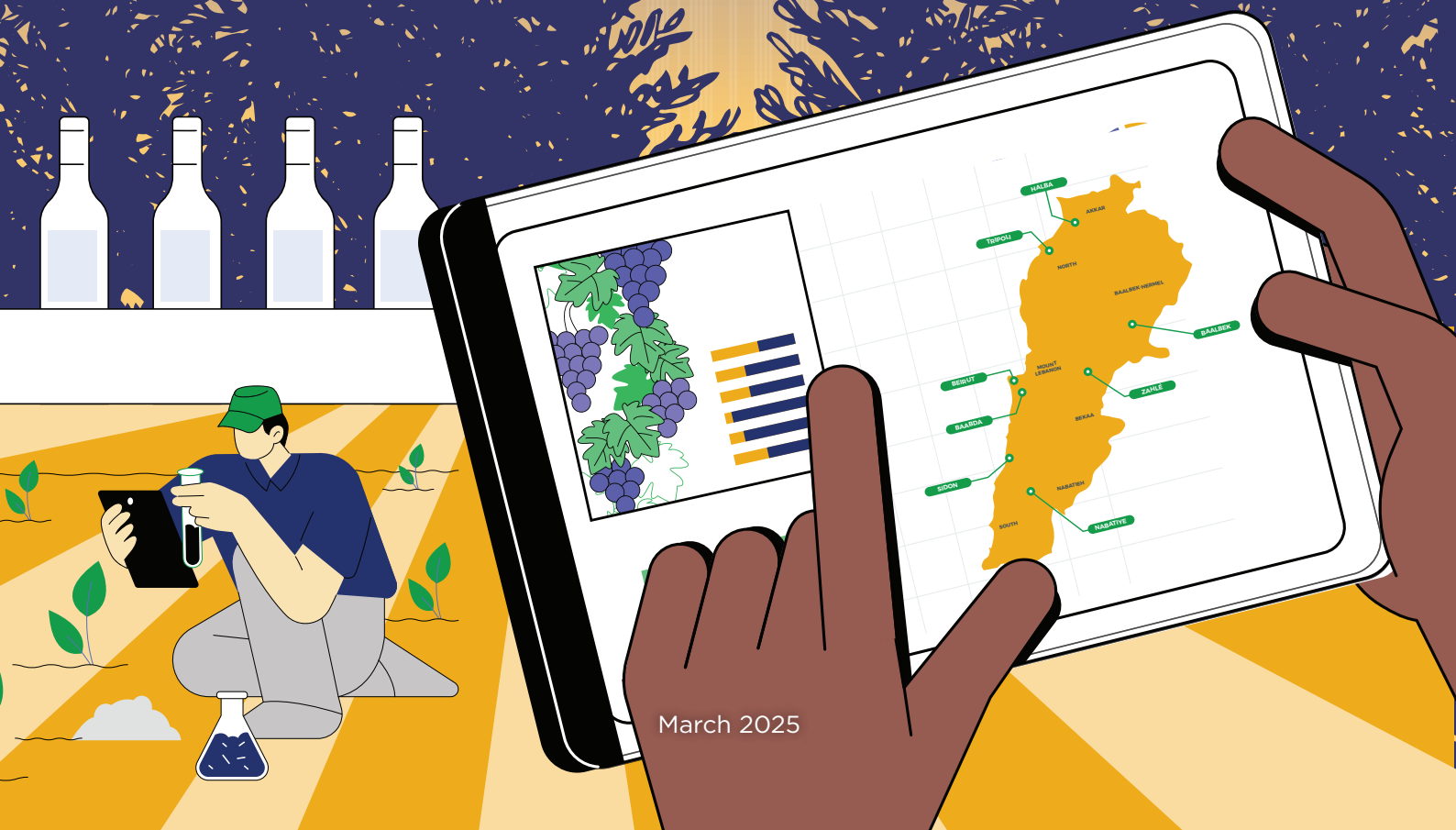
Use and Governance of AI in Food Security

THE CASE OF LEBANON



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USE AND GOVERNANCE OF AI IN FOOD SECURITY - THE CASE OF LEBANON

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ABSTRACT

Food security, as defined by FAO in 1996, relies on four basic pillars: food availability, access, utilization, and stability. Lebanon was recently hit by multiple crises shaking its security and economic, social, and political stability, thus compromising all four pillars of food security. Nevertheless, capitalizing on its human capital well noted for good innovation, education, and research potential, efforts to integrate AI in addressing the food security challenges are emerging. In the absence of any significant effort to generate and manage big data on any pillar of food security in Lebanon, this paper maps the most relevant attempts to use AI in agriculture, food processing and quality, food aid and distribution, etc. To that end, a desk research approach has been conducted and has reviewed the available literature about the broad interpretation of AI to include applications such as digital technology, IoT, online services, smart technologies, knowledge-sharing platforms, etc., when used in the Agri-food context. In parallel, opinions from experts involved in Agri-food technology research, governance, or practice have sought a contextualized perspective on existing gaps and potential opportunities for AI use in food security in Lebanon. The paper concludes with recommendations for moving forward with the responsible use of multiple AI technologies to ensure food security from farm to fork.

I. INTRODUCTION AND BACKGROUND

One of society's most pressing challenges revolves around achieving food security amid an anticipated population surge expected to reach just under 10 million by 2050.[1] The upward trajectory of average wealth also influences food consumption patterns and dietary preferences, placing added strains on the agricultural sector to meet growing demands.[2] Conventional agricultural practices are marked by excessive fertilizers, pesticides, antibiotics, the wide-scale use of monocropping systems, relatively inefficient irrigation, and numerous other unsustainable approaches. Although these practices have substantially increased agricultural productivity and efficiency, alleviating hunger in many parts of the world,[3] the upward productivity trends following these practices will significantly fall short of meeting future demands.[4] Furthermore, such a food system is not equipped to manage the increasing threats posed by climate change and environmental degradation. A new agricultural revolution is imperative to ensure a continuously growing food supply without compromising the environment's capacity to provide for this demand sustainably.

The emergence of AI and related technologies in agriculture, often referred to as the "Fourth Agricultural Revolution,"[5,6] has unlocked numerous opportunities in the realm of data analytics, marking a profound transition in the intersection of farming practices and advanced technology. The impact of AI extends across all stages of the agricultural process, significantly improving crop resilience and sustainability right from the initial pre-sowing stage. AI can significantly accelerate the production of improved crop varieties that demonstrate higher resilience to climate change while posing fewer environmental risks. It does this by accelerating and improving the efficacy of both plant breeding[7] and gene editing[8] processes. AI technologies have significantly advanced precision agricultural practices at the field level, resulting in more efficient resource allocation and optimized decision-making.[9]

Digital sensors, drones, and other data-collection methods have revolutionized data gathering, providing immediate insights into crop and

1 DESA, U. N. (2015). World population prospects: The 2015 revision, key findings and advance tables. *Working PaperNo*.

2 Vranken, L., Avermaete, T., Petalios, D., & Mathijs, E. (2014). Curbing global meat consumption: Emerging evidence of a second nutrition transition. *Environmental Science & Policy*, *39*, 95-106.

3 Pingali, P. L. (2012). Green revolution: impacts, limits, and the path ahead. *Proceedings of the national academy of sciences*, *109*(31), 12302-12308.

4 Ray, D. K., Mueller, N. D., West, P. C., & Foley, J. A. (2013). Yield trends are insufficient to double global crop production by 2050. *PloS one*, *8*(6), e66428.

5 Barrett, H., & Rose, D. C. (2022). Perceptions of the fourth agricultural revolution: what's in, what's out, and what consequences are anticipated?. *Sociologia Ruralis*, *62*(2), 162-189.

6 Boon, R. K. D., Price, C., & Schillings, J. (2022). The fourth agricultural revolution: technological developments in primary food production. *A Research Agenda for Food Systems*, 151.

7 Rai, K. K. (2022). Integrating speed breeding with artificial intelligence for developing climate-smart crops. Molecular Biology Reports, 49(12), 11385-11402.

8 Kaul, T., Sony, S. K., Bharti, J., Motelb, K. F. A., Verma, R., Thangaraj, A., ... & Eswaran, M. (2022). CRISPR genome editing brings global food security into the first Lane: Enhancing nutrition and stress resilience in crops. In *Next-generation plant breeding approaches for stress resilience in cereal crops* (pp. 285-344). Singapore: Springer Nature Singapore.

9 Misra, N. N., Dixit, Y., Al-Mallahi, A., Bhullar, M. S., Upadhyay, R., & Martynenko, A. (2020). IoT, big data, and artificial intelligence in the agriculture and food industry. IEEE Internet of Things Journal, 9(9), 6305-6324.

soil health. AI's ability to process large datasets has, therefore, greatly improved yields while reducing the use of harmful and unnecessary inputs. These technologies have also allowed for more efficient crop monitoring and management, posing as an early detection system for various diseases, pest outbreaks, and extreme weather events, among other environmental stressors.[10,11] By precisely identifying and targeting pests and weeds in the field, AI can eliminate external threats to crops with minimal chemical usage, resulting in fewer environmental risks associated with food production.[12,13] Applications of AI in agricultural supply chains also take on a wide range of uses, including the categorisation of goods for quality assurance,[14] the identification of defects in food processing,[15] and the monitoring of storage environments for optimal conditions.[16] Moreover, blockchain technology can significantly enhance the transparency of agri-value chains, increasing accountability and trust throughout the supply chain.[17]

Lebanon has been grappling with food insecurity due to many interconnected challenges, especially in recent years. A series of recent shocks, including political unrest and revolt, economic and financial crises, the COVID-19 pandemic, and the Beirut port explosion have compounded the issue, exacerbating poverty and food insecurity and landing Lebanon a good spot on the worst global economic crashes' list.[18] These challenges resulted in declining agricultural production due to farmers' diminishing purchasing power.[19] The country is highly import-dependent, importing around 80% of its food requirements,[20] which makes it highly vulnerable to global challenges such as climate change, supply chain disruptions, and price fluctuations. For example, the dependency on cereal imports (which constitute a large portion of the Lebanese diet) has contributed to the worsening food security and nutritional status following the Ukrainian-Russian conflict.[21] The Syrian refugee crisis also led to an influx of around 1.5 million refugees (almost 30% of Lebanon's population), adding additional strains on natural resources and land availability while increasing the demand for food.[22,,23] Despite these challenges, Lebanon possesses significant potential for adopting digital technologies in the agricultural sector.[24] These technologies can address the multifaceted challenges facing food production by optimizing resource management, improving productivity, and enhancing the sector's sustainability, all of which significantly alleviate food insecurity.

The aforementioned points raise many critical questions that necessitate an investigation of their outcomes in order to construct a clear understanding of the use and governance of AI for food security in Lebanon. The starting point is

10 Patil, S. S., & Thorat, S. A. (2016). Early detection of grapes diseases using machine learning and IoT. In 2016 second international conference on Cognitive Computing and Information Processing (CCIP) (pp. 1–5). IEEE.

11 Malhotra, C., & Anand, R. (2020, September). Accelerating public service delivery in India: application of internet of things and artificial intelligence in agriculture. In *Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance* (pp. 62-69).

12 Shah, F. M., & Razaq, M. (2020). From agriculture to sustainable agriculture: Prospects for improving pest management in industrial revolution 4.0. *Handbook of Smart Materials, Technologies, and Devices: Applications of Industry 4.0*, 1-18.

13 Partel, V., Kim, J., Costa, L., Pardalos, P. M., & Ampatzidis, Y. (2020). Smart Sprayer for Precision Weed Control Using Artificial Intelligence: Comparison of Deep Learning Frameworks. In *ISAIM*.

14 Zhao, J. C., Zhang, J. F., Feng, Y., & Guo, J. X. (2010, July). The study and application of the IOT technology in agriculture. In *2010 3rd international conference on computer science and information technology* (Vol. 2, pp. 462-465). IEEE.

15 Ganeshkumar, C., Jena, S. K., Sivakumar, A., & Nambirajan, T. (2023). Artificial intelligence in agricultural value chain: review and future directions. *Journal of Agribusiness in Developing and Emerging Economies*, *13*(3), 379-398.

16 Shariff, S. U., Gurubasavanna, M. G., & Byrareddy, C. R. (2019). IoT-based smart food storage monitoring and safety system. In *International Conference on Computer Networks and Communication Technologies: ICCNCT 2018* (pp. 623-638). Springer Singapore.

17 Kamilaris, A., Fonts, A., & Prenafeta-Boldú, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in food science & technology*, *91*, 640-652.

18 World Bank. (2021). *Lebanon Economic Monitor, Spring 2021: Lebanon Sinking (to the Top 3)*. World Bank.

19 UN World Food Programme, (2022). Global Report on Food Crises.

20 Halabi, S., & Ghanem, N. (2016). Strategic review of food and nutrition security in Lebanon. *Short Version. The United Nations Economic and Social Commission for West Asia (ESCWA), Beirut-Lebanon, p. 21pp*.

21 Yazbeck, N., Mansour, R., Salame, H., Chahine, N. B., & Hoteit, M. (2022). The Ukraine–Russia War Is Deepening Food Insecurity, Unhealthy Dietary Patterns and the Lack of Dietary Diversity in Lebanon: Prevalence, Correlates and Findings from a National Cross-Sectional Study. *Nutrients*, *14*(17), 3504.

22 Nassar, J., & Stel, N. (2019). Lebanon's response to the Syrian refugee crisis–Institutional ambiguity as a governance strategy. *Political Geography*, *70*, 44-54.

23 EU, (2019). Lebanon. European Union (EU): European Civil Protection and Humanitarian Aid Operations (ECHO). Beirut, Lebanon.

24 Bahn, R. A., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021a). Digital Revitalization of the Agri-food Sector in Mashreq.

mapping the existing applications and familiarizing ourselves with the current technological components and digital systems integrated into the Lebanese agro-food system and what their contribution could be in enhancing food security. Additionally to that baseline, to what extent can AI be integrated into the existing high-tech infrastructure in the agri-food sector to holistically optimize its operation? And what are its potential applications in improving decision-making related to food security? Finally, what are the limitations in such infrastructure that hinder the overall performance of the sector, and how can these gaps be identified and addressed in accordance with relative stakeholders?

The study embarks on its journey to establish a logical and practical linkage between the famous four pillars of Food Security as defined by the Food and Agriculture Organization of the United Nations and Artificial Intelligence. This interrelation serves as a stimulus to both parties; from one end AI is able to learn the fundamentals of Availability, Access, Utilization and Stability, while the Food Security discourse may need to adjust some of its narratives in order to adapt with the new paradigm and optimize the benefit that may come along from such a twinning.

II. METHODOLOGICAL FRAMEWORK

Conducting this research has required the use of desk research and review of available literature on the use of AI in the Agri-Food sector. Scientific databases have been consulted, as well as keywords to cover multiple dimensions of food security such as (but not limited to) Agriculture, Food Security, Food Access, Food Production, and Food Shopping. Additional keywords related to Artificial Intelligence in its broader perspective like Digital Technology, Social Media, Internet of Things (IoT), Smart Technology, Big Data, Precision Agriculture, and more. The entire approach has kept the four pillars of Food Security at the center of the debate/research in general, framing the macro aspect of the study.

Yet to delve into the subject in a more pragmatic way, semi-structured interviews and Focus Group Discussions with experts in Agri-Food technology research, governance, practice and commercialization have been conducted. Six semi-structured interviews and three Focus Group Discussions' opinions have been sought, notably about

- Strengths of existing AI infrastructure, policies and practices as related to one or more pillars of food security
- Opportunities for growth and improvement
- Weaknesses and gaps in existing AI infrastructure, policies and practices as related to one or more pillars of food security
- Recommendation for addressing the shortcomings by the relevant stakeholders in the AI and food security sector

Both semi-structured interviews and Focus Group Discussions were conducted online via Zoom meetings after all participants provided consent to take part in this study. Each of the semi-structured interview was lasting on average 30 minutes while the FGDs were taking between 60 to 80 minutes each given the additional number of people. All the information have been well documented, processed and used in the analysis of the study. The number of participants in each FGD is clarified in the below summary of each group, while guiding questions that were used for interviews and FGDs discussions are featured as an annex at the end of the study.

Those singular and group discussions have provided the research with insights into the present and future prospective role of AI in supporting Food Security and the needed action to that end. Technical experts in agriculture as well as researchers were designated to address the Availability and Stability pillars of the 4 pillars, while professionals in Food Security, Business people and Producers were designated to provide particular views about the Accessibility and Utilization pillars, both in quite a hybrid way without any restrictions or limitations.

The backgrounds and expertise of the six interviewed subject matter experts are:

- **Expert 1:** IT Specialist in Agriculture
- **Expert 2:** IT Specialist in Food Security and Big Data
- **Expert 3:** AI/IT Innovation and Entrepreneurship Specialist in the Food Sector
- **Expert 4:** Owner of a Major Trade Company in Fresh Fruits and Vegetables
- **Expert 5:** Economic Studies and Statistics Services Executive at the Ministry of Agriculture
- **Expert 6:** Professor of Food Processing and Packaging

While the background and expertise of the three Focus Group Discussions cohorts are:

- **Group 1:** Gathered Producers and Processors in the agri-food sector to focus on the preproduction and production. This group hosted an owner of a winery, owner of an organic processing firm, a program coordinator in an agricultural firm, and a senior agricultural Engineer. The total number of participants in this group was 4 and moderated by 2 researchers from the study cohort.

- **Group 2:** Gathered Business People active in the agri-food sector to focus on the commercial aspect. This group hosted a specialist in agri-food software and traceability, a business development expert, and an IoT Engineer working in an agricultural company. The total number of participants in this group was 4 and moderated by 2 researchers from the study cohort.

- **Group 3:** Gathered Researchers and Academics in multiple fields to focus on macro perspectives, notably policies. This group hosted a professor in e-finance, a chairperson in the department of agriculture of a local university, a professor in plant and forest health, an expert in environmental microbiology and composting and a professor in plant production and plant breeding. The total number of participants in this group was 5 and moderated by 2 researchers from the study cohort.


AI

III. RESULTS

a. Desk Research Findings

The use of AI in food production

Lebanon is still in the early stages of integrating AI/IT into agricultural production. However, notable progress is being made, potentially signaling a significant future shift in the agricultural sector. The Lebanese Agricultural Research Institute (LARI) is leading the effort in early weather warning systems, with weather stations deployed across the country providing forecasts and tailored recommendations to subscribed farmers through SMS, a mobile application, and directly via their website.[25,26] Farmers can then modify their farming practices, irrigating more efficiently, preparing for extreme weather events, and applying preventative pest measures. LARI also developed and tested a smart irrigation application that utilizes their weather forecasting data in conjunction with soil sensors to enhance the precision and efficiency of irrigation practices.[27] Similarly, the National Center for Remote Sensing (NCRS) has developed smart irrigation technologies that utilize satellite and atmospheric data to calculate evapotranspiration rates and estimate irrigation needs.[28]

LEBANESE VINEYARDS HAVE ALSO ADOPTED A RANGE OF PRECISION AGRICULTURE TECHNIQUES TO EVALUATE AND ENHANCE VINE PERFORMANCE.

Lebanese vineyards have also adopted a range of precision agriculture techniques to evaluate and enhance vine performance. Chateau Kefraya, for example, uses various sensors to automate data collection on environmental parameters such as soil humidity and temperature, luminosity, solar radiation, temperature, humidity, and atmospheric pressure.[29] Building on the success of this project, Ogero, Lebanon's largest telecom operator and partner in this endeavor, will develop a countrywide IoT low-power WAN network to facilitate similar future initiatives.[29,30] Domaine des Tourelles, another vineyard in Bekaa, uses remote-sensing drone technology to collect data on water levels and potential disease outbreaks in their vines.[26]

A study[31] conducted in the Bekaa Valley used remote sensing data from the Sentinel-2 satellites to monitor potato crop health through various vegetation indices. This can provide reliable data for precision agriculture, allowing farmers to monitor crop health and water content variability across fields, predict yields, and identify peak seasons at low costs. Combining such freely available satellite imagery with open-source software such as QGIS has the potential to be highly accessible to Lebanese farmers. Another study[32] aimed to address challenges associated with remote sensing data, such as cloud cover and low resolution, by developing a mathematical model to improve the accuracy of crop yield estimation in potato fields. This allows farmers to overcome data limitations that arise from satellite data, enhancing their decision-making process in agricultural management. Additionally, efforts have been made to use advanced remote sensing technologies coupled with an artificial neural network algorithm[33] to assess chlorophyll content in wheat crops, providing physiological crop data and a better understanding of responses to fertilizer application.

25 Jomaa, I., & Shaban, A. (2018). Improving water-Use efficiency and productivity in the Litani River basin. *The Litani River, Lebanon: An Assessment and Current Challenges*, 107-119.

26 Bahn, R. A., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021a). Digital Revitalization of the Agri-food Sector in Mashreq.

27 Abi Saab, M. T., Jomaa, I., Skaf, S., Fahed, S., & Todorovic, M. (2019). Assessment of a smartphone application for real-time irrigation scheduling in Mediterranean environments. *Water*, *11*(2), 252.

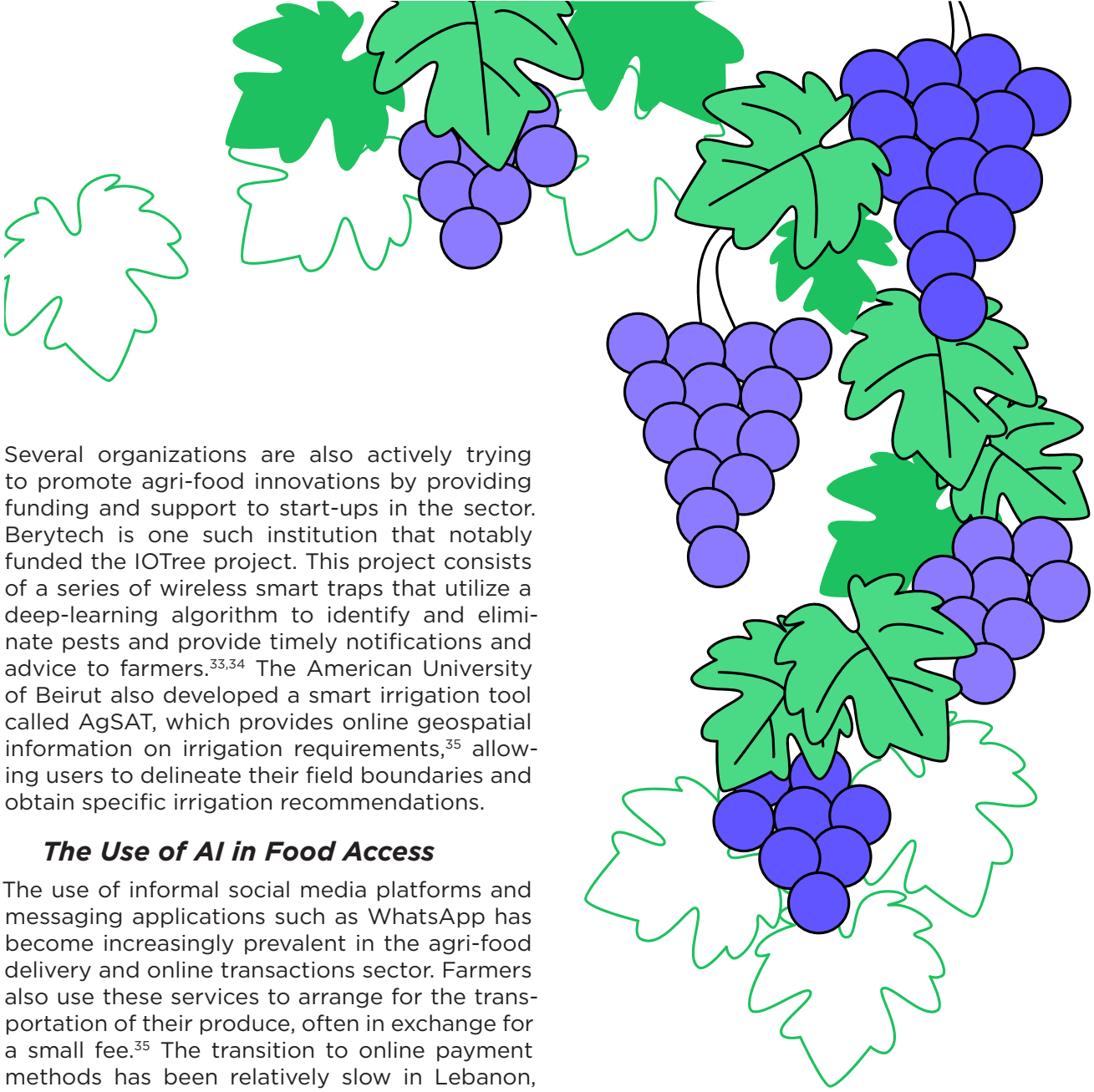
28 Mhawej, M., Caiserman, A., Nasrallah, A., Dawi, A., Bachour, R., & Faour, G. (2020). Automated evapotranspiration retrieval model with missing soil-related datasets: The proposal of SEBALI. *Agricultural Water Management*, *229*, 105938.

29 Libelium, (2017). The first Smart Vineyard in Lebanon chooses Libelium's Technology to face the Climate Change.

30 Kerlink, (2017). Kerlink Partners with Libatel to Deploy Lebanon's First Internet of Things Network for Smart Agriculture.

31 Abou Ali, H. (2018). *Precision Agriculture for Improving Potato Crop Management in Lebanon* (Doctoral dissertation, Idaho State University). See also: Hanan Abou Ali, M. S., Delparte, D., & Griffel, L. M. Utilizing Sentinel–2 Satellite Imagery For Precision Agriculture Over Potato Fields In Lebanon.

32 Awad, M. (2016, November). New mathematical models to estimate wheat Leaf Chlorophyll Content based on Artificial Neural Network and remote sensing data. In *2016 IEEE International Multidisciplinary Conference on Engineering Technology (IMCET)* (pp. 86-91). IEEE.



Several organizations are also actively trying to promote agri-food innovations by providing funding and support to start-ups in the sector. Berytech is one such institution that notably funded the IOTree project. This project consists of a series of wireless smart traps that utilize a deep-learning algorithm to identify and eliminate pests and provide timely notifications and advice to farmers.[33,34] The American University of Beirut also developed a smart irrigation tool called AgSAT, which provides online geospatial information on irrigation requirements,[35] allowing users to delineate their field boundaries and obtain specific irrigation recommendations.

The Use of AI in Food Access

The use of informal social media platforms and messaging applications such as WhatsApp has become increasingly prevalent in the agri-food delivery and online transactions sector. Farmers also use these services to arrange for the transportation of their produce, often in exchange for a small fee.[35] The transition to online payment methods has been relatively slow in Lebanon, partly due to a distrust of online purchasing,[35,36] exacerbated by the recent breakdown of the financial sector. The adoption of digital marketing among farmers is still limited and restricted to platforms such as Instagram and Facebook, with many struggling to use them effectively. Challenges in this aspect include the lack of expertise and financial restrictions, which also hinder them from hiring expert help.[37]

The AgVisor application has been developed to enhance the informational aspect of food access for farmers. This app provides national pricing information and serves as a directory for participants involved in agricultural value chains, empowering farmers to make better-informed decisions and reduce the occurrence of price manipulation.[38] However, such initiatives encounter several challenges, including issues surrounding data collection and updates.[35] Additionally, some Lebanese farmers are unable to benefit from these tools due to the prevalence of informal pre-paid credit arrangements that are characteristic of the agricultural financing sector in the country.[39] Similar applications, such as the Lebanese Olive Oil application, developed by the Ministry of Agriculture, serve as a bridge between farmers and consumers. This application links various actors across the val-

33 Executive Bulletin, (2019). Touch partners with IOTree for the First NB-IoT Application in Lebanon.

34 Bahn, R. A., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021a). Digital Revitalization of the Agri-food Sector in Mashreq.

35 AUB, (2021). AgHive publishes 'Revolutionizing Smart Irrigation with AgSAT' Story Map under 'SDGs Today' Collection.

36 Rahal, M. (2013). E-Commerce in Lebanon: An Overview.

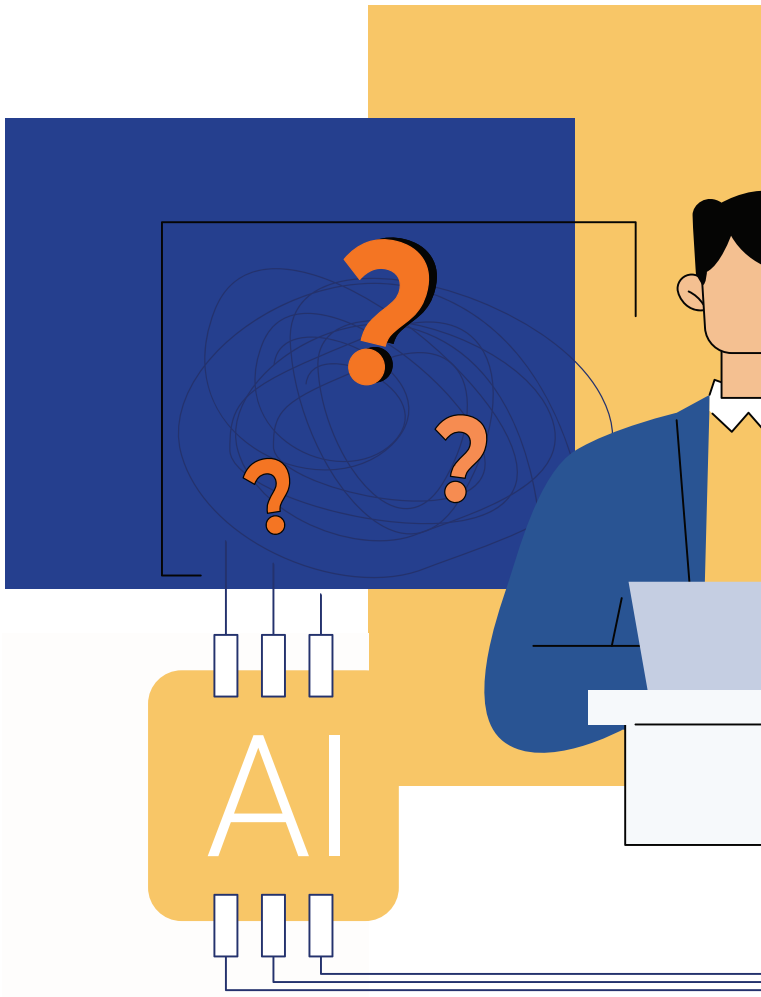
37 Personal communication with Marybel Imad from AUB's Environment and Sustainable Development Unit.

38 FAO, (2020). Digital Innovation for Promoting Agriculture 4.0 in the Near East and North Africa. FAO Regional Conference for the Near East.

39 Bahn, R., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021b). Harnessing the Power of Digital Agriculture Transformation in Mashreq. *American University of Beirut*.

ue chain, such as producers, olive mills, farmers, and relevant cooperatives, promoting and raising awareness of high-quality olive oil. As per its description on the app store, "The app "زيت لبنان" or "L'Olio Del Libano" has been developed within the framework of the project "Strengthening and enhancing quality olive oil chain in Lebanon (L'Olio Del Libano III)" which is financed by the Italian Government represented by the Italian Agency for Development Cooperation (AICS) and implemented by the International Center for Advanced Mediterranean Agronomic Studies (CIHEAM) Bari, in close cooperation with the Lebanese Ministry of Agriculture (MoA)".[40] Efforts have also been made by the International Labour Organization (ILO) to facilitate cooperation between farmers and enhance market access through applications.[41]

Efforts have also been undertaken to incorporate digital technology in addressing the country's multifaceted challenges and consequent poverty. For example, e-vouchers are being administered to address the Syrian refugee crisis.[42] The National Poverty Targeting Program (NPTP) also uses e-cards to support the economically disadvantaged by sending money digitally.[41,43] The government has also adopted remote sensing techniques through the NCRS to validate subsidy programs and reduce corruption.[41]



The Use of AI in Food Processing

Given Lebanon's history of food safety scandals, the implementation of AI/IT in food processing holds great potential when it comes to ensuring food safety and quality standards. 44The presence of pathogenic microorganisms and pesticide residues in Lebanese foods far exceeds international safety standards,[44,45,46] greatly hindering access to export markets. The country lacked a food safety law up until 2016 (No. 35), and the regulatory framework remains fragmented with overlapping institutional responsibilities. The public sector has taken some steps using information technology to combat this issue, including a database for food establishments to improve food safety monitoring, a registry system for farmers using remotely sensed data and GIS technology, and a series of web applications that enable monitoring and inspection for various sectors in the agri-food chain.[41] The private sector, specifically large-scale exporters, has seen the highest adoption rates for digital

40 Retrieved from the description on the App Store: https://play.google.com/store/apps/details?id=lb.com.fresh.oliodellibano&hl=en&gl=US

41 Bahn, R. A., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021a). Digital Revitalization of the Agri-food Sector in Mashreq.

42 Talhouk, R., Coles-Kemp, L., Jensen, R. B., Balaam, M., Garbett, A., Ghattas, H., ... & Montague, K. (2020). Food aid technology: the experience of a Syrian refugee community in coping with food insecurity. *Proceedings of the ACM on Human-Computer Interaction*, *4*(CSCW2), 1-25.

43 Bou Khater, L. (2020). Poverty Targeting is not the Solution for Much Needed Social Policy. The Lebanese Center for Policy Studies.

44 Harakeh, S., Yassine, H., Gharios, M., Barbour, E., Hajjar, S., El-Fadel, M., ... & Tannous, R. (2005). Isolation, molecular characterisation and antimicrobial resistance patterns of Salmonella and Escherichia coli isolates from meat-based fast food in Lebanon. *Science of the Total Environment*, *341*(1-3), 33-44.

45 Harakeh, S., Saleh, I., Zouhairi, O., Baydoun, E., Barbour, E., & Alwan, N. (2009). Antimicrobial resistance of Listeria monocytogenes isolated from dairy-based food products. *Science of the Total Environment*, *407*(13), 4022-4027.

46 El Hawari, K., Mokh, S., Al Iskandarani, M., Halloum, W., & Jaber, F. (2019). Pesticide residues inLebanese apples and health risk assessment. *Food Additives & Contaminants: Part B*, *12*(2), 81-89.

technologies in food processing and quality standards, securing international quality certifications for enhanced traceability and quality.[41] Some previous efforts have also been made in the private sector utilizing radio-frequency identification to optimize the distribution of cold-chain products, ensuring that the process includes minimal temperature fluctuations.[41] Some professors at the American University of Beirut have also developed a machine that selects and groups cucumbers based on their size and shape for pickling companies.[47] In addition, the expansion of various international companies into Lebanon has enhanced the utilization of blockchain technology.[48] For example, Making Cents International and BanQu are leading the effort to create digital economic identities for refugees and marginalized groups, which will greatly improve supply chain traceability, especially since refugees make up a substantial portion of the agricultural workforce.[49]

Available Big Data, Accessibility, Transparency, and Governance

The term "big data" doesn't adhere to a specified threshold but rather encompasses vast and complex datasets. In the case of the Lebanese agricultural sector, several elements closely resemble this broad definition. Examples include weather stations deployed across the country, which contribute to weather-related big data, the use of satellite remote sensing techniques, as well as sensor-generated data. The establishment of digital early warning systems and various applications that guide farmers on practices such as irrigation and pest management has greatly enhanced their access to agricultural data, which can facilitate decision-making.[48] These applications are generally free of charge and provide simplified timely updates via SMS, mobile applications, and websites.

Available Policies Related to AI/IT and Food Security

Government involvement in the Lebanese agricultural sector has historically been minimal, with the sector largely left to unregulated market forces within the private sector within a laissez-faire economic framework.[50] There are no existing policies or regulations addressing the use of AI/IT in agriculture. The Lebanon National Agricultural Strategy for 2020-2025, however, does address the use of innovative and modern technologies as an integral part of achieving increased agricultural production and productivity.[51,52] Interventions under this goal include promoting innovative technologies and R&D, improving access to credit for enhanced investment capabilities, facilitating knowledge sharing between relevant stakeholders, and improving extension/technical services. This document primarily outlines the objectives and priorities of the governmental agriculture strategy instead

47 Anderson, B. (2017). Agritech Sprouts Among Lebanon's Stratups. Wamda.

48 FAO, (2020). Digital Innovation for Promoting Agriculture 4.0 in the Near East and North Africa. FAO Regional Conference for the Near East.

49 Bahn, R. A., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021a). Digital Revitalization of the Agri-food Sector in Mashreq.

50 Bahn, R. A., Nisr, R., & El Labban, S. (2018). Food policy in Lebanon. *Reference Module in Food Science – Food Management, Policy, and Regulations.* New York: Elsevier. doi:10.1016/ B978-0-08-100596-5.22365-2.

51 NAS, (2020). Lebanon National Agricultural Strategy, 2020-2025. Lebanese Republic Ministry of Agriculture.

52 Dal, E., Díaz-González, A. M., Morales-Opazo, C., & Vigani, M. (2021). *Agricultural sector review in Lebanon* (Vol. 12). Food & Agriculture Org.

of a policy framework. However, it does touch upon policy interventions related to innovation and technology that come in the form of ad hoc input distributions that promote advanced technologies when a surplus budget is available. The legal framework for digital technology and finances has been adopted to some extent with data protection, online privacy, intellectual property rights, and protection against cybercrime.[48] These regulatory structures extend into the agricultural sector as it continues to undergo digitisation. So far, this has come in the form of data protection measures adopted by agricultural applications, as well as regulatory measures that reserve the right to access data to ensure compliance and prevent unlawful activities such as identity theft, violating intellectual property rights, etc. These are communicated to the farmers via the terms and conditions. A consumer protection framework is still absent within this evolving digital landscape.[52] Overall, more concentrated efforts are required to facilitate a safe digitalisation process and ensure that the rights of all stakeholders are protected.

Identification of existing challenges, gaps, strengths, and potential solutions

Integrating AI/IT in the Lebanese agricultural sector faces various challenges, with the most prominent issues being rooted in financial constraints. Currently, the adoption of these technologies has been limited to large-scale producers in the private sector.[53] Small-medium scale producers are financially constrained by several prevailing factors attributed to the ongoing financial and economic crises. The drastic devaluation of the Lebanese Lira has left farmers with limited purchasing power to import raw materials and invest in new technologies. This also halted the sector's primary funding mechanism, which occurred on a credit basis through agricultural input suppliers.[54] The collapse of the banking sector resulted in further limitations on accessing financial assets, leading to widespread distrust of the sector.[55] This also led to the termination of various online transactions, which considerably set back digitalisation efforts. The general absence of governmental engagement and investment in agricultural affairs[56] also limits the development of new technologies, leaving the private sector to finance these technologies while pursuing their agendas.[52] Loan acquisition is also particularly challenging for farmers due to high interest rates and their frequent inability to provide collateral. Other challenges include an aging agricultural workforce,[57] which also exacerbates the issues surrounding literacy and digital proficiency. Around 16% of farmers in Lebanon lack basic literacy skills, and just over 60% receive only primary-level education.[58,52] Digital connectivity is also quite low among farmers, and language barriers often hinder engagement with digital services.[59]

Despite these challenges, various opportunities exist for leveraging AI/IT to enhance food security, agricultural sustainability, and resource management in Lebanon. Enhanced agricultural input efficiency and increased yields can create greater prospects for exporting agricultural products to global markets. Lebanon has a reputation for excessive pesticide use and residue levels, which have previously deterred international buyers.[60]

53 Bahn, R. A., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021a). Digital Revitalization of the Agri-food Sector in Mashreq.

54 Saade, R. F. (2021) *Diagnosing the situation of Lebanese agriculture in light of the current financial and economic crisis, immediate solutions and a future vision.*

55 Khalife, D., Yammine, J., & El Bazi, T. (2022). How to Put the Collapsed Lebanese Banking Sector on the Right Track? *Arab Economic and Business Journal*, *14*(1), 31-46.

56 Bahn, R. A., Nisr, R., & El Labban, S. (2018). Food policy in Lebanon. *Reference Module in Food Science – Food Management, Policy, and Regulations.* New York: Elsevier. doi:10.1016/ B978-0-08-100596-5.22365-2.

57 Salameh, L. (2022). *Youth, Economic Crisis, and the 'Return to the Land', the Case Study of Agriculture and Livestock Farming in West Bekaa* (Doctoral dissertation).

58 UN World Food Programme, (2022). Global Report on Food Crises.

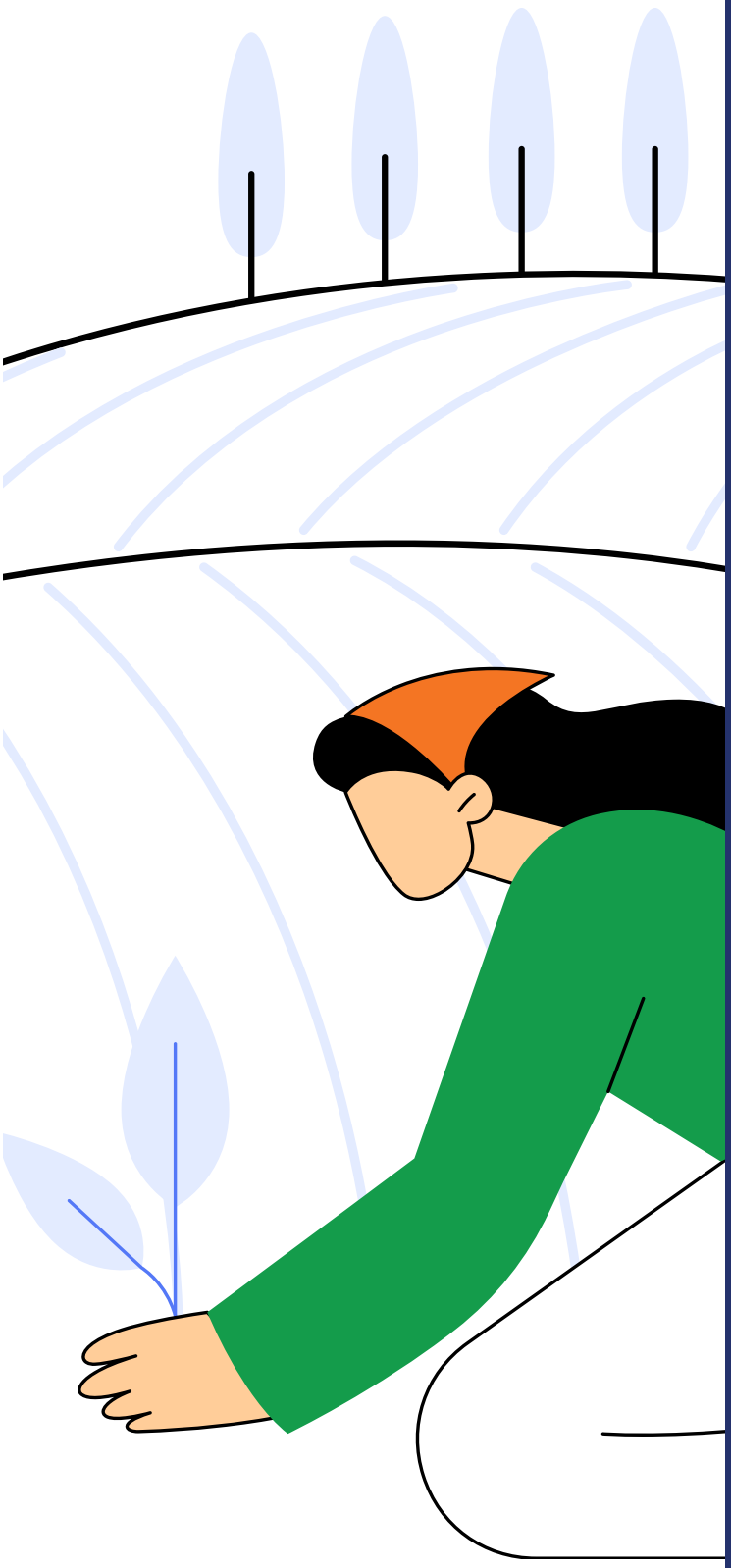
59 Bahn, R., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021b). Harnessing the Power of Digital Agriculture Transformation in Mashreq. *American University of Beirut*.

60 El Hawari, K., Mokh, S., Al Iskandarani, M., Halloum, W., & Jaber, F. (2019). Pesticide residues inLebanese apples and health risk assessment. *Food Additives & Contaminants: Part B*, *12*(2), 81-89.

Increasing agricultural exports can help alleviate Lebanon's foreign exchange balance while reducing import dependency.[52] AI/IT can also stimulate job creation, requiring new skills and expertise in the agricultural sector. This might also encourage younger generations to take up farming, potentially combating the sector's aging population issue. These opportunities for the growth of the agricultural sector could potentially trigger a multiplier effect on the overall economy,[61] mitigating the adverse effects of the recent economic collapse. One study[62] gauged Lebanese farmers' attitudes towards adopting smart irrigation tools and found that almost 90% were willing to use free smart technologies, and around 60% would happily pay for these technologies.

From an environmental perspective, integrating AI/IT in agriculture can safeguard the sector's long-term sustainability, ensuring continuous food production. This can be achieved by mitigating the effects of climate change and environmental degradation stemming from conventional agricultural practices through enhanced efficiency and decision-making processes. Furthermore, Lebanese produce is frequently at risk of contamination due to factors such as polluted water bodies, the excessive use of fertilizers and pesticides, and susceptibility to disease outbreaks. AI technologies can play a crucial role in mitigating these occurrences by accurately detecting and issuing warnings, thereby improving the country's food safety standards.

The desk research findings closely align with the four pillars outlined by the FAO, emphasizing the integral role that AI/IT can play in food security. The adoption of these technologies within the Lebanese agricultural sector holds great potential for optimizing food production, thereby improving availability, and facilitating supply chain connections through digital platforms, promoting access. Moreover, the optimization of food processing and quality standards aid in proper utilization, whereas data-driven decision-making (that can result from things like early warning systems) greatly enhances the stability of food provision. The proper application of AI/IT throughout the agricultural landscape can offer a comprehensive strategy that is consistent with the FAO pillars that strengthen national food security.



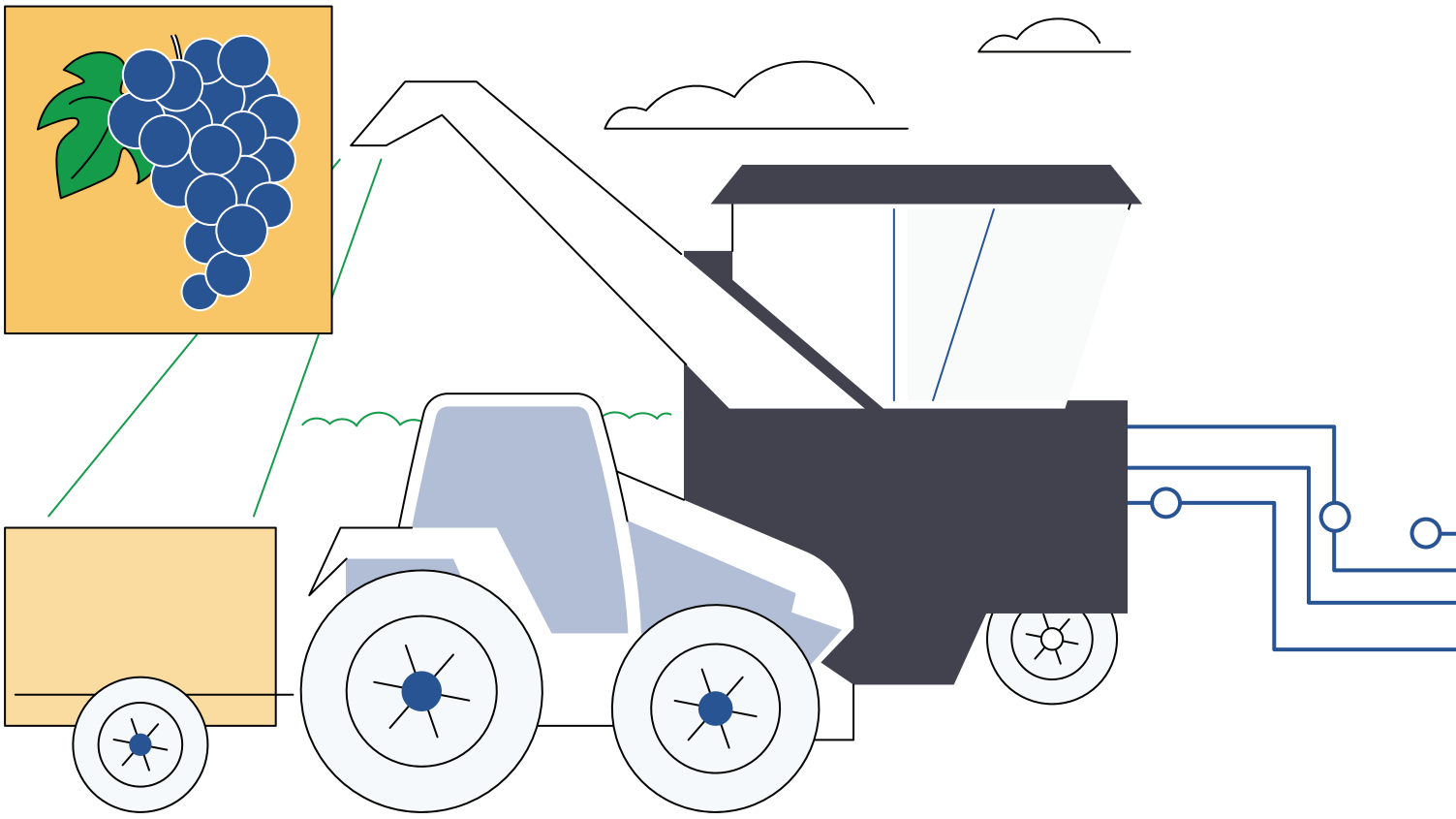
61 Yeboah, F. K., & Jayne, T. S. (2018). Africa's evolving employment trends. *The Journal of Development Studies*, *54*(5), 803-832.

62 Jaafar, H., & Kharroubi, S. A. (2021). Views, practices and knowledge of farmers regarding smart irrigation apps: A national cross-sectional study in Lebanon. *Agricultural Water Management*, *248*, 106759.

b. Expert Positions

The semi-Structured interviews with experts and the three Focus Group Discussions have generated multi-angles insights and notions. They are summarized in the below points and analyzed in the discussion.

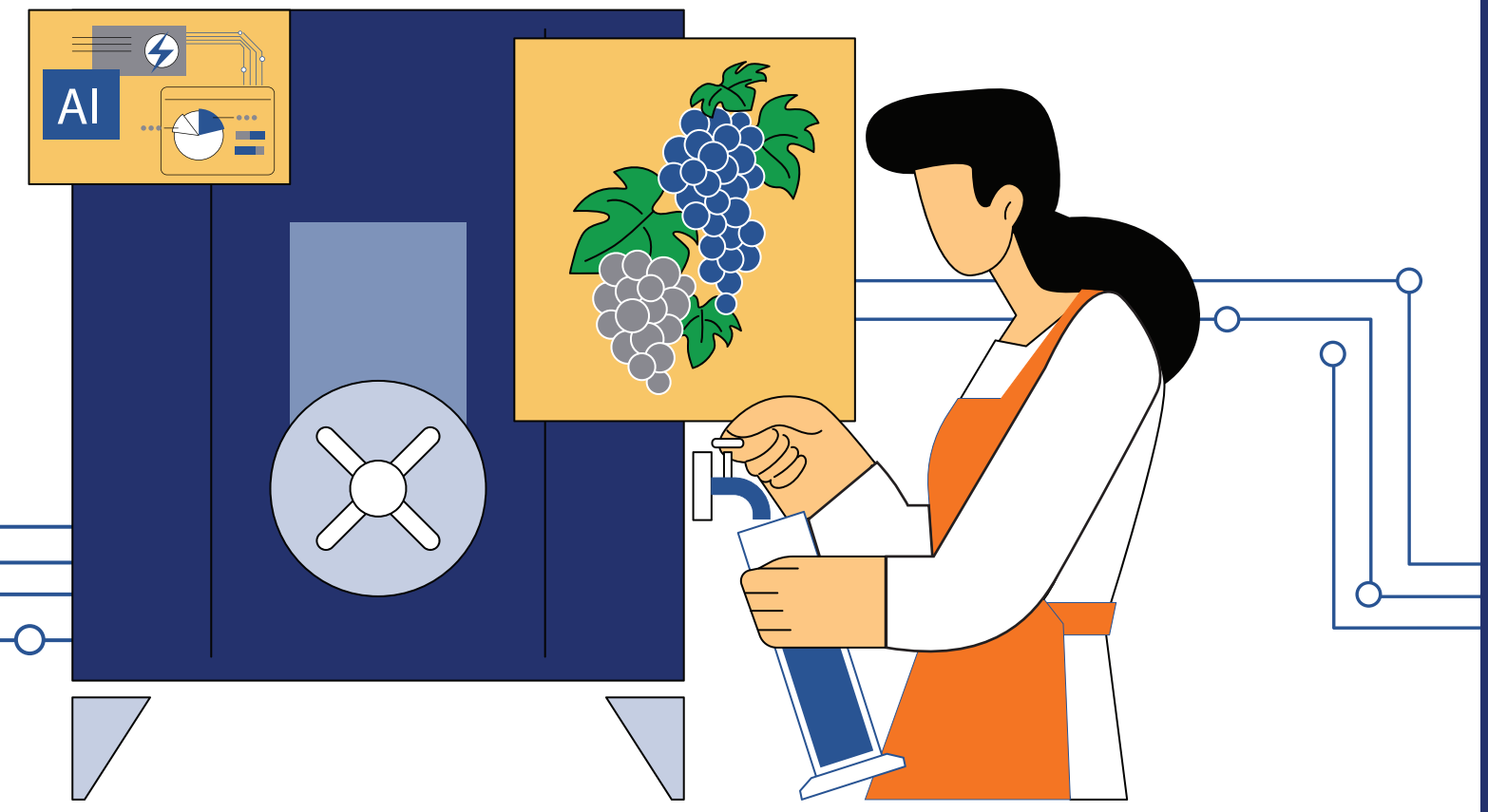
- The current state of AI and IT use in the Lebanese Agri-food Sector is finding its way in a very sporadic way in some applications and agricultural productions. The distinction between AI and High-Tech is deceiving here, as some approaches may not categorize as AI but rather high-tech but still considered significant progress in IT.
- The main challenges and gaps for AI and IT begin with the absence of proper R&D efforts as a primary barrier; and the resistance of old-school farmers that limits the progress to adopting new experiences. The decreased ability to acquire new technologies after the crisis has also played a major role.
- AI and IT play an important role in the post-production stages of the value chain in the Lebanese context, creating a linkage with customers, while their role remains limited in the earlier stages of the agri-food value chain.
- Internet connectivity and digital infrastructure are imperative technical bases needed to support AI and IT use. In addition, at the regulatory level, ethical and well-informed policies are required. A multi-stakeholders' approach is suggested since many aspects are engaged, mainly the education sector that is expected to spearhead the entire mechanism.
- A concerning absence of any regulatory/policy aspect within the Lebanese governing system to address the high-tech/AI topic in the country. The concern is even expanding towards the fact that the intention of addressing any regulatory framework is quasi-far in the list of national priorities.



IV. ANALYSIS AND DISCUSSION

The existing literature and the diversified panel of experts have provided extensive and rich outcomes to base the analysis and the discussion on. Currently, the adoption of artificial intelligence (AI) and information technology (IT) in the Lebanese agri-food sector is in its nascent stages. While AI is not yet widely integrated into agricultural production, it has found applications in data collection, production tracking, management, and marketing. Examples include its utilization in content development, product marketing, consumer trend analysis, and the development of stock management programs. Technology and digitalization in agriculture and food production are steadily growing, although they are still limited. Notably, experts say that the main growth in AI and IT use is observed in the food retail and post-harvest sectors, where consumers can shop for food products online in real-time, thereby contributing to food security. But not only, examples from focus group discussions have shown significant advancements in the grape and wine sector, notably grape production and monitoring, to wine bottling and aging, technology is playing a crucial role, aiming at efficient resource utilization and cost reduction. In the animal sector, prototypes are under development for large-scale monitoring of chickens, focusing on parameters such as temperature, humidity, and virus detection. These developments, although not strictly categorized as AI, represent important progress in the adoption of information technology, according to our interviewees. So does machine learning, as it made its entry into the Lebanese agri-food sector in 2020 with a project designed to supervise onion fields, including tasks like weeding, watering, and pesticide use. However, its progress has also been hindered by a lack of infrastructure and funding similarly to other components that will emerge momentarily in the discussion. It is worthy to note though, that the post-harvest stage for horticultural products, is still expected to witness substantial growth in AI adoption to enhance shelf life and minimize errors in handling sensitive products as highlighted by one expert in the private sector, given the already existing infrastructure on that level of the value chain compared to earlier stages.

Speaking of infrastructural challenges, the journey towards AI and IT adoption in Lebanon's agri-food sector faces several substantial fences. Chief among these is the lack of research and development (R&D) efforts to further pursue or develop machine learning for AI. Funding for technology research in food security domains is largely driven by NGOs with short-term projects, while high-tech development typically requires more extensive timeframes. More practically in the agricultural sector, technology adoption re-



mains limited due to several key factors. These include farmer resistance to change, lack of trust in technology, limited understanding of farmers' primary issues among technology experts, a shortage of awareness, skills, and training in technology and AI among traditional farmers, and the fear of making costly investments. Furthermore, the economic crisis in Lebanon has contributed to a slowdown in technology development, as people and farmers are struggling to afford expensive machines, which extends the concerns to exportation, particularly regarding the stringent criteria for the export of raw fruits and vegetables, as the high costs of investment and a lack of expertise are noted as significant obstacles to AI implementation and integration.

Despite these challenges, experts say that AI and IT have substantial roles to play in advancing food security in Lebanon. The reliance on food purchase over food production highlights the critical need for digitizing the agri-food system in a bid to balance the value chain. In other words, AI is poised to revolutionize post-harvest processes, where it can take on a vital role in sensory evaluation, grading products for further processing, and optimizing storage conditions to extend shelf life, and these are relevant attributes given the sensitivity of horticultural products. It is nevertheless crucial to incorporate AI into agriculture's earlier stages in order to enhance the quality and quantity of food production, and this is where the Lebanese sector has been found lacking. Context: if we trace it back to the post-civil war period in Lebanon (early to mid-90s), we could find a correlation between the nature of the established reforms and the emergence of the 'Supermarketization' in the country. The rural neglect that has deteriorated the agricultural and industrial sector back then, has triggered the need to import the majority of commodities. This has laid the foundations for post-harvest/post-production infrastructure (supermarkets, delivery applications, etc); and opportunities that shifted the attention from earlier stages of agri-food production and hence justifying the subsequent weaknesses.

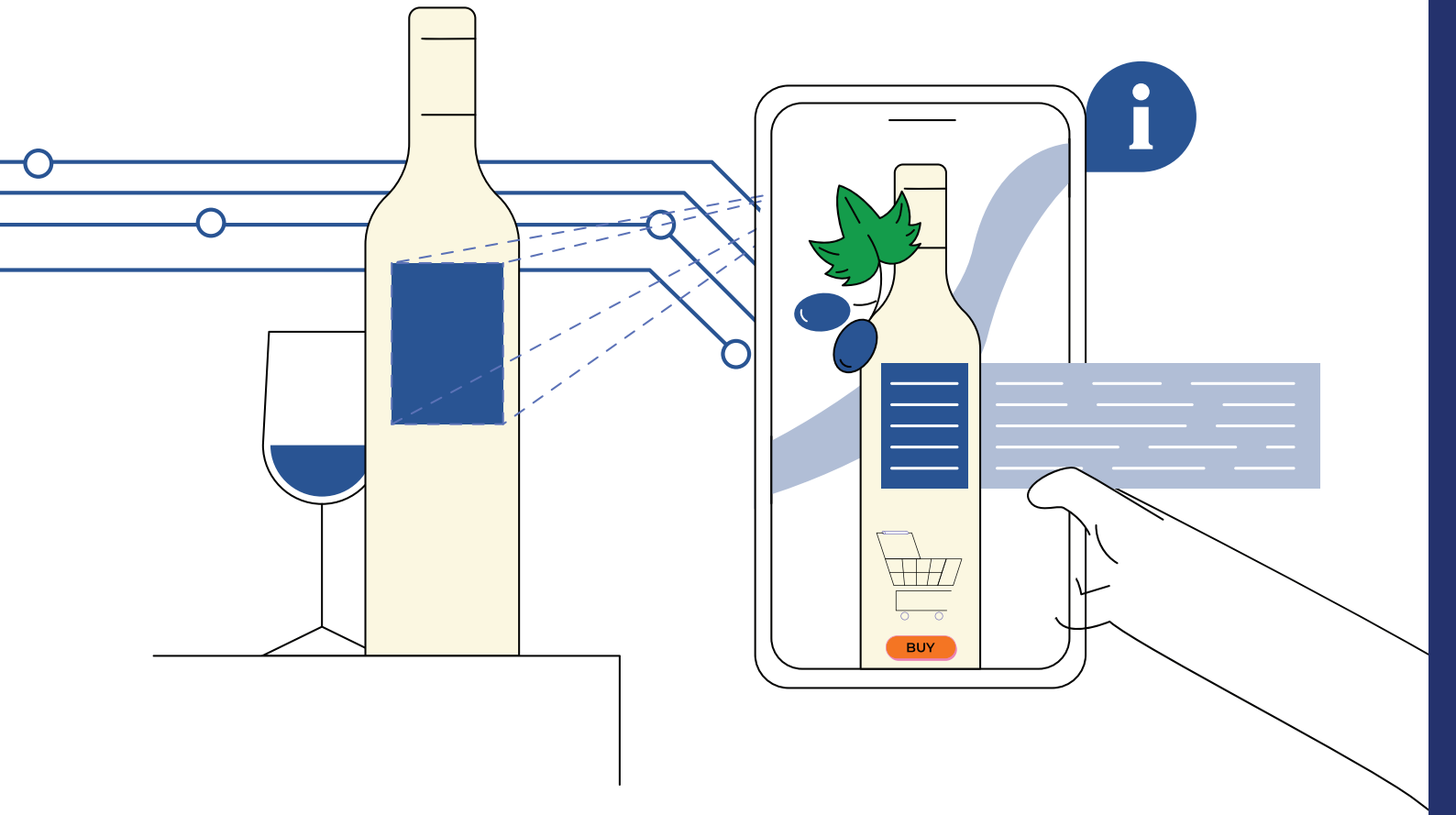
To promote the adoption of AI and IT in Lebanon's agri-food sector, a multifaceted approach is needed. Addressing infrastructure challenges is pivotal as agreed by the majority of our interviewees, with a focus on improving internet connectivity and digital infrastructure to facilitate AI and IT adoption. Moreover, comprehensive education and training programs should be developed to equip professionals, farmers, and the workforce with the essential skills for proficient AI and IT utilization. It is advised that the entire process takes into consideration the journey from low-tech to high-tech, in order to eventually reach a state where AI is nested. The low-tech situation in Lebanon is in dire need of a revisit before attempting any scaling or amplifying, but that is for another article.

For now, the establishment of ethical regulations governing AI use is necessary to ensure sustainable and responsible practices. Government ini-

tiatives may begin by raising awareness among farmers and promoting the adoption of appropriate reachable technology, without suggesting irrelevant and hard-to-acquire ones. In parallel, prioritizing fundamental infrastructures, such as internet accessibility and high-speed computers will also be essential for AI and IT adoption. Finally, and as iterated by academics during our semi-structured interviews, collaborative efforts that include research and development in alliance with funding agencies are the third helix which could turn out to be vital for minimizing risks associated with AI and IT adoption.

The integration of AI and IT into the agri-food sector holds immense potential for advancing food security in Lebanon, provided that these challenges are addressed comprehensively. For that matter, the data that have been retrieved has been classified into a SWOC Analysis and linked into the four pillars of Food Security: Accessibility, Availability, Utilization and Stability. A SWOC Analysis is a strategic planning method used to research external and internal factors that are directly related to success and growth. It determines the strengths, weaknesses, opportunities and challenges instead of the threats in the classical SWOT.

The table below showcases the SWOC Analysis of the use and governance of AI in the Lebanese Food Security sector, based on the multiple discussions and information received during the research phase, and based on the above analysis and discussion.



STRENGTHS	WEAKNESSES
1) Growing Use in Retail: AI and IT have gained traction in the food retail sector in Lebanon, allowing consumers to shop for food products online in real time.	1) Limited Digitalization: Technology and digitalization use in agriculture and food production remain limited, with minimal AI adoption, particularly in the agricultural production phase.
2) Efficient resource use in Agriculture: The agriculture sector has seen improvements with AI and IT technologies used in the grape and wine sector for resource-efficient and cost-effective practices.	2) Prohibitive Costs for SMEs: IT in the agri-food industry is primarily accessible to large producers, with prohibitive costs for small and medium-sized enterprises (SMEs).
3) Prototypes in the animal sector: Prototypes for monitoring large-scale chicken farming are being developed.	3) Resistance to Change: Farmers' resistance to change and a lack of trust in technology pose challenges to AI adoption, while traditional farmers may lack awareness, skills, and training in technology use.
4) Potential in post-harvest applications: AI is expected to play a significant role in enhancing the shelf life of horticultural products.	4) Economic Crisis: The economic crisis has slowed technology development, as people and farmers struggle to afford expensive AI technology.
5) Availability of local expertise: Lebanon possesses local expertise in AI and IT, with the potential for developing tailored solutions, at the service of different sector in the food value chains.	5) Export challenges: High costs and a lack of expertise in export criteria hinder AI integration for quality control and shelf life optimization.
	6) Data & AI Policy: Lack of comprehensive legislation, Inadequate privacy safeguards and Limited transparency and Accountability, leading to non-existent National Strategy and unclear regulatory mechanisms.

OPPORTUNITIES	CHALLENGES
1) Quality Control: AI can play a role in quality control, product sorting, grading, and sensory evaluation in the agrifood sector.	1) Lack of R&D: The absence of significant research and development for AI in the Lebanese agrifood sector hampers high-tech adoption.
2) Predictive Agriculture: AI can be utilized to predict agricultural variables such as weather, disease outbreaks, and production data to optimize resource use and reduce losses.	2) Short-Term Funding: Short-term project-based funding for technology research in food security domains may not align with the long-term development needs of AI.
3) Data-Driven Decision-Making: AI adoption can lead to data-driven decision-making in agriculture, improving resource management and production.	3) Cultural and Economic Barriers: Resistance to AI adoption, economic constraints, and potential job displacement due to AI adoption pose challenges.
4) Collaborative Research: Collaboration between academia, research institutions, and the industry can drive AI research and development in the agriculture sector.	4) Infrastructure and Funding Gaps: Limited infrastructure and funding hinder AI implementation, testing, and development in agriculture.
5) Sustainable Practices: AI can support environmentally smarter agriculture, reducing waste and improving resource efficiency.	5) Regulatory Ambiguities: Ambiguities in AI regulations and legal frameworks create uncertainties in AI governance and adoption.

Further analyzing the retrieved information, it is observed that AI has the potential to affect all four pillars of food security although unevenly.

Food availability is directly linked to local food production and food import as primary sources of food supply. AI and IT can directly local production to improve crop yields, reduce food losses, and develop new agricultural practices and technologies for efficient and sustainable use of resources. Precision or "smart" farming can help in optimizing the use of water, pesticides, fertilizers, etc while ensuring high yield of good quality products. While the technology is available for different crop and animal sectors, it remains restricted to large enterprises who can afford it and those who have the needed expertise for using this technology. Food supply through import has been greatly impacted by the recent COVID crisis , compounded by the Beirut port explosion in Lebanon. While AI can play an important role in projecting the food needs and ensuring the stability of the country's supplies based on demographic, environmental, world market and other influencing factors. Current data keeping and AI use to that end remain limited thus leading to occasional shortages and/or oversupply, with an impact on local food prices.

Food accessibility is probably the best served pillar by AI/IT in Lebanon. AI is able to improve the traceability of food supply chains. This could be achieved by predicting demand, optimising inventory levels, and integrating a farm-to-fork chain through adapted IT all the while ensuring food safety and quality along the process. The current Lebanese context seems ripe with opportunities in this domain including a booming online food marketing and delivery sector. However, it remains largely servicing the urban population which has better access to technological and financial resources, including options for online payments. On the other hand, farmers and rural retailers seem to be struggling in using such approaches to improve their direct sales to a wider customer range.

Food safety and nutritional quality are important factors in food utilization. AI is able to develop new food products and services that are more nutritious, affordable and sustainable. Personalized meals and recipes based on individual dietary needs and preferences, and more importantly new technologies for food processing and packaging that can extend shelf life. Although steps were taken at the national level to improve food safety monitoring in Lebanon, this issue remains largely controlled by the personal initiatives of the food processors and food producers themselves depending on their resources. The lack of rigorous food quality control has a double impact on food security as it reflects on food of questionable quality being supplied to the Lebanese market as well as difficulty in exporting Lebanese produce due to faulty quality standards.

Finally, food stability and sustainability ensure the availability of food at all times. The use of AI is able to assist farmers, producers, retailers, etc to better adapt to periodic market fluctuations as well as climate change induced disruption in food supply. AI applications in this domain range from R&D generated adapted technologies that respond to the local context to global scale models capable of making reliable predictions. Lebanon has the opportunity to advance in this level based on its available academic and professional expertise. However, linkage with multiple stakeholders is needed to ensure that solutions are customized to the local context and to provide the needed funding for such activities. It should be mentioned that food sustainability can not be ensured without sustainable food production systems which links this pillar back to the Food Availability discussion that highlighted a critical weakness in the Lebanese production systems that lag behind in sustainability and efficient resource management.

In summary, it seems clear that in Lebanon, Food Accessibility is the best served pillar by AI nowadays, given the significant efforts that are being invested in post-production/post-harvest applications. Food Availability is probably the least served pillar in Lebanon given the weakness of production capacity of the prevalent small holder farmers. It is worthy to note that Food Utilization is somehow beginning to adopt AI, notably with newly established SMEs and startups that are interested in tackling the dietary aspect as a solution, and that Food Stability can benefit greatly from AI once a conducive framework for food security is developed including all relevant stakeholders.

V. RECOMMENDATIONS AND CONCLUSION

In conclusion, the Lebanese agri-food sector faces significant challenges impeding its achievement of food security. The adoption of AI/IT can offer promising solutions, optimizing all stages along the agri-food chain while addressing the country's environmental concerns, providing employment opportunities for younger generations, and stimulating economic growth. The successful adaptation of these tools, however, greatly relies on accompanying support from the public sector. Government policies and regulations can expedite the adoption of digital technologies by providing the necessary support and framework by which farmers can integrate modern technologies into their practice.[63] This can be done through financial support, providing subsidies, grants, and tax benefits to incentivize the transition. Promoting public-private partnerships can also enhance the financing of adoption, as well as R&D. Concurrently, guidelines and regulations on data security and privacy ought to be improved to address possible concerns with data ownership and usage. Policies that enhance traceability and quality standards significantly expand export opportunities and attract foreign currency inflow. The below table summarizes in thematic headings the suggested policy-oriented goals based on this study's findings with concrete and best-practices examples:

THEMATIC HEADING	*Bridging the Digital Divide*	*Fostering Trust & Adoption*	*Strengthening the Innovation Ecosystem*
OBJECTIVE	*Increase AI adoption in SMEs*	*Educate farmers on AI benefits and uses.*	*Stimulate local R&D for AI in agriculture.*
POLICY-ORIENTED GOAL	*Develop financial support mechanisms for SMEs to access AI solutions.*	*Establish dedicated training programs and extension services.*	*Establish collaborative research hubs and funding mechanisms.*

63 Bahn, R. A., Juergenliemk, A., Zurayk, R., Debroux, L., Broka, S., & Mohtar, R. (2021a). Digital Revitalization of the Agri-food Sector in Mashreq.

BEST PRACTICE EXAMPLE	*Pilot projects: Launch small-scale projects in specific regions or with certain crops to demonstrate the value of AI and encourage broader adoption.* *Public-private partnerships: Collaborate with private companies and technology providers to develop affordable and accessible AI solutions for the Lebanese market.* *Digital literacy programs: Implement programs to educate farmers and rural communities on basic digital skills and the use of AI-powered tools.*	*Community engagement: Involve farmers in the development and testing of AI solutions to ensure they meet their needs and address their concerns.* *Success stories: Showcase successful applications of AI in agriculture to inspire and motivate other farmers to adopt the technology.* *Local language resources: Develop training materials and information about AI in local languages to ensure accessibility and understanding.*	*Data sharing platforms: Establish secure platforms for farmers and researchers to share data and collaborate on the development of AI solutions.* *Hackathons and innovation contests: Organize events to encourage the development of innovative AI solutions for local agricultural challenges.* *Talent development programs: Invest in training programs to cultivate a skilled workforce for the development, deployment, and maintenance of AI solutions in agriculture.*
ADDITIONAL OBJECTIVES			
THEMATIC HEADING	*Promote data governance & regulations*	*Invest in infrastructure & capacity building*	*Harness AI for climate resilience*
OBJECTIVE	*Develop clear and transparent regulations for data in AI applications.*	*Upgrade rural internet and train local technicians.*	*Develop AI-driven solutions for weather forecasting, disease prediction, and resource management.*
POLICY-ORIENTED GOAL	*Implement ethical data practices and build trust.*	*Ensure access and support for AI deployment in rural areas.*	*Help farmers adapt to climate change and protect food security.*

This, in turn, can create a ripple effect, leading to greater revenues and technological investments. Several other initiatives that will facilitate the transition include the improvement of infrastructure, such as the improvement of network infrastructure, the development of rural roads, and the expansion of reliable electricity supply. Lastly, a digital transition will require skills, language competency, and knowledge that many farmers currently do not have. Lebanon must address these shortcomings by providing training workshops, demonstrations of technology use, and a basic literacy education campaign. Embracing these recommendations is essential for improving the Lebanese agri-food sector's competitiveness, benefiting the economy, and contributing to the overall food security.

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ANNEX

I. Message and Guiding Questions for Semi-Structured Interviews and Focus Group Discussions

Dear XXX

I trust you had a good summer and are doing well.

I am reaching out to you on behalf of the Environment & Sustainable Development Unit (ESDU) from the Faculty of Agricultural and Food Sciences at the American University of Beirut. We are in the process of conducting research on the use of Artificial Intelligence (AI) in Food Security in collaboration with the American University of Cairo. The research is entitled "Use and Governance of AI in Food Security – Case of Lebanon" and aims to explore the various dimensions of AI applications, such as digital technology, IoT, online services, smart technologies, knowledge-sharing platforms, etc., in the context of Agri-food. Additionally, we intend to examine the involvement of the Agri-food sector in technology research, governance, and practice to contextualize perspectives on existing gaps and potential opportunities. We also aim to provide recommendations for the responsible use of various AI technologies to enhance food security along the value chain.

At this stage, we are planning to host an online Focus Group Discussion (FGD) of relevant stakeholders, such as yourself, who are concerned and involved in food security and/or AI in one perspective or the other. Your perspective, expertise, and suggestions would significantly enhance our investigation into this relatively unexplored subject. The FGD will take around 1 hour and will be conducted online in the afternoon at a specific date and time agreeable to all participants. We anticipate having up to five participants with similar occupations/interests in the FDG. Once you confirm your availability and willingness to join this activity, we will provide you with further information about the specific themes we'll be addressing and additional details about the FGD.

May I inquire about your availability for such an online discussion in the afternoon during the first week of October?

Looking forward to your positive reply.

Best regards,

Salwa Tohmé Tawk,

Member of the Environment & Sustainable Development Unit (ESDU)

Faculty of Agricultural and Food Sciences at the American University of Beirut

1 - *What's the current state of AI/IT use and applications in your field, in Lebanon?*

2 - *If applicable, kindly share how you implement AI in your professional domain.*

3 - *What do you consider to be the main challenges and gaps for adopting of AI/IT in your field, in Lebanon?*

4 - *Given your field's relation to one (or more) pillar of food security, what role do you think AI/IT can play toward food security in Lebanon.*

5 - *In your opinion, what infrastructure, skills, policies and governance are needed to support AI/IT adoption in your field for improved food security?*

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