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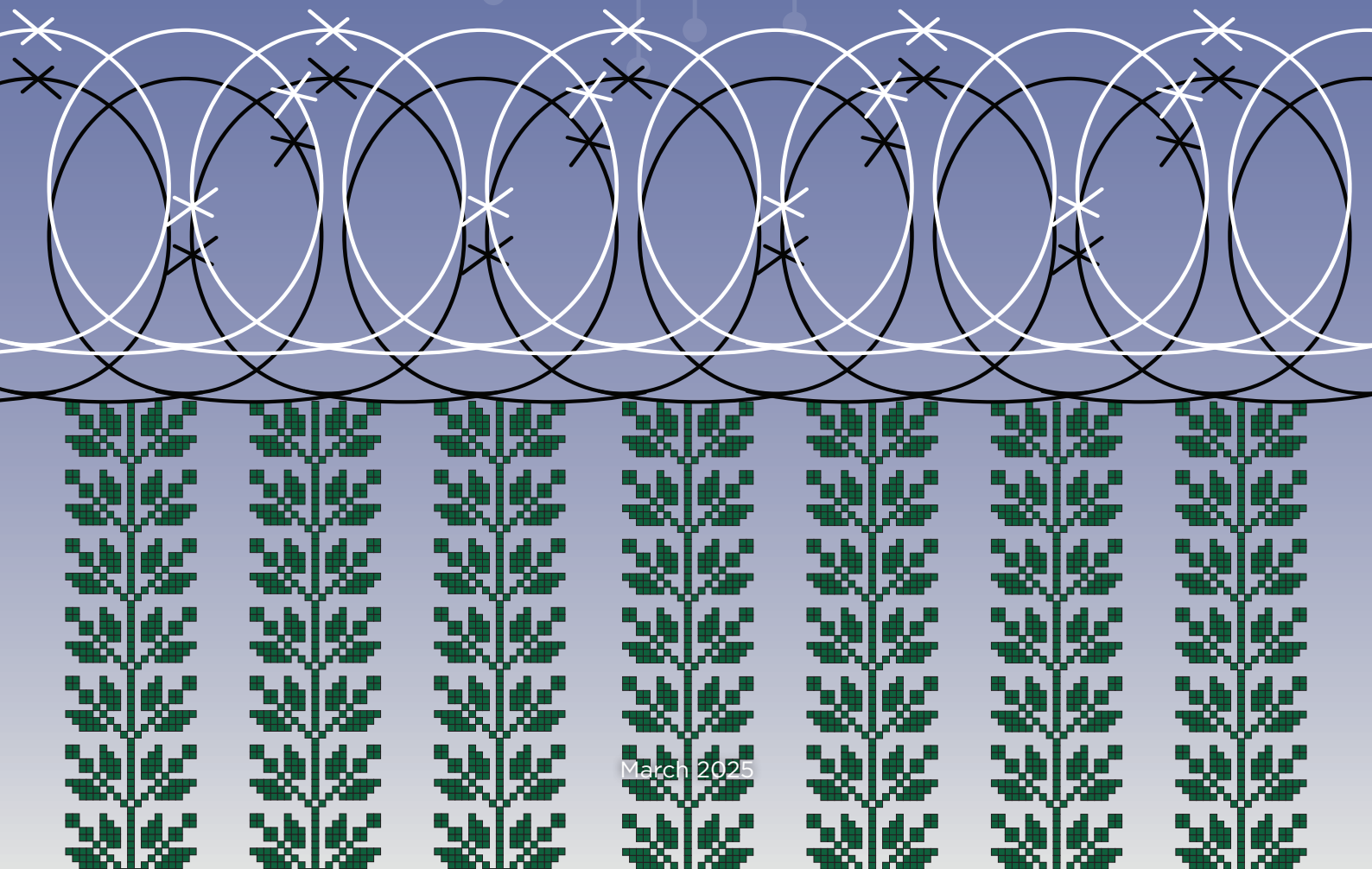
Optimizing Food Security in Gaza:

AI Opportunities, Barriers, and Recommendations for Sustainable Enhancement



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OPTIMIZING FOOD SECURITY IN GAZA: AI OPPORTUNITIES, BARRIERS, AND RECOMMENDATIONS FOR SUSTAINABLE ENHANCEMENT

Ahmed Abu Shaban
Gaza Urban and Peri-Urban Agriculture Platform (GUPAP)

This position paper delineates ongoing endeavors and potential pathways to fortify food security within the Gaza Strip by harnessing AI-driven solutions. It elucidates the primary barriers obstructing the introduction and scalability of this approach while offering comprehensive recommendations aimed at overcoming these obstacles.

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I. INTRODUCTION

Palestine is grappling with significant and interconnected political, economic and environmental challenges. Constraints on access to land, water and energy (not to mention the limitations of freedom of movement for people and goods imposed by the occupation have undermined Palestine's agricultural sector and the interrelated food, nutrition, water, energy and health security of its people).[1] Following the crisis that erupted in October, the landscape of food security in Gaza has rapidly deteriorated. The challenges described earlier, though significant, pale in comparison to the dire situation unfolding now. The ongoing conflict has intensified hardships, severely impacting access to food and vital resources. This escalation has plunged the region deeper into a humanitarian crisis, exacerbating the struggles faced by its inhabitants.

Agriculture is an integral component of Palestinian communal, cultural, economic and social life. For Palestinians, agriculture is a vital source of livelihood, the main route to food security and main resort to turn to difficult times[2]. The Gaza Strip is marked by a range of barriers that affect the performance of the agricultural sector, reducing food production and causing deterioration of food security. According to the United Nations (UN), in 2021, around 1.3 million people in Gaza, representing over 70 percent of the population at the time, needed humanitarian assistance, including food aid[3], and 64 percent of households experienced severe or moderate food insecurity[4]. The primary reason for food insecurity is insufficient financial resources.[5] According to the United Nations Food and Agriculture Organization (FAO), food security is defined as "when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"[6]. The four main dimensions of food security are (1) physical availability of food, (2) economic and physical access to food, (3) food utilization and lastly, (4) stability of the other three dimensions over time. Physical availability of food refers to the "supply side" of food security and is determined by the level of food production, stock levels and net trade. Economic and physical access to food addresses the issue of food security at the household level, which is not always guaranteed despite an adequate supply of food at the national or international level. Food utilization refers to the way the body makes the most of various nutrients in the food. Stability of the other three dimensions over time is important because even if food intake is adequate today, an individual is still considered food insecure if they have inadequate access to food periodically, risking a deterioration of their nutritional status[7].

Limited agricultural land, climate change, water scarcity, restrictions on imports and exports, as well as geopolitical context, are the main factors affecting the ability of the agricultural sector to meet food demand.[8][9] These barriers restrict the ability of actors along the food production value chain and its enabling environment, including policymakers and regulatory bodies, to adequately respond to and mitigate constraints arising from the adverse impacts of limiting factors. The ability of farmers, for example, to make technical, managerial and marketing decisions aiming to optimize the technical and economic performance at the farm level is hindered by the combined and accumulated experience of climate change and a deteriorating geopolitical context. Farmers are left with several unanswered questions, such as what to cultivate when to cultivate, how to irrigate and fertilize and how to effectively collaborate with other market actors. Other actors along the food value chain, including inputs and products traders and food handling and processing workers, face similar problems. [10]

This position paper aims to examine the transformative potential of artificial intelligence (AI) in addressing critical food security barriers within the Gaza Strip. In Palestine, food security faces a mix of challenges encompassing availability, access, utilization and stability. The Gaza Strip specifically grapples with issues of restricted access to arable land, inadequate infrastructure, economic constraints and political instability, exacerbating food insecurity. This paper will delineate how AI interventions can revolutionize these challenges, primarily through pre-

1 Stiftung, Heinrich Stiftung Böll. "Palestine: Environmental and Social Challenges." Boell, https://www.boell.de/sites/default/files/2021-06/Palestine_Environmental_and_Social_Challenges.pdf.

2 United Nations World Food Program (WFP), "Socioeconomic and Food Security Atlas, Palestine," 2010.

3 United Nations Office for the Coordination of Humanitarian Affairs (OCHA),"Gaza Strip: Humanitarian Needs Overview 2021."

4 WFP, "Palestine Monthly Market Dashboard," May 2022.

5 Ibid

6 Food and Agriculture Organization of the United Nations (FAO), "The state of food security and nutrition in the world," 2021.

7 Ibid.

8 Hejazi, et al, January 2023, "Impacts of Water Scarcity on Agricultural Production and Electricity Generation in the Middle East and North Africa," Frontiers, https://doi.org/10.3389/fenvs.2023.108293.

9 United Nations, "Water – at the Center of the Climate Crisis," https://www.un.org/en/climatechange/science/climate-issues/water.

10 World Economic Forum, "Climate Change and Food: The Potential Impact on Production and Prices," https://www.weforum.org/agenda/2021/12/climate-change-extreme-weather-food-shortages-rise-prices/.

dictive analytics for agricultural planning, precision farming techniques, efficient supply chain management and data-driven policy formulation. Drawing from primary data collection, the paper presents implemented AI pilots in Gaza, showcasing their varying degrees of success and failures. Additionally, it highlights the barriers impeding the introduction, scalability and success of AI deployment in the region. Insights from these implementations inform recommendations for optimal interventions and emphasize the need for collaborative partnerships, local capacity building, tailored technological solutions and policy support to overcome obstacles and realize the potential of AI in bolstering food security within the Gaza Strip.

II. METHODOLOGY

In assessing the potential of AI in bolstering food security, this study adopted a comprehensive methodological approach. The exploration of AI's opportunities within the four fundamental components of food security — availability, access, utilization and stability — was primarily drawn from a synthesis of existing models and applications worldwide derived from secondary data analysis. To complement this global perspective, primary data collection methods were employed specifically within the context of the Gaza Strip. This involved a description of AI models in relation to the four components of food security through on-the-ground research and consultation with diverse stakeholders. To enable the description along the four components of food security, stakeholder engagement encompassed a diverse set of actors within the food system, ranging from producers, distributors and consumers to representatives from the information and communications technology (ICT) sector, which is pivotal in driving technological advancements. Additionally, consultations were held with policymakers and regulatory bodies — entities shaping the enabling environment. This methodological synthesis between global models and localized primary data aims to provide a nuanced understanding of AI's potential, barriers to its implementation and necessary interventions in fortifying food security. The methodology employed in this study combines both secondary and primary data collection methods to comprehensively address the multifaceted challenges of food security in Gaza. The secondary data collected focuses on an in-depth reflection of the current food security situation in Gaza, describes challenges across the spectrum of availability, access, utilization and stability, and involves a rigorous review of existing literature, studies and reports, specifically emphasizing the role of AI in mitigating these challenges. Additionally, a thorough review of relevant national policies pertaining to agriculture, technology and food security was conducted to contextualize the policy landscape.

The primary data collection process for this study involved engaging various stakeholders in Gaza. One focus group discussion (FGD) with 10 participants was held with the farming community, while another gathered 9 participants representing different actors from within the food system under the Urban Women Agripreneurs Forum (UWAF). Key informant interviews (KIIs) were conducted with representatives from specific entities, namely the Gaza Urban & Peri-Urban Agriculture Platform (GUPAP), the Palestinian Information Technology Association (PITA), the Palestinian Agriculture Ministry, the Palestinian National Economy Ministry and an agri-tech startup focused on smart greenhouse systems in Gaza. These interactions provided diverse perspectives across the agriculture and ICT sectors and contributed comprehensive insights into current and potential AI applications for enhancing food security in the Gaza Strip. They also reflected barriers along the four main pillars of food security and guided the formulation of responsive recommendations to overcome the identified barriers.

The tools employed in this study annexed in Annex 1, were designed to align with the study's objectives, focusing on current AI initiatives being implemented within the pillars of food security. These tools were structured to unveil the barriers and opportunities arising from AI applications across the areas of availability, access, utilization and stability within the food security landscape. The design of these tools enabled a comprehensive examination of AI's role in enhancing food security across its foundational pillars, laying the groundwork for informed recommendations and strategies.

The FGDs each extended over a duration of 2 hours, allowing for comprehensive engagement with participants. Meanwhile, the KIIs spanned 1.5 to 2.5 hours, providing time to delve into nuanced perspectives. The sessions were recorded in note-form by an assistant to capture valuable insights as no audio-visual recordings were made due to participants' consent not being obtained for such documentation.

Data verification processes were integral to ensure accuracy and reliability. Verification was accomplished through cross-referencing information obtained from secondary sources with primary data findings, as well as conducting

workshops with stakeholders to validate and refine the gathered insights. The data analysis phase involved a meticulous examination of both secondary and primary data, utilizing qualitative and quantitative methodologies to extract meaningful patterns, trends and challenges related to AI implementation in enhancing food security.

Finally, the culmination of this methodology involved drafting the final report. This report synthesizes the findings from both secondary and primary data sources and highlights the identified challenges, the potential of AI solutions and recommendations for optimizing AI deployment to alleviate food security issues in Gaza. This integrated methodology ensures a comprehensive and robust analysis that underscores the transformative potential of AI while addressing the complexities of food insecurity in the region.

III. FOOD SECURITY BARRIERS IN THE GAZA STRIP

Food security is a critical issue in the Gaza Strip, which has been facing a protracted and complex humanitarian crisis for decades. The crisis is tied to prolonged occupation, internal political divisions and recurrent conflict that pose a threat to the stability and development of the Palestinian people. The continuous large-scale security and political unrest and the air blockade on the Gaza Strip have resulted in economic stagnation, loss of land, restricted trade and access to resources and high unemployment and poverty rates.[11] These circumstances continue to exacerbate the already dire humanitarian situation and pose serious challenges to the achievement of Sustainable Development Goal 2 in regards to food security and improved nutrition.

The barriers to food security in Gaza in 2022 can be classified into four components: physical availability of food, economic and physical access to food, food utilization and stability of the food supply[12].

1) **Physical availability of food:** Food availability addresses the "supply side" of food security and is determined by the level of food production, stock levels and net trade. The Gaza Strip has been facing a severe food shortage due to Israel's blockade which has limited the import of essential goods, including food, fuel and medicine. It has severely impacted the agricultural sector, which is a vital source of livelihood for many Palestinians in Gaza. Additionally, the Israeli military has destroyed thousands of acres of farmland, greenhouses and irrigation systems, which has led to a significant reduction in agricultural production[13].
2) **Economic and physical access to food:** An adequate supply of food at the national or international level does not in itself guarantee household-level food security. Economic and physical access to food is determined by household income and the prices of food in local markets. As of 2022, the unemployment rate in the Gaza Strip hovered around 45 percent, according to reports by the Palestinian Central Bureau of Statistics (PCBS).14 This staggering figure represents a persistent challenge, with nearly half of the population unable to secure formal employment. Additionally, poverty rates remained alarmingly high, with approximately 53 percent of the population living below the poverty line, as indicated by data from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) in the occupied Palestinian territory. The high unemployment rate, poverty and low purchasing power of Palestinians in Gaza have made it difficult for them to access food. The Israeli blockade has also led to a significant increase in food prices, making it even more challenging for Palestinians who can access food to afford it.
3) **Food utilization:** Food utilization refers to the body's ability to absorb and use the nutrients from food. Malnutrition is a significant problem in Gaza, with high rates of stunting, wasting and micronutrient deficiencies. The blockade has severely impacted the health sector, leading to a shortage of medical supplies, equipment and personnel. The lack of access to clean water and sanitation facilities has also contributed to the spread of waterborne diseases, which has further exacerbated the malnutrition problem in Gaza.[15]
4) **Stability of the food supply:** The stability of the food supply is determined by the availability of food over time. The recurrent conflict in Gaza has led to significant dis-

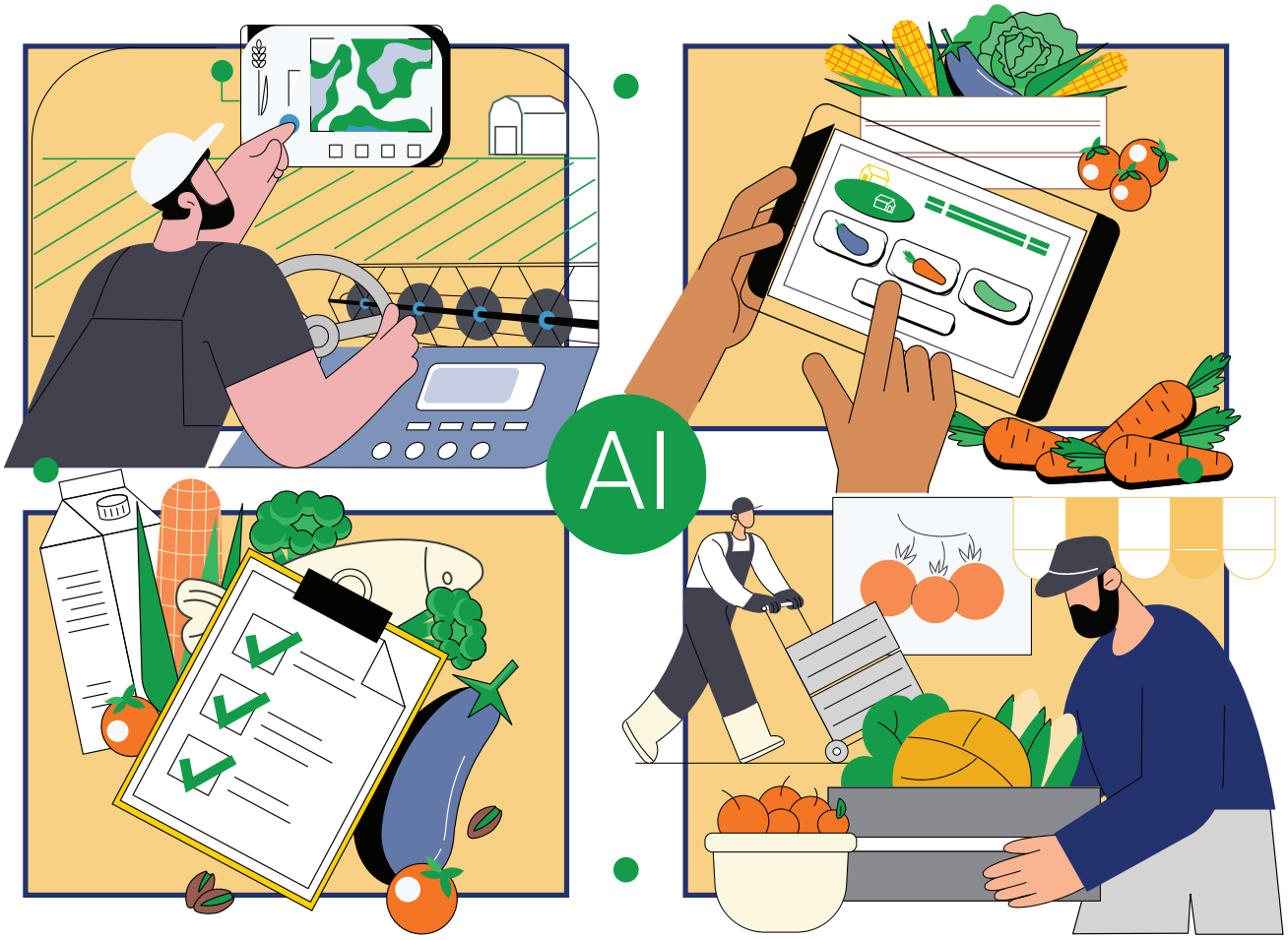
11 United Nations World Food Programme, "Palestine: World Food Programme," https://www.wfp.org/countries/palestine.

12 World Bank Group, "What is Food Security? There are Four Dimensions," https://www.worldbank.org/en/topic/agriculture/brief/food-security-update/what-is-food-security.

13 World Food Programme, 2021, "Gaza Emergency Food Security Assessment Following the escalation of hostilities and unrest in the State of Palestine in May 2021."

14 Palestinian Central Bureau of Statistics (PCBS), 2022, "Results Of The Labour Force Survey," https://www.pcbs.gov.ps/post.aspx?lang=en&ItemID=4421.

15 United Nations Office for the Coordination of Humanitarian Affairs, 2022, "The Gaza Strip|The humanitarian impact of 15 years of blockade–June 2022," https://www.unicef.org/mena/documents/gaza-strip-humanitarian-impact-15-years-blockade-june-2022.



ruptions in the food supply chain, making it difficult for Palestinians to access food. The Israeli blockade has also led to a significant reduction in the availability of food, making it challenging to maintain a stable food supply.

IV. THE POTENTIAL OF AI IN SOLVING FOOD SECURITY BARRIERS IN GAZA

Artificial intelligence (AI) has the potential to address some of the barriers to food security in Gaza. AI can be used to improve the efficiency of food production, distribution and utilization, and to enhance the resilience of food systems in the face of shocks and stresses.[16] Here are some ways in which AI can help address the four components of food security in Gaza:

1) **Physical availability of food:** AI can be used to optimize crop yields and reduce waste by providing real-time data on weather patterns, soil moisture and crop health.[17] AI can also be used to monitor and predict food shortages and identify areas where food aid is needed.[18]
2) **Economic and physical access to food:** AI can be used to improve the efficiency of food distribution systems, reducing the cost of food and increasing its availability.[19] It can also be used to develop new markets for locally produced food, increasing the income of small-scale farmers and improving access to fresh, nutritious food.[20]
3) **Food utilization:** AI can be used to develop personalized nutrition plans for individuals, based on their genetic makeup, lifestyle and health status, and can be used to

16 World Food Programme, 2021, "Artificial Intelligence for Food Security," https://www.wfp.org/innovation/artificial-intelligence-food-security.

17 Food and Agriculture Organization of the United Nations, 2021, "Artificial Intelligence in Agriculture," http://www.fao.org/3/cb1632en/cb1632en.pdf.

18 United Nations Development Programme, 2021, "Artificial Intelligence for Development," https://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/artificial-intelligence-for-development.html.

19 World Economic Forum, 2021, "How AI is Transforming the Future of Food," https://www.weforum.org/agenda/2021/03/how-ai-is-transforming-the-future-of-food/.

20 International Fund for Agricultural Development, 2021, "Artificial Intelligence for Smallholder Farmers," https://www.ifad.org/en/web/latest/-/news/ai-for-smallholder-farmers.

monitor and predict malnutrition, enabling early intervention and treatment. [21,22]

4) **Stability of the food supply:** AI can be used to predict and mitigate the impact of climate change on food systems, reducing the risk of crop failure and food shortages, and can also be used to develop early warning systems for food crises, enabling rapid response and reducing the impact of shocks and stresses on food systems.[23,24]

V. PILOTS AND PROJECTS TO DEPLOY AI IN FOOD SYSTEM IN GAZA

By extensively engaging with and analyzing inputs from vital stakeholders in both the food system and ICT sectors, the study reveals a compelling array of pilot initiatives centered on deploying AI solutions. These proposed endeavours capitalize on AI's potential to target pivotal aspects of food security, spanning food availability, accessibility, utilization and stability. The subsequent initiatives detailed in this report are categorized according to their alignment with specific components of food security.

V.1 Food Availability

Drawing from the data collected, a range of AI-driven initiatives emerged to bolster food availability. These initiatives were primarily aimed at enhancing the efficiency of scarce natural resources, particularly water, and reducing the costs of essential agricultural inputs. Various internationally funded projects supported startups and livelihood initiatives, integrating AI into production systems. However, the outcomes, listed below, varied:

1) An agritech startup was established to develop sensors for smart greenhouses, incubated through an entrepreneurship program funded by the United Nations Development Program. Despite initial support, challenges arose in product development, market awareness and the market's capacity to absorb the technology, leading to limited success.
2) Both the World Bank and the Swiss Agency for Development and Cooperation (SDC) funded projects to enhance Technical and Vocational Education and Training (TVET) institution capacities and pilot smart greenhouse projects at a research station, respectively. However, technical complexities, high establishment costs and the intricate nature of the technology hindered the scalability of these initiatives.
3) A fertigation device, introduced via a project funded by the German Agency for International Cooperation (GIZ), aimed to optimize irrigation and fertilization to cut production costs and enhance water resource productivity. Fertigation is a method of fertilizer application in which fertilizer is incorporated within the irrigation water by the drip irrigation system. In this system, fertilizer solution is distributed evenly in irrigation. Despite being positioned as a green economy solution, its scalability was constrained by the high cost of the imported device and limitations in its adaptability across different contexts.
4) In an effort funded by the International Committee of the Red Cross (ICRC), remote-controlled irrigation systems were introduced to help farmers in Access Restricted Areas in Gaza, aiming to minimize risks from the Israeli military. Challenges emerged due to farmers' limited knowledge in applying the system and financial constraints hindering its deployment.
5) UNIT One ICT firm engaged in discussions with an international ICT company regarding a prospective business deal to utilize photos and data analysis for the development of an AI-supported application for plant disease detection. Unfortunately, an agreement couldn't be reached. Nevertheless, this endeavor reveals substantial potential for a national firm to undertake the development of such an app. The firm based in Gaza holds a belief in its capacity to offer AI solutions for agricultural issues in the global market. However, they harbor doubts regarding the local food production system's demand for such services due to limited awareness about the added value they provide.

In conclusion, while these AI-driven initiatives showcased promising solutions to enhance food availability by optimizing resources and technology, challenges related to cost, scalability, tech-

21 : National Institutes of Health, "Artificial Intelligence for Personalized Nutrition," 2021, https://www.nih.gov/news-events/nih-research-matters/artificial-intelligence-personalized-nutrition.

22 United Nations Children's Fund, 2021, "Artificial Intelligence for Malnutrition," https://www.unicef.org/innovation/artificial-intelligence-malnutrition.

23 United Nations Framework Convention on Climate Change, 2021, "Artificial Intelligence for Climate Change," https://unfccc.int/process-and-meetings/bodies/constituted-bodies/subsidiary-body-for-scientific-and-technological-advice-sbsta/sbsta-items/sbsta-52/ai-for-climate-change.

24 United Nations Office for the Coordination of Humanitarian Affairs, 2021, "Artificial Intelligence for Humanitarian Action," Retrieved November 2023 from https://www.unocha.org/ai.

nical complexities, market readiness and adaptation across contexts emerged as key barriers. Addressing these challenges will be pivotal in realizing the full potential of AI in ensuring food security on a broader scale.

V.2 Access to food

The AI system's contribution to improving food access remains notably limited. Engagements with key stakeholders in the food system highlighted the possibility of creating an AI-supported decision guidance system to assist farmers in making informed choices regarding agricultural production and marketing. Additionally, the system would have the potential to guide consumers in accessing quality food at reasonable prices. However, the lack of data both at the farm and market levels, coupled with the absence of frameworks for data collection and accessibility, significantly hampers the potential for developing such initiatives.

The Cash-Based Transfer (CBT) voucher system implemented by the World Food Programme (WFP) stands as a robust AI-supported model significantly enhancing food accessibility in Gaza.[25] This innovative approach leverages AI algorithms to streamline and optimize the distribution of vouchers, ensuring efficient allocation and accessibility to essential food supplies.

The AI-driven CBT system effectively identifies and targets specific needs within the community, allowing for personalized assistance to vulnerable populations. By analyzing data on purchasing behaviors, dietary needs and market trends, the system tailors vouchers to individual or family requirements, ensuring they can access a diverse range of nutritious food items.

Furthermore, the AI integrated within the CBT system continuously learns and adapts based on evolving socio-economic conditions and food demands. This adaptability enhances the system's responsiveness, enabling it to address changing circumstances promptly, thereby ensuring consistent and sustained access to food for beneficiaries.

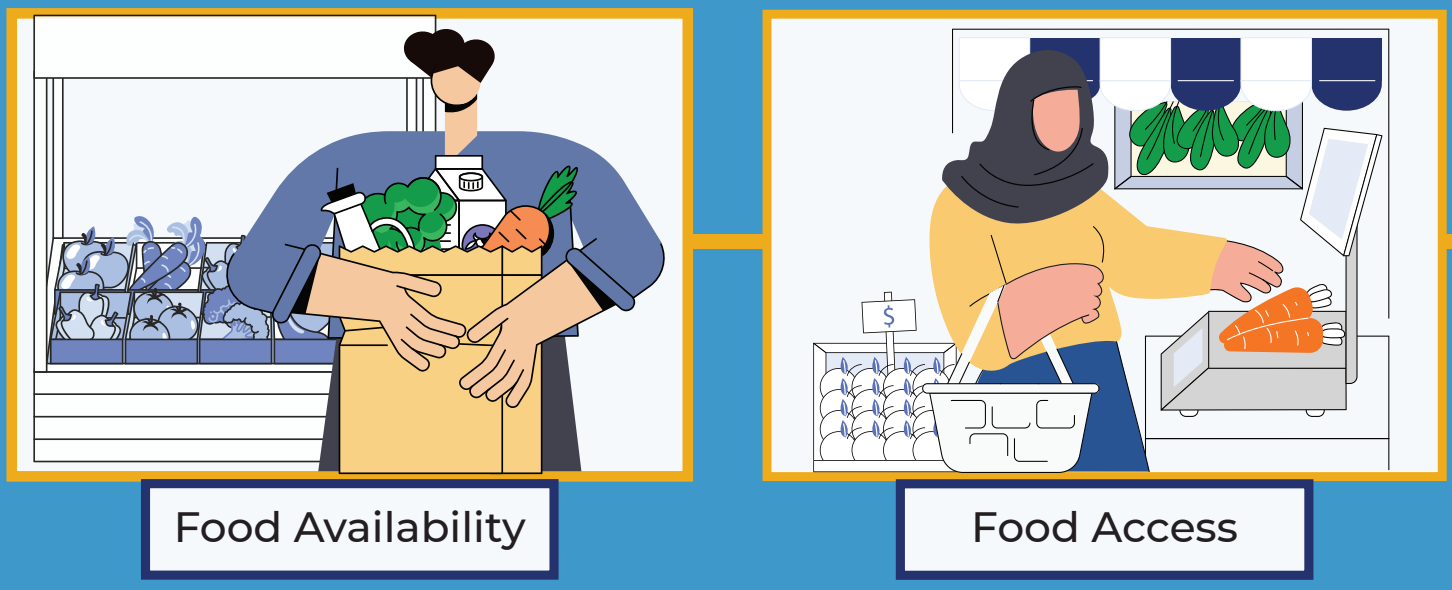
Moreover, the system enhances transparency and accountability in the distribution process. AI algorithms monitor and track voucher utilization, providing real-time insights into expenditure patterns, which aids in refining the assistance program and optimizing resource allocation.

Overall, the AI-supported CBT voucher system implemented by WFP in Gaza showcases how technology-driven models can effectively improve food accessibility by personalizing aid, adapting to dynamic conditions and ensuring efficient and transparent distribution of resources to those in need.

V.3 Utilization of food

In the Gaza Strip, the adoption of AI-supported models to improve people's food utilization, or the extent of physical benefit they gain from available food, is becoming increasingly prevalent, primarily propelled by large-scale compa-

25 World Food Program (WFP), 2017, "World Food Programme Cash-based transfers for delivering food assistance," https://documents.wfp.org/stellent/groups/public/documents/communications/wfp284171.pdf.



nies specialized in food, its processing, supply and trade, like Mazaj. These entities have leveraged AI technology to optimize various aspects of the food supply chain, while, at the individual level, nutrition-related AI-supported systems have been employed to enhance dietary choices and nutritional intake.

Large-scale food importing and trading companies, such as Mazaj, and large scale dairy processing factories, such as Hanover, have embraced AI-supported systems to revolutionize food utilization in Gaza. These companies utilize AI-powered inventory management systems that predict demand, streamline supply chains and minimize food waste. By analyzing real-time data and consumption patterns, these models ensure the efficient distribution and consumption of perishable goods, effectively reducing food waste along the supply chain.

At the individual level, nutrition-related AI-supported systems are gaining traction among households in Gaza. AI-powered mobile applications and personalized dietary assessment tools provide tailored nutritional guidance. These tools analyze dietary habits, health data and nutritional requirements to offer personalized dietary recommendations. This empowers individuals to make informed food choices, improving nutritional outcomes and minimizing food waste at the household level.

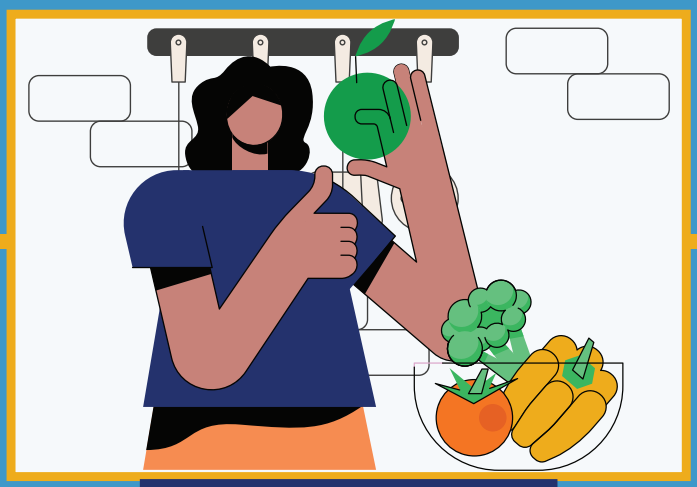
Despite these advancements, challenges persist in the comprehensive adoption of AI-supported models for food utilization in Gaza. Issues such as limited access to technology, infrastructure challenges and data privacy concerns need to be addressed for widespread implementation of these systems.

In conclusion, large-scale food importing and trading companies' integration of AI-supported models and individuals' use of nutrition-related AI systems reveal a potential to revolutionize food utilization in Gaza. These innovative approaches hold promise in reducing food waste, aligning production with demand and improving individual dietary choices, ultimately contributing to the development of food security and improving livelihoods in the region. Efforts to address existing challenges will be pivotal in maximizing the potential of these AI-supported models for sustainable food utilization in Gaza.

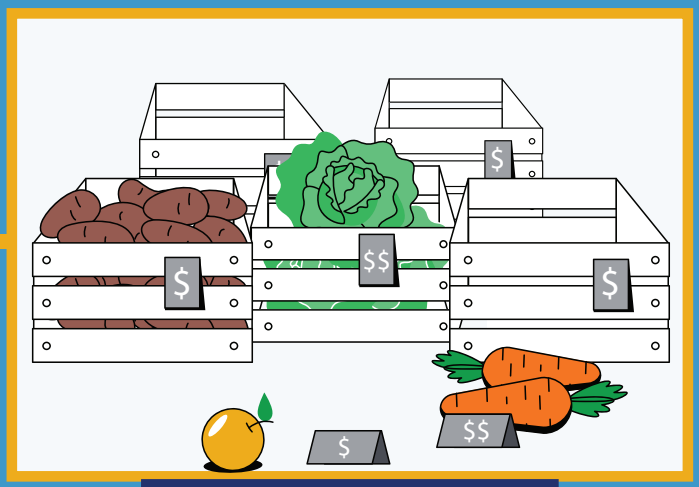
V.4 Stability of food supply

The Gaza Strip faces mounting challenges in securing a stable food supply, especially amid the escalating impacts of climate change and the recurrent regional conflicts. While an AI-supported early warning system remains a faraway goal, progressive steps have been initiated by various organizations to lay the foundation for its establishment.

The Food and Agriculture Organization (FAO) has secured funds from the Green Climate Fund (GCF) to bolster the Agriculture Ministry's efforts to construct an early warning system and pilot its operation. This initiative holds promise in leveraging AI technologies to analyze climate data, anticipate risks, and issue timely alerts to



Food Utilization



Food Stability

aid farmers in adapting to climate-induced challenges, thus fortifying food supply stability.

Furthermore, the German Agency for International Cooperation (GIZ) has committed funding to the establishment of a digital platform to seamlessly link farmers with other stakeholders in the food sector. The initiative intends to streamline operations, enhance collaboration and build resilience within Gaza's food supply chain by fostering information exchange and knowledge sharing.

The World Food Programme (WFP) is also actively developing a conceptual framework for a similar project. Their focus is on encouraging the use of early warning systems among Palestinian farmers in the West Bank and Gaza. WFP intends, through this endeavor, to harness AI-powered technologies to empower farmers with timely information and foster adaptive practices to mitigate climate-related risks.

The collaborative initiatives by FAO, GIZ and WFP illustrate concerted efforts to navigate the challenges obstructing the establishment and use of AI-driven early warning systems and digital platforms among farmers in Gaza. However, the hurdles posed by limited climate data availability, limited technical capacities and the limited sustainability of these initiatives remain pivotal areas of focus. The success and long-term impact of these endeavors hinge upon the collective ability to surmount these barriers and ensure the sustained functionality of these systems, fostering enhanced food supply stability in Gaza amid the challenges posed by climate change

It is crucial to note that these initiatives are in the nascent stages of design and planning. While significant strides have been made in obtaining funding and outlining project frameworks, the actual implementation and sustainability of these endeavors remain aspirational goals. Nonetheless, the collaborative efforts among these organizations signify a collective commitment to leveraging AI and technological innovations to address the challenges hindering food supply stability in Gaza.

In conclusion, the envisioned establishment of AI-supported early warning systems, coupled with collaborative endeavors spearheaded by FAO, GIZ and WFP, marks a promising trajectory toward fortifying food supply stability in Gaza. These initial strides hold the potential to revolutionize food security by harnessing AI technologies, yet the realization and continuity of these efforts will depend on effective implementation and sustained support in the region.

VI. OBSTACLES RESTRICTING AI SOLUTIONS IN FOOD SECURITY ENHANCEMENT

The identified barriers presented below are based on comprehensive research findings collected through interviews and focus group discussions (FGDs) conducted within the Gaza Strip. These insights, solely derived from these primary data collection methods, encapsulate the perspectives and experiences shared by diverse stakeholders directly involved in efforts to improve food security. By exclusively drawing from interviews and FGDs, these findings shed light on the challenges impeding the effective implementation and sustainability of AI initiatives aimed at enhancing food security in the Gaza Strip.

The landscape of AI-driven solutions for fortifying food security in Gaza is rife with promise, yet stakeholder consultations and the implemented AI models have brought to light a multitude of barriers obstructing their successful implementation and scalability. Delving into these challenges illuminates the complex web of obstacles impeding the advancement of AI solutions critical to augmenting food security in the region.

VI.1 Barriers to AI's Role in Enhancing the Food System: Perspectives from Users

The integration of AI solutions to fortify the food system encounters multifaceted barriers on the demand side. Users, comprising stakeholders across the food system, face several challenges that impede the effective adoption and utilization of AI-driven solutions. Understanding these barriers offers insights into the intricate dynamics restraining the transformative potential of AI in addressing food security challenges.

Lacking Awareness and Capacities Along the Food System

1) **Limited Awareness:** A noticeable deficit in understanding AI's capabilities exists within the farming community and between food sector stakeholders, which restricts enthusiasm for its adoption.
2) **Capacity Constraints:** Actors involved in food production, distribution and management often lack the necessary technical expertise to effectively comprehend, implement and leverage AI technologies. This knowledge gap hampers the seamless integration of AI solutions into existing practices.


AI

Limited knowledge of AI's value in solving food security challenges

1) **Lack of understanding:** The insufficient understanding of the benefits of AI in mitigating food security-related issues is a significant determinant affecting demand for AI solutions. Failure to recognize AI's potential contributions restrains enthusiasm for its adoption.
2) **Perceived benefits vs. traditional methods:** Users may struggle to perceive the advantages of AI solutions over traditional methods. Limited exposure or education regarding AI's transformative capabilities hinders the transition from conventional systems to AI-driven solutions.

Constraints imposed by traditional production systems

1) **Resistance to change:** Traditional production systems, deeply rooted in customary practices, exhibit resistance to embracing technological advancements, which impedes the transformative capacities of AI within these systems.
2) **Adaptability hurdles:** The rigidity of existing methods within traditional systems poses challenges for integrating AI solutions. The lack of flexibility and adaptability restricts the seamless incorporation of AI technologies.

Market system constraints in compensating AI technology costs

1) **Financial limitations:** The market system's restricted capacity to offset the high costs associated with AI technology in the agricultural sector poses a significant barrier. Inadequate financial mechanisms hinder the affordability and accessibility of AI solutions for users.

The barriers obstructing artificial intelligence from enhancing demand in the food sector include limited awareness and understanding and adaptability within traditional systems. Additionally, financial constraints within the market system pose a significant hurdle. Addressing these challenges necessitates focused educational initiatives, capacity-building efforts, and the establishment of conducive market frameworks to promote the value proposition of AI solutions. Overcoming these barriers is pivotal to unlocking the transformative capacities of AI, fostering its widespread adoption and ultimately fortifying a more resilient and efficient food system.

VI.2 Barriers hindering AI system developers and the ICT sector in empowering the food system

The integration of AI solutions into the food system faces substantial barriers at the supply side, particularly concerning developers of AI systems and the ICT sector. These barriers significantly impact the development, design and dissemination of AI-driven solutions aimed at enhancing food security. Understanding these challenges sheds light on the complexities hampering the transformative potential of AI in the food domain.

Limited connection with food system actors

1) **Disconnect between stakeholders:** The ICT sector faces limitations in establishing robust connections with actors across the food system. This disconnect inhibits a comprehensive understanding of the challenges faced by stakeholders, hampering the development of tailored AI solutions to address these specific issues.
2) **Lack of insight into issues:** Insufficient knowledge about the intricate problems within the food system impedes the ICT sector's ability to design responsive AI solutions. The absence of a nuanced understanding of these challenges restricts the development of effective and impactful technological interventions.

Capacities of the ICT sector need enhancement

1) **Skills and expertise gap:** The ICT sector's capacities need to be developed and augmented to foster the design and development of AI solutions. Enhancing technical expertise and skills within the sector is imperative to innovate and tailor AI technologies that effectively address food security challenges.
2) **Responsive design constraints:** Limited capacities hinder the ICT sector's ability to ideate and develop responsive AI solutions. Building the requisite capacities is crucial to enabling the design and deployment of adaptive technologies that align with the unique needs of the food system.

The above-mentioned impediments on the supply side substantially obstruct the development

of AI-driven solutions for Gaza's food system. Addressing these barriers requires concerted efforts to bridge the gap between the ICT sector and food system actors by fostering closer collaborations, enhancing sector-specific knowledge and investing in skill development within the ICT domain. Overcoming these obstacles is necessary to empower developers and the ICT sector to innovate and craft AI solutions that precisely cater to the food system's needs, thereby fostering a more resilient and efficient food ecosystem.

VI.3 Enabling environment challenges in advancing AI solutions for Gaza's food system

The development and deployment of AI solutions in Gaza's food system is obstructed by formidable barriers at the enabling environment level. These barriers — rooted in the inadequacies of policy frameworks, research and development (R&D) limitations and a deficiency in tailored support services — significantly impede the effective utilization of AI technologies to address food security challenges. Unraveling these challenges illuminates the complexities hindering the transformative potential of AI in Gaza's food landscape.

Policy deficiencies in data management and utilization

1) **Lack of regulatory frameworks:** Gaza faces a dearth of policies aimed at regulating and enhancing data collection, management and utilization. The absence of structured guidelines inhibits effective data governance and hampers the utilization of data for AI-driven solutions.
2) **Data scarcity at multiple levels:** Insufficient data availability, spanning from farm-level data to national-scale data, severely limits the development of effective AI solutions. The absence of comprehensive data impedes the design and implementation of tailored AI interventions.
3) **Lack of AI-driven policies and tools within the food system:** It's not uncommon for national agricultural strategies[26,27] to lack explicit mention or detailed approaches regarding AI implementation, despite the objectives aiming to enhance technology use and resource efficiency. These strategies often focus on broader goals without specifying the precise technological tools or methods for implementation.
4) **Lack of data policies and weak enforcement:** The legal framework for information technology in Palestine comprises crucial laws, like the electronic transactions law, the cybercrime law, the telecommunications law and the intellectual property law. These laws aim to regulate various aspects of Palestine's information technology sector, including electronic communications, cybercrime, telecommunications networks and intellectual property rights. However, despite the presence of robust policies and regulations governing data collection and management, the challenge lies in national institutions' enforcement capacities. The primary issue is not in the absence of regulations, but rather in the inadequacy of existing enforcement mechanisms due to weak institutional capacities. The capacity of national institutions to effectively enforce these laws requires significant improvements that should go beyond staff training and involve more robust steps toward bolstering institutional capabilities and upgrading relevant equipment.

   Enhancing Palestine's data landscape requires a multifaceted approach. Strengthening capacities for the enforcement of IT laws is crucial, complemented by the establishment of policies encouraging responsible and secure data collection and sharing. This entails developing comprehensive guidelines that prioritize privacy protection, consent mechanisms and interoperability standards. Additionally, frameworks and collaborative platforms must be established to foster and guarantee secure mechanisms for data exchange between authorized entities. Incentivizing ethical data practices and fostering public-private partnerships further would fortify this effort. Continuous evaluation ensures adaptability to evolving technological landscapes. This holistic approach aims to create a conducive environment for innovation and development while safeguarding data privacy and security for all stakeholders.

Limitations in Institutionalized R&D

1) **Absence of R&D infrastructure:** Gaza lacks institutionalized R&D facilities dedicated to exploring. The absence of research institutions and platforms restricts innovation

26 Palestinian Agriculture Ministry, National Agriculture Sector Strategy, "Resilience and Development," 2017-2022.

27 Palestinian Agriculture Ministry in Gaza, "Strategy for Sustainable Agricultural Development," 2010-2020.

and limits the understanding of AI's potential in addressing food security challenges.

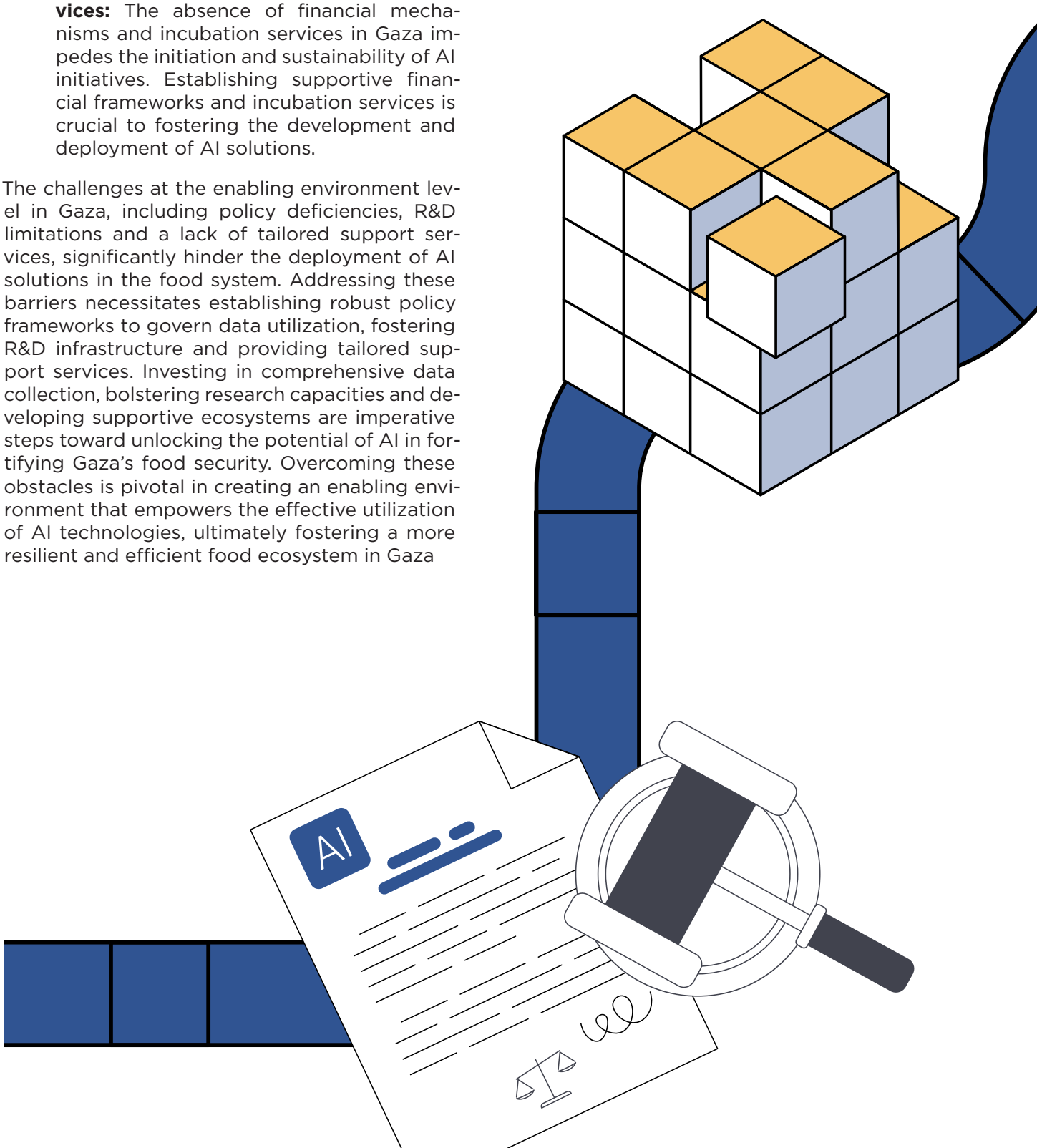
Lack of tailored support services

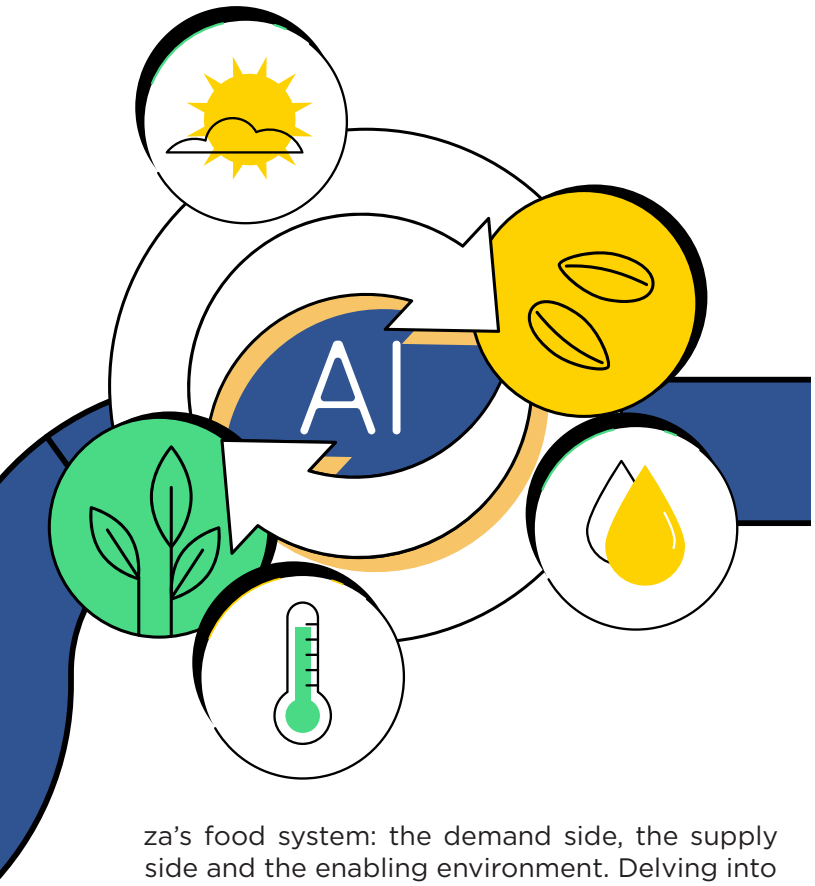
1) **Inadequate support infrastructure:** Gaza's enabling environment lacks tailored services to support the implementation of AI solutions in the food system. The absence of specialized support inhibits the seamless integration of AI technologies into existing practices.
2) **Need for financial and incubation services:** The absence of financial mechanisms and incubation services in Gaza impedes the initiation and sustainability of AI initiatives. Establishing supportive financial frameworks and incubation services is crucial to fostering the development and deployment of AI solutions.

The challenges at the enabling environment level in Gaza, including policy deficiencies, R&D limitations and a lack of tailored support services, significantly hinder the deployment of AI solutions in the food system. Addressing these barriers necessitates establishing robust policy frameworks to govern data utilization, fostering R&D infrastructure and providing tailored support services. Investing in comprehensive data collection, bolstering research capacities and developing supportive ecosystems are imperative steps toward unlocking the potential of AI in fortifying Gaza's food security. Overcoming these obstacles is pivotal in creating an enabling environment that empowers the effective utilization of AI technologies, ultimately fostering a more resilient and efficient food ecosystem in Gaza

VII. RECOMMENDATIONS

In the pursuit of fortifying Gaza's food system through advanced technological interventions, the integration of artificial intelligence (AI) holds immense promise. But this ambitious goal encounters an array of complex barriers spanning multiple facets of the food ecosystem. Understanding and overcoming these impediments is critical for the effective adoption and utilization of AI-driven solutions. This compendium of recommendations is meticulously crafted to address barriers at three pivotal levels within Ga-





za's food system: the demand side, the supply side and the enabling environment. Delving into the intricate challenges faced by users, developers and the overarching ecosystem, these recommendations aim to catalyze transformative change. This comprehensive guide seeks to pave the way for the seamless integration of AI technologies by offering nuanced insights and actionable strategies, ultimately fostering a more resilient and efficient food ecosystem in Gaza.

VII.1 Demand side recommendations:

1. **Awareness and capacity building initiatives:**
   - Implement educational campaigns targeted at stakeholders across the food system to enhance understanding of AI capabilities and benefits.
   - Offer specialized training programs for actors involved in food production, distribution and management to bridge the technical knowledge gap.
2. **Promoting AI value proposition:**
   - Launch awareness programs showcasing real-world examples that highlight AI's advantages over traditional methods.
   - Develop case studies and workshops demonstrating successful AI implementations in similar contexts to boost confidence in AI's transformative potential.
3. **Facilitating transition from traditional systems:**
   - Create transition plans with incentives to encourage traditional systems' gradual adoption of AI technologies.
   - Establish support mechanisms to facilitate a smoother integration process by addressing concerns and providing technical assistance.
4. **Market system enhancement:**
   - Introduce financial schemes or subsidies to alleviate the high costs associated with AI technology adoption in the agricultural sector.
   - Foster partnerships between financial institutions and AI developers to devise affordable financing options tailored for the agricultural industry.
   - Encourage market system research to explore the economic potential of different AI models along the food system in Gaza Strip.

VII.2 Supply side recommendations:

1. **Stakeholder engagement initiatives:**
   - Facilitate forums or workshops bringing together ICT sector representatives and food system actors to foster collaboration and understanding.
   - Establish platforms for continuous dialogue to ensure ICT developers gain insights into specific challenges faced by food system stakeholders.
2. **Capacity enhancement in the ICT sector:**
   - Develop specialized training programs aimed at enhancing technical expertise within the ICT sector focused on AI development for agriculture.
   - Offer incentives for upskilling programs to encourage ICT professionals to gain competencies relevant to food system challenges.

VII.3 Enabling environment-level recommendations:

1. **Policy and regulatory enhancements:**
   - Develop comprehensive regulatory frameworks to govern data collection,

management and utilization within the food system.

- Strengthen enforcement capacities of existing IT laws by investing in institutional capabilities and upgrading equipment.

2. R&D infrastructure establishment:

- Establish dedicated research institutions or centers focused on exploring AI's applications and impact on food security and assess the technical, economic and sociocultural viability to ensure scalability and sustainability.
- Allocate resources for R&D initiatives to incentivize innovation and support the development of tailored AI solutions.

3. Tailored support services development:

- Create specialized support infrastructure to assist in the implementation of AI technologies within the food system.
- Establish financial mechanisms and incubation services to foster the initiation and sustainability of AI initiatives.
- Addressing these recommendations collectively will pave the way for an environment more conducive to AI adoption, enabling the food system in Gaza to leverage the transformative potential of AI effectively.

ANNEXES

ANNEX 1: TOOLS FOR ASSESSING AI INITIATIVES ACROSS FOOD SECURITY PILLARS

Key informant interview questions

GUPAP key informant interview

- Where are the possible applications of AI used within Gaza's food systems?
- What are some food security models currently in use in Gaza? To what extent are they successful and what challenges do they face?
- What are major gaps and potentials within the enabling environment of food production?
- Can you elaborate on the institutional settings and viability of AI applications in the food system handling and marketing system?
- What potential do you see in utilizing AI to solve problems within the system?
- Can you describe barriers and possible responsive interventions?

ICT sector (Palestinian Information Technology Association) (PITA)

- What potential do you see in utilizing AI to support the sector?
- Can you share innovative AI-related ideas for agriculture and the food system in Gaza?
- Can you elaborate on AI solution initiatives currently applied within the Gaza Strip's food system? How successful are they?
- What are some potentials and barriers you see in the various applications of AI?
- What are the major capacities and gaps that you noticed in AI use within the sector?
- Can you explore possible interventions to develop AI solutions for the local food system?

Governmental institutions (MoA, MoNE)

- What are the AI initiatives currently applied in Gaza's food system?
- Can you describe the food information system's major gaps and challenges and identify opportunities where AI can be used to solve them?
- What challenges do you face in the food information system, and how can AI help?
- Can relevant policies and regulations be reviewed to suggest changes for AI use within Gaza's context?
- What are the major gaps obstructing the development of AI solutions?

Concept notes for the workshops and FGDs

The primary data collection stage includes two workshops and three FGDs:

1. Farmers' FGD

FGDs will target 8 to 12 farmers from each sector (plant and livestock farmers).

Purpose: Discover farmers' challenges and pinpoint where AI can be useful, while gauging their understanding of AI along the agricultural value chain (technical, business model, post harvest, handling, marketing, supporting function and enabling environment).

The FGD will start with an introduction of the study's objective, presenting a simple concept of AI application along the food system before starting a discussion with the whole group on the guiding questions.

FGD guiding questions:

- What are the major challenges that affect agricultural production and economic performance of the farming activities? (Technical, business, marketing)
- What are the main challenges along the value chain where AI can help?
  - Production technical problems?
  - Business development related problems
  - Post harvesting and food handling problems
  - Marketing related problems
  - Supporting Services (extension, financial transactions, collective organization etc..
- Can you describe main barriers that can limits the adaptation of AI
  - Awareness and production cultural setting
  - Knowledge and capacities
  - Resources

- Policies
- Institutional framework
- Market system (ability of the prices to bear the added cost of AI)

- What is needed to overcome the above-mentioned barriers

2. FGD with ICT actors with relevant experiences with AI in food sytems (canceled due to war conditions)

FGD will target actors (firms and individuals) to explore current and potential application of AI within the food system in the Gaza Strip. After introducing the objective of the FGD and briefly describing modalities of AI application that can support the food system, the facilitator will open the discussion based on the following guiding questions:

- What are current initiatives to apply AI in Gaza's food system?
- How successful are these initiatives and why? (strength and weaknesses)
- What potential do you see in applying AI to support the sector considering the chain described above?
  - Production technical problems?
  - Business development related problems?
  - Post harvesting and food handling problems?
  - Marketing related problems?

Supporting services (extension, financial transactions, collective organization etc…)

- What are the major capacities and gaps in AI applications in both the agriculture and IT sectors?

Awareness and production cultural setting

- Knowledge and capacities
- Resources
- Policies
- Institutional framework

Market system (ability of the prices to bear the added cost of AI)

- Can you describe the main barriers in the enabling environment and the necessary changes?

3. Verification workshop with food system actors (canceled due to war conditions)

The workshops will target two groups representing active actors within the local food system:

1) The first workshop was to be conducted with the City Food System Actors Network (CFSAN) of processors, handlers, traders and entrepreneurs.
2) The second workshop was to be conducted with the Urban Women Agripreneurs Forum (UWAF)

Both workshops have the same objectives and similar approaches.

Purpose: Explore how AI can support food processing, handling, trading and entrepreneurship; describe the local context and potential uses of AI in the food system; recommend how to promote and scale up the utilization of AI to overcome the challenges within the system.

Workshop breakdown:

- The first session (20 minutes) is an introduction of the objectives of the workshop, presenting the experiences of AI along the food system in a similar context.
- The second session (30 minutes) is to discuss the challenges faced by stakeholders in Gaza's food system and the main AI applications that can improve the situation.
- The third session (20 minutes) is to discuss AI initiatives currently in use in Gaza's food system and reflect with participants on their performance.
- The fourth session (30 minutes) will cover the potential to adopt AI in the food sector.
- The fifth session (30 minutes) focuses on barriers and recommendations of AI adoption.

MENA OBSERVATORY
ON RESPONSIBLE AI
مرصد الشرق الأوسط وشمال إفريقيا للذكاء الاصطناعي المسؤول

Governing Responsible Artificial Intelligence and Data in the Middle East and North Africa (MENA)

The American University in Cairo
Onsi Sawiris School of Business
Access to Knowledge for Development Center

IDRC · CRDI
International Development Research Centre
Centre de recherches pour le développement international

Canada