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تعزيز مرونة النظام الغذائي في مصر دراسة حالة عن نظام القمح

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المستخلص

يوضح هذا البحث أهمية مرونة نظام الغذاء في الوقت الحالي، الذي يعاني فيه العالم من تعدد الأزمات. وتعاني مصر من هشاشة نظام القمح، ويركز هذا البحث على استقصاء كيفية الوصول إلى مرونة نظام القمح، من خلال تحليل الجهات الفاعلة الرئيسية في العرض والطلب على القمح، والتي تتأثر أنشطتها بمجموعة من المحركات، بما في ذلك الضغوط والصدمات. وتم إنشاء إطار مفاهيمي لنظام القمح بنظرة شمولية. ونتج عن هذا التحليل الشمولي تحديد نقاط الارتكاز التي يمكن أن تؤثر على مرونة القمح في مصر، وكذلك اقتراح خيارات السياسات الملائمة لصانعي القرار. ويبين البحث أن خطورة الصدمات التي تواجه الواردات تقع في المقدمة، بسبب صعوبة السيطرة عليها وكذلك صعوبة التنبؤ بها، تليها الصدمات المتعلقة بالاستهلاك لأنها تتطلب إرادة سياسية وقرارات قد تؤدي إلى تأثيرات اجتماعية خطيرة وغضب شعبي، ثم تأتي في المرتبة الثالثة خطورة الصدمات في مرحلة الإنتاج، حيث أن طرق مواجهتها والتنبؤ بها والاستعداد لها أسهل من الصدمتين السابقتين. وقد تم اقتراح مجموعة من خيارات السياسات للتغلب على هذه المشكلة.

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Enhancing Egypt's Food System Resilience Case Study on Wheat System

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ABSTRACT

This research shows the importance of food system resilience in this era, in which the world suffers from a polycrisis. Egypt has a fragile wheat system, this research focuses on investigating how to reach a wheat system resilience, by analyzing the main actors of the wheat supply and demand, whose activities are influenced by a range of drivers, including stresses and shocks. A conceptual framework for the wheat system is created with a holistic view. This results in identifying the leverage points that can affect wheat resilience in Egypt and propose relevant policy options for decision-makers. The research shows that the seriousness of shocks facing imports at the forefront, due to the difficulty of controlling them as well as the difficulty of predicting them, followed by shocks related to consumption because they require political will and decisions that may result in serious social impacts and public anger, and then come in third place the seriousness of shocks in the production stage, since the ways to confront them, predicting them, and preparing for them is easier than the other two shocks. The research proposes some policy options to overcome this problem.

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1. Introduction

The concept of a food system has been gaining traction in recent years, as a solution to food insecurity issues. Food systems are defined by the International Food Policy Research Institute (IFPRI)[1] as "the sum of actors and interactions along the food value chain—from input supply and production of crops, livestock, fish, and other agricultural commodities to transportation, processing, retailing, wholesaling, and preparation of foods to consumption and disposal". Food systems are vulnerable to a variety of shocks and stresses, both of which can have a significant impact on key outcomes of the food system, including the provision of adequate quantities of high-quality food at reasonable prices, the provision of meaningful livelihoods, and the promotion of environmental sustainability.

Food System Resilience (FSR) is defined as the capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate, and accessible food to all, in the face of various and even unforeseen disturbances.[2] These disturbances are called shocks, defined as sudden events with varying probabilities of occurrence and impact, and can even be completely unexpected.[3] A better understanding of their vulnerabilities and dynamics can be gained from the effects of crises on food systems. For all stakeholders to respond appropriately and effectively, more understanding is needed about the capabilities and opportunities offered by food system resilience.

Numerous variables pose a threat to the security of food supplies in a world that is becoming more complicated and uncertain. These include various global change processes (such as population growth, fast urbanization, and climate change), unanticipated shocks (such as natural catastrophes, financial crises, and political unrest), and unanticipated reactions of food systems to these processes and events.

In the last decade, Egypt -and the whole world – has been suffering from what is called a poly-crisis,[4] it went through the effects of international and regional crises;

[1] https://www.ifpri.org/topic/food-systems.
[2] Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q.B., Krütli, P., Grant, M. and Six, J., 2015. Food system resilience: Defining the concept. Global Food Security, 6, pp.17-23.
[3] Zurek, M., Ingram, J., Sanderson Bellamy, A., Goold, C., Lyon, C., Alexander, P., Barnes, A., Bebber, D.P., Breeze, T.D., Bruce, A. and Collins, L.M., 2022. Food system resilience: concepts, issues, and challenges. Annual Review of Environment and Resources, 47, pp.511-534.
[4] UNICEF. 2023. Prospects for Children in the Polycrisis: A 2023 Global Outlook. UNICEF Innocenti – Global Office of Research and Foresight

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the COVID-19 pandemic, the Russia –Ukraine conflict, and recently the war in the Gaza Strip and its consequences on the region.

The research chose the wheat crop as a case study because it is one of the strategic food commodities that Egypt relies on importing nearly half of its consumer needs, which exposes it to many local and external shocks. Egypt depends basically on Russia and Ukraine to import grain. Grain trading is severely hindered by the direct effects of the Russia –Ukraine conflict and trade blockades.[5] Therefore, food system resilience becomes a priority for policymakers, they should be able to assess the effects of any intervention in a food system.

The paper is organized as follows; after the introduction, Section 2 contains the research problem and its importance. The aims of the research are presented in Section 3. Basic definitions of food system and food system resilience are in Section 4. Section 5 reviews the research papers and reports on food system resilience and the wheat system, which shows a lake of studies covering the wheat system resilience in Egypt. Section 6 presents the methodology used in the research. Section 7 shows the application and the results of the methodology it consists of two parts, the first one discusses the current situation of wheat production and consumption in Egypt, from which the main factors that affect the system are extracted, and the second part constructs a conceptual framework by using systems thinking approach, to analyze the wheat gap in Egypt. This is done to reach the policies needed to minimize this gap and increase the system's resilience by finding the leverage points through which it is possible to intervene and produce the desired effect. Section 8 represents some policy options to overcome this problem.

2. Research Problem

The wheat supply chain in Egypt suffers from many shortages, due to the challenges that face the wheat production in Egypt, which in turn affect the production efficiency and the import cost. That results in a huge financial burden for the Egyptian government, in the form of wheat subsidies, to satisfy the increased wheat consumption.

[5] Fonteijn, H., van Voorn, G., Hengeveld, G. and de Steenhuijsen Piters, B., 2022. Assessing the impact of interventions on food systems resilience (No. 2022-082). Wageningen Economic Research.

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Therefore, this research seeks to understand these shortages and work on eliminating their causes. Also, the research investigates how to reach a resilient wheat supply and demand, by creating a conceptual framework for wheat system resilience from a holistic standpoint. This leads to identifying the leverage points affecting wheat resilience in Egypt and proposing relevant policy options for decision-makers.

3. Research Objectives

The main objective of the research is to identify the ability of the wheat system in Egypt to withstand the unfavorable variables facing the production, import and consumption of wheat in Egypt through the system thinking approach.

The sub-objectives are as follows:

- Track and analyze the supply and demand chain for wheat to identify the most important strengths and weaknesses in this chain and monitor the causes of the gaps surrounding the chain
- Monitor the most important factors responsible for the decline in wheat production
- Monitor the most important factors responsible for the increase in wheat consumption
- Identify the risks associated with the wheat import gap
- Identify some policies and mechanisms that would enhance the resilience of wheat

4. Basic Definitions

4.1 Food System

The food system includes all the processes and activities, which are related to food production, processing, distribution, and utilization. In addition, the outcomes of the food system are related to food security, health, income distribution, employment, and environmental impacts.[6]

The food system consists mainly of two components: the food value chain, and the enabling environment. The first component is regarded as the heart of the food

[6] Van Berkum, S., Dengerink, J. and Ruben, R., 2018. The food systems approach: sustainable solutions for a sufficient supply of healthy food (No. 2018-064). Wageningen Economic Research.

supply system. It starts with food production and ends with food consumption. The second component of the food system decides the conditions in which the food system operates. The enabling environment includes infrastructure, regulations, networks, and institutional arrangements that affect the food system's efficiency.[7] The actors of the food system are not only food suppliers and producers, but also the logistic actors, who affect extensively the food supply chain.[8]

A food system is considered a complex network of activities, it operates at multiple spatial and organizational scales and spans social, ecological, and economic relationships.[9] The complexity of the food system makes measuring the impact of a policy intervention or investment on the food system (including resilience) is not straightforward, since interventions are likely to affect not only their specific targets but also other food system properties. An intervention or investment may enhance resilience for one part or segment of society of the food system, while simultaneously reducing the resilience of others.

The actors of the food system interact with each other, forming connected subsystems in which feedback loops affect the behavior of the whole food system. Consequently, the interaction among the food system actors and their connected subsystems cannot be regarded as a simple supply chain. Instead, the food system is characterized as a complex, nonlinear, unpredictable system.[10]

Traditionally, the analysis of the food system was concentrated only on its activities, ranging from production to consumption. However, this analysis has recently been insufficient and results in proposing misleading policies and outcomes of the food system. Consequently, the analysis of the food system starts to take into consideration the interaction among the actors of the enabling environment, the interaction among the food system activities, and the interaction among the food

[7] Ibid ref. (6)
[8] Saad, N.A., Elgazzar, S. and Saleh, G., 2016. The Impact of Implementing European Quality Labeling System on the Supply Chain Performance of Food Industry: An Empirical Study of the Egyptian Traditional Food Sector. International Journal of Economics and Management Engineering, 10(9), pp.3161-3167.
[9] Schipanski, M.E., MacDonald, G.K., Rosenzweig, S., Chappell, M.J., Bennett, E.M., Kerr, R.B., Blesh, J., Crews, T., Drinkwater, L., Lundgren, J.G. and Schnarr, C., 2016. Realizing resilient food systems. BioScience, 66(7), pp.600-610.
[10] Pircher, T.,Tiede, K., M. Ehret, M. Nertinger and C. Callenius, 2021. Food System Resilience - Recommendations for the EU-Africa R&I Partnership on FNSSA. University of Hohenheim.

system outcomes. This led to a more integrated and comprehensive analytical approach, and hence more reliable and accurate policy options.[11]

4.2 Food System Resilience

The Sustainable Development Goals seek to achieve food security through several goals, most notably the first goal (No poverty), and the second goal (No hunger) and the other goals which work together to achieve food security.

Food security is based on four main axes:

1. Availability: Increasing local production or self-sufficiency in a safe manner
2. Stability: the availability of food at all times and the flow of its supplies without being exposed to sharp fluctuations in the supply of food
3. Accessibility: Ensuring access to food means that it is affordable for everyone in terms of prices
4. Safety: Food safety by providing appropriate healthy food

This means that by strengthening the supply and demand chain for wheat the availability can be achieved, and by ensuring that there are no bottlenecks in the chain the stability will be improved. While working to ensure the provision of profitable product prices for the producer and low for the consumer, maintaining the strategic stock and rationalizing the import chain will enable everyone to obtain wheat at a reasonable price, thus achieving accessibility. Also, ensuring supervision of the production and consumption chain by officials and dealers in that chain will ensure food safety.

Resilience can be roughly characterized as the dynamic ability to continue achieving goals in the face of shocks and disturbances, while sustainability has been defined as the capacity to achieve today's goals without compromising the capability to achieve them in the future.[12] Thus, resilience and sustainability can be understood as complementary notions, as illustrated in Fig. (1).

[11] Ericksen, P.J., 2008. Conceptualizing food systems for global environmental change research. Global environmental change, 18(1), pp.234-245.
[12] Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q.B., Krütli, P., Grant, M. and Six, J., 2015. Food system resilience: Defining the concept. Global Food Security, 6, pp.17-23.

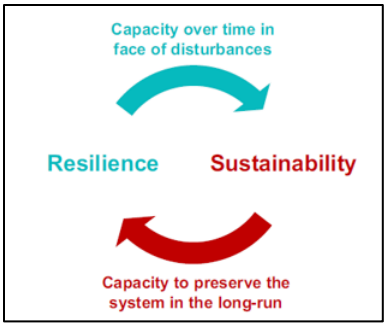

Figure (1): Resilience and sustainability as complementary concepts.

Source:
https://www.researchgate.net/publication/282577265_Food_system_resilience_Defining_the_concept.

Resilience in a food system is considered to be the capacity to adjust and adjust to shocks without losing its ability to function. Resilience in food systems, like in other complex social-ecological systems, cannot be measured on a single scale. As a result, while assessing resilience within the increasingly globalized food system, local, global, and cross-scale interactions must be considered. Furthermore, it is important to assess food systems considering both the immediate reactions and the longer-term elements that support resilience.[13]

While there is still a dearth of research on food system resilience, it is becoming increasingly clear that strengthening and safeguarding vulnerable populations' food security at the local and national levels depends on the ability to understand how local, national, and international food systems react to shocks and unfavorable events[14]. Fig. (2) shows the main feedback loops between the key functions of food systems and their resilience.

[13] Béné, C., Frankenberger, T.R., Nelson, S., Constas, M.A., Collins, G., Langworthy, M. and Fox, K., 2023. Food system resilience measurement: principles, framework and caveats. Food Security, 15(6), pp.1437-1458. 8

[14] Seekell, D., Carr, J., Dell'Angelo, J., D'Odorico, P., Fader, M., Gephart, J., Kummu, M., Magliocca, N., Porkka, M., Puma, M. and Ratajczak, Z., 2017. Resilience in the global food system. Environmental Research Letters, 12(2), p.025010.

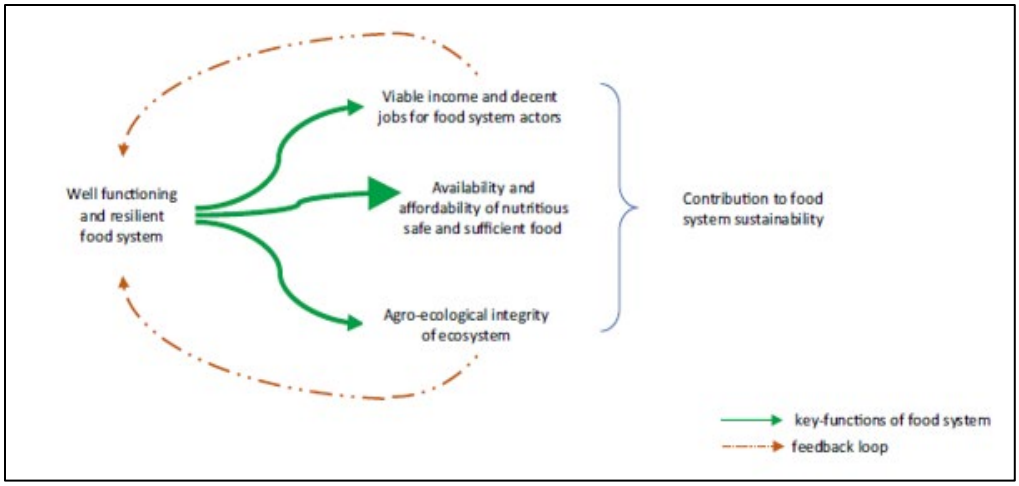

Figure (2): The main feedback loops between the key functions of food systems and their resilience

Source: https://link.springer.com/article/10.1007/s12571-023-01407-y

5. Literature Review

Many research papers studied Food System Resilience (FSR) from different aspects. The majority concentrate on agricultural production or other specific stages in the food value chain. [15] [16]. However, in Ericksen a comprehensive framework for the food system is created to highlight potential trade-offs and synergies between social, environmental, and nutritional consequences, to capture the intricate relationships between drivers and activities.[17] USDA's Economic Research Service mentioned that food insecurity is a complex problem in the United States that is caused by many socioeconomic factors and is associated with various health outcomes, and they analyze the problem to provide an overview of the factors at different levels contributing to food insecurity.[18]

A report by the European Union mentioned that the behavior of the food system is defined by an interplay of interacting subsystems, in which feedback plays a key role, rather than a simple chain of cause-effect relationships. Since this process

[15] Darnhofer, I., Bellon, S., Dedieu, B. and Milestad, R., 2010. Adaptiveness to enhance the sustainability of farming systems. A review. Agronomy for sustainable development, 30, pp.545-555.
[16] Milestad, R., Dedieu, B., Darnhofer, I. and Bellon, S., 2012. Farms and farmers facing change: The adaptive approach. In Farming Systems Research into the 21st century: The new dynamic (pp. 365-385). Dordrecht: Springer Netherlands.
[17] Ericksen, P.J., 2008. Conceptualizing food systems for global environmental change research. Global environmental change, 18(1), pp.234-245.
[18] https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/

includes feedback loops, the cause-effect relationships are not linear and often not predictable.[19] Also, a report by the European Commission stated that a variety of food system concepts and frameworks were developed in the last decade, resulting in different definitions regarding its components, boundaries, and the interactions between components in the systems.[20] Folke et al. examine specific aspects of resilience, such as adaptability and transformability.[21] As a result, many studies concentrate on certain food system components and frequently fail to take complicated cross-scale and cross-level interactions into consideration.[22] Berkum et al. show the importance of a food systems approach that can help find solutions that will provide the world's growing population with a sufficient supply of healthy food within environmental limits. It finds solutions by intervening in parts of the system or where necessary outside the system, other than where the problem occurs.[23]

Candy et al. outline a process for exploring food system vulnerability and resilience using scenario modelling with the Australian Stocks and Flows Framework. The framework simulates how diverse shocks and stressors affect food system behavior across multiple sectors—with diverse, interconnected, and dynamic variables shaping system response—renders the framework particularly suited for exploring complex issues of future food supply. the researchers used the framework to explore the significance of alternative agricultural policies for land use, crop production, livestock production, fisheries, food processing, transport, food waste, and ultimately food supply.[24]

Jose and Kopainsky used the system dynamics approach in resilience planning for food security in Guatemala. Through their analysis of the behavior and structure of this complex problem, they realized that food system stability depends upon strategic resources, which moderate environmental changes and food production and prices.

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[19] Pircher, T.,Tiede, K., M. Ehret, M. Nertinger and C. Callenius, 2021. Food System Resilience - Recommendations for the EU-Africa R&I Partnership on FNSSA. University of Hohenheim.

[20] Achterbosch, T.J., Escudero, A.G., Dengerink, J.D. and van Berkum, S., 2019. Synthesis of existing food systems studies and research projects in Europe. European Commission, Directorate-General for Research and Innovation.

[21] Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T. and Rockström, J., 2010. Resilience thinking: integrating resilience, adaptability and transformability. Ecology and society, 15(4).

[22] Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q.B., Krütli, P., Grant, M. and Six, J., 2015. Food system resilience: Defining the concept. Global Food Security, 6, pp.17-23.

[23] Van Berkum, S., Dengerink, J. and Ruben, R., 2018. The food systems approach: sustainable solutions for a sufficient supply of healthy food (No. 2018-064). Wageningen Economic Research.

[24] Candy, S., Biggs, C., Larsen, K. and Turner, G., 2015. Modelling food system resilience: a scenario-based simulation modelling approach to explore future shocks and adaptations in the Australian food system. Journal of Environmental Studies and Sciences, 5, pp.712-731.

Also, they showed that resilience policies are context-specific, and differ from one system to another, based on the dynamic complexity of each system.[25]

Anderson stated that there is an urgent need to shift globally toward a more resilient food system knowledge, to be able to achieve food security resilience. This is done first through making knowledge more responsive to food security needs. Then, it is followed by providing enough funds from concerned international organizations and countries to generate and disseminate resilient food system knowledge. Also, this shift requires more transparency in food system knowledge through open-source platforms. This will lead to more use and adaptation of the food system knowledge globally. [26]

Béné studied the food system resilience during the disruptions of the COVID-19 pandemic. It concluded that it is significant not to focus the analysis only on the impact of the initial shock, but to focus also on the responses of the different actors in the system to mitigate the effects of the initial shock. In addition, he shed light on the significance of the role of both capacity building and understanding the complexity of the food system to be able to achieve food system resilience within shocks and stressors.[27]

McDonald et al. showed that wheat productivity in India can be significantly improved through the establishment of a timely managed wheat mechanism, which is able to achieve climate resilience. This resulted in greater wheat yield potential in India through improving the anticipation ability of the wheat system and adjusting the annual cropping calendar due to climate changes. The authors concluding with providing different options and strategies that lead to greater wheat yield productivity and resilience.[28]

Zampieri et al. introduced a novel framework to assess wheat resilience. The authors applied this framework to forecast the production of wheat of the top ten wheat

[25] Jose, H., and Kopainsky, B., 2020. Do you bend or break? System dynamics in resilience planning for food security. System Dynamics Review.
[26] Anderson, M., D., 2015. The role of knowledge in building food security resilience across food system domains. Journal of Environmental Studies and Sciences.
[27] Béné, C., 2020. Resilience of local food systems and links to food security – A review of some important concepts in the context of COVID-19 and other shocks. Food Security, 12, pp. 805- 822.
[28] McDonald, A., Singh, B., Keil, A., Strivastava, A., Craufurd, P., Kishore, A., Kumar, V., Paudel, G., Singh, S., Singh, A., Sohane, R. Malik, R., 2022. Time management governs climate resilience and productivity in the coupled rice–wheat cropping systems of eastern India. Nature Food, 3, pp. 542–551.

producing countries in the Mediterranean and the Middle East region. This analysis proved the urgent need for these countries to design and follow effective climate change mitigation and adaptation strategies, in order not to suffer from huge losses in wheat production in the coming years.[29]

A study to impose water deficit on modern and wild wheat collections is made to identify drought-resilient genotypes in Egypt[30], it aimed to identify drought-tolerant wheat genotypes by evaluating 2,100 genotypes under water deficit and well-watered conditions in Egypt. Key traits like days to flowering, plant height, and grain yield were measured.

The impact of climate change on wheat productivity and crop water needs in various regions of Egypt is the focus of a study[31] that emphasizes the potential risk to the country's wheat self-sufficiency objectives. Data from 1987 to 2019 covering lower, middle, and upper Egypt, as well as regions beyond the Nile Valley were analyzed. The study recommends that strategies for achieving wheat self-sufficiency in Egypt and comparable climates should consider air temperature and wheat growing degree days. Suggestions include the adoption of heat, drought, and disease-resistant wheat varieties and the expansion of wheat cultivation in zones other than upper Egypt to address the challenges posed by climate change.

The factors that influence decision-making and the perspectives of small-scale wheat farmers in the Nile River Delta are examined in a recent study[32]. it found that the cultivation of wheat by smallholders is significantly impacted by internal factors, including the need for subsistence to meet household consumption and the presence and level of animal farming. Additionally, external factors such as government-set domestic wheat prices for each season and the timing of their announcement also play a role in influencing smallholders' choices to expand or reduce their wheat

[29] Zampieri, M., Toreti, A., Ceglar, A., Naumann, G., Turco, M. and Tebaldi, C., 2020. Climate resilience of the top ten wheat producers in the Mediterranean and the Middle East. Regional Environmental Change, pp. 20-41.
[30] Morsy, S.M., Elbasyoni, I.S., Abdallah, A.M. and Baenziger, P.S., 2022. Imposing water deficit on modern and wild wheat collections to identify drought-resilient genotypes. *Journal of Agronomy and Crop Science*, *208*(4), pp.427-440.
[31] Gamal, R., Abou-Hadid, A.F., Omar, M.E.D. and Elbana, M., 2024. Does climate change affect wheat productivity and water demand in arid regions? case study of Egypt. Journal of Agriculture and Food Research, 16, p.101181.
[32] Abdalla, A., Stellmacher, T. and Becker, M., 2023. Wheat Farmers' Perception of Constraints and Their Adaptive Capacity to Changing Demands in Egypt. Agriculture, 13(8), p.1554.

farming area. The research also indicated that the factors that impact the decisions of farmers to cultivate wheat or adopt innovative methods differ in different areas within the same region. Small-scale farmers face challenges with inadequate access to essential production resources and are dissatisfied with the limited availability of extension and support services, as well as the inadequate market structures. These limitations discourage small-scale farmers from producing (more) wheat. These issues need to be tackled and resolved to boost domestic production and lessen Egypt's reliance on costly and unreliable wheat imports.

Another recent research[33] mentioned that several improved management practices to increase wheat production were reviewed, namely reducing the reliance on chemical fertilizer in wheat production by application of organic fertilizer, legume crops preceding wheat, and wheat intercropping systems with legume crops. It found that inclusion of legume crop in wheat-base cropping system by intercropping could attain the sustainable use of land by increasing soil available nitrogen and organic matter. It attained the sustainable use of water by using the applied water to wheat to produce both fahl clover and wheat. Furthermore, it increased land productivity through increasing wheat yield, compared to wheat sole cultivation and produce two crops on the same piece of land.

A methodological framework that enables the calculation of the annual production resilience indicator from nonstationary time series was developed in a study[34] that showed the relation between Climate resilience and wheat producers in the Mediterranean and the Middle East. The approach has been utilized to analyze the wheat production of the top 10 producers in the Mediterranean and the Middle East. Our research indicates that without any adaptation, the reliability of wheat production in these regions will be at risk due to climate change even with just a 1.5 °C global warming. The average climate-related wheat production losses will surpass previous worst events, even if the 2 °C mitigation target is achieved. These findings emphasize the need for immediate action on climate change adaptation and

[33] Ouda, S. and Zohry, A.E.H., 2024. Increasing Land and Water Use Efficiencies of Wheat: Case Study of Egypt. In *Integration of Legume Crops with Cereal Crops Under Changing Climate: Sustainably Increasing Food Production* (pp. 35-63). Cham: Springer Nature Switzerland.

[34] Zampieri, M., Toreti, A., Ceglar, A., Naumann, G., Turco, M. and Tebaldi, C., 2020. Climate resilience of the top ten wheat producers in the Mediterranean and the Middle East. *Regional Environmental Change*, *20*, pp.1-9.

provide support for continued efforts in mitigation, aligning with the recommendations of the Paris Agreement.

6. Research Methodology

To answer the research question, first, the research analyzes the current situation of the wheat system, second it constructs a conceptual framework to show the actors, and boundaries of resilience in this strategic food and find the leverage points through which it is possible to intervene and produce the desired effect.

One of the effective methods in the literature that has been extensively utilized for comprehending such issues is systems thinking modeling.[35] [36] Systems thinking modeling, viewed from a system perspective, enables the identification of essential variables, the understanding of the interdependence and linkages among those variables, as well as the causal relationships inherent in such complicated issues. In these kinds of systems, system thinking modeling can also be used to evaluate the consequences of a long-term policy.

According to the systems thinking paradigm, a system's structure—which almost includes feedback—determines its behavior. It is more important to focus on comprehending the mechanisms that cause the system to change. Therefore, a system thinking approach will be used to pinpoint significant variables and gain a deeper understanding of how they achieve the wheat system resilience in Egypt.

The system represents wheat system resilience as a process that includes feedback loops, due to the cause-effect relationships between the actors; these relationships are not linear and often not predictable. Gaining a deeper understanding of this intricate issue and its underlying dynamics is the first step in evaluating and suggesting strategies that help reach food system resilience.

The system thinking approach is represented by causal loop diagrams. Causal Loop Diagrams (CLDs) are primarily used to identify the underlying, hidden structure that governs a system's behavior. This can be a valuable tool for conceptualizing real-world issues and supporting the implementation of accurate policies. It demonstrates

[35] Nguyen, T.V., Nguyen, N.C. and Bosch, O.J., 2015. Developing Causal Loop Diagrams for Coffee Supply Chain: Supporting to Enhance the Competitive Advantages of A Vietnamese Coffee. In Proceedings of the 59th Annual Meeting of the ISSS-2015 Berlin, Germany (Vol. 1, No. 1).

[36] Van Berkum, S., Dengerink, J. and Ruben, R., 2018. The food systems approach: sustainable solutions for a sufficient supply of healthy food (No. 2018-064). Wageningen Economic Research.

how actions taken to address one problem in the system can have an unintended and often undesirable large-scale impact on other problems in the system, as well as how to target system leverage points that, when affected, can lead to desired solutions.

CLD is a visual representation of the system under investigation. It consists of variables and links between related ones. The direction (polarity) on each link is determined; the relationships between variables can be in the same direction (+), which means that when a variable increases (decreases), it affects the increase (decrease) of the other variable. A reinforcing (R) feedback loop is created if starting from one variable and returning to it in a way that magnifies changes (exponential growth or decline). If the two variables are in the opposite direction (-), i.e., when a variable increases (decreases), it affects the decrease (the increase) of the other variable, if the loop is created in this way a Balancing (B) feedback loop is obtained that act to stabilize system behavior over time. Hash marks (||) represent a Delay, a situation where it takes time before the effect plays out37. Analyze the diagram, and find key leverage points, then Identification and development of systemic intervention strategies can be obtained.

7. Application and Results

7.1 Current Situation of Wheat Production and Consumption in Egypt

Wheat is deemed a strategic crop and holds significant importance in Egypt's grain production. It receives significant attention from farmers and the government alike due to its main role in achieving food security. Primarily utilized in bread production and various food items, wheat stands as a cornerstone in the Egyptian dietary regimen, particularly for low-income individuals. Moreover, wheat byproducts such as straw and bran serve as vital sources of animal feed. Egyptians obtain one-third of their daily calorie intake and 45% of their protein from wheat-based foods.[38]

Egypt is recognized as one of the world's foremost consumers and importers of wheat, importing nearly half of its consumption needs. This reliance presents a significant challenge to Egypt's food security and exacerbates the existing supply gap, particularly vulnerable to geopolitical, international, and regional fluctuations

[37] Haraldsson, H.V., 2004. Introduction to system thinking and causal loop diagrams (pp. 3-4). Lund, Sweden: Department of chemical engineering, Lund University.

[38] Abdalla, A., Stellmacher, T. and Becker, M., 2022. Trends and prospects of change in wheat self-sufficiency in Egypt. Agriculture, 13(1), p.7.

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and their consequences. Scarcely had the world begun to recover from the impacts of the COVID-19 pandemic when the Russian-Ukrainian conflict started, coinciding with the Gaza conflict. This situation signals a growing peril marked by various adverse effects on supply value, including the surge in global wheat prices and the heightened cost of procurement, alongside essential production inputs such as fertilizers and energy. Furthermore, climate change and weather variations have also adversely impacted global wheat production. The rise in temperature and drought experienced by many wheat-exporting countries has led to a decrease in production. Additionally, the quality of wheat has deteriorated due to a large portion of its cultivation areas being exposed to risks of disease and pests that have emerged with climate change.

7.1.1 The Development of Wheat-Cultivated Area and Productivity

Over the past thirteen years, Egypt has expanded local wheat production. The cultivated area increased from approximately 3 million acres in 2010 to around 3.4 million acres in 2022, achieving an annual growth rate of 0.61%. Despite the growth, the wheat cultivation area has witnessed significant annual fluctuations. It reached a peak of about 3.5 million acres in 2015 and dropped to 2.9 million acres in 2017 (Figure (3)). The cultivated wheat area is mainly concentrated in the old lands within the Nile Valley, accounting for approximately 74.8% of the total. The remaining 14.6% is outside the valley, and 10.6% is in new lands. Half of the wheat-cultivation area is located in the coastal governorates of the Nile Delta[39]. The weak growth rate and fluctuations can be attributed to limitations in agricultural resources and policies[40]. Arable land and water availability are crucial factors, but their per capita share has been declining due to population growth.

The individual's share of land in 2021 was approximately 0.09 acres, which was the lowest globally[41]. Their share of water was about 547 cubic meters annually, representing less than 55% of the global water poverty threshold[42]. Deficiencies in agricultural and pricing policies for wheat have hindered its cultivation expansion.

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[39] Ministry of Agriculture and Land Reclamation. October 2023. Current Situation and Future Prospect of Wheat. Agricultural Research Centre, Agricultural Economics Research Institute.

[40] أميرة محمد على وسمر محمود القاضي. 2017. دراسة تحليلية لأهم العوامل الاقتصادية المؤثرة على إنتاج محصول القمح في مصر. مجلة حوليات العلوم الزراعية بمشتهر. مجلد 55 (3)

[41] Central Agency for Public Mobilization and Statistics. 2023. Statistical Yearbook.

[42] Central Agency for Public Mobilization and Statistics. 2014. Bulletin of Water Resources and Rationalization of their Use in Egypt.

Winter crops like perennial clover, sugar beet, and local beans have become more competitive due to their higher net return per cultivated acre compared to wheat. For instance, perennial clover yields nearly 17 thousand pounds per acre, while broad beans reach 7.6 thousand pounds per acre in 2021.[43] The shortage of foreign currencies for feed imports, coupled with rising prices, has led to an expansion of fodder crops and perennial clover cultivation. Government wheat procurement policies have not incentivized farmers to expand wheat cultivation due to consistently lower net returns compared to global wheat prices. Announcement timing of procurement prices has also affected farmers' decisions regarding wheat cultivation.

Regarding the productivity development of wheat during the study period, it is observed that it has taken an overall increasing trend. It rose from 2.39 tons per acre in 2010 to 2.82 tons per acre in 2022, achieving a relatively weak growth rate of 0.52% (Fig. (3)). Despite the government's efforts to improve wheat productivity by increasing the cultivated areas with high-yield varieties, distributing a greater quantity of certified seeds to farmers, employing laser leveling, and expanding farming, Egyptian wheat productivity - despite its high quality - still lags significantly behind many other countries.

Egyptian wheat productivity reached about 2.88 tons per acre during the same year, ranking it 12th globally. This indicates a productivity gap of up to 1.5 tons per acre, representing 34.2% of the highest global productivity.[44]

Low growth rate in wheat productivity can be attributed to numerous general agricultural challenges as well as specific challenges related to wheat cultivation. General challenges include a decrease in the fertility of agricultural lands, with approximately 30% of them affected by salinity in 2021,[45] resulting in reduced productivity. Moreover, there is fragmentation of agricultural land ownership, with the average farm size being approximately 1.5 acres and 80% of farmers owning less than two acres,[46] hindering the adoption of modern technologies that could enhance productivity. Inefficient water usage for irrigation, weak research and development

[43] Ministry of Agriculture and Land Reclamation. 2022. Cost and Net Return Statistics Bulletin 2021.
[44] https://www.fao.org/faostat/en/#data/QCL
[45] https: //saline agriculture. com /en/ news salinity problem – in Egypt
[46] Ministry of Agriculture and Land Reclamation. 2009/2010. General Administration of Census.

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systems, and shortcomings in agricultural extension services further exacerbate these challenges for farmers.

As for the challenges specific to wheat cultivation, the most significant is the low coverage of wheat crops by certified seeds, ranging from only 40-50% during the period (2020-2022)[47] due to the limited capabilities of seed multiplication fields under Central Administration for Seed Production. This forces farmers to use seeds of unknown origin or seeds from the previous year's wheat crop stock. Additionally, there is a shortage of subsidized fertilizers allocated to wheat farmers, which leads to decreased productivity.

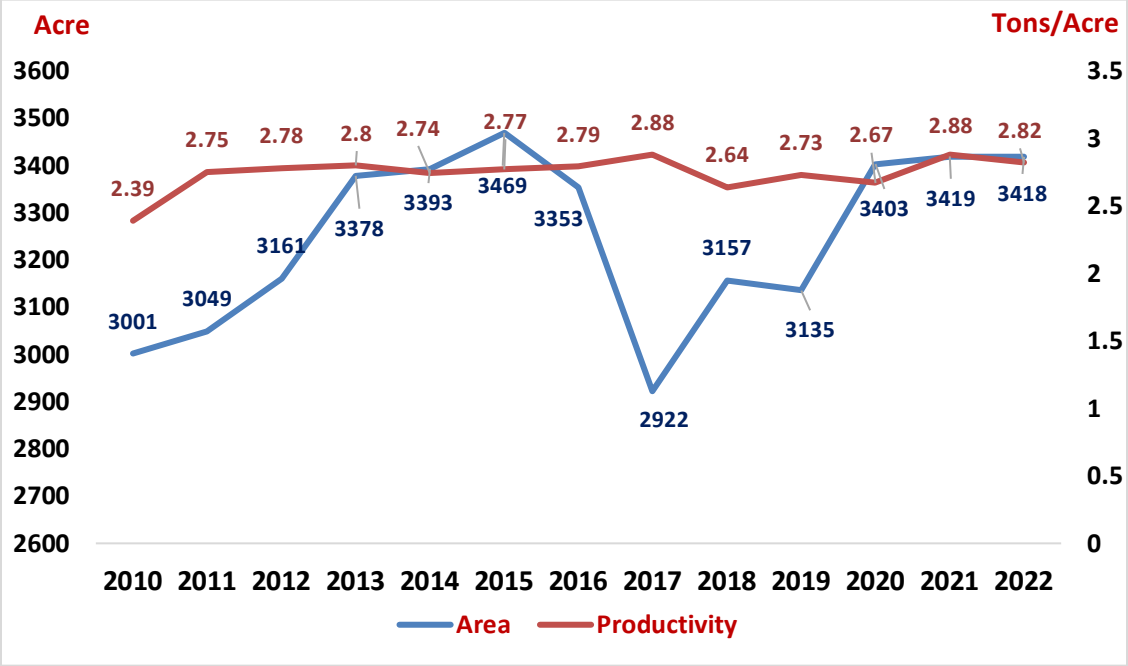

Figure (3): Evolution of Wheat cultivated area and Productivity

Source: Compiled and calculated from:

- Food Balance Sheets - Economic Affairs Sector - Ministry of Agriculture and Land Reclamation - Various issues.
- Annual Bulletin of Crop Areas and Plant Production Statistics - Central Agency for Public Mobilization and Statistics - Various issues.

[47] Ministry of Agriculture and Land Reclamation. Central Administration for Seed Inspection and Certification, Information and Data Documentation Center, unpublished data.

7.1.2 Development of Wheat Production and Consumption

Considering the increasing growth rates of both of the area, and productivity of wheat, annual production has witnessed a general upward trend during the research and study years. It rose from 7.16 million tons in 2010 to 9.62 million tons in 2022, achieving an annual growth rate of 1.14% (figure (4)). The growth rate in cultivated areas contributes more predominantly to the increase in production compared to the growth rate in productivity. This implies that horizontal expansion has played a larger role than vertical expansion in augmenting wheat production.

The contribution of both old and new lands constitutes approximately 74.8% and 10.6% respectively of the total production at the national level.[48] Additionally, the available wheat for consumption has also witnessed a general upward trend, increasing from around 14.98 million tons in 2010 to 18.69 million tons in 2022. This signifies an increase in consumption at an annual growth rate of 2.59% (Figure (4)), exceeding the growth rate achieved in production. Despite allocating a portion of the available wheat and seeds for purposes other than human consumption, the quantity available for human consumption reached approximately 16.3 million tons in 2022, equivalent to 87.2% of the total available for consumption.[49]

The total amount of wheat available for consumption increased during the year 2023 to more than 20 million tons. This quantity represents approximately 2.6% of the global consumption volume according to the report of the US Department of Agriculture in 2023. This increase is primarily attributed to the surge in wheat imports, which rose by 14.7% compared to 2022. The volume of domestic wheat consumption is distributed between approximately 9 - 9.5 million tons allocated to the Ministry of Supply represented by the General Authority for Supply Commodities, devoted to subsidized bread production benefiting around 72 million citizens restricted by 21 million ration cards. This quantity is utilized in producing approximately 118.9 billion loaves annually (Ministry of Finance, 2023).[50] Meanwhile, the remaining quantity (about 50% of the available) is consumed to meet the needs of the free market for bread, flour, and private-sector products made from wheat flour.

[48] Ibid – ref no (26)
[49] Ibid – ref no (26).
[50] Ministry of Finance, State Budget Sector, unpublished data.

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The significant increase in the available wheat for consumption can be attributed to several reasons, foremost among them being the population growth rate.[51] Additionally, the per capita wheat share has increased, reaching nearly 182 kilograms per year in 2022, significantly surpassing many other countries and exceeding the global average (estimated at around 67 kilograms) by approximately 115 kilograms. It is noteworthy to reiterate that the per capita food availability in Egypt reached approximately 158 kilograms during the mentioned year,[52] indicating a diversion of wheat for non-human consumption purposes due to the previously mentioned price distortions.

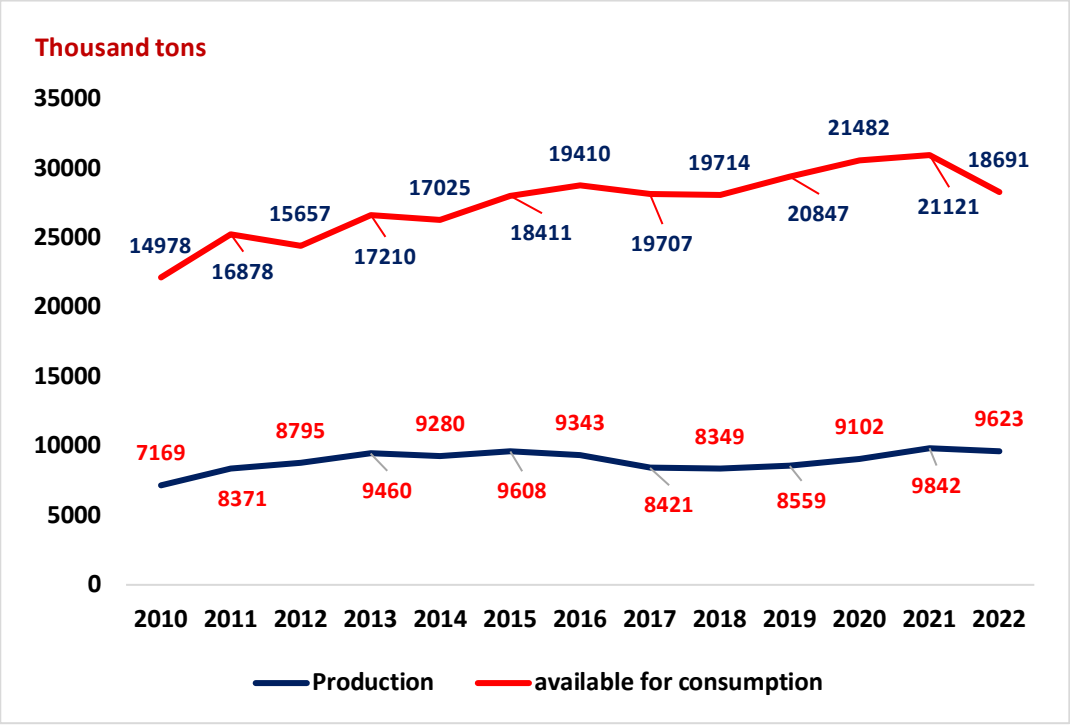

Figure (4): Development of Wheat Production and Consumption

Source: Compiled and calculated from:

- Food Balance Sheets - Economic Affairs Sector - Ministry of Agriculture and Land Reclamation - Various issues.
- Annual Bulletin of Crop Areas and Plant Production Statistics - Central Agency for Public Mobilization and Statistics - Various issues.

[51] The population of Egypt has increased by 20.75 million individuals over the past ten years, rising from 85.1 million individuals on January 1, 2014, to approximately 105.85 million individuals on January 1, 2024. Central Agency for Public Mobilization and Statistics, https://www.capmas.gov.eg/

[52] Ibid – ref no (25).

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7.1.3 Development of the Percentage of Self-Sufficiency and Imports of Wheat

The acceleration in consumption growth rates compared to production has widened the gap between them, as shown in Figure (4). This situation has reflected Egypt's achievement of low levels of self-sufficiency, reaching a maximum of 56% in 2012. Subsequently, this percentage began to decline annually until it reached its lowest level of 41% in 2019. However, the percentage then started to increase again, reaching 51% in 2022 (Figure (5)). It is noteworthy that the increase in self-sufficiency during the last year was not due to an increase in wheat production, which witnessed a decrease during that year. Instead, it resulted from a decrease in wheat imports by about 2 million tons compared to the previous year, amidst the rise in global wheat prices and the foreign currency crisis that worsened during that year, preventing importers from paying for the wheat stuck in Egyptian ports.[53]

Egypt’s self-sufficiency in wheat declined from a peak of 56% in 2012 to a low of 41% in 2019, however, it increased again to 51% in 2022 (Figure (5)). Notably, this increase was not due to higher wheat production but rather a decrease in wheat imports by about 2 million tons. Wheat imports increased annually from 2010 to 2022 at a growth rate of 3.76%. During 2021-2022, imports decreased due to rising global wheat prices. In 2023, imports resumed their upward trend, reaching 10.9 million tons (Figure (5)), with the General Authority for Supply Commodities accounting for over half of them.

It is worth mentioning that despite the Russian-Ukrainian war, imports of Russian wheat increased to constitute about 69% of Egypt's total wheat imports in 2023, despite the increase in the number of wheat import sources to about 22 origins. Additionally, imports from Ukraine increased to nearly 12% of the total wheat imports, with the remaining quantities distributed among several other sources, including France, Romania, Bulgaria, and Australia.[54] Furthermore, in November 2022, wheat trading began on the Egyptian Commodity Exchange, where the General Authority for Supply Commodities purchased more wheat to sell to the private sector through the exchange. This was an attempt to address distortions

[53] أسماء أحمد إبراهيم كريم. 2023. دراسة تحليلية لأثر المتغيرات المحلية والدولية على تحقيق الأمن الغذائي من محصول القمح في مصر. المجلة المصرية للاقتصاد الزراعيز مجلد 33 (2).

[54] https://2u.pw/naCYqmzt

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caused by price increases in the private sector, which subsequently led to a significant rise in the prices of non-subsidized bread.

The exacerbation of the risk posed by the increase in Egypt's wheat imports is further heightened by the significant rise in the import bill, amidst the challenging foreign currency management crisis that Egypt faces due to current global and regional geopolitical shifts. Despite the annual fluctuations, the value of wheat imports reached its highest value in 2022, amounting to $3.8 billion, an increase of 54.3% compared to the previous year. Conversely, the lowest value, amounting to $721 million, was recorded in 2013.

The main reason for the significant increase in the value of wheat imports starting from 2020 can be attributed to the substantial rise in global wheat prices due to the negative repercussions of the COVID-19 crisis and the Russian-Ukrainian war on wheat supply value. Prices surged from around $201.69 per ton in 2019 to a peak of $429.97 per ton in 2022, more than doubling in value.[55] The annual rate of change in global wheat prices during 2021 and 2022 exceeded 36%. To mitigate the worsening effects of these repercussions on the provision of wheat consumption needs, Egypt has focused over the past three years on expanding the construction of modern silos until the number in 2023 reached about 75 silos and increased their capacity to more than 4.5 million tons. Additionally, efforts have been made to develop storage facilities to increase the strategic wheat reserve sufficiently to cover local consumption for 4.7 months, according to a statement from the Cabinet[56] .

[55] ITC Calculations based on UN COMTRADE Statics.
[56] Ministry of Supply and Internal Trade Database - Unpublished Data

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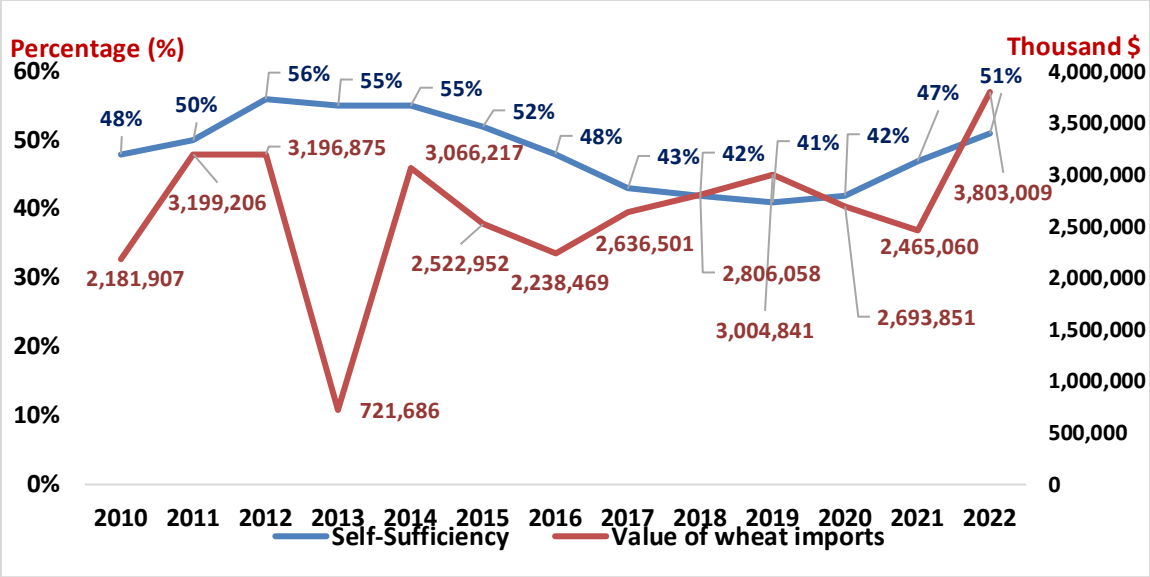

Figure (5): Evolution of the percentage of self-sufficiency and imports of wheat

Source: Compiled and calculated from:

- Food Balance Sheets - Economic Affairs Sector - Ministry of Agriculture and Land Reclamation - Various issues.
- Annual Bulletin of Crop Areas and Plant Production Statistics - Central Agency for Public Mobilization and Statistics - Various issues.
- Bloomberg; US Department of Agriculture; World Bank.
- ITC calculations based on UN COMTRADE statistics.

Figure (6) below shows the wheat supply chain during the year 2023.

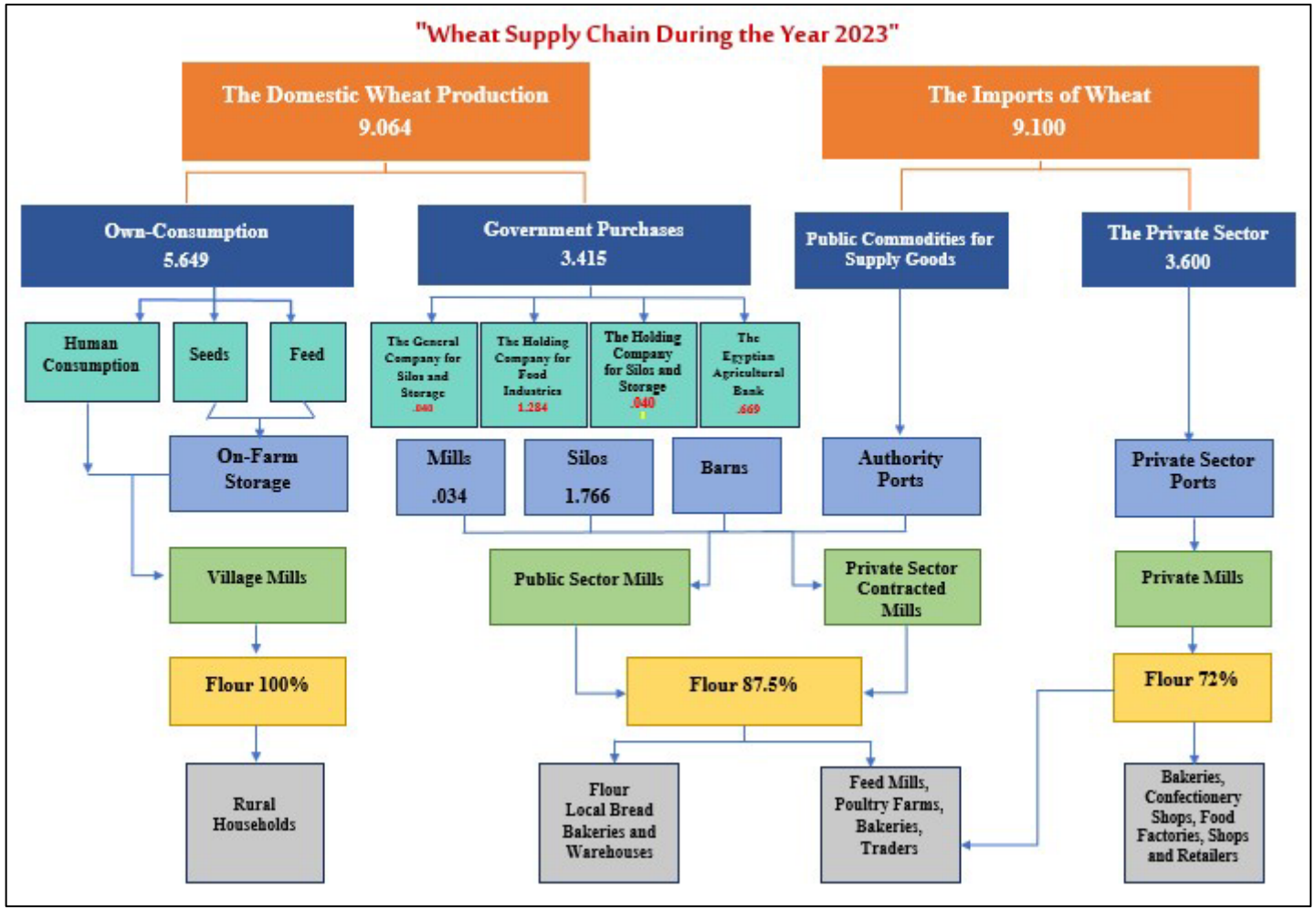

Figure (6): Wheat supply chain during the year 2023

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7.2 Application of systems thinking approach to analyze the wheat gap in Egypt

A systems thinking approach is applied to analyze the wheat gap in Egypt. This is done to reach the policies needed to minimize this gap and increase the system's resilience. The conceptual model shows the dynamics underlying interactions among system components, using Causal Loop Diagrams (CLDs). Through the CLDs, an explicit understanding of the problem can be generated, identifying the relationships between the components of the structure, namely the wheat supply and the wheat demand. The components of the wheat gap are shown in Fig. (7). The wheat gap is equal to the difference between wheat demand and wheat supply[57, 58], where the wheat supply consists of domestic wheat and imported wheat. A CLD for each of these sub-systems is shown in this part.

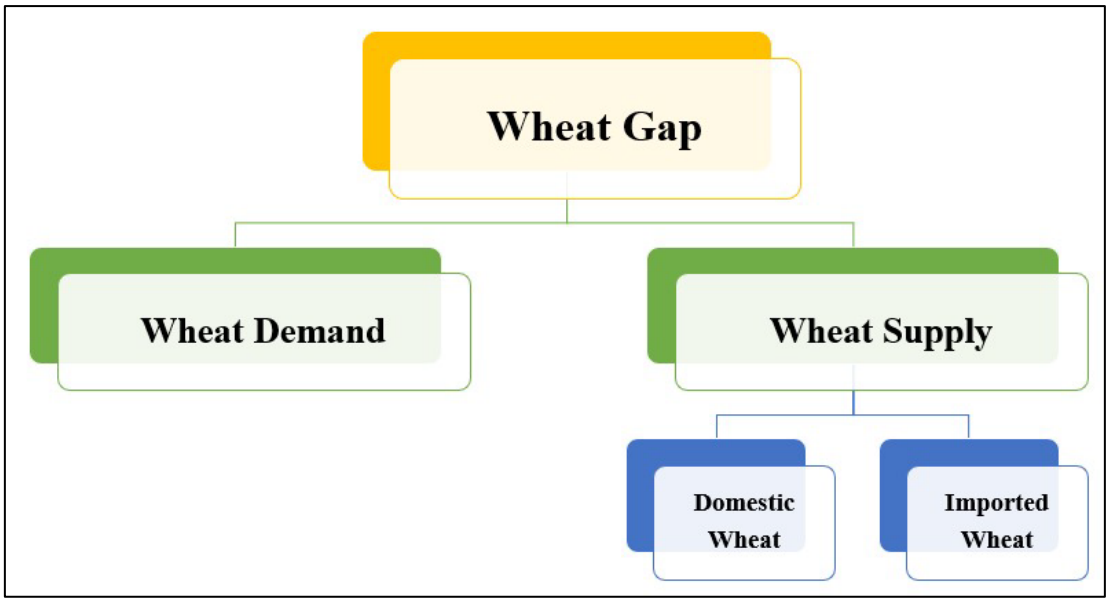

Figure (7): Wheat Gap Components

7.2.1. Wheat Gap – Demand Loops

The interactions within the components of the wheat demand sub-system in Egypt are shown in Fig. (8).

[57] حسين حسن على آدم. 2016. دراسة اقتصادية لإنتاج محصول القمح في مصر "دراسة حالة محافظة أسوان". المجلة المصرية للاقتصاد الزراعي. مجلد 26 (3)

[58] سهام عبد المولى محمد قنديل وفاطمة حسين محمد. 2019. دراسة اقتصادية للفجوة الغذائية من محصول القمح في مصر. المجلة المصرية للاقتصاد الزراعي. مجلد 29 (2).

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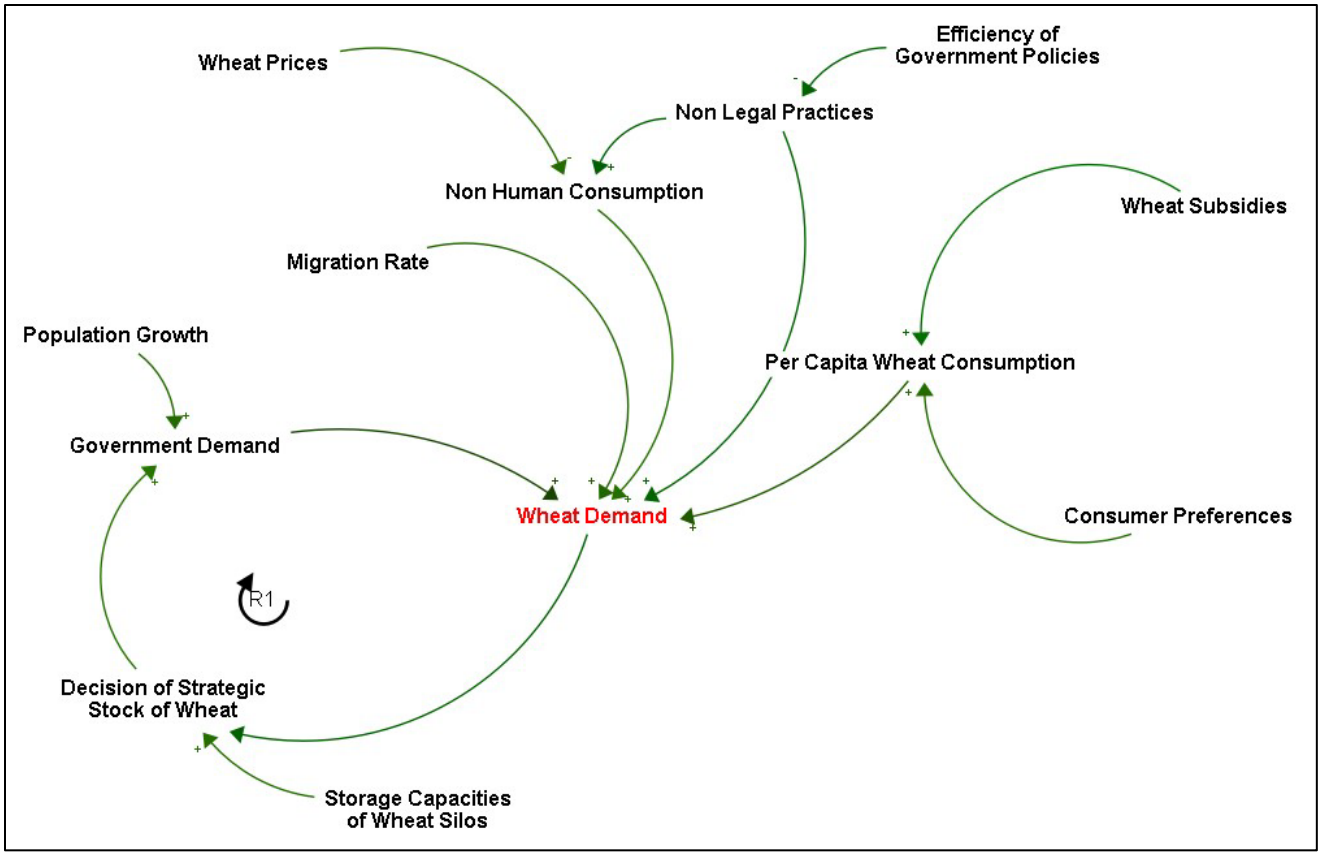

Figure (8): Demand Causal Loop Diagram

The developed causal loop diagram shows that the wheat demand is influenced by many factors. ***The first factor*** is population growth, which is indicated as a reinforcing loop (positive loop), named R1. As the population grows at higher rates, the Egyptian government must demand more wheat to fulfill the needs of this growing population. This is translated into the government decision for strategic stock of wheat, which in turn is based upon the storage capacities of the wheat silos in Egypt.

The second factor that influences the wheat demand is the migration rate. As more people migrate to Egypt, the demand for wheat increases. According to the International Organization for Migration (IOM), the current number of international migrants residing in Egypt has reached a total of 9 million migrants and refugees in 2023. There has been a notable increase in the number of migrants stock since 2019 in Egypt, due to protracted instability in the neighboring countries, that have driven

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thousands of Sudanese, Palestinian, Syrians, Ethiopian, Iraqi, and Yemeni individuals to find refuge in Egypt.[59]

The third factor that affects the wheat demand is non-human consumption. This factor is influenced by the free market prices of wheat, as the market price of wheat increases, non-human consumption decreases, and hence the wheat demand decreases. However, there is another factor that affects non-human consumption, which is the non-legal practice of buying wheat and bread for non-human consumption at the government-subsidized price instead of buying it at the free market price. This is done through selling the subsidized wheat in the black market at higher prices by the bakery owners. This takes place in periods when the domestic prices of animals' feed are above the government-subsidized price of domestic wheat. It is noted that subsidized Baladi bread costs the state budget about 91 billion Egyptian pounds in 2023/2024, compared to 51 billion Egyptian pounds in 2022/2023, due to the increases in prices of domestic and imported wheat[60]. That is why the efficiency of government policies plays a pivotal role in minimizing these non-legal practices, and hence decreasing the demand for wheat.

The fourth factor that influences the wheat demand is the per capita wheat consumption, which in turn is affected by wheat subsidies and consumer preferences. As wheat subsidies increase, this encourages consumers to demand more wheat, as this means lower prices for wheat-subsidized products. Besides, consumer preferences play a pivotal role in determining the per capita consumption of wheat, since the Egyptians regard wheat products as a necessary food in their food bundles, especially the Baladi bread.

7.2.2. Wheat Gap – Supply Loops

Two sub-systems comprise the wheat supply in Egypt, namely the domestic wheat and the imported wheat.

- **Supply Loops – Domestic Wheat**

The interactions within the components of the domestic wheat supply sub-system in Egypt are shown in Fig. (9). The developed causal loop diagram shows that the domestic wheat supply is influenced by many factors.

[59] https://egypt.iom.int/news/iom-egypt.
[60] Latterly, the government has increased the price of Baladi bread from 5 piasters to 20 piasters.

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The first factor is the efficiency of the wheat production system, which is indicated as a reinforcing loop (positive loop), named R2. As the efficiency of the wheat production system is improved, the cultivated area of wheat will increase, and hence the quantity of domestic wheat will increase. It is noticed that the efficiency of the wheat production system is affected in this loop by data availability. As timely data for the domestic suppliers of wheat becomes more available and reliable, this helps the decision makers to be able to make more informed decisions. Besides, data availability is affected negatively by agricultural fragmentation, as it makes data collection less accurate, more costly, and takes more time. This agricultural fragmentation has also negative impacts on irrigation water consumption and productivity, due to utilizing outdated agricultural technology and poor marketing strategies. However, this situation can be improved by issuing government legislation and policies that work to group micro and small farms into larger agricultural entities, in addition to improving the efficiency of cooperatives. improving the efficiency of cooperatives, which have a significant role in improving the potential of small farmers, through investing in their human and physical capital, providing production inputs, constructing large advanced agricultural clusters, and marketing agricultural products. In this regard, it is worth noting that the agricultural cooperative in Egypt suffers from many obstacles that prevent them from efficiently fulfilling their assigned roles.

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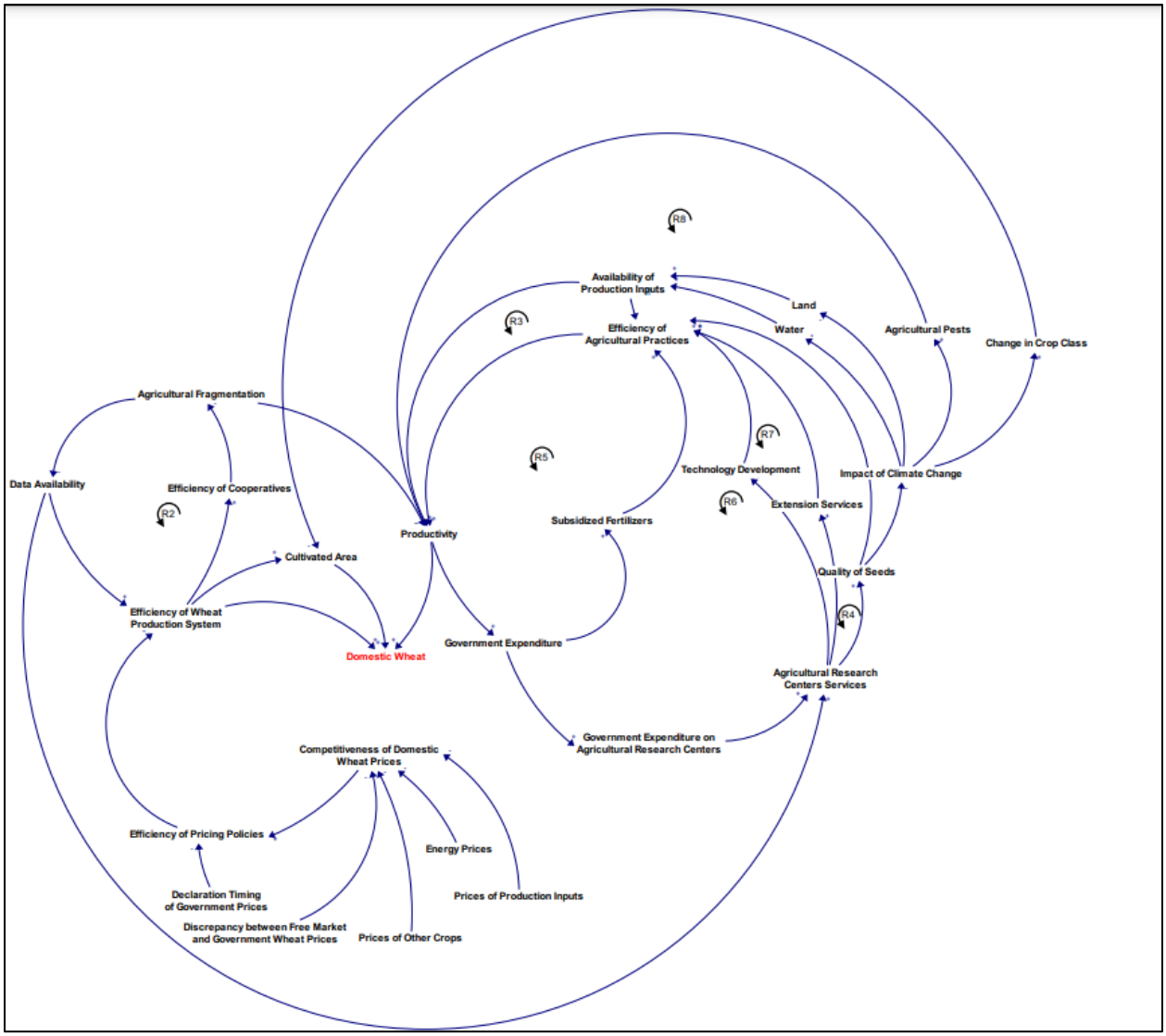

Figure (9): Supply Loops – Domestic Wheat Causal Loop Diagram

The second factor that affects the domestic wheat supply is the government expenditure on agricultural research centers and subsidized fertilizers, which are indicated as reinforcing loops, named R3, R4, R5, R6, R7, and R8. As the government expenditure on subsidized fertilizers this enables more productivity, and as expenditure on agricultural research centers increases, this enables these research centers to provide highly qualified services, which have many positive impacts on the productivity of wheat-cultivated areas, which in turn increases the supply of domestic wheat.

The Central Administration for Seed Production is the responsible body for producing seeds for field crops. The feedback loop R3 showed that the quality of seeds has a crucial role in mitigating the negative impacts of climate change on both wheat productivity and wheat cultivated areas. Egypt is regarded as one of the most vulnerable countries in the world to the impacts of climate change. Besides, a recent study[61] proved that wheat productivity will decrease by 9% and the water consumption of wheat will increase by 6.2% if the temperature rises by two degrees Celsius.

On one side, the negative impacts of climate change on wheat productivity can be seen through its negative impacts on the quantity of water and quality of agricultural land, which negatively affect the availability of natural agricultural resources, and hence decrease wheat productivity.

On the other side, the negative impacts of climate change on wheat productivity can be seen through its impact on spreading agricultural pests, hence decreasing the wheat productivity as shown in R8. Additionally, the negative impacts of climate change on wheat-cultivated areas can be seen through its impact on sudden and unfamiliar changes in the geographical distribution map of crops, which in turn affects wheat-cultivated areas negatively. In this regard, it is relevant to activate the role of the Central Laboratory for Agricultural Climate in Egypt. The feedback loop R4 showed that as the quantity and quality of seeds increase, the efficiency of agricultural practices will be improved, and hence the productivity of wheat-cultivated areas will also be improved.

In addition, the agricultural research centers in Egypt are responsible for developing improved seeds. After that, the responsibility of the Services Sector in the Ministry of Agriculture is to distribute these accredited seeds to wheat farmers. The feedback loop R5 showed that as the quantity and quality of these subsidized fertilizers increase, the efficiency of agricultural practices will be improved, and hence the productivity of wheat-cultivated areas will also be improved. In this regard, it is noted that the quantity that is distributed to wheat farmers as accredited fertilizers is

[61] Mostafa, S.M., Wahed, O., El-Nashar, W.Y., El-Marsafawy, S.M. and Abd-Elhamid, H.F., 2021. Impact of climate change on water resources and crop yield in the Middle Egypt region. *AQUA—Water Infrastructure, Ecosystems and Society*, *70*(7), pp.1066-1084.

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not sufficient, which forces the farmers to buy the needed qualified fertilizers at higher free market prices.

Another role of the agricultural research centers in Egypt is represented by the positive feedback loop R6, which shows that developing advanced agricultural technology and applying it will lead to improving the efficiency of agricultural practices, and consequently improving wheat productivity. It is noted in this regard that wheat agriculture in Egypt did not utilize and apply advanced agricultural technologies such as smart irrigation, laser levelling, robotics, Artificial Intelligence (AI), and solar energy. This led to a slow growth rate in wheat productivity in Egypt during the last 10 years. Many developing countries uses technology for improve farmer productivity, for example, Pakistan used zero tillage method for wheat cultivation, and found that it is the most economical and attractive option for farming community[62]. In Ethiopia, research done to study the impact of agricultural technology adoption on wheat productivity in north Shewa zone of the Amhara region, Ethiopia. It reveals that agricultural technology adoptions are affected by the education level of the household head, off-farm employment, tropical livestock, access to credit, household saving, extension visit, and distance from the market. It also shows that the adoption of fertilizer and/or improved seed increases wheat productivity significantly[63]. Research in Egypt[64] shows that the key advancements of improving wheat productivity are the raised bed method, ideal sowing dates, surge flow irrigation, laser leveling, fertilizers, and intercropping, it also showed that 97% of the yield increase was due to new varieties and techniques, while 1.5% was due to expanded planting areas. It is worth noting that it may be difficult to apply these technologies in the whole Egyptian agriculture lands due to the small size of farms and the limited financial resources of farmers. However, if small holdings can be

[62] Sarwar, M.N. and Goheer, M.A., 2007, March. Adoption and impact of zero tillage technology for wheat in rice-wheat system—water and cost saving technology. A case study from Pakistan (Punjab). In *International Forum on Water Environmental Governance in Asia* (pp. 14-15). Princeton, NJ: Citeseer.

[63] Belay, M., Hailu, A. and Bizualem, A., 2022. Impact of agricultural technology adoption on wheat productivity: evidence from north shewa zone, Amhara region, Ethiopia. *Cogent Economics & Finance*, *10*(1), p.2101223.

[64] Abdelmageed, K., Chang, X.H., Wang, D.M., Wang, Y.J., Yang, Y.S., Zhao, G.C. and Tao, Z.Q., 2019. Evolution of varieties and development of production technology in Egypt wheat: A review. *Journal of integrative agriculture*, *18*(3), pp.483-495.

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combined to grow wheat in larger areas and the state helps farmers in providing some of these technologies and guiding them on how to use them and their returns, this may lead to improving wheat productivity.

Another crucial role of The Agricultural Guidance Department of the General Administration of the Ministry of Agriculture and Land Reclamation is represented by the positive feedback loop R7, which shows that providing qualified agricultural extension services to wheat farmers will lead to improving the efficiency of agricultural practices, and consequently improving wheat productivity. However, it is worth noting that the department is currently not performing as intended, due to the low number of agricultural extension workers, as they are estimated to be only 2500 workers, and the ages of most of them exceed 50 years[65].

The third factor that affects the supply of domestic wheat is the efficiency of pricing policies. As the pricing policies of domestic wheat become more efficient, the available quantity of domestic wheat will increase. It is noted that the efficiency of pricing policies of domestic wheat is based upon two factors, namely the competitiveness of the domestic wheat prices and the declaration timing of government prices.

The competitiveness of domestic wheat prices is affected by prices of the production inputs of wheat, energy prices, prices of other crops, and the relationship between the free market and government wheat supply prices. As the production input prices and the energy prices increase, the price of domestic wheat becomes more costly. It is noted in this regard that the government procurement price of domestic wheat in Egypt in 2022/2023 is 1500 Egyptian pounds per wheat ardeb, which is always lower than the international prices of wheat, which is estimated at 1800 Egyptian pounds per wheat ardeb (after adding shipping cost)[66], This can be seen by the domestic farmers as the Egyptian government supports imported wheat, despite its low quality, at the expense of domestic wheat. Egyptian wheat is considered the best type of wheat due to its hardness, in addition to the fact that it contains a high percentage

[65] هدى النمر وآخرون. دور التقنيات الزراعية الحديثة وتطبيقاتها في تعزيز استدامة الزراعة والغذاء في مصر: التحديات والفرص. سلسلة قضايا التخطيط والتنمية. معهد التخطيط القومي. (تحت النشر).

[66] Wally, A. (2023). ***Grain and Feed Update: Egypt*** (Report No. EG2023-0025). USDA & GAIN. https://apps.fas.usda.gov/api/Report/

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of protein and a low percentage of moisture, which is what distinguishes it and makes it the best type of wheat.

Besides, as the prices of other competitive crops increase the farmers will prefer to plant these crops instead of wheat, which means that the supply price of domestic wheat becomes less competitive, compared to the supply prices of other crops. Another factor that affects the competitiveness of domestic wheat supply prices is the discrepancy between free-market and government wheat supply prices. As the free market prices of wheat are far beyond the government wheat supply prices, this encourages the wheat farmers to sell their wheat crops in the free market. The farmer is required to supply a portion of 12 ardebs per acre to the General Authority for Supply Commodities, and it is prohibited to sell local wheat to the private sector without obtaining approval from the responsible authorities. However, this law is not fully applied, as the wheat farmers do not adhere to delivering the supply quotas targeted to be achieved by the government, and they prefer to pay the prescribed fines instead.

On the other hand, the efficiency of pricing policies of domestic wheat is based also on the declaration timing of government prices. As the government declares the supply price of domestic wheat earlier than the time of start planting wheat, and given that it is a competitive price, this will give the farmers enough time to decide to plant wheat instead of other competitive crops. In this regard, the Egyptian government started in 2021 to declare the price of domestic wheat early in November, which is earlier than the wheat planting season. However, this declaration timing is still too late to some extent to decide on planting wheat in some governorates in Egypt.

- **Supply Loops – Imported Wheat**

The interactions within the components of the imported wheat supply sub-system in Egypt are shown in Fig. (10). The developed causal loop diagram shows that the imported wheat supply is influenced by many factors.

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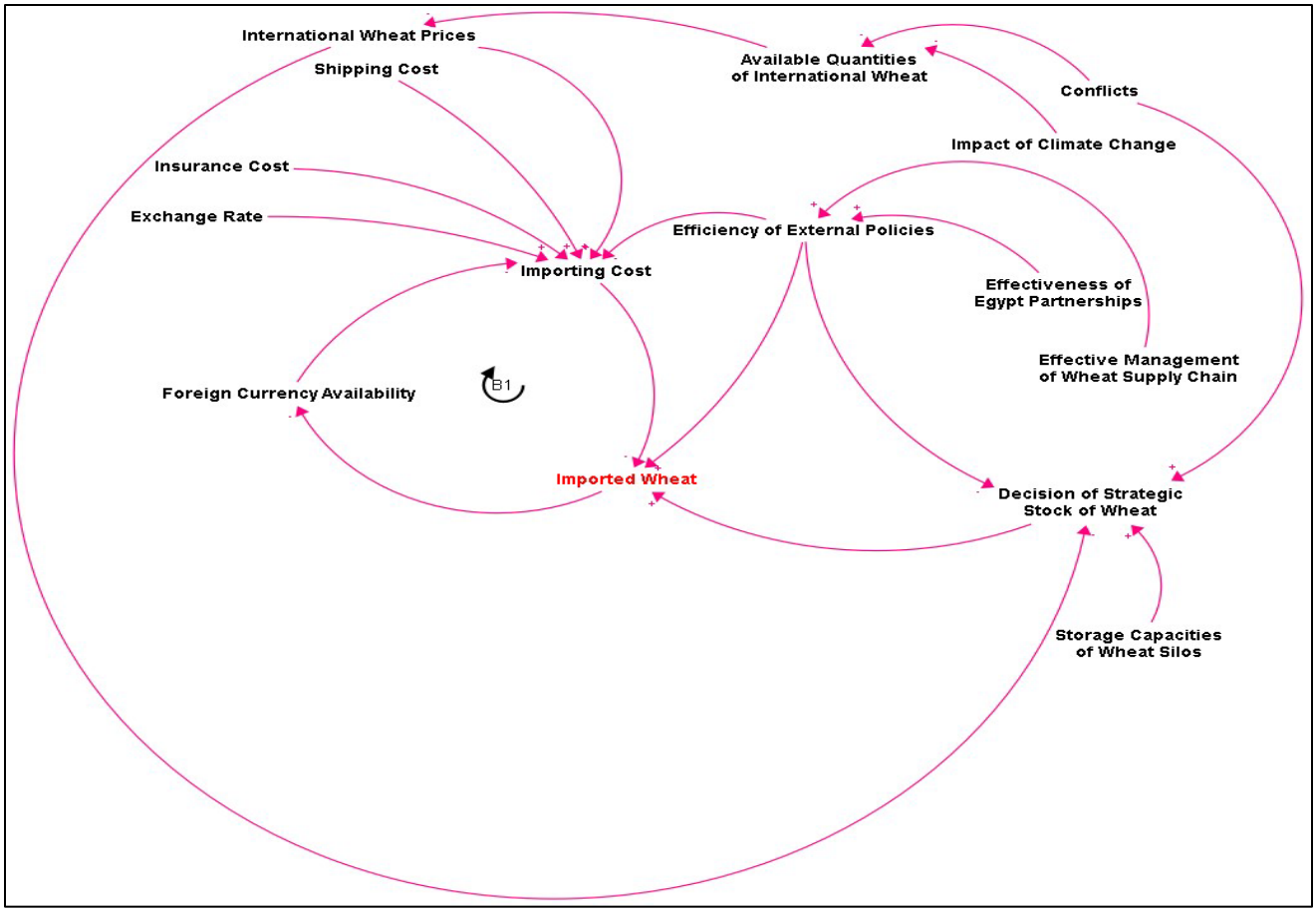

Figure (10): Supply Loops – Imported Wheat Causal Loop Diagram

The first factor that affects the imported wheat supply is the importing cost of wheat, as indicated by a balancing loop (negative loop), named B1. As the importing cost of wheat increases, the amount of imported wheat decreases, which in turn decreases the demand for foreign currency, and increases its availability. However, the availability of foreign currency is regarded as one of the factors that reduces the importing cost of wheat, as it helps in eliminating the black market of foreign currency.

Other factors that affect the importing cost of wheat include international wheat prices. In this regard, international wheat prices are affected by the available quantities of international wheat, which in turn are affected negatively by two forces, namely the conflicts and the impact of climate change. Regarding the impact of conflicts on decreasing the available quantities of international wheat, Egypt witnessed a decrease in the available quantities of international wheat due to the

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Russian-Ukrainian war, since Egypt regarded these two countries as its major importers of wheat, due to the competitiveness of their wheat prices and the low shipment cost because of geographic proximity. On the other hand, regarding the impact of climate change on decreasing the available quantities of international wheat, this can be seen through analyzing the negative impacts of climate change on both wheat productivity and wheat cultivated area, as discussed earlier in the supply of domestic wheat.

Additionally, other factors affect the importing cost of wheat, namely the shipping and insurance costs, and the exchange rate. Regarding the shipping and insurance costs, the repercussions of the Russian-Ukrainian war caused huge disruptions in the international wheat supply value, which in turn resulted in large jumps in the shipping and insurance costs. Regarding the exchange rate, as there is a depreciation of the Egyptian pound, the importing cost will increase.

Finally, it is found that the efficiency of import strategy affects positively the amount of imported wheat, both directly and indirectly (through its impact on the importing cost of wheat). The direct impact of the efficiency of external policies on increasing the amount of imported wheat can be interpreted as follows. As Egypt improves the efficiency of its external policies, this will enable it to have access to more wheat from the international market. The indirect impact of the efficiency of external policies takes place through its impact on decreasing the importing cost, due to better terms of agreement and more competitive international prices, which eventually enable Egypt to have access to more wheat from the international market.

In this regard, it is noted that the efficiency of external policies is based upon two factors, namely the effectiveness of Egypt partnerships and the effective management of the wheat supply value. As the effectiveness of Egypt's partnerships with the rest of the world is improved, this enables the Egyptian government to have better terms of agreement. On the other hand, as the management of the wheat supply value becomes more effective, this facilitates finding alternative suppliers of wheat in the international market at competitive prices. On the other side, the efficiency of external policies has an impact on the decision of strategic stock of wheat, as when the external policies are more efficient, the government can decide to decrease the amount of strategic stock of wheat. Hence, the government will need to make lower investments in expanding the storage capacities of wheat silos. This means more cost

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savings for the government as a reward for the efficiency of its external policies with the rest of the world.

Finally, it is important to note that the decision of strategic stock of wheat is regarded as one of the factors that impact the amount of imported wheat. The decision to strategic stock of wheat is based upon three factors, namely the storage capacities of wheat silos, conflicts, and international wheat prices. Regarding the first factor, as the storage capacities of wheat silos increase, this enables the government from deciding to demand larger strategic stock of wheat. In this regard, the Egyptian government has increased the storage capacities of wheat silos as mentioned before. Regarding the second factor, namely the conflicts, as there are more conflicts in the world, this means less stability and a higher potential for supply value disruptions, which in turn encourages the government to be on the safe side and increase the amount of strategic stock of wheat. The third factor is the international wheat prices, since higher international wheat prices convince the government to demand a lower strategic stock of wheat, due to the high importing cost.

From the above analysis, many factors affect the resilience wheat system, but some can be improved through governmental intervention, and others through awareness.

8. Policy Options

As discussed above we find that the seriousness of shocks facing imports at the forefront, due to the difficulty of controlling them as well as the difficulty of predicting them, followed by shocks related to consumption because they require political will and decisions that may result in serious social impacts and public anger, and then come in third place the seriousness of shocks in the production stage, since the ways to confront them, predicting them, and preparing for them is easier than the other two shocks. The research proposes some policy options to overcome this problem.

The research proposes the following policy options:

I. Policies to Develop Domestic Production Capabilities (Local Supply)

- Horizontal and Vertical Expansion**:**
  - **Horizontal expansion**: Cultivate wheat in **new reclamation lands.**
  - **Vertical expansion**: Improve productivity per acre by:
    - Applying **good agricultural practices.**

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- Developing **new wheat varieties.**
- Producing and distributing **high-quality seeds.**
- Strengthening the role of **agricultural research centers.**

– **Support for Wheat Production**:
  - Provide more **support for wheat production requirements.**
  - Grant **incentives and financing facilities** to wheat farmers.
  - Offer **technical support.**
– **Wheat Pricing and Supply System Improvement**:
  - Announce the **supply price of wheat** well before planting to aid authorities and farmers.
  - Focus on providing **logistical facilities and positive non-price incentives** for crop cultivation.
  - Commit to supplying specified quantities (instead of imposing ineffective fines and penalties).
  - Determine a **remunerative price for farmers**, considering production costs and international prices.
– **Policy Development and Legal Framework**:
  - Develop and review **public policies** to stimulate wheat cultivation.
  - Address credit, lending, and investment policies related to new lands.
  - Facilitate land allocation to farmers and investors.
  - **Address the fragmentation of old lands into larger entities, enabling modern technologies and increasing production and local marketing.**
  - Enhance the **agricultural extension system.**
– **Scientific Research and Legal Updates**:
  - **Support the budget for scientific research equipment.**
  - **Review and update agricultural laws and legislation.**

II. Policies to Hedge against Shortages in International Wheat Supplies (Wheat Imports)

– **Diversification of Supply Chain**:
  - **Prioritize stable, lowest-priced, and highest-quality countries** such as Bulgaria, Romania, and France.
  - Aim to reduce reliance on specific sources.
– **Equal Deals System**:
  - **Consider re-dealing** with the equal deals system.
  - Explore ways to enhance trade agreements.
– **Futures Contracts and International Tenders**:
  - **Expand futures contracts** to manage risks.

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- **Issue international tenders** at appropriate times for efficient procurement.

– **Alternative Payment Systems**:
- Explore **non-SWIFT payment systems** settled in currencies other than the dollar.
- Enhance financial flexibility for wheat imports.

– **Infrastructure Improvement**:
- **Increase and develop storage capacities of silos.**
- Strengthen storage infrastructure to manage wheat supplies.

III. Wheat Rationalization Policies

– Wheat Substitutes and Loss Reduction**:**
- Explore **wheat substitutes** in bread production.
- **Minimize wheat and flour loss** during production, marketing, trading, and manufacturing.
- Reduce consumer loss of **subsidized bread.**

– **Cash Support and Price Adjustment**:
- Convert **in-kind bread support to cash** to reduce non-human consumption.
- Consider raising the **selling price of subsidized bread**, and the value of bread exchange points can be increased from the current value estimated at 10 piasters per loaf, which reduces the subsidy burden on the state's general budget and rationalizes the consumption of subsidized bread from which it benefits more than 72 million citizens.
- Increase the value of **bread exchange points** to alleviate the subsidy burden on the state budget.

– **Consumption Rationalization**:
- Promote awareness about the importance of **rationalizing consumption.**
- Encourage **alternative food group consumption.**

– **Oversight and Targeting Mechanism**:
- **Strengthen oversight** of subsidized bread distribution.
- Reconsider the **targeting mechanism** for eligible families.

Limitation and Future Work

This research uses a qualitative model (System Thinking) to have a holistic view of the wheat system resilience, which did not use numerical values for the system,

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another study is to be done using a quantitative model (System Dynamics), which allows to apply simulation using real values representing the system.

Conclusion

This research investigates the answers to a main question, which can be stated as "How can Egypt prepare to withstand unexpected shocks and have a resilient wheat system". The research shows the current situation of wheat production and consumption in Egypt, and analyzes the wheat system in a holistic view by using the systems thinking approach. The systems thinking approach is used in this paper, because it is a useful tool for creating policies. Using the Causal Loop Diagrams allows to comprehend the interaction between components that reflect this complex system and their overall impact on system outcomes, which in turn can aid in identifying the core causes of the problem and designing solutions that have a higher chance of success.

Therefore, using this methodology, three causal loop diagrams are constructed to analyze the wheat gap; which analyzes the demand side loops, and the supply side loops, consisting of both the domestic wheat, and imported wheat. This analysis results in proposing the main policies that the Egyptian government can intervene with to have a resilient wheat system. Three policy options are proposed for the policymakers to improve local supply, wheat imports, and rationalization policies.

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