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Towards Resilient and Sustainable Food Systems: Integrating Agricultural Production Efficiency and Food Security

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Abstract This study explores the nexus between agricultural production efficiency and food security, globally and within Turkey. It analyzes agricultural data, emphasizing strategies to enhance productivity while ensuring access to nutritious food. Key areas include reducing food loss, promoting sustainable practices, ensuring safety, enhancing consumer awareness, and preserving resources. The article also outlines the six dimensions of food security availability, access, utilization, stability, agency, and sustainability and their policy implications. By integrating insights from diverse studies and emphasizing context-specific approaches, it advocates for holistic strategies tailored to each agricultural landscape's unique challenges. Ultimately, the pursuit of agricultural efficiency and food security is positioned as both a moral imperative and an economic necessity. Through research, policy reforms, and stakeholder collaboration, nations can work towards resilient and sustainable food systems for present and future generations. In the study, it was determined that labor productivity was not taken into account sufficiently and the data was insufficient to measure labor and labor productivity in agricultural production. The study aims to contribute to strategic decision-making and local-global policies to increase agricultural and resource use efficiency.

Index Terms Agricultural economics, agricultural productivity, food security, sustainable agriculture

I. Introduction

Agricultural productivity and food security are paramount concerns in the context of global sustainability and human welfare. As the world's population continues to grow, surpassing nine billion by 2050 according to projections [1], ensuring efficient agricultural production while safeguarding access to nutritious food becomes increasingly challenging. Numerous studies underscore the multifaceted nature of these challenges and advocate for the implementation of comprehensive strategies to address them effectively.

One key area of focus in enhancing agricultural productivity is the reduction of food loss and waste throughout the supply chain. Research by FAO (Food and Agriculture Organization of the United Nations) emphasizes the need to minimize post-harvest losses, which can account for a significant portion of total food production [2]. Strategies such as improved storage facilities, transportation infrastructure, and market access have been proposed to mitigate these losses and optimize resource utilization.

In addition to addressing food loss, promoting sustainable agricultural practices is essential for long-term food security. The concept of sustainable intensification, as advocated by Tilman et al. [3], emphasizes the importance of increasing productivity while minimizing environmental impacts. This approach involves optimizing resource use, enhancing soil fertility, and adopting precision agriculture techniques to achieve higher yields with reduced inputs.

Quality control measures also play a crucial role in ensuring food safety and consumer confidence. Studies have highlighted the importance of stringent quality standards, monitoring systems, and certification schemes to uphold the integrity of food products and protect public health [2]. Strengthening regulatory frameworks and investing in food safety infrastructure are vital steps towards achieving this goal.

Moreover, enhancing consumer awareness and education is integral to promoting healthy eating habits and sustainable food consumption. The role of nutrition education, labeling initiatives, and public outreach campaigns in empowering consumers to make informed choices and demand nutritious, sustainably produced food.

Finally, the sustainable use of agricultural land is paramount for maintaining long-term productivity and ecosystem health. Balancing agricultural expansion with conservation efforts, agroforestry practices, and land-use planning is essential for preserving biodiversity, mitigating climate change, and safeguarding natural resources [3].

In summary, the literature underscores the complexity of agricultural productivity and food security challenges and ad-

vocates for a holistic approach encompassing multiple strategies, including reducing food loss, promoting sustainable agriculture, ensuring food safety, enhancing consumer awareness, and preserving natural resources. By addressing these interconnected issues comprehensively, Turkey and other nations can strive towards achieving resilient and sustainable food systems to meet the needs of present and future generations.

Several studies have addressed the issue of increasing productivity in Turkey's agricultural sector. [4] conducted a case study on water resources management and water productivity in Turkey, shedding light on the importance of efficient water use. [5] the impact of agricultural land fragmentation on agricultural income, highlighting its effects on the sector. Tekgüç [6] explored the adoption of technology in agriculture and its influence on agricultural productivity in Turkey, providing evidence on its significance. Additionally, Uzun and Cilasun [7] examined agricultural policy developments in Turkey, emphasizing the transition towards new support mechanisms and their implications for the sector. These studies collectively contribute to understanding the challenges and potential strategies for enhancing productivity in Turkey's agricultural sector.

II. Results and Discussion

A. Agricultural Economics and Productivity

Agricultural productivity is the ratio of the quantity of food produced to the resources utilized. Higher agricultural productivity implies producing more food with fewer resources. This becomes increasingly significant with the growing global population and increasing food demand. Various strategies are employed to enhance agricultural productivity, including the adoption of more efficient farming methods, improved soil management, better irrigation techniques, the use of superior seeds, and the implementation of advanced animal husbandry practices. The subject of agricultural productivity in agricultural economics has been the focus of numerous academic studies over the years. These studies have examined the effects of different strategies employed to increase agricultural productivity.

For instance, in a study conducted by Jia et al. [8], the effects of various strategies employed to enhance agricultural productivity in China were examined. This study demonstrated that the utilization of superior seeds, improved irrigation methods, and better soil management practices were effective in increasing agricultural productivity.

Similarly, research has shown that raising awareness among farmers about the use of agricultural technologies can also enhance agricultural productivity [9]. Moreover, the subject of agricultural productivity in agricultural economics is also examined using economic models and mathematical analyses. For example, in a study by Kumbhakar and Tsionas [10], the impact of different agricultural methods on productivity was investigated using a mathematical model.

B. Food Security

Food security and productivity are recognized as significant global concerns. As the world's population grows, it becomes increasingly necessary to enhance food production and ensure sustainability. Therefore, research efforts addressing food security and productivity are of paramount importance, aiming to increase food production, reduce food losses, and meet the food needs of future generations.

Various international organizations are engaged in studies concerning food security, productivity, and sustainability worldwide. Notable among these are the World Food Program (WFP), the Food and Agriculture Organization of the United Nations (FAO), the International Food Science and Technology Institute (IFT), and the Food and Agriculture Cooperation.

According to FAO, the definition of food security has evolved over time and exhibited variations among different organizations. For instance, while FAO defined food security as continuous physical and economic access to basic food, the World Bank distinguished between chronic and transitory food insecurity. The 1996 World Food Summit defined food security in terms of food access, availability, utilization, and stability, emphasizing the multidimensional nature of food security [11].

Food security and productivity are widely acknowledged as significant global concerns. As the world's population increases, there is a pressing need to enhance food production and ensure sustainability. Research efforts addressing food security and productivity are of great importance, aiming to increase food production, reduce food losses, and meet the food needs of future generations.

As per the Food and Agriculture Organization of the United Nations (FAO) declaration in 1996, food security refers to a situation where all people have physical and economic access to safe, nutritious, and sufficient food at all times. This definition underscores the multidimensional aspects of food security, encompassing elements such as availability, stability, and accessibility. Availability denotes the provision of adequate food to meet consumer demand, stability refers to ensuring food supply during periods of severe food shortage, and accessibility ensures that everyone has the opportunity to access basic food [12].

Food productivity, on the other hand, pertains to the efficient utilization of resources in food production and the efficient execution of production processes. Effective land use, proper water management, judicious use of fertilizers and agrochemicals, adoption of modern agricultural techniques, and appropriate selection of soil tillage methods are essential for food productivity.

Food sustainability involves ensuring that food production meets the needs of future generations. Consequently, preserving natural resources, maintaining agricultural lands, preventing soil erosion, sustainably managing water resources, and employing environmentally friendly agricultural practices are crucial for food sustainability.

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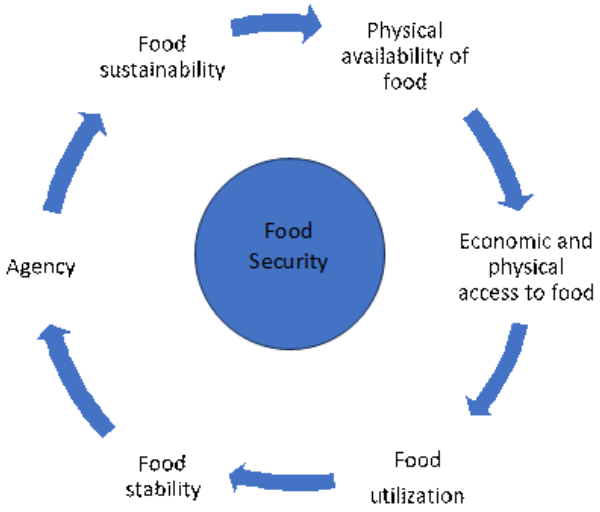

Figure 1: Six Dimensions of Food Security [26]

C. Six Dimensions of Food Security

Ensuring access to safe and nutritious food is a crucial factor in reducing poverty. Policymakers and researchers should consider the various dimensions of food security when designing interventions to improve food security and reduce poverty.

The definition of food security has evolved over time since it was first used in policy contexts in the early 1970s. Over the years, food security has acquired a broad understanding based on four fundamental pillars: availability, access, utilization, and stability. Since the food crisis of 2007-08, the framework delineated by these four pillars has been adopted by the United Nations Committee on World Food Security (CFS) and the FAO. For instance, in the CFS's [13] reform document, alongside the definition of food security, these four pillars hold significant importance.

In recent years, there has been increased awareness about significant challenges affecting hunger and malnutrition, such as growing inequalities in food systems, imbalances in power dynamics, and global climate and ecological crises. These developments have raised important questions about whether the four-pillar approach to conceptualizing food security adequately encompasses all dimensions crucial for food security.

In this regard, discussions in the literature have increased regarding the necessity of six dimensions of food security. Thus, The High-Level Panel of Experts on Food Security and Nutrition [14], a body of the CFS responsible for evaluating scientific developments related to global food security and nutrition, has suggested that food security can be evaluated in terms of six dimensions: physical availability of food, economic and physical access to food, food utilization, food stability, agency, and food sustainability.

Figure 1 aims to illustrate the six dimensions of food security. Policymakers incorporating each dimension into their decisions regarding food security and adopting a holistic approach may assist in more effective, efficient, and impactful actions.

Physical Availability of Food: This dimension focuses on the availability and supply of food, including production levels, stock quantities, and distribution processes. It involves ensuring that enough food is produced and distributed to meet the needs of individuals and communities [1], [15]–[17].

Economic and Physical Access to Food: This dimension pertains to individuals' ability to access food, both economically and physically. It involves factors such as income levels, market accessibility, and trade policies that influence the affordability and availability of food for different populations [15], [17], [18].

Food Utilization: This dimension concerns the quality and nutritional value of the food accessible to individuals. It emphasizes the importance of consuming food that is nutritious, safe, and suitable for meeting dietary needs, as well as ensuring that individuals have the knowledge and resources to utilize food effectively [15], [18].

Food Stability: This dimension addresses the resilience of food systems to shocks and disruptions over time. It involves considerations of both chronic and temporary food insecurity, such as environmental disasters, conflicts, and economic instability, and the ability of food systems to maintain consistent access to food [15], [19].

Agency: This dimension focuses on the capacity of individuals and communities to participate in decision-making processes within food systems. It encompasses factors such as empowerment, governance structures, and the ability to shape food production, distribution, and consumption patterns [20], [21].

Food Sustainability: This dimension encompasses the long-term viability of food systems, considering ecological, social, and economic factors. It involves promoting practices that contribute to the renewal of natural resources, support social equity, and ensure food security for future generations while minimizing negative environmental impacts [14], [22]–[25]. Integrating these dimensions into food security policies and interventions is essential for addressing the complex and multifaceted challenges associated with ensuring access to safe, nutritious, and sustainable food for all individuals and communities.

D. Agricultural Productivity in the World

The topic of agricultural economics productivity has been the subject of numerous academic studies for many years. In these studies, the effects of various strategies employed to enhance agricultural productivity have been examined. For instance, in a study conducted by Jia et al. [8], the effects of various strategies used to increase agricultural productivity in China were investigated. The study demonstrated that improved seed usage, better irrigation methods, and enhanced soil management practices are effective in increasing agricultural productivity. Similarly, research has shown that raising awareness among farmers about the use of agricultural technologies can also increase agricultural productivity [9].

Figure 2 may contribute for the importance of considering various factors holistically in understanding wheat produc-

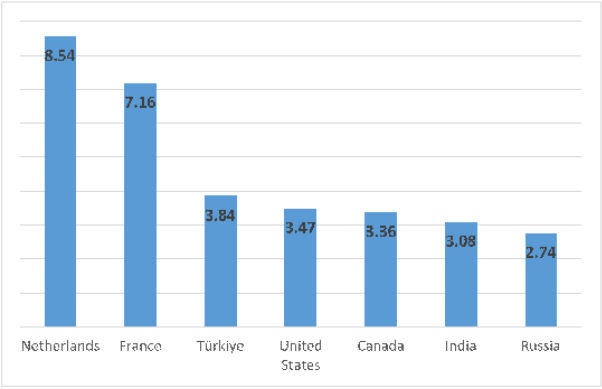

Figure 2: Average wheat productivity (ton/ha) – 2022 [27]

tivity, as an example of agricultural productivity. The figure illustrates the average wheat productivity (ton/ha) for various countries in the year 2022. The data shows that the Netherlands recorded the highest average wheat productivity at 8.54 tons per hectare, followed by France at 7.16 tons per hectare. Turkey ranked third with an average wheat productivity of 3.84 tons per hectare, while the United States, Canada, India, and Russia reported average wheat productivities of 3.47, 3.36, 3.08, and 2.74 tons per hectare, respectively.

Multiple variables interplay in shaping wheat productivity. Thus an analysis is warranted to explore the reasons behind the Netherlands' higher average wheat productivity in comparison to Turkey, despite Turkey's third place ranking within the provided data.

Climatic Conditions: The Netherlands typically has a mild, maritime climate with moderate rainfall, which is generally favorable for wheat cultivation. This consistency in climate conditions throughout the year provides an optimal environment for wheat growth. In contrast, Turkey's climate varies significantly across regions, with some areas experiencing harsher conditions such as extreme temperatures and less predictable rainfall patterns. These variations can impact wheat productivity, with certain regions facing challenges in providing ideal conditions for wheat cultivation.

Soil Composition: The Netherlands predominantly has sandy loam soil, which is well-suited for wheat production due to its good drainage properties and nutrient retention. Turkey, on the other hand, has diverse soil types, including loamy, sandy, and clay soils. While some regions may have suitable soil conditions for wheat cultivation, others may require more extensive soil management practices to optimize productivity.

Irrigation Infrastructure: The Netherlands boasts a highly developed irrigation system, ensuring consistent water supply to support wheat growth throughout the growing season. In Turkey, while irrigation infrastructure exists, it may not be as uniformly developed across all regions. Some areas may rely more heavily on rainfed agriculture, which can lead to fluctuations in wheat productivity depending on annual rainfall patterns.

Fertilization Practices: Dutch farmers typically have access to advanced agricultural practices, including efficient fertilization techniques and readily available, affordable fertilizers. This enables them to optimize soil fertility and enhance wheat yields. In Turkey, while fertilization practices may vary depending on the region and farming practices, access to affordable fertilizers and the adoption of modern fertilization methods may not be as widespread, potentially impacting wheat productivity. Crop Varieties: The Netherlands invests in research and development of high-yielding wheat varieties adapted to local conditions, providing farmers with access to advanced cultivars that can maximize productivity. Turkey also has a diverse range of wheat varieties, but adoption rates of high-yielding cultivars may vary among farmers, and certain regions may have limited access to improved varieties.

Overall, while Turkey ranks third in the list provided, factors such as variability in climatic conditions, soil composition, irrigation infrastructure, fertilization practices, and crop varieties may contribute to differences in wheat productivity compared to the Netherlands. Each of these variables interacts in complex ways, ultimately influencing wheat yields in both countries.

The subject of agricultural economics efficiency is also investigated using economic models and mathematical analyses. For instance, in a study conducted by Kumbhakar and Tsionas [10], the impact of different agricultural methods on efficiency was examined using a mathematical model.

Studies conducted worldwide [1]–[3] indicate the necessity of implementing various strategies related to food security and efficiency. These strategies include reducing food losses, promoting organic farming, implementing quality control measures for food products, increasing consumer awareness, labeling food products, and ensuring the sustainable use of agricultural land.

E. Agricultural Productivity in Turkey

Turkey holds a significant position in terms of its agricultural sector. The agricultural industry serves as a primary source of livelihood for a considerable portion of the population. However, it faces several challenges in enhancing productivity. These challenges include inadequacy of water resources, fragmentation of agricultural land, insufficient utilization of technology, and inadequacy of taxes and subsidies applied to agricultural products.

Several studies have addressed the issue of increasing productivity in Turkey's agricultural sector. [4] conducted a case study on water resources management and water productivity in Turkey, shedding light on the importance of efficient water use. Şeker and Sarıdoğan [5] investigated the impact of agricultural land fragmentation on agricultural income, highlighting its effects on the sector. Tekgüç [6]explored the adoption of technology in agriculture and its influence on agricultural productivity in Turkey, providing evidence on its significance. Additionally, Uzun and Cilasun [7] examined agricultural policy developments in Turkey, emphasizing the transition towards new support mechanisms and their implications for the sector. These studies collectively contribute

to understanding the challenges and potential strategies for enhancing productivity in Turkey's agricultural sector.

Studies conducted for Turkey indicate that various strategies need to be implemented to increase productivity in the agricultural sector. These strategies include efficient use of water resources, consolidation of agricultural land, utilization of modern technologies, providing education to farmers, supporting research and development efforts, and increasing subsidies for agricultural products.

However, it is also observed that studies on the productivity of the agricultural sector in Turkey are not yet at a sufficient level. Therefore, efforts to ensure the sustainability of the agricultural sector should continue, and the results should be integrated into the sector.

Enhancing the productivity of the agricultural sector not only contributes to Turkey's food production independence but also can have positive effects on the national economy. The agricultural sector is one of the major sources of employment, and thus, increasing its productivity can contribute to the national economy.

The findings of studies on agricultural economy productivity in Turkey can contribute to the more efficient utilization of resources in the sector and the enhancement of productivity in production. Therefore, it is important for research efforts in the agricultural sector to persist, and their results to be integrated into the sector.

III. Conclusion

In conclusion, the pursuit of agricultural production efficiency and food security demands a multifaceted approach that integrates various dimensions of analysis and action. From addressing the intricate challenges of food loss reduction to promoting sustainable agricultural practices, ensuring food safety, enhancing consumer education, and preserving natural resources, the journey towards resilient and sustainable food systems is complex yet imperative.

As delineated through the six dimensions of food security physical availability, economic and physical access, food utilization, food stability, agency, and food sustainability policy interventions and research endeavors must embrace a comprehensive understanding of the intricate web of factors influencing food security. By adopting a holistic perspective, policymakers can develop strategies that not only enhance agricultural productivity but also safeguard access to safe, nutritious, and sustainable food for present and future generations.

Moreover, insights gleaned from studies on agricultural productivity in countries like Turkey underscore the importance of context-specific approaches tailored to the unique challenges and opportunities within each agricultural landscape. From efficient water resource management to the adoption of modern technologies and policy reforms, enhancing productivity in Turkey's agricultural sector requires targeted interventions informed by rigorous research and analysis.

Ultimately, the pursuit of agricultural production efficiency and food security is not merely an academic endeavor but a moral imperative and an economic necessity. By harnessing the collective wisdom of researchers, policymakers, and stakeholders, nations can chart a course towards a future where food is abundant, accessible, and sustainable for all.

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