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STATISTICAL MODELING OF SUSTAINABLE FOOD SECURITY AND AGRICULTURE FOR THE GHANAIAN ECONOMY

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Abstract
The Ghanaian economy is faced with mismatch with regard to the average cost of a healthy diet and food affordability index despite the progress made over the years towards ensuring sustainable food security and affordable food for consumers to curb hunger, thereby resulting in a moderate level of hunger level as depicted by global hunger index (GHI). Urgent action and policy solutions are needed to achieve zero hunger by 2030, addressing inequalities, transforming food systems, and promoting sustainable agriculture in order to achieve sustainable development goal 2. The study seeks to statistically model the projected affordability index (AI), self-sufficiency ratio (SSR) and the global hunger index for a robust and sustainable agriculture to achieve sustainable food security and agriculture in ending hunger in Ghana. The study used secondary data from Census of Agriculture contained in the Statsbank of Ghana Statistical Service. The results reveal Ghana's global hunger index is projected to improve from moderate to low hunger with a GHI score of 8.5, whilst the self-sufficiency ratio (SSR) on the other hand is projected to hover around 97.3 and moderate affordability index. Innovative policies are informed by the results and the conclusion of the study.

Introduction

Hunger and malnutrition are barriers to sustainable development because hungry people are less productive, more prone to diseases, and less able to improve their livelihoods. In 2022, about 9.2 per cent of the world population was facing chronic hunger, equivalent to about 735 million people, which was 122 million more than the situation in 2019 (United Nations, 2023).

Sub-Saharan Africa scores an average of 47 points on its overall food security environment in the 2022 Global Food Security Initiative (GFSI), making it the least food secure region globally. Out of the four pillars of the index, the region performs best in the Quality and Safety pillar (50.3) and weakest in the Affordability pillar (44.8). Although scores in the quality and safety pillar are relatively high compared to those for other pillars. A lack of relevant food safety legislation and access to drinking water in countries within the region present food safety challenges, suggesting that food security in the region needs to be improved across all four pillars (The Economist Impact, 2022).

Ghana ranks 83rd out of 113 countries in the index, with an overall food security environment score of 52.6. Of the 28 Sub-Saharan African countries, Ghana ranks 3rd. Ghana's strongest performance is in the affordability pillar (59.9), and its weakest score is in sustainability and adaptation (45.1). Both Ghana's overall performance and its pillar scores are below the global average (The Economist Impact, 2022). Although Ghana has made some progress over the years towards ensuring affordable food for consumers to curb hunger, however, its global hunger index (GHI) of 13.9 at present represent a moderate condition (International Food Policy Research Institute, 2024). Lastly, the average cost of a healthy diet in Ghana remains at Gh 66 compared to the daily minimum wage of Gh 18.15 implying affordability remains challenge (Food and Agriculture Organization, 2024).

To achieve zero hunger by 2030, urgent coordinated action and policy solutions are imperative to address entrenched inequalities, transform food systems, invest in sustainable agricultural practices, increased affordability on global nutrition and food security (Beltran-Peña et al., 2020).

It is in the light of the above that Sustainable Development Goal (SDG) 2, which seeks to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture, was proposed by the United Nations (United Nations, 2017). This paper therefore focused on Sustainable Development Goal (SDG) 2 which aims to end hunger, achieve food security, improve nutrition and to promote sustainable agriculture through statistical analysis of sustainable food security in and agriculture for the Ghanaian economy using data extensively from the STATSBANK for informed policy decision purposes.

Materials and Methods

Data and source

Data relating to agricultural statistics and others obtained from the Ghana Statistical Service (GSS) STATBANK accessed from `https://statsbank.statsghana.gov.gh/` were extensively used. The data specifically included the following: Population and Housing Census (Aggregated Data on PHC 2021); Macro-Economic Indicators (Aggregated Data on Macro Economic Indicators); Population and Housing Census 2010 (Aggregated Data on PHC 2010); Annual Household Income and Expenditure Survey (Aggregated Data on AHIES); Ghana Census of Agric (GCA) 2017 (Aggregated Data on GCA); Trade Indicators (Aggregated Data on Trade); Ghana Living Standard Survey Round 7(GLSS 7) Aggregated Data on GLSS 7; and Ghana Demographic and Health Survey Report.

Statistical Modelling

The model uses developed algorithms to estimate the Self Sufficiency Ratio (SSR) which is a function given by:

$$SGD\ 2 = f(SSR,\ FSSR,\ NAR,\ FSRR,\ AI) \tag{1}$$

Where;
SGD 2 is defined to be the realization of sustainable development goal 2; SSR is the Self-Sufficiency Ratio which is the measure of the availability of overall food product.
In the simplest form factorising the Agricultural Production(AP), Import(I) and Export(E) as:

$$FSSR = \left(\frac{AP}{AP + I - E}\right) 100 \tag{2}$$

Where;
$AP = \Sigma Arable\ Crops + Treecrops + Livestock + Acquaculture$; TAP is the Total Agricultural Production.

Again, in specific food crop terms, the SSR is modified FSSR and derived by:

$$SSR = SSR_i = \left(\frac{AP_i}{(AP + I - E)_i}\right) 100 \tag{3}$$

i = Specific Crop(e.g Maize, Rice, Cassava, Livestock

Therefore, FSSR measures the self-sufficiency ratio for specific food items. It reflects the average amount of a particular food item available per person.
Based on the estimated SSR and SSRi, the projections are developed using the formulations below:
The projected Self Sufficiency Ratios are given as:

$$Projected\ SSR_i = \left(\frac{Projected\ AP_i}{Projected\ AP_i + PI_i - PE_i}\right) 100 \tag{4}$$

Also, projected Food Self Sufficiency Ratio is given as:

$$Projected\ FSSR_i = \left(\frac{Projected\ AP_i}{Projected\ AP_i + PI_i - PE_i}\right) 100 \tag{5}$$

Where Projected AP_i = The Projected Agricultural Production of the specific crop *i*; PI = The Projected Import of the specific crop *i*; PE = The Projection Export of the specific crop; The equations 5 and 6 are estimable base on the following estimations; Projected Agricultural Production

$$Projected\ AP_i = AP_c\ (1 + GRAP)^t \tag{6}$$

Projected Import

$$Projected\ I_i = I_c\ (1 + GRI)^t \tag{7}$$

Projected Export

$$Projected\ PE_i = E_c\ (1 + GRE)^t \tag{8}$$

Growth Rate in Agricultural Production (AP)

$$Growth\ Rate\ AP_i = \left(\frac{AP_c}{AP_p} - 1\right) 100 \tag{9}$$

Growth Rate in Import (I)

$$Growth\ Rate\ I_i = \left(\frac{I_c}{I_p} - 1\right) 100 \tag{10}$$

Growth Rate in Export (E)

$$Growth\ Rate\ E_i = \left(\frac{E_c}{E_p} - 1\right) 100 \tag{11}$$

Decision/Interpretation

1. SSR < 100%: This indicates that the country is not producing enough food to meet its consumption needs. A ratio below 100% suggests reliance on imports to fill the gap, which can lead to vulnerabilities in food security, especially during global supply chain disruptions.
2. SSR = 100%: A ratio of exactly 100% signifies that domestic production perfectly meets domestic consumption. This is often seen as an ideal scenario for food security.
3. SSR > 100%: A ratio above 100% indicates that the region produces more food than it consumes, allowing for potential exports. This is typically a sign of a strong agricultural sector and can contribute positively to the economy.

Results and Discussion

Ghana's Self-Sufficiency Ratio (SSR) and Food Self-Sufficiency Ratio (FSSR)

The self-sufficiency ratios and as well as the food self-sufficiency ratios which are the indicators of the percentage (%) of domestic consumption in relation to the local agricultural production reveals varying outcomes for different consecutive periods as far as the Ghanaian economy is concerned. These results are presented and subsequently discussed as follows.
The Table 1 provides an overall Ghana's Self-Sufficiency Ratio (SSR) and Food Self-Sufficiency Ratio (FSSR) for various food items in 2017. The SSR/FSSR indicates the percentage of domestic consumption that is met by local production, with values above 100% signifying surplus production and values

Table 1. Ghana's Self-Sufficiency Ratio (SSR) and Food Self-Sufficiency Ratio (FSSR) for 2017

Food Items	**Production** (t)	**Import** (t)	**Export** (t)	**Consumption** (t)	**SSR/FSSR** (%)
Ghana	58302114	5872170	2084680	62089604	93.9
Palm Oil	1517327	370000	102000	1785327	84.98874
Coffee	683	3000	88	3595	18.99861
Cocoa	1130137	1000	917000	214137	527.76350
Maize	2011179.40	48000	4000	2055179.40	97.85907
Tomatoes	370158.12	661000	99000	932158.12	39.70980
Rice	722080.11	1367000	0	2089080.10	34.56450
Yam	7856898.60	0	16000	7840898.60	100.20410
Millet	163483.97	1000	0	164483.97	99.39204

Table 2. Ghana's Self-Sufficiency Ratio (SSR) and Food Self-Sufficiency Ratio (FSSR) for 2021

Food Items	**Production** (t)	**Import** (t)	**Export** (t)	**Consumption** (t)	**FSSR** (%)
Ghana	57639035.64	6732628.19	2089635.30	62282028.55	92.54521240
Palm Oil	272306400.00	336255700.00	85947830.00	522614270.00	52.10466220
Coffee	736000.00	1059110	1078090	717020	102.64706700
Cocoa	1047385000	110220	892128650	155366570	674.13794360
Maize	3203000000	87339830	5642500	3284697330	97.51278971
Tomatoes	383720700	67493880	9083730	442130850	86.78894495
Rice	1143000000	2765332080	2562194	3905769886	29.26439686
Yam	10278000000	26100	49892550	10228133550	100.48754200
Millet	188000000	120720	61610	188059110	99.96856839

below 100% indicating reliance on imports.

In 2017, Ghana's overall Self-Sufficiency Ratio (SSR) was 93.9%, indicating that domestic food production met the vast majority of the country's consumption needs, with the remaining 6.1% covered by imports. For palm oil, the SSR stood at 84.99%, signifying that while domestic production was substantial, the country still relied on imports for about 15% of its demand.

Coffee presented a different picture, with a very low SSR of 18.99%, indicating a heavy dependence on imports, as domestic production accounted for only a small fraction of total consumption. In contrast, cocoa had an exceptionally high SSR of 527.76%, indicating that production far exceeded local consumption, making it a major export commodity and a key economic driver for Ghana.

The SSR for maize was 97.86%, showing that almost all of Ghana's maize consumption was satisfied by domestic production, with minimal imports required. However, for tomatoes, the SSR was 39.71%, indicating a significant reliance on imports, as domestic production accounted for less than half of the country's demand.

The SSR for rice was relatively low at 34.56%, indicating substantial dependency on imports to meet the growing domestic demand for this staple. Yam, on the other hand, achieved self-sufficiency with an SSR of 100.2%, slightly surpassing the country's consumption needs. Similarly, millet had an SSR of 99.39%, showing that domestic production almost entirely met local consumption, with only minimal imports required. Ghana is self-sufficient in certain staples such as yam and millet, and it is a net exporter of cocoa. However, the country heavily relies on imports for key food items like rice, tomatoes, and coffee, indicating areas where domestic agricultural production needs to be strengthened to improve food security.

The Table 2 presents data on the overall Ghana's Self-Sufficiency Ratio (SSR) and Food Self-Sufficiency Ratio (FSSR) for various food items in 2021, which reflect the ability of domestic production to meet the nation's consumption needs. A higher FSSR indicates greater reliance on domestic production, while lower values indicate dependence on imports.

In 2021, Ghana's overall Food Self-Sufficiency Ratio (FSSR) was 92.55%, indicating that domestic production met the vast majority of the country's food consumption needs, with only about 7.45% fulfilled by imports. For palm oil, the FSSR was 52.10%, meaning that just over half of the country's demand was met by domestic production, with significant reliance on imports to make up the shortfall.

Coffee had an FSSR of 102.65%, indicating that domestic production slightly exceeded consumption, allowing for exports. Cocoa continued to be a significant export crop, with an FSSR of 674.14%, far surpassing domestic consumption, making it a crucial contributor to Ghana's agricultural economy. The FSSR for maize remained strong at 97.51%, reflecting near self-sufficiency, with minimal reliance on imports. For toma-

Table 3. Farm Characteristics

Item	Production (t)	Import (t)	Export (t)	Consumption (t)	SSR/FSSR (%)
Ghana	58826140	5010200	2164550	61671790	95.3858158
Palm Oil	269000	180000	65361.23	383638.8	70.1180400
Coffee	1000	3000	3000	1000	100
Cocoa	1109000	2000	863000	248000	447.1774000
Maize	3256000	83000	1000	3338000	97.5434400
Tomatoes	382000	477000	93000	766000	49.8694500
Rice	1283000	812000	2000	2093000	61.2995700
Yam	10718000	0	58000	10660000	100.5441000
Millet	196000	2000	0	198000	98.9899000

toes, the FSSR was 86.79%, showing that while domestic production met most consumption needs, imports still played a notable role in satisfying demand. Rice, however, had a low FSSR of 29.26%, indicating that domestic production covered less than a third of the country's consumption needs, with a high dependence on imports. Yam maintained a high level of self-sufficiency with an FSSR of 100.49%, slightly exceeding consumption, reinforcing its status as a staple food in Ghana. Similarly, millet had an almost perfect FSSR of 99.97%, indicating that domestic production almost fully met local consumption needs, with minimal reliance on imports.

In 2021, Ghana demonstrated high self-sufficiency in cocoa, yam, and millet, with cocoa being a particularly strong export crop. Coffee achieved slight self-sufficiency, while maize remained close to full self-sufficie-ncy. However, significant challenges remain with rice and palm oil, where imports continue to play a crucial role in meeting consumption needs. Improving domestic production of these key items could help reduce Ghana's reliance on imports and enhance the nation's food security.

The Table 3 provides the estimates of Ghana's overall SSR and Food Self-Sufficiency Ratios (FSSR) for 2022 for various food items. While the SSR for Ghana as a whole was found to be 95.38581578 in 2022, indicating that domestic production met 95.39% of the country's food consumption needs, with the remaining demand supplied by imports. The Food Self-Sufficiency Ratio (FSSR) for various food items revealed both improvements and declines in self-sufficiency.

For palm oil, the FSSR in 2022 was 70.12%, showing a decline in self-sufficiency compared to earlier years. Despite an increase in domestic production, imports were still necessary to meet about 30% of the demand. In contrast, coffee achieved a perfect FSSR of 100%, indicating that domestic production fully met consumption needs, balancing both imports and exports.

Cocoa continued to be a major export crop with an FSSR of 447.18%, meaning production far exceeded domestic consumption, allowing for significant export quantities. The FSSR for maize remained high at 97.54%, reflecting near self-sufficiency, with only a small portion of demand met through imports. For tomatoes, the FSSR increased to 49.87% in 2022, indicating an improvement in domestic production, though imports still supplied half of the country's consumption. The FSSR for rice was 61.30%, showing some progress compared to earlier years, but the country continued to rely heavily on imports to meet local demand.

Yam remained self-sufficient with an FSSR of 100.54%, meaning domestic production slightly exceeded consumption, maintaining its status as a staple crop. Similarly, millet had a high FSSR of 98.99%, indicating near-complete self-sufficiency, with minimal reliance on import.

Ghana's overall SSR from 2022 shows that the country was almost self-sufficient in food production, with 93.9% of total consumption met by domestic production. In 2022, several food items showed improvements or declines in their self-sufficiency levels. Cocoa, yam, and millet remain self-sufficient, while crops like palm oil, tomatoes, and rice continue to rely on imports to meet domestic demand. Coffee saw a significant improvement, achieving 100% self-sufficiency. Moving forward, further focus on improving domestic production for items like rice and tomatoes could help reduce import dependency.

Ghana's Projected Food Self-Sufficiency Ratios (FSSR) for 2030

The Table 4 presents projections for Ghana's Food Self-Sufficiency Ratios (FSSR) for various key crops in 2030, based on growth rates of agricultural production (GRAPi) and consumption (GRCi). These ratios provide relevant information relating to the extent to which Ghana's domestic production will meet future consumption needs.

The projected Food Self-Sufficiency Ratio (FSSR) for 2030 reveals Ghana's future reliance on domestic production compared with imports for key food items. For palm oil, the FSSR is expected to be 69.97%, meaning that while a substantial portion of demand will be met through domestic production, about 30% of consumption will still rely on imports. Coffee is projected to maintain an FSSR of 100.03%, indicating that domestic production will fully satisfy local consumption, with a slight surplus available for export.

Cocoa remains a crucial export crop for Ghana, with a projected FSSR of 449.13%, meaning production will far exceed domestic consumption, solidifying its position as a major export commodity. The FSSR for maize is projected to be

Table 4. Ghana's Projected Food Self-Sufficiency Ratios (FSSR) for 2030

Food Items	GRAPi (%)	PAPt for 2030 (t)	GRCi (%)	PCt for 2030 (t)	PFSSR (%)
Palm Oil	-99.901214	2.46e21	-99.9265924	3.52e21	69.9743
Coffee	-99.864130	9.13e18	-99.8605339	9.12e18	100.0290
Cocoa	-99.894117	1.01e22	-99.8403775	2.26e21	449.1260
Maize	-99.898345	2.98e22	-99.8983772	3.05e22	97.5432
Tomatoes	-99.900448	3.50e21	-99.8267481	6.97e21	50.1678
Rice	-99.887752	1.17e22	-99.9464126	1.92e22	61.0094
Yam	-99.895719	9.81e22	-99.8957777	9.75e22	100.5440
Millet	-99.895745	1.79e21	-99.8947140	1.81e21	98.9982

97.54%, reflecting near self-sufficiency, as domestic production will meet almost all local consumption needs with minimal imports.

The projected FSSR for tomatoes is 50.17%, suggesting that although there will be some improvements in domestic production, the country will still depend heavily on imports to meet about half of its consumption needs. Rice will continue to pose a challenge for self-sufficiency, with a projected FSSR of 61.01%. Domestic production will cover just over 60% of consumption, leaving a significant portion of demand to be met through imports.

Yam is projected to maintain strong self-sufficiency, with an FSSR of 100.54%, indicating that domestic production will slightly exceed consumption, securing yam's role as a staple food in Ghana. Similarly, millet is projected to have an FSSR of 98.99%, reflecting near-total self-sufficiency, with minimal reliance on imports.

The projections for 2030 indicate that Ghana will continue to be self-sufficient in crops such as cocoa, coffee, yam, and millet, with surplus production available for export, particularly in the case of cocoa. Maize is expected to remain close to full self-sufficiency. However, challenges remain with palm oil, rice, and tomatoes, where significant import dependence is likely to persist. To improve food security by 2030, there will need to be increased efforts to boost domestic production of these key food items.

Discussion

The results on Ghana's self-sufficiency ratios (SSR) and food self-sufficiency ratios (FSSR) from 2017 to 2022, along with projections for 2030, provide a clear picture of the country's progress toward sustainable food security. The findings reveal significant achievements in specific crops, ongoing challenges in meeting domestic demand for others, and areas requiring targeted policy interventions.

In 2017, Ghana achieved an overall SSR of 93.9%, indicating that domestic production met the majority of its food consumption needs, with a 6.1% reliance on imports. Cocoa stood out with an SSR of 527.76%, reflecting its pivotal role as a major export commodity and a cornerstone of Ghana's agricultural economy. The high self-sufficiency in cocoa aligns with studies emphasizing its significant contribution to Ghana's GDP and export earnings, as well as its serious role in rural livelihoods (Quarm and Begho, 2024). Staple crops like yam and millet also demonstrated strong self-sufficiency, with SSR values of 100.20% and 99.39%, respectively. According to Adjei-Mantey et al. (2022) yam's importance as a food security crop in West Africa, where its robust yields and cultural significance contribute to household nutrition and income.

However, the reliance on imports for rice (SSR: 34.56%) and tomatoes (SSR: 39.71%) emphasizes persistent challenges in these sectors. Similar patterns are observed in sub-Saharan Africa, where limited access to irrigation, high production costs, and inefficient value chains undermine efforts to boost domestic production (Quarm and Begho, 2024). Coffee, with an SSR of only 18.99%, further illustrates the vulnerabilities in Ghana's agricultural system, particularly for high-value cash crops. Studies from other regions, such as India, suggest that strategic investments in coffee production, coupled with access to global markets, can transform such low-performing sectors into significant economic contributors (Singh et al., 2024).

By 2021, Ghana's overall FSSR slightly declined to 92.55%, signaling increased dependency on imports. Cocoa maintained its dominance, with an FSSR of 674.14%, reaffirming its role as a major export crop. The improvement in coffee production, with an FSSR of 102.65%, suggests that targeted interventions, such as better farming practices and improved market access, may have yielded positive results. Studies by Papargyropoulou et al. (2024) showed how government support and public-private partnerships can significantly enhance the performance of cash crop sectors. Despite these gains, rice and palm oil recorded FSSR values of 29.26% and 52.10%, respectively, highlighting the challenges of achieving self-sufficiency in these sectors. The high reliance on imports for staple crops is a recurring issue across developing economies, driven by inadequate investments in irrigation and mechanization Adjei-Mantey et al. (2022). Tomatoes showed some improvement, with an FSSR of 86.79%, but imports continued to play a significant role in meeting domestic demand. These findings reflect the need for enhanced value chain development, advocating for better post-harvest management and market integration to boost local production (Alam et al., 2023).

Ghana's overall SSR improved to 95.39% in 2022, reflecting incremental progress in domestic food production. Cocoa continued to lead, with an FSSR of 447.18%, while yam and millet remained staples with near-total self-sufficiency. Coffee achieved full self-sufficiency, with production balancing consumption and export demand. These results support evidence that strong export crops can coexist with self-sufficient staples to drive both economic growth and food security Adjei-Mantey et al. (2022). However, palm oil (70.12%), rice (61.30%), and tomatoes (49.87%) remained reliant on imports. Studies by Salisu et al. (2024) on sub-Saharan Africa's food systems reveal that insufficient investment in infrastructure, limited farmer access to credit, and dependence on rain-fed agriculture are key drivers of low self-sufficiency. These findings emphasize the need for targeted policy interventions, such as subsidies for irrigation equipment and investments in mechanized farming, as recommended in global studies on agricultural modernization (Quarm and Begho, 2024).

Projections for 2030 suggest that Ghana will maintain self-sufficiency in cocoa, yam, and millet, with FSSR values of 449.13%, 100.54%, and 98.99%, respectively. However, rice and tomatoes are projected to remain import-dependent, with FSSR values of 61.01% and 50.17%, respectively. These projections align with evidence that achieving full self-sufficiency in import-reliant crops requires sustained investments in production systems and improved market access (Papargyropoulou et al., 2024). Palm oil, with a projected FSSR of 69.97%, illustrates the ongoing challenges of reducing import reliance in this sector. According to (Singh et al., 2024) study from Southeast Asia suggest that increasing palm oil production requires not only investments in plantation infrastructure but also policies promoting sustainable practices to ensure environmental balance.

The findings emphasize the importance of prioritizing crops with low FSSR values, such as rice and tomatoes, to reduce Ghana's reliance on imports. Literature highlights the critical role of irrigation and mechanization in boosting yields, particularly for water-intensive crops like rice Adjei-Mantey et al. (2022). Additionally, policies incentivizing local production through subsidies, tariffs on imports, and better access to agricultural inputs can strengthen Ghana's agricultural sector. Targeted urban interventions, such as promoting urban agriculture and expanding food assistance programs, can address food security challenges in urban areas, where dependence on imported foods is highest. Studies on urban food systems suggest that integrating peri-urban farming with existing value chains can help bridge production gaps while enhancing the affordability of nutritious foods (Quarm and Begho, 2024).

Ghana's progress in achieving food self-sufficiency for certain staples is evident, but challenges persist for import-reliant crops like rice, tomatoes, and palm oil. Linking these findings to the broader literature underscores the need for sustained investments, policy reforms, and targeted interventions to strengthen Ghana's agricultural sector. Implementing best practices from other regions and addressing systemic constraints, Ghana can enhance its food security while contributing to global efforts to achieve Sustainable Development Goal 2.

Conclusion

The results from the self-sufficiency ratio (SSR), food self-sufficiency ratio (FSSR), projected self-sufficiency ratio (PSSR), and projected food self-sufficiency ratio (PFSSR) indicate that achieving Sustainable Development Goal 2 (SDG 2) through agricultural activities is feasible. The statistical model developed provides an empirical basis for real-time analysis, supporting policy decisions aimed at improving food security and sustainable agriculture.

While the model effectively captures food availability and self-sufficiency, achieving zero hunger requires a broader perspective that extends beyond production levels. The economic accessibility of food remains a decisive aspect of food security, as increased production does not necessarily ensure affordability for all populations. A more comprehensive approach would integrate economic factors such as pricing trends, income levels, and the cost of a healthy diet, allowing for a more holistic evaluation of food security outcomes. Future research should expand on these dimensions to strengthen policy interventions that address both food availability and affordability, ensuring sustainable access to nutritious food for all.

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