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ECONOMIC SUSTAINABILITY OF FOOD SUPPLY IN THE REPUBLIC OF TAJIKISTAN AMID CLIMATE AND DEMOGRAPHIC CHANGES

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This article examines the economic sustainability of food supply in the Republic of Tajikistan under the combined effects of climate and demographic changes. The study extends the statistical and economic assessment of long-term transformations in the country's agricultural sector and shifts the focus from the analysis of individual climatic and production indicators to evaluating the capacity of agricultural production to meet the food needs of a growing population. The empirical basis of the study comprises data from the Agency on Statistics under the President of the Republic of Tajikistan, FAOSTAT, the World Bank, and NASA POWER. The sustainability of food supply is assessed through the interrelationship between population dynamics, cereal production, crop yields, harvested areas, climatic parameters, and indicators of the economic accessibility and affordability of food. Particular attention is paid to per capita grain production as an indicator reflecting the combined effects of changes in agricultural production capacity and demographic pressure. The research methodology includes time-series analysis, assessment of variability and interrelationships among indicators, estimation of econometric relationships, and scenario-based calculations. The study aims to determine the contribution of production, climatic, and demographic factors to changes in the level of food supply, as well as to estimate the required increase in cereal yields needed to offset population growth and the potential intensification of climate-related risks. The findings can be used to substantiate policy and strategic measures aimed at improving agricultural productivity and strengthening the resilience of the national agri-food system.

Keywords: food supply, economic sustainability, climate change, demographic growth, grain production, crop yield, grain imports.

КЛИМАТТЫҚ ЖӘНЕ ДЕМОГРАФИЯЛЫҚ ӨЗГЕРІСТЕР ЖАҒДАЙЫНДАҒЫ ТӘЖІКСТАН РЕСПУБЛИКАСЫНЫҢ АЗЫҚ-ТҮЛІКПЕН ҚАМТАМАСЫЗ ЕТУ ЖҮЙЕСІНІҢ ЭКОНОМИКАЛЫҚ ТҰРАҚТЫЛЫҒЫ

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Мақалада климаттық және демографиялық өзгерістердің қатар жүруі жағдайында Тәжікстан Республикасының азық-түлікпен қамтамасыз ету жүйесінің экономикалық тұрақтылығы зерттеледі. Зерттеу елдің аграрлық секторындағы ұзақ мерзімді өзгерістерді статистикалық-экономикалық бағалауды жалғастыра отырып, жекелеген климаттық және өндірістік көрсеткіштерді талдаудан ауыл шаруашылығы өндірісінің өсіп келе жатқан халықтың азық-түлікке деген қажеттілігін қамтамасыз ету әлеуетін бағалауға басымдық береді. Зерттеудің ақпараттық базасын Тәжікстан Республикасы Президенті жанындағы Статистика агенттігінің, FAOSTAT дерекқорының, Дүниежүзілік банктің және NASA POWER жүйесінің ресми статистикалық деректері құрайды. Азық-түлікпен қамтамасыз етудің экономикалық тұрақтылығын халық санының динамикасы, дәнді дақылдар өндірісінің көлемі, олардың өнімділігі, егіс алқаптарының мөлшері, климаттық параметрлер және азық-түліктің экономикалық қолжетімділігін сипаттайтын көрсеткіштер жүйесі негізінде бағалау ұсынылады. Өндірістік әлеует пен демографиялық жүктемедегі бірлескен өзгерістердің нәтижесін сипаттайтын маңызды индикатор ретінде жан басына шаққандағы астық өндірісіне

ерекше назар аударылады. Зерттеу әдістемесі динамикалық қатарларды талдауды, көрсеткіштердің вариациясын және олардың өзара байланысын бағалауды, эконометриялық модельдер құруды, сондай-ақ сценарийлік есептеулер жүргізуді қамтиды. Зерттеу барысында азық-түлікпен қамтамасыз ету деңгейінің өзгеруіне өндірістік, климаттық және демографиялық факторлардың ықпал ету дәрежесін айқындау, сондай-ақ халық санының өсуінен туындайтын демографиялық қысымды және климаттық тәуекелдердің ықтимал күшеюін теңгеру үшін дәнді дақылдар өнімділігінің қажетті өсу қарқынын бағалау көзделеді. Зерттеу нәтижелері ауыл шаруашылығы өндірісінің өнімділігін арттыру, азық-түлікпен қамтамасыз етудің экономикалық тұрақтылығын нығайту және ұлттық агро-азық-түлік жүйесінің орнықтылығын қамтамасыз ету бағыттарын ғылыми тұрғыдан негіздеуде пайдаланылуы мүмкін.

Түйін сөздер: азық-түлікпен қамтамасыз ету, экономикалық тұрақтылық, климаттың өзгеруі, демографиялық өсім, астық өндірісі, дақылдардың өнімділігі, астық импорты.

ЭКОНОМИЧЕСКАЯ УСТОЙЧИВОСТЬ ПРОДОВОЛЬСТВЕННОГО ОБЕСПЕЧЕНИЯ РЕСПУБЛИКИ ТАДЖИКИСТАН В УСЛОВИЯХ КЛИМАТИЧЕСКИХ И ДЕМОГРАФИЧЕСКИХ ИЗМЕНЕНИЙ

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В статье исследуется экономическая устойчивость продовольственного обеспечения Республики Таджикистан в условиях одновременного воздействия климатических и демографических изменений. Исследование продолжает статистико-экономическую оценку долгосрочных изменений аграрного сектора страны и переносит акцент с анализа отдельных климатических и производственных показателей на оценку способности сельскохозяйственного производства обеспечивать растущую численность населения. Информационную базу составляют данные Агентства по статистике при Президенте Республики Таджикистан, FAOSTAT, Всемирного банка и NASA POWER. Предлагается оценивать устойчивость продовольственного обеспечения через соотношение динамики численности населения, производства зерновых культур, урожайности, посевных площадей, климатических параметров и показателей экономической доступности продовольствия. Особое внимание уделяется производству зерна в расчете на душу населения как показателю, отражающему результат совместного изменения производственного потенциала и демографической нагрузки. Методика исследования предусматривает анализ динамических рядов, оценку вариации и взаимосвязей показателей, построение эконометрических зависимостей и сценарные расчеты. Предполагается определить вклад производственных, климатических и демографических факторов в изменение уровня продовольственного обеспечения, а также оценить необходимый рост урожайности зерновых культур для компенсации увеличения численности населения и возможного усиления климатических рисков. Полученные результаты могут быть использованы при обосновании направлений повышения производительности сельского хозяйства и устойчивости национальной агропродовольственной системы.

Ключевые слова: продовольственное обеспечение, экономическая устойчивость, изменение климата, демографический рост, зерновое производство, урожайность, импорт зерновых.

Introduction

Ensuring a sustainable food supply for the population is one of the fundamental conditions of a country's socio-economic stability. For countries with limited land and water resources, this issue is determined not only by the absolute volume of agricultural production, but also by the relationship between changes in production capacity, population dynamics, and shifts in natural and climatic conditions. As the population grows, an increase in gross agricultural output alone does not necessarily guarantee a corresponding improvement in food availability if production growth is insufficient to offset additional domestic demand [1].

For the Republic of Tajikistan, this issue is particularly important due to the combination of limited land suitable for agricultural use, the significant role of irrigated agriculture, and crop production's dependence on water availability. Climate change further complicates this relationship [2]. Rising air temperatures increase evapotranspiration and crop water requirements, while the uneven distribution of precipitation raises the risk of moisture deficits during specific stages of the growing season. Previous research has shown that the

sensitivity of agricultural production in Tajikistan is shaped by a combination of climatic, water-related, and technological factors [3].

Contemporary studies of food supply sustainability in Tajikistan examine this issue both at the level of agricultural production and from the perspective of the resilience of farms and households. Egamberdiev et al. identified a positive relationship between farm resilience and food security indicators in Tajikistan [4]. Another study by these authors confirms the role of household resilience and adaptation strategies in reducing vulnerability to food insecurity [5]. Research on the grain sector indicates that the sustainability of wheat production is associated with crop yields, seed quality, and the technological characteristics of production [6]. At the same time, farmers' crop choices and adaptive behavior depend on a combination of economic, resource-related, and external factors [7]. Nevertheless, the quantitative relationship between grain production dynamics, demographic pressure, and external trade-based food supply at the national level remains insufficiently studied, which defines the focus of the present research.

At the same time, the long-term development of the agricultural sector has been characterized by a substantial increase in production capacity. The results of previous research show that gross output grew more rapidly than the area under crops, indicating the increasing importance of crop yields and other factors associated with the intensification of agricultural production. In particular, over the period studied, a strong relationship was found between gross grain production and crop yield ($r=0.984$ $r = 0.984$), whereas the relationship between gross grain production and the size of the cultivated area was considerably weaker ($r=0.564$ $r = 0.564$) [8].

However, an increase in aggregate production does not necessarily result in a proportional improvement in food availability for the population. Per capita grain production exhibited less stable dynamics than aggregate production: its maximum value was recorded in 2009, while the average level for 2020–2024 was lower than that observed during 2010–2019. This makes it possible to approach the economic sustainability of food supply from a broader perspective: not only as the ability of the agricultural sector to increase production, but also as its capacity to maintain an adequate level of output relative to a changing population under climate-related constraints.

The economic dimension of food supply sustainability is likewise not limited to the physical availability of agricultural products. Growth in household income determines the capacity for effective demand, while food imports can partially compensate for insufficient domestic production. In previous research, GDP per capita was identified as an indirect indicator of the economic accessibility of food and was considered in conjunction with agricultural production, cereal yields, imports, population size, food prices, and climatic parameters [9].

Accordingly, the aim of this study is to assess the economic sustainability of food supply in the Republic of Tajikistan by quantitatively determining the relationship between agricultural production dynamics, demographic pressure, and climatic factors, as well as by identifying the level of grain production productivity required to maintain an adequate level of food supply for the population.

To achieve this aim, the study examines the dynamics of cereal production and population size; assesses changes in per capita grain production; identifies statistical relationships between climatic conditions, crop yields, and grain production; determines the impact of population growth on per capita food availability; develops scenarios of changes in food supply; and estimates the level of cereal yield required to offset demographic and climate-related pressures.

Materials and Methods

The empirical basis of the study consists of official statistical publications of the Agency on Statistics under the President of the Republic of Tajikistan [10], FAOSTAT data on cereal production, harvested area and yield [11], World Development Indicators data on population dynamics [12], and meteorological data from the NASA POWER system [13].

Data for 2020–2024 are used to assess the current situation. For the analysis of long-term relationships and subsequent econometric modeling, it is appropriate to use a comparable annual time series covering 1993–2024. A five-year period alone is insufficient for the reliable estimation of multivariate econometric models and is therefore used primarily to characterize current structural trends.

According to FAOSTAT methodology, cereal indicators refer to crops harvested for dry grain. Crops harvested for hay, green fodder, or silage are not included in this category. In addition, the FAOSTAT area indicator refers to harvested area, rather than sown area in the narrow statistical sense. Therefore, the term “harvested area of cereal crops” is used throughout the calculations in this study.

To assess demographic pressure, per capita grain production is calculated as follows:

$$GPC_t = \frac{G_t}{POP_t} \quad (1)$$

where GPC_t is the volume of domestic grain production per capita in year t , t/person; G_t is the total volume of grain production in year t , t; POP_t is the population in year t , people.

If the volume of grain production is expressed in tons, and the indicator needs to be presented in kilograms per person, the formula is used:

$$GPC_t = \frac{G_t \times 1000}{POP_t} \quad (2)$$

In this case, GPC_t is measured in kg/person.

This indicator allows us to determine whether the dynamics of domestic production are consistent with the rate of population change. An increase in G_t with a simultaneous decline or stagnation in GPC_t indicates that the increase in gross output is largely absorbed by demographic growth.

However, for a country that relies on grain imports to meet domestic needs, the indicator of domestic per capita production does not reflect the full volume of available resources. Therefore, an additional indicator of gross available grain resources is calculated:

$$GR_t = G_t + IMP_t - EXP_t \quad (3)$$

where GR_t is gross available grain resources; G_t is domestic production; IMP_t is import; EXP_t is export.

Accordingly, the provision of gross grain resources per capita is determined as:

$$GRPC_t = \frac{G_t + IMP_t - EXP_t}{POP_t} \quad (4)$$

$GRPC_t$ indicator is more meaningful for analyzing the resource side of food supply, as it takes into account both domestic production and foreign trade. However, it should not be interpreted as the actual grain consumption of the population. The formula does not account for changes in stocks, seed use, feed purposes, technological processing, and losses. Therefore, the indicator is used as an analytical indicator of gross resource security, rather than as a direct indicator of food consumption.

To analyze the factors of change in grain production, the production ratio is used:

$$Gt = At \times Yt / 1000 \quad (5)$$

where Gt is cereal production in year t , tonnes; At is the harvested area of cereal crops in year t , ha ; and Yt is cereal yield in year t , kg/ha . Division by 1,000 converts kilograms into tonnes.. This relationship makes it possible to distinguish between the extensive component of production growth, associated with changes in harvested area, and the intensive component, associated with changes in yield. To characterize the dynamics of indicators, absolute and relative changes are calculated:

$$\Delta X = X_t - X_0$$

$$T_X = \left(\frac{X_t}{X_0} - 1 \right) \times 100\% \quad (6)$$

where X_0 and X_t are the values of the analyzed indicator in the base and reporting periods, respectively.

Of particular importance in the study is the calculation of the crop yield required to compensate for population growth. If the target level is the basic domestic grain production per capita q_0 , then the required crop yield is determined:

$$Y_t^{req} = \frac{q_0 \times POP_t}{A_t} \quad (7)$$

Where

$$q_0 = \frac{G_0}{POP_0} \quad (8)$$

The economic meaning of the formula is that, given a known population size and a limited area of grain crops, it is possible to determine the minimum yield necessary to maintain the basic volume of domestic grain production per capita.

Taking into account foreign trade, the formula expands:

$$Y_t^{req} = \frac{GRPC^* \times POP_t - IMP_t + EXP_t}{A_t} \quad (9)$$

where $GRPC^*$ is the target level of grain resources per capita. This formulation allows us to assess the extent to which the required domestic yield depends on the scale of import coverage.

When modeling the possible reduction in yield due to climate impact of magnitude δ , the required potential yield can be calculated as follows:

$$Y_t^{clim} = \frac{Y_t^{req}}{1 - \delta} \quad (10)$$

For example, with an expected climate-induced reduction in actual crop yields by 5%, the production and technological potential must exceed the normal calculated level so that, after the climate risk has been realized, the actual crop yields do not fall below the level necessary to maintain the specified per capita supply.

The climate research block is formed on the basis of NASA data POWER [13]. The system provides time series of meteorological parameters, including air temperature and precipitation, with daily data available since 1981, ensuring temporal comparability with the main study period. For agricultural analysis, it is advisable to use average air temperature and precipitation for both the calendar year and the main growing seasons. Given the pronounced spatial heterogeneity of Tajikistan's territory, climate data should be aggregated across major agricultural zones, rather than presented as the value of a single arbitrary geographic point.

The econometric stage primarily involves assessing the impact of climatic factors on crop yield, since regressing production simultaneously on area and crop yield would largely reproduce the arithmetic identity $G_t = A_t \times Y_t / 1000$. In general, the crop yield model can be represented as:

$$\ln Y_t = \alpha + \beta_1 T_t + \beta_2 P_t + \beta_3 Trend_t + \varepsilon_t \quad (11)$$

where T_t is the temperature indicator, P_t is the amount of precipitation, $Trend_t$ is the time trend reflecting the combined impact of technological and organizational-economic changes, ε_t is the random error.

Before estimating the models, the time series should be tested for trends and stationarity. If non-stationarity is detected, growth rates, first differences, or other appropriate transformations should be applied to reduce the risk of spurious regression. In addition, autocorrelation, heteroscedasticity, and multicollinearity should be diagnosed.

Food accessibility is considered an additional dimension of sustainability. GDP per capita, income dynamics, the consumer price index for food, and import costs can be used as macroeconomic indicators. However, GDP per capita is considered only as an indirect indicator of potential solvency, not as a direct measure of food accessibility for individual households.

Results and discussion

An analysis of indicators for 2020–2024 reveals significant differences in the dynamics of production and demographic factors.

Table 1 – Key Indicators of Cereal Production and Demographic Dynamics in Tajikistan, 2020–2024

Year	Population, people	Harvested area of grain, ha	Yield, kg/ha	Grain production, t	Production per capita, kg/person.
2020	9,749,310	372,860	3,526	1,313,000	134.7
2021	9 966 908	377 362	3,885	1,465,000	147.0
2022	10 182 222	372 191	3,926	1,460,000	143.4
2023	10,389,799	373,837	3,733	1,395,442	134.3
2024	10,590,927	376 457	4 124	1,552,464	146.6

Source: compiled by the authors based on FAOSTAT [11] and World Development Indicators [12];

World Bank data [12] confirm that Tajikistan's population reached 10,590,927 in 2024, while updated FAO data report cereal production of 1,552,464 tonnes and a cereal yield of 4,124 kg/ha.

Over the period under review, the harvested area of cereal crops increased from 372.9 to 376.5 thousand hectares, or by only 0.96%. At the same time, cereal yield rose from 35.26 to 41.24 centners per hectare, corresponding to an increase of approximately 16.96%. Cereal production increased by about 18.2%. These dynamics indicate that expansion of the physical land base was not the main source of output growth. Production growth was driven primarily by higher output per unit of land.

This result is of fundamental importance for assessing the future sustainability of food supply. With the harvested area remaining virtually stable, the scope for extensive expansion of cereal production is limited. Consequently, further compensation for population growth should be achieved primarily through higher yields, lower production losses, and more efficient use of water, material, technical, and technological resources.

At the same time, the country's population increased by approximately 8.6% during 2020–2024. Despite the higher growth rate of gross cereal production, per capita production did not follow a consistently upward trend. In 2020, the indicator was approximately 134.7 kg per person; it increased to 147.0 kg in 2021, declined again to 134.3 kg in 2023, and recovered to 146.6 kg only in 2024.

Therefore, growth in gross production and growth in per capita availability are not identical processes. During periods of unfavorable yield dynamics, population growth can significantly intensify the decline in the per capita indicator. Thus, between 2022 and 2023, continued population growth coincided with a decline in gross grain production, resulting in lower domestic production per capita. This confirms the need to account for the demographic factor when assessing the development of the agricultural sector.

The positive outcome observed in 2024 also requires substantive interpretation. Compared with 2023, cereal production increased by approximately 11.3%, whereas harvested area grew by only 0.7%. Yield increased by about 10.5% over the same period. Thus, almost the entire increase in output was again associated with the intensive factor. Updated FAO data report cereal yields in Tajikistan at 4,124 kg/ha in 2024, compared with 3,733 kg/ha in 2023.

The increasing role of yield has a dual significance for economic sustainability. On the one hand, intensification makes it possible to increase output under conditions of limited land availability. On the other hand, the strong dependence of production outcomes on yield increases the importance of the factors that directly determine yield fluctuations, particularly water availability, temperature, the amount and seasonal

distribution of precipitation, the quality of agricultural technologies, and the condition of irrigation infrastructure. This dependence is especially important for Tajikistan, where irrigation is a critical component of agricultural production and food supply.

A second important dimension of sustainability is related to foreign trade in cereals. In 2024, cereal imports amounted to 1,334,115 tonnes, compared with 1,175,745 tonnes in 2023, representing an increase of 13.47%. Exports remained negligible, at approximately 2 tonnes in 2024 and 18 tonnes in 2023. The substantial scale of cereal imports makes it necessary to consider not only their physical volume, but also their value characteristics and their contribution to the formation of the country's total grain resource base.

To quantitatively assess the foreign trade component of food supply, data from the FAOSTAT Detailed Trade Matrix were used. This database provides information on the physical volumes and monetary values of imports and exports of agricultural products. Its use makes it possible to assess not only the scale of external cereal supplies, but also their contribution to the formation of the country's overall resource availability [14].

Table 2 – Indicators of Cereal Imports and Their Role in the Resource Supply of the Republic of Tajikistan, 2023–2024

Indicator	2023	2024	Absolute change	Rate of change, %
Cereal imports, tonnes	1 175 745	1 334 115	+158 370	+13,47
Value of cereal imports, USD million	331,804	324,727	–7,077	-2,13
Average unit value, USD/tonne	282,21	243,40	–38,81	-13,75
Cereal imports per capita, kg/person	113,16	125,97	+12,81	+11,32
Ratio of imports to domestic production, %	84,26	85,94	+1,68 п.п.	-
Share of imports in gross grain resources, %	45,73	46,22	+0,49 п.п.	-

Source: compiled by the authors based on data from the FAOSTAT Detailed Trade Matrix [14] and World Development Indicators [12];

The data presented in Table 2 demonstrate the substantial role of external supplies in the formation of grain resources in the Republic of Tajikistan. In 2024, the physical volume of cereal imports reached 1,334.1 thousand tonnes, increasing by 158.4 thousand tonnes, or 13.47%, compared with 2023. At the same time, the total value of cereal imports decreased from USD 331.8 million to USD 324.7 million, or by 2.13%. As a result, the average estimated unit value of imported cereals declined from USD 282.21 to USD 243.40 per tonne, representing a decrease of 13.75%. This indicator is calculated as the ratio of the total value of cereal imports to their physical volume and should not be interpreted as the market price of any individual type of cereal product.

The significance of the foreign trade factor is also confirmed by FAO estimates: imports account for more than half of Tajikistan's domestic cereal requirements, while wheat represents more than 90% of total cereal imports [15].

On a per capita basis, cereal imports increased from 113.16 kg in 2023 to 125.97 kg in 2024, or by 11.32%. At the same time, the ratio of imports to domestic cereal production rose from 84.26% to 85.94%, while the share of imports in estimated gross grain resources increased from 45.73% to 46.22%. These ratios confirm the substantial compensatory role of imports in supplying the domestic market with grain resources. However, significant dependence on external supplies also increases the sensitivity of the national food system to changes in global market conditions, import costs, exchange-rate movements, and the reliability of transport and logistics channels. Therefore, the assessment of the economic sustainability of food supply should take into account both the production potential of domestic agriculture and the scale and economic characteristics of external trade-based supply.

For the quantitative assessment of overall resource availability, the following analysis uses indicators of estimated gross grain resources. Based on the proposed formula, gross grain resources in 2023 amounted to:

$$GR_{2023} = 1\,395\,442 + 1\,175\,745 - 18 = 2\,571\,169$$

Per capita, t/person:

$$GRPC_{2023} = \frac{2\,571\,169}{10\,389\,799} = 0,2475$$

This corresponds to 247.5 kg per capita. For 2024, gross available grain resources amounted to, tonnes:

$$GR_{2024} = 1\,552\,464 + 1\,334\,115 - 2 = 2\,886\,577$$

Per capita grain resource availability was, t/person:

$$GRPC_{2024} = \frac{2\,886\,577}{10\,590\,927} = 0,2726$$

The resulting value corresponds to 272.6 kg of grain resources per capita.

Consequently, gross grain resources increased by approximately 12.3% in 2024 compared with 2023, while the per capita indicator rose by about 10.1%. Thus, during this period, growth in domestic production was supplemented by an increase in imports, allowing total resource availability to expand more rapidly than the population.

However, the structure of these resources highlights the substantial role of the external market. In 2024, the volume of cereal imports was equivalent to approximately 86% of domestic cereal production, while their share in the estimated gross grain resources reached about 46%. Imports therefore perform an important compensatory function, but at the same time create another type of economic risk. The sustainability of food supply becomes dependent not only on the condition of domestic agriculture, but also on world market prices, the purchasing capacity of the economy, exchange-rate movements, transportation costs, and the reliability of trade channels.

Accordingly, an increase in imports cannot be interpreted unequivocally as either a deterioration or an improvement in food supply sustainability. From the perspective of physical availability, additional imports can compensate for insufficient domestic production. From the perspective of economic sustainability, excessive dependence on imports may increase exposure to external price and logistics shocks. Therefore, it is analytically important to distinguish between self-sufficiency based on domestic production and overall resource availability that takes foreign trade into account.

The results also confirm the need for a separate analysis of climatic factors. Since cereal-growing areas have changed only slightly in recent years, while most of the increase in production has been driven by higher yields, climate-induced fluctuations in crop yields may have a stronger effect on food availability than changes in land area. Rising temperatures and more frequent periods of extreme heat increase the importance of efficient irrigation and water-saving technologies. The World Bank directly links the modernization of Tajikistan's irrigation infrastructure with greater climate resilience in agriculture and improved food security [16].

From an economic perspective, this means that the principal reserve for improving domestic food supply lies not in the mechanical expansion of cultivated areas, but in increasing the productivity of the resources already in use. Given persistent land constraints, the sustainability of the system will depend on its ability to maintain rates of yield growth that exceed, or at least offset, the increase in demographic pressure and potential climate-related losses.

Several limitations should be taken into account when interpreting the results. First, data for 2020–2024 make it possible to characterize the current situation, but are insufficient for the reliable identification of long-term econometric relationships. Second, the gross grain resources indicator does not account for changes in stocks or the different end uses of grain. Third, national and international statistical databases may apply different methodologies and may subsequently revise previously published data. Therefore, when constructing a time series for 1993–2024, it is essential to use a single internally consistent FAOSTAT series and to avoid mechanically combining values from different statistical revisions.

Conclusion

The analysis demonstrates that the economic sustainability of food supply in the Republic of Tajikistan should be assessed not only on the basis of changes in gross agricultural production, but also by taking into account the relationship between production capacity, population size, foreign trade flows, and climatic constraints.

During 2020–2024, cereal production increased considerably faster than harvested area. While harvested area expanded by approximately 1%, cereal yield increased by almost 17%, and gross production rose by more than 18%. This indicates the predominance of an intensive pattern of production growth and confirms the key role of yield improvement in further increasing the domestic supply of grain.

At the same time, the country's population increased by approximately 8.6% over the period under review. As a result, the dynamics of per capita grain production were more volatile than those of gross production: increases in the per capita indicator in some years were followed by declines in others. Consequently, population growth partially absorbs the effect of expanding agricultural production and should therefore be considered an independent source of pressure on the national agri-food system.

Calculations incorporating foreign trade show that imports represent a significant component of Tajikistan's grain resource base. In 2024, cereal imports reached 1.334 million tonnes, while domestic production amounted to 1.552 million tonnes. The estimated volume of gross available grain resources was approximately 2.887 million tonnes, or 272.6 kg per capita. This is substantially higher than the indicator calculated on the basis of domestic production alone, which amounted to 146.6 kg per capita. Therefore, excluding imports from the analysis would provide an incomplete representation of the actual resource base of food supply.

At the same time, the substantial role of imports creates a tension between physical and economic sustainability. On the one hand, external supplies make it possible to compensate for insufficient domestic production. On the other hand, they increase the exposure of the food system to international market conditions, prices, exchange-rate developments, and transport and logistics risks. Therefore, the strategic objective should not be the complete substitution of imports at any cost, but rather the formation of a rational balance between improvements in domestic productivity and the use of foreign trade mechanisms to stabilize food supply.

Given the limited scope for expanding cereal-growing areas, yield growth remains the principal domestic reserve for strengthening sustainability. In this context, particular importance should be attached to improving irrigation efficiency, introducing water-saving technologies, upgrading agricultural practices, using more resilient crop varieties, reducing production losses, and adapting agricultural production to changing climatic conditions.

The proposed methodology makes it possible to quantitatively determine the level of cereal yield required to offset population growth and, when a scenario-based climate coefficient is incorporated, to estimate the additional productivity increase needed to compensate for potential climate-related losses. Thus, the economic sustainability of food supply is viewed not as a static condition, but as the capacity of the agri-food system to maintain an acceptable level of resource availability for the population under the simultaneous influence of demographic, production, foreign trade, and climatic factors.

Further research should be based on a single, internally consistent time series for 1993–2024, incorporating cereal production, harvested area, crop yields, population size, imports and exports, as well as temperature and precipitation indicators from NASA POWER. This would make it possible to move from the structural patterns identified in the present study to an econometric assessment of the sensitivity of cereal yields to climate change and to the development of food supply scenarios for Tajikistan under alternative trajectories of population growth.

Conflict of interest: The authors declare no conflict of interest.

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