KAPITEL 2 / *CHAPTER 2* [2]
COMPARATIVE ANALYSIS OF THE EFFICIENCY OF SORGHUM CULTIVATION IN UKRAINE AND LEADING COUNTRIES WORLDWIDE

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Introduction.

Climate change is one of the most critical challenges of our time. Climate shifts in Ukrainian agriculture are primarily driven by global warming, the direct consequence of which is drought. Droughts can significantly impact crop yields, as weather factors can cause yield fluctuations of up to 50%, particularly in the southern regions of the country. Therefore, one of the primary tasks for agricultural producers is to enhance existing crop cultivation technologies and develop new measures to ensure the stability of the farm sector and reduce its dependence on climatic factors [1, p. 139; 2, p. 14].

Global warming can have a profound impact on the cultivation of grain crops. In particular, the increase in air and soil temperatures may lead to reduced yields and lower crop quality. High temperatures can cause fires that destroy fields and harvests. Moreover, global warming can lead to decreased precipitation, which negatively impacts plant growth and development throughout the vegetation period [3, p. 18; 4, p. 173; 5, p. 6].

It is also worth noting that global warming may lead to a decrease in groundwater and surface water levels, which can reduce both the yield and quality of cultivated crops. The reduction of water levels may also lead to the expansion of saline soils and other soil degradation issues.

Analysis of Recent Studies and Publications

Under arid climatic conditions, grain crops generally require and utilize significantly less water than in years with normal optimal moisture levels. Since water is a limited resource, farmers must ensure the efficient use of water for grain crops. This can be achieved through the use of drip irrigation systems, which allow precise control of the amount of water supplied to plants. In the absence of irrigation, it is

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advisable to apply other methods, such as conserving water in the soil and enhancing its effective uptake by plants. This is achieved through mulching and increasing the organic matter content in the soil. Another critical factor is the selection of drought-tolerant crops with high potential for efficient water use, such as sorghum [6, pp. 39–40; 7, p. 14, 8].

Sorghum is one of the most drought-resistant crops that can be grown under limited water supply conditions. It has a well-developed root system capable of providing plants with adequate moisture. Additionally, sorghum has a high water-saving potential due to its ability to retain water in its leaves and stems [9, p. 212].

Moreover, sorghum exhibits a high level of resistance to diseases and pests, making it less susceptible to climate change and ensuring higher yields. Equally important is the fact that sorghum grain has a high energy value, making it attractive for use in feed production, as well as in the production of biofuels and other products [10, p. 58; 11, p. 185].

Among the many crops used for ethanol production, sorghum is considered one of the most promising [12, p. 13; 14]. It has high photosynthetic efficiency and can quickly form substantial, energy-rich biomass. Furthermore, a significant portion of the plant's energy is contained in compounds that are easily converted into ethanol. Sweet sorghum contains a complete complex of sugars and grain starch. The starch yield from sorghum grain is significantly higher than that from corn (for example, 74% compared to 67% for corn). The alcohol yield from sweet sorghum is also substantially higher. Future bioethanol production is expected to rely increasingly on this crop [14]. If both straw and grain are used for bioethanol production, up to 7,000 liters of bioethanol per hectare per year can be obtained. Moreover, sorghum is well adapted to cultivation across most regions of Ukraine [15–21].

Thus, sorghum is an essential crop for ensuring food security under conditions of climate change and increasing aridity.

Problem Statement

The purpose of this research was to analyze the dynamics of sorghum grain production, based on areas under cultivation and crop yields, in Ukraine, leading

sorghum-producing countries, and globally, for the period from 2000 to 2023.

Presentation of the Main Research Material

As sorghum continues to gain popularity, the cultivated area under this crop is increasing. In terms of production volume, sorghum ranks fourth globally, after wheat, maize, and rice. According to FAOSTAT data for 2023, the largest producers of sorghum are located in Africa, which is the leading region with the most extensive areas devoted to its cultivation (Fig. 1).

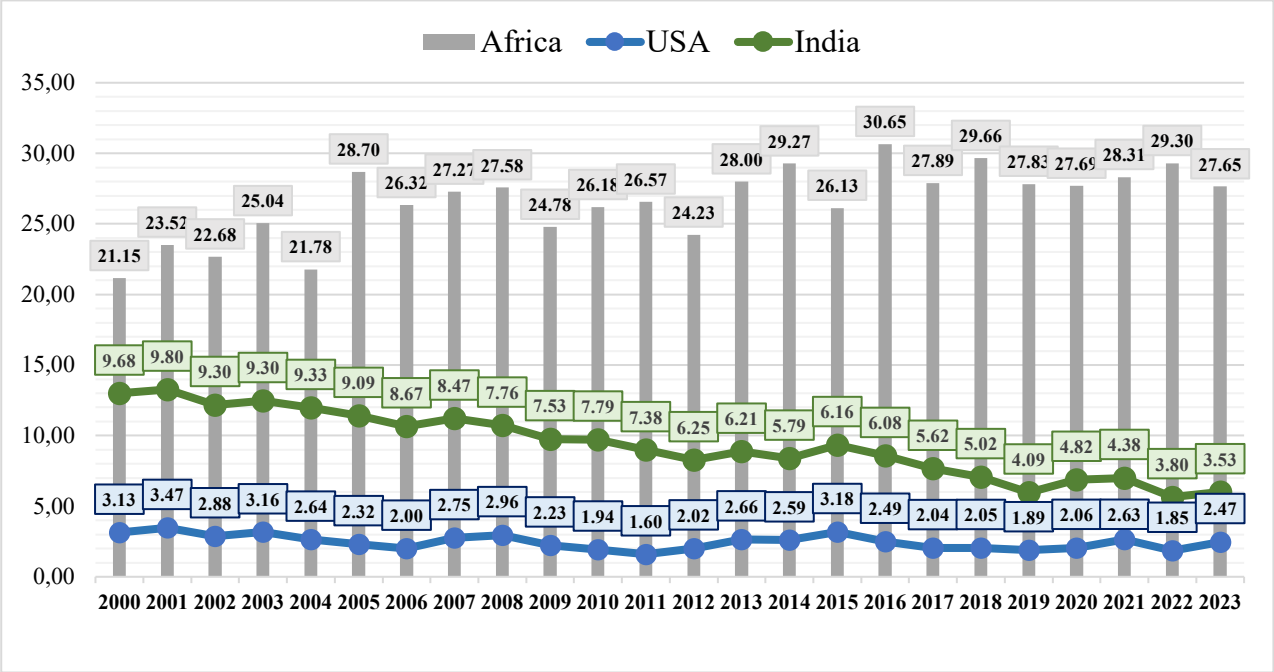

Figure 1 - Areas under grain sorghum cultivation in Africa, India, and the USA, million ha

source: FAOSTAT, 2025

In 2000, the area under sorghum cultivation was 21.15 million hectares, and a gradual expansion was observed in subsequent years, reaching 30.65 million hectares by 2017. After that, the area under sorghum stabilized somewhat, remaining within the range of 28–29 million hectares.

In Australia, the area under sorghum cultivation fluctuated between 0.5 and 1.0 million hectares, with notable declines observed in 2009 (0.5 million ha) and 2018–2020 (0.2–0.55 million ha) (Fig. 2). The maximum area was recorded in 2007, 0.94

million ha, indicating an expansion of production during years with favorable moisture conditions. In subsequent years, however, the sown areas decreased due to frequent droughts typical of the country's northern regions.

For Ethiopia, sorghum production has been characterized by a significantly higher and more stable cultivation level, ranging from 1.1 to 1.9 million hectares. The most significant areas were observed between 2011 and 2013 (1.9–1.92 million ha), after which the indicator remained consistently high (1.7–1.9 million ha) until 2019. In 2023, the area under sorghum cultivation in Ethiopia was 1.48 million hectares, while in Australia, it was 0.70 million hectares, which is approximately half the size.

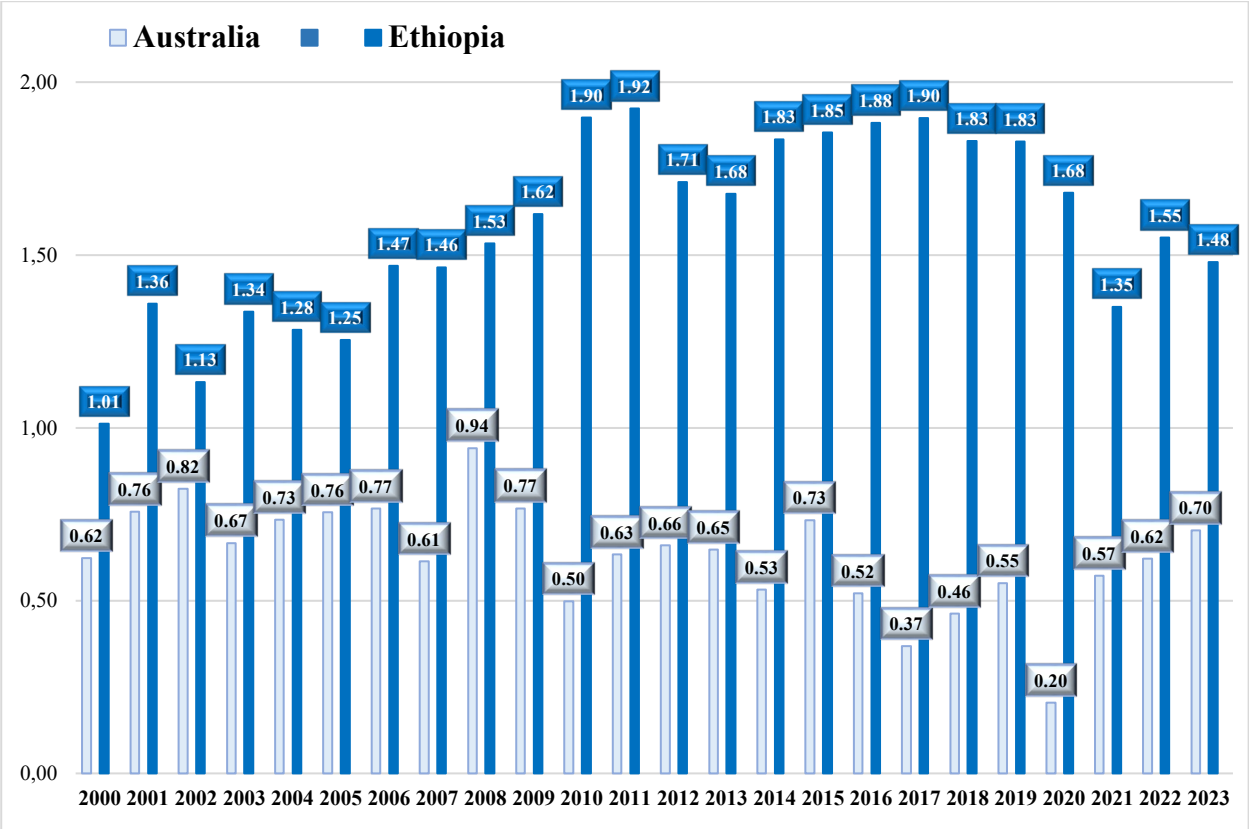

Figure 2 - Areas under grain sorghum cultivation in Australia and Ethiopia, million ha

source: FAOSTAT, 2025

In India, there has been a gradual decline in sorghum cultivation areas –from 9.86 million hectares in 2000 to 3.53 million hectares in 2023. This decline is primarily attributed to changes in cropping structures and a shift by farmers toward more

profitable crops.

In the United States, sorghum areas have remained relatively stable, ranging from 2.3 to 4.6 million hectares, with minor fluctuations from year to year.

Globally, in recent years, a downward trend in sorghum cultivation areas has been observed, driven by economic, climatic, and market factors (Fig. 3). One of the key reasons is the decrease in the crop's competitiveness compared to corn and wheat, which provide higher yields and have a more consistent market demand.

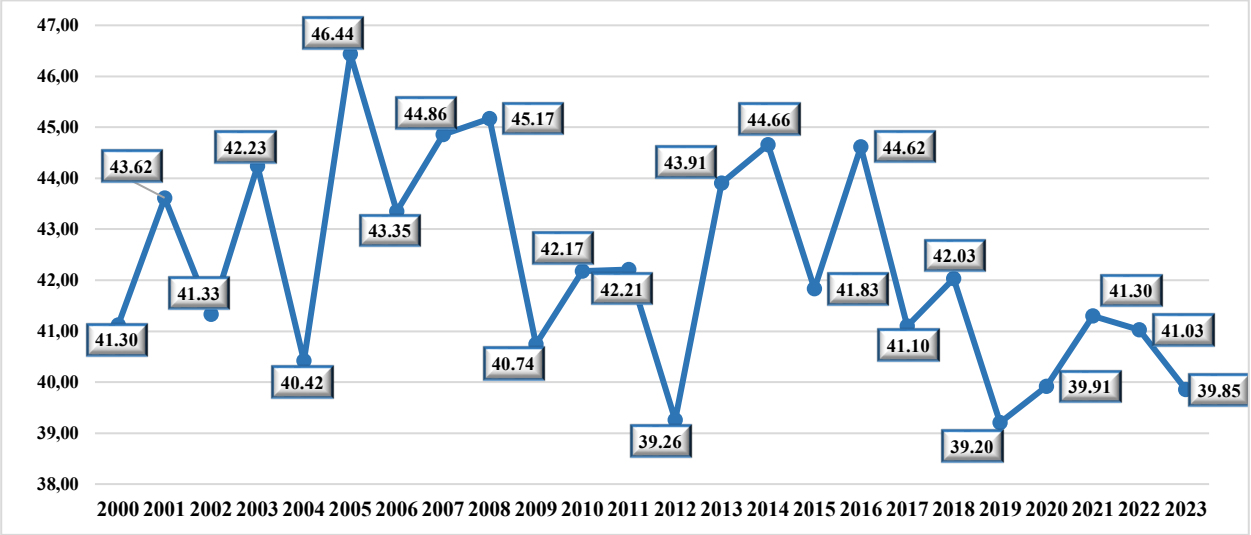

Figure 3 - Grain sorghum sowing areas worldwide, million ha

source: FAOSTAT, 2025)

Climate change, exceptionally prolonged droughts, and extreme temperature events have led to unstable yields, even for drought-tolerant crops like sorghum, thereby reducing the economic attractiveness of its production. Furthermore, demand for sorghum in the feed and food industries has declined as higher-yielding crops have replaced it.

Nevertheless, sorghum remains a promising crop for regions with limited water availability, owing to its drought resistance, adaptability, and ability to produce stable yields on low-fertility soils.

The largest grain sorghum sowing area in Ukraine was recorded in 2012, amounting to 136.9 thousand hectares. Afterward, the area steadily declined, and in

recent years, from 2018 to 2021, it fluctuated between 41.7 and 47.2 thousand hectares (Fig. 4). In 2021, the sorghum sowing area reached 41.7 thousand hectares, which is 2.9 times larger than the area sown in 2000.

The reduction of grain sorghum sowing areas in Ukraine during 2022–2023 was caused by a combination of military, economic, and agro-climatic factors that significantly affected agricultural production. First of all, the hostilities and occupation of parts of the southern and eastern regions – including Mykolaiv, Kherson, and Zaporizhzhia oblasts – resulted in the loss of large areas of agricultural land traditionally used for sorghum cultivation. Due to mine contamination and the threat of combat operations, sowing campaigns in these regions were wholly or partially disrupted.

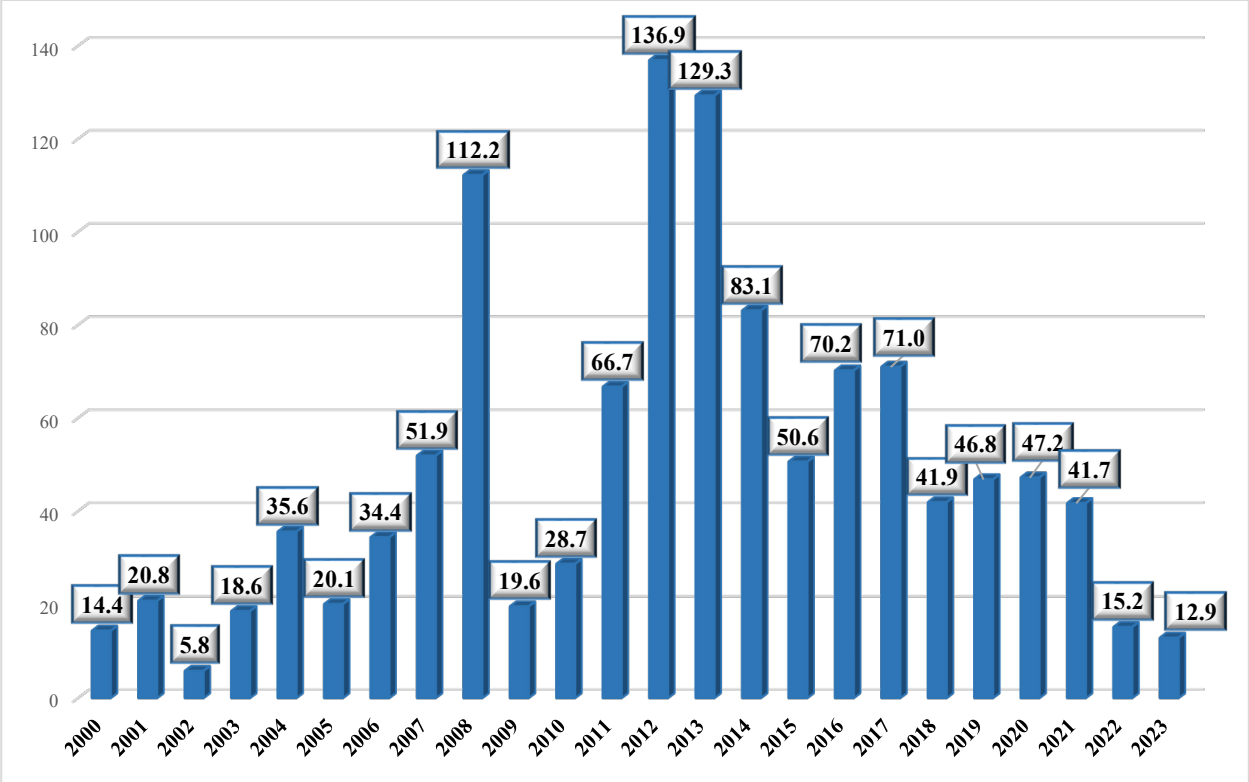

Figure 4. Grain sorghum sowing areas in Ukraine, thousand ha

according to FAOSTAT, 2025

An additional negative factor was the disruption of logistics routes and the blockade of seaports, which limited export opportunities and reduced the profitability

of production. As a result, farmers shifted their focus to more marketable crops such as wheat, barley, and sunflowers, which have more stable sales channels. Moreover, the increase in fuel, fertilizer, and seed prices, along with resource shortages under wartime conditions, led to higher production costs, forcing producers to reduce areas under less profitable crops, including sorghum.

To some extent, unfavorable weather conditions also contributed to the decline in sorghum planting areas, as extremely high temperatures and a lack of rainfall during critical growth periods in southern regions negatively affected production. Altogether, these factors led to a temporary decrease in farmers' interest in sorghum cultivation, despite its drought tolerance and adaptability to the conditions of the Southern Steppe of Ukraine.

It is worth noting that increased yields partly offset the decline in planting areas. Analysis of sorghum yield data in Ukraine since 2000 shows a generally upward trend, reaching a maximum of 4.63 t/ha in 2018 (Fig. 5). On average, during the study period, yield levels were around 2.5 t/ha, showing improvement in recent years due to the introduction of new hybrids, irrigation systems, and optimized mineral nutrition.

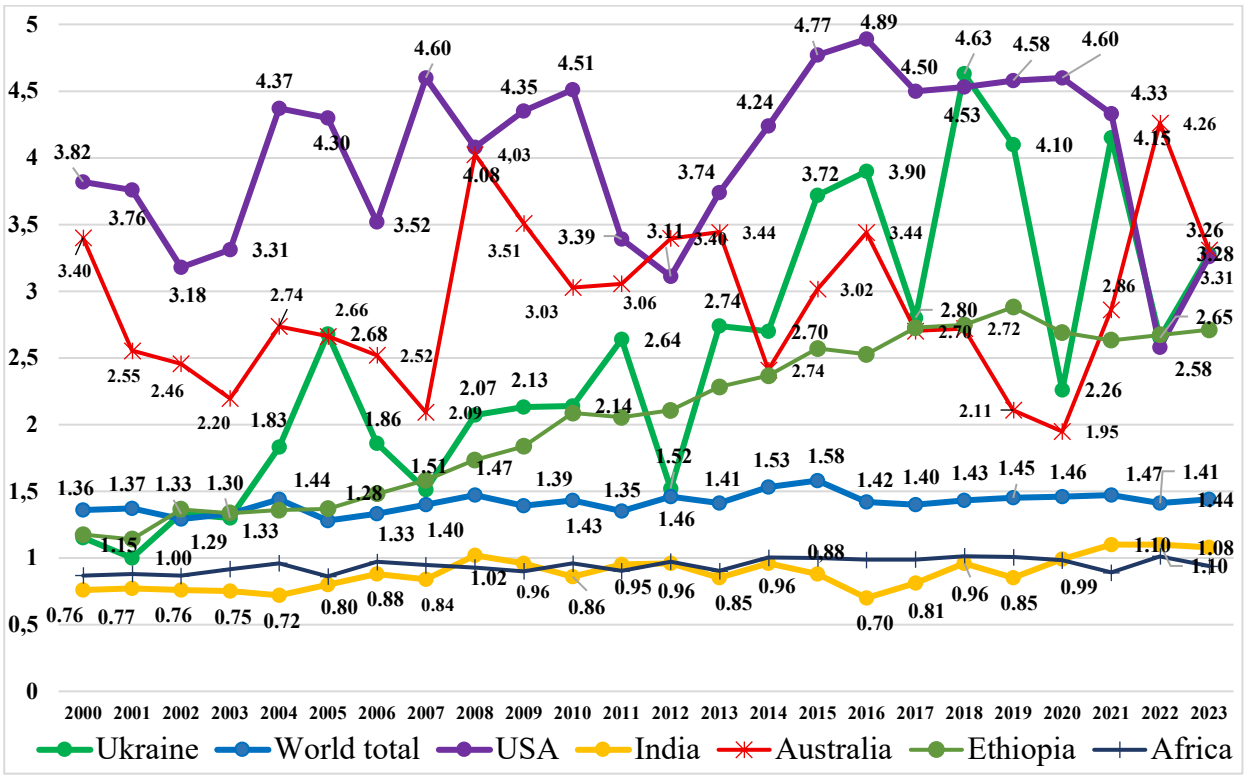

Figure 5 - Grain sorghum yield, t/ha

according to FAOSTAT, 2025

Globally, sorghum yield averaged 1.3–1.5 t/ha and remained relatively stable throughout the period. The highest yields were achieved in the United States (3.1–4.9 t/ha), due to the high level of production technology, use of intensive hybrids, and efficient fertilization and irrigation systems. In India, yields were significantly lower (0.7–1.1 t/ha) due to arid conditions, the predominance of traditional varieties, and low levels of agricultural technology.

High productivity was also recorded in Australia (2.1–4.4 t/ha), where sorghum is mainly grown on irrigated land. In Ethiopia and other African countries, yields remained the lowest (1.1–2.7 t/ha), although a gradual increase has been observed due to the introduction of modern hybrids and improved farming practices.

Thus, it can be summarized that sorghum productivity depends on the level of technological support, moisture availability, and adaptability of hybrids to climate conditions. Over the past decade, Ukraine has significantly improved its performance, reaching yield levels close to those of global leaders.

According to expert assessments, Ukraine has been among the top five global sorghum exporters for several years, despite relatively small sowing areas. However, in terms of production volume and cultivation area, the country does not yet rank among the top ten producers. According to the Ministry of Agrarian Policy and Food of Ukraine, the country ranks third globally in sorghum exports. In the 2019/2020 marketing year, Ukraine exported approximately 1.3 million tons of sorghum, accounting for around 8% of global sorghum exports. The leading importers of Ukrainian sorghum are China, Spain, and Italy.

The largest importers of sorghum grain from Ukraine are European countries – Spain, Italy, and Poland. In recent years, Ukraine has also exported sorghum grain to Israel and Turkey. According to Ukrainian experts, the country has promising prospects for expanding sorghum exports, particularly given that the primary consumers of sorghum grain are located in the Middle East, Africa, and the European Union. Ukraine has a more favorable geographical location than the world's leading sorghum producers – the USA, India, Mexico, and Argentina. It is also predicted that, in terms of export potential, China is the most promising market for Ukraine.

The primary reasons for the currently underdeveloped sorghum market in Ukraine are the low awareness of producers regarding its cultivation technology, the underdeveloped processing and marketing infrastructure, and significant fluctuations in the profitability of growing this crop. Nevertheless, given the rapid climate changes in Ukraine and worldwide, the growing deficit of natural moisture, and the ability of this crop to maintain stable productivity on various soil types – that is, its unpretentiousness to growing conditions – analysts and specialists increasingly assert that under these circumstances Ukrainian agricultural producers will need to diversify their production and reorient towards new, drought-resistant crops such as sorghum.

Knowledge of the total gross harvest volume is essential for the country's economy and financial policy. The assessment of the national economic situation, particularly the gross harvest volume, is one of the key indicators of economic development, as it enables the evaluation of the overall condition, production volume, sales, and profitability of the agricultural sector.

It is worth noting that the gross grain harvest of sorghum in Ukraine has been steadily increasing over the past twenty years. However, it remains significantly lower compared to the world's major producing countries (Table 1).

The dynamics of sorghum gross yields demonstrate dependence on yield levels and the area under cultivation. Between 2000 and 2003, the total sorghum harvest in Ukraine was relatively low, ranging from 7.7 to 24.0 thousand tons per year. However, a steady increase was observed after 2010. The highest harvest volumes were recorded in 2013 (354.4 thousand tons), which corresponded with the highest yield levels. Considerable sorghum grain harvests were also obtained in 2008 and 2016. It should be emphasized that the gross harvest largely depends on yield levels. For example, in 2016, the average sorghum grain yield in Ukraine reached 3.9 t/ha, whereas in 2008, it was significantly lower at 2.07 t/ha; however, the cultivated area was 112.2 thousand ha in 2008 and 70.2 thousand ha in 2016. After 2019, production declined due to increasing aridity in the southern regions and a reduction in sowing areas.

Global sorghum production has remained within the range of 55–68 million tons, with the United States, Africa, and India leading the way. The African continent

consistently accounts for almost half of global production, although the average yield remains low (0.9–1.1 t/ha), mainly due to the extensive nature of farming practices.

Table 1 - Dynamics of gross sorghum grain production in Ukraine, the world, the USA, and India, thousand tons (according to FAOSTAT, 2022)

Year	Ukraine	World total	USA	India	Africa	Ethiopia	Australia
2000	16.5	55821.0	11951.9	7529.4	18366.0	1188.1	2115.9
2001	20.7	59789.8	13057.2	7556.8	20709.1	1548.7	1935.1
2002	7.7	53442.8	9162.5	7070.0	19636.4	1546.2	2020.8
2003	24.0	58852.7	10445.4	7012.4	22933.3	1784.3	1464.5
2004	65.0	58090.2	11522.1	6681.3	20903.3	1742.5	2009.4
2005	53.9	59557.7	9976.0	7244.3	24737.2	1716.0	2010.6
2006	63.9	57702.3	7031.7	7629.6	25534.0	2173.6	1932.4
2007	78.2	62756.6	12635.7	7150.8	25785.5	2316.0	1283.0
2008	231.8	66350.3	12087.3	7925.6	25616.1	2659.1	3789.9
2009	41.7	56742.2	9693.2	7245.6	22295.7	2971.3	2691.8
2010	61.4	60181.4	8775.2	6698.2	25073.3	3959.9	1507.6
2011	175.9	56808.0	5410.3	7003.1	23992.1	3951.3	1934.5
2012	208.5	57321.0	6293.0	5980.0	23582.9	3604.3	2238.9
2013	354.4	61894.9	9965.7	5280.0	25285.4	3828.9	2229.7
2014	224.2	68300.9	10987.9	5540.0	29321.9	4339.1	1282.0
2015	188.3	65939.2	15158.2	5450.0	26111.8	4765.6	2209.2
2016	273.7	63385.8	12199.2	4240.0	30237.2	4752.1	1790.6
2017	198.5	57593.4	9192.0	4567.9	275576.0	5169.3	994.0
2018	194.0	60032.3	9271.1	4803.4	30031.7	5024.4	1257.2
2019	192.0	56706.0	8673.5	3475.1	28025.6	5265.6	1160.5
2020	106.6	58920.8	9473.6	4772.1	27230.5	4517.4	397.5
2021	173.2	60908.0	11374.9	4812.1	25192.0	3553.7	1639.0
2022	40.3	57660.4	4770.0	4150.6	29655.9	4140.0	2648.1
2023	42.34	57298.3	8071.1	3814.2	25954.5	4010.0	2326.3

In Australia, high yield levels (2.5–4.3 t/ha) are accompanied by significant fluctuations in gross harvests, primarily because of the strong dependence on rainfall. Meanwhile, Ethiopia has shown steady growth in both yield (from 1.1 to 2.7 t/ha) and gross harvest (reaching 5.2 million tons in 2019), indicating the adoption of improved technological approaches and better agronomic practices.

Thus, it can be concluded that the main factors determining sorghum yield and production volume include hydrothermal conditions, technological elements (such as fertilization systems), and the use of adapted hybrids. Ukraine demonstrates a clear

trend toward improving the efficiency of sorghum cultivation, making it a promising grain and forage crop for areas with a high risk of agriculture.

Conclusions and Recommendations

The conducted analysis shows that grain sorghum is one of the leading crops in global agriculture, ranking fourth in total sown area after wheat, maize, and rice. Between 2000 and 2023, global sorghum cultivation areas remained relatively stable at 28–30 million hectares, although the growth rate of production has slowed due to economic challenges and climatic changes. Nevertheless, sorghum continues to play a strategic role in regions with water scarcity, owing to its drought tolerance and adaptability to extreme conditions.

In Ukraine, the dynamics of sorghum production have shown considerable fluctuations. The largest sown area was recorded in 2012 (136.9 thousand ha), after which it declined due to military actions, economic instability, and climate risks. Despite these challenges, sorghum yield has shown a steady upward trend — from 1.5 to 2.0 t/ha in the early 2000s to over 4.0 t/ha in 2018. This improvement reflects the adoption of modern hybrids, enhanced fertilizer management, and broader implementation of irrigation technologies.

An analysis of gross sorghum grain harvests also indicates a gradual increase over the past two decades, with peak production recorded in 2013 (354.4 thousand tons). Although these figures remain lower than those of the world's leading producers (the USA, India, and African countries), Ukraine ranks among the top three global exporters of sorghum. The leading importers of Ukrainian sorghum grain are EU countries, China, and Turkey, highlighting the high export potential of this sector.

Therefore, sorghum is an up-and-coming crop for the further development of Ukraine's agricultural sector, especially under conditions of climate change and increasing water scarcity. Expanding the area under sorghum cultivation, improving production technologies, and developing processing and marketing infrastructure can significantly enhance national food security and Ukraine's export potential.