

Global barley production 2025–2035: Forecasting market shifts and policy implications for emerging producers*

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Abstract: Barley, which holds a significant share among cereals, is a strategic crop for the feed and food industries as well as the beverage sector. Adaptable to Türkiye's climatic and soil conditions, barley occupies a noteworthy position in agricultural production systems due to its production volume and diversity of uses. With the growth of the livestock sector, the importance of barley in the compound feed industry has increased; its high energy value and good digestibility have made it a preferred raw material. In the food industry, barley is used in the production of traditional and functional products owing to its richness in dietary fiber. In recent years, with the growing trend toward healthy eating, the consumption of barley flour, bran, and whole grain form has become more widespread. The main objective of this study is to generate production forecasts for the 2025–2035 period using the production data from 1961 to 2023 of prominent barley-producing countries around the world. In the study, the most suitable time series model (ARIMA) was identified for each country, and forecasts for future production were made accordingly. The findings reveal that the center of production power in global barley cultivation is shifting geographically from the west to the east and towards the southern hemisphere. Countries such as Türkiye, Russia, and Australia are expected to increase their production shares, whereas traditional producers like the United States, Germany, and Canada are projected to experience a decline. It is anticipated that Türkiye will hold a more prominent position in global production in the future. The findings clearly indicate a shift in barley global production. While countries traditionally known for barley production, such as the United States, Germany, Canada, the United Kingdom, and Spain, are expected to see a significant decrease in their global production shares over the next decade, countries like Türkiye, Russia, Australia, and Ukraine are projected to achieve notable increases in production volume. Notably, Türkiye's share in global barley production is estimated to rise from 4% to 6%, signaling a strengthening of the country's position in the global barley market. This development presents strategic opportunities in terms of meeting domestic demand as well as increasing export potential. The forecasts obtained through the ARIMA model not only reflect production trends but also provide guiding data for decision-making processes of policymakers, investors, and sector stakeholders. Therefore, the outcomes of this study serve as a valuable reference for developing data-driven strategies in agricultural production planning.

Keywords: Agricultural marketing strategy, Agricultural policy, Forecasting, Barley production, ARIMA

Küresel arpa üretimi 2025-2035: Yükselen üreticiler için piyasa değişimlerinin tahmini ve politika etkileri

Öz: Hububat içerisinde önemli bir paya sahip olan arpa, başta yem ve gıda sektörü olmak üzere içecek sektörü açısından da stratejik bir üründür. Türkiye'nin iklim ve toprak koşullarına uyum sağlayabilen arpa bitkisi hem üretim hacmi hem de kullanım çeşitliliği bakımından tarımsal üretim sisteminde kayda değer bir yere sahiptir. Özellikle hayvancılık sektörünün büyümesiyle birlikte karma yem sanayiinde arpanın önemi artmış; yüksek enerji değerine sahip olması ve sindirilebilirliğinin iyi olması nedeniyle tercih edilirliliği yükselmiştir. Gıda sanayisinde ise arpa, lif bakımından zengin bir besin kaynağı olması nedeniyle geleneksel ve fonksiyonel ürünlerin üretiminde kullanılmaktadır. Son yıllarda sağlıklı beslenme eğilimlerinin artmasıyla birlikte arpa unu, kepeği ve taneli formda tüketimi yaygınlaşmaktadır. Yürütülen bu çalışmanın temel amacı, dünya genelinde öne çıkan arpa üreticisi ülkelerin 1961–2023 dönemine ait üretim verilerini kullanarak 2025–2035 dönemi için üretim tahminleri

oluşturmaktır. Çalışmada, her ülke için en uygun zaman serisi modeli (ARIMA) belirlenmiş ve bu doğrultuda geleceğe yönelik üretim öngörülmesi yapılmıştır. Elde edilen bulgular, arpa üretiminde üretim gücünün coğrafi olarak batıdan doğuya ve güney yarımküreye doğru kaymakta olduğunu göstermektedir. Türkiye, Rusya ve Avustralya gibi ülkelerin üretim paylarının artması dikkat çekerken, ABD, Almanya ve Kanada gibi geleneksel üreticilerin paylarında azalma öngörülmüştür. Türkiye'nin gelecekte küresel üretimde daha belirgin bir konumda yer alacağı tahmin edilmektedir. Elde edilen bulgular, dünya arpa üretiminin yön değiştirmekte olduğunu açıkça ortaya koymaktadır. Geleneksel üretici ülkelerden olan ABD, Almanya, Kanada, İngiltere ve İspanya'nın küresel üretimden aldığı payların önümüzdeki on yıllık dönemde önemli oranda azalacağı tahmin edilirken; Türkiye, Rusya, Avustralya ve Ukrayna gibi ülkelerin üretim hacimlerinde kayda değer artışlar olacağı öngörülmektedir. Özellikle Türkiye'nin dünya üretiminden aldığı payın %4'ten %6'ya yükselmesi, ülkenin küresel arpa piyasasındaki konumunu güçlendireceğine işaret etmektedir. Bu durum hem iç pazar ihtiyacının karşılanması hem de ihracat potansiyelinin artması açısından stratejik fırsatlar sunmaktadır. ARIMA modeliyle elde edilen öngörüler, yalnızca üretim trendlerini yansıtmakla kalmayıp, aynı zamanda politika yapımcılar, yatırımcılar ve sektör aktörleri için karar alma süreçlerinde yönlendirici veriler sunmaktadır. Dolayısıyla bu çalışmanın çıktıları, tarımsal üretim planlamasında veri temelli strateji geliştirme açısından önemli bir referans niteliği taşımaktadır.

Anahtar kelimeler: Tarımsal pazarlama stratejisi, Tarım politikası, Tahminleme, Arpa üretimi, ARIMA

1. Introduction

Cereals hold a strategic position in the agricultural sectors and economies of countries due to their role as staple food sources and their use as animal feed. Among globally significant cereals, barley (*Hordeum vulgare* L.) stands out for its high adaptability to various climatic conditions, short growth cycle, and wide range of utilization. These characteristics make it a prominent crop in global agriculture. Barley plays a critical role in both economic and environmental sustainability, as it enables viable agricultural production under limited water resources, especially in arid and semi-arid regions (OECD-FAO, 2022).

Globally, barley is utilized predominantly in industrial sectors such as animal feed and the food industry, rather than for direct human consumption. Approximately 70% of total global barley production is used in the feed sector as animal fodder (USDA, 2023). Both production and consumption levels fluctuate over time due to the influence of multifaceted factors such as climate change, input prices, agricultural subsidies, and trade policies (Alexandratos & Bruinsma, 2012).

Thanks to its agricultural characteristics and favorable ecological conditions, Türkiye holds a significant share in global barley production. According to data from the TÜİK (Turkish Statistical Institute), Türkiye produced approximately 9.2 million tons of barley in 2023, accounting for 10.7% of the country's total cereal production (TÜİK, 2023). In Türkiye, barley cultivation is predominantly concentrated in the Central Anatolia, Southeastern Anatolia, and Eastern Anatolia regions. Barley is a vital crop that meets approximately 90% of the country's demand for roughage and compound feed

in the livestock sector, serves as a raw material for the malt industry, and, in recent years, has gained increasing potential for use in human nutrition (Dağ & Aktaş, 2024; Taşcı & Bayramoğlu, 2020). The feed industry, which accounts for most of the barley usage, is directly linked to the existence and scale of the livestock sector within the country. In this context, fluctuations in barley production over the years are closely associated with the development of both cattle and small ruminant farming. Particularly during periods of rising feed prices, variations in barley production can significantly impact both producer incomes and cost structures within the livestock sector.

In recent years, the fluctuations observed in barley production in Türkiye have largely stemmed from two main factors: the continuous increase in agricultural input costs and the occurrence of severe climatic events such as droughts and frosts particularly during the 2021–2022 period linked to global climate change. Like other agricultural products, these factors have led to a significant decline in barley yields. These adverse conditions have caused sudden and unstable increases in barley and consequently, feed prices, negatively affecting the livestock sector (TÜİK, 2023; FAO, 2023). As a result of these production fluctuations, Türkiye has occasionally been compelled to import barley in recent years to meet the rising domestic demand for animal feed.

The primary challenge facing the global barley sector over the next decade is the need to manage the supply-demand balance on three simultaneous fronts: (i) the pressure of climate uncertainty on yields, (ii) increasing demand driven by malt, feed, and functional food

applications, and (iii) rising price volatility. According to the OECD-FAO Agricultural Outlook 2024–2033, despite an anticipated annual growth of 1.1% in barley production by 2030, prices are expected to remain above inflation levels—mainly due to the concentration of demand in Asia and Africa (OECD/FAO, 2024). Similarly, a 2025 scenario study published in PNAS indicates that under the current climate trajectory (SSP2-4.5), yield growth may erode by 6–8%, and in some producing regions, may even turn into negative growth (Lobell and Di Tammasso, 2025). The ongoing expansion in the malt industry and in beta-glucan-rich functional foods is also expected to place additional demand-side pressure on the market, pushing the barley market—valued at USD 22.1 billion in 2025—up to USD 26.2 billion by 2030 (Arthur, 2024). This combined picture renders historical trend-based production projections insufficient and underscores the need for holistic approaches that incorporate climate, technology, and market dynamics.

These multilayered pressures in the barley sector have led to increasing calls in the literature to expand the set of variables shaping production forecasts. However, a significant portion of current research remains limited to univariate time-series approaches, and there are very few studies that integrate climate scenarios, demand segmentation, and policy instruments within a unified modeling framework. In the following literature review, recent studies will be systematically summarized—starting with global production and trade trends, followed by climate-based yield models, and finally demand-side dynamics. This will clearly reveal the theoretical and methodological gap that this study seeks to address.

1.1. Barley Cultivation and Its Significance

Barley, a member of the Poaceae (grass) family, is a cereal crop of strategic importance in global agriculture. According to 2023 data from the Food and Agriculture Organization of the United Nations (FAO), approximately 46.3 million hectares of land were harvested for barley worldwide, yielding around 146 million tons of production (FAO, 2023). Barley is a critical crop in both animal feed and industrial production particularly in the malt industry and beer manufacturing. The leading producer countries include Russia, Germany, France, and Canada.

The role of barley in agricultural production and national economies is undeniable. Although it primarily serves as a key input in the feed industry, barley flour,

oat blends for human consumption, and especially malting barley are also in high demand, particularly in the brewing industry. Malting barley generates higher added value compared to other varieties due to its stringent quality standards. Owing to its climatic adaptability, barley is well-suited for cultivation in arid regions and marginal agricultural lands. Compared to wheat, it requires less water, which makes it a valuable crop for enhancing sustainability in agricultural production under climate change-related risks. One of the key aspects of crop production is maintaining soil fertility and disrupting disease cycles, for which crop rotation is widely practiced. In this context, barley offers an advantage as it can be rotated with crops such as wheat and maize, making it a preferred option in cereal-based crop rotations.

According to 2023 data, Türkiye harvested 9.2 million tons of barley from 3.2 million hectares of land (TUİK, 2023). In terms of both cultivated area and production volume, Türkiye ranks among the top ten countries globally. However, to fully leverage this production potential in international markets, it is crucial to establish brand value, export high value-added products, and conduct targeted market analyses. While the majority of barley production is utilized as feed barley, malting barley production is particularly concentrated in the Thrace and Central Anatolia regions. Nonetheless, there is a growing need to increase the production of high-quality malting barley to meet the domestic malt industry's demand. Türkiye is a significant supplier of animal feed and food-grade barley exports to the Middle East and North Africa (MENA) region. However, to enhance its competitiveness and marketing power in the international arena, several structural reforms are needed—such as improving quality standards, establishing supply chains for the malt industry through contract farming, and modernizing the logistics infrastructure. Greater emphasis should be placed on branding strategies in export markets, and policies and strategies must be developed to strengthen the sector's competitive capacity.

In line with the strategic significance of barley at both global and national levels, the aim of this study is to analyze production changes in Türkiye, worldwide, and in major barley-producing countries during the period 1961–2023, and to provide production forecasts for the 2025–2035 period based on historical production trends. Given barley's production potential among

cereals and its diverse areas of utilization, this study seeks to project future production trends and thereby contributes to the development of scientifically grounded and data-driven agricultural policies. Moreover, integrating barley production trends with international marketing strategies holds potential for enhancing Türkiye's competitiveness in export markets. Supplying feed and malting barley varieties in accordance with market-relevant quality standards will support the achievement of a sustainable market share in foreign trade. The findings are expected to inform not only production planning but also the formulation of import and export policies, while contributing to the sustainability of supply-demand balance in the feed and food sectors. Furthermore, the study aims to offer strategic insights to policymakers and producers regarding the effectiveness of agricultural support mechanisms currently implemented across the country.

Barley holds a strategic position in the global grain economy, both in supporting food security and in meeting the raw material needs of the feed, malt, and functional food industries. With an annual production volume exceeding 150 million tons, barley ranks third after wheat and corn. Although it is a climate-resilient crop, its yield growth rate has slowed in recent years, and increasing commercial uncertainties have brought it under close scrutiny by policymakers and researchers. Price volatility in the barley market is also strongly influenced by stockpiling and trade policies implemented in exporting countries.

The existing literature predominantly forecasts barley's historical production patterns using univariate ARIMA models, rarely incorporating exogenous variables such as climate shocks, input prices, or trade constraints. For example, a recent study on grain production in Iraq showed that while the ARIMA approach provides reasonable accuracy for medium- to long-term forecasts, it falls short in generating scenarios that test policy alternatives (Abdulqader & Ahmed, 2025). Similarly, FAO's 2025 Cereal Supply and Demand Brief emphasizes that even with a global stock-to-use ratio of 29.8%, price fluctuations cannot be entirely mitigated, highlighting the need to incorporate stock management and trade flexibility into models (FAO, 2025). On the demand side, rapid transformation—particularly the growth in malt and beta-glucan-rich functional foods—necessitates the enhancement of production projections through ARIMAX, VECM, or machine learning-based hybrid models. In this way, the

interactions between climate adaptation, value chain optimization, and price stabilization policies can be analytically demonstrated. For instance, in their study, Rodini et al. (2024) used the ARIMAX model to estimate date production in Pakistan and examined the effects of climate-related variables such as fertilizer use, CO₂ levels, temperature, and precipitation. Their results demonstrated the potential of the ARIMAX model to analyze trends and accurately forecast future production. Integrating such models into barley forecasting efforts will help identify more effective strategies. In this context, the present study integrates time series projections of barley production with climate, demand, and trade indicators. The following section presents our data sources, variable selection, and model design in detail.

2. Materials and Methods

The primary data for this study were obtained from secondary sources, specifically the statistical databases of the Food and Agriculture Organization of the United Nations (FAO). A table was constructed showing annual barley production volumes worldwide and by country for the period between 1961 and 2023. The production quantities of the top 10 countries—accounting for 70% of total global production—were compared alongside global totals and those of other countries.

A time series is a dataset composed of numerical observations of a defined variable collected at generally equal intervals over time (Altuntaş & Özdemir, 2025). Time series analysis is used in studies to analyze trends, identify seasonality, and make forecasts.

The ARIMA model, a widely used method in time series analysis, consists of three main components. The ARIMA model is an integrated analytical approach that includes the autoregressive term (AR, p), the differencing required to achieve stationarity (Integrated, d), and the moving average component capturing the lag of forecast errors (MA, q). ARIMA is a model employed in time series analysis, and the procedure used to construct the model is known as the Box-Jenkins methodology. In this approach, the initial step involves testing for stationarity. If the series is found to be non-stationary—as ARIMA models require stationary data—differencing is applied. This involves computing the difference between consecutive observations in the time series. Once stationarity is achieved, the model specification step follows, during which the appropriate values of p , d , and q are selected.

Subsequently, the model parameters are estimated. In the final stage, the model's performance is assessed through residual diagnostics, and its validity is evaluated.

In this study, modeling and analysis were conducted using the barley production dataset covering the period from 1961 to 2023. During the specified timeframe, a total of 8,998,477,044 tons of barley were produced globally. Based on these data, production forecasts for the 2025–2035 period were generated using the ARIMA model.

To construct the comparison and forecast table, time series graphs of annual production volumes were examined for selected countries, the global total, and

the group labeled as "other countries." Initially, sequence charts were used for preliminary inspection. For non-stationary series, first-order differencing was applied. Autocorrelation (ACF) and partial autocorrelation (PACF) graphs were analyzed to determine stationarity, which guided the selection of appropriate ARIMA models. In determining the AR (p) parameter, the lag at which the partial autocorrelation dropped to non-significant levels was considered. The differencing order d was defined based on the number of differences required to achieve stationarity, and for the MA (q) component, the significant lags observed in the autocorrelation function were considered. These components were used to form model alternatives for each series.

Table 1. Model Selection Criteria and Results

Country/Region	Model	R-Squared (R ²)	MAPE*	BIC	Ljung-Box Q (p-value)
World	ARIMA (2,0,1)	0.787	6.364	18.994	0.628
Other Countries	ARIMA (2,1,1)	0.801	5.382	16.487	0.509
Russia	ARIMA (2,2,1)	0.728	17.322	18.15	0.216
Germany	ARIMA (1,1,2)	0.847	7.499	14.189	0.314
Canada	ARIMA (2,1,2)	0.657	13.83	15.237	0.882
France	ARIMA (3,1,3)	0.488	8.691	14.548	0.688
United Kingdom	ARIMA (1,0,2)	0.731	8.664	13.818	0.534
United States	ARIMA (0,1,0)	0.805	13.376	14.33	0.514
Spain	ARIMA (3,1,2)	0.561	11.45	15.638	0.631
Türkiye	ARIMA (1,1,0)	0.749	9.83	13.926	0.783
Australia	ARIMA (2,1,1)	0.845	16.854	14.774	0.224
Ukraine	ARIMA (2,0,0)	0.453	20.154	15.884	0.695

*MaPe ≤10 very good, 10-20 good

As shown in Table 1, the most appropriate ARIMA models were selected among the alternatives. The R² values indicate a strong fit between the data sets and the corresponding models, while the Mean Absolute Percentage Error (MAPE) values range between 5.382 and 20.154, suggesting that the level of error remains within an acceptable range. In terms of the Bayesian Information Criterion (BIC), the model with the lowest value was selected when compared with alternative models. Additionally, the Ljung-Box Q test results indicate no significant autocorrelation in the residuals, confirming the adequacy of the model fits across all-time series.

Table 1 below displays the results of the criteria used for estimating model parameters and evaluating residuals in the production forecasting process. Among these criteria, the R-squared (R²) value is particularly important. This statistic measures the extent to which a model explains the variability within the dataset and

indicates how well the time series data fit the model. A high R² value suggests a good model fit and is preferred for forecasting purposes. Given that the dataset covers an extensive annual timespan and that the absolute values of barley production are extremely high (measured in thousands of tons), absolute error metrics such as Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) were not used for model evaluation. Instead, the Mean Absolute Percentage Error (MAPE) was considered. A MAPE value below 10% is interpreted as "very good," while values between 10% and 20% are deemed "good." In this case, the MAPE value of 6.364% indicates a highly accurate model. The Bayesian Information Criterion (BIC) evaluates both model complexity and goodness of fit; lower BIC values are preferred when comparing models. The Ljung-Box Q test assesses whether there is autocorrelation in the residuals. A significance level of $p > 0.05$ suggests that the residuals are random and that

the model is appropriate implying the absence of autocorrelation in the model's residuals.

3. Results and Discussion

Between 1961 and 2023, total global barley production amounted to approximately 8,998,477 thousand tons. Using the ARIMA (2,0,1) model, the projected global production for the 2025–2035 period is estimated at 1,903,768 thousand tons.

Russia produced a total of 1,754.36 thousand tons of barley over the 62-year period from 1961 to 2023, accounting for 19% of global production during that time. The ARIMA (2,2,1) model was selected for forecasting the 2025–2035 period, and it is estimated that Russia will produce 423,127 thousand tons of barley, representing an increased share of 22% of global production.

Germany, which held an 8% share in global barley production between 1961 and 2023, is projected to produce 108,645 thousand tons between 2025 and 2035 according to the ARIMA (1,1,2) model. This suggests a decline in Germany's global share to 6% during that period.

Canada, with 631,170 thousand tons of production and a 7% share in global barley production between 1961 and 2023, is expected to experience a 2% decline in its share for 2025–2035. Using the ARIMA (2,1,2) model, total production for the forecast period is estimated at 102,062 thousand tons, corresponding to a 5% share globally.

France produced 630,366 thousand tons of barley from 1961 to 2023, holding a 7% share of global production. The ARIMA (3,1,3) model predicts that France will produce 146,961 thousand tons between 2025 and 2035, increasing its share to 8%.

The United Kingdom is one of the major barley producers, accounting for 5% of global production between 1961 and 2023. Based on the ARIMA (1,0,2) model, its share is expected to decrease to 4% over the 2025–2035 period.

Forecasting based on historical production data is critical for identifying trends and informing policy decisions. The United States, which held a 5% share similar to that of the UK during

1961–2023, is projected to experience a significant decrease to 2% in the 2025–2035 period, according to the ARIMA (0,1,0) model.

A similar trend is expected for Spain. Between 1961 and 2023, Spain produced 445,293 thousand tons of barley. The ARIMA (3,1,2) model forecasts that Spain will hold a 2% share in global production during 2025–2035.

Türkiye produced a total of 397,257 thousand tons of barley between 1961 and 2023, accounting for 4% of global output. According to the ARIMA (1,1,0) model, Türkiye is expected to produce 113,540 thousand tons from 2025 to 2035, raising its share to 6%.

Australia, a key barley producer in Oceania and a major supplier to East Asia and neighboring countries, held a 4% share of global production from 1961 to 2023. Based on the ARIMA (2,1,1) model, Australia is expected to produce 169,996 thousand tons in the 2025–2035 period, increasing its global share to 9%.

Ukraine, which gained independence in 1991 and began publishing official statistics in 1992, has established itself as a noteworthy barley producer with a 3% share of global output from 1992 to 2023. According to the ARIMA (2,0,0) model, it is forecasted to produce 82,387 thousand tons between 2025 and 2035, accounting for 4% of global production.

Finally, countries classified as "other countries"—those outside the group of top producers who accounted for approximately 70% of global production between 1961 and 2023—are projected to collectively produce 568,426 thousand tons of barley between 2025 and 2035. Their total share of global production is expected to decrease slightly, from 32% to 30%.

The "other countries" category presented in Table 2 includes all producers outside the top 10 countries that accounted for 70% of global barley production during the 1961–2023 period. The reason for excluding these countries from the analysis is either their lack of statistically significant production shares (for example, major producers like China play a marginal role in barley production) or the inconsistency of data (for instance, interrupted data series in some African countries). However, the decrease in their share of total production from 32% to 30% can be explained by two main factors:

Consolidation in production: The increasing shares of leading producers (Russia, Australia, Türkiye) have led to the relative shrinking of the "other countries" group.

Climate and economic vulnerabilities: Many countries in this group (e.g., in the Middle East and North Africa) are unable to sustain production growth due to water scarcity and deficiencies in agricultural policies.

Table 2. Global Barley Production (1961–2023) and Forecast for 2025–2035

Country/Region	Total Production (1961–2023) [1,000 tons]	Share (1961–2023)	Forecasted Production (2025–2035) [1,000 tons]	Forecasted Share (2025–2035)	Change in Share (%)
World	8.998.477	100%	1.903.768	100%	
Other Countries	2.893.816	32%	568.426	30%	-2%
Russia	1.754.361	19%	423.127	22%	+3%
Germany	676.740	8%	108.645	6%	-2%
Canada	631.710	7%	102.062	5%	-2%
France	630.366	7%	146.961	8%	+1%
United Kingdom	482.223	5%	84.782	4%	-1%
United States	463.361	5%	33.374	2%	-3%
Spain	445.293	5%	46.717	2%	-3%
Türkiye	397.257	4%	113.540	6%	+2%
Australia	342.454	4%	169.996	9%	+5%
Ukraine*	280.896	3%	82.387	4%	+1%

This table presents the total barley production volumes between 1961 and 2023, along with the projected production values for the 2025–2035 period. It also shows the share of global production accounted for by each country during these periods, highlighting how the top ten barley-producing countries are expected to perform in terms of their respective shares in the coming years.

Figure 1, presented below, illustrates the projected shares of global barley production for the 2025–2035 period. The figure clearly indicates that the balance of power in barley production is expected to shift over the next decade. While Russia is projected to maintain—and even strengthen—its position, an increase in the production share of countries categorized as “other” (i.e., those outside the top producers) is also anticipated.

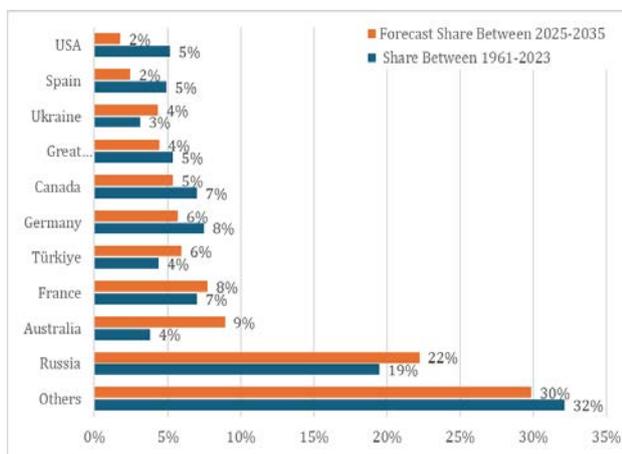


Figure 1. Estimated Barley Production Share Change Between 2025-2035 (%)

Figure 1 presents the projected changes in barley production shares for the 2025–2035 period, ranked

from highest to lowest. The most significant increase is expected in Australia, with a projected growth of 5%. Russia is anticipated to experience a 3% increase, followed by Türkiye with 2%, and Ukraine with a 1% rise in its share of global barley production.

4. Conclusion

The primary objective of this study was to forecast the total barley production volumes of the world’s leading producer countries for the 2025–2035 period based on historical data, and to identify future production trends. Additionally, the study aimed to assess potential shifts in the geographical distribution of production power and to evaluate the changing roles of key actors in barley production over time. Based on the analysis of data from 1961 to 2023, several conclusions have been drawn. Structural changes in global barley production are anticipated in the near future. In particular, Russia, Germany, and France are expected to remain prominent in terms of both historical and projected production over the next decade. However, a decline in production shares is forecasted for some traditional barley-producing countries, including Germany, Canada, the United Kingdom, the United States, and Spain. Therefore, it is expected that the balance of global barley production will undergo reconfiguration. As some countries’ shares diminish, other countries are likely to increase their contributions, leading to a shift in the overall structure of global barley production.

When evaluated by country, Russia is expected to remain a key player in barley production. Between 1961 and 2023, it accounted for 19% of global production and is projected to increase its share to 22%, maintaining its leading position. Türkiye, which

had a 4% share in the 1961–2023 period, is expected to increase its share to 6% in 2025–2035, indicating a relative rise in its production. With this increase, Türkiye is projected to surpass countries like Spain and the United States in production share.

In contrast, barley production in the United States is on a declining trend. Its 5% share is expected to drop to 2% in the 2025–2035 period. This decrease may be attributed to the country's shift toward other agricultural products, productivity challenges, substitution of feed barley with corn and soybean meal in livestock rations, a decrease in the number of livestock farmers, and shrinking demand from the alcoholic beverage industry (Bailey, 2024).

Ukraine, known as the grain basket of Europe and a major supplier to the Middle East, North Africa, and China, is anticipated to maintain its strategic role in global barley production and trade (World Economic Forum, 2023). Despite its significance, uncertainties remain due to seasonal supply fluctuations, changes in consumer demand, and price volatility.

Australia is projected to make significant advances in barley production between 2025 and 2035. Its share is expected to increase from 4% to 9%, driven by expanded cultivation areas and advances in irrigation technologies. The "Opportunities for the Australian Barley Market Toward 2030" report, published by the Australian Government's Grains Research and Development Corporation, highlights growing demand for new barley varieties and characteristics from markets such as China, Vietnam, South Korea, India, Japan, Saudi Arabia, Iran, Thailand, the Philippines, Indonesia, South America, and Sub-Saharan Africa. This underscores the importance of strengthening Australia's position in these regions. Thus, the projections in this study align with market forecasts (Raynes, 2021).

Spain is forecasted to experience a decline in barley production, with its share dropping from 5% to 2%. This is likely due to the country's Mediterranean climate, which causes high interannual variability in production. Additionally, a decrease in barley cultivation areas—partly replaced by olive groves—has been observed (Martínez-Moreno, 2024). Cammarano et al. (2019) also predict significant yield reductions in barley across the Mediterranean Basin due to climate change, supporting the projections presented in this study.

In the United Kingdom and France, no sharp changes are anticipated. This is consistent with existing literature. For example, Yawson et al. (2016) evaluated the potential impact of climate change on barley yields across 14 administrative regions in the UK. Their simulations, based on emissions scenarios for 2030–2040 and 2050, suggest stable yields in the near term but a substantial increase in the long term due to hydropower developments. In France, Reportlinker (2023) projects steady and modest growth in barley production between 2024 and 2028, with an expected annual growth rate of 0.34%.

Geographical analysis shows that European countries (Germany, UK, France, and Spain) collectively account for 20% of global production. Russia and Ukraine together represent 26%, emphasizing the prominence of Eastern Europe in barley production. These findings indicate that barley production will undergo not only quantitative growth but also significant geographical redistribution. The increasing prominence of Eastern Europe, the Asia-Pacific region, and select non-Mediterranean countries points to a future shaped by climate change, technological advances, and market demand. This transformation holds the potential to redefine competitive dynamics in global agriculture. Therefore, countries are advised to formulate strategies in both production planning and international trade.

For Türkiye, strategic preparation is imperative. Developing climate-resilient seeds and barley varieties will significantly enhance production capacity. The adoption and dissemination of precision agriculture practices, digital technologies, and sensor-based decision support systems should be prioritized. Such efforts can be implemented through regional and local collaborations with universities and research institutions. With its increasing barley production, Türkiye is expected to expand its export potential. Thus, it is recommended that market analyses of foreign trade partners be conducted. A comprehensive export strategy focused not only on quantity but also on value creation—through quality, standardization, logistics, and branding—will position Türkiye as a more sustainable and competitive actor in global grain trade. The projections presented in this study are vital for countries seeking to revise their agricultural production policies. For countries like Türkiye that are expected to increase their production share, it is strategically necessary to implement supportive agricultural policies, increase R&D investments, and

diversify export channels. Global trends in barley production also suggest that private sector stakeholders should reevaluate their investment decisions.

The projection results obtained in this study indicate that global barley production will show a significant upward trend during the 2025–2035 period. However, this growth trend will not be homogeneous across all countries; the findings suggest that production in some producing countries will remain stagnant or even decline. This situation implies that the regional impacts of climate change, differences in agricultural infrastructure, and the decisive role of policy interventions will influence production dynamics. The consistency of forecasts for some countries with reports from institutions such as the FAO and OECD supports the reliability of time series models under certain conditions. Nevertheless, univariate ARIMA models based solely on historical data offer a limited policy perspective as they do not account for external factors such as climate shocks, volatility in input prices, and demand-driven fluctuations. It is therefore recommended that future studies in this direction consider these limitations. Indeed, the FAO's 2025 supply-demand analyses highlight that current stock-to-use ratios fail to dampen market volatility, underscoring the need for more flexible and multivariate modeling approaches.

Within this framework, the study's findings suggest three key policy recommendations for the future of the barley sector. First, it is a strategic necessity to concentrate on production in regions least affected by climate change and to promote adaptive varieties in these areas. Second, considering the value chain's shift towards malt and functional food segments, production planning should incorporate not only quantity but also quality and processability criteria. Third, to establish a market structure resilient to external shocks, a more holistic approach to stock management, export quotas, and price stabilization mechanisms is essential. Furthermore, this study focused exclusively on production volume and did not integrate variables such as productivity, cultivated area, and technological factors into the model. Therefore, future research is encouraged to employ multivariate forecasting systems using hybrid modeling techniques like ARIMAX, VECM, or artificial neural networks. Such approaches will enhance forecasting accuracy and provide a more robust foundation for policy development.

Although the ARIMA model used in this study provides robust forecasts based on historical data, future research can incorporate the effects of climate change and technological adaptation by employing the ARIMAX model. For example, temperature and precipitation projections from IPCC's SSP scenarios (such as SSP2-4.5) can be integrated into the model as additional variables. Additionally, productivity parameters, such as the adoption rate of precision agriculture technologies (e.g., sensors, drone-based monitoring), can be included in the model as a "technology adaptation index."

Variations in production shares among countries indicate broader trends that may also apply to other cereal crops such as maize, wheat, and oats. Future studies could explore similar dynamics in these crops.

Lastly, to enhance the effectiveness of agricultural policies, climate-resilient seed support could be provided specifically for Türkiye: subsidized distribution of drought-tolerant barley varieties (e.g., *Hordeum vulgare* L. cv. Tarm-92) to producers, as well as the introduction of production quotas and quality standards for domestic malt factories, may be important for the future. At the global level, establishing an emergency barley reserve led by the FAO could help reduce price volatility. Additionally, strengthening the logistics infrastructure for barley coming from key supplier regions such as Ukraine and Russia (for example, the Black Sea grain corridor) is considered beneficial.

This study reveals that despite a nominal increase in global barley production between 2025 and 2035, the supply-demand balance will remain fragile due to climate pressures, demand-driven momentum, and trade uncertainties. If policymakers simultaneously implement climate-smart breeding strategies, flexible stock policies, and investments in high value-added processing capacity, the barley market may follow a sustainable growth path. Otherwise, current production growth will be insufficient to offset market volatility.

Conflict of interest

The authors declare no conflicts of interest.

Authorship contribution statement

N.K.K and B.A: The authors declare that they have contributed equally to the article

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