

Dynamics of alfalfa production in Hungary: Changes in harvested area, yield, and total production over 30 years (1990–2024)

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SUMMARY

Alfalfa is a crucial forage crop in Hungary, contributing to sustaining livestock feed and soil fertility management. To assess the dynamics of alfalfa crop production in the country, this study examines the variations and patterns in harvested area, total production, arable land area, and average yield of alfalfa over the previous three decades (1990 to 2024). Our findings reveal fluctuating patterns, with periods of increase and decrease in all parameters under study. While certain years exhibit growth due to favourable climatic conditions and improved agricultural practices, others show declines, potentially influenced by economic factors, changes in crop demand due to a decline in livestock production, and unfavourable climatic conditions, particularly drought. The analysis highlights the complication of alfalfa production trends, underscoring the need for expanding land area and adaptive strategies in Hungarian forage crop management to enhance alfalfa crop production to sustain livestock's feeding system.

Keywords: Alfalfa; total production; average yield; harvested area

INTRODUCTION

Alfalfa, also referred to as Lucerne (*Medicago sativa* L.) is among the most valuable perennial crops grown in the world for forage in addition to cereals such as rye and maize (Ren et al., 2021; Latif et al., 2023; Ji et al., 2025). The crop is known for its good health benefits, as a cholesterol-lowering feed (Wang et al., 2024), and soil fertility improving ability (El Moussaoui et al., 2024). Countries, specifically Hungary, have benefited from the growing of alfalfa in support of the beef and dairy industry through cattle feeding (Várhidi et al., 2022). As a country known for its robust farming heritage, Hungary has undergone a long history in the production of alfalfa, pronounced by several influences such as economic shifts, adjustments in agricultural policies, climate change, and technological paradigms (Biró and Toldi, 2022). Due to such and many other factors, alfalfa production has evolved in Hungary between 1990 and 2024 with a focus on planted area, output, and gross production in phases (Erdős and Szöllősi, 2022).

The chronological record of events for alfalfa production began with the phase of 1990 to early 2000s where Hungary transitioned to a market-oriented economy after years of a centrally planned economy (Lennert and Farkas, 2020). Within this phase, farmers faced difficulties related to changes in market that prompted the allocation of vast areas of land for the growing of alfalfa. This is reported by Laczka and Soós (2003) where the situation had served as a remedy for the existing dynamics in land use, agricultural practices, and subsidies that had worsened the status quo. According to the Hungarian Statistical Office on Integrated Farm Statistics data of

2023, the shift appeared broad enough to define a more diversified farming that influenced the allocation of resources, specifically land for the growing of forage crops. Relatedly, as reported by the Food and Agriculture Organisation (FAO) of the United Nations (UN) (2018), this period characterised by economic changes, both global and national, marked the onset of new shifts in alfalfa production.

As a result of the initial shifts, the early 2000s propelled Hungarian agriculture to a remarkable level at a time when the country was accessing the European Union (EU) membership (Bakucs et al., 2018). Earlier, Kovács (2015) noted that such agricultural accession brought along positive outcomes for farmers in Hungary including subsidies and modern practices attached to EU agriculture. Consequently, these policy changes ushered in increased investment in facilities such as irrigation (Süle et al., 2024) which could influence the yields of alfalfa. As a way of sustaining the operations of alfalfa production, farmers looked for ways of enhancing the production efficiency in order to address the crop's question of yield per hectare. This decision in turn provided a positive response to soil infertility and changing weather patterns in the country.

Additionally, 2010 to 2020 was a phase pronounced for the initiation of farming under precision technology but with a bias on environmental sustainability in Hungary (Balogh et al., 2021). Due to the escalating global climate change, alfalfa production was earmarked for the new environmental conditions since the crop is known for being hardy and adaptable to a range of climates (El-Ramady et al., 2020). Nevertheless, changes in agricultural policies, persistent weather extremes, and the demand for

animal feed were some of the driving factors for the harvested area, yield, and total production of alfalfa. At the same time, with the growing of other crops such as vegetables, fruit, and aromatic crops, there were concerns raised about the role of alfalfa in the agricultural sector of Hungary's future.

Finally, as a way of projecting the future of Hungary's agriculture, the production of alfalfa is likely to be under the influence of changing environmental factors, technology, and policy that will shape the crop's trend, as highlighted by del Portillo et al. (2022). However, the ability of alfalfa to fix nitrogen in the soil by symbiosis cannot be underestimated in a situation where farmers seek to gradually replace the use of synthetic fertilisers in crop growing (Ladha et al., 2022). On the other hand, advanced technology in plant breeding, nutrient supply (Appiah et al., 2024), irrigation, and biotechnology may provide substituting solutions to challenges such as nutrient imbalance, pest and disease pressure and water requirements that have since been traditional barriers to alfalfa production (Agho et al., 2024). Consequently, the aim of this study is to delve into the way alfalfa production has evolved in Hungary from 1990 to 2024. Through examining the changes in harvested area, yield, and total production over 30 years, the study offers important perspectives on the factors influencing Hungary's alfalfa industry and provides forecasts for its future development.

MATERIALS AND METHODS

We extracted data for the general arable land area under cultivation and narrowed it down to the harvested area, average yield and total production of alfalfa for over 30 years (1990 to 2024) from the Hungarian Central Statistical Office (HCSO). A descriptive analysis was conducted to evaluate the variation and standard deviation and the mean values for these parameters using Excel software. Pearson correlation was used to explore the relationships between arable land area under cultivation, harvested area, average yield and total production of alfalfa. We also utilized linear regression to statistically process the data, and a trend analysis was performed to evaluate the rate of increase or decrease in the time series over the study period. Additionally, exponential smoothing forecasting model was used to predict average yield of alfalfa production for the next five years:

$$Y_t = \alpha Y_{t-1} + (1 - \alpha) \hat{Y}_{t-1}$$

Where:

Y_t = Forecasted yield at time t

Y_{t-1} = Actual yield at time $t-1$

$\hat{Y}_{t-1}$ = Forecasted yield at time $t-1$

α = Smoothing constant ($0 < \alpha \leq 1$)

RESULTS AND DISCUSSION

Changes in arable land area and harvested area of alfalfa in Hungary

Hungary's arable land area in general and the harvested area of forage crops particularly alfalfa has experienced significant changes from 1990 to 2024. These changes are from decreasing arable land area, reduced alfalfa yields, and fluctuations in harvested areas and total production. *Table 1* shows a descriptive evaluation of arable area, harvested area, average yield and total production of alfalfa crop.

The analysis revealed an average mean arable land area of 4460.43 thousand hectares, with a minimum value of 4037.13 and a maximum value of 4715.9 thousand hectares. Similarly, the harvested area mean of 188.97 (thousand hectares) with minimum and maximum values ranging from 123.0 to 302 thousand hectares was noted (*Table 1*). *Figures 1* and *2* show the trend analysis indicating a tremendous decrease and slight rise in arable land area and harvested area of alfalfa crop. Between 1990 to 1999, 2000 to 2009, and 2010 to 2019 Hungary's arable land was stable however, a noticeable declined by 4.42%, 3.98% and 6.49% were noted from 1999 to 2000, 2009 to 2010 and 2019 to 2020 (*Figure 1*). The results further show a slight increase or stabilization in arable land by 2.35% from 2020 to 2024 (*Figure 1*). The linear trend line depicts a constant decrease in the arable land area by 18.906 (thousand hectares) yearly. R square value of 91% suggest that arable land area has been steadily decreasing over time, and future predictions using this model will likely be reliable. However, the reduction in arable area under cultivation could be associated with unfavourable climatic conditions and the current CAP (Common Agricultural Policy) subsidies and regulation and transformation of co-operations own lands to private ownerships. Vityi (2014) reports that, converting arable lands to grassland to earn support could limit the amount of available land for traditional crop production resulting in a decrease in overall agricultural productivity. According to (Lang et al., 2007) environmental challenges, such as drought, floods, and inland waterways, have also played a role in a decline in agricultural areas under cultivation particularly in high-risk regions like the Great Plains. Other studies attributed the trend reduction of land under cultivation to the interplay of certain factors including social, economic and environmental considerations (Terres et al., 2015; Zanden et al., 2017). Additionally, Raven and Wagner (2021) regarded the tendency of agricultural intensification as the primary reason for the decline in agricultural land area under cultivation. On the other hand, the harvested area follows a similar trend. The harvested area declined by 178 thousand hectares from 1990 to 2011 which accounted for 58.94%, followed by an increase of 76 thousand hectares which accounted for 61.29% from 2011 to 2024 (*Figure 2*). The linear trend shows a steady decline in harvested area by 2.5569 thousand hectares representing 25.0% (*Figure 2*). Our trend analysis showed a 58.94% decrease between 1990 and

2011, which may have been caused by a decline in livestock production. According to a study by Farkas et al. (2023), as livestock production continues to lag, the demand for forage crops, including alfalfa, may decrease because fewer animals require fewer feeds. This indicates that when livestock productivity

declines, farmers may limit the area cultivated or convert alfalfa farms to other crops, which will affect forage crop productivity. According to Vityi (2014), the Common Agricultural Policy's (CAP) restrictions on the conversion of arable land seem to deter farmers from selecting which crops to grow.

Table 1. Descriptive analysis for agricultural area, harvested area (ha), total production (t) and average yield (kg ha⁻¹) in Hungary

	Arable land area (thousand hectare)	Total production (tons)	Harvested area (thousand hectare)	Average yield (kg ha ⁻¹)
Mean	4460.43	886342.50	188.97	4629.42
Minimum	4037.13	464894.00	123.00	3120.00
Maximum	4715.9	1811997.00	302.00	6090.00
standard deviation	202.99	298670.00	52.39	668.19

Figure 1. Arable land area in Hungary from 1990 to 2024 (source: KSH, 2024)

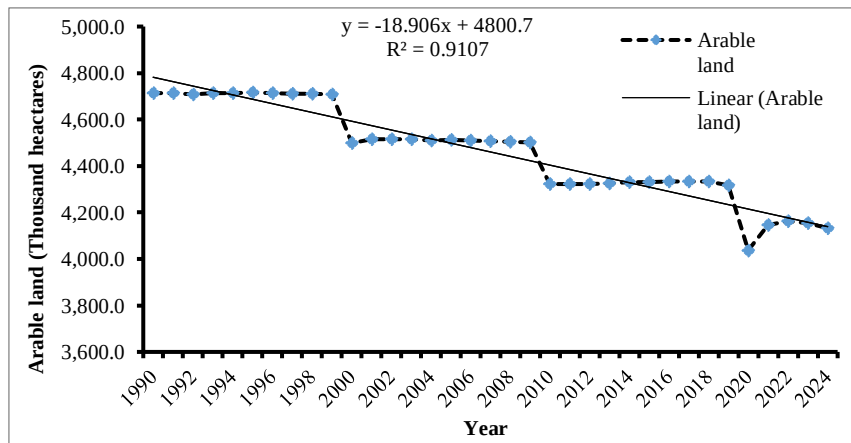
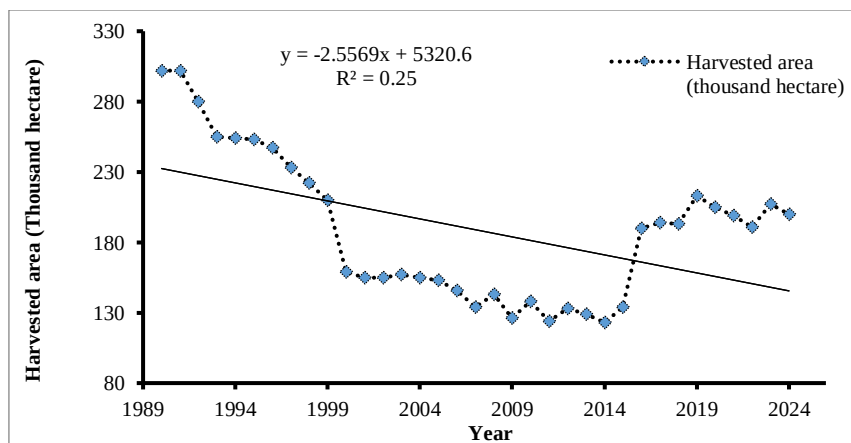


Table 2. Correlation analysis among arable land area, total production, harvested area and average yield of alfalfa

	Total production (tons)	Harvested area (thousand hectare)	Average yield (kg ha ⁻¹)	Arable land area (thousand hectare)
Total production (tons)	1			
Harvested area (thousand hectare)	0.898757968	1		
Average yield (kg ha ⁻¹)	0.492226083	0.079984716	1	
Arable land area (thousand hectare)	0.586071939	0.47498806	0.372479087	1

Figure 2. Harvested area of Alfalfa in Hungary from 1990 to 2024 (source: KSH, 2024)



Changes in total production and average yield of alfalfa in Hungary

The descriptive analysis revealed an average mean of 886342 tons for total production with minimum and maximum total production ranges from 464894.0 to 1811997.0 tons (*Table 1*). While 4629.42 kg ha⁻¹ was noted for the average yield with minimum and maximum average yield of alfalfa ranging from 3120.0 to 6090.0 kg ha⁻¹ (*Table 1*). *Figures 3* and *4* show the trend analysis for total production and average yield of alfalfa in Hungary revealing steady fluctuations in total production and an average yield of alfalfa from the past three decades. For example, a decrease of 270,230 tons of total production was noted from 1990 to 1999 which accounted for 18.93% reduction. Similarly, total production further decreased by 692080 tons from 1999 to 2012 which accounted for 59.81% (*Figure 3*). However, from 2012 to 2019 total production rebounded significantly, increasing by 563450 tons which accounted for 121.1% before the decline of 309460 tons which also accounted 30.09% reduction in total production of alfalfa crop (*Figure 3*). The linear trend line depicts a steady decrease of total production by 16748 tons indicating a 33.02%. The average yield of alfalfa on the other hand also exhibited similar fluctuations. A decrease of 380 kg ha⁻¹ was noted from 1990 to 1995 which accounted for 8.03% (*Figure 4*), followed by a further decline of 890 kg ha⁻¹ (20.4%) between 1995 and 2003. However, yield improved significantly, with an increase of 1780 kg ha⁻¹ from 2003 to 2018 representing 51.4% before dropping again by 1640 kg ha⁻¹ from the past six years (2018 to 2024) representing 31.29% (*Figure 4*). The linear trend line for average yield consistently decreased by 8.02%, this reduction could be attributed to extreme weather conditions like drought which may be the major cause of the decline in average yield and overall production. Hungary has been through its worst drought since 1901 in 2022 alone, which may have contributed to the yield and overall production seen in 2022–2024 (KSH, 2024). Severe drought conditions and a lack of precipitation led to extremely low agricultural production, which caused forage crops to decline by 4.6% and other cereal crops to decline by a specific amount. Many studies have shown alfalfa yield loss due to unfavourable climatic conditions (Evenson, 1979; Thivierge et al., 2016; Fink, 2021; Ren, 2021) for instance a study by Pourshirazi et al. (2022) reported a decrease in alfalfa yield by 33% as a result of cold weather. Similar other

studies suggested that cold weather negatively declines alfalfa total production annually due to delays of regrowth and limited harvesting per growing season (Evenson, 1979; Fink, 2021). Baral et al. (2022) reported that water stress can adversely impact alfalfa survival, growth and development, biochemical, physiological process and final biomass yield. Despite these challenges, an increase in average yield by 51.4% noted from 2003 to 2018 cropping year suggests that better field management, good policies, appropriate agronomic practice and an effective approach to combat unfavourable weather conditions could boost alfalfa biomass yield. In addition, the upward trend offers prospects for the future growth of the livestock industry, since the production of alfalfa, the queen of forage crops, serves as the foundation for livestock production development.

Figure 5 presents the forecast of the average yield production of alfalfa crops for the next five years (2025 to 2030). The forecast indicated a steady decrease in the average yield of alfalfa production from 1121.97 kg ha⁻¹ in 2025 to 2.726 kg ha⁻¹ in 2030. This reduction in the average yield of alfalfa production presents a threat to an opportunity to improve the livestock sector in the future because alfalfa ‘‘Queen of forage crops’’ presents the basis for livestock production improvement, indicating the need to rise alfalfa production to sustain livestock production and overall agricultural productivity. *Table 2* shows the correlation coefficient between the parameters (arable land area, alfalfa harvested area, alfalfa average yield and alfalfa total production) evaluated. The result indicates that the harvested area of alfalfa had a strong positive correlation with total production ($r=0.898$) while total production moderately correlated with average yield ($r=0.492$) and arable land area ($r=0.626$) respectively. This positive relationship between harvested area and total production implies expanding land area can lead to an increase in alfalfa crop grown per area and harvested leading to higher total production. On the other hand, the relationship between total production and average yield could be attributed to improvement in alfalfa varieties and improved farming practices could result in efficient production leading to higher yields. These findings suggest that expanding land area for alfalfa cultivation and improving agronomic management practices can improve alfalfa crop production, leading to yield enhancement and improved agricultural sustainability.

Figure 3. Total production of Alfalfa in Hungary from 1990 to 2024 (source: KSH, 2024)

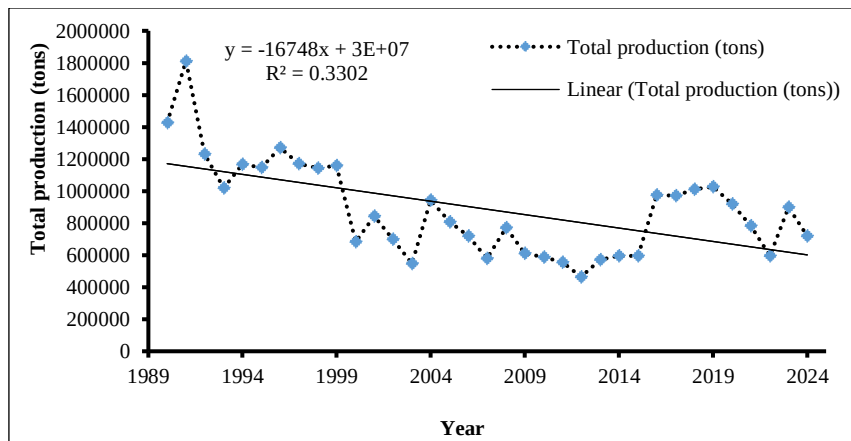


Figure 4. Average yield (kg ha^{-1}) of Alfalfa in Hungary from 1990 to 2024 source: KSH, 2024

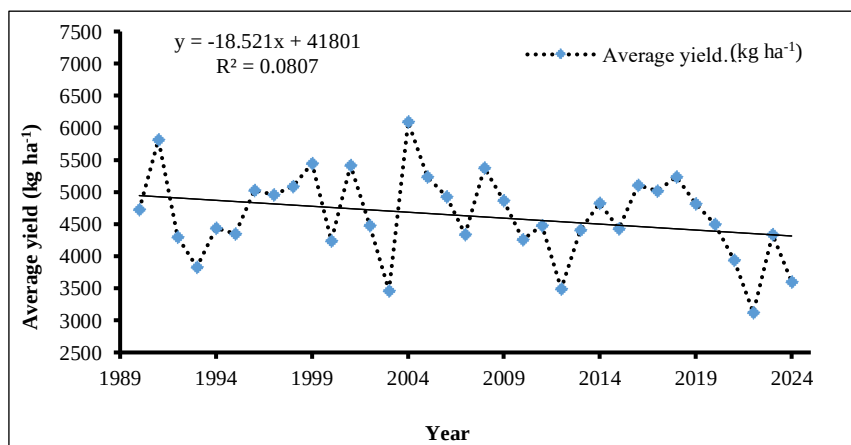
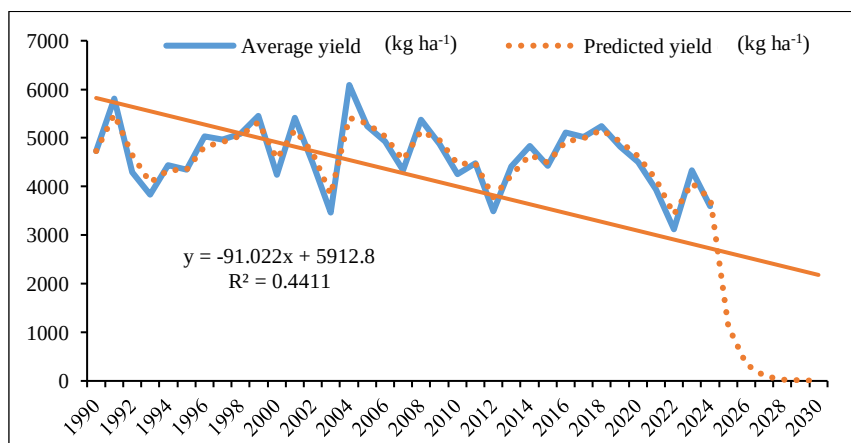


Figure 5. A five year forecast of alfalfa average yield (kg ha^{-1}) (2025 to 2030)



CONCLUSIONS

The analysis reveals significant fluctuations in Hungary's arable land under cultivation, alfalfa harvested area, alfalfa total production, and average yield from 1990 to 2024. We observed that the declining trends are driven by policy changes, land privatization, economic shifts, and environmental

factors, particularly drought. Moreover, while arable land area and harvested areas have steadily declined, total production and yield have fluctuated, with occasional periods of growth due to improved management practices. Strengthening policy frameworks, promoting sustainable land use, and implementing climate-resilient agricultural techniques could help stabilize alfalfa production and support

Hungary's livestock industry. Future efforts should focus on mitigating the adverse effects of climate

change and optimizing resource allocation to sustain alfalfa production in the long term.

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