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DYNAMICS AND FORECASTING OF GOATS ARTIFICIAL INSEMINATION PROCEDURES IN ROMANIA

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Abstract

The efficient breeding of dairy goats depends on the quality of the breeds and the number of high-producing animals, but it also depends to a large extent on the fertility of the goats, their ability to reproduce offspring with normal reproductive functions. Although goat research worldwide is older and more developed than in Romania, information on this species has been limited for a long time, as most research institutes have presented their results jointly for small ruminants, especially sheep and goats. Artificial insemination (AI) is an assisted reproductive technology that involves the manual placement of semen into the female's reproductive tract through means other than natural mating. This method facilitates the meeting of gametes, namely sperm and oocytes, resulting in the formation of offspring. The conventional method for artificial insemination (AI) in sheep and goats in Romania involves the use of fresh or chilled semen, which has provided satisfactory fertility outcomes. The implementation of genetic enhancement techniques and the utilization of imported semen that meets safety standards, necessitating the use of cryopreservation, have the potential to significantly improve milk yield. The objective of this study was to examine the dynamics of artificial insemination (AI) in goats within Romania and to generate a short-term forecast regarding the utilization of this biotechnology in the country's farming conditions. The analysis of the forecast data indicates a positive trajectory in the quantity of AI within the time frame of 2022 to 2026. Specifically, it is anticipated that the number of AI will rise from 2956 in 2023 to 3603 in 2026, signifying an approximate 18% increase. The upper confidence limit suggests that the range of AI could potentially reach between 4310 in 2023 and 6311 in 2026.

Key words*: artificial insemination, efficiency, forecast, goats.*

INTRODUCTION

The significance of goats in various regions of Europe, particularly in hilly and mountainous terrains, as well as in remote, marginalized, and semi-arid regions, is noteworthy (Lu, 2019; Haenlein, 2017). Goats have the ability to acclimate to diverse agricultural methodologies, environmental circumstances, and topographical landscapes, thereby utilizing substandard resources and converting them into superior products. Goats hold significant cultural importance in various festivals and celebrations, including "Kukeri" in Bulgaria and "Capra" in Romania, as well as other customary folk practices. Dairy goats in Europe serve a multitude of purposes, as outlined by Ribeiro (2010). These include their primary function at the farm level, which involves the production of milk and meat products. Additionally, they serve a secondary function within the industry or supply chain by supplying and processing dairy and meat products. Furthermore, they serve various tertiary functions, such as having a socio-cultural impact on the rural community, maintaining the balance of the land, enhancing landscape aesthetics, providing nutritional value, ensuring food security, facilitating hunting, promoting tourism, and aiding in fire protection.

The majority of goat farming systems prioritizes meat production, accounting for approximately 80% of the industry. However, in developed nations, there is a greater emphasis on dairy goat production and the production of fibers such as cashmere and mohair. The breeding programs for dairy goats that are most advanced are situated in France and are founded on a robust market for goat cheese. Caprigene France conducts selection programs for the Saanen and Alpine breeds, utilizing AI and milk recording. The program encompasses 300000 animals across 2500 herds, which are registered for their milk characteristics. According to Moore's (2017) findings, dairy goat production is also present on a smaller scale in Italy, Norway, and Spain, with a limited number of animals registered in other nations. The primary characteristics pertaining to milk production in goats include the overall milk yield and the protein and fat content of the milk (Popica, 2015; Priseceanu, 2015). Sex-limited traits, which are only measurable after the production of the first offspring, could potentially be improved through the implementation of marker-assisted selection techniques. The production of goat meat is prevalent in various developing nations, albeit with limited noteworthy breeding initiatives. In Australia and South Africa, genetic assessment is being conducted for Boer and other meat breeds of goats, wherein the primary trait evaluated is typically the weaning weight. The utilization of ultrasound technology for assessing fat and muscle traits in goats is not as prevalent compared to other applications. Additionally, reproductive traits in goats have not been extensively studied, likely attributed to their low heritability and the fact that goats are multiparous in nature.

The effectiveness of dairy goat breeding is contingent upon the quality of the breeds and the quantity of animals that exhibit high productivity. The extent to which goats are able to reproduce offspring with normal reproductive functions, known as fertility is a significant determining factor. The capacity in question is influenced by a variety of factors, including environmental conditions, nutritional intake, breeding techniques, and breeding proficiency, as noted by Miao (2016). The functional trait of goat fertility holds significant importance as it stands as a primary selection criteria for small ruminants, as stated by Malher X. in 2001. The enhancement of goat fertility has been a significant focus within the Asian goat industry. Various techniques, including crossbreeding, feed management, oestrus control, artificial insemination (AI), and transcervical embryo transfer (TE), have been employed to achieve this objective. As a result, notable economic gains have been realized (Miao, 2016). Insufficient investigation and analysis in the fields of reproductive physiology and fertility control have resulted in unfavourable breeding outcomes being attributed to an inadequate and short-sighted breeding strategy. The implementation of heat synchronization techniques has been extensively employed in inducing cycles in dairy goats during non-breeding seasons and in synchronizing oestrus, resulting in the standardization of calving intervals and lactation periods (Holtz, 2005; Arredondo, 2015). According to Rahman (2008), the implementation of suitable synchronization protocols can have a notable impact on the timing, frequency, and length of oestrus, as well as the rates of gestation and calving. According to Pendleton (1992), the dairy goat industry commonly employs PMSG + CIDR or FSH + CIDR protocols as efficacious methods for synchronization or superovulation. Drion P.V. (1992) reported a decrease in reproductive performance among female subjects subjected to repeated gonadotropin treatment in farming practices. Research has demonstrated that excessive repetition of superovulation through the use of PMSG or FSH can result in negative effects on both ovarian development and reproductive performance. According to Swanson (1996) and Combelles (2003), repeated induction of superovulation in an animal can lead to a decrease in treatment response and gamete quality. The occurrence of reduced fertility rates subsequent to repeated gonadotropin treatments has been associated with an elevation in anti-FSH (Baril, 1992) or anti-PMSG (Swanson, 1996) antibodies. There is speculation that the administration of multiple treatments may trigger an immune response that effectively neutralizes the biological activity of gonadotropins. In animals, elevated levels of anti-PMSG or anti-

FSH antibodies have been linked to ovarian refractoriness, as noted by Bavister (1986) and Remy (1991). The utilization of artificial insemination (AI) in sheep and goats has conventionally involved the use of fresh or chilled semen, yielding satisfactory fertility outcomes. The utilization of exotic breeds, genetic enhancement, and safe' semen from foreign nations requires the utilization of cryopreserved semen to enable the examination of pollutants or illnesses in the 'donor' male before the administration of semen doses for artificial insemination. The acceptability of post-thaw motility of frozen semen from goats and sheep is generally acknowledged; however, its utilization in artificial insemination (AI) has been linked to reduced fertility, primarily attributable to a shorter lifespan of sperm.

MATERIALS AND METHODS

The objective of this study was to examine the AI trends in the Romanian goat industry and generate a projection regarding the growth trajectory of this market segment at a national level.

The examination of the AI dynamics in Romania and the formulation of a brief and intermediate-term projection of AI utilization were conducted utilizing information sourced from the records of various entities with the consent of their proprietors, facilitated by the ANCC-CAPRIROM Association and ANARZ. ANCC-CAPRIROM is the accredited association for the management of the herd book of most breeds bred in the country and to carry out production control on these goats. Since 2000, it is affiliated to the International Goat Association (IGA, 2019 www.goatworld.org). Artificial insemination activities in goats in Romania are carried out only through this association.

The research employed a dynamic or time series methodology to account for the variability of data on the dynamics of AI in the studied species. The methodology involved the use of fixed-base forecast indicators calculated through the application of the exponential smoothing method.

Dynamic/time series highlight the temporal character of phenomena and are an important tool in the context of macroeconomic analyses. Specific to dynamic series is that they are defined for complex entities, characterised by a high level of variation in indicator data, including structural time variations to which they are subject and the actions involved in this study (AI). The statistical analysis of the data utilized in the current study was carried out through Microsoft's Analysis ToolPak and Microsoft Excel 2016 software. Furthermore, the statistical interpretation of each graph was completed within the context of the results obtained. Regression analysis was conducted on each dynamic series, given that it is a well-established model in the field of numerical simulation. This model aids in the interpretation of algorithms that have practical applications in various fields, including but not limited to advertising, medical research, and agricultural sciences. The interpretation of R^2 in linear regression models pertains to its function as a measure of goodness of fit. The assessment considers the degree of correlation between the model and the dependent variable. The range of the limit is between 0 and 100 %. The utilization of regression analysis facilitated the examination of the association between the independent variables, also known as explanatory variables, and the dependent variables, also known as response variables. This facilitated the assessment of the proximity between the approximated value and the actual value. The regression equation was generated utilizing the Analysis ToolPak technique, wherein statistical parameters are utilized to represent the relationship between the explanatory variable and the response variable. The R^2 coefficient is employed to examine the extent to which variations in one variable can be accounted for by variations in a second variable. R^2 indicates the extent to which the independent variable accounts for the variation in the dependent variable. The interval spans from zero to one, indicating that the variable x can account for up to 100% of the variability in y.

RESULTS AND DISCUSSIONS

Results and discussion on AI dynamics per total goat herd in Romania

The total number of AI in the total goat herd of our country during 2010-2022 was 25908. Their distribution by years is shown in Figure

1. An increase in the number of AI doses, i.e. number of AIs in goats in the period 2010-2019, is observed from 260 in 2010, a doubling of this number in 2011, then an increase of 16.6% to 88% in the period 2011 - 2019. This is followed by a decrease of 38.9% during 2019-2020 and about 14% in 2020-2021. In 2022 there was an increase of about 29%. We explain this decrease in the number of AIs against the background of the COVID-19 pandemic, which has affected, as we know, all socio-human activities and probably also this sector.

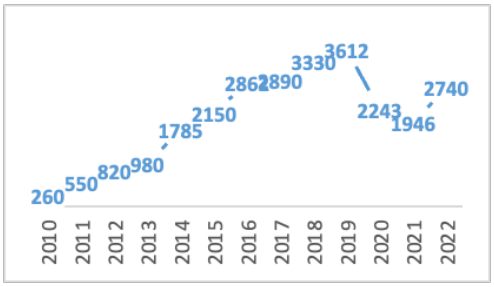

Figure 1. Dynamics of the AIs number in Romania during 2010-2022

Carpathian breed AI dynamics results and discussion

As known from INSSE data, the Carpathian breed is mostly spread in the lowland areas and represents about 85-90% of the total goat herd raised in the country. The ancestor of the Carpathian breed is the Prisca goat and is characterised by a great variability in coat colour, body conformation and productivity. The notable heterogeneity observed in this species can be attributed to the absence of systematic breeding practices, whereby the species has undergone self-breeding and improvement solely through the indigenous knowledge of the breeders. The objective of the genetic resource conservation and utilization initiative for the Carpathian goat breed is to enhance the breed's genetic makeup through biotechnological breeding techniques, such as artificial insemination. According to data provided by ANCC-CAPRIROM and ANARZ, Figure 2 illustrates the frequency of artificial insemination procedures conducted within this particular breed from 2010 to 2022. The data indicates a rise in the quantity of artificial insemination commencing in 2010 and persisting until 2019, followed by a decline of approximately 40% in 2020 and 30% in 2021. The current year has witnessed a rise of approximately 35% in the aggregate count of artificial insemination (AI) within this particular breed.

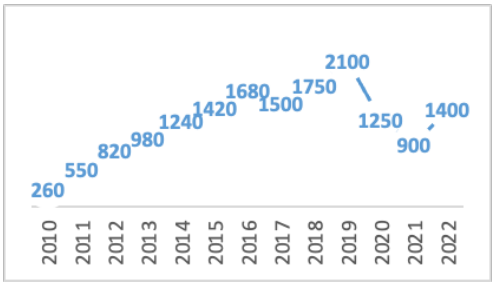

Figure 2. Dynamics of the AI number in the Carpathian breed during 2010 and 2022

French Alpine breed AI dynamics results and discussion

The integration of our country into the European Union has meant the opening up of a vast market for agri-food products, characterised by high absorption potential, high purchasing power and relative price stability. The application of modern goat breeding systems has meant supplementing the traditional methods used to improve genetic potential with methods for assessing the herd base and their productive capacity so that faster and more efficient decisions can be made in the selection and breeding process. Thus, French Alpine goats are included in the national breeding programme, with more than 3900 females included so far. Figure 3 shows the number of AI achieved in females of this breed since 2014. An upward trend was observed during the period spanning from 2014 to 2016, which was followed by a modest decline from 2018 to 2021, amounting to a reduction of 12.5%. Subsequently, there was a rise of approximately 7% in 2022. At the current stage of improvement, in the French Alpine breed where the availability of purebred males is low, there is a ranking of females distributed in a decreasing way to purebred males also ranked. Caprirom's recommendation is to use artificial insemination with semen from breeding males. By changing males every 4-5 years or using artificial insemination, inbreeding at farm level is also avoided. Therefore, following the

ranking of females based on the breeding value of milk production and the ranking of males based on the breeding value of the dam, ANCC-CAPRIROM is the company that recommends the breeding system for goat farms in the herd book and suggests an increase in the number of AI in this breed.

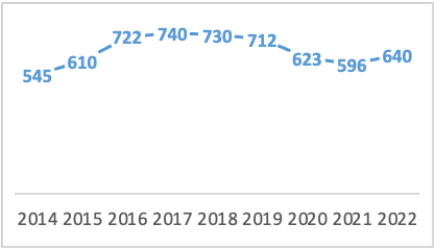

Figure 3. Dynamics of the AI number in the French Alpine breed during 2014 and 2022

Results and discussion on AI dynamics in the Saanen breed

As in the case of the French Alpine breed, in Romania, the Swiss-breed, Saanen is included in the goat herd improvement programme and participates with a herd of more than 4600 females and 250 goats and calves. Figure 4 details the number of AI carried out between 2015 and 2022. It shows an increase in the number of AI from 2015 up to and including 2018, from only 120 doses to 850 doses, followed by a decrease of more than 50% in 2020. The situation has recovered, with an increase of up to 52.8% in 2022.

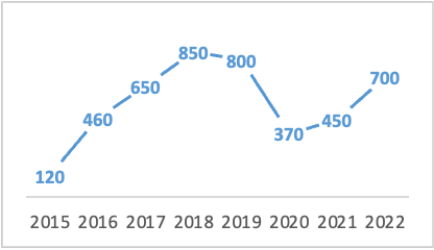

Figure 4. Dynamics of the AI number in the Saanen breed during 2015 and 2022

According to ANCC-CAPRIROM's analysis of the dynamics of the number of AIs by breed in Romania, the Carpathian breed recorded the highest number of AIs, rising from 260 in 2010 to 2100 in 2019. Regarding the French Alpine breed that was selectively bred in Romania, the initial artificial insemination report was documented in 2014, with a cumulative count of 545 AI procedures conducted throughout the year. Subsequent to an initial rise, there was a subsequent peak in 2017, wherein a cumulative sum of 740 AI was documented, followed by a gradual decline culminating in 596 AI doses in 2021. By December 1st of 2022, there had been a notable advancement in the field, with a total of 640 inoculated females. The initial documentation of the Saanen breed, which was selectively bred in Romania, dates back to 2015, specifically with regards to 120 artificial inseminations. Subsequent to an exponential surge, the number of artificial inseminations recorded in 2018 amounted to 850. This number remained stable in the year following but experienced a marked decline in 2020, with only 370 AI cases being recorded. However, in the subsequent two years, there was an upward trajectory, culminating in 700 AI cases being recorded. Upon analysis of AI number in goats in Romania, a discernible trend emerges: a decline in AI number during the period of 2019-2020. This trend is likely attributable to the global situation resulting from the COVID-19 pandemic, which has had a detrimental effect on the livestock service sectors of numerous countries. This finding serves to reaffirm the idea that external factors, specifically those pertaining to the social environment, have the potential to cause disturbances in the execution of economic service operations. Globally, artificial insemination stands as the sole biotechnical approach accessible to breeders for enhancing production efficiency in goats. The key prerequisite for attaining this favourable outcome is the identification of goats with the greatest breeding potential, whose genetic advancements can be disseminated across goat farms over time and space.

Results and discussion on AI forecasting in goats in Romania

In Romania, although there are national goat breed improvement programmes and the number of goat holdings exploited for milk is high and at the same time the number of goats, contrary to our expectations, the AI situation in goats has not improved in a remarkable way, as overall the fecundity by using AI in this species

does not exceed the value obtained by natural service and at the same time the milk production recorded in official control does not seem to excel. Improvement programmes for dairy goats also include the use of natural service systems, which achieve fecundity indices above 85%.

Results and discussion on AI forecasting per total goat herd in Romania

The situation of the forecast of the total goat herd at national level where AI was used is shown in Figure 5.

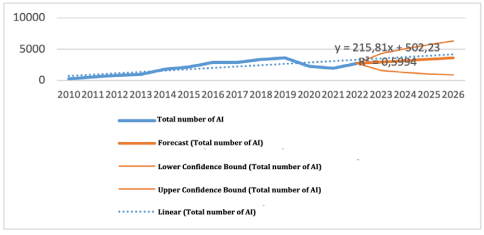

Figure 5. Short-term forecast of the number of AIs in Romania

The graphical representation of the regression equation indicates a positive trend in the number of AIs from 2022 to 2026, with a coefficient of determination of approximately 60%, suggesting a likelihood of increased AIs. The forecast calculations indicate an anticipated rise in the number of AIs from 2956 in 2023 to 3603 in 2026, signifying a growth of nearly 18%. The range of the projected values lies between 4310 AIs in 2023 and 6311 AIs in 2026, as presented in Table 1.

Table 1. Forecasted number of AIs in Romania for 2023-2026

Year	AI estimated number	Lower confidence bound	Upper confidence bound
2023	2.956	1.602	4.310
2024	3.172	1.258	5.085
2025	3.387	1.043	5.731
2026	3.603	896	6.311

Results and discussion on AI forecast for the Carpathian breed

The Carpathian breed, representing almost 78% of the national goat population, was used for AI by the breeding programme proposed by ANCC-CAPRIROM. Based on the data recorded by this association, Figure 6 shows the dynamics and the short-term AI forecast for this breed. Based on the regression equation, the forecast values for the number of artificial insemination in this breed for the period 2022 - 2026 were calculated (Table 2). The trend shown graphically is upward, with values ranging from 1481 AI in 2023 to 1725 AI in 2026. In the same sense, taking into account the coefficient of determination of 58%, we can estimate higher values for the mentioned interval, namely 2378 AI in 2023 and 3198 AI in 2026.

Table 2. Number of AIs in the Carpathian breed forecast for the period 2023-2026

Year	AI estimated number	Lower confidence bound	Upper confidence bound
2023	1.481	584	2.378
2024	1.562	440	2.684
2025	1.643	334	2.952
2026	1.725	252	3.198

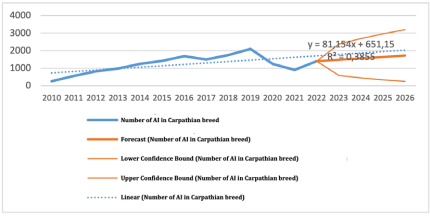

Figure 6. Short-term forecast of the number of AI in the Carpathian breed

Results and discussion on AI forecast for Alpine breed

The French Alpine breed has been imported into our country from Eastern European countries during the last 12 years. Due to improper exploitation, i.e. not respecting the feeding technology, milking rhythm and maintenance conditions, the goat herds have registered extremely low values, although it is included in the clean breed improvement program, in order to increase milk production and to achieve characteristic performances in the breeding and climate conditions specific to our country. The graphical representation depicted in Figure 7 presents a short-term projection of the expected number of artificial

insemination procedures to be conducted on the French Alpine breed within Romania in the near future. Table 3 illustrates a modest upward trajectory, wherein the mean values fluctuate between 644 AI in 2023 and 655 AI in 2026, indicating a yearly growth rate of merely 4-6%. By utilizing the regression equation, it is possible to make an estimation of the attainable quantity of artificial inseminations under optimal circumstances, specifically 915 AI by the year 2026.

Table 3. Number of AI in the French Alpine breed forecast for the period 2023-2026

Year	AI estimated number	Lower confidence bound	Upper confidence bound
2023	644	531	757
2024	647	480	815
2025	651	436	866
2026	655	395	915

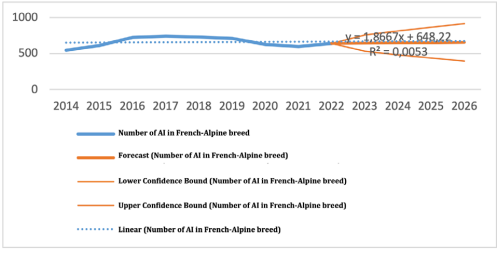

Figure 7. Short-term forecast of the number of AI in Romania in the French Alpine breed

Results and discussion on AI forecast for the Saanen breed

The breeding programme of the Saanen breed in Romania aims to achieve the performance characteristic of the breed in the country of origin, under the specific growing and climatic conditions of our country, i.e. to improve milk production characteristics. The breed is very robust and hardy and has adapted well to different climatic and feeding conditions. The breed is sensitive to sunlight and is more productive if kept in cooler premises. The Saanen breed goat is easy to maintain and can be reared very well in intensive systems for milk production, with good adaptability to mechanic milking and environmental conditions. Chart 8 depicts the trend of artificial insemination (AI) utilization within this particular breed in Romania, indicating a modest upward trajectory in the forthcoming period. Table 4 presents the anticipated numerical values for artificial intelligence during the timeframe spanning from 2023 to 2026.

Table 4. Numbers of Saanen breed AIs forecast for 2023 - 2026

Year	AI estimated number	Lower confidence bound	Upper confidence bound
2023	716	260	1.172
2024	754	140	1.368
2025	791	52	1.530
2026	829	-17	1.675

Based on the confidence interval analysis, it can be inferred that the estimated count of AI in the Saanen breed in Romania falls within the range of 261 to 1175. It is noteworthy that this range may indicate a marginal decline in the count, subject to certain conditions.

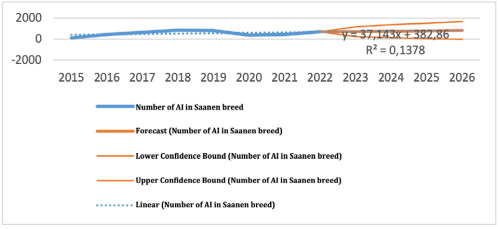

Figure 8. Short-term forecast of the number of AI in the Saanen breed

CONCLUSIONS

The general trend in Romania regarding the total number of AIs has exhibited an upward trajectory from 2010 to 2019, with numbers rising from 260 AIs in 2010 to 3612 AIs in 2019. However, there was a subsequent decline in the years 2020 and 2021, with 2243 AIs and 1946 AIs, respectively. Nonetheless, there was a subsequent increase of approximately 29% in 2022, with 2740 AIs. Upon analysis of the AI population dynamics across various breeds in Romania, it is evident that the Carpathian breed has consistently maintained the highest number of AIs. This trend is reflected in the data reported by ANCC-CAPRIROM, which indicates that the number of AIs for this breed

has increased from 260 in 2010 to 2100 in 2019. Regarding the French Alpine breed in Romania, the initial artificial insemination (AI) report was documented in 2014, with a cumulative count of 545 AI procedures performed throughout the year. Following an initial rise, there was a subsequent peak in 2017, with a cumulative count of 740 AI. This was then followed by a modest decline, culminating in a total of 596 AI doses in 2021. By December 1st, 2022, there had been notable advancements in the field, with a total of 640 inoculated females. The initial documentation of the Saanen breed in Romania dates back to 2015, when 120 artificial insemination procedures were conducted. Subsequent to an exponential surge, the number of artificial insemination (AI) cases escalated to 850 in 2018 and then stabilized at a plateau in the subsequent year. However, a marked decline was observed in 2020, with only 370 AI cases being recorded. In the ensuing two years, there was an upward trajectory, culminating in the attainment of 700 AI instances. Upon analyzing the dynamics of artificial insemination (AI) numbers in the goat population of Romania, a salient trend emerges: a decline in AI numbers during 2019-2020. This phenomenon is plausibly attributable to the global situation stemming from the COVID-19 pandemic, which has adversely affected the livestock service industries in numerous nations. This finding serves as further evidence that external factors, specifically those pertaining to the social environment, have the potential to cause disturbances in the execution of economic service operations. The analysis of the forecast indicates an upward trajectory in the quantity of AIs during the period spanning from 2022 to 2026. It is projected that the number of AIs will rise from 2956 in 2023 to 3603 in 2026, reflecting an increase of nearly 18%. The upper confidence limit suggests that the range of AIs could be between 4310 in 2023 and 6311 in 2026. According to the projected estimates, the Carpathian breed exhibits a discernible upward trend, with mean values ranging from 1481 AI in 2023 to 1725 AI in 2026. Additionally, there is a possibility of surpassing this figure up to 3198 AI in 2026, as indicated by the upper confidence limit. The French Alpine breed exhibits a modest positive trend, with mean values ranging from 644 AI in 2023 to 655 AI in 2026, indicating an annual growth rate of merely 4-6%. There is a likelihood of a moderate increase in the population of Saanen AIs in Romania in the foreseeable future. Based on the confidence interval analysis, the estimated range for the number of artificial inseminations (AI) in the Saanen breed in Romania falls between 261 and 1175. This range may indicate a slight downward trend, as suggested by the upper, middle, and lower confidence limits. While goat production may not be a globally significant sub-sector of livestock in terms of economic value, it holds significant environmental and social importance. Therefore, it is a strategic sector that warrants maintenance and improvement. Despite the increasing prevalence and intensification of European goat farming, there remain numerous regions where goats maintain significant connections with the surrounding environment, thereby producing valuable ecosystem services. Further enhancements are required to the facets that can render this undertaking lucrative and appealing to the youth demographic, with the aim of increasing recognition of the worth of goat-derived products and securing corresponding remuneration. Additionally, it is imperative to acknowledge and appreciate the societal and environmental contributions of goat farming, particularly in underprivileged rural regions. In summary, it can be asserted that information regarding the efficacy of artificial insemination in this particular animal species, its patterns of behaviour, and a forecast of its utilization in the near and intermediate future would be highly beneficial in devising tactics to enhance the production of milk and meat in this species.

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