Forecasting Inputs Demands on the Quality of Animal Breeding Public Services in Uganda: A Supply Chain Perspective

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Abstract: The study focused on supply chain forecasts for inputs on the quality of animal breeding public services in selected cattle corridor districts (Mbarara, Mubende, Luwero and Soroti) of Uganda. The key question was, what effect key breeding inputs (liquid nitrogen and frozen semen) had on quality of animal breeding services. The research adopted cross-sectional survey design embracing quantitative approaches. Data was captured using review of records from the Genetic Centre, Artificial Insemination (AI) technicians, and Field Extension workers. The work included forecasting and trend analysis for liquid nitrogen and frozen semen production and costs for the period 2019-2023 at the current level of inputs and manpower at the National Animal Genetic Resources Centre and Data Bank. The study established that 77.3% of the produced liquid nitrogen will be utilized by the year 2023. In the same vein, 62.6% of the frozen semen produced will be utilized by the year 2023. The study predicted the costs related to production, maintenance and repairs for liquid nitrogen plants and projected semen production, maintenance of the bulls, and veterinary costs. Other forecasted costs were for semen importation per annum for breeds and genetic diversity in the country. The study guides NAGRC&DB and other players in the animal resources value chain to undertake forecasts and trend analysis for better planning, budgeting, strategy and delivery of quality animal breeding services in selected cattle corridor districts of Uganda. The topic of operational efficiencies for the circulation and usage of key breeding inputs dependent on farming system and agro-ecology should be explored in Uganda.

Keywords: Breeding Inputs, Frozen Semen, Genetic Centre, Liquid Nitrogen, Trends Analysis.

INTRODUCTION

Globally, efficient and effective genetic and breed improvement programs in livestock is through assisted reproductive technologies (ARTs). One of such ARTs is Artificial Insemination (AI) services [3, 5, 8, 14, 17]. Even though AI services programs are successful in developed countries like the United States, Canada, South Korea, Denmark, the Netherlands, Brazil among others, the use of AI in Uganda is still rather low with less than 10 % of the country's herd been bred using artificial insemination [7]. The use of AI in Uganda increased from approximately 5 % in 2004 to 7 % in 2008. There are also big variations of AI use within the country with the highest adoption in the central parts and only 2 % use in the northern parts of the country [13]. However, AI services are critical if one is concerned about breed improvement programs for dairy and beef cattle including goats, sheep, pigs and rabbits [3, 14].

The Supply Chain Operations Reference Model (SCOR) prescribes that key stakeholders are engaged in discussing, developing and communicating supply chain management decisions including an organization's suppliers and clients [4, 18]. This results into high quality animal breeding services with improved production and productivity for a country like Uganda. In line with the supply chain operations reference model (SCOR), the government of Uganda through the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) and her agencies namely; Dairy Development Authority (DDA), the National Agricultural Advisory Services (NAADS), the National Animal Genetic Resources Centre and Data Bank (NAGRC&DB), the National Agricultural Research Organization (NARO) and Local Governments (LGs) have undertaken a number of livestock development and improvement programs including; breeding and genetics programs in selected cattle corridor districts of Uganda. The support by the public agencies include infrastructure development, restocking, cattle markets, animal health, animal nutrition, management, vaccination programs and biosecurity interventions among others [11, 12].

Over 90% of Uganda's livestock are indigenous with relatively low productivity status when compared with developed countries. In a drive for livestock development, a number of biological and scientific factors related to animal health, animal nutrition, husbandry management practices and the quality of AI technicians are being addressed through various programs in ministries, department and agencies.

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However, AI adoption and services penetration still face enormous challenges among the farmers in general and selected cattle corridor districts of Uganda in particular. Hence its (AI) low levels of uptake [21]. This is in spite of the fore mentioned wide support and measures that have been put in place. If nothing is done to increase efficiency and effectiveness especially the supply chain management processes in forecasting demand for breeding inputs, this would affect the quality of animal breeding, public services and the performance of the livestock sector in general [20].

Accordingly, Uganda would continue to experience poor breeds for dairy and beef cattle and other livestock. Inbreeding activities will continue through the use of bulls and the quality and quantity of livestock may be grossly undermined with a resultant effect of failure to effectively meet both domestic and export demands for dairy and beef products in the region and beyond; due to poor quality of livestock [21]. As a result, the aspects of food security and improved household incomes would not be met due to the low productivity of individual livestock. For instance, the mean milk production per cow in Uganda was estimated at only 8.5 liter/week attributable to low genetic potential among other reasons [11]. Such low production rate would be enhanced through use of improved cattle and modern breeding techniques such as AI [12]. The purpose of this study, therefore, was to undertake forecasting of liquid nitrogen and frozen semen (an ingredient in AI processes) demands on the quality of animal breeding public services in selected cattle corridor districts of Uganda.

MATERIALS AND METHODS

The study undertook review of previous records of the production of liquid nitrogen and frozen semen and other associated costs in production and maintenance from the National Animal Genetic Resources and Data Bank (NAGRC&DB) in Entebbe, Uganda. A comprehensive document review checklist was developed and it involved use of particular items on the specific themes of production quantities, costs and maintenance that had been recorded in NAGRC&DB center for a period of time i.e. from 2014 to 2018. The review of records was important to pick information to determine trends and make forecasts for better planning, strategy and implementation modalities for key breeding inputs [1]. Forecasts of the production of liquid nitrogen and frozen semen and other associated costs in production and maintenance for the next 5 years (2019 to 2023) were made based on the current and past data i.e. from the year 2014 to 2018. This helps in planning and putting in place effective mechanisms for forecasting, and delivery of breeding inputs to users and other supply chain actors.

Data Analysis

The study explored use of previous records (2014 to 2018) to derive trends in the production of liquid nitrogen and frozen semen and other associated costs in production and maintenance over the selected time period using trend analysis. The fitted trend equation was later used to make forecasts for the subsequent 5 years (2019 to 2023). These time series forecasts were based on the tolerably reliable premise that the past trends will extrapolate uniformly into the future [21] .The mean absolute percent error (MAPE) which expresses accuracy as a percentage of the error was used to assess the correctness of the forecasts (https://support.minitab.com/en-us/minitab-express/1/). This is because the MAPE being a percentage is easily understood than the other accuracy measure statistics i.e. mean absolute deviation (MAD) and mean square deviation (MSD). The MAPE values were interpreted following [9]. The trend analysis and forecasting were done using Minitab 17 statistical software.

RESULTS

Demand Forecasting and Trend Analysis of Liquid Nitrogen and Semen in the Delivery of Animal Breeding Services in Selected Cattle Corridor Districts of Uganda

Total Liquid Nitrogen Produced and Utilized in Litres Per Annum from the Genetic Centre

Production forecasts help in planning for demand, avoid bullwhip effects and bridges efficiency in supply chains for the key breeding inputs in the delivery of quality animal breeding services in Uganda. Figure **1** illustrates the total liquid nitrogen production in litres at the National Animal Genetic Resources and Data Bank at Entebbe headquarters to be supplied to the whole country to meet the expectations of users country-wide and the total liquid nitrogen actually utilized per annum from the genetic centre.

The forecast for total liquid nitrogen produced per annum from the genetic centre with a mean absolute percent error (MAPE) of 33.53 (i.e. forecast off by 33.53% and correct by 66.47%) increased from the year 2019 (73,086 litres) and rose to 119,577 litres in the year 2023. From Figure **1**, the projected total liquid

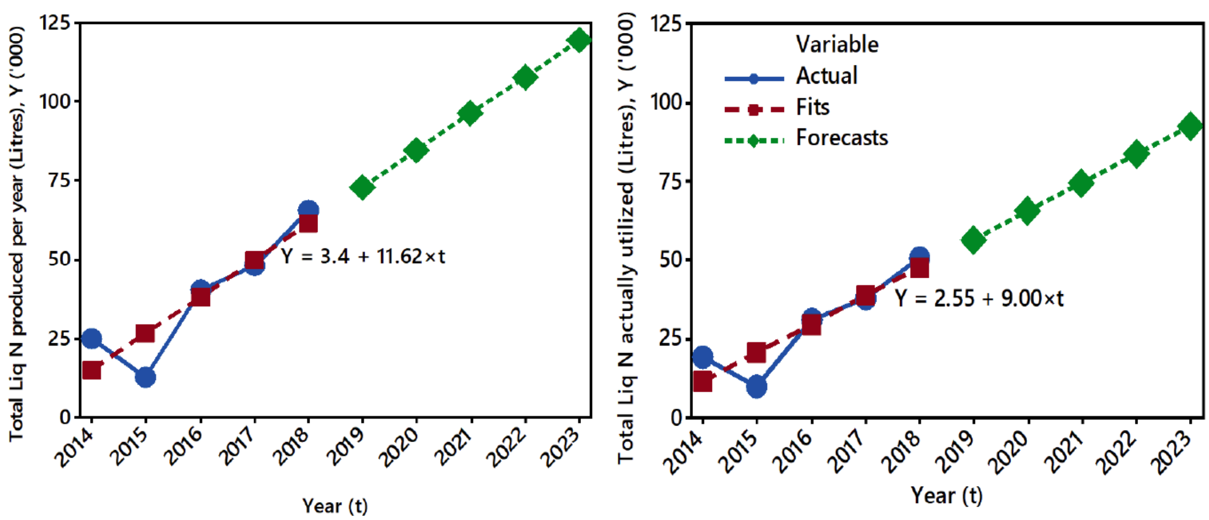

Figure 1: Total liquid nitrogen in litres produced and actually utilized per annum from the Genetic Centre.

Source: [16].

nitrogen actually utilized (MAPE=33.24) for the year 2019 is 56,547.7 litres and will increase rapidly for the subsequent 4 years with an amount of 92,547.3 litres in 2023. The amount of liquid nitrogen actually utilized is less than the total liquid nitrogen that will be produced per annum from NAGRC&DB.

The forecasts of expected quantities of liquid nitrogen to be used assists management to put in place strategies to improve supply chain resilience, reduce supply chain risk and put in place effective mechanisms to deliver breeding inputs. Specifically the liquid nitrogen levels that help the farmer access the services with efficiency and effectiveness for undertaking AI services in their areas.

Total Cost of Production of Liquid Nitrogen (Per Year) from the Genetic Centre

Supply chain costs forecast is key for planning, budgeting, resources mobilization and also guides management to be effective and make timely accurate decisions. In addition, forecasts engender motivated management in supply chains. The forecasts for the production costs of Liquid Nitrogen were established through trend analysis (MAPE=2.79) as displayed in Figure **2**.

Based on the current levels of costs for producing Liquid Nitrogen, the cost in 2019 is 391,033 USD and projected in 2023 to be 575,660 USD.

Electricity Costs

Electricity is used to provide electric power to run the liquid nitrogen plant for production of liquid nitrogen for the genetic center. Electricity is one of the major production costs for running the liquid Nitrogen Plant. Figure **3** shows projections for electricity costs to run the Liquid Nitrogen plant at the genetic centre (MAPE=10.17).

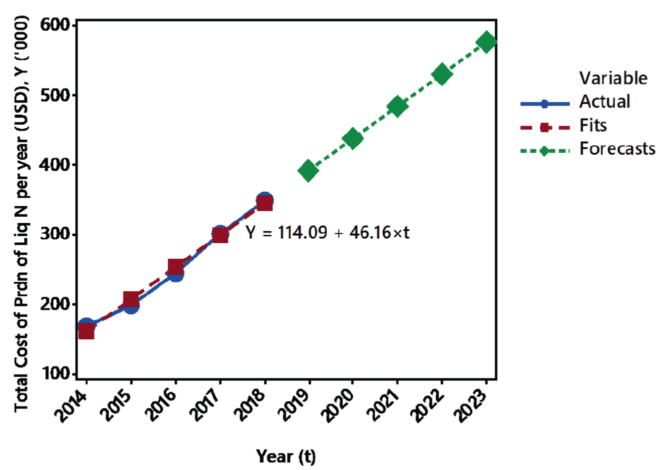

Figure 2: Total cost of production of liquid nitrogen (per year) from the genetic centre.

(1 United States Dollar (USD) = 3,700 Uganda Shillings (UGX)).

Source: [15].

Electricity cost was 177,459 USD in 2019 and projected to be 288,811 USD in the year 2023. The genetic centre relies on the electricity provided by Umeme Uganda Limited, Uganda's main electricity distribution company. It is expected that as production quantities go up, the electricity costs also go up and this will have to be managed to take care of industrial rates and to limit worrying about cost management of the genetic centre.

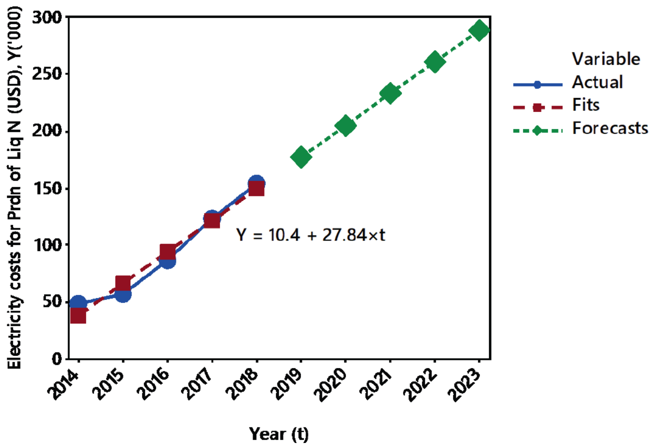

Figure 3: The projections for electricity costs for the period 2019- 2023.

(1 United States Dollar = 3,700 Uganda Shillings (UGX)).

Source: [16].

Repair and Maintenance Costs

Both repair and replacement of the liquid nitrogen plant parts including routine maintenance services constitute key drivers for repair and maintenance costs. Figure **4** displays forecast in terms of repair and maintenance costs for the plant (MAPE=4.63).

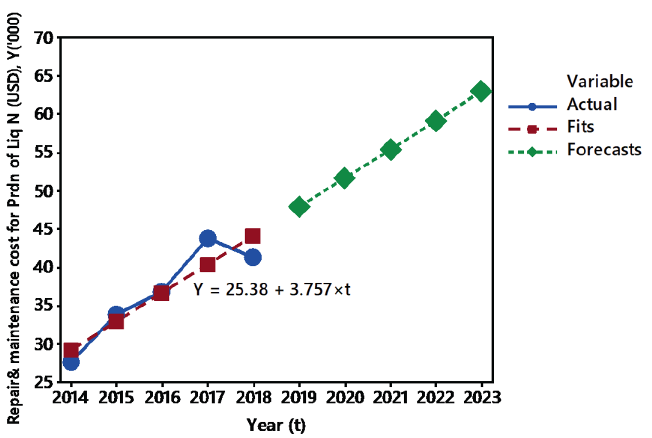

Figure 4: Projections for the repair and maintenance costs for the plant.

(1 United States Dollar = 3,700 Uganda Shillings (UGX)).

Source: [16].

Figure **4** presents the projections for the repair and maintenance costs for the liquid nitrogen plant as 47,919 USD in 2019 and 62,946 USD for the year 2023. These costs have to be controlled by management so that they do not escalate turbulently. This ensures that right quantities are produced profitably and for resilient supply chains, minimizing risks and ensuring strategic efforts for sustainable supply of breeding inputs to the livestock farmers.

Fuel and other Lubricants

Fuel and lubricants are other key inputs used to operate the generators for running the liquid Nitrogen plant in case the Umeme electricity is unstable. Projections for fuel and other lubricants for the period 2019-2023 are shown in Figure **5** (MAPE=4.04).

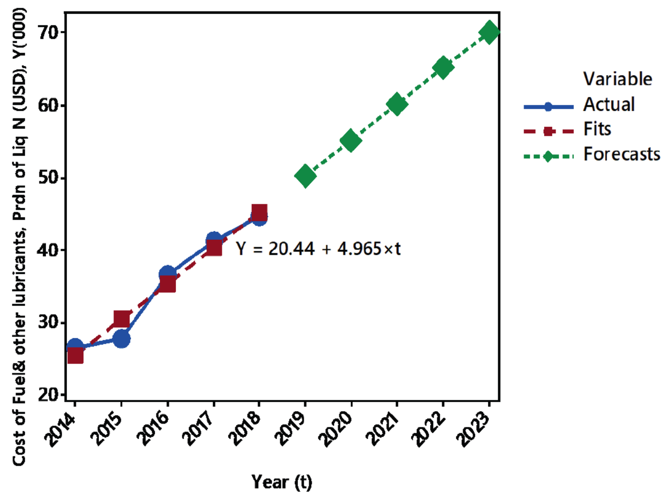

Figure 5: Projections for fuel and other lubricants for production of liquid nitrogen for the period 2019-2023.

(1 United States Dollar = 3,700 Uganda Shillings (UGX)).

Source: [16].

In the forecasts, the 2019 fuel and lubricants costs were projected to be 50,230 USD while that of the year 2023 is 70,089 USD. The forecasts for fuel and lubricants is key in the supply chain in order to budget appropriately and commit resources to meet the production and to mitigate the risks of load shedding. Hence creating resilient supply chains in the production process.

Labour Cost to Run the Liquid Nitrogen Plant

Labour is a factor of production and personnel with skills key to operate the liquid nitrogen plant, collect liquid Nitrogen and store it for use at the different parts of the country. Figure **6** presents the forecasts for labour requirements to run the liquid nitrogen plant to produce the amount of liquid nitrogen at the right time and efficiency desired (MAPE=4.05).

The labour requirements for 2019 was 86,081 USD and will be 108,568 USD by the year 2023. The implication is either employing more skilled staff or retraining and retooling the existing labour force. This will require collaborative effort for funding from Government and other stakeholders.

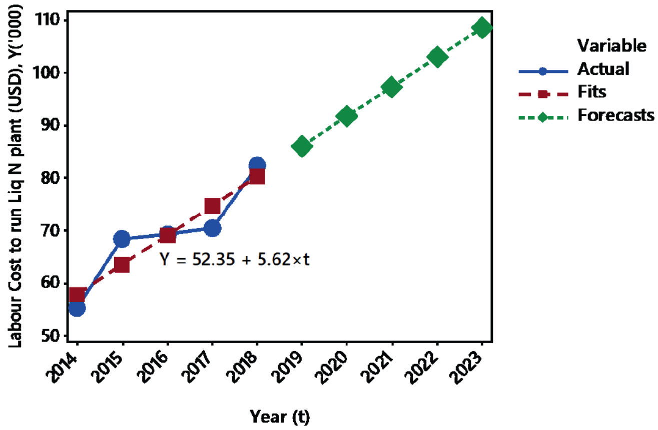

Figure 6: Projections for labour costs to run the liquid nitrogen plant.

(1 United States Dollar = 3,700 Uganda Shillings (UGX)).

Source: [16].

Production Quantities of Frozen Semen (Straws) at the Genetic Centre

Total Frozen Semen (Straws) Produced Per Annum

Forecasting in semen straws production is key to determine the demand, distribution and utilization and hence ensuring sustainable supply chains in the frozen semen production.

Projections for Total frozen semen (straws) produced per annum (MAPE=64.40) increased from the period 2019 (48,055 straws) to the year 2023 (73,354 straws) as shown in Figure **7**. One of the implications of this is that the centre has to train more artificial insemination technicians, retool them and concentrate on massive sensitization of the farmers to enhance adoption and demand for the artificial insemination services. The genetic centre may also have to put in place necessary supply chain conditions for resilient supply chain, avoid bullwhip effects on supply breeding inputs and mitigate risks related to service provision to the farmers.

Total Frozen Semen (Straws) Actually Utilized

The planned forecasts for semen to be utilized (MAPE=40.12) were 28,127 straws in 2019 and the projected number of 45,930 straws in 2023 (Figure **7**). This means the genetic center must put in place effective supply chain systems for creating demand and ensuring that the breeding inputs uptake among the users are improved beyond the current rate and uptake by the technicians and livestock farmers. More novel efforts in terms of regional approach, efficiency in frozen semen distribution and utilization needs to be instituted for sustainable supply chains.

Projections for the Total Cost of Production of Frozen Semen

Knowing the total costs of semen production helps management in appropriate planning including budgeting and coordinated efforts to source materials in a timely manner to avoid bullwhip effects hence putting in place a sustainable and resilient supply system. Figure **8** illustrates the projections for the total

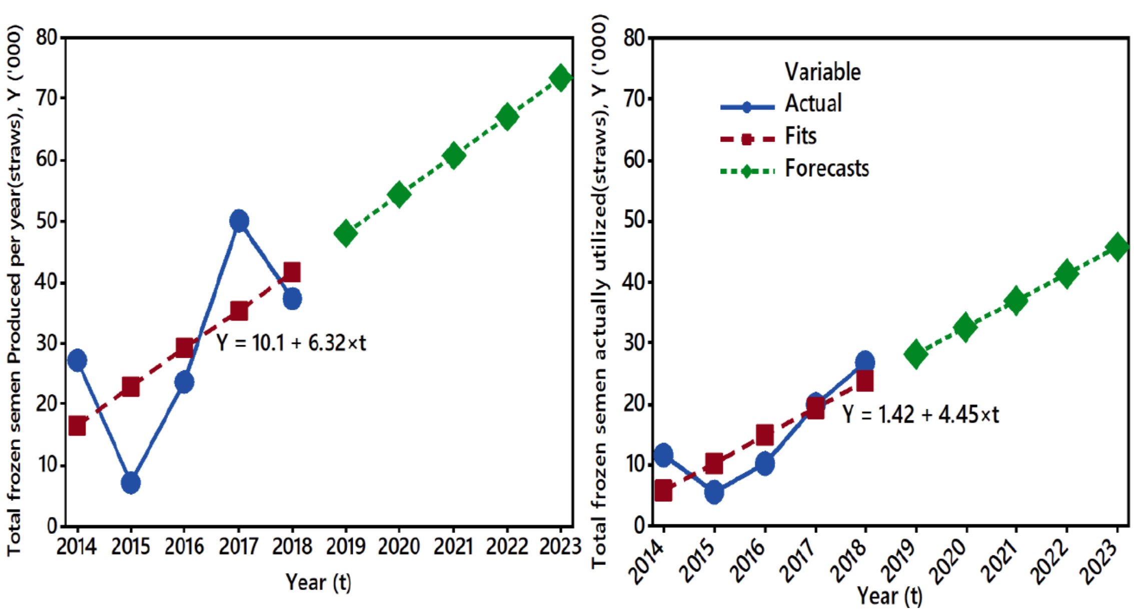

Figure 7: Projections for total frozen semen (straws) produced and actually utilized per annum 2019-2023.

Source: [16].

cost of production of frozen semen at the genetic centre for the period 2019- 2023 (MAPE=13.58).

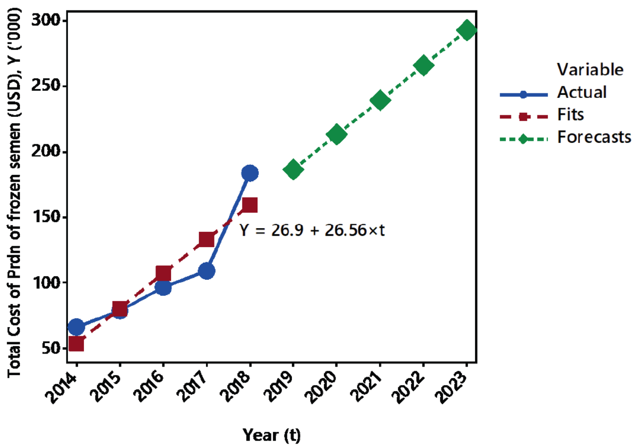

Figure 8: Total Cost of Production of frozen semen.

(1 United States Dollar = 3,700 Uganda Shillings (UGX)).

Source: [16].

Trend analysis projected the total cost of production of frozen semen in the year 2019 as 186,281 USD and 292,508 USD for 2023. This is an upward swing in semen production by the center. This calls for better planning in order to fully utilize the semen produced for breed, genetic diversity and overall productivity improvement programs.

Maintenance Cost for the Bulls

The maintenance costs for bulls help management to plan better and help mitigate supply chain risks that could have negative consequences on the production of quality semen. Figure **9** illustrates the projections for the maintenance costs for the bulls for the period 2019-2023 at the Genetic Centre (MAPE=5.92).

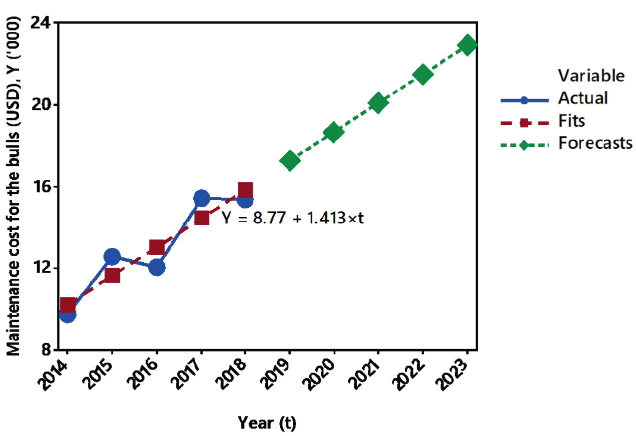

Figure 9: Maintenance costs for the bulls for the period 2019-2023.

(1 United States Dollar = 3,700 Uganda Shillings (UGX)).

Source: [16].

In 2019, the maintenance cost was 17,250 USD and in 2023 it will escalate to 22,900 USD. Maintenance costs for the bulls are necessary to facilitate acquisition of nutritional feed ingredients, feed supplements, labour to feed and ensuring hygiene at the bull stud. The bulls at the stud are necessary to ensure local production of semen for processing, storage and utilization by some segments of farmers who would like genetic diversity in their herds hence preventing cases of inbreeding that often lead to low productivity.

Veterinary Care Costs

The veterinary care costs are mainly for treating the animals when they fall sick, prophylactic treatments, vaccinations and availing drugs for treatment to improve the fertility and semen quality of the bulls at the stud situated at the genetic Centre, Entebbe. Figure **10** illustrates the projections for veterinary care costs for the Period 2019- 2023 by the genetic Centre (MAPE=16.71).

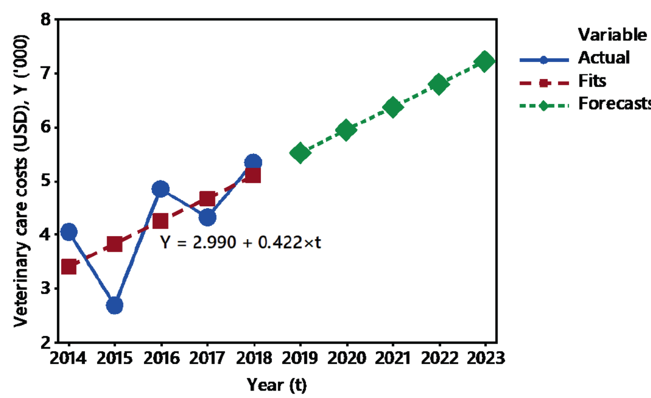

Figure 10: Projections for Veterinary Care costs for the period 2019-2023.

(1 United States Dollar = 3,700 Uganda Shillings (UGX)).

Source: [16].

The veterinary care costs for 2019 was 5,525 USD and forecasts will be 7,215 USD for 2023. Veterinary costs are necessary for prevention against notifiable and zoonotic diseases. This is to ensure that the bulls are in a healthy status in order to get semen that are of high quality and free from notifiable and zoonotic diseases.

Total Frozen Semen (Straws) Imported and Utilized Per Annum

Imported semen is the basis for diversifying the genetic pool for improving the quality of indigenous animal genetic resources for productivity of milk and meat. Projections for quantities of semen to be

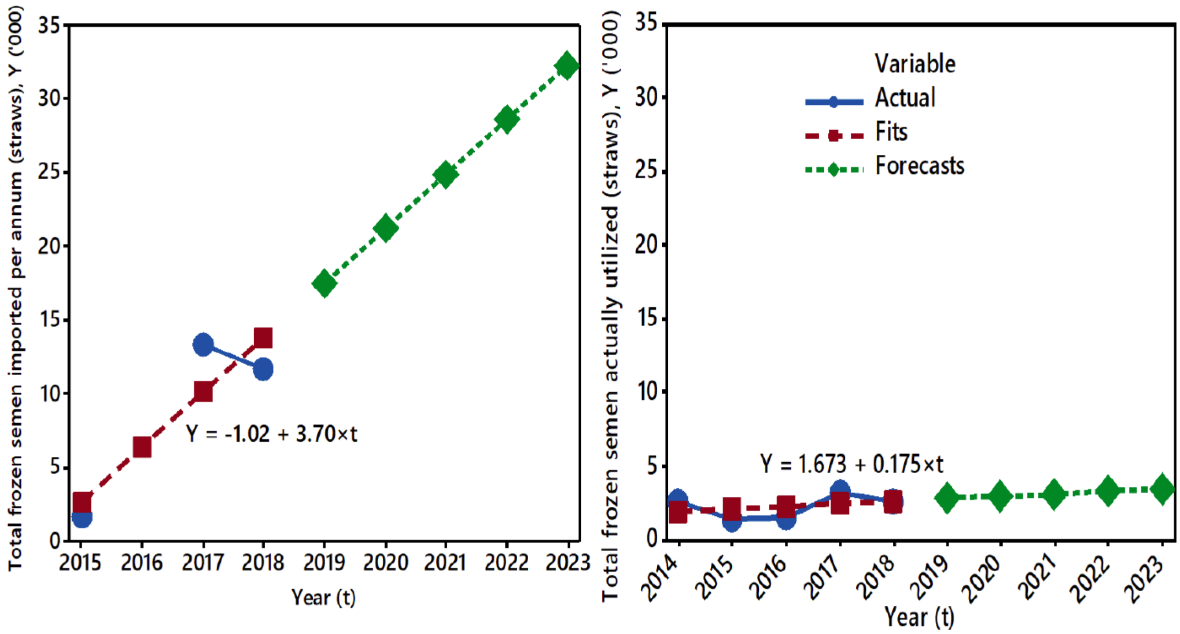

Figure 11: Projections for the total frozen semen imported and actually utilized (straws) per annum for the period 2019-2023. (1 United States Dollar = 3,700 Uganda Shillings (UGX)).
Source: [16].

imported is essential to guide management to plan, budget, control and stratify use of imported semen to the countryside based on demands and breeding plans and objectives. The projections are based on current data and forecasts made to project possible quantities of semen straws to be brought by the genetic centre. Figure **11** presents the projections for the total frozen semen imported (MAPE=36.91) and actually utilized (straws; MAPE=31.43) per annum for the period 2019-2023 by the genetic centre.

In 2019, the total frozen semen imported per annum was projected to be 17,488 straws and 32,293 straws in 2023. From Figure **11**, the projected total frozen semen (straws) actually utilized in 2019 was 2,722 straws while that in 2023 is expected to be 3,421 straws at the current level of human resources and strategy.

Information on imported semen is a basis for deepening supply chains for AI services to various categories of farmers. Therefore, it is necessary to strategize with the novel approaches such as upscaling the services on assisted reproductive technologies to improve the productivity of animals in the country. The numbers of straws projected to be utilized is minimal compared to quantities imported. This may be due to low demands for AI services and inadequate marketing of imported semen at the genetic centre.

DISCUSSION OF RESULTS

Demand Forecasting and Trend Analysis of Liquid Nitrogen and Frozen Semen on the Delivery of Animal Breeding Services in Selected Cattle Corridor Districts of Uganda

Demand forecasting was undertaken based on the projected trend of liquid nitrogen and frozen semen in the delivery of animal breeding public services in the selected cattle corridor districts of Uganda. These forecasts are often required for decision making [21].

Basing on [9] interpretation, MAPE values <10 showed highly accurate forecasting of production costs of liquid nitrogen, repair and maintenance costs at the liquid nitrogen plant, costs for fuel and other lubricants, labour costs to run the liquid nitrogen plant and maintenance costs for the bulls at NAGRC&DB for the period 2019-2023. On the other hand, MAPE values (10-20) indicated good forecasting for electricity costs to run the liquid nitrogen plant, total cost of production of frozen semen and veterinary care costs at NAGRC&DB for the Period 2019- 2023. Furthermore, MAPE values (20-50) signified reasonable forecasting for total liquid nitrogen produced, total liquid nitrogen actually utilized, semen to be utilized, total frozen semen imported and frozen semen actually utilized per annum from NAGRC&DB. However MAPE value >50 implied inaccurate forecasting of total frozen semen produced per annum at NAGRC&DB for the period 2019- 2023.

By the year 2023, based on the current knowledge, attitude, practices and trends, the genetic centre will produce a total of 107,954 litres of liquid nitrogen (Figure **1**) which is still far below the production capacity of the liquid nitrogen plant that is capable of producing 324,850 litres per annum at an average of 89 litres of liquid nitrogen per day (10 working hours).

The forecasts and production quantities must go beyond the current quantities if the Genetic Centre is expected to meet the demands for animal source foods, which is increasing quite rapidly with exploding human population at 3.4 % per annum according to [21] that must be fed with high-quality animal source foods. Out of the 107,954 litres expected, forecast of liquid nitrogen production, a total of 92,547 litres (85.7%) will be utilized (Figure **1**) based on the current operational modalities for the delivery of AI services in selected cattle corridor districts of Uganda.

The study also captured forecasts for the total cost of production of liquid nitrogen per annum by the genetic centre for the period 2019 to 2023 (Figure **2**). It was projected that by the year 2023, the centre will spend a total of 575,660 USD per annum on liquid nitrogen production. The costs are mainly to meet electricity costs (Figure **3**) totaling to 288,811 USD (50.2%) of the production costs by 2023; repair and maintenance costs will cost 62,946 USD (Figure **4**) by 2023; Fuel and lubricants to run the generator in case of load shedding will cost 70,089 USD by 2023 (Figure **5**); labour costs to run the liquid nitrogen plant will cost 108,568 USD by 2023 (Figure **6**).

Inspite of the high MAPE value (>50), the study established tentative forecasts and predictions for production quantities of frozen semen (straws) at the genetic Centre (Figure **7**). The forecast for total frozen semen to be produced by the year 2023 is 73,354 straws at the current rate, momentum and staffing levels. The frozen semen quantities are far below the production capacities of the semen processing machine at the genetic centre. This is explained by the fact that some of the bulls may be old and may have stayed at the bull stud for many years not yet culled. The various husbandry practices including health status of the bulls may have effects on their semen production capacity. The management of the genetic center should ensure putting in place robust herd health, nutritional supplementation and husbandry management at the bull stud. There is need for an effective supply chain strategies to galvanize efforts to demand for frozen semen among the livestock farmers with ultimate considerable increase in demand.

The study forecast estimates that frozen semen to be utilized by 2023 will be 45,930 straws (Figure **7**). This is short of what will be produced by the genetic centre. The study also made projections for the total costs of production of frozen semen. The estimated total cost of production for the year 2023 at the current level of production is 292,508 USD only (Figure **8**).

The costs for maintenance of the bulls at the genetic center are projected to be 22,900 USD for the year 2023 (Figure **9**); another charge is veterinary care projected at 7,215 USD for the year 2023 (Figure **10**). The study further captured information on total frozen semen imported per annum through the genetic Centre. For the year 2023, the total quantity of imported semen will be 32, 293 straws of imported semen (Figure **11**). Out of that imported semen, a total of 3,421 (10.6%) will be utilized by 2023 (Figure **11**).

The rationale for importing frozen semen outside Uganda is presumably that imported semen have high genetic merit, hence high genetic gain. It will assist to diversify the genetic pool in selected cattle corridor districts of Uganda thus avoiding inbreeding. It will also assist to improve the quality of indigenous animal genetic resources such as the long-horned Ankole Cattle, the small East African Zebu cattle thereby increasing milk and meat productivity per animal [6, 13, 14, 16].

The projections and forecasts for imported semen are essential in the supply chain for the genetic centre to timely plan, budget, and control and put in place effective mechanisms for supply chain, distribution and utilization based on demands, breeding plans and breeding objectives [9, 18].

The study observed that it is important to forecast imported semen as a basis for developing supply chain for artificial insemination (AI) services to livestock value chain actors by the genetic centre with innovative methodologies or paradigm shifts to upscale its services on assisted reproduction services (ARTs) as an overall strategy to advance the productivity of livestock in selected cattle corridor districts of Uganda.

There are different pricing strategies although its implementation is complex. Like the genetic centre, a successful pricing strategy is hinged on the pillars of functional areas such as marketing, sales, capacity management and finance. All these depend on the level of organization, timely and accurate information and appropriately motivated management [2, 9].

A highly motivated team, a strategy for coordinating supply chain of liquid nitrogen and frozen semen has to be put in place, coordinating the production, storage, distribution and utilization including the feedback for the genetic centre and the entire value chain actors for the livestock sector to prosper as expected [9].

CONCLUSION AND RECOMMENDATIONS

Demand forecasts and trends for liquid nitrogen and semen production quantities and their costs are expected to give the NAGRC&DB targets to accomplish production tasks in a business perspective and to avoid 'laissez faire' approach for appropriate delivery of acceptable animal breeding services in selected cattle corridor districts of Uganda.

The study guides the Genetic Centre and other players in the animal resources value chain to undertake forecasts and trend analysis for better planning, budgeting, strategy and delivery of quality animal breeding services in selected cattle corridor districts of Uganda. The topic of operational efficiencies for the circulation and usage of key breeding inputs dependent on farming system and agro-ecology should be explored.

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