Scientific Research Publishing

Open Journal of Veterinary Medicine, 2023, 13, 193-220
https://www.scirp.org/journal/ojvm
ISSN Online: 2165-3364
ISSN Print: 2165-3356

Leveraging on Flock Dynamics and Farmers' Production Constraints in Designing Flock Health Program for Accelerated Goat Production

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How to cite this paper: Guma, W., Baguma, S.D., Asekenye, L.P. and Tumwesige, I. (2023) Leveraging on Flock Dynamics and Farmers' Production Constraints in Designing Flock Health Program for Accelerated Goat Production. *Open Journal of Veterinary Medicine*, **13**, 193-220.
https://doi.org/10.4236/ojvm.2023.1311017

Received: June 17, 2023
Accepted: November 18, 2023
Published: November 21, 2023

Abstract

Compliance with appropriate flock health program is vital for preventing introduction and minimizing impact of diseases in goat farms. Unfortunately, most goat farms in Uganda, especially in the Albertine Graben Zone lack flock health program. The associated frequent outbreaks slow down effort aimed at commercializing goat production. In this study, we documented flock dynamics, identified and prioritized pressing challenges experienced by goat farms during the year 2022 and generated appropriate flock health program and packaged it for dissemination to farmers. **Materials and Methods:** Using a cross-sectional design, semi-structured questionnaire, data were collected and analyzed with MS Excel 2013. The data included: location and socio-demographics of household, farming system, flock dynamics, housing, feeding system, health management, challenges encountered by goat farm and suggested solutions. **Results:** Beginning January 2022 to December 2022, the number of goats reared in all the 45 sample farms increased from 2128 to 2220 goats. Results showed that 884 kids were produced and 88 breeding goats were introduced into the farms. Three hundred ninety-nine goats died due to mainly diseases and 435 goats got withdrawn through nondeath. The average farm level and overall mortality rate were 21 goats per 1000 goatmonths and 15 goats per 1000 goatmonths respectively. The most pressing challenges encountered by sample farms were death of goats especially due to diseases, poor access to veterinary extension services, high cost of inputs and feed scarcity. Solutions suggested by sample farms were improved access to veterinary services, improved housing, enhanced vaccination of goats against diseases, and enhanced grazing land management and feed conservation, all of which were incorporated into the flock health program. **Conclusion and**

Recommendations: An appropriate flock health program was generated based on flock dynamics and production constraints which reveal high mortality and limited access to veterinary services respectively. Actors are recommended to promote adoption and adherence to the flock health program so as to increase goat production and access to wider market.

Keywords

Flock Dynamics, Flock Health Program, Goat Production, Albertine Graben

1. Introduction

1.1. Background

The Albertine Graben, a 20,000 km^2 region covering 8 districts has a human population of 2.5 million and a flock of 704,259 goats compared to national and global goat population which currently stands at 14.8 million [1] and 1.034 billion goats respectively. The goats are reared for meat, skin, byproducts and several socio-cultural purposes. It's a fact that goat meat has on average 75.42% water, 3.55% fat, 19.95% protein, 1.06% mineral matter and 580 kJ per 100 g [2]. It's also known that goat meat contains low saturated fatty acids and cholesterol compared to mutton, beef and chicken. The protein in goat meat has significant levels of essential amino acids such as lysine, threonine and tryptophan. Farmers sell live goats, products and by-products to earn income, and improve savings, which in turn contribute greatly to the improvement of livelihoods and rural development. Goat feeding on a wide range of forage, higher reproduction rate (multiple kids per birth), shorter generation intervals and small body size capable of producing meat in small readily usable quantities make them suitable for both subsistence and commercial production. The goat value chain employs a sizable number of producers, agro processers and various traders.

The huge potential of goats to reduce poverty which currently stands at 10% in the Albertine Graben can be exploited if interventions are directed towards commercialization of goat production and value chain. This will fasten realization of objectives of Agro Industrialization Programme (AGI) under National Development Plan III (NDPIII) hence Uganda Vision 2040 of Government of Uganda [3].

The cornerstone for commercialization of goat value chain entails increasing production and productivity, value addition and access to markets. These can be achieved if farms score nicely across key performance indicators like increase in flock size, reproductive performance and survival, increased breeding of consumer preferred goat breeds, and efficient traceability system.

1.2. Problem Statement

Low application and adherence to appropriate flock health program across over

80% of goat farms in the Albertine Graben is creating fertile conditions for frequent and severe diseases outbreaks. This frustrates effort aimed at commercializing goat production. Inadequate information on flock dynamics and prevailing epidemiologic challenges facing farms is making it more difficult for veterinarians to generate appropriate flock health programs for dissemination to farmers. It is also making it difficult to assess farm level and sub-agroecological flock performance indicators and design appropriate farm management decisions. Most farmers try as much as possible to acquire veterinary pharmaceuticals through copying from fellow farmers but without appropriate flock health programs, disease prevention and control activities remain largely not tactical and strategic leading to continuous death of goats in high proportions. Facts on flock dynamics of goat farms in a given locality also provide information for estimating animal populations under various production systems.

District Veterinary Officers (DVOs) in Uganda are mandated to generate data, fill monthly disease surveillance forms and transmit to National Animal Diseases Diagnostic and Epidemiology center (NADDEC) in Department of Animal Health, Ministry of Agriculture Animal Industry and Fisheries (MAAIF). Part of the form captures aggregate data on animal production and farming systems at district level. However, they face difficulty in doing so due to lack of accurate farm records and automated data collection system for local and national flock. Yet projections of goat populations by Uganda Bureau of Statistics yearly statistical abstracts and animal census reports lack accurate details on yearly changes in flock size at individual farm, regional and national level which are vitally needed in prioritizing interventions aimed at increasing production of goats. One of the many interventions is appropriate flock health program.

1.3. Objectives

The objectives of this study were to:

1) Document flock dynamics and priority constraints encountered by selected goat farms in the Albertine Graben zone.

2) Design appropriate flock health program for goat farms in the Albertine Graben zone.

1.4. Justification

Application of professionally designed flock health programs based on accurate information on flock dynamics and prioritized constraints can significantly reduce mortalities and morbidities associated with diseases subsequently leading to increased survival and multiplication. Consequently, increase in flock size under fairly constant production costs improves farm outputs in terms of number of live goats, meat and by-products such as skin, dung, urine, etc. Farmers will then observe improvement in farm profitability and production efficiency. Local and transnational trade in live goats and products meeting sanitary requirements of niche markets reduces household level poverty and hence increases the country's foreign earnings (**Figure 1**).

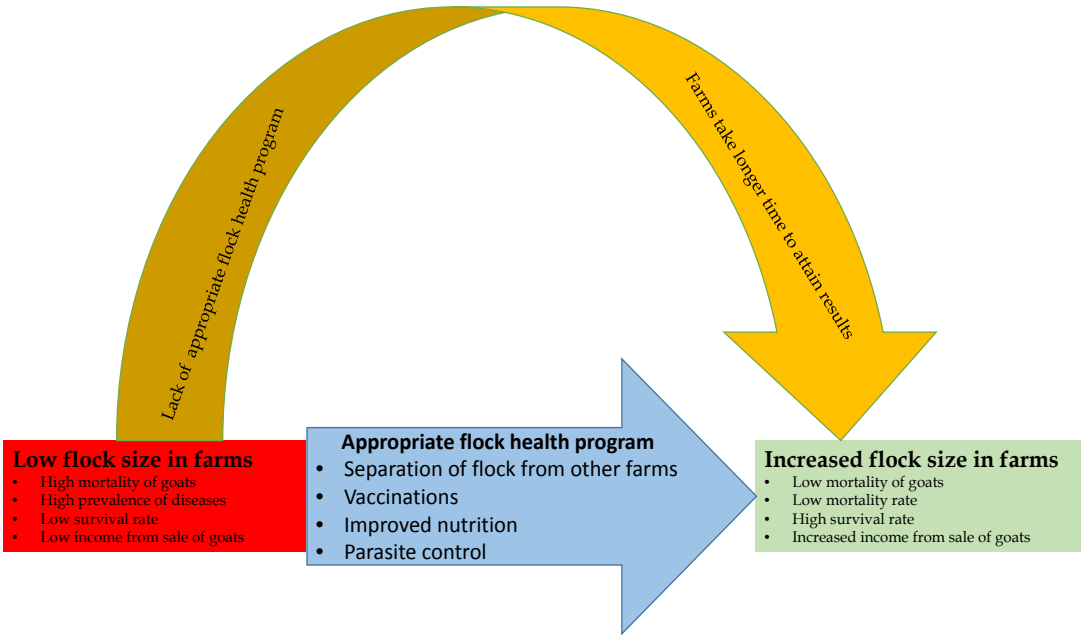

Figure 1. Flock dynamics, constraints encountered by farms in 2022 and appropriate flock health program for increased production of goats.

2. Literature Review

2.1. Flock Dynamics

Understanding of population dynamics is a central issue for managing herds of animals [4]. Knowledge on structural characteristics and trends in farm and zonal flock of goats helps farmers to forecast consequences of new flock management decisions on the production level and temporal distribution of production [5].

The commonest indices relevant for describing flock dynamics in goat farms are; 1) number and structure of goats at start, 2) number of goats born over the period (kidding), 3) number of goats introduced (purchases, receipts from donors, straying in) into the farm(s) over the period, 4) number of goats that died over the period, 5) number and structure of goats withdrawn from the population through non-death e.g. sale, slaughter, theft, straying etc., 6) number of goats in the farm at end of the period, 7) mortality rate and, 8) survival rate.

The population of goats in farms increases through inward movements or in flaws which occur via acquisition of breeding stock and unsolicited entries. It also occurs through kidding of goats. Detailed knowledge on sources, purposes and destinations for all inward movement of goats into a farm or zone helps in designing appropriate biosecurity measures and allocating resources for accommodating and feeding increasing flock of goats. Conversely the number of goats in the farms reduces through outward movement or outlaw of goats via sale, donations, theft and straying. Knowledge on timings and destinations of all outward movements of goats through non death helps in designing appropriate remedy such as marketing strategy and security plan. Reduction in flock size also

occurs through mortality of goats due to various causes ranging from infectious to non-infectious. Accurate and comprehensive information on mortality of goats in terms of frequency (quantity, percentages, proportions and rate), pattern (age group, breed & location) and related influencing factors helps in designing and evaluating the effectiveness of health management interventions. The population of goats in the whole world is estimated at 1034 billion [6] [7], in Uganda is 14.8 million and Albertine Graben is 704,259 goats [1]. The per capita consumption of meat in general and goat meat specifically in Uganda stands at 11 kg/person/year and 1 kg/person/year respectively. Just like the demand for products of other domestic animal species, the demand for goat meat and other products in Uganda outpaces production [8]. This is mainly due to rapid population growth, urbanization, increased incomes and changing lifestyles. The situation is pilling pressure on producers and government to increase contribution of goat production to local and global food security and poverty reduction amidst declining production, limited value addition and poor access to the market. This therefore makes monitoring undesirable changes in goat population and associated challenges a fantastic basis for designing interventions.

2.2. Challenges to Goat Production

The major constraints to goat production stifle farm(s) production/productivity. They center on gaps in production system, breeding, feeding, housing, health management and general care. The intensity and impact of these constraints vary depending on socio cultural, economic, environmental and political factors. According to Aldridge *et al.* [9], one of the major constraint to goat production is inadequate education and training fronts which requires; 1) promoting interest in animal science in the new generation, 2) goat and sheep science in curricula of undergraduate and graduate and veterinary medicine, 3) training extension agents in goat production, 4) training producers on best practices in goat production, and 5) educating the public about goat and sheep production.

Limited access to veterinary services as noted by Maesela *et al.* (2017) [10] is a major cause of mortality of goats and low productivity in farms. Veterinary services encompasses diagnosis, treatments, trainings sensitizations, demonstrations, breeding, medicines and devices, vaccinations, feeding, control of animal movements, inspection and certifications, diseases surveillance, zoonotic diseases control, research etc. Inadequate training of farmers is seen in the fact that there is an extremely high degree of variability in vaccination and deworming programs among producers [11].

Another major production constraint to goat farming is nutritional challenges experienced due to variations in feed availability causing feed scarcity especially in areas with shrinking grazing land or lacking grazing land [12].

2.3. Flock Health Program

Flock health program involves veterinary activities scheduled and implemented

to prevent introduction of diseases into the farms and minimize their impact in case they occur [13]. The activities are designed to optimize animal health and productivity [14]. It helps to control or eradicate economic and zoonotic diseases, ensure animal health and welfare, food safety and low ecosystem and environmental impacts in relation to chemical residues and pathogen circulation [15] [16]. Since each herd is in a different situation and groups of goat farms in zones varies in management and ecological conditions with minor commonalities, each farm owner or groups of farm owners are encouraged to work with their veterinarian to create their own herd health plan [17]. The flock health is dependent on balance between flock immunity and diseases challenge. A flock of goats remain healthy provided level of flock immunity is above level of disease challenge [18]. Disease outbreak occurs in a flock if diseases challenge outweighs flock immunity or during situations of lowered immunity (**Figure 2**). Activities aimed at preventing introduction of pathogens into the farm and catered for in the flock health program include [18]: 1) farm biosecurity such as adopting production system that limits contact of goats in the farm from goats of other farms. The most preferred production system for meat goats is paddocking production system where goats graze on controlled grazing land having shrubs, woody weeds, herbs and different pasture types. The area can be paddocked using fences; live fence, mesh fences, barbed wire, electric fence, energized barbed

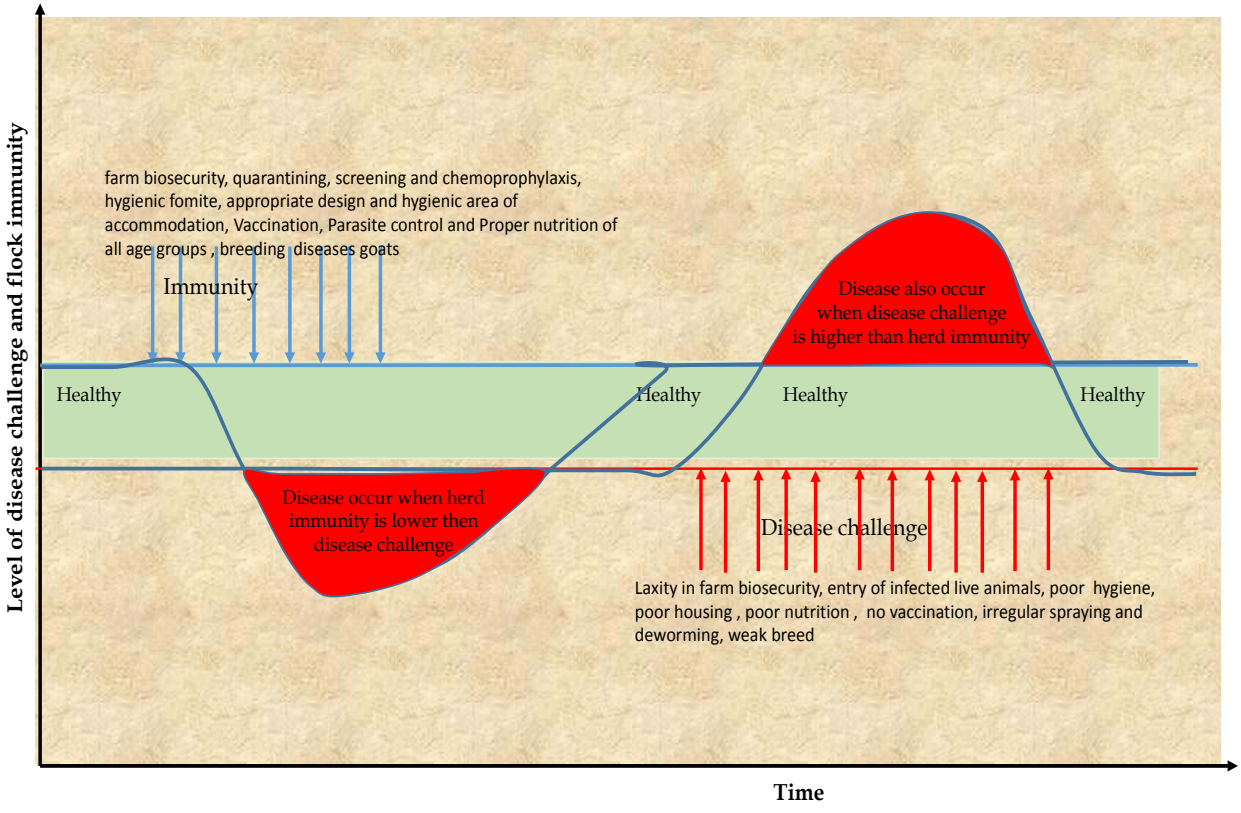

Figure 2. Illustration of disease occurrence among flock of goats (adapted from illustration in Herd health programs for a beef cattle enterprise, 2005) [18].

wire etc. 2) Quarantining, screening and chemoprophylaxis of all incoming goats to limit introduction of diseases goats into the farm. A part from purchasing breeding goats from known health farms ensure they are tested for trade and reproductive diseases. 3) Ensuring all fomites such as feed resources, implements and vehicles entering the farms are free of contamination and, 4) appropriate design, construction and maintenance of hygiene within area of accommodation for the goats through effective waste separation and management. 5) Another set of activities captured in the flock health program are those that minimizes impact (burden) of diseases in case they occur. The most important of all is vaccination of goats against common epidemics. Disease outbreaks occur when flock immunity is lower than disease challenge. Vaccination increases flock immunity against common epidemics in the zone e.g. Clostridial diseases, PPR, CCPP, RVF. 6) Parasite control through regular deworming and spraying with appropriate medicine. Ectoparasite and endo parasites infestation weaken the immune system and affect nutrient absorption and utilization 7) Proper nutrition of all age groups of goats; kids, weaners, yearlings and breeding goats. Nutrition affects the time at which puberty starts, the conception rate at first estrus in doelings, the length of the postpartum interval, the health and vigor of newborn lambs kids, changes in body condition before and during the breeding season affect reproductive performance in terms of services per conception, kidding intervals, and the percentages of open ewes and does and, 8) breeding for increased tolerance to common diseases.

3. Materials and Methods

3.1. Location

The study was conducted in goat farms located in selected sub-counties of Kibaale, Kagadi, Hoima, and Masindi districts of the Albertine Graben (**Figure 3**).

Data captured from Bulindi Zonal Agricultural Research and Development Institute (BuZARDI) weather station indicates the average temperature recorded in the year 2022 was 23˚C, annual rainfall 1709 mm, soil temperature 26.4˚C (**Table 1**).

3.2. Design

A cross sectional study involving use of quantitative and qualitative approaches was employed. Independent and dependent variables listed below were captured concurrently and described to illustrate the rationality for suggested flock health program.

3.3. Study Population, Sampling, and Sample Size

Goat farms in the Albertine Graben zone formed the study population. The sampling units were individual goat farms selected in high goat population areas at convenience of extension workers. Sixty goat farms were targeted but full responses were obtained from 45 farms located in four districts. We used GPS, mobile

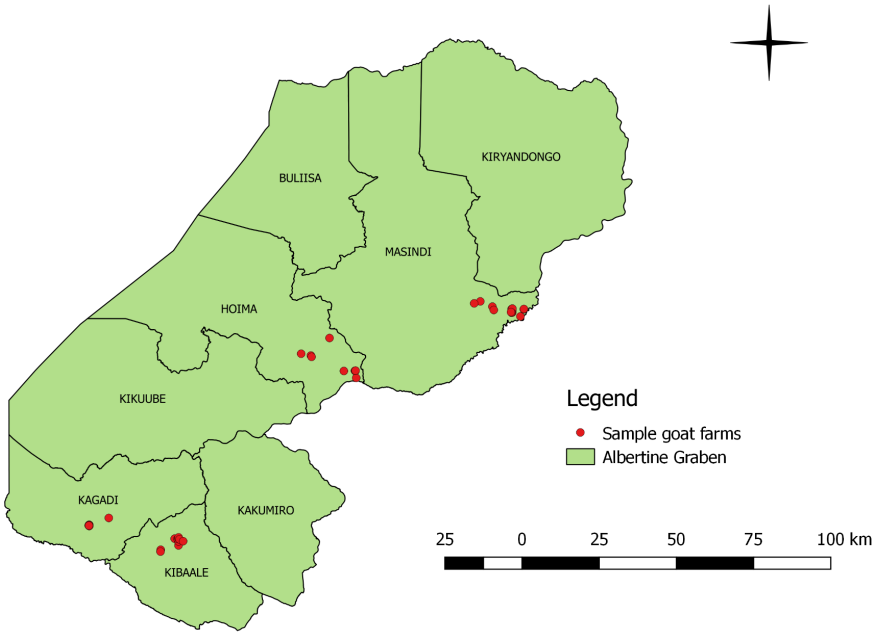

Figure 3. Map of Albertine Graben showing location of sample goat farmers.

Table 1. Weather for the year 2022.

Parameter	Indicator	Value
Temperature (˚C)	Average max	29.5
	Average Min	16.6
	Annual average	23.0
	Standard Dev	1.366
Rainfall (mm)	Annual total	1709
Relative humidity	Max	92
	Min	0
	Average	71.947
	Standard Dev	8.596
Soil temperature at 0.5 meter depth (˚C)	max	27.7
	Min	24.9
	Average	26.497
	Standard Dev	0.4989

smartphones, vehicle and motorcycle, books and pens to collect data digitally from selected farms (**Figure 4**).

3.4. Data Collection, Management and Analysis

Semi-structured questionnaire in hard copies and XLS forms were used by trained technicians to capture and transmit data from selected goat farms; location and socio-demographics of household (name, sex, marital status and education level,

Figure 4. A goat farm in Kibaale district and Ms. Lydia administering questionnaire to a farmer in Kimengo sub-county Masindi district.

district, sub county, parish, village and GPS coordinates), goat farming system, flock dynamics (flock record book, flock health program, number of goats at beginning and end of 2022, kidding, dead, introduced, and lost from the farm over 2022), goat housing (presence, type, size, condition of the roof, wall and floor), feeding system at the farm(system, pasture land, fodder, conservation, equipment), challenges encountered by goat farm in 2022 and suggested solutions (biosecurity, parasite control and frequency, vaccinations and frequency).

Data on hard copy were entered in excel (MS 2013) merged with those transmitted through Kobocollect cleaned, validated and stored. Data were then exported to SPSS (Verson 22) and R (Ver 4.4.2) for analysis. Descriptive statistics were computed and relationship between changes in flock size and farm practices was assessed. Inferences were based on appropriate statistics and P value at 5% level of significance.

4. Results

4.1. Socio-Demographic Characteristics of the Respondents

A seven-day exercise involving mapping, mobilization and capture of data using

a semi-structured questionnaire via Kobocollect and hard copies from sample farmers was carried from 23rd January 2023 to 27 January 2023. In total 45 goat farmers drawn from Kibaale, Kagadi, Hoima and Masindi responded fully (Table 2). They comprise of 76% male & 24% female. This was representative of the culture of communities in the zone where men are more preferred to own animals than women. Although majority of the respondents were primary and secondary school levers (64.5%), a significant percentage (15.6%) of the respondents have not had formal education. In married homes more family member's participation lowers cost of labor for rearing goats, fortunately majority of the respondents were married (73.4%) compared to single (8.9%) ones (Table 2).

4.2. Production Systems

Majority of the farms employ range and paddocking production system combined (57.8%). This is where goats controllably graze and browse on large portions of land ranging between 5 acres to 1 km^2 in size (Figure 5). This is followed by tethering production system (28.9%) in which goats tied on approximately 3 - 5 meters long ropes graze on grass and shrubs within radius equaling to the length of the rope. Free range goat production system was being practiced by 13.3% of sampled farms. It is the riskiest production system because of uncontrolled interaction of the farm goats with others predisposing to diseases, disappearances and theft. The home range of goats in most of the farms overlaps with that of goats in other farms.

4.3. Accommodation of the Goats

Goat houses are very important for accommodating various age groups of goats especially during adverse environmental conditions. Houses insulate goats against extreme coldness at night or during rain. The survey found out that up to 76% of goat farms lack goat houses predisposing goats to the risk of environment insults, predators and theft. This leads to frequent disease outbreaks such as pneumonia (Table 3). Most of the goat houses owned by the farms are semi-permanent (53%)

Table 2. Socio-demographic characteristics of the respondents.

Variables	Levels	Number	Percentage (%)
Sex	Female	11	24.4
	Male	34	75.6
Education	No formal education	7	15.6
	Primary	13	28.9
	Secondary	16	35.6
	Tertiary	6	13.3
	University	3	6.7
Marital status	Married	36	73.4
	Single	4	8.9
	Widowed	8	17.8

Table 3. Housing of goats in the farm.

Variable	Levels	Responses		Percent of Cases
		p	Percent (%)	
Presence of goat house in the farm	yes	11	24.0	
	no	34	76.0	
	subtotal	45	100.0	
Materials constituting the roof[a]	iron sheet	29	90.6	
	grass thatched	2	6.3	
	polythene/tarpaulin	1	3.1	
	subtotal	32	100.0	
Materials constituting the wall[a]	poles	10	23.8	32.30%
	wire mesh	2	4.8	6.50%
	bricks	3	7.1	9.70%
	timbers	27	64.3	87.10%
	subtotal	42	100.0	135.50%
Materials constituting the floor[a]	soil and not covered with anything	14	41.2	
	porous platform which allows feces to drop down	20	58.8	
	subtotal	34	100.0	

[a]Number of positive responses for the variable.

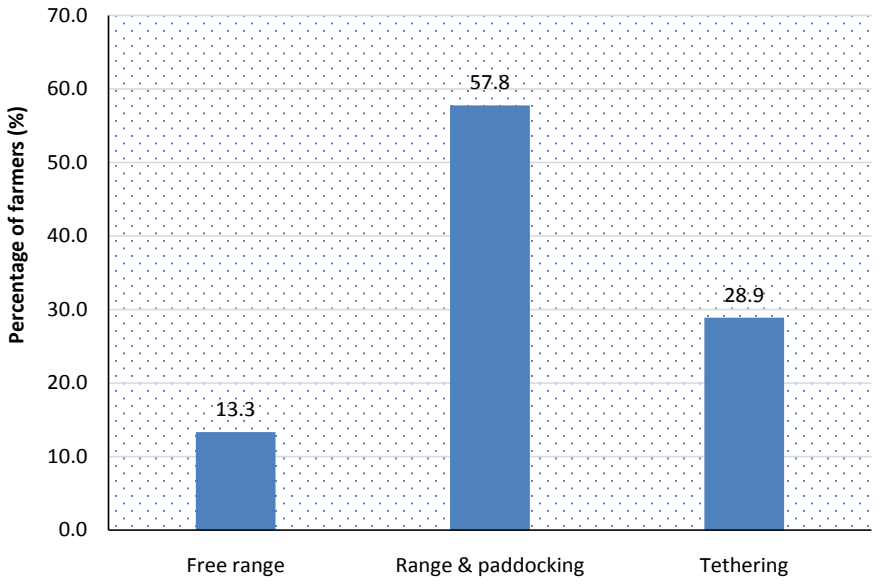

Figure 5. Percentage of farms practicing respective goat production system.

and temporary in nature (16%) (Figure 6). The roof of 90% of goat houses are made of iron sheets, walls are majorly made up of timbers and offcuts (64.3%) and floors of most of the houses are made of porous platforms which permits dung to drop down thereby enhancing hygiene.

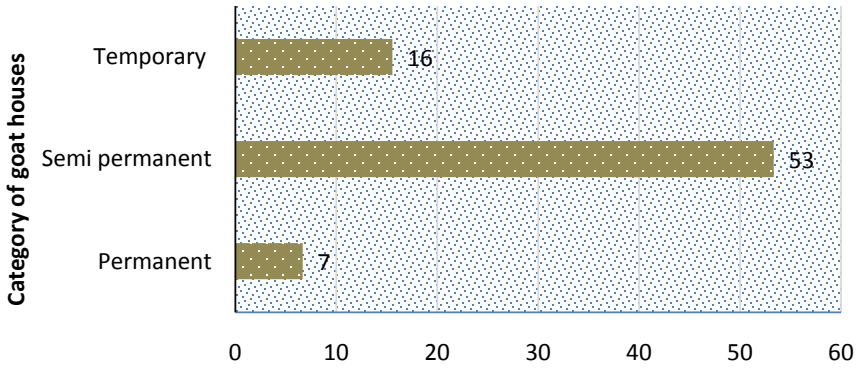

Figure 6. Category of goat houses.

4.4. Health Management

Involves deliberate plan to prevent, detect and response to health related conditions of entire flock of goats in the farm [19]. This mainly encompasses biosecurity, vaccinations, parasite control and proper nutrition. It is very crucial for all farms to record plans and activities executed to manage health of goats in the farm.

The survey established that 89% of goat farms sampled lack flock health record books and up to 80% of goat farms lack formal flock health programs. According to Uganda Bureau of Statistics (2020), the national level literacy rate (percentage of population aged 10 years and above that can read with understanding and write a simple sentence meaningfully in any language) was 73.5% (male (77.5%) and female (69.9%)). The very low percentage of farms having formal flock records and flock health programs amidst moderate level of literacy rate is probably due to laziness of farmers and poor access to veterinary services. During the interviews some respondents blatantly stated "*we have farm books but don't know what to write and purposes*" other respondents described their goatherds as lazy "*our goatherd is just lazy and doesn't take records as important*", Mr. Atungoza Milton Isaac (Kimego, Masindi district). There is complete lack of schedule and commitment on activities for preventing diseases and minimizing their impact in case of occurrence. Most of the production system can't separate goats in the farm with goats of other farms (no fences) and coupled with open population, uncontrolled traffic, lack of screening of new goats for trade sensitive diseases, lack of sufficient vaccination, parasite control and nutrition, outbreaks of diseases are frequent among the farms.

Nearly half of the sample farms do not regularly deworm their goats (**Figure 7**), hence increasing the risk and burden of worm infestation. The farms also don't seek services for regular fecal sample collection and analysis for various worms, larvae and eggs making accurate prescription difficult.

Regarding the spraying of goats against ectoparasite (ticks, lice, fleas, mites etc.), the results show that only 46.7% of farms spray their goats weekly, the remaining either spray goats once per month (17.8%), once per year (11.1%) or not at all (9%) (**Figure 8**). Farmers also do not get adequate support from veterinary

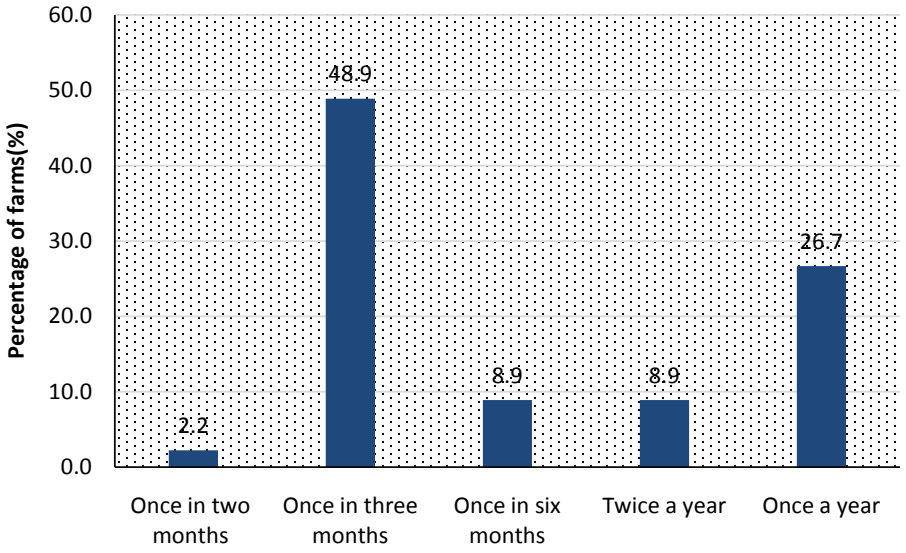

Figure 7. Frequency of deworming goats.

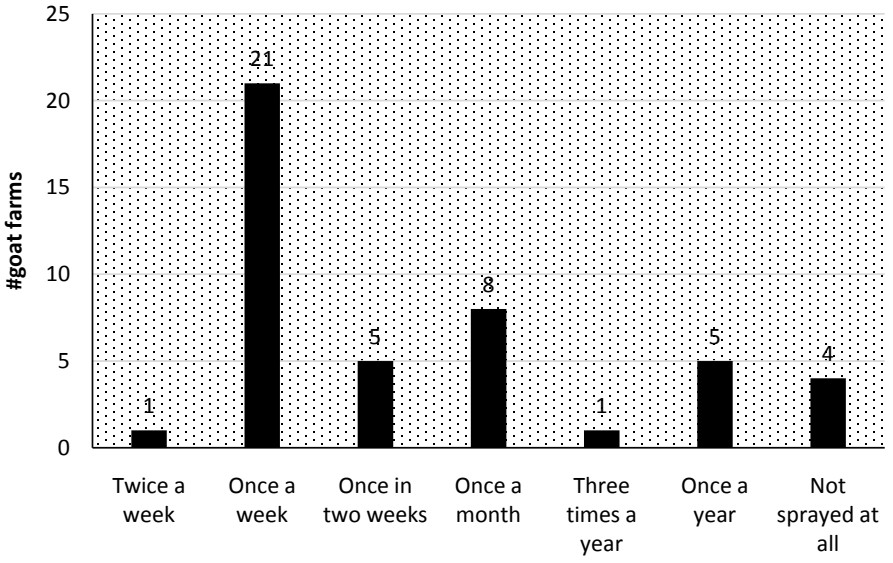

Figure 8. Frequency of spraying of goats against ectoparasite.

officers for evidence based use of acaricide which is possible if on farm tick samples are collected and analyzed for presence acaricide resistance.

Analysis of goat vaccination against common epidemics reveals that only 13% of sample goat farms vaccinate their goats against diseases (**Figure 9**).

The vaccination is mainly against PPR (83%) and Clostridial diseases (17%) (**Figure 10**). The vaccination regimes being practiced by sample goat farms are not appropriate for the production system and environment. According to earlier research work by Tumusiime, *et al.* [20] [21] and drawing from the records and experiences of District Veterinary workforce, the most common outbreaks are caused by Contagious Caprine Pleuropneumonia, Pest des petit ruminates, Clostridial diseases, Orf and Rift Valley Fever.

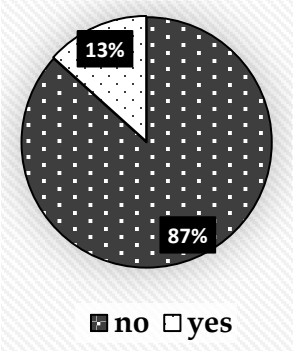

Figure 9. Percentage of farms that vaccinate their goats against diseases.

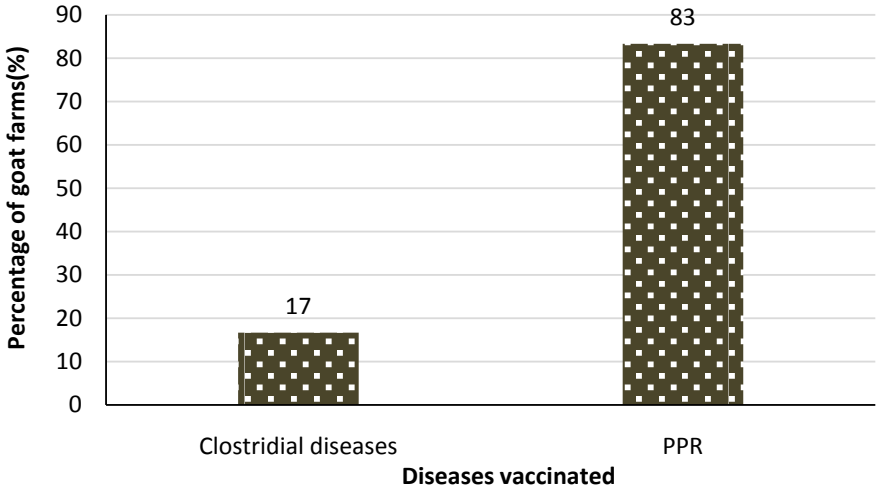

Figure 10. Percentage of farms that covered goats against respective diseases last one year.

4.5. Challenges Encountered by Goat Farms in the Year 2022

The study results (Table 4) reveal that the most pressing challenges encountered by goat farms in the year 2022 were death of goats due to diseases (21.2%), followed by poor access to veterinary extension services (12.1%), high cost of inputs such as acaricide, dewormers vaccines, fencing and house construction materials (9.7%), feed scarcity (9.1%), lack of improved breeds (9.1%), straying of goats (8.5%) and others (30.3%).

4.6. Suggested Solutions by Goat Farms

Improved access to veterinary extension services was the most common solution suggested for improved production of goats (22.1%), followed by improved housing of goats (16%), enhanced vaccination of goats against diseases (15%), grazing land management, feed conservation and storage (15%), improved security (12.1%), and others (19.8%) (Table 4).

4.7. Flock Dynamics of Goats among Selected Farms

The following indices computed from the data describe flock dynamics of sample goat farms in the Albertine Graben (Figure 11).

Table 4. Challenges faced by goat farms in 2022 and suggested solutions.

Variable	Levels	Responses	
		N	Percent (%)
Challenges faced in goat farms[a]	Death of goats	35	21.2
	Theft of goats	13	7.9
	Feed scarcity	15	9.1
	Lack of improved breeds	15	9.1
	Straying of goats	14	8.5
	high cost of inputs such as drugs	16	9.7
	lack of market	4	2.4
	low pricing	14	8.5
	poor access to veterinary extension services	20	12.1
	Extreme weather conditions	5	3.0
	Other	14	8.5
	Subtotal	165	100.0
Suggested solutions to challenges faced[a]	Improved access to veterinary extension services	31	22.1
	Feed conservation and storage	21	15.0
	Improved housing of goats	23	16.4
	Improved waste management	15	10.7
	Vaccination of goats against diseases	21	15.0
	Formation of marketing groups	12	8.6
	Improved security	17	12.1
	Subtotal	140	100.0

[a]Number of positive responses for the variable.

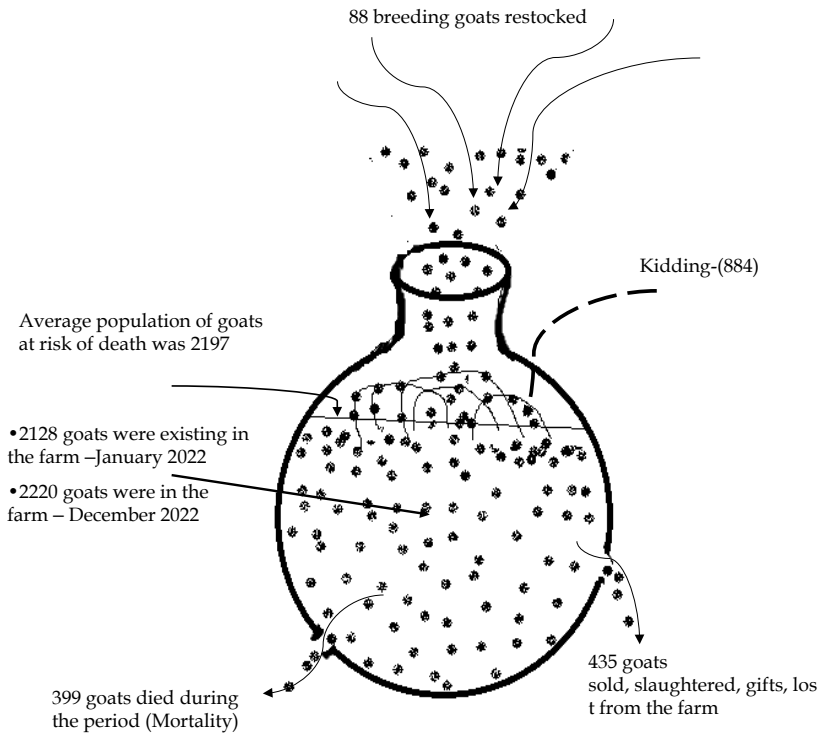

Figure 11. Presentation of flock dynamics of sample goat farms over the year 2022.

The number of goats in all the sample farms by January 2022 was 2128 goats and is represented by (a) in the formula. The number of goats acquired through kidding by Does in the sample farms over the year 2022 was 884 goats and is represented as (b). The number of goats acquired by all the sample farms through purchases and receipts during the year was 88 goats and many of them were received as breeding stock. It is represented as (c). The number of goats that died over the year (d) was 399 goats. Several causes led accounted for the deaths. The number of goats withdrawn from flock of goats in all the sample farms through non-death e.g. sale, slaughter, theft, straying etc. (e) was 435 goats. The number of goats in all the sample farms by December 2022 was 2220 goats. The duration in which goats were kept in the sample farms (g) was 12 months.

Based on below formula, individual farm level mortality rate among flock of goats from each of the sample farms were computed;

$$\text{Mortality rate} = \frac{\text{Number of goats that died in the farm over the period}}{\left\{\left[\text{Nstart} + \frac{1}{2}\text{Nnew}\right] - \left[\frac{1}{2}\left(\text{Nwithdrawn} + \text{Ndeaths}\right)\right]\right\} \times \text{time}}$$

$$\text{Mortality rate} = \frac{\text{Number of goats that died in the farm over the period}}{\left\{\left[\text{Nstart} + \frac{1}{2}\left(\text{Nkids} + \text{Npurchased}\right)\right] - \left[\frac{1}{2}\left(\left(\text{Nsold} + \text{slaughtered} + \text{theft}\right) + \text{Ndeaths}\right)\right]\right\} \times \text{time}}$$

From values obtained for each farm, average individual farm level mortality rate among the goats was computed to be 0.021 or 21 goats per 1000 goatmonths (SEM = 5).

Zone level mortality rate among flock of goats from all sample farms [22]

$$\text{Mortality rate} = \frac{\text{Number of goats that died in the farm over the period}}{\left\{\left[\text{Nstart} + \frac{1}{2}\text{Nnew}\right] - \left[\frac{1}{2}\left(\text{Nwithdrawn} + \text{Ndeaths}\right)\right]\right\} \times \text{time}}$$

$$\text{Mortality rate} = \frac{\text{Number of goats that died in the farm over the period}}{\left\{\left[\text{Nstart} + \frac{1}{2}\left(\text{Nkids} + \text{Npurchased}\right)\right] - \left[\frac{1}{2}\left(\left(\text{Nsold} + \text{slaughtered} + \text{theft}\right) + \text{Ndeaths}\right)\right]\right\} \times \text{time}}$$

$$\text{Mortality rate}\left(\frac{\text{goats}}{\text{goatmonths}}\right) = \frac{d}{\left\{\left[a + \frac{1}{2}\left(b + c\right)\right] - \left[\frac{1}{2}\left(e + d\right)\right]\right\}\text{goat} \times g}$$

$$\text{Mortality rate}\left(\frac{\text{goats}}{\text{goatmonths}}\right) = \frac{399}{\left\{\left[2128 + \frac{1}{2}\left(884 + 88\right)\right] - \left[\frac{1}{2}\left(435 + 399\right)\right]\right\}\text{goat} \times 12}$$

Mortality rate = 0.015 or 15 goats/1000 goatmonths

5. Discussion

5.1. Flock Dynamics

During the period January 2022 to December 2022, the number of goats reared in all the sample farms increased from 2128 goats to 2220 goats. Eight hundred

eighty-four kids were born, eighty-eight goats were sourced and introduced into the farm as breeding stock, bringing total flock of 3100 goats if no sales and death occurred. But in the same period 399 goats died due to mainly diseases and 435 goats were sold, lost or given out as donations. The average population of goats at risk of death was 2197 goats (**Figure 11**). The average individual farm level mortality rate was 21 goats per 1000 goatmonths and overall mortality rate among flock of goats from all sampled farms was 15 goats per 1000 goatmonths. Although the average farm level mortality rate was computed from figures captured based on farmer's recall (which often bears reasonable recall bias), it is not statistically different from that obtained by Guma *et al.* (2022) among flock of Mubende goats reared under semi-intensive farming system at BuZARDI which stood at 27 goats per 1000 goatmonths where better practices exists.

Up to 89% of the farms lack formal records in which deaths are recorded and up to 80% of them also lack appropriate flock health program where disease prevention and control activities including treatments of goats are recorded. There is a high tendency amongst farmers to forget kid mortalities. The implication is that if a farm having 1000 goats keep the goats for one year it's expected to lose 252 goats valued at UGX 75,600,000 (20,432 USD).

5.2. Challenges Encountered by Farms in the Year 2022 and Suggested Solutions for Enhanced Production of Goats

Every market-oriented goat farmer desire successful operation which are indicated by: 1) the percentage of doelings and does conceiving timely and regularly; 2) the percentage of Does and Doelings kidding successfully, 3) the percentage of kids weaned; 4) the percentage of weaned goats/growers successfully raised to 1 year and; 5) the number of goats marketed each year. The prolificacy, growth rate, survival rate and mortality rate are other alternative indicators for measuring success in goat rearing enterprises. Across the world producers face several challenges categorically related to environmental conditions, production systems, gaps in husbandry practices and governance of veterinary services & the country in general, limited value addition and access to market.

The findings related to most pressing challenges encountered by sample farms in the year 2022 ranked death of goats especially due to diseases as the worst (**Table 4**). And out of the 399 goats that died over the year 2022, 282 (70.7%) were kids which is reflective of an on-station study at BuZARDI conducted by Guma *et al.* (2022) [23] which further ranked worm infestation as the leading cause of kid mortality [23]. Similar studies conducted in Mount Kenya goat farms also ranked diseases as the most pressing constraint to goat production [24]. This calls for more effort in control of diseases [25]. Poor access to veterinary extension services was the second most pressing challenge faced by the sample farms in 2022 (**Table 3**), veterinary services entails; diagnosis, treatments, trainings sensitizations, demonstrations, breeding, medicines and devices, vaccinations, control of animal movements, inspection and certifications, diseases surveillance, zoonotic diseases control, research etc. Improved access to

veterinary services in turn enhances famer's skills in animal husbandry practices with emphasis on diseases prevention and management and other husbandry practices. The finding is similar to that of a study conducted by Maesela *et al.* (2017) in Sekhukhune District of Limpopo province, South Africa which found out that fewer groups of dairy-goat farmers (14.5%) accessed veterinary services while majority of them (85.5%) complains of lack of access to veterinary health service [10]. This, according District Veterinary Officers in Albertine Graben, was due to inadequate facilitation for sub-county based veterinarians. The third most pressing challenge encountered by farmers in 2022 was high cost of inputs such as acaricide, dewormers, vaccines, fencing and house construction materials. This directly increases variable and fixed costs for production of goats in the study area. This can be mitigated through multi-stakeholder collaboration involving farmers, veterinarians and input traders. Next was the feed scarcity especially during prolonged drought period which results into malnutrition, straying and death of goats. The situation was being exacerbated by inadequate knowledge of the farmers in feed conservation, grazing land management and fodder production. Another challenge captured from sample goat farms was lack of improved breeds which elsewhere has also been reported by small holder goat farmers in three Districts of Botswana [26] [27]. It was being worsened by ongoing inbreeding among flock of goats within individual farms. This can be solved better by instituting community based breeding programs and training of farmers on goat breeding and record management.

5.3. Suggested Flock Health Program

Flock health program involves activities scheduled to prevent introduction of diseases into the farms and minimize their impact in case they occur [13]. All the vital activities applicable to goat flock health are organized into a simple, usable, and easily remembered format [28]. Overall goal of the flock health program is to control or eradicate economic and zoonotic diseases, ensure animal health and welfare, food safety and low ecosystem and environmental impacts in relation to chemical residues and pathogen circulation [15] [16]. It's important to note that feeding, accommodation or breeding of goats alone can't guarantee maximum productivity without good health [29]. Activities aimed at preventing introduction of pathogens into the farm and catered for in the flock health program include: 1) farm biosecurity such as adopting production system that limits contact of goats in the farm from goats of other farms. The most preferred production system for meat goats is paddocking production system where goats graze on controlled grazing land having shrubs, woody weeds, herbs and different pasture types. The area can be paddocked using fences; live fence, mesh fences, barbed wire, electric fence, energized barbed wire etc. 2) Quarantining, screening and chemoprophylaxis of all incoming goats to limit introduction of diseases goats into the farm. 3) Ensuring all fomites such as feed resources, implements and vehicles are free of contamination and, 4) appropriate design, con-

struction and maintenance hygiene within area of accommodation for the goats through effective waste separation and management. Another set of activities captured in the flock health program are those that minimizes impact (burden) of diseases in case they occur. 5) Vaccination of goats against common epidemics, diseases outbreaks occur when flock immunity is lower than diseases challenge. Vaccination increases flock immunity against common epidemics in the zone e.g. Clostridial diseases, PPR, CCPP, RVF, FMD, etc. 6) Parasite control through regular deworming and spraying with appropriate medicine. 7) proper nutrition of all age groups of goats; kids, weaners, yearlings and breeding goats and, 8) breeding for increased tolerance to common diseases [30] [31].

The suggested flock health program takes into consideration the survey result that found out that up to 80% of goat farms lack formal flock health program, with many also having poor access to veterinary services (diagnosis, treatments, trainings, sensitizations, demonstrations, breeding, medicines and devices, vaccinations, control of animal movements, inspection and certifications, diseases surveillance, zoonotic diseases control, research, etc.) making it very difficult to guarantee implementation of time bound disease prevention and control activities, also taking note that most of the outbreaks occur during rainy season (April-May & July-November) while others occur during dry season (January-March & June) of every year. A part from environmental factors, other factors considered are increased trade and uncontrolled movement of goats, free range production system etc. all of which increase incidences and prevalence of diseases in the zone. **Table 5**, shows above outlined activities and time frame. The farm manager is the person responsible for timely implementation of all activities.

In order to track improvements in performance of goat farms applying prescribed flock health program, financial health and meet trade and legislative obligations farmers are advised to record inventory, restocking, kidding, breeding, spraying, deworming, mortalities and disposals using the following templates [32] [33]:

(a) SOPs and template for taking flock inventory/journal (for determining flock size and structure)

i) Collect flock size and structure data at least quarterly.

ii) Ensure all goats have identification ear tags.

iii) Use a digital weighing scale, round weighing scale and sac or weigh bridge for weighing the goats.

iv) Fill the template ID, sex, breed, color, age group, weight, disability in **Table 6**.

v) Compute flock size (total number of goats in the farm) instantly.

vi) Summarize flock structure by sex, breed, color, age group and disaggregated average weight instantly.

(b) 3.0 SOPs and template for capturing data of goats restocked or received

Table 5. Proposed flock health program (Land scape with visible cell lines).

S/no	Activities		Time frame										
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	Improve and maintain farm biosecurity by adopting paddocking production system that helps in separating goats in the farm from goats of other farms. This can best be done using fences													
2	Source new goats from known healthy farms and test them for Brucellosis, CCPP, RVF and PPR at reputable lab and treat all incoming goats.													
3	Ensuring all fomites such as feed resources, implements and vehicles are free of contamination and													
4	Appropriate design and maintenance of accommodation infrastructure (houses) for the goats and effective waste management.													
5	Vaccination of goats against common epidemics, diseases outbreaks occur when flock immunity is lower than diseases challenge,	Yearly vaccination of goats against Clostridial diseases												
		Yearly vaccination of goats against CCPP												
		Yearly vaccination of goats against PPR												
6	Parasite control through regular deworming and spraying with appropriate medicine,	Weekly spraying of goats against Ticks, Fleas, Mites and Flies												
		Quarterly deworming of goats against worms												
7	Proper nutrition of all age groups of goats; kids, weaners, yearlings and breeding goats	Manage grazing land properly, remove toxic plants, spot planting with grazeable fodder												
8	Breeding for increased tolerance to common diseases, stress and fertility	Flock record, kidding record, mortality record												

Table 6. Template for flock inventory.

S/no	ID	Sex	breed	Color	age group	weight	disability
1							
2							

i) All goats acquired by the farm for breeding must be recorded. This may be through purchases, receipts from donors, projects, and well-wishers, etc.

ii) Ensure each of them have identification ear tags.

iii) Use a round weighing scale and sac or weigh bridge for weighing the goats.

iv) Fill the template ID, sex, breed, color, age group, weight, disability and ori-

gin/source (Table 7).

v) Compute proportion of goats per sex, breed, color, age group and disaggregated average weight instantly.

(c) SOPs and template for recording data on kidding in the farm

i) Kidding record should be filled in real time following delivery of the kid.

ii) The ear tag number and parity of the doe are very crucial and must be entered even if the buck can't be traced.

iii) Use digital weighing scale to measure weight of the kid.

iv) Date of kidding, ID (Doe), parity of doe, No kids delivered, Type of kidding, adequacy of milk, kid suckling, health status of doe, health status of kid, weight of kid at day 1 (Table 8).

v) Compute the number of Does that delivered every quarter, number of Does that delivered twins, triplets, quadruplets etc., number of kids born alive, and proportion of Does that had multiple kids per birth over the quarter.

vi) Compute proportion of still birth, neonatal mortality and abortions.

vii) Does and kids delivered very weak and exhibiting signs of Vitamin E and selenium deficiency should be administered vitamin E injection.

(d) SOPs and template for capturing data for determining growth rate of goats

i) Identify kids born in the same period.

ii) Weigh each kid.

iii) Fill the ID, sex, breed, color, age group, weight and group average (Table 9).

iv) Compute average weight for kids born in the same period, sample and select for breeding based on your chosen criteria.

Table 7. Restocking or receipts record.

S/no	Date	ID	Sex	breed	color	age group	weight	disability	Origin/source
1									
2									

Table 8. Kidding record.

S/no	Date of kidding	ID (doe)	Parity of doe	No kids delivered	Type of kidding	Adequacy of milk	kid suckling	health status of doe	health status of kid	weight of kid at day 1
1										
2										
3										

Table 9. Template for collecting data for determining growth rate of goats.

S/no	ID	sex	breed	color	age group	weight	Gp Average
1							
2							

(e) SOPs and template for Mortality record

i) Every time a goat dies, enter the record in real time even if the cause of death is not yet ascertained.

ii) Fill in Date of death, ID, breed, color, age group, sex, weight, Cause of death? (Table 10).

iii) Compute number of goats in the farm that died over the quarter.

iv) Disaggregate the number by breed, color, age group, sex and weight.

v) Compute the mortality rate over the quarter or year.

vi)

$$\text{Mortality rate}\left(\frac{\text{goats}}{\text{goatmonths}}\right) = \frac{\text{Number of goats that died in the farm over the period}}{\left\{\left[\text{Nstart}+\frac{1}{2}\left(\text{Nkids}+\text{Npurchased}\right)\right]-\left[\frac{1}{2}\left(\left(\text{Nsold}+\text{slaughtered}+\text{theft}\right)+\text{Ndeaths}\right)\right]\right\}\times\text{time}}$$

(f) SOPs and template for disposal or trade (sale, donations, loss etc.) record

i) The record of any goat disposed from the flock should be entered in the form immediately and clearly indicate the reason for disposal; sale, slaughter, donation, battering, theft, straying etc.

ii) Fill in Date of disposal, ID, sex, breed, color, age group, weight, Reasons for disposal and value (Table 11).

iii) Disaggregate the number, average weight and value (UGX) per age group and reasons for disposal.

iv) Compute income from sale of goats, products and byproducts.

(g) SOPs and template for capturing data on deworming of goats

i) Deworm all the goats every quarter—4 times per year.

ii) Collect dung sample and submit to a reputable lab for worm analysis.

iii) Use dewormers prescribed by veterinarian and purchased from licensed veterinary drug shop.

iv) Read the direction for use and dosage carefully be administration.

v) Fill in date, dewormer & batch number, active ingredient, dosage, route of administration and number of animals dewormed. Sum number of goats dewormed (Table 12).

Table 10. Mortality record.

S/no	Date of death	ID	breed	color	age group	sex	weight	Cause of death?
1								
2								

Table 11. Disposal record.

S/no	Date of disposal	ID	sex	breed	color	age group	weight	Reasons for disposal	Value
1									
2									

(h) SOPs and Template for Spraying of goats in the farm

i) Spray all the goats weekly during rainy season and every two weeks during dry season—52 times per year.

ii) Collect tick sample and submit to a reputable lab for acaricide resistance every year.

iii) Separate kids from adult goats and spray them separately.

iv) Use acaricide prescribed by veterinarian and purchased from licensed veterinary drug shop. Use effective spray pump such as foot spray pump.

v) Read the direction for use and dilution rate carefully before spraying.

vi) Fill in Date, acaricide, active ingredient, dilution rate, spray pump and number of animals sprayed (Table 13).

Table 12. Template for deworming goats.

S/no	Date	Dewormer	Active ingredient	Dosage	Route of administration	number of animals dewormed
1						
2						

Table 13. A record of spraying animals.

S/no	Date	Acaricide	Active ingredient	Dilution rate	Spray pump	Number of animals sprayed
1						
2						

Table 14. Vaccination record.

S/no	Date	Vaccine	Active ingredient	Dosage	Route of administration	Number of goats vaccinated
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						

vii) Enter number of goats sprayed immediately.

viii) Draw a graph showing number of goats sprayed against weeks of the year

(i) SOPs and Template for vaccination of goats

i) All the goats must be vaccinated against Clostridial diseases, PPR, CCPP and RVF at least once per year.

ii) Collect serum sample and submit to a reputable lab for antibody titer analysis.

iii) Use vaccines prescribed by veterinarian and purchased from licensed veterinary drug shop. Ensure all vaccines are valid and kept under strict cold chain system; vaccine fridge has thermometer and vaccine carriers having ice packs.

iv) Read the direction for use and dosage carefully before administration.

v) Enter number of goats vaccinated immediately (Table 14).

6. Conclusions and Recommendations

6.1. Conclusions

The main objectives of this study are to; i) document flock dynamics and priority constraints encountered by selected goat farms in the Albertine Graben zone and, ii) design appropriate flock health program for goat farms in the Albertine Graben zone. Related to objective (i), the flock size increased from 2128 goats to 2220 goats. Eight hundred eighty-four kids were born, and eighty-eight goats were sourced and introduced into the farm as breeding stock. But in the same period 399 goats died due to mainly diseases and 435 goats were sold for income, lost or given out as donations. The individual goat farm level and zonal level mortality rates were 21 goats per 1000 goatmonths and 15 goats per 1000 goatmonths respectively. The most pressing challenges encountered by the farms were; high losses due to death of goats resulting from diseases, poor access to veterinary extension services, high cost of inputs such as acaricide, dewormers vaccines, fencing and house construction materials, feed scarcity, lack of improved breeds and wrong production system matching land size.

Related to objective (ii), based on flock dynamics and production constraints, the flock health program generated encompasses: improving farm biosecurity, quarantining, screening and chemoprophylaxis of all incoming goats, ensuring all fomites such as feed resources, implements and vehicles are free of contamination, appropriate design and maintenance of accommodation infrastructure (houses) for the goats through effective waste management, vaccination of goats against common epidemics, parasite control through regular deworming and spraying with appropriate medicine, proper nutrition of all age groups of goats; kids, weaners, yearlings and breeding goats and breeding for increased tolerance to common diseases and reproductive health. The study was, however, limited by lack of formal records at most goat farm.

6.2. Recommendations

In order to minimize high mortality of goats as noted in the flock dynamics goat

farms and other stakeholders in the Albertine Graben are recommended to adopt and promote; i) improved access to veterinary services, ii) limiting interaction of the flock from goats of other farms by paddocking production system with better grazing land management practices and feed supplementation and improve housing for goats. The study highly recommend adoption of formal farm record keeping and adoption of our designed flock health program which is aimed at reducing prevailing mortality rate (21 goats per 1000 goatmonths) by 75% in the next 3 years. More research is recommended to develop accurate methods of evaluating efficacy of developed flock health programs and accelerating dissemination to farmers through uptake pathways.

6.3. Contribution to the Existing Knowledge

The study is deepening the practice of generating flock health program based on facts on flock dynamics and major production constraints.

6.4. Implications of This Research

a) Policy

Within the provisions of the policy for delivery of Veterinary Services 1997 and in order to enhance contribution of goat farming towards realizing specific aspirations of Agriculture Extension Policy III, The National Development Plan III and guideline for implementation of The Agro Industrialization Program, there is need to; i) increase access of farmers to extension services by deploying competent and motivated personnel rationally, ii) promote interest in animal science among producers and extension workers, iii) train extension agents in goat production with emphasis on developing flock health program, iv) equip producers with best goat production practices with emphasis on adherence to flock health program.

It is advisable for goat farmers in Albertine Graben to synchronize health and production management practices tailored for specific ecological zones and production systems. This will make it easier for them to comply with sanitary requirements of national and transnational niche markets.

b) Practitioners;

Agricultural and Veterinary extension workers need to be armed with factually generated flock health program for dissemination to farmers in the Albertine Graben. This can be easily done if extension workers, statisticians and researchers work collaboratively. There is need for practitioners to inculcate culture of farm record among farmers. Address the issue of high mortality of goats in the farms by emphasizing adherence to flock health program.

c) Academia

Members of academia community need to develop formal and automated applications for capturing data from representative goat farms for generating analyzed information on flock dynamics. An easier way is required for integrating animal population data to national statistical dash boards. Appropriate methods

are also required for evaluating efficacy and efficiency of flock health programs adopted by farmers in the Albertine Graben Zone and Uganda in general.

Acknowledgements

The authors are highly grateful to the Director General NARO who extended to us a competitive research grant. Special appreciation goes to the research and administrative team of BuZARDI comprising; Mr. Joseph Magala, Ms. Nakimuli Madina Mable (HR), Ms. Rosette Kabikuru (AA), Mr. Daniel Musasizi (AA), Gladys Nasali (AA) and Mr. Andama Joackin (FM) for their great support. Lastly, the authors acknowledge all goat farmers and staff of District Veterinary Offices of Kibaale (Dr. Ahisibwe James), Masindi (Dr. Fred Ssebuguzi & Mr. Bbira Johnson), Hoima (Dr. Patrick Ndorwa) and Kagadi district for their collaboration during the exercise.

Ethical Statement

The authors confirm that the ethical policies of the journal's author guideline page and applicable national guidelines have been adhered to. The protocol of this non-invasive study on farm animals has been approved by the institute's Scientific Committee.

Conflicts of Interest

The authors declare that no situation of ethical conflict and moral distress was experienced during the study.

Statement on Data Availability

The primary and secondary datasets generated during this study are available from the corresponding author and can be accessed freely on reasonable request.

Authors' Contributions

This study is part of the job description of the first author WG. SDB, LPA and IT are members of the research team. Thanks to all authors for respective contribution in shaping the study design, data collection, analysis, reporting and logistics. SDB contributed in study design and editing, LPA and IT participated in data collection and validation.

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