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Research Article

Influence of Improved Husbandry Practices on Productivity and Greenhouse Gas Emissions in Agropastoral Meat Goat Production System in a Semi-arid Kenya

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Abstract

In Kenya, demand for goat meat is projected to continue rising and farmers in low input agropastoral production system are responding to the growing demand by increasing goat population, perpetuating rise in absolute and intensity of greenhouse gas (GHG) emissions. This study assessed influence of improved husbandry on protein food production and GHG emissions. The study was conducted in agropastoral meat goat system in Baringo county where a random sample of 124 smallholder meat goat farmers was interviewed through a cross-sectional farm survey. Descriptive statistics from primary data collected in cross-sectional farm survey was the model base input for simulation modelling using GLEAM-i tool to estimate GHG emissions and productivity. Referenced on average flock performance as base situation, improved husbandry was reflected as change in flock composition towards fewer adult males, increase in slaughter (market) weight and survival rate of young stock, earlier age at first kidding, shorter kidding interval and longer productive life. Improvement in base flock performance value was either to 25th or 75th percentile value to objectively reflect potential attainable improvement in the flock. Relative to the base situation, fewer adult males in the flock resulted in 26.9% increase in productivity but absolute emissions increased by 10.1% while emission intensity reduced by 13.4%. Improving reproductive performance increased protein production by 8.4% with a reduction of 8.3% in emission intensity and 1.1% in absolute emissions. Increasing the survival of young animals and slaughter weight increased protein production by 8.4% with an increase of 3.8% in absolute emissions and a reduction of 4.1% in emission intensity. These findings show that improved flock composition, by keeping fewer adult males and more adult females have a larger potential of increasing protein production and reducing emission intensity, implying that regular off- take of unproductive animal classes in the flock can enhance sustainability of smallholder meat goat production systems. The results will guide extension service providers and policy makers in developing climate-smart interventions for increasing goat meat production while reducing emission intensity.

Keywords

Absolute, Emission Intensity, GLEAM-i, Productivity

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1. Introduction

Goat (*Capra hircus*) is an important livestock in the provision of multiple benefits, including animal source food (ASF), income from the sale of stock, milk, fiber, and manure as well as intangible social and cultural functions [1, 2]. These provisions are critical in the harsh environmental conditions where goats thrive as a result of relevant attributes, including small body size, adaptable feeding habits, high adaptability to harsh environmental conditions and shorter reproductive cycle [3]. Their other attributes include low maintenance costs, ability to survive in areas with feed and water scarcity, low mortality rates and quicker recovery from diseases as well as rapid maturity to market weight than cattle.

Kenya is ranked third goat producing country in Africa after Sudan and Nigeria, with a population of 38.4 million heads comprising of 98.3% meat goats [4]. In Kenya, goats are predominantly reared in the Arid and Semi-Arid counties, such as Baringo county that has an estimated meat goat population of 1.04 million heads [4]. Meat goats here are reared under pastoral, agropastoral or mixed-crop production systems, with natural pastures and crop residues being the dominant feed resources in pastoral and agropastoral systems. Limited supplementation is practiced in agropastoral and mixed crop systems [2, 5]. These production systems are characterized by high vulnerability to climate change-related stresses and also low productivity, high absolute and intensity of greenhouse gas (GHG) emissions [6]. Yet, it is from these systems that Kenya will continue to source goat meat needed for a rapidly growing population and urbanization [7]. The consumption demand for goat meat is further fueled by larger urban population with more disposal incomes who are changing eating habits and expressing strong preference for meat [8].

Interventions for improving goat production in low-input production systems found in the arid and semi-arid lands have been mostly directed to increasing goat numbers rather than productivity. Consequently, goat population increased by 76% between 1977 and 2016 [9], and a 29.3% increase from 27 million in 2009 to 38.4 million heads in 2023 [4, 10]. This implies that increase in goat meat production is reliant on increasing the number of goats, but with low external input use. Without improved husbandry, this strategy is expected to increase dependency on natural feed resources, leading to adverse degradation as well as increasing GHG emissions, both absolute and intensity.

Goats contribute 4.9% of enteric methane emissions globally [3], which could further increase with business-as-usual husbandry scenario. These emissions vary depending on feed resources and feeding practices, husbandry practices as well as production environment, and recent studies show that GHG emissions from agropastoral meat goat production systems in semi-arid lands have not been adequately documented [3]. This necessitates urgency for identifying appropriate interventions that would increase meat goat productivity whilst minimizing GHG emissions. Increase in goat meat productivity is achievable with changes in flock husbandry decisions, such as changing flock structure and improving health, feeding and reproductive performance [11]. Change in flock structure by reducing the proportion of non-productive animal classes increases more productive classes, which may subsequently influence productivity and GHG emissions, both absolute and intensity [12]. Realizing reduced mortality of young animals in the flock is an indicator of improved flock health, potentially resulting in more kids reared [13], or rapid growth to attain slaughter weight earlier, which could reduce emissions per kg of meat produced [14]. Attaining earlier age at first kidding reduces the unproductive phases and subsequently lowers emission intensity [15]. Similarly, shorter kidding interval leads to more kids in the productive life of a doe, higher meat output and a subsequent reduction in emission intensity [16]. A longer productive life reduces the need for frequent replacement, thereby lowering the energy and emissions associated with raising unproductive replacement animals [17].

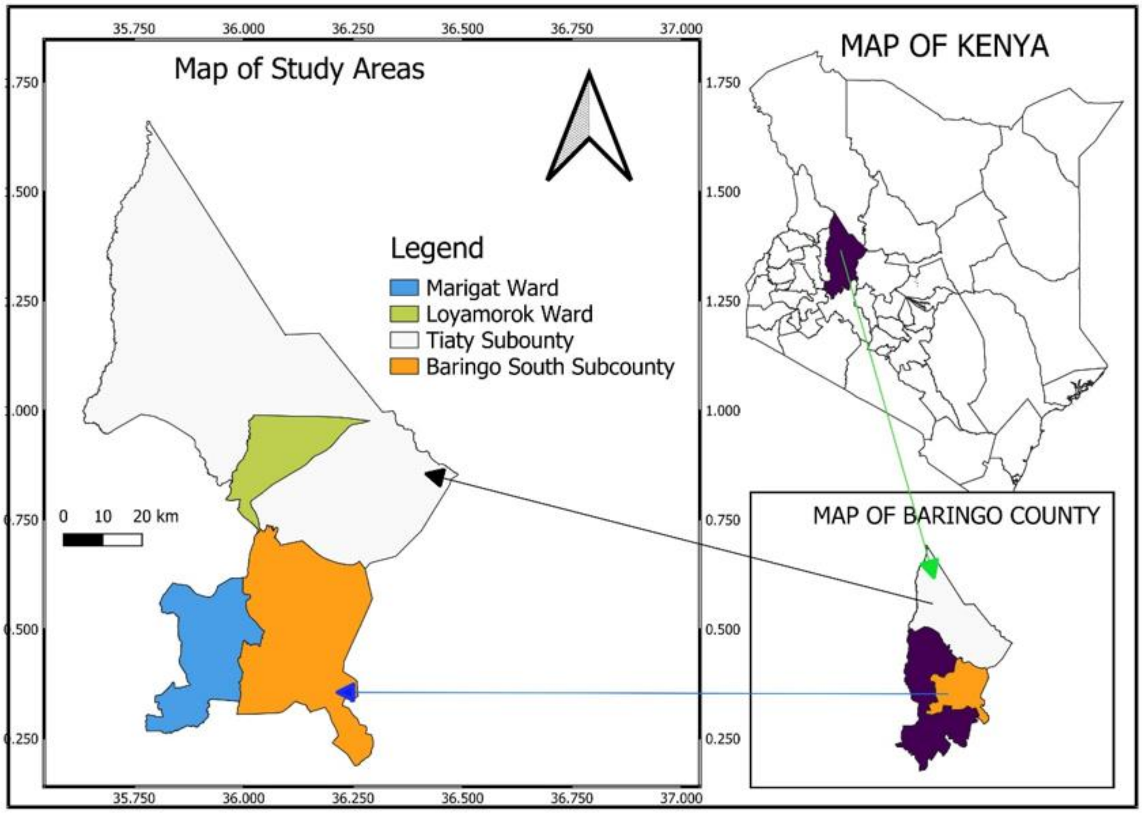
Previous studies present evidence showing the influence of improved husbandry practices, manifesting in change in flock composition, production and reproductive performance on protein production and GHG emissions, however, that evidence has been generated from dairy and beef herd. The information remains scanty on meat goats under low input, rangeland agropastoral production system in Kenya, yet it is needed to inform appropriate and urgent interventions that mitigate emissions whilst increasing production of animal source food. In filling this knowledge gap, this study therefore assessed influence of improved husbandry practices on protein food production and GHG emissions, both absolute and intensity in agropastoral meat goat production system.

2. Materials and Methods

2.1. Study Area

The study was conducted in agropastoral communities of Baringo County (Figure 1), which is a semi-arid ecosystem where meat goats are central livelihood assets, integrated with cattle keeping, sheep rearing, bee keeping, and fishing as well as tourism [18]. Baringo county has an estimated meat goat population of 1.04 million heads [4]. The county is located approximately between Latitudes 0.25° and 1.75° and longitudes 35.75° and 37.00° East. Approximately, the county covers an area of 10,951.61 km^2 with an estimated human population of 666,763 [19]. The county experiences bimodal rainfall pattern, with long rains occurring from March to July and short rains from September to November. The rainfall ranges from 300-700mm in the lowlands and 1000- 1,500mm in the highlands [20]. The county has humid climate in the highlands while lowlands are arid with a temperature range of 10°C to 35°C [21]. The altitude ranges from 715m to 3014m above the sea level [22]. The most common soil types include Lithic

Leptosols, Calcaric Regosols, and Chromic Luvisols [20]. In the study area, goats are grazed on natural pastures on community land and sometimes grazed around homesteads where they are offered some supplemental feeding (crop residues, agroforestry products, and kitchen leftovers).



Source: Author

Figure 1. *Map of the study area.*

2.2. Study Design and Sampling Procedure

The study was conducted in two wards (Marigat and Loyamorok) of Baringo county, Kenya. A total of 124 meat goat smallholder farmers were sampled in a cross-sectional farm survey using a pre-tested structured questionnaire. The farmers were beneficiaries of Kenya Livestock Commercialization Project (KeLCoP), that provided access to their beneficiary villages with the list of farmers from where a sample of 124 smallholder meat goat farmers were randomly selected.

2.3. Data Collection

A structured questionnaire was used to collect primary data using both qualitative and quantitative measurements on individual and herd characteristics. The interest was on measurements of animal production performance (survival rate, animal liveweights, birthweight, litter size) and reproductive performance (age at first kidding, kidding interval, productive life). Animal live weight was estimated using a heart girth tape measure [23]. Data on flock size was from recording the number of goats that belonged to different age classes. Data on the number of kids that were born on the farm in the last 12 months and those that died were recorded to derive crude deathrate of young animals [24]. Reproductive performance data was recorded on performance of individual does on the farm, supplemented with prompting for historical performance. Other data included feed resources and manure management practices (pasture/paddock/range, daily spread, solid storage, dry lot, liquid/slurry, composting, burned for fuel, anaerobic digester as well as uncovered lagoon), and these were collected by interviewing and observation [25].

2.4. Data Analysis

The collected data was sorted, cleaned, edited and checked for completeness in Microsoft Excel 2016 spreadsheet then analyzed descriptively to obtain sample mean, frequencies, percentages and percentiles for flock composition, production and reproduction performance, manure management and feed resource use. These flock descriptive statistics presented in

Table 1 formed the base model inputs for the different modules of the Global Livestock Assessment Model (GLEAM-i) tool (version 3) integrated in estimating the base protein food production and GHG emissions, both absolute and intensity [25].

Table 1. Input parameters for estimating base GHG emissions and protein production.

Variable	Units	Mean ± SD	25th percentile	Median	75th percentile
Adult males	Number	8.4 ± 9.39	3	6	11
Adult females	Number	19.4 ± 14.70	9	15.5	23
Age at first kidding	Months	15.0 ± 1.83	14	15	16.4
Litter size	Number	1.5 ± 0.34	1.2	1.48	2.0
Kidding interval	Months	8.0 ± 0.96	7.1	8.0	8.4
Productive life	Years	7.5 ± 2.09	5.83	7.4	8.83
Birth weight	Kg	2.0 ± 0.36	1.75	2.0	2.25
Live weight of animals at slaughter (meat males)	Kg	27.2 ± 3.33	25.0	27.0	29.0
Live weight of animals at slaughter (meat females)	Kg	26.0 ± 3.32	24.0	26.0	28.0
Live weight (adult females)	Kg	35.0 ± 4.17	32.0	35.0	38.0
Live weight (adult males)	Kg	40.0 ± 5.82	35.0	40.0	45.0
Crude death rate of young animals	%	16.8 ± 14.04	6.7	12.3	26.6
Crude death rate of adult animals	%	10.14 ± 10.29	1.73	6.3	15.0

The GLEAM-i used is a free tool developed by the Food and Agriculture Organization (FAO) of the United Nations, to estimate GHG emissions (CH_4, N_2O and CO_2) from production systems of the major livestock species including cattle, sheep, goats, buffalo, pigs and chicken [26]. Use of GLEAM-i makes it possible to generate disaggregated estimates of GHG emissions and emission intensities for the primary livestock products, agricultural systems and global regions [27]. GLEAM-i tool has been used to estimate absolute and intensity of greenhouse gas emissions and productivity in various livestock production systems [28]. It also generates baseline and improved scenarios of herd management (including reproduction and health), feeding and manure management systems [27]. The model simulates biophysical processes and activities along livestock supply chains using a life cycle assessment system boundaries approach in compliance with ISO 14044:2006 standards. The GLEAM-i emission estimations are based on Tier-II approaches of the Intergovernmental Panel on Climate Change (IPCC) guidelines for metabolic energy partitioning, calculations of emissions from enteric fermentations and manure management.

The GLEAM-i tool comprises of five modules, namely, herd module, feed module, manure module, system module and allocation module [26], which are used for estimating the GHG emissions from respective modules of the livestock production system. Herd, feed and manure modules are used to estimate GHG from animals, feed (production and processing) and manure management, respectively. Furthermore, the system module is used to estimate the GHG from the overall system, while the allocation module is used to allocate emission for each module [2].

The GLEAM-i model was used to estimate CO_2, CH_4 and N_2O emissions from cradle to farm gate, that are associated with changes in flock composition, reduced death rate of young animals, increased slaughter (market) weight, earlier age at first kidding, shorter kidding interval and longer productive life relative to base flock average performance (farm survey data) of meat goats for agropastoral system. However, the use of cross-sectional farm survey data in simulation modelling only gives a general overview of production conditions without capturing seasonal variations in management and feed resources. Also, relying on farmer recall may bring errors while reporting. In addition, the use of GLEAM-i in simulation modelling depends on the accuracy of input data and underlying assumptions, bringing uncertainty in the emission estimates. Furthermore, there was no any validation procedures applied to assess the reliability of the model outputs because there were no direct field measurements.

2.5. Developing Mitigation Scenarios

To assess the influence of different husbandry practices, three scenarios were simulated. Scenario one was change in flock composition by reducing proportion of adult males in the flock. The second scenario was reducing young mortality rate, and increasing slaughter weight, while the third scenario was reducing age at first kidding and kidding interval and increasing productive life. Improved scenarios were simulated for flock performance attaining either 25th percentile for flock composition, young mortality rate, age at first kidding, and kidding interval because lower values for these indicators show that farms are exhibiting better reproductive and survival performance. The 75th percentile was used for slaughter weight and productive life because higher values for these indicators are desirable for farms to reflect better production performance. This aligns with the description by [29], of herd management strategies for greenhouse gas emission mitigation in dairy production. Improvement in base flock performance value to either 25th or 75th percentile value from the survey data was to objectively reflect potential attainable improvements by a proportion of farmers in the study population, showing that achieving attainable improvements may be through adoption of already existing husbandry practices. This approach contrasts other approaches that assume some percentage improvement in performance indicators [28].

2.6. System Boundary

The system boundary defined in using the GLEAM-i tool accounted for all emissions during the process of goat meat production from cradle up to the farm gate. This is because the study focused on the management practices that farmers can influence, through improved feeding, health, reproduction, and manure handling. Emissions associated with transport, processing, and retail are influenced by other value chain actors post the farmgate. This cradle-to-farm gate system boundary was appropriate for assessing mitigation options within the production system, excluding emissions beyond the farmgate. Also excluded were CO_2 from respiration of goats because CO_2 from respiration of livestock can be approximated to be equal to the CO_2 uptake or sequestration by plants for the photosynthesis process [27].

3. Results

3.1. Base Protein Food Production and Associated GHG Emissions

Results of the base protein food production and GHG emissions are presented in Table 2. On average, an agropastoral smallholder meat goat farm in Baringo county produces protein food (meat) of 119 kg protein/ year from feed intake of 15,808 kg DM/year. This level of protein food production is associated with 11,598 kg CO_2-eq/year of absolute GHG emissions and emission intensity of 97 kg CO_2-eq/kg protein. The GHG emissions comprised (Figure 2) mostly enteric methane (74.6%) relative to nitrous oxide (14.8%) and carbon dioxide (10.6%).

Table 2. *Base protein food production and GHG emissions.*

Absolute emissions (kgCO_2-eq/year)	Emission intensity (kgCO_2-eq/kg protein)	Protein production (kg protein/ year)	Feed intake (Kg DM/ year)
11,598	97	119	15,808

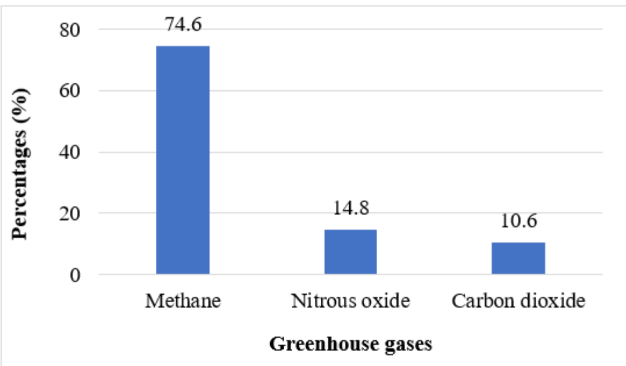


Figure 2. *Contribution of different greenhouse gases to absolute emissions of base performance.*

3.2. Influence of Improved Husbandry Scenarios on Protein Food Production and GHG Mitigation Effects

3.2.1. Scenario I: Effect of Change in Flock Composition on Productivity and Greenhouse Gas Emissions

Change in flock composition was through reducing the proportion of adult males in the flock to 25th percentile value and comparing protein food production and GHG emissions with the base flock average value. The protein food production (Table 3) increased by 26.9% from 119 to 151 kg protein/ year with feed intake increasing from 15,808 to 17,811 kg DM/year to 15,448 kg DM/year. The increase in protein food production was accompanied with 10.1% increase in absolute emissions, from 11,598 to 12,767 kg CO_2-eq/year and a reduction in emission intensity by 13.4% from 97 to 84 kg CO_2-eq/kg protein.

3.2.2. Scenario II: Effect of Reduced Mortality of Young Animals and Increased Slaughter Weight on Productivity and Greenhouse Gas Emissions

In this scenario, mortality of young animals was reduced to 25th percentile value and slaughter weight increased to 75th percentile value of the flock. With these improvements in the flock, protein food production increased by 8.4% from 119 to 129 kg protein/ year, utilizing increased feed intake (Table 3) from 15,808 to 16,503 kg DM/year. The increased protein food production was associated with absolute emissions increase of 3.8% from 11,598 to 12,037 kgCO_2-eq/year accompanied with a 4.1% reduction in emission intensity from 97 to 93 kgCO_2-eq/kg protein.

3.2.3. Scenario III: Effect of Improved Reproductive Performance on Productivity and Greenhouse Gas Emissions

This scenario examined effect of earlier age at first kidding and shorter kidding interval, assuming attaining flock 25th percentile value and increasing productive life to flock 75th percentile value. The performance improvement in the flock generated 8.4% increase in protein food production from 119 to 129 kg protein/ year, with some reduction (Table 3) in feed intake from 15,808 to 15,618 kg DM/year. The realized increase in protein food production was associated with a marginal reduction of 1.1% in absolute emissions from 11,598 to 11,467 kgCO_2-eq/year, but a larger reduction in emission intensity by 8.3% from 97 to 89 kgCO_2-eq/kg protein.

Table 3. *Effect of mitigation scenarios on protein production (kg protein/ year) and GHG emissions, both absolute (kgCO_2-eq/year) and intensity (kgCO_2-eq/kg protein).*

Mitigation scenarios	Protein production	% Change in protein production	Absolute emissions	% Change in absolute emissions	Emission intensity	% Change in emission intensity
Baseline	119		11,598		97	
Scenario I	151	+26.9	12,767	+10.1	84	-13.4
Scenario II	129	+8.4	12,037	+3.8	93	-4.1
Scenario III	129	+8.4	11,467	-1.1	89	-8.3

4. Discussion

This study addressed the knowledge gap about the effect of improved goat husbandry on food productivity and greenhouse gas emissions in agropastoral meat goat systems in the arid and semi-arid lands. It is aimed at informing appropriate and urgent interventions that mitigate emissions whilst increasing production of animal source food. This aspect has not been addressed in rangeland agropastoral meat goat systems.

The emission intensity of the present study (97 kgCO_2-eq/kg protein) was higher than the one reported in Kenya's NDC [30], and that reported in SSA and for the global average [28]. The higher emission intensity is attributed to low productivity of meat goats as a result of high mortality brought about by drought, low animal weights resulting from low quality feeds, and poor management practices such as disease control [16, 31]. Methane took the highest percentage among the greenhouse gas types followed by nitrous oxide as this is in agreement with the findings of the previous studies [2, 28]. The high percentage of enteric methane indicates that goats are ruminants with a unique digestive system having a rumen where fermentation takes place giving out methane as a by-product [32]. In addition to that, the high percentage of enteric methane could also be attributed to poor quality feeds with low digestibility that stay longer in the rumen before being digested [33, 34]. The nitrous oxide emission could be as a result of poor manure management systems and the presence of undigested materials in the manure while the lower percentage of carbon dioxide is as a result of less feed production in the agropastoral meat goat production system which is always dominated by roughages with less feed production and processing [2, 28].

A change in flock composition by reducing proportion of unproductive animal class resulted in increased productivity with a reduction in the intensity of greenhouse gas emissions but the absolute emission increased. This result concurs with the findings of the previous studies [25], which reported that reducing the proportion of unproductive animals in the flock increases efficiency with which the consumed feed resources are converted into saleable products. The reduction in emission intensity is as a result of a high proportion of productive females in the flock with improved biological efficiency whereby a large proportion of feed resources was directed to them, producing more kids and increasing meat output produced per unit of greenhouse gases emitted [16]. Also, the emissions were distributed over a relatively higher quantity of meat produced because of increased number of animals that directly contribute to meat production, lowering emission intensity. Similarly, review studies of GHG mitigation strategies in goats reported that reducing the proportion of non-productive animals in the flock can increase productivity and lower emission intensity by allocating feed and other resources to animals that directly contribute to meat production [14].

Though reducing the proportion of unproductive animal class reduced emission intensity, it increased absolute emissions. Improving flock composition involved maintaining a large proportion of productive animals in the flock that produce more kids, increasing feed consumption and emitting more gases [28]. This is reflected in Tier II approach that adapts life cycle analysis integrated in GLEAM-i tool. The study findings suggest that goat farmers can reduce the environmental footprint from goat production through reducing the proportion of unproductive animals and maintaining the breeding females as this can increase meat production without necessarily increasing the flock sizes.

The reduced emission intensity (4.1%) with improvement in survival of young animals and slaughter weight concurs with the results of [28], in Ethiopia obtained using GLEAM-i tool. This can be attributed to increased number of animals that survive up to market age, which contribute to increased productivity, evidenced by increase in protein production (8.4%). This reflects utilization of resources being converted into meat [35]. Also, improved slaughter weight increases carcass weight, which is also a measure of animal productivity, by increasing the quantity of edible product per animal [36], consequently can be associated with reduction in emission intensity.

Though the intervention reduced emission intensity, the absolute GHGs emission increased (3.8%). Though the findings are similar to those of [37], it may be resulting from increased number of animals on the farm being maintained with external inputs, especially feeds [28], reflected in use of Tier II approach of life cycle analysis integrated in GLEAM-i tool. It may also be that animals matured slowly to reach slaughter weight, thus staying longer in the herd which could be associated with increased amount of feed consumed by animals to reach market weights, allowing a period for enteric methane emissions, emissions from manure as well as emissions associated with feed production to happen [38]. These study findings show that farmers can enhance sustainable goat production through interventions that reduce mortality of young animals such as improved disease management and better nutrition [13]. In addition, increasing slaughter weight through better nutrition and improve growth management may increase meat production while reducing emission intensity [14]. Farmer training services should therefore emphasize improved health, improved feeding and better overall management and improving farmers' access to quality feeds and animal health inputs, and supporting climate-smart livestock extension programs could facilitate the adoption of these practices.

The reduced emission intensity (8.3%) with improvement in age at first kidding, kidding interval and productive life concurs with the findings of the previous studies done in Ethiopia using GLEAM-i tool [28]. This can be attributed to increased meat production (8.4%), evidenced by increase in protein production that outweighs increase in absolute emissions [16]. Reducing age at first kidding reduces the unproductive phase of does enabling them to produce their first kids early and more kids throughout their reproductive cycles that contribute directly to meat production [15]. Shorter kidding intervals increase the number of kids produced increasing herd efficiency that reduced emissions per output [35], and a relatively longer productive life of does that distributes the emitted emissions during unproductive period to the several productive cycles [39]. All these improvements increase the efficiency with which available resources are converted into meat reducing the emission intensity per output of meat.

The reduction in absolute emissions (1.1%) with the improvement disagrees with the findings of the previous studies done in Ethiopia using GLEAM-i tool [2], which may be resulting from reduced unproductive periods between one kidding to another and also animals taking a short time to produce their first kids reducing on their feed requirements and emissions that are associated with feed production [40], that is reflected in use of Tier II approach of life cycle analysis integrated in GLEAM-i tool. The reduction can also be attributed to a relatively longer doe productive life that reduces the need for frequent replacement, thereby lowering the energy and emissions associated with raising unproductive replacement animals [41]. The findings show that goat farmers can increase meat production and reduce GHG emissions by adopting management practices such as improved feeding, disease control and proper breeding that improve reproductive performance. Livestock extension service providers should therefore focus on training farmers on reproductive management, nutrition and animal health to improve flock efficiency.

5. Conclusion

The study assessed the influence of improved goat husbandry on food productivity and greenhouse gas emissions in agropastoral meat goat systems in the arid and semi-arid lands. It was evidenced that improvements in flock composition, survival of young animals, slaughter weight, age at first kidding, kidding interval and productive life can increase protein production and reduce emission intensity from agropastoral meat goats. The study findings suggest that livestock extension programs should focus on training farmers on how to improve reproductive performance and kid survival as well as improved flock management practices. In addition, climate mitigation policies should focus on encouraging the adoption of interventions that increase productivity as part of climate-smart livestock development strategies. The study however used cross-sectional survey data and simulation modelling using GLEAM-i, which may not have captured seasonal variation and local production dynamics. Further studies should focus on longitudinal data collection and direct field measurements of greenhouse gases for validation of the reliability of the model outputs to further improve the understanding of mitigation strategies in smallholder agropastoral meat goat production systems.

6. Recommendations

1) Livestock extension programs should promote extension services and capacity building that encourage farmers to regular off- take of unproductive animal classes in the flock needs as a way of managing the flock.
2) Adoption of management practices that improve reproductive performance can increase productivity and reduce emission intensity.
3) Implementation of husbandry practices that increase survival of young animals and slaughter weight can increase productivity and reduce emission intensity.

Abbreviations

ASF	Animal Source Food
GHG	Greenhouse gas
KeLCoP	Kenya Livestock Commercialization Project
GLEAM	Global Livestock Environmental Assessment Model
FAO	Food and Agriculture Organization
IPCC	Intergovernmental Panel on Climate Change

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Author Contributions

Cecilia Akolebirungi: Conceptualization, Formal Analysis, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing

Thomas Kainga Muasya: Investigation, Methodology, Supervision, Validation, Writing – review & editing

Bockline Omedo Bebe: Investigation, Methodology, Supervision, Validation, Writing – review & editing

Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Field

Akolebirungi Cecilia: Livestock Production Systems, Livestock Husbandry Practices, Change Adaptation and Mitigation, Animal Nutrition, Animal Breeding

Thomas Kainga Muasya: Animal breeding and Genetics, Animal Genomics. Livestock Production Systems, Dairy Cattle Improvement, Climate Adaptation in Livestock

Bockline Omedo Bebe: Livestock Production Systems, Livestock Husbandry Practices, Animal Breeding, Sustainable Food Systems, Climate Change Adaptation and Mitigation, Animal Nutrition