Essentials for Sustainable Dairy goat Breeding Program in Tanzania

Viktige faktorar for å etablera eit varig avlsprogram for mjølkegeit i Tanzania

Philosophie Doctor (PhD) Thesis

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Ås, May, 2016

Contents

Abbreviations

AI	Artificial insemination
BLUP	Best Linear Unbiased Prediction
DASP	Department of Animal Science and Production
DNA	Deoxyribonucleic Acid
EBVs	Estimated Breeding Values
EPINAV	Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistical Databases
GDP	Gross Domestic Product
GM	Gross Margin
HH	Household
IHA	Department of Animal and Aquacultural Sciences
LP	Linear Programing
MoLFD	Ministry of Livestock and Fisheries Development
MPT	Multipurpose tree
DMY	Daily milk yield
NMBU	Norwegian University of Life Sciences
PPP	Public Private Partnerships
SUA	Sokoine University of Agriculture
SWOT	Strengths, Weaknesses, Opportunities and Threats
TALIRI	Tanzania Livestock Research Institution
TALIRO	Tanzania Livestock Research Organization
TZS	Tanzanian Shillings
URT	United Republic of Tanzania

Summary

The overall objective of this thesis was to develop building blocks essential for establishing a sustainable dairy goat breeding program in Tanzania. To fulfil this objective, three approaches were employed. This included field survey (paper I &II), simulation study (paper III) and on-farm experiment and lesson learnt (paper IV). The production systems optimization in paper I showed that dairy goat production brings assurance of less variation in production income in the long term compared to other production systems. However, to achieve this in Tanzania it is necessary to purchase more concentrate feed and implement goat breeding principles. Paper II found that of the 125 respondents, many (35.2%) keep dairy goats for milk production, as many as 30.6% to obtain offspring and sell them, and 24.1% of the respondents emphasized the value of manure. In the study areas, manure was sold to obtain income. High producing goats (33.7%), tolerance to diseases (20%), and high twinning ability (14%) were the most preferred traits by respondents. In addition, the farmers lack knowledge on selection, recording, and animal identification. Paper III found that testing between 20 and 30 bucks per year could lead to a good breeding program with acceptable level of accuracy under local conditions in Tanzania. Testing 30 bucks per year is recommended for Mgeta. Part of paper III also outlines elements necessary for breeding program sustainability. A schematic figure is included to illustrate how selection can be performed through progeny testing to fit current situation in Mgeta. The SWOT analysis in paper IV reveals that Tanzania has a potential for dairy goat development. Strengths are: good policy, presence of research and academic institutions, readiness of private sectors to participate in the dairy goat industry, availability of resources, and that many rural famers already own dairy goats. Weaknesses are: insufficient support from the government, low formal education of farmers, lack of clear breeding goals, and lack of sustainability of breeding selection programs established. These pull back progress in the dairy goat sector. However, there are several opportunities such that information towards solving the

limitations are available. In Europe, for example, they seem to do better with animal breeding programs. Quality genetic materials from these successful programs can be accessed by other countries like Tanzania through markets, given that the policy allows. On these grounds in paper IV, occasional import of dairy goat semen for AI to use in a nucleus breeding herd is proposed. Both bucks and female offspring born in such a herd may be supplied to farmers. Quality dairy goats is already a business in Tanzania, hence participation of private sectors in the industry should be encouraged. The government and academic institutions may be watchdogs of what should be happening regarding dairy goats in the country. Threats may include change in policy regarding export/import of buck semen, farmers' willingness to pay for price of quality bucks, and how quick the market for surplus milk is growing, and participation of milk processors and marketing of derived products. This thesis proposes possibilities of establishing dairy goat breeding program under small scale farms in Tanzania given that better on-farm recording systems including pedigree information is developed. Setting clear breeding goals with a few traits, e.g. milk yield and survival in this case, is recommended. Because of the various practical options and accessibility to new knowledge, it is necessary to revise breeding schemes from time to time. Lastly, this thesis raises the question; "How many dairy goat breeds are needed in Tanzania?". This can be a future TALIRI job.

Samandrag

Det overordna målet for denne avhandlinga var å utvikla byggjesteinar som er essensielle for å etablera eit bærekraftig avlsprogram for mjølkegeit i Tanzania. For å nå dette målet, blei tre angrepsmåtar brukt: feltstudiar (artikkel I & II), simuleringsstudie (artikkel III) og utprøving i felt og kunnskapsinnsamling (artikkel IV).

I arbeidet med å optimalisera produksjonssystemet (artikkel I) viste eg at mjølkeproduksjon fører til mindre variasjon i produksjonsinntekt på lang sikt enn andre produksjonssystem. Men for å oppnå dette i Tanzania bør ein kjøpa meir kraftfôr og nytta moderne avlsprinsipp. I artikkel II fann eg at av dei 125 respondentane, ville mange (35,2%) ha ei geit med høg mjølkeproduksjon. Så mange som 30,6% vil ha fleire avkom per geit (mange tvillingar), og 24,1% av respondentane understreka nytten av gjødsel frå geitene. I dei områda der respondentane blei intervjua blei gjødsel selt og utgjorde ei inntekt frå geitehaldet. Eigenskapar som ein ønskjer å endra var høgare mjølkeproduksjon (33,7%), sjukdomstoleranse (20%), og høgare tvillingfrekvens (14%). I tillegg mangla bøndene kunnskap om utval av avlsdyr, husdyrkontroll og individmerking. I artikkel III fann eg at testing av mellom 20 og 30 bukkar per år kan gje eit godt avlsprogram med akseptabel sikkerheit for å rekna ut avlsverdar. For Mgeta anbefaler vi testing av 30 bukkar per år. I artikkel III skisserte eg òg faktorar som er nødvendige for å få etablert eit varig avlsprogram. Eit skjema som illustrerer korleis eit avlsprogram med avkomsgransking av testbukkar i Mgeta kan gjennomførast er òg tatt med. SWOT-analysen i artikkel IV viser eg at Tanzania har potensiale for å utvikla mjølkeproduksjon på geit vidare. Styrkar i landet er ein god politikk, at det finst forskings- og akademiske institusjonar, at privat sektor er villig til å delta i sektoren, at fôrresursar finst, og at mange bønder alt eig mjølkegeiter. Svakhetar er at det ikkje er nok støtte frå regjeringa, bøndene har lite skulegang, mangel på klare avlsmål, og at avlstiltak ikkje varer. Dette bremsar framgangen i sektoren. Men løysingar på slike problem finst. I Europa, for eksempel, synest dei å lykkast med avlsprogram for husdyr. Genetisk kvalitetsmateriale frå desse

vellykka programma kan andre land som Tanzania få del i ved kjøp, gitt at ein får løyve til det. Difor foreslår eg i artikkel IV sporadisk import av sæd for å bruka det i ein elitebuskap for mjølkegeit i Tanzania. Både bukkar og geitekje fødde i ein slik flokk kan seljast til bønder. Mjølkegeiter blir alt nå omsette i Tanzania og slike initiativ i privat sektor bør oppmuntrast. Offentleg sektor kan passa på kva som bør skje med mjølkegeiter i landet. Truslar kan vera endringar i politikken når det gjeld import av genetisk materiale, bønders vilje til å betala for verdifulle avlsdyr, kor raskt mjølkeomsetninga aukar og utvikling av meieri og omsetning av mjølkeprodukt.

I denne avhandlinga foreslår eg mulege måtar å få til eit avlsprogram for mjølkegeit gjennom eit samarbeid mellom små mjølkeprodusentar i Tanzania. For å lukkast med dette må mjølkekontroll og individinformasjon innhentast på slike gardar. Klare avlsmål med få eigenskapar, for eksempel mjølkemengde og overleving, blir anbefalt. På grunn av kva som er praktisk mulig og tilgjengeleg kunnskap til ei kvar tid, er det nødvendig å revidere avlsprogram frå tid til anna. Til slutt reiser eg i avhandlinga spørsmålet: «Kor mange mjølkegeitrasar trengst i Tanzania?. Å svara på dette, kan vera ein jobb for forskarane som arbeider ved TALIRI.

List of papers

This thesis is based on the following original research papers – one published, one submitted and accepted, and two manuscripts submitted. The papers are listed as follows:

I. **Nziku, C.Z.,** Asheim, L. J., Eik, L.O., Mwaseba, D. and Kifaro, G. C. 2016. Climate change adaptation in vulnerable crop and livestock production systems in Mgeta, Tanzania. (Accepted: *AJFAND*).

II. **Nziku, C.Z.,** Kifaro, G.C., Eik, L.O., Steine, T. and Ådnøy, T. 2016. Reasons for keeping dairy goats in Tanzania, and possible goals for a sustainable breeding program. (*Animal Production Science.* http://dx.doi.org/10.1071/AN15423 *)*.

III. **Nziku, C.Z.,** Kifaro, G.C., Eik, L.O., Steine, T. and Ådnøy, T. 2016. Towards developing a sustainable dairy goat breeding program in Tanzania by BLUP approach. (S*ubmitted: Journal of Animal Production-AN16269*).

IV. **Nziku, C.Z.,** Kifaro, G.C., Eik, L.O., Steine, T., Msalya, G. and Ådnøy, T. 2016. Situation analysis and prospects for establishing a dairy goat breeding program in Tanzania. (*Submitted: Journal of Animal Production-AN16270)*

1.0 General introduction

1.1 Dairy goat breeding program

In the world dairy goats are distributed across most continents. South Asia, Mediterranean, Africa, and parts of Latin America, are areas with high numbers of this genetic resource. Although a high number of dairy goats are in developing countries, good examples for breeding programs are in developed countries like Norway, France, Australia, and North America (FAOSTAT, 2013; Ådnøy, 2014). Reasons for success and failures are proposed (FAO, 2010; Philipson *et al.* 2011; Ådnøy, 2014), and organizing a breeding program requires careful consideration of a number of issues. The success of a breeding program will largely depend upon the ability of breeders to manage those issues. Tanzania has been importing dairy goats from developed countries through charity supports or institutional collaborations since before the 1980s. Due to biological limitations and genetic principles, genetic improvement is a continuous process. Although techniques and theories for establishing animal breeding improvement programs are available, genetic improvement programs across all livestock species are missing in Tanzania. BLUP for example, is a robust technique for predicting breeding values, also accuracy important for estimating genetic gain. BLUP is commonly used in animal breeding programs today (Mrode, 2014). The BLUP methodology has made a significant revolution in genetic evolution, especially in the developed world. Advancement in technology and use of DNA information has brought it a further step ahead in exploring possibilities of animal evaluation (Al-Atiyat and Aljumaah, 2013; Meuwissen *et al.* 2013). For example, the genomic selection can improve accuracy of breeding values but is quite expensive and requires technical expertise. However, an important thing to understand here is that almost all “high tech genetic evaluations” requires phenotypic information from a training population. Thus, building capacity on how to manage appropriate breeding programs in developing countries with the emphasis on better recording of phenotypes is necessary.

1.2 Sustainable breeding program

Depending on the intent of the society, it is important that a breeding program should be relevant and as sustainable as possible, aimed at solving specific societal problems, milk and income in this case. Today, principles and guidelines for sustainable animal breeding programs are well documented (FAO, 2010; Philipson *et al.* 2011). The major concern is putting these principles into practice under different production systems with different socio-economic characteristics. Attempts for genetic improvement program in most livestock species in developing countries are many; however, most programs have collapsed (Rewe *et al.* 2009; Philipson *et al.* 2011). Factors like the complexity of the designed breeding programs, overlooking adaptability traits, lack of knowledge on what farmers want (breeding goals), lack of collaborative elements (farmers – researchers – institutions – other stakeholders) along the breeding program market value chain, lack of performance recording, lack of long term funding (both local and foreign), and lack of motivation among the owners of animals, are proposed as reasons for such collapses. These aspects are important because they define important features for a sustainable dairy breeding program. Performance records is a prime requirement for genetic evaluation and improvement. The questions about what method and how to do recording, ownership of recorded information, who should keep/store performance records, who has access to records, and who own breeding bucks, need to be answered. And, importantly, farmers' motivations need to be clearly understood (e.g. issue certificates to best buck producers, own good producing goats).

Perspectives of genetic improvement is all about change. Benefits to the community is the increased productivity of animals due to the genetic change. To get these benefits several issues need to be clarified. For example the economic, environmental, and social setting in which the program intended to function. The idea of sustainability has been difficult to conceptualize. Depending on the referred context, a sustainable breeding program can be defined in many ways (Gamborg and Sandøe, 2003; Phillipson *et al.* 2011). In the context of this thesis, a sustainable breeding program is a program that lasts for a long time, as opposed to interventions that last as long as there is external funding. In Tanzania, good possibilities for establishing sustainable dairy goat breeding programs exist, provided essential motivating factors of stakeholders working along the breeding program are well defined. Clear understanding of the production and market systems, breeding goals, ownership of data and genetic improvers (bucks) are needed. Moreover a reliable performance recording system and flow of recorded information are required.

1.3 What is being a dairy goat breeder in Tanzania today?

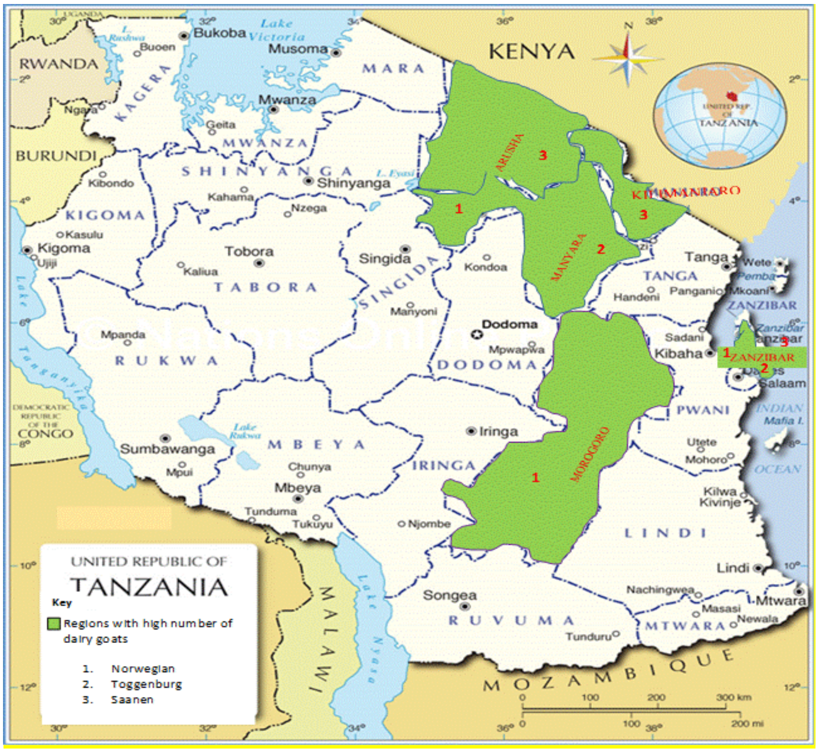
1.3.1 Demographic factors

Tanzania is a low income country, populated with about 52 million people – the majority being children (0-14years, 44.7%), or young (15-24, 19.5%), and few (2.9%) being 65 years and above. About 66% of the population are economically active in agriculture. According to the government official statistics, the annual growth rates of GDP is 7.1% (http://www.nbs.go.tz/). The contribution of livestock to the GDP by 2016 based on objectively verifiable indicators could reach 5% (MoLFD, 2011b). Dairy goats have an important contribution to the first three sustainable development goals in Tanzania (1. No poverty, 2. No hunger, and 3. Good health. – Government official statistics: http://www.nbs.go.tz/).

1.3.2 Dairy goat genetic resources

The goat population in Tanzania is approximately 17 million, but dairy goats account only for 2% of this population, or equivalent to 320000 dairy goat heads (MoLFD, 2011a). The Saanen, Toggenburg, Alpine, Anglo Nubian, Norwegian, and their crosses with

Small East African goats are the main dairy breeds (Nziku *et al.* 2016). They are distributed over the country including Zanzibar. Morogoro, Arusha, Manyara, and Kilimanjaro. These are the leading regions in terms of dairy goat numbers (Figure 1). Morogoro is populated with the Norwegian dairy goat breed. A census by Kifaro *et al.* 2013 (unpublished data) in 490 households (HH) in Mgeta division of Mvomero district in Morogoro counted >2000 dairy goats, equivalent to at least four goats per HH. Moreover, they projected that more than 3000 families keep goats in the area. Thus, considering 4 goats per HH * 3000 HHs is equivalent to 120000 dairy goats just from one division. Based on this background, it seems the 2% dairy goats for the complete Tanzania mainland and across breeds is underestimated. There is need for dairy goat census in the country in order to obtain data useful for breeders and policy makers.



Source: Nziku et al. 2016, Mtenga and Kifaro, 1993, (Kifaro, 2016 – personal comm.)

Figure 1. Map of Tanzania illustrates dairy goat distribution by breed and region.

1.3.3 Dairy goat production systems and management

In Tanzania, dairy goat keeping is an important and integral part of crop-livestock mixed farming systems in some rural families. In addition, research centres and academic institutions keep small numbers of dairy goats, mainly for training and research purposes. Today, at least there is no single good example of a farmer keeping dairy goats commercially in the country. As in many other African countries, dairy goat keeping is special to vulnerable groups e.g. people living in rural areas and especially women (Escareño *et al.* 2012; Peacock *et al*. 2011), because dairy goats serve for different welfares such as milk, income, manure, meat, and social functions, and can do well in a range of environmental conditions. According to Chenyambuga *et al.* (2014) in Tanzania dairy goats contribute up to 31% of the total household income depending on the breed and location, among other factors. Dairy goats have become important for the economy and health of many rural families (Eik *et al.* 2008; Escareño *et al.* 2012). According to FAOSTAT, (2013) dairy goats in East Africa produce on average 50.8 kg of milk per dairy goat per year compared to 278.9kg in Europe. The difference is big. One may imagine that it may be the low input production system, the lack of genetic improvement, and environmental stress in Africa that contributed most to such poor production. However, these figures are lower than that reported by Ahuya *et al.* (2009) and Lie *et al.* (2012) for East Africa. Management practices are better for dairy than meat goats. For example, elevated platform housing, semi-intensive feeding system (graze during daytime and feed grass indoors), supplemented with concentrates (Eik *et al.* 2008; Rufino *et al.* 2012) are common for dairy goats. Goats are hand milked usually once per day. Most dairy goat farmers in Tanzania received training on a range of dairy goat management aspects including feeding, health, breeding, and milk processing (value added), and marketing of live animals and milk or milk products (Kifaro *et al.* 2012; Eik *et al.* 2008). However, it is speculated that dairy goat keepers in Tanzania should be doing much better than now because they got a lot of facilitations from different stakeholders and projects but less has been realized on the ground, especially in recording and recruitment of replacement stock.

1.3.4 Dairy goat breeding practices

Breeders know that traditional goats have high potential for adaptability traits but low potential for productivity traits. Because of that in 1980s, Tanzania started genetic improvement efforts for both meat and dairy traits in goats (TALIRO, 1980; Mtenga and Kifaro, 1993). For improvement of meat trait, a synthetic goat breed called Malya/Blended was formed, composed of 55% Kamorai goats from Kenya, 30% Boer goats from South Africa and 15 % the Small East African in Tanzania goat breeds (Das and Sendalo, 1990). The Malya goat is a dual-purpose (meat and milk) breed and is an important source of goat meat in Tanzania. Although some farmers keep this goat breed, today a large proportion is found in government research centres. For milk yield, many goats were imported from European countries; this included Norwegian dairy goats, Saanen, Toggenburg, Alpine, and Anglo Nubian breeds. However, it seems goats were distributed without strategic breeding plans in place. Small-scale farmers manage the goats, each with only a few, numbers ranging between 4 and 10 dairy heads per farm (Kifaro *et al.* 2012). Small herd sizes limit on-farm selection breeding programs, unless a cooperative breeding program is employed. In addition, it is common to find that male kids are raised together with their mothers although they are mature enough to mate. Under such management system, breeding and genetics principles could be hard to apply. Establishing appropriate dairy goat breeding program in those areas may help. Through institution collaborations, bucks and semen have been imported aimed at maintaining the genetic pool of dairy breeds like the Norwegian goats in Mgeta and Toggenburg in Babati. The latter have periodically imported bucks from Mt. Meru area in Kenya. Some of the bucks supplied are still available and most of them had many daughters and granddaughters in their areas (Nziku *et al.* 2016). Continued use of these bucks may increases the chances of inbreeding in those areas. However, relying on projects' supply of breeding bucks cannot be a sustainable way as far as breeding program is concerned. In such a situation, developing capacity for recruiting replacement bucks raised in the same environment is worthwhile.

Crossbreeding is also common among the farmers where it is done mainly by crossing indigenous does with dairy bucks (Ojango *et al.* 2010; Escareño *et al.* 2012; Kifaro *et al.* 2012). Such initiatives indicate that farmers are motivated to keep milking goats and hence breeders need to work more on developing appropriate breeding programs for them. Even though approaches for breeding and genetic improvement under their small-scale systems is missing, farmers have demonstrated their readiness. The main challenge is availability of reliable data for performance evaluation, usually, none or scant and unsystematic information can be found from farmers. The emphasis should be to come up with a feasible and reliable package for on-farm dairy goat recording system in Tanzania.

1.3.5 Opportunities

Tanzania has different goat genetic resources, local feed varieties, grazing land and water. The high population of youth are a potential group for agriculture, although they require capacity building. The establishment of the National Public Private Partnership policy (PPP), opens up more opportunities for partnerships to invest along the goat milk value chain. In such a scenario, in Tanzania and possibly elsewhere in Africa, private milk companies stand a better chance to strengthen goat milk processing capacity and gain access to milk markets to capture the increase in supply. In addition, private ranches/farms are crucial for dairy goat breeding, so that quality dairy goats are available for supply to farmers. However, it is important to address in clear terms what is required and possible between the collaborating parties. Information presented in this thesis can be useful to people interested in doing breeding in developing countries like Tanzania.

1.4 Statistical approaches useful for breeding program decisions

Decisions for any breeding program firstly require reasonably reliable data. Depending on what aspects you are looking at, different approaches can be used to gather useful information for analyses. These may include conducting a survey, setting up animal experiment, simulation based on the existing situation, and review of already existing information. A survey approach is useful for capturing data mingled with social aspects; however, a rather large sample size is required as the answers may vary much (Marsland *et al.* 2001; Suresh and Chandrashekara, 2012). BLUP is the method of choice especially for breeders for genetic evaluation of linear traits (e.g. milk and growth). In addition, BLUP methodology may be useful for optimizing breeding programs, e.g. finding accuracy of prediction (Mrode, 2014). Different software or computer programs may be useful for evaluating genetic parameters essential for breeding programs. Examples are Excel, R, Matlab, SPSS, SAS, ASREML, WOMBAT, DMU, etc. The R program can be relevant under Tanzanian situation since it is free licenced and is efficient with many contributors. In the current thesis, the social (survey) data were analysed by SPSS and outputs were reported in terms of figures and tables with numbers and frequency. Further, the Excel computer program was used for pedigree simulation, calculation of selection intensity and genetic gain, and for plotting of figures. Matlab R2013a (students' version) was used for predicting accuracy of selection using BLUP principles. Advanced statistical approaches for breeding program evaluation which include genomic selection and alike are available and efficient (Bajagai, 2013; Meuwissen *et al.* 2013), but due to cost and expertise requirements may not be feasible in most developing countries unless heavily supported.

1.5 Usefulness of information developed in this thesis

Considering the current reality and preferred future of Tanzania in the context of dairy goat breeding programs, knowledge generated in this thesis may be useful because it contributes to at least five key questions:

i. **How do dairy goats perform economically under crop-livestock integrated production systems, given resource utilization in Tanzania now and in the light of climate change?** This information is an important motivation for developing a breeding program as it gives knowledge on how dairy goats fit into the existing production systems now and in the future considering climate change effects.

ii. **What type of dairy goats do farmers want and what are the possible limitations for them to practice breeding principles in Tanzania?** The knowledge developed could help breeders to better understand the primary breeding goals (e.g. kilos of milk was found in this case as opposed to quality contents in Europe today) and traits for improvement, and possible limitations for successful dairy goat breeding programs in Tanzania.

iii. **What is the optimal number of test bucks per year that could give the best breeding program in areas fitting current Mgeta situations?** The knowledge generated here contributes to more understanding of that it is possible to select best bucks under small scale production systems in Tanzania. In addition, part of this thesis showed that the BLUP technique used to predict breeding values can also be used for breeding program optimization to find accuracy of prediction as opposed to traditional index theory, and is closer to what breeders use today.

iv. **A schematic diagram for progeny test selection scheme is developed**. A simple diagram showing steps to follow in selection of both bucks and females for replacement, which can be useful to both breeders and academics e.g. teaching purposes, is presented. The diagram is an example and can be modified to different situations. In addition, part of this thesis outlines the importance of cooperative breeding program under Mgeta situation and how it should work. Essential elements for program sustainability is included.

v. **A SWOT analysis for establishing a dairy goat breeding program in Tanzania today.** Examples of successful dairy goat breeding programs exist, especially around Europe. Failures in developing countries and the reasons to why it is so are suggested. The knowledge generated in this article gives a better understanding of the prerequisites for sustainable dairy goat breeding programs in Tanzania, and part of this thesis has used the SWOT analysis to develop a strategy that gives possibilities for reliable sources of quality dairy goats in the country both in the short and the long run. In addition, a system for involving private and public sector to collaborative in the dairy goat industry is suggested. For example, one nucleus dairy goat breeding herd is established by private sector/farm using AI with imported semen. The offspring from such a herd are distributed to farmers through government institutions. The proposed strategy can be duplicated to other important livestock species and traits like meat goats.

1.6 Objectives of the study

The overall objectives of this thesis was to establish essentials for a sustainable dairy goat breeding program and propose a way forward to considered in Tanzania To achieve that the following topics were studied:

Paper I: Climate change adaptation in vulnerable crop and livestock production systems in Mgeta, Tanzania.

Paper II: Reasons for keeping dairy goats in Tanzania, and possible goals for a sustainable breeding program.

Paper III: Towards developing a sustainable dairy goat breeding program in Tanzania by BLUP approach.

Paper IV: Situation analysis and prospects for establishing a dairy goat breeding program in Tanzania.

2.0 A brief summary of the papers

All the goat materials and data used in this study originated or was extrapolated from Tanzania: Survey data for paper I and II, simulated data for paper III, and primary data and lessons learnt for paper IV.

2.1 Climate change adaptation in vulnerable crop and livestock production systems in Mgeta, Tanzania

Currently, the effects and awareness of climate change on the livelihood and environment are becoming more apparent than at any time before. Mgeta is at high altitude and an important water catchment area. People practice crop-livestock integrated farming. Crops are mainly vegetables of different types while dairy goats, meat goats, and pigs are the main livestock kept. Demand for both crop and livestock (e.g. dairy goats) from this area is high. Considering the climate change effects, need for water by people in this area and in the lowland areas, need for improved productivity of both crops and livestock (dairy and meat goats, and pigs), etc., intensifying both crop and livestock production to meet the demand without considering other factors e.g. the effects on the environment, can be a wrong approach. An optimal production system for the area should be found. To achieve that a questionnaire survey study, to evaluate the current production systems and explore opportunities regarding economic performance and environmental impact, was conducted. In total 60 respondents were interviewed. A linear programming (LP) model was developed in Excel computer program for the optimization. Data were analysed for cases both with and without dairy goat production systems in Mgeta, and risk analyses by Simetar computer software were done considering both the current and climate change scenarios.

2.1.1 Main results

- Under a basic scenario: without dairy goats, farmers would choose rather extensive vegetable cropping. In Mgeta, meat goat production is less profitable. They will only utilize communal land. Farmers will have pigs to utilize crop leftovers.
- When dairy goats are permitted in the model the amounts of grass and multipurpose trees (MPTs) increase and farmers start to purchase considerable amounts of concentrates for feeding the goats. Subsequently, the cultivation of vegetable crops declines to a minimum.
- Dairy goats seem to do better under climate change as farm Gross Margin (GM) declines by 3.5% compared to 9.6% without dairy goats.

2.1.2 Conclusion

The analysis shows that the crop-dairy goat integrated production system in Mgeta outperforms the other integrated production systems both from economic and environmental viewpoints. However, initiatives for better breeding and feeding programs, and disease control for the goats can help to realize even more productive performance.

2.2 Reasons for keeping dairy goats in Tanzania, and possible goals for a sustainable breeding program.

In Tanzania and elsewhere in Africa, the demand for dairy goat breeding stock has been increasing, suggesting that farmers are motivated to keep dairy goats. In these countries dairy goat breeding programs had been established. However, experiences show that most of the established programs did not last. Among the reasons for these failures were lack of knowledge of what farmers want and challenges for doing breeding under given circumstances. These aspects define important features which affect motivation and profitability of long-term breeding programs. In order for Tanzania to sustainably meet the increasing demand for dairy goats and dairy goat products, establishment of an appropriate dairy goat breeding program is highly needed. A questionnaire survey study was conducted in three districts, each representing a unique dairy goat breed-type; namely Mvomero (Norwegian breed), Arumeru (Saanen breed), and Babati (Toggenburg breed). In total for the three districts, 125 respondents were interviewed. The Statistical Package for Social Science (SPSS v19) computer software was used for data analyses. Results were presented in numbers and percentages.

2.2.1 Main results

- The three top reasons for keeping dairy goats given by respondents were: more milk production per goat per day (35.2%), sale of young (3-7 months age) breeding stock (30.6%), and manure (24.1%). Only sale of breeding stock showed significant (Chi-square test, $p<0.05$) differences between the districts.
- The three traits ranked highest by respondents for breeding goals were: milk yield (33.7%), disease tolerance (20.0%), and twinning ability (14.0%).
- The most important perceived challenges for dairy goat breeding program in Tanzania were those related to animal identification, recording, keeping of breeding buck, and cost of hiring a breeding buck.

2.2.2 Conclusion

There are possibilities for establishing sustainable dairy goat breeding programs in Tanzania.

Dairy goat farmers know what is important for them as breeding goals, thus breeders should abide by farmers preferences. However, design of simple and manageable goat breeding programs is necessary.

2.3 Towards developing a sustainable dairy goat breeding program in Tanzania by BLUP approach.

The genetic merit of individuals is based on the evaluation of recorded pedigree and performance information. Individuals with the highest predicted genetic merit will stand a better chance to become future parents. Accuracy of prediction matters in decision making. Its prediction depends largely on the quantity and quality of the individual records available, and the heritability of the traits used in the prediction. The method of choice for genetic evaluation of linear traits by most livestock breeders now is the best linear unbiased prediction (BLUP). Today in most livestock breeding companies, countries and livestock species the BLUP method is routinely used. Traditionally Selection Index theory has been used to find accuracy of prediction, today BLUP theory can perform similar work in a different fashion.

The BLUP method for predicting genetic gain was applied to a proposed cooperative breeding scheme. Calculations were inspired by the availability of 1000 female goats in Mgeta. The goats' identities are listed in an Excel sheet. A pedigree file with 4400 individuals covering four generations (1100 in base generation, 3000 in first through third generation and 300 in the fourth generation) was simulated in Excel computer program. Seven strategies to find optimal number of test bucks (5, 10, 20, 30, 50, 70, and 100) per year were simulated. In each strategy, the test bucks produced 1000 offspring (500 male and 500 female) in generation one through the fourth generation. The test bucks were randomly selected out of the 500 male offspring born in a year using Excel function "RandomSelection" (http://www.extendoffice.com/documents/excel) by randomizing the IDs in the Excel sheet then deleting some to keep the required number. The results for the test bucks are known in third generation and elite bucks may be selected. In the fourth generation test bucks produced 880 offspring (440 male and 440 female) and the elite bucks were assumed to contribute 120 offspring (60 males and 60 females) equivalent to mating 12% of all the females available in a year (1000). The bucks' testing program assumed to cut across the three cooperating wards of Nyandira, Tchenzema and Mwarazi in Mgeta division, Tanzania.

The daily milk production (DMY) of daughters of the tested bucks was used to select elite bucks from the test bucks. The different breeding strategies possible for Mgeta area were compared. The genetic variance (0.0532 kg^2) and permanent environment variances

($0.1531\ kg^2*2 = 0.3062\ kg^2$ in this case) for milk yield per day trait were adopted from Norwegian dairy goat breeding scheme (Dagnachew *et al*. 2011). Moreover, all goats are assumed to have one common mean (fixed effect) in the analysis.

2.3.1 Main results

- Testing between 20 to 30 young bucks could be optimal in situations similar to Mgeta. That may give a good dairy goat breeding program fitting the Mgeta area. By testing 30 bucks, 2 to 2.6% genetic response for milk yield trait per year was obtained and corresponded to 42% and 53% accuracy of prediction for the test bucks at 0.1 and 0.2 heritability.
- BLUP theory can be used for breeding program optimizations similar to the traditional Index theory.
- Aspects for sustainable breeding program under cooperating farms in Mgeta Tanzania are included.
- Design of simple dairy goat breeding program is developed.

2.3.2 Conclusion

Under Mgeta situation testing 30 bucks per year is feasible, however, the proposed breeding program may not necessarily be picture-perfect in future because of the practical options and new accessible knowledge. Thus, it becomes necessary to revise breeding programs from time to time.

2.4 Situation analysis and prospects for establishing dairy goat breeding program in Tanzania

Over 30 years now different development partners have been using dairy goats as a tool to improve livelihood of the rural families in Tanzania. Studies show that demand for sale of goats (live dairy goats) is increasing, suggesting that many farmers join dairy goat production for that purpose. One reason could be that keeping dairy goats pays. Availability of reliable source for supplying quality dairy goats in these areas is important.

Production of quality goats requires that a breeding program is in place. Paper IV aimed at studying the SWOT for dairy goat breeding program in the country and develop a strategic roadmap so that farmers can tap the genetic resource from a reliable source. To achieve this study both a review in developed vs developing country and data from three years of dairy goat control experiment (2012 to 2014) in Tanzania were used. Both published and unpublished information and infrastructures necessary for dairy goat breeding practices in the countries were important.

2.4.1 Main results

- **Strengths**: Tanzania farmers are motivated to keep dairy goats, presence of good policy for livestock development, good public and private sectors collaborations, presence of infrastructures and resources necessary for animal breeding programs.
- **Weaknesses**: Insufficient financial resource to support long term animal breeding programs, farmers lack skills on recording, identification and selection. – Most farmers have low formal education, no or weak farmers' associations, lack of clear breeding goals.
- **Opportunities**: Information on successful breeding program in overseas countries are available (Paulenz *et al.* 2005; Meuwissen *et al.* 2013; Ådnøy, 2014; Skeie, 2014;), current policy allows share of genetic material, the presence of Private-Public-Partnerships (PPP) policy in Tanzania (URT, 2009), readiness of both farmers and private sectors to participate in dairy goat breeding, and agriculture being the main employer of Tanzanians.
- **Threats**: AI service and their related challenges e.g. getting import and export permits on time, the sustainability of the good policies established, farmers' willingness to pay for quality genetic material from private sectors, sustainability of financial support for breeding program, and genetic dilution of local goats.

Future breeding strategy: A strategy with a nucleus breeding herd using overseas semen for AI from countries with outstanding dairy goat breeding programs was developed so that offspring from such nucleus herds would be supplied to farmers.

2.4.2 Conclusion

It is difficult now to obtain on-farm recording data useful for dairy goat genetic improvement, unless solutions for better recording system and flow of information become a reality in Tanzania.

Farmers' awareness on why they should do recording, and availability of facilities necessary for recording without depending on external project supports, are important aspects which require special attention.

The overseas genetic material from countries with a history of genetic progress in dairy goats could be integrated successfully into Tanzanian flocks with immediate effect.

The proposed breeding strategy could let farmers have a reliable source of quality dairy goats from outside their community. However, this can work as a temporary solution while in the long run it could be wise to select best animals from within their dairy goat populations.

3.0 General discussion

3.1 Dairy goats under crop-livestock production system

Small-scale farmers in most developing countries practice integrated crop-livestock farming system (Ramrao *et al.* 2006; FAO, 2010; Gupta *et al.* 2012.). This is the farming system where farmer mix different crop productions and keep livestock. This kind of production system stands as a risk absorber during some calamities e.g. extended drought, and floods (Braimoh *et al.* 2013; Baudron *et al.* 2014). It has advantages and disadvantages depending on the situation like nature of the environment, level of civilization of the society, and skills of farmers (FAO, 2010; Braimoh *et al.* 2013). Livestock and vegetables are both parts of the agricultural production systems and crucial trade-off commodities for livelihood and environment in Mgeta, Tanzania (Eik *et al.* 2008; Kifaro *et al.* 2012). As time passes, competing demands and need for sustainable use of natural resources will definitely continue to increase (Herrero *et al.* 2009). Capitalizing on sustainable utilization of the local resources might help to attain the goals of supporting both livelihood and the environment in these areas. Moreover, optimizing of production systems in such an area can help to decide which production system is beneficial in the long-term (Luenberger, 1984). Crop-dairy goat production system is beneficial both environmentally and economically, both under current situation and when there is climate change (paper I). Shifting from a diverse farming system (cropping and many types of livestock e.g. pigs, meat goats) to more crop-dairy goats production system is recommended in Mgeta. The shift would require improving dairy goat management practices such as breeding, feeding, and disease control, accompanied by fodder production and planting of MPTs. In so doing goat productivity will likely increase and thus improving the households' purchasing power and the environment too. Hence, dairy goat breeding program could be sustainable in the area. The transformation to more market economy could be difficult, but gradually the system should stabilize at the micro level (paper I). According to Rosegrant *et al.* (2009), shifting in agriculture production system cannot happen automatically as it will require different approaches, which may include technological dimensions, policy formulation and market solutions especially for those who involved in the referred production system. Alternatively, farmers should move their settlements and farming activities from the high altitude to the lowland areas. Consequently, this could results into more water in the low land areas which will be good for the environment. The later aspect was not included in the model and needs further study. Measures in adoption of the proposed farming model in Mgeta will require careful considerations. This is because the primary goal of smallholder farmers in this area would be satisfying food security at household level rather than profit maximization. In addition, indoor dairy goat keeping should be a priority, as the calculations for the maximum number of animals that can be permitted in Mgeta areas was not included.

3.2 What dairy goat farmers want in Tanzania

The aim of doing breeding is to deliver appropriate animals to the needs of both producers, clients, and environments by reducing the unwanted traits and improve the wanted/desired ones (genetic improvement). For a breeding program to be efficient it requires defining in advance the breeding goals (Byrne *et al.* 2011). Depending on the context of the breeding, breeding goals can be for long or short-term need for the animals to fit a purpose (Nielsen *et al.* 2011). Breeders also need to be aware that new demands may arise along the way (Byrne *et al.* 2011) and hence the need for flexibility in setting the breeding goals. In Europe for example, in the past selection focused mainly on production traits and less emphasis were given on fitness related traits (Nielsen *et al*. 2006 and 2011; Ådnøy 2014). Due to the change in demand, in the past 15 to 20 years most European countries, especially Nordic, improved settings of breeding goals to accommodate fitness related traits (Oltenacu and Broom, 2010; Blichfeldt, 2013;). Under tropical contexts adaptive traits need to been emphasized in breeding goals (Philipsson *et* *al*. 2011). In paper II, the reasons of keeping dairy goats emphasized by respondents include milk yield, sale of live animals and manure. These reasons are meaningful in the context of Tanzania today, where low input production systems, and small herd size per farmer is practiced. High milk production, tolerance to diseases and high twinning ability are the most valued traits by dairy goat farmers in Tanzania. These traits are important to producers, consumers, environmentalists as well as socio-economists. However, starting with few (e.g. two) traits in a breeding goal traits is necessary.

3.3 Challenges in dairy goat breeding practices in Tanzania

The emerging technologies on dairy goat breeding are necessary. However, for efficiency application of such technologies, adjustment is necessary to fit in different society like those in Tanzania. Goat farming is not new and has been practiced for thousands of years. Yet, today farmers still experience some difficulties in implementing goat breeding principles. The challenges may vary between countries and farmers (Philipsson *et al.* 2011). In Tanzania, proper identification, recording including pedigree information, and selection of replacement stock were challenges perceived to affect most the farmers (paper II). These challenges can be viewed as a result of farmers' knowledge gaps, low education level and un-changed mind-set on management of dairy goats which require solutions. However, a collective efforts among stakeholders along the dairy goat breeding and marketing value chain could help to minimize the problems. The challenges affecting animal breeding decisions appear to be common (Kosgey *et al.* 2011; Philipsson *et al.* 2011). The cultural, environment, policy and socio-economic factors of the farmers are important and should influence breeding decisions. Given the value of dairy goats for Tanzanians, the findings in this study are considered a step toward in developing a sustainable dairy goat breeding programs in the country. However, for better outcomes appropriate design of breeding programs in the context of Tanzanian farmers is important.

3.4 Number of test bucks per year optimization

In paper III a pragmatic study of simulation similar to Haile *et al.* (2011), Herold *et al.* (2012), Meuwissen *et al.* (2013), Abegaz *et al.* (2014)and optimization similar to Joezy-Shekalgorabi and Shadparvar, (2011) for number of test bucks per year was conducted. The simulation fitted the existing situation of dairy goat breeding in Mgeta, where 1000 female dairy goats and 100 bucks available today were assumed. The selection intensity, accuracy of prediction, and genetic gain for 0.1 (low) and 0.2 (medium) heritability were decision criteria used. For economical and biological efficiency reasons, optimization of number of test bucks is important in animal breeding program (Joezy-Shekalgorabi and Shadparvar, 2011; Bourdon, 2000).

Testing 100 bucks per year was found to give the highest genetic gain. However testing 20 to 30 test bucks per year in Mgeta area is practical. That gives an accuracy of 42 to 53% and genetic gain of 2 to 2.6% for heritability 0.1 and 0.2 with 30 test bucks. Natural mating, small herd sizes (~5 goats per farmer), cooperative breeding, bad land terrain with steep slopes between the cooperating villages and dairy goat units, long distances between farmers, and selecting three elite bucks were considered (paper III). The increase in accuracy with testing fewer bucks, agreed with several authors (Dekkers *et al.* 2004; Kahi and Hirooka, 2005; Van Grevenhof *et al*. 2012). Testing fewer bucks' results in more daughters per buck and therefore more accurate test buck breeding values predicted. The problem with many bucks that was not accounted for in the simulations is the confounding of buck effect on daughters with the herd environment effect when a buck has few daughters. The heterogeneity of the flocks has not been taken into account in current calculation except as a general heritability effect.

The genetic gain values estimated in this part of the thesis were comparable to Shumbusho *et al.* (2013) and Colleau *et al.* (2011). Many factors may affect genetic gain estimation like the population size, testing capacity, heritability, use of elite bucks with or without AI, and possibly the evaluation techniques used e.g. selection index, BLUP, genomics etc. The estimated genetic change in the current thesis shows a possible practical number of test bucks under Mgeta conditions. If AI becomes an option in the future, the number of test bucks per year can be reduced.

3.5 The BLUP technique

The use of BLUP (Mrode, 2014) as opposed to Index theory (Bijma, 2012; Gizaw *et al*. 2013) in animal breeding optimization should be possible to do/practice in Tanzania. Since powerful computers, information via internet and institution collaborations are more easily accessible today than before. However, the emphasis should be on recording as better predictions rely on better recorded information. Poor animal recording has often been reported as one of the challenges in genetic improvement (Philipsson *et al.* 2011; Meuwissen *et al.* 2013; Biscarini, *et al.* 2015; paper IV). In areas similar to Mgeta to start a breeding program by recording few traits is proposed (paper II & III).

3.6 Cooperative breeding program

Cooperative breeding program as used in this thesis is a practice whereby animals from different herds participate in a selective breeding scheme. The cooperation was proposed (paper II & III) because of the small herd sizes per farmer (~5 goats) mainly. Cooperative breeding program is not new. For example, in Ethiopia there is the community sheep breeding (Mirkena *et al.* 2012; Gizaw *et al.* 2014), in Kenya the community based goat breeding scheme (Bett *et al.* 2012), and in Uganda a community breeding program for indigenous cattle (Rewe *et al.* 2009). Besides, they reported that greater genetic gain can be attained by employing community breeding program selection. However, no single example was found from Tanzania. This is considered as an opportunity to set up a feasible animal breeding scheme in Tanzania. However, a major concern is how these collaborating partners especially farmers be motivated. Motivation may be crucial for the sustainability of a breeding program (paper II).

3.7 Mating of elite bucks

Controlled mating gives assurance of improving animals in the desired direction (more milk producing goats; more kg of milk per day in this case). Farmers should be encouraged to use the elite or test bucks. The 3 elite bucks should mate to 12% of the best females in the population and the rest be mated to test bucks (paper III). Other bucks born in the cooperating herds should be avoided in mating by culling them immediately after weaning or for example selling them out or castrating them if they are not good for breeding elsewhere. Faster genetic progress could be expected by increasing the number of females mated to elites, while keeping the same testing capacity for test bucks. A breeding buck should serve in a radius of 2.5 km or less (paper III). Because of distance from one herd to another and the bad land terrain in Mgeta. In paper IV a mating house in primary school areas is proposed. A breeding buck will be kept in such a house and female goats on heat are brought for mating was proposed.

3.8 The SWOT analysis

The SWOT results suggested that running a sustainable breeding program requires collective responsibilities involving both farmers, private sectors, government and academic institutions (paper IV). It is suggested that not much is happening for any of these in Tanzania (Paper II). There are several reasons contributing to this mess, however, lack of sustainable funding for livestock research and poor recording system are the major causes (paper II & IV).

The observed poor data structure recorded by farmers in Mgeta area (paper IV) can be improved if farmers realize the value of keeping good records. For example, if farmers get good feedback e.g. realizing that by owning better producing animals due to use of data collected could help.

Currently, Tanzania has a good policy that favours livestock development through collaboration with both local and international developmental partners (URT, 2009).

However, policies change, hence building capacity for on farm recoding has to be further emphasized (paper III & IV).

The proposed strategy in paper IV can be feasible given that collaborating partners work towards achieving the common goals.

4.0 General conclusions

In Tanzania, breeding programs of most livestock species are missing. This PhD thesis tried to establish cornerstones/bench marks for sustainable dairy goat breeding in the country.

- Dairy goats is a future option under integrated crop-livestock production system, because the analysis shows the system does better economically in both current situation and in climate change consideration compared to other systems under similar conditions.
- Quantity of milk per goat per day, high twinning rate, and adaptability traits are important dairy goat breeding goals in Tanzania.
- The knowledge gaps in proper identification, recording basic information, and selection of replacement stock are the main challenges limiting farmers in Tanzania to practice animal breeding principles.
- Testing 30 bucks per year is feasible under Mgeta conditions. That could lead to a breeding program with a genetic response of 2 to 2.6% for daily milk yield for dairy goats.
- Finding accuracy of selection by BLUP approach could be an option for breeding program optimization.
- The developed progeny test breeding plan for Mgeta is just a model and can be adjusted in several ways fitting different situations.
- It is difficult now to obtain on-farm recording data useful for dairy goat genetic improvement in Tanzania. A simple recording scheme should be developed e.g. mobile phone.
- Genetic materials from developed countries with good history of genetic progress in dairy goats could be successfully introduced into Tanzanian flocks as an immediate measure.

- The proposed dairy goat breeding program with a nucleus breeding herd model could sustain if the collaborating parts participate well to achieve the intended goal. The model can be copied for other breeding programs e.g. the improvement of meat goats.
- Lastly, a sustainable dairy goat breeding program under small scale farming system in Tanzania is possible, provided better recording and cooperative breeding program are opted for.

5.0 Areas for further research

I. How many breeds of dairy goats are needed in Tanzania, given the diverse in altitudes, temperatures, pastures availability and types, prevalence of diseases, and production systems?

II. How can recording take off from farmers' point of view?

III. How can long term funding for research and breeding purpose be obtained?

IV. What factors could influence sustainability of the private-public partnerships in animal breeding programs?

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Paper I

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CLIMATE CHANGE ADAPTATION IN VULNERABLE CROP AND LIVESTOCK PRODUCTION SYSTEMS IN MGETA, TANZANIA

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ABSTRACT

Increased occurrences of drought and dry spells during the growing season have resulted in increased interest in protection of tropical water catchment areas. In Mgeta, a water catchment area in the Uluguru Mountains in Tanzania, water used for vegetable and fruit production is provided through canals from the Uluguru South Forest Reserve. The clearing of forestland for cultivation in the steep slopes in the area is causing severe land degradation, which is threatening the water catchment area, livelihoods, and food security of the local communities, as well as the major population centers in the lowlands. In this paper, the economic performance of a traditional cropping-livestock system with East African (EA)-goats and pigs and extensive vegetable production is compared with a more sustainable and environmentally friendly crop-dairy goat production system. A linear programming (LP) crop-livestock model, maximizing farm income considering the environmental constraints in the area was applied for studying the economic performance of dairy goats in the production system. The model was worked out for the rainy and dry seasons and the analysis was conducted for a basic scenario representing the current situation, based on the variability in the 30 years period from 1982-2012, and in a scenario of both lower crop yields and increased crop variability due to climate change. Data obtained from a sample of 60 farmers that were interviewed using a questionnaire was used to develop and parameterize the model. The study found that in the steep slopes of the area, a crop-dairy goat system with extensive use of grass and multipurpose trees (MPTs) would do better than the traditional vegetable gardening with the EA goat production system. The crop-dairy goat system was superior both in the basic and in a climate change scenario since the yield variation of the grass and MPTs system was less affected compared to vegetable crops due to more tree cover and the use of perennial grasses. However, the goat milk production in the area was constrained by inadequate feeding and lack of an appropriate breeding program. Hence, farmers should enhance goat milk production by supplementing with more concentrate feed and by implementing goat-breeding principles. Moreover, policy measures to promote such a development are briefly discussed.

Key words: dairy goats, climate change, risk analysis, Tanzania, production system

INTRODUCTION

For more than a decade, climate change and variability have featured strongly in the development discourse across the world, and awareness and effects of climate change on the environment and livelihoods are becoming more apparent than ever before [1,2]. In Tanzania, much attention has been paid to the performance of different farming production systems.

Among the farming systems that have particularly attracted the attention of scholars are those in Mgeta, a high altitude water catchment area in the Uluguru Mountains. Generally, a review of literature on agriculture in Mgeta reveals that the farming systems in the area have evolved from being centered on cereals, through being based on vegetables with East African (EA) goats and other livestock species, to the current system in which dairy goat production is an integrated component. In the earlier systems, land degradation has been widely reported [3]. In some places of Mgeta, the land degradation is currently so severe that it is threatening not only the water catchment for domestic use but also the livelihoods of the local communities. Increased occurrences of drought and dry spells during the growing seasons in recent years might have reinforced the problem. Developing and expanding a robust cropping system that would be more appropriate in the steep slopes to replace some of the most erosion-vulnerable vegetable crops is clearly needed if agriculture is to persist in the area. Integrating dairy goats into such a system could improve the environmental situation, since dairy goats are more productive and can be tethered or stall-fed while using minimal land area, thus avoiding land degradation due to overgrazing [4].

Farmers in Mgeta grow vegetable crops in pure stand and in intercropping systems on bench terraces and in steep slopes, especially tomatoes, potatoes, cabbage, beans, green peas and maize. In early 1988, dairy goats were introduced through a project implemented by Sokoine University of Agriculture (SUA) with Norwegian governmental support [4, 5]. In addition to dairy goats, East African meat goats (EA-goats) and pigs were kept for meat and provision of manure for vegetables. Due to the need for milk by the family, farmers upgrade the EA-goats to dairy breed by crossing with Norwegian dairy bucks. Moreover, increasing goat milk production might be advantageous since a market for milk or milk products such as yoghurt can be found both locally and in the neighboring towns. However, the production of yoghurt needs to be developed to take advantage of the market opportunities [6]. Currently, dairy goat milk production is limited due to inadequate breeding and feeding practices and intervention in those areas could become a long-term strategy for increasing goat milk production in the Mgeta area.

In this study, the current production system was assessed and opportunities for improvements concerning economic performance and environmental impact explored. In particular, a traditional cropping-livestock system with EA-goats and pigs and extensive vegetable production is compared to a system with dairy goats and more use of MPTs and grass and with less vegetable production. A linear programming (LP) model was developed for the comparison. Further, the description of field data collected in Mgeta and the economic analysis conducted are shown. This is followed by a presentation of model results and a discussion of policies for promoting a sustainable and more environmentally friendly production system in the area.

MATERIALS AND METHODS

The study area and sampling

The study was undertaken in Mgeta, a high altitude water catchment area located in Mvomero District of the Morogoro region, eastern Tanzania, about 50 km from Morogoro town (Figure 1). The Mgeta division sits in undulating hills ranging from 1100 to 1900 m above sea level. Two season cycles (rainy and dry) are important to farmers. The climate is sub-tropical with regular rainfalls, which favor intensive cropping of rain fed or irrigation based vegetables which are combined with livestock especially dairy and meat goats, pigs and poultry, and aquaculture.

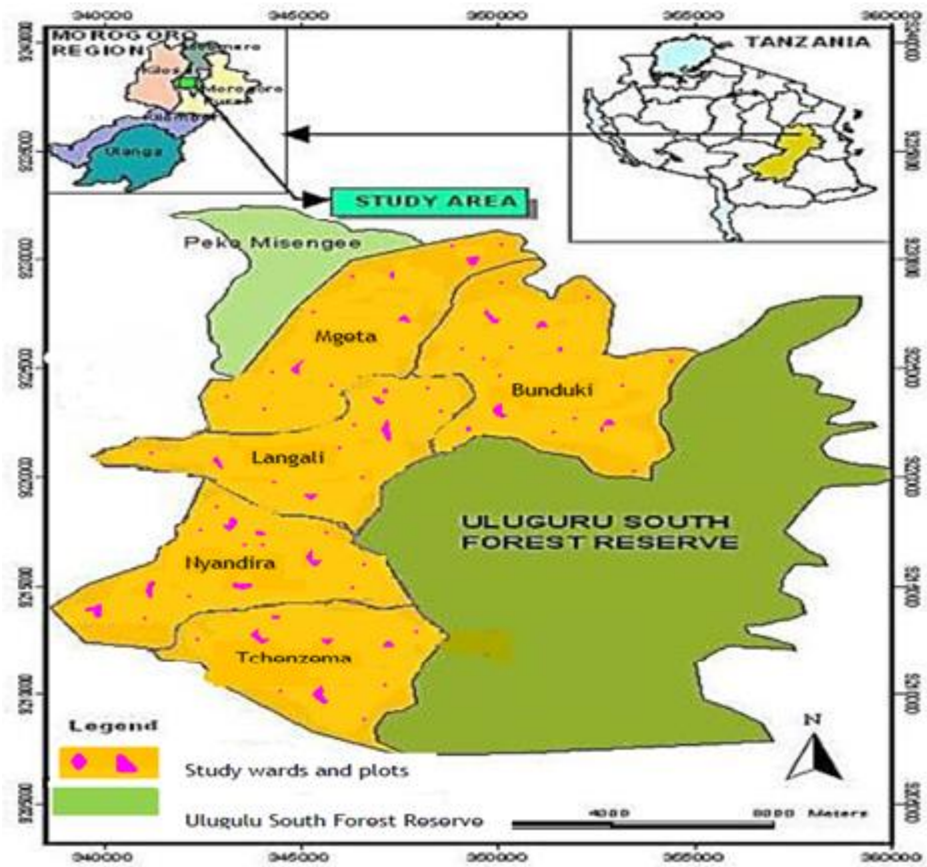

Fig.1: Map of the Mgeta study area

The purposive sampling technique was used to sample farmers in both wards and villages in the study area. A total of 60 farmers within five out of the seven wards of the Mgeta division namely: Tchenzema, Nyandira, Mgeta, Langali and Bunduki (Figure 1), were interviewed. In each ward three villages, each with four households, were selected. Interviews with farmers, guided by a pretested structured questionnaire were conducted in July and August 2012. The data collected included general household information, parcel characteristics, crop and livestock production characteristics and their respective assumed labor requirements. In addition, characteristics regarding grass, multipurpose trees (MPTs) and fruit trees were quantified. The data were summarized and analyzed using SPSS (http://ebookbrowsee.net/spss-base-user-s-guide-16-0-pdf) to calculate standardized values (z scores) including sample size, means and standard deviations (SDs).

The LP model

The results and values obtained from the questionnaire were used to develop and parameterize a general linear programming farm model encompassing dairy goats, EA-goats, pigs and different kinds of vegetables in the two seasons (rainy and dry). The LP technique is based on constrained optimization that can be said to reproduce the reality of farmers who strive to maximize their income while facing several constraints. In farm, LP models [7] several activities, restrictions and production techniques are considered simultaneously and the effects of changing technical specifications and biological responses or right hand side parameters can easily be assessed. The mathematical model of a primal LP problem [8]:

Max $Z = c'x$, subject to $Ax < b$, $x \geq 0$,

where: Z= objective function, farm gross margin (GM),

c'= a vector of marginal activity GMs,

x = a vector of activity levels,

A= a matrix of activity resource requirements, and

b = a vector of resources such as land, work hours.

Based on the questionnaire model, activities for tomatoes, potatoes and cabbage as well as the N-fixing crops beans and green peas, were developed on land close to the farm homestead. Two complete crop production seasons, the rainy period of approximately 270 days from September to May and the dry period, 95 days from June to August, were considered. The vegetable crops were grown under fruit trees, which were limited to one fruit tree per 100m^2. In the model plums, which give yield only in the rainy season were assumed. On distant higher lying farmland, beans and maize can be grown in both seasons. Intercropping was assumed in both seasons for potatoes and green peas on homestead area and for maize and beans in higher lying farmland area. Estimated area of tomatoes may constitute a maximum of 30% of the homestead area in either season due to need for crop rotation. Moreover, it was assumed, based on the size of the farming households, that the family's own needs will require 10% of the homestead area for tomatoes and potatoes and another 5% for cabbage. Farmers used urea and manure to increase soil nutrients, separate model constraints balance the supplies, and use of fertilizers and manure with purchased fertilizers and farm produced manure.

The gross margins were calculated by multiplying expected yields and prices and subtracting the crop specific variable costs for each crop in the 2012 price level. The expected normal yields in the area were derived from the questionnaire and the feeding values were based on Solaiman [9]. As for the grass and MPTs, 192 MJ of energy from $10m^2$ were applied. There were no purchased inputs for this process but there may be some work to maintain the grass sward.

The variation in annual rainfalls in the area was considered as the best proxy for long-term crop yield variation. Data for annual rainfalls in Mgeta was not available. However, in a study of rainfall trends and variability in Tanzania [10], standard deviation (SD) for Morogoro was estimated to constitute 21.4% of average annual rainfall for the 30 years period from 1982 to 2012 (Table 1). The annual rainfalls in the high altitude Mgeta part of the Mvomero District were assumed somewhat more stable than in the lowland Morogoro town nearby. Moreover, the extensive use of irrigation in Mgeta agriculture will moderate the effects of droughts on crop yields that presumably will vary less in Mgeta than in Morogoro. In a basic scenario, all yields were assumed to be normally distributed with SD of 10%, which was reasonably in line with those data and considerations. In general, climate change was assumed to have two effects on crop yields: a lower yield level and more yield variation. However, the effects were assumed dependent on the crop in question with open field vegetables being especially exposed to drought due to higher temperatures. In a climate change scenario the expected normal crop yields were assumed to be lowered by 10% for all vegetable crops and by 5% for the grass and MPTs yields. Regarding the effects of climate change on yield variation, it was assumed that the SDs would increase to 20% on vegetable crop yields and to 15% on grass and MPTs.

The animal activities consisted of dairy and EA-goats and pig keeping. Separate processes provided replacements for the goats. The replacement rate was 0.4 for both dairy and EA-goats. The piglets were assumed to be purchased and the cost of one piglet was subtracted from the objective function of pig production. East African-goats were free roaming, while dairy goats were assumed to be tethered or fed indoors. The pigs used crop leftovers including some of the yields from tomatoes, potatoes and fruits while other crops leftovers were assumed to be used by the goats. Maize bran can be purchased for supplementary feeding. The work requirements for crops and livestock were developed according to season and farmers could hire labor if the family workforce was insufficient.

The goats utilize grass, leaves and branches of multipurpose trees (MPTs), particularly Mulberry and *Leucaena leucocephala*, grown on their own land or on communal land. The feeding of dairy goats was taken care of in five constraints, energy and protein requirements for milk production in the two seasons and a constraint for maintenance feed which was assumed to be provided by grass and MPTs in both seasons. Based on maintenance feed requirement for dairy goats was calculated to 9.4 MJ of energy per day and production feed for milk to be 19.9MJ of energy and 130 gram of protein per day [9]. For replacement kids, values at 50% of adult animals were assumed. For EA-goats, the values for maintenance and growth equal were set to 70% of the maintenance feed of dairy goats and no production feed, as they were not milked. For pigs, 35.2 MJ of energy and 155 gram of protein per day for maintenance and growth were applied in both seasons.

The vector "b" of right-hand side values constraints the activities to the available fixed assets of the two categories of farmland, either near the homestead (2093 m^2) or more distant (3475 m^2), based on the questionnaire. The land can be used in both seasons but may be left idle in either season. Usable communal land was assumed to constitute 20% of the homestead land or 418 m^2, which limited the amount of grass and MPTs from communal land. The model, consisting of 31 activities and 35 constraints, was specified and solved in an Excel spreadsheet supported with Simetar to undertake a risk analysis [11].

RESULTS

The model was run both with and without dairy goats in the two scenarios. The main results are summarized in Table 1.

The results demonstrate that farmers would choose rather extensive vegetable cropping in a basic scenario when dairy goats were not an option. The EA-goats were less profitable, utilized only communal land and farmers will rather have pigs to utilize crop leftovers. However, the number of pigs kept depended on the available amount of crop leftovers (the calculations resulted in less than 0.5 pigs). When dairy goats were permitted in the model the amounts of grass and MPTs increased, and farmers started to purchase considerable amounts of maize bran for feeding the goats. Due to the need for land to produce goat feed, the cultivation of vegetable crops declined to the minimum, which were the amounts considered necessary to provide for the need of the farming household. Evidently, alternatives with dairy goats, MPTs and grass production did better in both scenarios, considering climate change impacts. Under the climate change scenario, the results suggested that alternatives with dairy goats would do 21.4% better than unilateral vegetable production compared to 13.8% under the basic scenario. The probability density functions (PDF) of the farm GM for the alternatives with and without dairy goats in the basic scenario (Figure 2) and in the climate change scenario (Figure 3) are shown below.

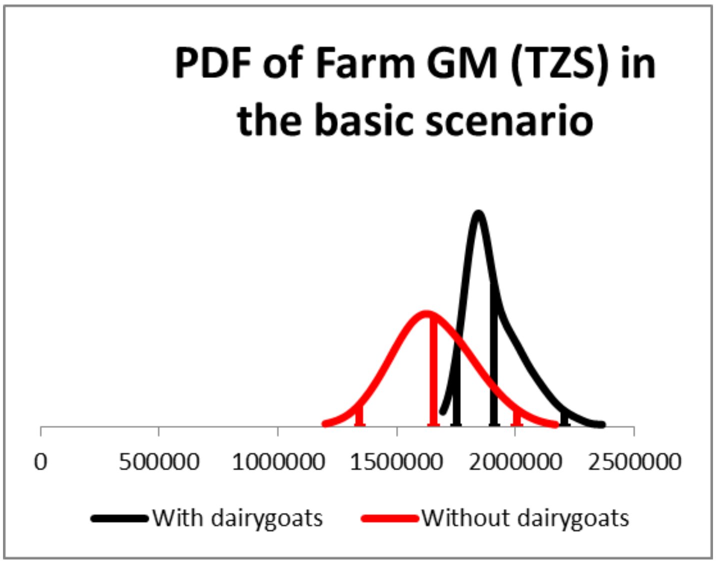

Fig. 2: Probability density functions of farm gross margin (TZS) in the basic scenario with and without dairy goats

A comparison of the model results in the figures 2 and 3 reveals that in addition to the better results achieved with dairy goats, the farming results should be expected to be more stable over time when dairy goats were an option since the dependence on the stochastic crop yields was lowered in the scenarios with dairy goats.

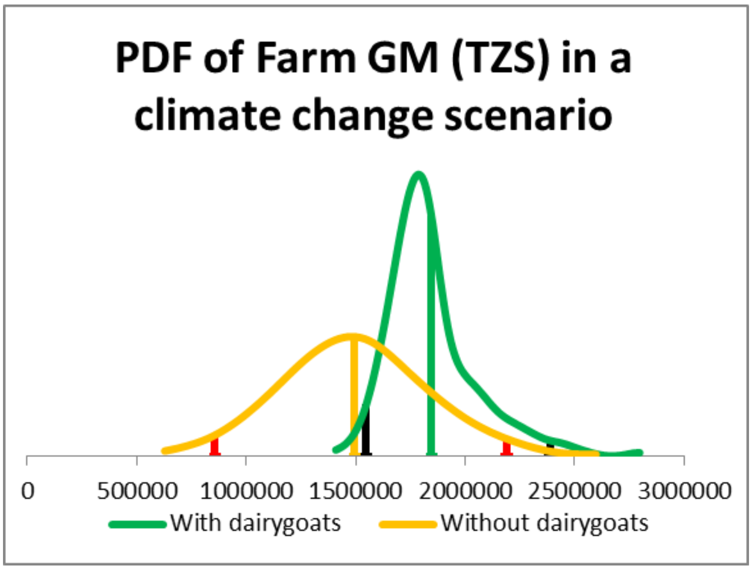

Fig. 3: Probability density functions of farm gross margin (TZS) in a climate change scenario

with and without dairy goats

Farm policy measures to promote or enhance more dairy goats have not been examined but could include such measures as (a) subsidies for increased concentrate feed purchase, (b) investment support and other measures for developing yoghurt production or other goat milk processing industries or (c) introducing subsidy payment for permanent grassland and MPTs.

DISCUSSION

Livestock and vegetables are both components of the agricultural production systems and crucial trade-off commodities for livelihood and environment in Mgeta. In Mgeta, land degradation has been widely reported [3]. The situation is threatening the livelihoods of the local communities. As time passes, competing demands and the need for sustainable use of natural resources will definitely continue to increase [12]. Capitalizing on the sustainable utilization of the local resources might help to attain the goals of supporting both livelihood and the environment in these vulnerable areas. Keeping dairy goats might be an important strategy to improve food security and livelihoods in vulnerable communities like Mgeta [13]. Likewise, dairy goats under certain constraints regarding grazing and browsing behavior may provide opportunities for a more environmentally friendly use of the farmland compared to vegetable cultivation or browsing EA-goats. Many studies suggest that in the course of climate change, demand for sustainable food security to support livelihoods in the study area will increase tremendously. For instance, according to Thornton & Herrero and Steinfeld *et al.* [14, 15], by 2050 annual per capita consumption of milk will increase by 28% in developing countries including Tanzania. The estimated probability function for farm gross margin revealed that one should expect considerably more income variations for vegetable production as compared to dairy goats. One reason the MPTs system was assumed to be less affected by climate change compared to vegetable crops was the tree cover, which will limit evaporation. Moreover, in the steep slopes of Mgeta, dried land was assumed to be more exposed to landslides when heavy rain follows a prolonged period of drought, assumed to be an effect of climate change. Perennial grasses under a tree canopy were considered likely to do better in such a case. Change in length of the growing season, extended drought, shortage of water for irrigation, and increase in crop diseases were some of the many suggested causes for the variation [16, 17].

Considering that Mgeta is located at a high altitude with steep land terrain and has the potential as a water catchment area, intensifying dairy goat keeping could be the best option to improve livelihood needs and sustainable use of natural resources. Such strategies may reduce pressure on the environmental resources such as land and water [13, 18, 19]. More importantly, farmers could increase productivity per unit of resource.

The model results suggest that under the climate change scenario, unlike vegetables, EA meat goats and pig production system, keeping dairy goats was a more worthwhile production system in both economic and environmental perspectives. Contrary to EA-goats, dairy goats can be partly stall-fed and still give more products of economic value. The model results were in line with the findings by Thornton and Herrero (2001) who reported on the productivity potential of dairy goats under smallholder farming systems [14]. In this regard, there are opportunities in the dairy agriculture sector with significant future contributions to the livelihoods of the poor communities like Mgeta.

In cognizant of the above, farmers in Mgeta should shift from crop-livestock integration to intensive dairy goat production. The shift would require improving management practices such as breeding, feeding and disease control, accompanied by fodder production and planting of multipurpose trees. In so doing productivity will likely increase, enabling the household purchasing power to improve. Adaptation of the transformation to a more market economy could be somehow difficult but gradually the system should stabilize at the micro level.

At the macro level, adaptation of such a production system is expected to restore the depleted water catchment areas along the Uluguru Mountains, ensure better community livelihoods, and more environmentally friendly area use. However, literature suggests that such a shift cannot happen automatically, as it will require different approaches, regarding both the technology dimensions and policy and market solutions that work for those involved in dairy goat production systems [13, 15]. Almost thirty years of research with dairy goats in Mgeta has developed several technology packages including breeding practices, yoghurt making and local capacity for milk processing [6].

Regarding policy issues, the implementation of the National Public Private Partnership Policy [18] opens up more opportunities for partnerships to invest along the milk value chain. In such a scenario, Shambani Graduates, a private milk processing company based in Morogoro stands a better chance to strengthen goat milk processing capacity and gain access to the milk market to capture the increase in supply. Further, adaptation of innovations by farmers would depend on whether the innovation fits their farming priorities, characteristics of household and available resources [19, 20]. Thus, it remains debatable whether the vulnerable and poor people in Mgeta will and can be interested in capitalizing their struggles to better livelihoods and sustainable use of scarce natural resources through improving the dairy goat production systems.

CONCLUSION

The current study in Mgeta indicates that a changeover from a seasonal vegetable crop system to a system with dairy goats and more permanent grass and multipurpose fodder trees would increase farm gross margin by roughly 14%. Moreover, this system also seems to do better under a climate change scenario in which average farm GM was found to decline by only 3.5% compared to 9.6% without dairy goats. The result was due to a smaller decline in yields and less increase in yield variation compared to seasonal vegetable crops since perennial grasses under a multipurpose tree canopy were likely to be less affected in this situation.

RECOMMENDATIONS

Based on the conclusions drawn, it is recommended that the community gradually improve dairy goat feeding and breeding management; and increase establishment of grass and fodder trees, particularly in the steep terrain and mostly erosion-vulnerable parts of the area to counter some of the expected effects of climate change. Also, there is need to develop different policy measures to promote this development.

List of Tables

Table 1: Model solutions for farming in Mgeta with and without dairy goats in a basic scenario compared to a climate change scenario

Scenario	Land use*, m^2					Grass MPTs	Goats		Pigs	Feeds	FGM
	T	PGp	C	B	MB		Dairy	Meat		TZS	
Basic											
Without dairy goats	2512	1423	251	2412	3831	419	0	3	0	0	1644461
With dairy goats	502	1005	251	2119	2617	1633	8	0	0	15842861	1871378
Climate change											
Without dairy goats	1512	1423	251	968	2236	419	0	3	0	0	1487230
With dairy goats	502	1005	251	565	954	1633	8	0	0	15842861	1805026

T=Tomatoes, PGp=Potatoes & green peas, C=Cabbage, B=Beans, MB=Maize & Beans (distance land), MPT=Multipurpose trees, TZS=Tanzania Shillings, and FGM=Farm Gross Margin.

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Reasons for keeping dairy goats in Tanzania, and possible goals for a sustainable breeding program

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Reasons for keeping dairy goats in Tanzania, and possible goals for a sustainable breeding program

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Abstract. This research aimed at describing reasons for keeping dairy goats in Tanzania, and possible goals for a sustainable breeding program. Three districts, each representing a unique dairy goat breed population, were selected for the study. The Saanen, Toggenburg and Norwegian were the main dairy goat breeds in Arumeru, Babati, and Mvomero districts, respectively. A total of 125 dairy goat farmers were interviewed. A holistic approach of both quantitative and qualitative research methods was used to study the perceptions of farmers. More milk yield, sale of breeding stock and manure were the highest ranked reasons for keeping dairy goats. The reasons were coherent to the production systems. The three most preferred traits for improvement were milk yield, adaptability and twinning ability. These preferences were absolutely important in the context of the referred production system. Selection of replacement stock, animal identification and performance recording were the main challenges emphasised by farmers. The present study views these challenges as a result of knowledge gaps in animal breeding that require solutions. Based on result findings it is suggested that the milk yield and survival traits should be the primary dairy goat breeding goals. Generally, there are possibilities for developing sustainable dairy goat breeding programs in the surveyed areas given relevant breeding goals are incorporated. The design of simple and manageable dairy goat breeding schemes is necessary.

Additional keywords: breeding goals, Tanzania.

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Introduction

The goat is important for the economy and food security in Tanzania, ranking second only to cattle in production (MoLFD 2012*a*). It is estimated that over 15.6 million goats are available in the country. About 98% are indigenous breeds (MoLFD 2012*a*). It is estimated that there are 419 533 dairy goats of different breeds (NBS 2012). Most of these goats are found in the medium to highland areas of the country with over 60% of the dairy goats being raised in regions of northern Tanzania (NBS 2012). Generally, dairy goat breeding offers a significant opportunity to alleviate poverty and malnutrition in most rural families of developing countries (Eik *et al*. 2008; Swai and Karimuribo 2011).

The Toggenburg, Saanen, Norwegian, Alpine, Anglo Nubian and their crosses with local Tanzanian goats are the predominant dairy goat breeds in the country (MoLFD 2012*a*). Mostly, the imported goat breeds are now managed under a small-scale farming system. This farming system is characterised by, among others, inadequate essential genetic improvement infrastructures and farmers do not keep records (Ogola *et al*. 2010; Kosgey *et al*. 2011). Depending on the production environment and management, a maximum of ~1–2.5 kg milk yield per day per dairy goat between the different genetic groups is documented (Ogola *et al*. 2010; Lie *et al*. 2011). However, it should be possible to get more milk yield from these animals if better management systems are employed. In Tanzania and elsewhere in Africa, dairy goats are doing well and the demand for dairy goat breeding stock has been increasing (Peacock *et al*. 2011), suggesting that farmers are motivated to keep dairy goats. Currently, some farmers have been upgrading their local goats by crossing with dairy bucks, a strategy that has been recommended as the best for animal genetic improvement in the tropics (FAO *et al*. 2012).

For a sustainable breeding program, knowledge of breeding goals, trait preferences and challenges for dairy goat breeding is essential (FAO 2010; van Arendonk 2011). Such knowledge is indispensable in defining important features which affect motivation and profitability of long-term breeding programs. Breeding goals, if they are well defined, indicate how each trait contributes to profits with genetic change (Byrne *et al*.

2011; Nielsen *et al.* 2011). Understanding the roles of animals and how they fit in the targeted systems are also of importance. The emphasis on a certain trait will depend on the type of animal, the production system, market, and the geographical location. For example, in Europe the emphasis now is more on the content than the amount of milk produced whereas the opposite can be true in developing countries. Goat owners' trait preferences provide guidance in deciding breeding goals (Duguma *et al.* 2010; Philipsson *et al.* 2011). Recent studies by Bett *et al.* (2012) and Gebreyesus *et al.* (2013) showed that milk yield, reproductive traits, conformation, body size and adaptability were the most preferred traits by dairy goat farmers in Kenya and Ethiopia. However, scant information was found in the literature regarding trait preferences for dairy goats in Tanzania.

Experience shows that running animal breeding programs in developing countries is often complex (Philipsson *et al.* 2011; van Arendonk 2011). The lack of knowledge on breeding goals, trait preferences, breeding challenges, and farmers' involvement are some of the factors suggested to influence the complexity (Byrne 2012).

Tanzania has a diverse dairy goat genetic resource, as well as a diverse climate, motivated farmers to participate in breeding programs, and good government policy statement for dairy goats (MoLFD 2012*b*). There have been attempts to compare performance of the breed crosses adopted in different agro-ecological zones of the country. However, no documented information on farmers' breeding goals, preferred traits and hindrances to sustainable dairy goats breeding seem to be available. Thus, this study aimed at describing farmers' breeding goals, trait preferences and challenges of dairy goat breeding in Tanzania.

Materials and methods

Description of the study areas

The study was conducted in three districts of Tanzania: Mvomero, Arumeru, and Babati (Fig. 1). Across the districts, dairy goat farmers live in high-altitude areas between 1000 and 2450 m above sea level. About 90% of the farmers are small-scale producers practicing semi-traditional agriculture, characterised by a crop-livestock integrated production system. Mvomero is in the Western part of Morogoro municipality and administratively comprises 17 wards. The most studied ward was Mgeta, which is ~50 km from Morogoro town (http://www.latlong.net/place/mvomero-tanzania-10466.html, verified 8 November 2015). Arumeru is on the Eastern side of Arusha region and

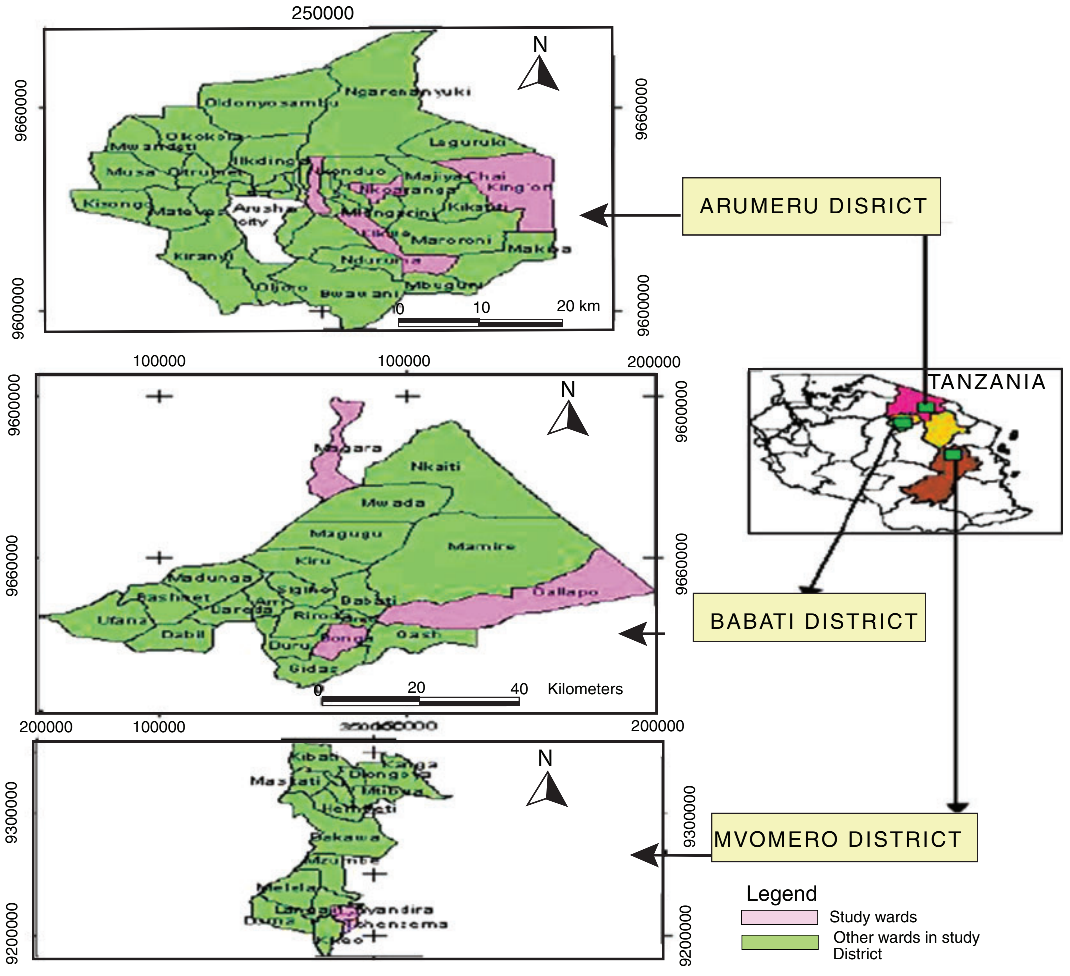

Fig. 1. Maps showing the surveyed areas in the districts.

comprises 37 wards (http://merudc.blogspot.com/, verified 8 November 2015). Babati is a district of Manyara region ~172 km south-west of Arusha region (http://www.manyara.go.tz/wilaya.php?page=babatiDcMain, verified 8 November 2015).

The predominant dairy goat breeds in the districts studied were Norwegian in Mvomero, Saanen in Arumeru, and Toggenburg in Babati. Crossbred goats were common in most of the surveyed households and were raised together with the exotic breeds. This study considered both exotic and crossbreds as one herd of dairy goats as information on their individual exotic blood levels was not always clear. The main ethnic groups in the surveyed districts were the Luguru in Mvomero, Meru in Arumeru, and Fyomi/Gorowa in Babati.

Interviewing techniques adopted

The districts were sampled on the basis that they were populated with dairy goats and that people had a long experience of raising them. The district government officers responsible for livestock development participated in the study. The officers played a role in strategically sampling areas with large numbers of dairy goats. In each of the three districts 42 households were sampled based on the geographical distribution of households with dairy goats. For each surveyed household, the head or spouse of the household was requested to participate in the interview. It was assumed that farmers in the same locality had most cultural, economic and social characteristics in common and, therefore, the farmers are deemed to represent the communities within the districts. Most farmers did not keep records and, subsequently, the accuracy of most of the information collected depended on individual's ability to recall, and on their perception.

The study applied qualitative and quantitative research techniques as defined by Marsland *et al*. (2001). The household survey was performed during January and February 2013. The questionnaire focussed on possibilities for the establishment of a sustainable dairy goat breeding program in the study areas. Both open- and closed-ended questions were designed to serve the purpose. For milk yield, farmers were asked to identify the best doe and to state the daily milk yield in kilograms. Farmers were given freedom to answer questions that they could recall or understand. Moreover, they were told to only consider the year from December 2012 to December 2013. There were 42 completed responses from Mvomero, 41 from Arumeru, and 42 from Babati. The respondents were interviewed about dairy goats using the Kiswahili language by the same person.

Data analyses

Analysis of field data used Statistical Package for the Social Science (SPSS) version 19 (SPSS 2010) computer software. A standard procedure was used to obtain a summary for quantitative data, for example number of does kidded, kids born per doe and kids lost. The crosstabs procedure was used to calculate descriptive statistics for qualitative information, for example breeding goals, trait preferences and challenges. The multiple response option was used to cater for analysis of multiple answers. The Pearson chi-square test was employed for qualitative data to test if there were any significant deviations of frequencies between the districts. The results for qualitative data are presented as counts of responses and discussed based on the overall column percentage.

Results and discussion

Sources for dairy goats

Most (45.6%) of the respondents acquired dairy goats through purchase, and others acquired them through project support, gifts, or through inheritance (Table 1). The number of farmers who purchased initial stock was higher in Mvomero than in Arumeru and Babati districts. This is probably because people there knew more about the benefits of keeping dairy goats. The area is close to Sokoine University of Agriculture, which is assumed to have contributed to creating awareness of the benefits of dairy goats in the area. In the tropics, starting dairy goat keeping through buying initial breeding stock is commonly practiced (Ogola *et al*. 2010; Semakula *et al*. 2010).

Flock dynamics

The dairy goat flock dynamics in the study areas are presented in Table 2. Of all adult goats, 73% were females. The remaining 27% were males, some assumed to be kept for breeding and some for meat purposes. Castration was not common. Moreover; the average herd size per household was 4.3. Under small-scale farming systems, the observed small herd size may be regarded as sufficient by the owners, but also may reflect high off-take rate because of high demand for dairy goats. Female to male population is one of the limiting factors in the development of a breeding program. Genetic improvement under such a situation is challenging. A study by Bett *et al*. (2012) found that herd size mainly affects genetic gain in breeding programs because of low selection intensity. A scheme suggested by Terefe *et al*. (2012) could consider flocks within a village as having the same environment.

For all adult does (those kidded at least once) in the present study, 64% kidded in the year studied. This proportion is low. Possibly there was poor feeding, illness, inbreeding, shortage of breeding bucks, and management-associated problems playing a role (Marete *et al*. 2011). Among the kidded does, 41% kidded two or more kids per birth. The tendency of single, twining and triplet are common in both sheep and goats. The observed twinning proportion was relatively low compared with 58% for Norwegian dairy goats (Massawe 2010), 51% for Toggenburg (Ogola *et al*. 2010), but comparable to 42.3% for an observation in Saanen (Ince 2010). A total of 159

Table 1. Origin of dairy goats' source of interviewed persons using closed-end questions in three districts of Tanzania

Source	District (breed name)			Total	%
	Mvomero (Norwegian)	Arumeru (Saanen)	Babati (Toggenburg)		
Bought	30	9	18	57	45.6
Project	7	20	12	39	31.2
Given	2	10	9	21	16.8
Inherited	3	2	3	8	6.4
Total respondents	42	41	42	125	100.0

Table 2. Herd dynamics for dairy goats in study areas in three districts of Tanzania December 2012–December 2013
HH, household; n.a., not applicable

Characteristics	District (breed name)						Total	
	Mvomero (Norwegian)		Arumeru (Saanen)		Babati (Toggenburg)			
	Goats	HH	Goats	HH	Goats	HH	Goats	HH
Adult males	72	32	38	24	36	23	146	79
Adult females	173	41	111	38	108	29	392	108
Herd size per HH	5.8	n.a.	3.6	n.a.	3.4	n.a.	4.3	n.a.
Does kidded	109	35	52	27	90	35	251	97
Kidding rate (%)	63.0	n.a.	46.8	n.a.	83.3	n.a.	64.0	n.a.
Does kidded >1 kid	46	22	27	17	30	20	103	59
Total kids born	159	63	80	42	127	56	366	161
Kids per doe kidded	1.5	n.a.	1.5	n.a.	1.4	n.a.	1.5	n.a.
Female kids born (%)	50.3	n.a.	57.5	n.a.	55.9	n.a.	163.7	n.a.
Male kids born (%)	49.7	n.a.	42.5	n.a.	44.1	n.a.	136.3	n.a.
Pre-weaning death	27	18	12	10	18	15	57	43
Post weaning death	9	7	5	4	6	6	20	17
Kids deaths (%)	22.6	n.a.	21.3	n.a.	18.9	n.a.	62.8	n.a.

Norwegian, 80 Saanen and 127 Toggenburg kids were born in the year studied (Table 2). Of these new born across the breeds and districts, ~45% were male and 55% female kids. For breeding it is not only a question of how many kids are born, but how many survive to maturity in both sexes. Overall kid loss for pre- and post-weaning was 22.1%. This kid loss is somewhat higher compared with 14.8% (Norwegian) and 13.4% (Toggenburg), but comparable to 21% (Saanen), reported for dairy goats under similar conditions (Eik *et al*. 2008; Ince 2010; Jackson *et al*. 2012). The kid loss before weaning age was 15.6%. Genetic group, litter size, birthweight and season of birth might have influence on kid loss (Debele *et al*. 2011), but management and environment (feed and diseases) certainly are decisive causes. Numbers of replacement kids in both sexes per year offer the possibility for a sustainable breeding program.

Milk yield

Milk yield per day of the perceived best dairy goats are presented in Fig. 2. Across the study areas the best goat was perceived to produce 1.2 kg of milk per day. Under low input systems, this performance may be considered acceptable although a lot less than 3.5 kg for Saanen, 3.4 kg for Toggenburg and 2.3 kg for Norwegian dairy goats under other management systems (Sæther 2002; García-Peniche *et al*. 2012; Åby *et al*. 2014). Lower yields in our study may be explained by feeding conditions. The genotype × environment effect may have played a role because most of these breeds were imported. The present study suggests that better milk yield may be expected from these goats provided strategies for selection of improved replacement stock are in place.

Purpose of keeping dairy goats

The reasons for raising dairy goats of respondents are summarised in Table 3. Results show that dairy goats in Tanzania are also multi-purpose animals. Tangible benefits (milk, sale of live goats, manure and meat) and intangible

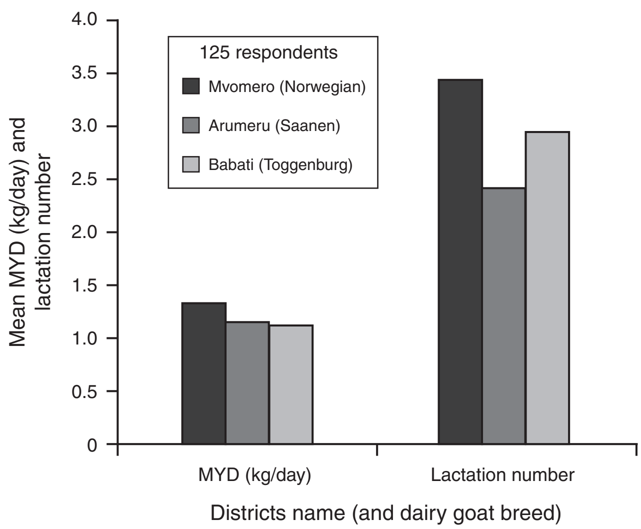

Fig. 2. Perceived milk yield (kg) per day (MYD) for dairy goats in three districts of Tanzania.

Table 3. Reasons for keeping dairy goats in three districts of Tanzania
Numbers of answers form open-ended questions

Breeding objectives	District (breed name)			Total	%
	Mvomero (Norwegian)	Arumeru (Saanen)	Babati (Toggenburg)		
Milk	37	38	40	115	35.2
Live goats[A]	41	20	39	100	30.6
Manure	40	18	21	79	24.1
Meat	15	7	9	31	9.5
Social	0	2	0	2	0.6
Total responses	133	85	109	327	100.0

[A]Keeping goat to get kids for sale at the age of 4–7 months.

benefit (social functions) were the main motives for keeping dairy goats. Across the districts, many (35.2%) respondents emphasised milk yield as an important goal. For economic reasons it is easier to raise dairy goats for milk than cows. Many studies have revealed similar priority breeding goals by dairy goat keepers, for example Bett *et al*. (2009) in Kenya, Ejlertsen *et al*. (2012) in Gambia and Gebreyesus *et al*. (2013) in Ethiopia. As many as 30.6% of farmers put emphasis on the sale of live breeding stock. Live breeding stock in this context are weaned kids, preferably females, to be used as future parents. There was a significant difference (χ^2, $P < 0.05$) between the districts only for selling of live goats (Table 3). Today the interest in keeping dairy goats in the country is higher than any time before. This observation is assumed to contribute significantly to farmers selling live goats as opposed to keeping them for milk. Goats of 4–7 months old were sold at as much as 150 000 Tanzanian shillings (TZS), which is ~71 US dollars (USD) in 2015. Another reason for the importance of selling live goats was the lack of a market for raw milk and milk value-added technologies like yoghurt making. The work by Bett *et al*. (2009) and Ogola *et al*. (2010) reported similar findings in Kenya. The sale of replacement stock is an alternative to the sale of milk and milk products. However, the frequent sale of young stock may limit selection of the best future parents, if this selling results in a decrease in population size and therefore selection intensity.

Across the districts, 'manure' received ~24.1% emphasis as an important reason for keeping goats. In developing countries, farmers value goat manure a lot (Maerere *et al*. 2001; Ogola and Kosgey 2012). Goats manure is valuable because studied areas had vegetable production industries and there is no cattle manure, for example Mgeta (Lie *et al*. 2011). During this study it was noted that goat manure was sold to obtain economic value. Studies show that goat manure is far more important than dairy cow manure and it ranks second after poultry manure in terms of mineralisation of organic nitrogen and phosphorus (Maerere *et al*. 2001). However, it would not be viable to include manure as a trait in the breeding program. Perhaps the emphasis should be to increase the number of goats per household. 'Meat' was also felt important by 9.5% of the respondents. Moreover, social function received the least emphasis, of only 0.6% of respondents. Perhaps this is because the breed is new to them. Excluding the breeding for social functions is considered good for sustainability of the breeding program.

The ultimate goal of a dairy goat farmer would be the increased income due to increased milk yield. For the breeding goals to really reflect the desires of farmers genetic improvement should consider the market requirements, production environments and flock sizes available (Lopes *et al*. 2012*a*, 2012*b*). Multistage interventions are recommended because farmers, for example, may be willing to support the implementation of a genetic improvement program, but government policy may not consider it a priority.

Trait preferences

Table 4 presents the owners' trait preferences for dairy goats. Milk yield (33.7%), disease tolerance (20.0%), and twinning ability (14.0%) were traits with high emphasis. Coat colour (9.6%), body size (9.4%), fast growth (8.0%), and mothering ability (5.3%) were also preferred traits but to lesser extents. These preferred traits can be improved through selection.

Table 4. Traits preferred by farmers for dairy goat improvement in three districts of Tanzania

Numbers of answers from open-ended questions

Traits preferences	District (breed name)			Total	%
	Mvomero (Norwegian)	Arumeru (Saanen)	Babati (Toggenburg)		
Milk yield	31	35	35	101	33.7
Disease tolerance	12	23	25	60	20.0
Twinning ability	8	14	20	42	14.0
Coat colour[A]	7	16	6	29	9.6
Body size	2	12	14	28	9.4
Fast growth rate	2	12	10	24	8.0
Mothering ability	0	6	10	16	5.3
Total responses	62	118	120	300	100.0

[A]Colour of pure dairy goat of a particular breed.

The emphasis given to the first three traits concurs with the breeders' expectations of maximising production. Good dairy goats are those which can survive long enough, produce adequate milk, can reproduce, and grow well. The findings of the present study were in accordance with those reported by Berhanu *et al*. (2012) for farmers of dairy goats in Kenya and Terefe *et al*. (2012) for cattle Ethiopia. The survival trait for animals in the tropics needs great attention, as the environment is challenging in many ways (Ogola and Kosgey 2012). Further, priority for goats with twinning ability is important because it offers opportunity for a quick increase in the number of breeding stock for replacement or sale. However, the high twinning rate will require more management attention. Depending on the economic status, more kids per doe may influence higher incidences of kid mortality (Ogola *et al*. 2010). Although traits like coat colour, large body size, fast growth rate and good mothering ability for does were given low rating in preference, they are crucial for breeding under Tanzanian environments. For example, coat colour plays a role in animal adaptation (Adedeji 2012) whereas body size and growth rate traits may affect marketability especially for sale of live goats. Moreover, mothering ability increases the chance of survival of young goats (Ince 2010). It is recommended that in any breeding program, traits to be considered should reflect breeding goals, be measurable, genetically easily transferable, and few (Stewart and Hayes 2011; Gebreyesus *et al*. 2013). Largely, the trait preferences found in this study concur well with the reported studies. For sustainability of the breeding program, knowledge of economic capabilities, the production system and the environment should be reflected.

Selection criteria

The priorities that farmers gave to criteria used for selection of breeding bucks and does are presented in Table 5. Across the three districts, the lowest response rate was realised in Mvomero. This might suggest that selection for breeding bucks and does was not common practice in Mvomero district.

Table 5. Farmers' criteria for selection of buck and doe dairy goat in three districts of Tanzania

Numbers of answers from open-ended questions

Criteria for:	District (breed name)			Total	%
	Mvomero (Norwegian)	Arumeru (Saanen)	Babati (Toggenburg)		
(1) Buck selection					
Body size	3	29	23	55	30.9
Disease tolerance	2	15	23	40	22.5
Long legs	1	15	18	34	19.1
Long horns	0	17	12	29	16.3
Coat colour	2	12	6	20	11.2
Total responses	8	88	82	178	100.0
(2) Doe selection					
Udder size	7	22	28	57	33.4
Milk yield	9	11	11	31	18.1
Body size	1	14	10	25	14.6
Coat colour	1	11	10	22	12.8
Health status	3	7	11	21	12.3
Twinning ability	8	3	4	15	8.8
Total responses	29	68	74	171	100.0

Body size (good conformation, height and body length) (30.9%), tolerance (ability to survive in the production environment) (22.5%), goats with long legs (19.1%), and long horns (16.3%), and coat colour of the breed (11.2%) were the main criteria for buck selection across the three districts studied. A large and well attached udder (33.4%), production of high amount of milk (18.1%), body size (good conformation, height and body length) (14.6%), coat colour of the breed (12.8%), good health status (12.3%), and high twinning ability (8.8%) were criteria for doe selection. The emphasised criteria were of economic importance and improvement should be possible under the production systems in the present study. The priorities of the criteria for buck or doe selection were different. For example, for bucks the body size criterion was ranked first, whereas in doe selection it was third. The fact that criteria are different for bucks and does expresses existence of indigenous knowledge on what is important in selecting animals for future breeding. The knowledge should go along with performance recording and prediction of breeding values for such criteria (Lopes *et al*. 2012*a*). Unfortunately, performance recording for goats in the present study areas was scarce. Consequently, the selection criteria may be more subjective than objective. Unexpectedly, male goats were found to graze and live together with does in the study area. Under such practice selection efforts may be hindered. Based on the findings of the present study and those reported by Berhanu *et al*. (2012) and Ejlertsen *et al*. (2012), selection criteria for bucks and does in the tropics should consider production, adaptability and reproduction aspects.

Challenges of dairy goat breeding

Different challenges in dairy goat breeding in three districts of Tanzania are presented in Table 6. Results show fewer answers in Mvomero than in Arumeru and Babati districts.

Table 6. Reasons for challenges in dairy goat breeding in three districts of Tanzania

Numbers of answers from open-ended questions. ID, identification

Reasons to the challenge of:	District (breed name)			Total	%
	Mvomero (Norwegian)	Arumeru (Saanen)	Babati (Toggenburg)		
Selection					
Low flock size	30	26	38	94	48.2
No records	4	26	29	59	30.3
Lack of knowledge	5	18	19	42	21.5
Total responses	39	70	86	195	100.0
Identification					
Lack of ID material	10	19	29	58	40
Lack of knowledge	5	22	19	46	31.7
ID not important	7	13	5	25	17.2
Cost of ID material	4	3	9	16	11.1
Total responses	26	57	62	145	100.0
Recording					
Too busy	6	12	21	39	29.3
Lack of material	8	8	16	31	23.3
Lack of knowledge	7	8	16	30	22.6
No simple technique	6	1	7	13	10.0
Cost of material	3	2	6	12	9.8
It is not important	1	0	6	8	6.0
Total responses	31	30	72	133	100.0
Keeping breeding bucks					
Management cost	3	21	19	43	67.2
Destructive/aggressive	3	6	12	21	32.8
Total responses	6	27	31	64	100.0
Cost of hiring bucks					
High	10	7	17	34	33.3
Normal	27	11	10	48	47.1
Cheap	1	11	8	20	19.6
Total responses	38	29	35	102	100.0

However, being close to Sokoine University of Agriculture it may be assumed that farmers in Mvomero received more frequent extension services than those in Arumeru and Babati districts. Challenges mentioned: small flock size (48.2%), lack of performance recording (30.3%) and technical know-how (21.5%) were challenges in selection of dairy goats. These elements are extremely important in developing a breeding program because they affect selection of parents for the future generation. A large population size and performance records are important for selection intensity and genetic gain (Shumbusho *et al*. 2013). However, lack of sustainable performance recording in livestock has been a problem in most developing countries (Philipsson *et al*. 2011). It has been suggested that simple recording techniques be implemented by farmers. For example, we are proposing the use of mobile phones in future.

From the multiple response questions, the present study identified four main challenges:

(1) Animal identification (ID);
(2) Recording;
(3) Keeping of breeding bucks; and
(4) Cost of hiring breeding bucks.

Animal identification

About 40% of the respondents mentioned lack of ID materials as a challenge, 31.7% mentioned technical know-how, 17.2% mentioned that ID was not important, and 11.1% felt it was costly to buy ID. In the study areas some animals were ear tagged, especially goats supplied by projects. The general impression was that goat farmers themselves did not ear tag their animals. Perhaps, government initiatives in collaboration with other stakeholders in the goat industry should take the lead in this matter. Training of farmers on the importance of animal ID and assurance of constant supply of ID materials at a subsidised price may assist to alleviate the problem.

Recording

Reasons reported for this problem were: too busy (29.3%), lack of recording materials (e.g. log books, pen and computers in areas with electricity) (23.3%), lack of knowledge on recording (22.6%), no simple techniques of recording (9.8%), recording material are expensive (9.0%), and recording is not important (6.0%). Being too busy was mentioned probably because normally smallholder farmers are characterised by many and diverse activities including crop, livestock and off-farm activities (Lwelamira *et al*. 2010). Phenotypic data recording is a challenge in most breeding programs, at least in Africa (Ogola *et al*. 2010; Philipsson *et al*. 2011). Principally, every production system requires a certain recording system and the kind of management system may dictate the possible level of recording (FAO 2010). Additionally, ID and performance recording are two interdepending practices. Normally, recording is done on each individual animal, which has been identified uniquely. Development of an effective ID and performance recording scheme should be practical, simple, and affordable and based on traits of economic importance.

Keeping of breeding bucks

Farmers in the present study areas revealed that keeping breeding bucks was difficult because of management cost (67.2%) and their aggressive behaviour (32.8%). For a successful breeding program, the bucks need to be monitored closely. Perhaps, training to farmers on buck handling and establishment of artificial insemination techniques need to be thought of as future alternatives.

Cost of hiring breeding bucks

Across the study sites, 32.5% of the 125 respondents owned breeding bucks. This observation is higher than <20% of farmers owning breeding bucks in Uganda (Semakula *et al*. 2010). The accessibility of bucks for hire was easy to ~84.4% of respondents. In the Mvomero district, for example, hiring cost of a dairy goat breeding buck was 3000TZS (~2 USD) for non-members and 2000TZS (~1 USD) for members per service. This cost of hiring a buck was indicated as high by ~33.3% of the respondents. Low economic power among the dairy goat keepers could probably be the reason for the complaints about high costs. What might be an issue from this is that, a doe might come on heat when a farmer does not have money to pay for the service. Despite the risk of disease transmission, sharing of breeding bucks under a smallholder farmer's situation is indeed important. Gebreyesus *et al*. (2013) suggested that, for an efficient buck sharing, the referred production system, a maximum distance from farmer to the buck keeper, and clear terms of sharing a buck are vital elements to be considered. The revealed challenges are essential elements in genetic improvement and development of sustainable breeding programs. Generally, most of the challenges reflected existence of gaps in knowledge related to dairy goat breeding in this study. It is expected that by managing the challenges, farmers in study areas may offer possibilities of developing sustainable breeding programs.

Conclusions

In Tanzania, dairy goats serve as multipurpose animals. Farmers emphasise milk yield, sale of breeding stock, and manure as their primary reasons for keeping dairy goats. Farmers prefer dairy goats that can produce more milk, are adaptable to the environment, and with high twinning ability. Selection of the best future parents, managing breeding bucks, ID, recording and costs linked to hiring breeding bucks were the main challenges found in the present study. The gaps on goat ID, recording techniques and what to record were the major challenges. Based on the present study findings, perhaps breeding goals should limit to two traits (milk yield and survival) and then with time as farmers develop ability to perform proper recording more goals can be included. Moreover, there are possibilities for establishing sustainable dairy goat breeding schemes in the study areas. However, design of simple and manageable goat breeding schemes is necessary.

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Towards developing dairy goat breeding program in Tanzania by BLUP approach

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Paper III

Towards developing a dairy goat breeding program in Tanzania by BLUP approach

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Abstract

This paper presents suggestions for establishing and optimizing a dairy goat breeding program in Tanzania using standard best linear unbiased prediction (BLUP) methodology and a pedigree made in an Excel computer program. Prediction of accuracy and genetic gain by BLUP is a newer theory than selection index theory. Seven strategies (5, 10, 20, 30, 50, 70, 100 test bucks) were simulated. A progeny test based selection breeding program fitting Mgeta (Morogoro, Tanzania) situation was optimized. The selection intensity, accuracy of prediction, and genetic gain of milk yield (kg) per day at heritability 0.1 and 0.2 are discussed. Use of natural mating for 1000 goats, in cooperating villages, were assumed. Three elite bucks were selected for breeding with 12% of the best females. Outlines of essential elements for a local sustainable dairy goat breeding program in Tanzania are included with a schematic figure showing selection steps for dairy goat breeding scheme fitting in Mgeta area. This study found that selection intensity gained when testing many bucks is more important for daily milk yield (DMY) (kg) genetic gain than the extra accuracy gained when testing fewer bucks. Mgeta has a mountainous terrain, small herd sizes per farmer and long distance from one cooperating village to another. Testing 30 bucks is practical for Mgeta. That gives relatively high (42% or 53%) accuracy of selection and genetic gain (2% or 2.6% for 0.1 or 0.2 heritability). The current results of estimated genetic gain are close to reported findings under other environments. Based on dairy goats of Norwegian breed in Tanzania, milked once daily, if 210 days of milking and an average of 1 litre milk yield is considered, the possible genetic gain per year in this program is equivalent to an increase of 4.2kg for 0.1 heritability and 5.5kg of milk per doe for 0.2 heritability of the trait. Such an increase in amount of milk due to a breeding program under the considered environment is promising. Collaborative efforts from farmers to consumers along the dairy goat market chain remain important elements to realize a sustainable high gain. The proposed breeding program may not be perfect in future because of practical options and accessibility to new knowledge. Thus, it becomes indispensable to revise breeding programs.

Key words: dairy goat, test bucks, Tanzania

1.0 INTRODUCTION

Animal performance is influenced by both genetic (G) and environment (E) factors, and sometimes there is an interaction of the two (G x E – Falconer and Mackay, 1996). This implies that the best animal selected under temperate environment may not be the best under tropical conditions.

In 1988, a few breeding females and bucks of Norwegian dairy breed were sent to Mgeta, Tanzania (Mtenga and Kifaro, 1993). At different times, replacement has been through importing live dairy bucks or semen for AI (Kifaro et al. 2007). However, some of the imported bucks did not perform as expected and some died before mating. AI was an alternative, but a low conception rate and low numbers of new born bucks (6 to 12) were some of the key challenges. For example, out of 46 goats that were inseminated 25 (54%) conceived but only 20 does (43%) completed the gestation period (Kifaro et al., 2007). Recruiting breeding bucks from Mgeta is assumed to have a greater genetic impact in Mgeta area than importing from temperate environments mainly because of the G x E effects. The current dairy goat population in seven villages of Mgeta was > 2000 heads (Kifaro et al. 2012). This population should be large enough to do selection; however, farmers are scattered so across village breeding schemes may be needed.

Establishing a livestock breeding scheme requires guidance. This study is devoted to develop guidance for a dairy goat breeding scheme through developing recommendations that are building blocks essential for sustainable dairy goat breeding schemes under Tanzanian conditions. To achieve this, a simple simulation technique was used to optimize the number of test bucks per year reflecting Mgeta area breeding scheme conditions. In this study decision on which breeding strategy to opt for, depended on the relationship between intensity of selection (i), accuracy of breeding value prediction (r), and expected genetic gain estimation at a heritability of 0.1 or 0.2. The overall aim was to develop the optimal number of test bucks required in the dairy goat-breeding program including 1000 does, using Mgeta, Tanzania as a case study.

2.0 MATERIALS AND METHODS

2.1 The projected production environment

Tanzanian dairy goat breeding structures were simulated based on Mgeta production system. The area is of high altitude ranging from 1100 to 1900m above sea level. Mgeta villages are about 50km southwest of Morogoro town. Smallholder farmers are predominantly practicing crop-livestock integrated production systems. They practice low input, high labour, vegetable gardening integrated with small animals like goats, pigs, and poultry. Over 2000 dairy goats are available in the area (Kifaro et al. 2012). The goats are stall fed, tethered, and sometimes grazed in both communal and own farm plots. The average number of dairy goats per household is 5. There are buck keepers in the different villages. Annually bucks are rotated within and between villages. Cattle rearing is not common, possibly due to the steep terrain.

2.2 Pedigree

Inspired by the available goat population in Mgeta, identities of 1000 female goats were listed in an excel sheet. Only 100 of the females were considered in generation zero to have known parents. The females were assumed to be mated to 100 bucks (i.e. each buck 10 females) at the same time to form generation one. All kids born in generation one had known identity (ID) of their mother and father. The kids' IDs were also listed in the same excel sheet. In later generations the number of kids per buck depended on the number of test bucks considered. Each year a doe was assumed to have a twining rate of 1.1, equivalent to 1100 kids born per generation (550 male and 550 female). Considering 10% mortality, 1000 kids remain (500 female and 500 male, see Figure 3). Culling of kids used an Excel function "RandomSelection" (http://www.extendoffice.com/documents/excel) to randomize the IDs in the excel sheet, then some were deleted to keep the required number. For does, culling assumed that under natural circumstances the oldest animals in the sheet die before the younger ones. Each year 30% of the oldest does were culled and replaced with weaned female kids. In addition, the non-selected tested young bucks and three elite bucks were replaced yearly.

Four generations followed generation zero, making a pedigree of 4400 individuals (1100 in generation zero, 3000 in first through third generation and 300 in the fourth generation). In each year, 1000 individuals (50%-male and 50%-female) are born and registered with a unique ID.

Age at first mating is one year and kidding is at around 1.5 years. The productive life cycle assumed is 3 to 4 years for both sexes. Generation interval is 4.5 years for elite bucks, and 1.5 years for test bucks. The simulation assumed that all goats come from the same breeding population and have the same conception and survival rates after weaning.

2.3 Traits recorded

The DMY of daughters of the tested bucks were used to compare the different breeding strategies possible for the Mgeta area. Milk yield is the most important trait in the breeding goals of dairy goat farmers in Tanzania (Nziku et al. 2016). Performance of the 300 progeny of test bucks were used directly to evaluate their sires, but through the pedigree they would contribute to prediction of all relatives' breeding values using BLUP. The Norwegian dairy goats in Mgeta could produce an average of around 210kg of milk through 210 days (seven months) of lactation (Sonola, 2015). In the calculations all goats are assumed to have one common mean (fixed effect), that is same environmental effect.

2.5 Testing young bucks based on daughters' DMY and selection of three new elite breeding bucks

Seven alternatives for test bucks were simulated (5, 10, 20, 30, 50, 70, and 100 bucks tested per generation). In each strategy, the test bucks produced 1000 (500 male and 500 female) offspring in generation one through three. The test bucks were randomly selected out of the 500 male offspring in a year. When daughters of test bucks have produced milk that is registered in a dairy control, BLUP breeding values are to be calculated for the test bucks, and the three best are selected as elite bucks. The remaining may be sold or slaughtered. The elite bucks become known in the third generation and are included in the mating to produce the fourth generation. So the test bucks only produced 880 (440 males and 440 females) offspring in the fourth generation. The three elite bucks used in mating to produce generation four were selected from the first batch of test bucks. In the fourth generation, the elite bucks were assumed to contribute 120 offspring (60 males and 60 females). Buck kids for testing were then recruited from the three elite sires. The bucks' testing program was assumed to cut across the three cooperating wards of Nyandira, Tchenzema and Mwarazi in Mgeta division, Tanzania.

2.6 Optimization of number of bucks tested

The accuracy (r) and selection intensity (i), leading to genetic gain (ΔG), were the criteria for searching for an optimal number of test bucks per year. Both licensed MatlabR2013a and Excel 2013 computer programs were used for simulation and analyses of data. However, free software like R computer program can be used for similar purposes. Calculations considered the genetic gain for the whole population coming from selection of the three elite sires from the test bucks.

2.7 Accuracy $\left(r_{a,\tilde{a}}\right)$

The BLUP technique was used to find accuracy of predicted breeding values for test bucks in the alternative breeding schemes. The accuracy of prediction is the correlation between true (a) and predicted ($\tilde{a}$) additive breeding values and can be found using the coefficient matrix of the mixed model equations based on the Animal Model (Mrode, 2014). In the Animal Model ‘y’ referred to milk records for does:

$$y = Xb + Za + \varepsilon \quad (1)$$

var(a) = G = sig2a A, var(ε) = R = sig2e I.

For the calculations here it was assumed just one common mean for all observations, so “X” is just a column of 1s, and the “b” is the common mean (μ) for milk yield.

The vector “a” contains the unknown true breeding values for the trait for all animals included in the pedigree. “A” is the relationship matrix for the animals in the pedigree was calculated by readlongped.m and amatrix.m matlab functions (see appendix), and “Z” assigns the breeding values of the observed animals to their observations. ‘I’ is an identity matrix of the same size as the number of observations in “y”. The additive genetic variance of the trait is sig2a, and the residual and environmental variance of the trait is sig2e.

The solutions for the “b” and “a” of the model are given by the mixed model equations;

$$\begin{bmatrix} \tilde{\mu} \\ \tilde{a} \end{bmatrix} = \begin{bmatrix} X'R^{-1}X & X'R^{-1}Z \\ Z'R^{-1}X & Z'R^{-1}Z + G^{-1} \end{bmatrix}^{-1} \begin{bmatrix} X'R^{-1}y \\ Z'R^{-1}y \end{bmatrix} \quad (2)$$

Where $G^{-1} = A^{-1} * (sig2a)^{-1}$ and $R^{-1} = I * (sig2e)^{-1}$ (3)

Since errors are independently distributed with variance sig2e, it is possible to omit them in equation (2) and replace with “ α ” as in (4) (Mrode, 2014).

$$\begin{bmatrix} X'X & X'Z \\ Z'X & Z'Z + A^{-1}\alpha \end{bmatrix}^{-1} = C = \begin{bmatrix} C^{11} & C^{12} \\ C^{21} & C^{22} \end{bmatrix} \quad (4)$$

The $\alpha = (1 - h^2)/h^2$ (5)

According to Mrode (2014) the diagonal element of the inverse of the coefficient matrix C in equation (4) for animal i, the ii element of $C^{22} = C^{ii}$ gives information needed to calculate reliability and accuracy. (The "Offset" function in Excel computer program was used to extract diagonal elements.)

The reliability ($r^2{}_{a,\tilde{a}}$) of evaluation is expressed as $=1-C^{ii}\alpha$ (6)

The accuracy of predicted breeding value is $\sqrt{r^2}\ {}_{a,\tilde{a}}$ (7)

2.8 Genetic gain (ΔG)

The genetic superiority (ΔG) of selected individuals was estimated by $\frac{i * r_{a,\tilde{a}} * \sigma_a}{L}$ (8)

Where

i = Intensity of selection, the differential expressed as fractions of phenotypic standard deviations (Lynch and Walsh, 1998). The intensity of selection (i) = z/p (9)

Where

z = The height of normal distribution at the truncation point 'x', which is given by z = $\frac{e^{-1/2x^2}}{\sqrt{2\pi}}$

and π is 3.14. (10)

p = Selected individuals/Tested individuals (s/n).

$r_{a,\tilde{a}}$ = The accuracy of prediction, which measures how well the true genetic value can be predicted.

σ_a = Additive genetic standard deviation of the trait (DMY),

L = Generation interval as the average age in years of parents at the birth of offspring.

The heritabilities adopted were based on variance component estimates in Norwegian dairy goat control test day records for kg milk (Dagnachew et al., 2011): 0.0532kg^2 for additive and 0.1531kg^2 for the residual for the DMY trait. The residual variance was multiplied by a factor of two: 0.1531kg^2 * 2 = 0.3062kg^2 because it was assumed that there was a lower quality of data in the simulated production system than where estimates were made. These variance components were equivalent to a heritability of 0.148. In the calculations heritability levels of 0.1 (low), and 0.2 (high) for DMY were used.

Further the genetic gain formula was decomposed to:

$$\Delta G / year = \frac{(i_{sse} * r_{BV,\tilde{B}Vsse} + p i_{sdt} * r_{BV,\tilde{B}Vsdt} + (1-p) i_{sde} * r_{BV,\tilde{B}Vsde} + i_{ms} * r_{BV,\tilde{B}Vms} + i_{md} * r_{BV,\tilde{B}Vmd}) * \sigma_{BV}}{L_{sse} + pL_{sdt} + (1-p)L_{sde} + L_{ms} + L_{md}}$$

Where:

sse = elite buck - son

sde= elite buck - daughter

sdt = test buck - daughter

ms = mother - son

md = mother - daughter

i = selection intensity (for sdt, ms, and md i = 0 = no selection)

$r_{BV,\tilde{B}V}$ = correlation between true and estimated breeding values

σBV = genetic standard deviation

L = generation interval

p = proportion of does mated to test bucks

In this case, the following parameters were used:

p	0.88
1-p	0.12
Lsse	4.5
Lsdt	1.5
Lsde	4.5
Lms	1.5
Lmd	1.5

σ_{Bv} =sqrt(0.0532kg^2)=0.23065kg

Mothers and test bucks were assumed to be unselected and therefore their i-s are 0. The needed accuracies were therefore for selection of test bucks to become elite bucks only.

3.0 RESULTS AND DISCUSSION

In a breeding program the important phenomenon to understand is the reproductive success maximization of individuals. Bateman's (1948) principle states that the reproductive success variance is low among females and high among males. This principle explains why breeders place a stronger selection on males than on females.

3.1 Selection intensity

Table 1 shows change in selection intensity when three elite bucks are selected from a varied number of test bucks per year. Selection intensity is one of the factors in breeding scheme optimizations (Bourdon, 2000). As expected, with stronger selection, selection intensity becomes higher. The observed increase in selection intensity comes with the increased number of test bucks while constantly selecting three elite bucks. Testing fewer bucks resulted in decreased intensity of selection. The higher the intensity of selection the better for quick genetic change (Van de Werf, 2000; 2006). With 100 tested bucks selection intensity is at its highest in these calculations, and although the accuracy was low the genetic gain was maximized (Figure 1a-b).

Table 1: Selection intensity (i) for 3 elite bucks when 5, 10, 20, 30, 50, 70, or 100 test bucks are available for selection

Number of test bucks	Number of elite bucks selected	p	x	z	i
100	3	0.03	1.88	0.07	2.3
70	3	0.04	1.72	0.09	2.1
50	3	0.06	1.55	0.12	2.0
30	3	0.10	1.28	0.18	1.8
20	3	0.15	1.04	0.23	1.6
10	3	0.30	0.52	0.35	1.2
5	3	0.60	-0.25	0.39	0.6

p = proportion of individuals selected, x = truncation point, z = the height of normal distribution at the truncation point x, i = intensity of selection

3.2 Accuracy

The higher the accuracy the better the prediction of breeding values before selecting the test bucks to become elite bucks. Figure 1a and 1b show that higher accuracy is obtained by testing fewer test bucks per year. This is because the number of daughters per test buck increases (Kahi and Hirooka, 2005, Dekkers et al., 2004, Van Grevenhof et al., 2012; Kahi and Hirooka, 2005). Thomas (2014) reminds of the importance of statistical procedure, quantity and quality of data for accuracy determination. Schefers and Weigel (2012) suggested that for a breeding program that involves progeny testing, the accuracy of selection depends on several factors: testing capacity, heritability, and number of offspring per buck. Increasing from 1000 to more goats available in Mgeta would also increase the testing capacity and hence could increase accuracy of prediction in the area if number of test bucks was constant. The effect of heritability on accuracy of prediction is shown by comparing Figure 1a and b, confirming that heritability of a trait is an important factor to consider in a breeding program (Van der Werf, 2000). Mgeta should start with few traits of economic importance and with reasonably high heritability, for example, milk yield per day and growth rate.

3.3 Genetic gain

Figure 1a and 1b present how good generation 4 goats are expected to be when accuracy of prediction and estimated genetic gain for DMY (kg) trait per year in a population is considered. The result shows that testing 100 bucks gives the highest genetic gain, but suffers from high loss in accuracy. Selection intensity and heritability play a major role for the observed results. Herd effect was assumed not to exist, but is an important factor in real situations. Testing 20-30 bucks per year could be more practical than testing more in Mgeta. Because of the bad land terrain of Mgeta, long distance between one dairy goat keeper and another, and small herd sizes of about 5 goats per farmer, testing 30 bucks is feasible in the area. That also gives relatively high (0.42 or 0.53) accuracy of selection, and genetic gain of DMY (0.020 or 0.026 kg per day, or 4.2 or 5.2 kg per 210 day lactation) – for heritability of 0.1 or 0.2. Testing fewer bucks result in more daughters per buck, therefore the test bucks' breeding values are more accurately predicted. The problem with many bucks will be confounding of buck effect with the effect of the daughters' herd environment. The heterogeneity of the flocks has not been taken into account in the current calculation except as a general lower heritability effect. In an applied breeding scheme dams could have estimated breeding values (EBVs) with lower accuracy than test bucks, and kids to be test bucks could be selected based on mothers' EBVs for amount of milk, and also for own growth ability. This is not included in the presented calculations. The estimated genetic progress obtained by testing 30 bucks per year in the current study is promising. The values were comparable to Shumbusho et al. (2013) and Colleau et al. (2011). Many factors may affect genetic gain estimation like the population size, testing capacity, heritability, generation interval, use of elite bucks with or without AI, and possibly the evaluation techniques used e.g. selection index (Bijma 2012), BLUP, genomics etc. With emerging new technologies, it is possible to reduce generation interval by use of genomic selection technique (Schefers and Weigel, 2012). However, genomic selection has limitations associated with high costs and technology requirements, especially where a 1000 goats' population under conditions like in Mgeta is considered.

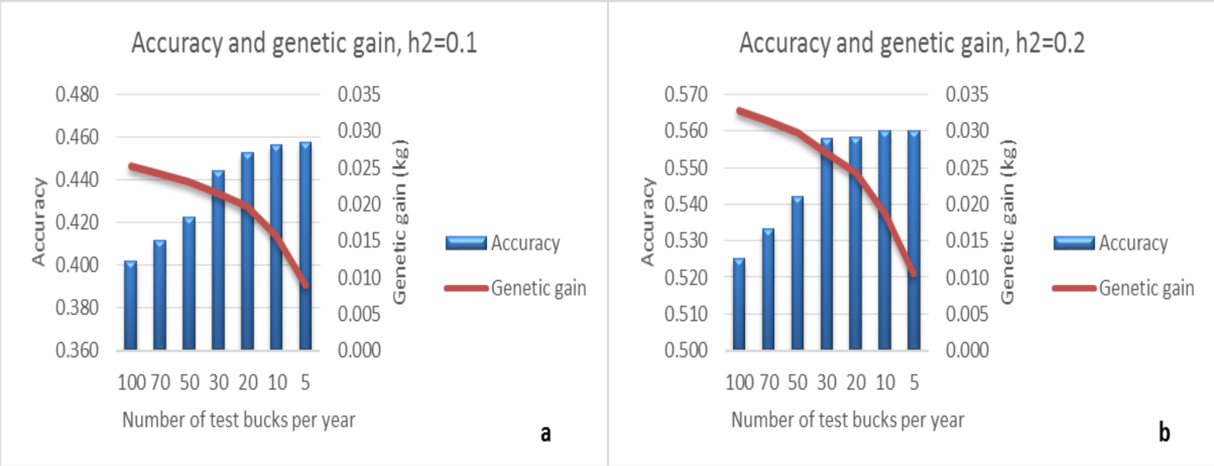

Figure 1a-b: *Accuracy (r) of test bucks from generation 1, and genetic gain of generation 4. Test bucks from generation 3 and three selected elite bucks from generation 1 sired generation 4. Gain per year is in kg of milk yield per day. Progeny tested bucks were selected for additive milk yield trait after the 1000 female goat populations were mated to 5, 10, 20, 30, 50, 70, or 100 test bucks. The evaluation is shown for two heritabilities: 0.1 (a) and 0.2 (b).*

3.3 Time scale of progeny test selection scheme

The current study shows progeny testing selection schemes for goats requires at least 3.5 years to identify elite bucks and four or so years for sons and daughters of the elite buck to be born (Figure 2). The time scale to identify the elite buck is long and is a natural barrier for faster genetic progress under progeny test schemes. Experience shows that generation interval for buck selection varies between 3 and 5.5 years (Al-Atiyat and Aljumaah, 2013; Danchin-Burge, 2011; Facó et al. 2011). Long generation interval reduces the genetic progress per year. Alternatives that makes it possible to shorten the generation interval by genomic selection or multiple ovulation schemes in dairy animals are developed (Meuwissen et al. 2013; Bajagai, 2013; Mapletoft, 2013), but are not be feasible for farmers in Tanzania today. Thus, a well-designed mating system, and breeders’ commitments over time remain essential.

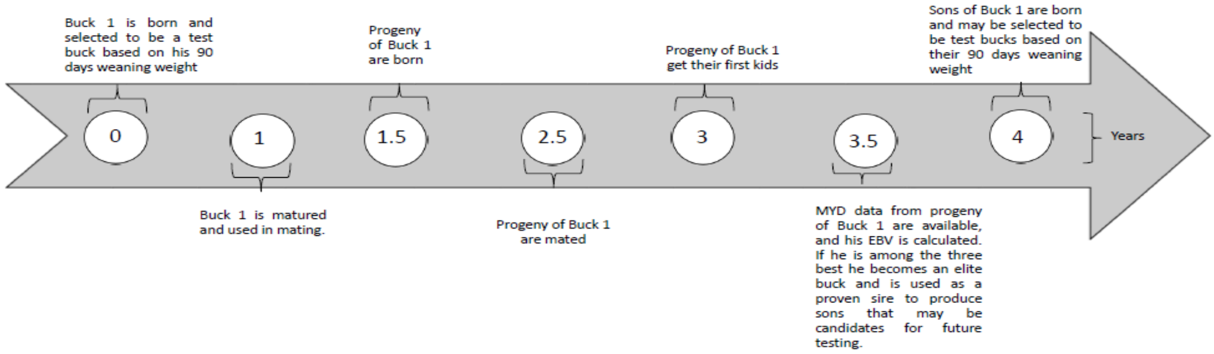

Figure *2. Timescale of progeny testing breeding scheme for dairy bucks based on natural mating. DMY=Daily milk yield, and EBVs=estimated breeding values.*

3.4 Breeding scheme under cooperating farms (dairy units)

This section proposes an effective progeny testing breeding scheme under cooperative farms from different villages. Cooperation between dairy goat units is proposed because of the small number of goats per unit (~ 5 goats). The strategy is not new in developing countries and has proven to be an efficient breeding scheme (Shumbusho et al. 2013; Gizaw et al. 2013). The current study recommends a village breeding program and buck rotation (elite and test bucks). The elite buck rotation could make better distribution of the elite bucks' daughters in the cooperating villages in addition to producing sons for future testing (Fernándeza et al. 2011; Ådnøy et al. 2000). Representatives of the dairy goat association in the area should take the lead in scheduling and controlling buck movements in their areas. Training on why and how buck rotation should be and monitoring would increase efficiency.

3.5 Mating plans for Mgeta

In the current study 12% of all does or ~120 of the youngest females in the pedigree were mated to elite sires. The remaining 88% ~880 of does composed of young and old females were mated to test bucks (Figure 3). Current Mgeta farmers choose buck keepers they like based on the good behaviour and interaction she/he has to members of the association. Buck rotations can be done within villages and between villages. The current study proposes presence of breeding houses – a place where farmers could bring their does for mating. School area can be appropriate areas to construct such houses, because:

- Usually the area is accessible to the majority of communities around.
- These are public premises which give more freedom to farmers to visit.
- The ongoing activities regarding mating and feeding of goats at such a house is an opportunity for school children to learn about goat management.

- Feeding of the breeding bucks and does present at the mating house could be managed by a school. In Mgeta some schools are keeping dairy goats managed by the school children.

However, local arrangements are necessary. According to Sonola (2015) peak kidding is in August and September meaning that many conceptions take place in March and April. This is the time when there are plenty of green pastures and good weather for kids to grow.

3.6 Data bank for dairy goats

Effective selection breeding scheme requires EBVs of individuals. The available individual information for EBV estimation should be as reliable as possible and efficiently utilized. To achieve that individual performance information should flow in all the time starting from the goat owners to trained performance evaluators. The goat owners are responsible for collecting information of individuals; such as weaning weight, milk yield etc. In Mgeta, this has been found to be somewhat of a challenge (Kifaro et al., 2012; Nziku et al., 2016). Perhaps working in collaboration with private sectors under the framework of the Private Public Partnerships policy (URT, 2009), could help to strengthen the recording process. For example, mobile phones can act as an alternative interface for data transferring from farmers to the server. Technically this can be possible in the near future, as similar techniques seem to be functioning well in most of developing countries e.g. mobile banking. However, farmers' motivation is a key issue in this regard.

3.7 Motivation for genetic improvement

A genetic improvement scheme has several demanding requirements. For example, the need for unique animal identification, data to be collected and stored, having parentage file of each animal, understanding statistical techniques for performance evaluations, and possession of computing facilities, are some of the basic requirements. Studies show that motivation is an essential factor for breeding schemes' success and sustainability (FAO, 2010; Philipsson et al. 2011; Ogola and Kosgey, 2012). Harris and Newman (1994) in a review paper of breeding for profit stated that breeders would be motivated if given assurance that greater income is possible by owning the best animals. Finding elements that could motivate dairy goat farmers like those in Mgeta is indispensable, for example award certificate to farmer with the best buck.

3.8 Step by step selection of dairy goat breeding program for Mgeta

Selection of test buck in Mgeta area today could be done by following the simplified diagram in Figure 3. The sketch is a representation and can be adjusted in many ways fitting different situations of selection breeding program of goats.

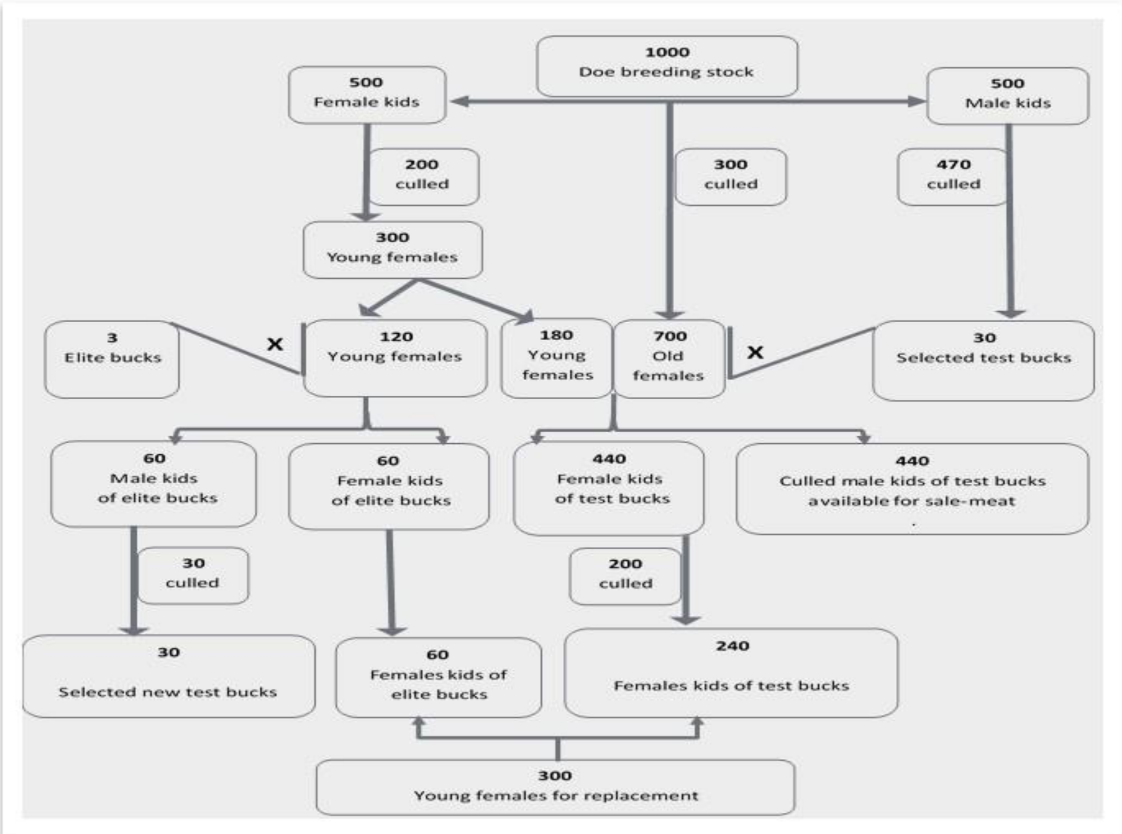

***Figure** 3: Schematic figure proposed for dairy goat selection breeding scheme in reference to 1000 breeding stock and selection of three elite bucks per year*

4.0 CONCLUSIONS

Higher genetic gain and scheme sustainability can be expected if farmers and their organizations are able to play major roles in the scheme implementation while working closely with research and academic institutions.

Under Mgeta situation testing 30 young bucks per year may be the current option, however, the proposed breeding program may not be perfect in the future because of the practical options and accessible knowledge. Thus, it becomes necessary to revise breeding programs from time to time.

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5.0 APPENDIX

Matlab functions.

```
function [pdg,a]=readlongped(pedigreefile);
% 'pedigreefile' is a textfile with three blank-separated columns.
%                Ex: the file idsirdam.txt may look like this (without % in
front):
%                 12345678901234567890l                   0
23
%                  12345678901234567890 2Ada                   0
0
%                            400     12345678901234567890l
12345678901234567890 2Ada

% In your matlab program write Ped=readlongped('idsirdam.txt') to get new
matrix
% with renamed identities in the matrix Ped:
%                                                1     0     0
%                                                2     0     0
%                                                3     1     2
% or [Ped,Id]=readlongped('idsirdam.txt') to also receive transformed
identities in Id.
% The function is made to replace long identities with short ones.
% Only identities in the first column are assigned new values, the rest are
0 (eg 23).
% Made by Tormod Ådnøy october 2003 with help of Arne Gjuvsland.

[a,b,c] = textread(pedigreefile,'%s %s %s');

n=length(a)
%pdg=zeros(n,3); % sets all elements of matrix pdg to 0
for i=1:n
for j=1:n
    if strcmp( a(i), a(j) );  pdg(i,1)=j; end   % finds new identity for a
    if strcmp( b(i), a(j) );  pdg(i,2)=j; end   % finds new identity for b
    if strcmp( c(i), a(j) );  pdg(i,3)=j; end   % finds new identity for c
```

```
end
end
```

```
function a = amatrix(pf,ks,kd)
% function a = amatrix(pf,ks,kd)
% parent IDs are in columns ks &kd
% default ks=2,kd=3
% unknown parents denoted with ID <=0
%  RL Quaas, Cornell University
if nargin==1, ks=2;kd=3;end
numan=size(pf,1);a=sparse(numan,numan);
for i=1:numan;

  if pf(i,ks)<=0;
    a(i,i)=1.0;
  elseif pf(i,kd)<=0;
    a(i,i)=1.0;
  else a(i,i)=1+0.5*a(pf(i,ks),pf(i,kd));
  end;

  for j=i+1:numan;
    if pf(j,ks)>0;
      k=pf(j,ks);
      rel=0.5*a(i,k);
    else rel=0.0;
    end;
    if pf(j,kd)>0;
      kk=pf(j,kd);
      rel=rel+0.5*a(i,kk);
    else rel=rel;
    end

    a(i,j)=rel;a(j,i)=rel;rel=0.0;
  end;

end;
-----------------------------------------------------------------------------
```

Situation analysis and prospects of establishing dairy goat breed program in Tanzania

Z. C. Nziku, G. C. Kifaro, L. O. Eik, T. Steine, G. Msalya and T. Ådnøy

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Paper IV

Situation analysis and prospects for establishing a dairy goat breeding program in Tanzania

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Abstract

The total number of goats in Tanzania mainland is about 17 million. Only two percent are counted as dairy breeds (MoLDF, 2015). Toggenburg, Saanen, Norwegian, Anglo Nubian and French alpine are the main imported dairy breeds. Today they are distributed in all regions of Tanzania. Manyara, Morogoro, Arusha and Kilimanjaro are the regions with abundance in dairy goat numbers. Non-governmental organizations (NGOs) and community-based projects with integration of dairy goats in Tanzania contributed to create awareness among farmers about the dairy breeds. For example, the collaboration between SUA and NMBU participated in a project of establishing on-farm Norwegian dairy goat (called Norwegian white (NW)-goats) recording system involving 62 farmers in Mgeta, Tanzania, between 2011 and 201 4. The FARM Africa (Food and Agricultural Research Management) and HPI (Heifer Project International) imported and distributed dairy goats in the country especially the Toggenburg and Saanen dairy goats (Chenyambuga et al. 2014; FARM Africa, 2006; HPI, 2006). Furthermore individuals, farmers' associations, and charity organizations (e.g. churches) have played similar roles. The support with dairy goats has proven to be rather effective in improving food security and livelihood of people who owned them (Amati & Parkins, 2011; Eik et al., 2008). Long term benefits of the goats can be realized if breeding principles are well considered e.g. reliable source of replacement breeding stock. Quality replacement stock could be found through an organized breeding program, which is missing in Tanzania. Community developmental projects and other support projects are time limited, thus finding a sustainable way of supplying quality dairy goats' replacement stock in Tanzania is necessary. As a step towards achieving that, a Strength, Weakness, Opportunity and Threats (SWOT) analysis of a dairy goat breeding program in Tanzania today was analysed in this paper. The analysis revealed potential possibilities for establishing sustainable dairy goat breeding program in the country. Dairy goat control at farm level is challenged by poor and unreliable records. Alternative plans to get data from farmers while continuing supply of dairy goats in Tanzania are available. A simplified breeding plan is proposed that benefits from progress made elsewhere through occasional semen import for AI in one breeding nucleus herd in the country. Key roles and risks of private and government institutions participating in implementing the goat-breeding plan are highlighted.

Key words: Dairy goat, breeding program, SWOT.

Introduction

In Tanzania, goats are popular and a large population of indigenous Small East African (SEA) goats are kept under extensive management systems (MoLDF, 2015). Imported breeds are also available and kept by rural families. They account for about 2% of the about 17 million goats available in the country. Arusha, Morogoro, Manyara, and Kilimanjaro are the regions with highest numbers of dairy goats. Toggenburg, Saanen, Norwegian, French alpine and Anglo Nubian are the often mentioned dairy breeds found in Tanzania mainland and on the islands of Zanzibar.

Non-governmental organizations (NGOs) and community-based projects with integration of dairy goats have contributed to supply dairy goats among farmers in Tanzania. Norwegian dairy goats (called Norwegian white (NW)-goats) were imported to Tanzania in 1983 as part of on institutional cooperation (SUA and NMBU) (Mtenga et al., 2002). FARM Africa (Food and Agricultural Research Management) and HPI (Heifer Project International) have imported and distributed dairy goats in the country especially the Toggenburg and Saanen breeds (Chenyambuga et al. 2014; FARM Africa, 2006; HPI, 2006). Furthermore, individuals, farmers' associations, and charity organizations (e.g. churches) have played similar roles. The support with dairy goats has proved to be quite effective in improving food security and livelihood of people owning them (Amati & Parkins, 2011; Eik et al., 2008). Better long term benefits of the improved goats can be realized by the farmers if breeding principles are well considered so that reliable sources of replacement breeding stocks exist. Quality replacement stock could be found through an organized breeding program, which is missing in Tanzania. Community projects and supporting projects are time limited, thus finding a sustainable way of supplying quality dairy goats' replacement stock is required. SUA and NMBU recently collaborated in a project of establishing an on-farm NW goat recording system involving 62 farmers in Mgeta, Tanzania, between 2011 and 2014 (Kifaro et al., 2012).

As a step towards achieving a sustainable supply of quality dairy goats, a Strength, Weakness, Opportunity and Threats (SWOT) analysis for a dairy goat breeding program in Tanzania was done. Based on the SWOT analysis, a simplified breeding plan is proposed that benefits from progress made elsewhere through occasional semen import for AI in one breeding nucleus herd in the country. Key roles and risks of private and government institutions participating in implementing the goat breeding plan are highlighted.

Material and methods

A review of dairy goat breeding practices in both Tanzania and Norway was conducted. Norway represented countries with well-functioning dairy goat breeding programs. In Tanzania, data from 62 households' dairy goat control herds in Mgeta during a three years period from 2012 to 2014 was analyzed. The information on parentage identities (ID of individual, sire, and dam), birth date, sex, milk-yield/day, growth performance, mortality, head dynamics (number born, died, sold, slaughtered), mating (buck ID and date) and health (e.g. type of disease and measures taken) were the information available from the dairy goat recording trial. The current study analyzed individual identities (ID), parentage (buck and doe IDs), and birth date, sex, and milk yield/day parameters. Each farmer was trained in record keeping such as weekly and monthly milk and body weight measurements. In order to undertake the work, farmers received recording sheets, milk recording cylinders and weighing scales (Kifaro et al. 2012).

To understand the dataset structure is an important step towards genetic evaluation. The "count A" procedure in Excel computer program was used to summarize the number of recorded information between 2012 and 2014. In addition, both published and unpublished information on dairy goats, information on available resources necessary for animal breeding program in public institutions, in particular the Tanzania Livestock Research Institute (TALIRI) and SUA, as well as from the private sector organizations engaged in livestock related activities, and milk processing companies, were used as important resources for the SWOT analysis.

Dairy goat breeding program practices in Norway

During at least the last four decades, Norwegian goat farmers have participated in a comprehensive recording and breeding scheme for Norwegian Landrace Goats. To develop an efficient selection program, while at the same time conserving indigenous breeds are two main objectives for the on-going work (Ådnøy, 2014). The program includes 31000 dairy goats in 340 herds producing 19 million liters of milk per year (Blichfeldt, 2013; SSB, 2016). Most of the milk is used to make traditional brown whey cheeses, the popular "Gudbrandsdalsost". In recent years, a rennet coagulated white spreadable cheese "Snøfrisk" (Snow Fresh) has also become popular. Ninety percent of the dairy goat farmers participate in the goat recording scheme operated by the Farmers Dairy Cooperative (TINE) in Norway. Based on these data, specialists at the Norwegian association of sheep and goat breeders (NSG) estimate breeding values for all goats participating in the scheme. A total of eight traits: daily milk yield, milks' content (%) of DM (dry matter), CP (crude protein), fat, lactose, in addition to udder/teat conformation, milking speed, free fatty acid content, and occurrence of mastitis are included in the breeding goals. To avoid overproduction of milk, farmers must adhere to a quota system. According to SSB (2014), for years Norway has experienced a stable high milk production reaching 20000 tons per year, which is equivalent to the current market demand for goats' milk. Figure 1 shows development of milk content.

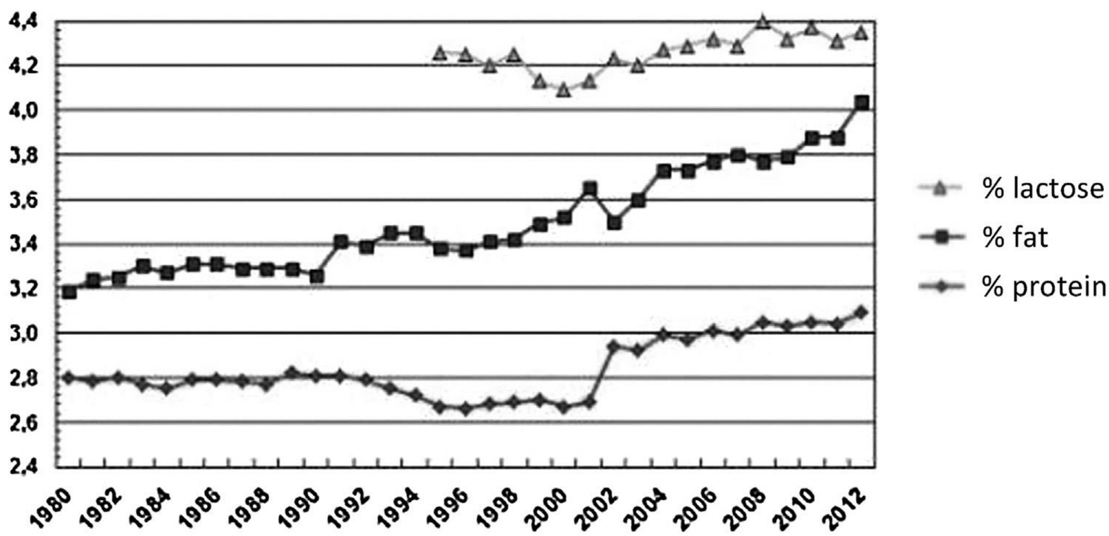


Fig.1. Percentage content of protein, fat and lactose in Norwegian Dairy Goat Recording Scheme 1980-2012 (Tine, 2013).

In the recording scheme, annually farmers are required to record does' milk yield five times and milk contents three times. In addition, all individuals are registered in a pedigree for their parentage information. Test bucks were selected based on a "buck circle strategy" until 2005 when the practice ended due to the risk of transmitting diseases between herds (Ådnøy et al. 2000; Blichfeldt, 2013). Farmers are now encouraged to test best buck kids within own herd and use semen for introducing new genes and for comparison of production level of daughters of own test bucks and AI bucks. This is possible since farmers have large herds and keep adequate records.

Both performance recording and selection for replacement bucks is done at farm level. Farmers' organizations control what should happen and continue to happen at the farm level. Infrastructures necessary for goat recording and performance evaluation from farm to the institutional level is well articulated. For example, animal ID in Europe is the first link and is unique to all animals in the country (Blichfeldt, 2013). Moreover, both farmers and scientists are quick to learn and apply emerging technologies such as use of electronic tagging, AI, and genome based breeding (i.e. including information obtained through DNA analysis in breeding) (Ådnøy, 2014). To keep genetic variation high and increase milk quality, Norway has imported some semen from other countries. For example, between 2007 and 2011, French Alpine semen was imported and made available to farmers (Ådnøy, 2014).

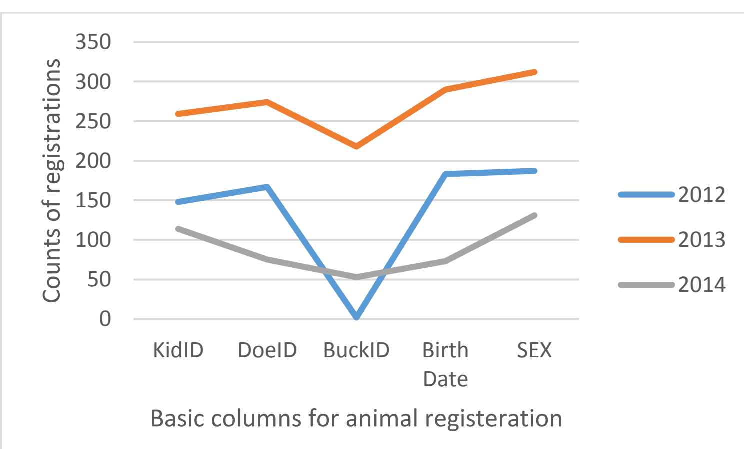
Every year, semen from elite bucks is stored for possible future use (Blichfeldt, 2013). In addition, genotypes from special populations, i.e. wild goats, are secured in the same manner. By doing so, it is possible to safeguard biodiversity and adapt the breeding goals if needed. For the last decades, farmers keep dairy goats for milk only and surplus goat kids are often disposed of after delivery without utilizing the meat. Due to the climate and small farms, the agricultural sector receives governmental support (Ådnøy, 2014), which is not the case for most developing countries including Tanzania. In summary, the long-term successful breeding program for goats in Norway may be attributed to several factors such as presence of enough expertise in the field of animal breeding and genetics, high level of income and education among farmers, strong governmental support and a spirit of collaboration among farmers and institutions working along the dairy goats breeding program.

Dairy goat breeding program practices in Tanzania

Goat breeding in Tanzania is still in infancy stage and the herd sizes are often very small – five goats per farmer as opposed to around 100 in Norway. This makes on-farm selection difficult unless a cooperative breeding program is employed (Nziku et al., 2016). Governmental support is also insufficient, making collaborative efforts and implementation of long term projects more difficult.

Several attempts have been made to establish goat genetic improvement programs in Tanzania. In the 1980s, the Tanzania Livestock Research Organization (TALIRO) established an important base for animal breeding that included an intensive recording system, and introduction of improved goat breeds for both milk and meat (TALIRO, 1980). The Toggenburg and Saanen breeds were the selected breeds for milk while the Kamorai and Boar goats were imported for meat improvement. Unfortunately, these efforts did not sustain after the program ended in 1992. Today, the dairy goat sector in Tanzania is active mainly because of the community development projects tailored to dairy goats (RIPAT, 2015; EPINAV, 2011; FARM Africa, 2006; HPI, 2006). These projects come with different technology packages and themes regarding dairy goats, which include feeding, marketing, breeding, disease control, capacity building, malnutrition alleviation and the like. It seems these and previous similar projects had less focus on maintaining genetic potential of the exotic goats than impact on famers.

For the last five years, a dairy goat breeding project was implemented by SUA and NMBU in collaboration with 62 dairy goat farmers in Mgeta (EPINAV, 2011). The analyses of registered basic and milk yield per day data from dairy goat recording in the project are shown in Figure 2 and 3. Results show a complex data set that is difficult to use for genetic improvement. There was no uniformity in the counted numbers of recorded information and a lot of missing cells for information like the parent IDs. Buck (sire) ID was least registered. Mgeta is considered a reliable place for goat breeding in Tanzania. The complexity observed suggest that at this point in time, and under the given circumstances, it is difficult to operate an on-farm dairy goat breeding program in Tanzania. Still the information gathered in the project is an important indicator that future breeding of goats in the country can be decided. Parentage information is a basic requirement in conducting modern breeding (El-Kassaby et al. 2011). The estimation of additive genetic relationship depends on parentage information, something which seemed to be a challenge in Mgeta.



ID= identity

Fig. 2. Basic information from dairy goat recording in Mgeta, Tanzania 2012-2014. Counts of registered identities (ID) for the newborn kids, does and bucks, birth date and sex. The total count of registered information in 2012, 2013 and 2014 was 687, 1353 and 446. (The KidID

may reoccur as DoeID or BuckID several times if they become parents of offspring in subsequent generations.)

Figure 3 shows the uneven flow of milk yield information between the different months and years. For example more records were obtained in 2013 than in 2014. This could be due to efficiency of the assistants involved in data collection or number of does available for recording during a specific period. Lack of on-farm project sustainability is common in developing countries (FAO, 2010; Gamborg and Sandøe, 2005). Most farmers in Mgeta are poor with limited formal education, and daily they are engaged in several activities including cropping, grazing, water and firewood fetching to mention a few (Asheim et al., 2015). These activities may limit their capacity to participate in a long-term goat breeding program.

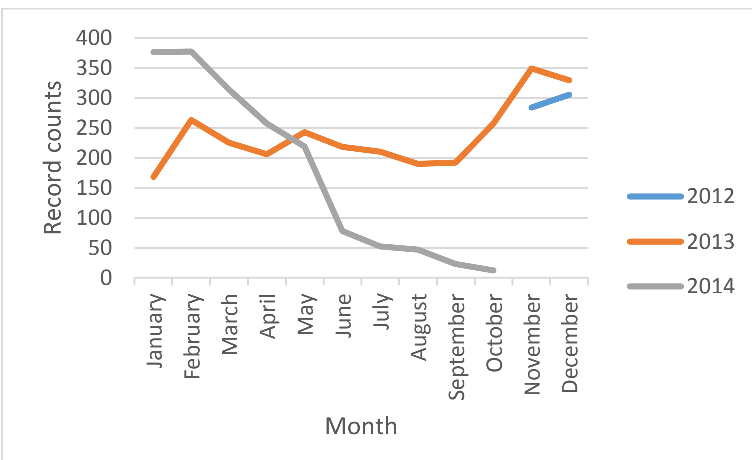


Fig. 3. Counts of registered milk yield information from dairy goat recording in Mgeta, Tanzania 2012-2014. Total milk yield records in 2012, 2013 and 2014 were 656, 2850 and 1755. Milk yield records were supposed to be measured four times in a month by farmers.

In Mgeta better recording could be expected if fewer traits and number of recording times were done, information transfer process shortened (from farmers to data base/server) as opposed to the four registration gathering steps (farmers > agriculture extension agent > research assistant coding data in excel computer program > project leader keeps data files > data users/researchers) adopted in this study. The system may have high risk of human error and delay in getting information available for use. Electronic tools (e.g. cellphone) for data entry and transfer from farmers to the server could help. More importantly motivation factors of farmers, and others involved, to continue recording should been identified.

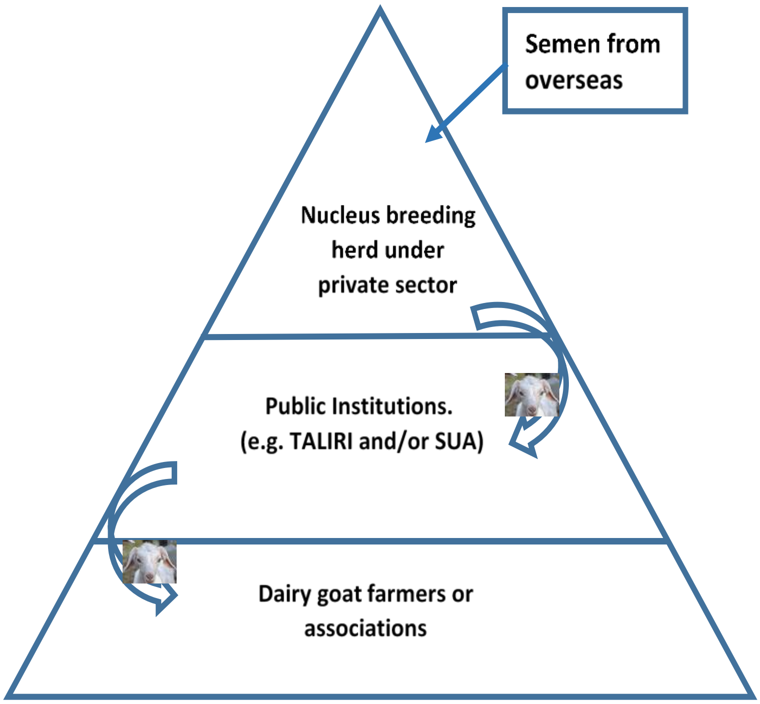
Recommendations from results in Figure 2 and 3:

- On-farm recording is challenging, hence limits dairy goats selection program in Tanzania.
- Farmers are self-motivated to keep dairy goats, but less on recording, hence identification of motivating factors becomes even more necessary.
- To develop a reliable supply of quality dairy goats in the country is required.

Based on this background, this paper proposes an alternative breeding strategy to increase potential for milk yield while keeping inbreeding low in the Norwegian goats' population in Tanzania. The novel strategy is to rely on the selection of dairy traits which depends on progeny test based on recording of performance of daughters in Norway, while some traits like survival, color, and body conformation, shape of udder, temperament could be selected for in Tanzania.

Prospects of dairy goat breeding program in Tanzania

In most developing countries including Tanzania, the private sector is the main employer generating viable income opportunities to poor people (FAO, 2007). The private sectors in this case includes individual farmers or associations, companies (cropping and livestock keeping, milk processing and marketing) and the public sectors as research and academic institutions, in this case TALIRI and SUA. Together, they can mainstream the dairy goat breeding program activities into the general agricultural policies of the country. The new strategy builds on the concept of Public Private Partnerships (PPP) (URT, 2009) in Tanzania. The milestones of the new breeding strategy consists of four grounds, each with unique responsibilities (Fig. 4) as follows:



i. Establish a nucleus breeding herd from private sector.
ii. Import of semen and use in this nucleus breeding herd only.
iii. Connect the nucleus breeding herd to Public Institutions.
iv. Farmers (individuals and associations) tap dairy goat genetic resource through public institution.

Fig.4. Proposed dairy goat breeding pyramid with a nucleus breeding herd under private sector. Imported semen is only used in such a herd and only the offspring are sold out to farmers/associations through public institutions in Tanzania.

Nucleus breeding herd under private sector

The nucleus herd should have at least 100 does year round. All male weaned kids should join a bachelor group (a group with only male goats) to avoid unplanned mating in the nucleus herd. The plan is to use AI and possibly selected young bucks for mating. For the doe side: 30% replacement per year coming from young female kids in the nucleus herd with AI sire. However, before replacement kids should be selected for adaptability traits under Tanzanian conditions. The rest of the female kids may be sold to farmers who wish to keep milking goats. Government subsidy to farmers is encouraged even at this stage for buying quality breeding stock. If the strategy is well managed it could results in a huge impact in genetic improvement of dairy goats in Tanzania, and therefore contribute to the rural economy that the majority of livelihood depends (WB, 2011).

Specific responsibilities for the nucleus breeding unit:

- Buy semen of the dairy goat breed.

- Control breeding in the nucleus herd.
- Record parentage information, sex, growth, milk yield and mortality.
- Sell quality goats to farmers and/or associations through public institutions e.g. TALIRI-West Kilimanjaro is proposed in this case.
- Collaborate with the public institutions by sharing information regarding the dairy goats.

Motivation of private farm

- Income from selling quality breeding stock: around 150,000 Tanzanian shillings ~ 68.7 USD per weaner kid of 4-7 months old (Nziku et al. 2016).
- Recognition from local and international parts involved in dairy goat sector.
- Collaborations with scientist in the animal field.
- The involvement of institutions (academic, research and church missionaries) and individuals as development partners from local and international would be motivated by doing good things for Tanzanians.

Public institution

The TALIRI-West Kilimanjaro is a public Livestock Research Center which has been mandated to coordinate small ruminant research in Tanzania (MoLDF, 2015). The center owns about 5723 ha of land – a resource important for livestock research purpose. In addition the center is equipped with experimental goat barns, personnel working at the center (PhD, MSc, Diploma, and Certificate holders), sheep and goats of different genotypes are kept for different purposes including conservation.

Specific responsibilities of the institution can be:

- Link dairy goat farmers and other stakeholders to nucleus breeding herd.
- Facilitate formation and strengthen dairy goat farmers' associations.
- Rank the best young bucks.
- Receive and process applications for dairy goats from farmers/dairy goat farmers' association.
- Collaborate with academic institutions through local and foreign student visitors for research purposes. The emphasis for this institution should be to involve students and

young scientists in most of the planned agriculture field activities, hoping that they will take the lead in dairy goat improvement in near future.

- Conduct research and share the results on various aspects of dairy goats in the country.
- Collaborate with milk processors and marketing companies on the use of milk collected and quality records.
- Collaborate with the nucleus herd staff to participate in agriculture shows in the country as one way to spread information about the goat breed.
- Should play a role in providing necessary training to farmers on various aspects related to dairy goat keeping (breeding, feeding, disease control, and marketing).
- Should conduct research to answer the question of how many dairy goat breeds are needed in Tanzania and whether pure or crosses (100%, 75%, >50%) are best suited depending on environment. Environments are not uniform. Highlands, low lands, dry and humid areas, diseases, feed availability, and production systems vary throughout the country.

Motivation

- o Information about the dairy goat breed made more available and possible to trace.
- o Opportunities for more research regarding the dairy goat breed.
- o Learning opportunities of researchers (AI, breeding plan, and evaluation of genetic parameters).
- o Availability of experimental units (animals in the country for research reasons).

Farmers / associations

The primary breeding goal at farm level is to increase milk supply while developing farmers' attitude to recording and to increase economy of rural families. The farmers' associations are important as they have a strong influence on policy and research (Umeh and Odom, 2011). They also bring farmers and other stakeholders together to share experiences about dairy goat breeding practices, have a voice on prices of milk or milk production, prices of live goats, assist in input supply and manage buck rotation.

Dairy goat farmers / associations in the country should make it possible to tap the dairy goat genetic resource from reliable sources under private sector through public institutions. Use of public institutions is important to have proper documentation and know distribution of the resources in the country for future monitoring of performance and reporting. In this context, farmers are responsible for:

- Acquiring the dairy goats and replacement bucks from the nucleus breeding herd through the public institutions.
- Milk the goats and sell surplus milk e.g. to processors through farmers' association in their localities.
- Keep simple records (e.g. registering the newborn goats including their parents and mortality information, milk yield once per month).
- Involve their school children at home in goat breeding practices, hoping that they will develop interest in agriculture aspects and attitude for self-reliance.
- Encourage buck rotation technique so that the progeny are evenly distributed in the area (Ådnøy et al. 2000).
- Organize acquisition of livestock inputs for selling to members to enhance easy supply of inputs

Motivation

- Reliable source of quality replacement stock.
- High producing goats.
- Possible to get subsidies.
- Accumulation of capital of the associations for their better performance

Milk processing and marketing companies – Private

Cow milk processing factories are many, but almost no factory processes goat milk in Tanzania. These factories stand a better chance if they work closely with dairy goat farmers and get more milk to process.

Their main roles could be:

- Buying surplus milk from farmers.
- Process the milk and market.

- Establish milk collection centers where they keep track of milk supplied, e.g. source, quantity, and quality. Such records will help breeders in making various decisions related to future improvement of the dairy goats.

The central government

The central government through the Ministry of Livestock and Fisheries Development (MoLFD) is also an important partner in this regard such that they have to:

- Formulate good policy for livestock farmers.
- Provide subsidies e.g. buying semen or bucks, livestock inputs e.g. veterinary drugs because most of the farmers in the country are of low economy and practicing low inputs farming systems.
- Capacity building of relevant staff on different livestock technologies e.g. AI.
- Establish small ruminant semen collection center in Tanzania.
- Institute and monitor a working dairy goat extension service in areas where dairy goats are being raised.

Motivation

- o Poverty alleviation rural families of Tanzania.
- o Information for planning/budgeting.
- o Criteria for subsidy to farmers planning.
- o A practically working dairy goat breeding in the country

SWOT summary as for 2015 in developing dairy goat breeding program in Tanzania

Main strengths: Farmers are motivated to keep dairy goats. There is a good policy for livestock development in the country. A government unit responsible for small ruminants' research in the country is present. Enough land and natural feed resources are available. Academic institutions teaching both agriculture & livestock at Certificate, Diploma, and Degree level are available. The private sector which exists is ready to participate in dairy goat development for the farmers.

Main weaknesses: Insufficient financial and logistical support from the government. Most farmers lack good skills for recording. Lack of an outstanding breeding association that belongs to farmers. Lack of feasible dairy goats recording system under small scale farmers' conditions. Lack of well-defined breeding goals for dairy goats and other livestock.

Main opportunities: Information about why other countries (Norway, for example) have succeeded in dairy goat breeding program is available (Ådnøy, 2014; Dagnachew and Ådnøy, 2014; Skeie, 2014; Blichfeldt, 2013; Meuwissen *et al.* 2013; Paulenz *et al.* 2005; Ådnøy *et al.* 2000). There are high possibilities of starting testing of bucks locally, provided that data for genetic evaluation are available. Tanzania has good international relationship with other countries. Private sector keeping pure dairy goat flocks e.g. the NW-goat breed at Mulbadaw farm LTD in Tanzania exists. The established PPP policy in Tanzania (URT, 2009). Progeny tested bucks' semen can be imported to Tanzania as an immediate solution.

Main threats: Challenges related to AI service including expenses, change of policies, and technical knowhow on the Tanzania side. Farmers will be willing to pay a price for quality goats from the private sectors, but will government institutions like TALIRI-West Kilimanjaro have enough funds to participate sustainably in the proposed program? What if the majority goat farmers shift from keeping more meat goats to dairy goats? Threats to diversity need to be noted as one of the possible effect in the long run. Which breed to be kept where?

Conclusions

The potential of dairy goats under small scale farming systems in Tanzania have stimulated both local, regional, and international developmental partners to join force against poverty through dairy goat supply to rural families.

Farmers and other key beneficiaries along the dairy goats' market chain in Tanzania could benefit more if they collaborate and participate to their best level to work along with the proposed breeding strategy.

Capacity building of staff from public institutions on small ruminant e.g. for AI technology is highly required.

Faster genetic progress for dairy goats in Tanzania can be tapped from foreign running breeding program while continuing to develop own capacity to run dairy goat breeding program.

Needful research

Develop possible and reliable recording system under small scale farming settings.

Establish small ruminant semen collection center in Tanzania is also a good proposition.

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