SUSTAINABLE USE OF ESTRUS SYNCHRONIZATION AND ARTIFICIAL INSEMINATION IN SAHIWAL CATTLE FOR IMPROVED PERFORMANCE OF PASTORAL HERDS IN SEMI-ARID KENYA

FREDRICK ODIWUOR AGUTU

A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Doctor of Philosophy Degree in Animal Sciences of Egerton University

EGERTON UNIVERSITY

SEPTEMBER, 2024

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this university or any other for the award of a degree.

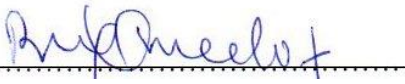
Signature:  _____ Date: 01/09/ 2024

Agutu Fredrick Odiwuor

KD11/16511/18

Recommendation

This thesis has been submitted with our approval as University supervisors

Signature:  Date: 10/09/ 2024

Prof. Bockline Omedo Bebe, PhD

Department of Animal Sciences

Egerton University

Signature:  Date: 10/ 09/2024

Prof. James Ombiro Ondiek, PhD

Department of Animal Sciences

Egerton University

Signature:  Date: 10/09/ 2024

Dr. Samuel Mwanzia Mbuku, PhD

Dairy Research Institute, Naivasha

Kenya Agricultural and Livestock Research Organization,

COPYRIGHT

DEDICATION

This thesis is dedicated to my late parents Jack Agutu and Jenipher Adhiambo, my guardians the late James Ongany and Nick Ouma and finally my siblings Christine, Bounventure, Nick, Benard and Winnie. I love you all.

ACKNOWLEDGEMENTS

I would like to thank the Almighty God for the continued protection, guidance, directions and good health throughout the course of my PhD studies. I further express my sincere gratitude to Egerton University and Africa Centre of Excellence in Sustainable Agriculture and Agribusiness Management (CEESAM) program funded by the World Bank for offering me the opportunity and scholarship to pursue this PhD Degree Programme in Livestock Production Systems at Egerton University. The learning environment and experience during both course and research work was most encouraging and motivating. Extended gratitude towards research fieldwork goes to CEESAM and Dairy Genetics Project supported by the Government of Kenya through National Research Fund (NRF/1/MMC/370) and led by the Kenya Agricultural and Livestock Research Organization (KALRO). The latter was implemented in collaboration with the Livestock Recording Centre and the Kenya Animal Genetic Resources Centre. I also express my deepest gratitude to my supervisors: Prof. Bockline Omedo Bebe and Prof. James Ombiro Ondiek from the Department of Animal Sciences, Egerton University, Kenya; and Dr. Samuel Mwanzia Mbuku from KALRO, Veterinary Science Research Institute, Muguga for their encouragement, guidance, corrections and unconditional support during the entire period from proposal development to preparation of this PhD thesis. Besides them, my sincere gratitude also goes to Mr. Thomas Magothe from Livestock Recording Centre in Naivasha and Dr. Daniel Mwangi from Kenya Animal Genetic Resources Centre (KAGRC).

I also acknowledge the support offered to me by Mr. Wilson Kipeno during inception of the project, identification of farmers and continuous interpretation from local dialect during the study. Besides him, appreciation also goes to the many pastoral communities in Trans Mara West Sub-county who shared with us their experiences and plight during the study. Your support, interactions and learning experiences during fieldwork was overwhelming. I also thank my family members, guardians, friends and fellow students for their continued support, prayers and encouragements that gave the moral support and strength to finish this PhD thesis. I finally express profound appreciation to anyone and all concerned that directly or indirectly helped me during my study years at Egerton University.

Thank you all and God bless you.

ABSTRACT

Fixed timed artificial insemination and use of high-grade Sahiwal cattle breed are technologies that can increase herd reproductive performance. However, their sustainable use as breeding interventions are uncertain in pastoral rangelands where preference is high for natural bull service. The study determined: pastoral herd owners' willingness to pay for artificial insemination service delivery post subsidy; influence of sire and dam mating criteria on conception rates; preferential use of bull calves and benefit-cost of utilizing artificial insemination amongst pastoral herds. The study sampled 130 herd owners in Trans Mara West Sub-County of Narok County and accessed cattle records from the project database, direct on-farm observations and personal interviews for data sources. Willingness to pay was estimated from double bounded dichotomous contingent valuation model based on hypothesized bid levels. Conception rate was calculated as a ratio of total number of confirmed to conceptions ascertained by rectal palpations 90 days' post-insemination. Preferential use of bull calves was assessed in a choice experiment based on perceived bull calve associated attributes. Economic viability was assessed using three key financial parameters involving Net Present Value, Benefit-Cost Ratio and Internal Rate of Return. Willingness to pay amount averaged Kenya Shillings 3,643, equivalent to 21.4% premium with reference to base market price of Kenya Shillings 3,000. Seven in ten (67%) of the pastoral herd owners expressed willingness to pay above the hypothesized market price. Conception rate averaged 61% and was higher among cows (P <0.05) than heifers (72% versus 54%), second parity cows (76%) than first parity (69%) or third parity cows (66%). Majority (54%) of the pastoral herd owners preferred retaining the progeny bull calves within their herds for future breeding purposes relative to immediately selling for income (44%). In Benefit-Cost analysis, optimal husbandry practices had 45% more Net Present Values than low input husbandry practices (Kenya Shillings 9,966 versus 5,462). Sensitivity analysis indicated that application of the technology is not a viable investment under low input husbandry practices when milk prices decreases (-10%), inflation rate increases (+3%) and feeding and watering costs increases (+10%). The study results show a higher likelihood of herd owners continuing to use the technology at market price. In Sahiwal upgrading, higher conception rates can be attainable with low parity cows, sires of foundation and appendix upgrading class; and with sexed semen. It is economically viable for pastoral herd owners to use the technology while applying optimal husbandry practices. Implications are that improved extension service to pastoral herd owners is necessary to improve husbandry practices in scaling and upgrading of Sahiwal farming. Policy interventions need to be directed to enabling private sector deliver synchronization protocol and insemination efficiently.

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATION II
COPYRIGHT III
DEDICATION IV
ACKNOWLEDGEMENTS V
ABSTRACT VI
LIST OF TABLES XII
LIST OF FIGURES XIV
LIST OF PLATES XV
LIST OF ABBREVIATIONS AND ACRONYMS XVI
CHAPTER ONE 1
INTRODUCTION 1
1.1 Background Information 1
1.2 Statement of the Problem 4
1.3 Objectives 5
1.3.1 Broad objective 5
1.3.2 Specific objectives 5
1.4 Research questions 5
1.5 Justification 5
1.6 Assumptions/ Scope and Limitations 7
1.7 Definition of terms 8
1.8 Organization of the thesis 10
CHAPTER TWO 11
LITERATURE REVIEW 11
2.1 Introduction 11
2.2 Cattle Production in Arid and Semi-Arid Lands (ASALs) 12
2.3 Sahiwal breed characteristics and conservation in Kenya 13
2.4 Distribution and multiplication of Sahiwal cattle breed in Kenya 15
2.5 Pastoral Production systems supporting Sahiwal cattle farming 17
2.5.1 Large scale dairy-meat production systems 18
2.5.2 Small scale dairy- beef production system 20
2.6 Breeding programs while utilizing Sahiwal genetic resources 21
2.6.1 Natural mating 21
2.7 Use of Assisted Reproductive Technologies (ART's) 22

2.7.1 Estrus Synchronization....23
2.7.2 Artificial Insemination (AI)....26
2.7.3 Multiple ovulation embryo transfer (MOET)....29
2.7.4 In-vitro embryo production (IVEP)....29
2.8 Conception Rates in cattle herd following OvSynch and Artificial Insemination (AI)....30
2.8.1 Intrinsic Factors Affecting Conception Success....30
2.8.2 Extrinsic Factors Affecting Conception Success Rates....30
2.8.3 Semen sexing technology use in breeding programs....31
2.8.4 Modelling Conception Rates with Bull and Cow Characteristics....33
2.9 Willingness to Pay for Assisted Reproductive Technologies Post Support Period....33
2.9.1 Factors Affecting Willingness to Pay (WTP) for Agricultural Technologies....34
2.9.2 Quantifying Willingness to Pay (WTP)....34
2.10 Performances of selected cattle breeds amongst pastoral herd....35
2.10.1 Productive performances....36
2.10.2 Reproductive performances....37
2.11 Benefits of Sahiwal cattle breed amongst pastoral communities....40
2.11.1 Tangible benefits....40
2.11.2 Intangible benefits....41
2.12 Sahiwal Bull calves within pastoral herd....42
2.12.1 Assessing preferential use of Sahiwal bull calves within pastoral herd utilizing OvSynch and fixed time artificial insemination....43
2.13 Economic Valuations of new technologies or interventions....43
2.13.1 Quantifying Economic Viability using Benefit-Cost Analysis....43
2.14 Opportunities and Challenges for Sahiwal farming within the rangelands....44
2.15 General considerations and Conclusions....46
2.16 Conceptual Framework....46
CHAPTER THREE....49
WILLINGNESS TO PAY FOR OVSYNCH AND FIXED TIME ARTIFICIAL INSEMINATION AMONG PASTORAL HERD OWNERS IN SOUTHERN RANGELANDS OF KENYA....49
Abstract....49
3.1 Introduction....50
3.2 Materials and methods....52
3.2.1 Description of the study area....52

3.2.2 Sampling procedure and sample size 52
3.2.3 Techniques for data collection 54
3.2.4 Analytical framework 54
3.2.5 Data analysis 56
3.3 Results 57
3.3.1 Characteristics of the herd owners 57
3.3.2 The willingness to pay for OvSynch and fixed TAI 58
3.4 Discussion 61
3.5 Conclusion 62
CHAPTER FOUR 63
INFLUENCE OF MATING DECISIONS ON CONCEPTION RATES OF SAHIWAL COWS AND HEIFERS ON OVSYNCH AND FIXED TIME ARTIFICIAL INSEMINATION IN THE SOUTHERN RANGELANDS OF KENYA 63
Abstract 63
4.1 Introduction 63
4.2 Materials and methods 65
4.2.1 Study area and data source 65
4.2.2 Evaluation of cows and heifers for mating decisions 65
4.2.3 Estrus synchronization 66
4.2.4 Artificial insemination of synchronized cows and heifers 69
4.2.5 Conception outcomes 70
4.2.6 Data analysis 71
4.3 Results 72
4.4 Discussion 75
4.5 Conclusion 78
CHAPTER FIVE 79
PREFERENTIAL USE OF SAHIWAL BULL CALVES BY BENEFICIARIES OF OVSYNCH AND FIXED TIME ARTIFICIAL INSEMINATION IN SOUTHERN RANGELANDS OF KENYA 79
Abstract 79
5.1 Introduction 80
5.2 Materials and methods 81
5.2.1 Study area 81
5.2.2 Analytical framework 82

5.2.3 Experimental design and statistical description 83
5.2.4 Conceptualized framework for preferential use of bull calves 83
5.2.5 Data analysis 85
5.3 Results 86
5.4 Discussion 89
5.5 Conclusion 92
CHAPTER SIX 93
ECONOMIC VIABILITY OF USING OVSYNCH AND FIXED TIMED ARTIFICIAL INSEMINATION IN BREEDING IMPROVEMENT OF SAHIWAL HERDS IN THE RANGELANDS 93
Abstract 93
6.1 Introduction 93
6.2 Materials and methods 95
6.2.1 Study area 95
6.2.2 Sampling procedure and data collection 96
6.2.3 Production system scenarios 96
6.2.4 Model description 99
6.2.5 Data analysis 102
6.2.6 Sensitivity analysis 103
6.3 Results 105
6.4 Discussion 109
6.5 Conclusion 111
CHAPTER SEVEN 112
GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS 112
7.1 General discussions 112
7.1.1 Research issues addressed 112
7.1.2 Methodological approaches 113
7.1.3 Willingness to pay (WTP) for OvSynch and fixed TAI among ranch and pastoral herd owners in southern rangelands of Kenya 115
7.1.4 Influence of sire and dam mating criteria on conception success and calf performance 117
7.1.5 Preferential use of bull calves in pastoral herd utilizing OvSynch and fixed TAI 118
7.1.6 Benefit-Cost of utilizing OvSynch and fixed TAI in producing heifer and bull calves in pastoral herd 120

7.2 Proposed breeding framework 122
7.3 Conclusions 123
7.4 Recommendations 124
7.5 Areas for further research 124
REFERENCES 125
APPENDICES 142
Appendix A: Questionnaire for field data collection 142
Appendix B: Photos of offspring calves from OvSynch and fixed Time Artificial Insemination protocol in Trans Mara Sub-county, Narok County 150
Appendix C: Published paper on objective one 150
Appendix D: Published paper on objective three 152
Appendix E: Published manuscript on objective four 153
Appendix F: Selected analyzed result outputs for various objectives in this thesis 155
Appendix G: NACOSTI approval permit 157

LIST OF TABLES

Table 2.1: Major commercial ranches and Sahiwal herd sizes in Kenya 16
Table 2.2: Reproductive tract score (RTS) system 25
Table 2.3: Estrus synchronization and fixed artificial insemination procedures 25
Table 2.4: Possible Outcomes of Double Bounded Dichotomous Choice Questions on WTP 35
Table 2.5: Mean productive traits for different breeds of dairy cattle in Kenya.....36
Table 2.6: Average values for reproductive traits in different dairy cattle breeds in Kenya ..38
Table 2.7: Effect of genotypes on Performances of Kenyan Sahiwal cattle breed and crosses based on birth, weaning, yearling, pre-weaning ADG and mature weights in pastoral environments.....39
T**able 3.1:** Possible outcomes of double bounded dichotomous choice questions on WTP ...55
Table 3.2: Various socioeconomic indicator variable definitions and their measurements....56
Table 3.3: Descriptive statistics of identified indicator variables in scale measurements.....57
Table 3.4: Socioeconomic characteristics pastoral herd owners in frequencies.....58
Table 3.5: Estimated costs (KES)[a] on mean WTP values based on gender, production system, age and first choice attributes by pastoral herd owners 59
Table 3.6: Distribution by gender, age and 1st choice attributes that influence the willingness to pay (WTP) above or below the hypothesized market price of accessing for OvSynch and fixed TAI in pastoral rangelands.....60
Table 3.7: Logistic regression coefficient estimates for socio economic factors influencing WTP for OvSynch and fixed TAI.....60
Table 4.1: Summary of the insemination period and number of cattle inseminated 69
Table 4.2: Summary of cattle insemination data available for analysis.....71
Table 4.3: Frequency outcomes for conception rates (%) 72
Table 4.4: Summary results of cow characteristics on the insemination conception rates.....73
Table 4.5: Effect of sire characteristics on 1st insemination conception rates of pastoral herd 74
Table 4.6: Logistic regression results showing cow and bull influence on conception rates .75
Table 5.1: Variables indicating possible uses and description of bull calves in pastoral herd83
Table 5.2: Demographic characteristics of interviewed pastoral herd owners in relation to the various production systems within the study area 86
Table 5.3: Frequency distribution for function of progeny bull calves in pastoral rangelands by socioeconomic characteristics of herd owners.....88

Table 5.4: Logistic regression coefficient estimates for socio economic factors influencing preference for functions of progeny bull calves 89
Table 6.1: Production and reproduction indicators for herds with optimal and low input husbandry levels.....98
Table 6.2: Estimated unit cost of economic variables (in Kenya Shillings)[a] as used in pastoral herd applying optimal and low input base scenarios 104
Table 6.3: Annual estimates comparing best and worst case scenarios under optimal herd practices within pastoral systems.....106
Table 6.4: Economic analysis of the various production systems using identified financial indicators.....107
Table 6.5: Sensitivity analysis of percentage (%) change in selected variable values on financial appraisal indicators 108

LIST OF FIGURES

Figure 2.1: Population of various livestock species supporting Kenyan livestock sector.....11
Figure 2.2: National and pastoral cattle population for the year 2010 - 2015.....13
Figure 2.3: Sahiwal rearing sites and counties in Kenya.....15
Figure 2.4: Livelihood pathways in pastoral rangelands.....19
Figure 2.5: Research conceptual framework illustrating interacting hypothesized (H_{01} to H_{05}) elements in the use of OvSynch and fixed TAI in pastoral and ranch cattle herds with the goal of attaining improved livelihoods through upgraded Sahiwal cattle.....48
Figure 3.1: Map of Trans Mara West Sub County indicating the distribution of study areas and sampling sites.....53
Figure 4.1: Field procedures undertaken on selected cows and heifers during the OvSynch and fixed TAI in Trans Mara West sub-county.....68
Figure 5.1: Conceptualized illustration of the probable use of progeny bull calves within pastoral herd.....84
Figure 5.2: Overall results for first and second choice preferences on functions of progeny bull calves as perceived by pastoral herd owners utilizing OvSynch and fixed TAI.....87
Figure 6.1: Conceptual model of the pastoral herd model utilizing OvSynch and fixed TAI.....100
Figure 6.2: Sensitivity analysis of % changes in input parameters on the Net Present values.....107
Figure 6.3: Sensitivity analysis of % changes in input parameters on BCR values.....108

LIST OF PLATES

Plate 2.1: Illustration of a Sahiwal bull and cows used for breeding purposes within pastoral rangelands 22

Plate 4.1: Illustration of; (a) pastoral herd selection of cows and heifers for insemination; (b) confinement of cows/ heifers in cattle crush for hormonal injections; and (c) types of hormonal injections (GnRH and PGF2α) used during the breeding program for synchronization processes 67

Plate 4.2: Semen thawed artificial insemination process in selected cows confined in community crushes in the view of pastoral herd owner 70

Plate 6.1: Direct (individual and joint) interviews with pastoral herd owners (a and c) and pooled mineral licking by pastoral herd (b).....97

LIST OF ABBREVIATIONS AND ACRONYMS

AFC	Age at First Calving
AHAs	Animal Health Assistants
ART	Assisted Reproductive Technologies
ASAL	Arid And Semi-Arid Lands
BCR	Benefit Cost Ratio
BCS	Body Condition Score
CBBP	Community Based Breeding Programs
CBK	Central Bank of Kenya
CESAAM	Centre of Excellence in Sustainable Agriculture and Agribusiness Management
CI	Calving Interval
CIDP	County Integrated Development Plan
CL	Corpus Luteum
CR	Conception Rate
CV	Contingent Valuation
DR	Discounting Rate
ECF	East Coast Fever
F_1	First filial generation
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agricultural Organization of the United Nations Statistics
FMD	Foot and Mouth Disease
GDP	Gross Domestic Product
GLM	Generalized Linear Model
GnRH	Gonadotropin-releasing hormone
GPS	Global Positioning System
HPI	Heifer Project International
ILRI	International Livestock Research Institute
IRR	Internal Rate of Return
IVEP	In-vitro embryo production
KAGRC	Kenya Animal Genetic Resource Centre
KALRO	Kenya Agricultural and Livestock Research Organization
KLBO	Kenya Livestock Breeders Organization

KMT	Kenya Market Trust
KNBS	Kenya National Bureau of Statistics
LH	Luteinizing Hormone
LL	Lactation Length
LRC	Livestock Recording Centre
MG	Microgram
MNL	Multinomial Logit
MoAL&F	Ministry of Agriculture, Livestock and Fisheries
MoALF&I	Ministry of Agriculture, Livestock, Fisheries and Irrigation
MoLD	Ministry of Livestock Development
NAHRC	National Animal Husbandry Research Centre
NPV	Net Present Value
NRF	National Research Fund
NSS	National Sahiwal Stud
OvSynch	Estrus Synchronization protocol
PD	Pregnancy Diagnosis
$PGF_{2\alpha}$	Prostaglandin $F_{2\alpha}$
RoK	Republic of Kenya
RPL	Random Parameter Logit
RTS	Reproductive tract score
SAS	Statistical Analysis System
SAS	Statistical Analysis System
SCBS	Sahiwal Cattle Breeders Society of Kenya
SDGS	Sustainable Development Goals
SEAZ	Small East African Zebu
SIFET	Sexed In-vitro Fertilization Embryo Transfer
SPSS	Statistical Package for Social Sciences
TAI	Timed Artificial Insemination
USA	United States of America
USAID	United States Agency for International Development
USD	United States Dollar
WTP	Willingness To Pay

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Pastoralism is a land use involving adaptation to marginal environments characterized by climate uncertainty, utilizing resources at high risk of degradation and continuous strategic mobility in search of key resources including pastures, nutrients and water for livestock (Hatfield *et al.*, 2006; MoALF&I, 2019). Cattle rearing in the arid and semi-arid lands (ASALs) provide important livelihood benefits, both tangible (meat, milk) and non-tangible (insurance against economic bottlenecks, dowry) (Rege *et al*., 2001). Traditionally, pastoral herd owners reveal higher preference towards local indigenous cattle breeds that are adaptable to high environmental temperatures, high disease incidences, feed and water scarcity and seasonal rainfall with capacity for trekking long distances (Ilatsia *et al.*, 2012). In Kenya, these cattle breeds include Small East African zebu, Boran and Sahiwal cattle, utilized for livelihoods and income generation in pastoral rangelands in Kenya (Mwacharo & Rege, 2002). Though the indigenous cattle breeds are adapted to ASAL pastoral production systems, several studies have reported low herd performances which are likely associated with productive, reproductive and economic loses (Kanuya *et al*., 2006; Segura Correa *et al*., 2017).

Of the local indigenous breeds, Sahiwal cattle are popular among Maasai pastoral community for their good adaptation and production performance under ASAL pastoral rangeland production environment (Rege *et al*., 2001). Sahiwal cattle breed either in pure and/ or crossbreeds, are associated with high milk and meat production potential, good reproductive ability, adaptation to heat load, feed scarcity and disease infections, which are prevalent in the pastoral rangelands (Ilatsia *et al.*, 2011). In possessing these attributes, Sahiwal cattle breed have the potential to provide increased food (milk, meat), higher economic return (cash income), wealth accumulation, financing and insurance values to the pastoral communities.

Development agencies consider Sahiwal cattle as a promising means to improve livelihood needs of pastoral households because the breed is adaptable to environmental stresses prevalent in the pastoral rangelands (Ilatsia *et al.*, 2011; Khainga, 2015). Besides these, Sahiwal cattle has direct and indirect contributions to the Kenyan economy through sale of stock (calves, heifers, cows and bulls), milk and meat products and employment in these commodity value in the ASALs (Ketere-Lelgut, 2021). To further increase the economic contributions, development agencies promoted Sahiwal cattle breed through integration in community based genetic improvement and multiplication program involving use of estrus synchronization protocol and fixed time artificial insemination (OvSynch and fixed TAI) using

frozen semen. This breeding intervention accelerated the rate of genetic improvement, rapidly multiplied, and widely distributed top proven semen for improved herd performance in the rangelands. It is deliberated that a high grade or upgraded Sahiwal cattle breed would have higher potential for meat and milk production as compared to the local indigenous cattle breeds (Ilatsia *et al*., 2012). With OvSynch and fixed TAI, it was hypothesized that there would be a faster increase in the number of superior genetics, improved heifers and bulls comparable or even with higher genetic potential relative to the community or individual Sahiwal bull commonly used for mating purposes (Rege *et al.*, 2001).

Combined use of OvSynch and fixed TAI can bring about increased access of Sahiwal semen, rapid genetic improvement in cattle and improve on reproductive performance including conception and pregnancy rates (Saha *et al.*, 2014). Through implementation of the community-based multiplication and dissemination program in the low input livestock production systems, pastoral herd owners have accessed high quality superior Sahiwal semen for upgrading within their herds. The beneficiary pastoral herd owners are expected to access improved heifers, bulls and high quality Sahiwal semen which are comparable or even have higher genetic potential relative to the community or individual Sahiwal bull semen commonly used for mating purposes (Rege *et al.*, 2001).

Over the years, utilisation of crossbred and pure and Sahiwal cattle in the pastoral rangelands has been possible through mating with community or individual bulls sourced from either the National Sahiwal Stud (NSS) in Naivasha or commercial private pastoral ranches and model farms (Ilatsia *et al*., 2012). This has overtime been unable to meet the surging demand for quality Sahiwal bulls and heifers by pastoral herd owners (Mbuku *et al.*, 2019). Moreover, reliance on available community bulls or purchase of culled bulls from other ranches have sometimes recorded negative outcomes such as poor libido, and poor semen quality leading to sub-optimal reproductive efficiency (Mukhopadhyay *et al.*, 2010).

Potentially, the net effect of this translated to increased economic loses, in breeding and loss of genetic diversity in absence of planned upgrading programme. Despite the possibilities of delayed reproductive performances, transmission of diseases and injuries to young heifers, pastoral herd owners continue to use own or community breeding bulls in open mating while grazing in the field (Rege *et al*., 2001). Presently, accessibility to top proven superior Sahiwal breeding bulls at affordable prices has been a major challenge for many herd owners across the country. Up scaling the use of OvSynch and fixed TAI of pure and crossbreed Sahiwal heifers and cows was critical for increased access to superior genetic resources within the pastoral rangelands thus its introduction within Trans Mara West Sub-county.

Prior to OvSynch and fixed TAI of identified cows and heifers, an initial evaluation criteria of body conformation traits (body condition, percent Sahiwal levels) and reference to animal records (age, parity), was undertaken to inform mating decision. The evaluation criteria ensured that a selected cow or heifer was clinically healthy, of good body condition score (BCS); known Sahiwal upgrade level; and of known parity, normal reproductive organs as well as clear estrus signs at the time of estrus event. The evaluation informed matching the best cow with a suited bull (based on performance traits) to obtain high value heifer calves, which were to be progressively upgraded to pedigree status. It was hypothesized that the combination of top proven Sahiwal bull and well performing cow or heifer would produce high quality Sahiwal calves with superior traits. This approach would improve productive and reproductive performance in the herd. Despite the positive attributes, utilization of OvSynch and fixed TAI; and high-grade Sahiwal cattle in ranches and pastoral herds in rangelands has raised sustainability concerns.

To be sustainable, use of OvSynch and fixed TAI; and upgraded high-grade Sahiwal cattle has to be adaptive to internal and external stresses of pastoral and ranching production environments. This necessitates managerial changes in animal husbandry, which can be associated with additional resource investment that could be limiting for subsequent use of OvSynch and fixed TAI; and high-grade Sahiwal cattle. Furthermore, additional resource investment in meeting increased requirements of the herd, can negatively affect the overall profitability and economic returns from Sahiwal farming and later reduced livelihood benefits derived from pastoral herd unless those resources are efficiently used.

Reliance on subsidies during up scaling through the use of OvSynch and TAI in accessing and upgrading Sahiwal may not guarantee sustainability, especially when pastoral herd owners are to meet own direct cost of service delivery at the market price. Currently development partners have subsidized the cost of accessing OvSynch and fixed TAI to increase access and utilization of superior Sahiwal semen in the pastoral rangelands (Mbuku *et al.*, 2019). This is not viable in the long-run because it is unknown to what extent ranch and pastoral herd owners would be willing to pay for the cost of accessing OvSynch and fixed TAI; and service delivery charges post subsidy period to sustain continuous use and production of high-grade Sahiwal cattle. As promoted, ARTs and upgrading of Sahiwal cattle, presently focuses on rearing upgraded heifers but this requires implementing best calf management practices to maximise returns. The willingness of herd owners to adjust calf management practices may be a challenge because of associated additional investments in health, housing, feeding, disease and parasite control; and herd recording.

Mating with Sahiwal bulls has some social prestige among the Maasai community, which may pose barriers in the use of OvSynch and fixed TAI when to replace bull service. Prior to the introduction and acceptance of ARTs amongst pastoral rangelands, Gamba (2006) reported the preference of bull service at 70% amongst herd owners. This indicates a higher appreciation of the ART-bull offspring calves especially from superior and top proven bulls and cow mating within the community. Such a situation would possibly pose a competition with use of OvSynch and fixed TAI on affordability and possibly conception success rates (Khainga, 2015). Uptake of OvSynch and fixed TAI in pastoral breeding programs would be encouraged with good conception and pregnancy success rates above those realised with the use of bull services.

1.2 Statement of the Problem

Growing demand for quality Sahiwal breeding stock necessitated an alternative breeding tool; the use of estrus synchronization and fixed timed artificial insemination (OvSynch and fixed TAI). This breeding intervention can rapidly multiply and upgrade indigenous and crossbreed Sahiwal cattle to pure breed to increase herd performance and deliver improved livelihoods to pastoral communities reliant on rangelands resources. However, when utilising OvSynch and fixed TAI; and pure breed Sahiwal cattle in rangeland pastoral and ranching herds, affordability of the technology and systems adjustments become necessary in animal husbandry practices. Though subsidized in a community based breeding program, the willingness of herd owners to pay for service delivery post subsidy support period is uncertain. When using OvSynch and fixed TAI, mating decisions consider cow conformation traits and the pedigree level in order to appropriately match with the sire genetic merit, but conception success rates and performance of resulting progeny calves could be unsatisfactory to the community, thus introducing source of uncertainty and risks. A strong cultural, social prestige and preference for use of bull calves, especially progenies of high genetic merit Sahiwal cattle could impede uptake of OvSynch and fixed TAI among the Maasai community. In addition, economic feasibility of using the reproductive technology in producing heifers and bull calves remains unclear to guide investment decisions. Adaptability to heat load, nutritional scarcity and disease infections in the pastoral rangelands could be a concern for successful utilisation of progeny calves. These are too many uncertainties associated with use of OvSynch and fixed TAI that need data evidence to support informed investments decisions during utilization in Sahiwal breeding programs under pastoral rangelands.

1.3 Objectives

1.3.1 Broad objective

To contribute to sustainable Sahiwal cattle breed production for improved livelihood through utilization of OvSynch and fixed TAI, upgraded Sahiwal cattle and effective management practices in pastoral production systems

1.3.2 Specific objectives

The specific objectives of the study were:

i. To estimate the willingness of ranch and pastoral herd owners to pay for the attributes associated with utilization of OvSynch and fixed TAI.
ii. To establish influence of sire and dam mating criteria on conception success with application of OvSynch and fixed TAI in ranching and pastoral herds.
iii. To quantify tangible and intangible benefits of progeny bull calves from utilizing OvSynch and fixed TAI in ranching and pastoral herds.
iv. To estimate Benefit-Cost of producing progeny heifer and bull calves with application of OvSynch and fixed TAI in ranching and pastoral herds.

1.4 Research questions

The study sought to answer the following research questions;

i. To what extent would, ranch and pastoral herd owners be willing to pay for the attributes from OvSynch and fixed TAI use without subsidy support?
ii. Does the sire and dam mating criteria significantly influence conception rates in pastoral and ranching herds utilizing OvSynch and fixed TAI?
iii. What are the tangible and intangible benefits of progeny bull calves from OvSynch and fixed TAI use in pastoral and ranching herds?
iv. What is the economic viability of producing heifers and bull calves with application of OvSynch and fixed TAI under pastoral and ranching herds?

1.5 Justification

This study was designed to provide the empirical evidence on sustainable utilization of OvSynch and fixed TAI, in increasing the rate of genetic progress through upgrading and easy access to quality Sahiwal semen for breeding in ranching and pastoral herd. The results would assist and guide both the national and county governments, private service providers and other livestock value chain actors in ensuring genetic improvement, multiplication, continuous sensitization and service delivery of OvSynch and fixed TAI for sustainable breeding programs

in pastoral rangelands. This would further aid in designing multiplication programs for dissemination of top proven Sahiwal genetic resources to pastoral herd owners thereby bridging the gap for high demand of Sahiwal bulls for improved herd productivity. With high productive cattle, farmers would be assuring environmental health, as the number of cattle per herd would be significantly reduced.

Assessment of herd owners' Willingness to Pay (WTP) provided insight into the continued use of OvSynch and fixed TAI by pastoral herd owners post subsidy support and private entrepreneurs take over last mile service delivery. It further provided avenues and opportunities for private sector participation in OvSynch and fixed TAI service delivery and up-scaling to increase access of superior Sahiwal genetic resources in pastoral herds. Knowledge on sustainable use of OvSynch and fixed TAI in ranch and pastoral herds also offers informed interventions for unexpected economic and social sustainability issues; and calf management practices that would ensure improved Sahiwal herd performance is achieved with minimal associated trade-offs. This would further assist in identifying an efficient delivery model for use in faster multiplication and distribution of proven Sahiwal genetic resources for increased herd performances in pastoral rangelands. This will simultaneously inform policy and scale-up production in pastoral production circumstances.

The study generated baseline information on the application of other assisted reproductive technologies in similar pastoral rangelands. The applied methods and procedures could aid in assessing use of other reproductive technologies such as Multiple Ovulation and Embryo Transfer (MOET), In vitro Embryo Transfer to improve reproductive performance in Sahiwal cattle farming. Herd owners, national and county government, non-technical decision makers and researchers would benefit from the results in optimizing production and reproduction performances of Sahiwal cattle breed towards sustainability of breeding programs in pastoral systems. The good husbandry practices as well as sustainable utilization of OvSynch and fixed TAI will increase access of superior genetic resources and continuous upgrade to pure Sahiwal breed within the pastoral rangelands.

This will guarantee increased herd productivity (milk and meat), food and nutrition security, poverty reduction (improved income) and economic development of pastoral rangelands in Kenya. It is true that rangelands are an essential part of the complex and diverse livestock production and biodiversity conservation systems necessary for sustainable human development and global climate regulation mechanisms. Increased milk production and economic returns would make significant contributions and opportunities for investment towards Kenya's Bottom up transformative Agenda (BETA) with priority on dairy value chain,

and sustainable development goals (SDG 1- No poverty, 2-No hunger, 3- Good health, 8- Good jobs and economic growth, 12- Responsible consumption) whose vision is to create a better, fairer world by 2030.

1.6 Assumptions/ Scope and Limitations

The scope of the present study was within Trans Mara West sub County, comprising Maasai pastoralists who benefited from a community based Sahiwal upgrading program. It was assumed that economic conditions in southern rangelands of Kenya were to continue improving under initiatives of the national and county governments. Though, the findings cannot be generalized into the whole Southern rangelands of Kenya, it provides detailed information that give insights into sustainable use of OvSynch and fixed TAI among the Maasai community. It was assumed that Sahiwal cattle farming was the main livelihood source for increased milk production and income thereby offering good data source for answering the research questions. The study further assumed that the respondents had Sahiwal cows and / or heifers previously inseminated using top proven bull semen superior bull semen through the subsidized of OvSynch and fixed TAI program.

In some circumstances, the study was limited by language barrier especially during interviews and group discussions. Most of the respondents from the Maasai community could not effectively read and/ or write English or Kiswahili due to low literacy levels as observed within the rangelands. This prompted the use of community interpreters who might have distorted the targeted questions and /or responses from the respondents during the indirect exchanges. However, the study ensured that the interpreters were well trained and conversant with the questions before the commencement of the survey to interpret as accurately as possible and reduce distortions during the interviews. To minimize biasness that could originate from personal opinions during interviews, the study organized small group discussions based on participatory rural appraisal amongst the program beneficiaries. This was to aimed at probing further, complementing and triangulating field information collected using the structured questionnaires during field interviews.

The study was limited to respondents' views during the cross sectional survey based on observable characteristics while ignoring unobservable characteristics that could create biasness in the generated results. The study also assumed that prior to artificial insemination; the available community bulls inseminated none of the selected and hormonally injected cows or heifers within the study areas. It was assumed that the unfavorable weather conditions such as regular droughts and animal health constraints within the study areas, did not affect the

reproductive performance of the inseminated cows and heifers at the time of study. In assessing the economic feasibility of using OvSynch and fixed TAI, the study was limited to considering Sahiwal cattle breed as a dairy breed for milk production and sale over a period of 5 years rather than rearing as a dual purpose breed and selling at earlier age within the high end markets for increased income.

1.7 Definition of terms

***ad lib* (ad libitum**): Technical term used in animal feeding that means provision as much or as often as necessary or desired to satisfy the individual animal nutrient requirements.

Agro-pastoral system: Denotes pastoral land use system in which incorporates both livestock husbandry and cropping in association within the same area.

Assisted Reproductive Technologies (ARTs): Technologies used in dairy cows to improve the reproductive performance of cattle in various production systems. For the current study, ART used was fixed Time Artificial Insemination (TAI) applying OvSynch protocol.

Artificial Insemination (AI): Reproductive management tool for genetic improvement in farm animals, which involves the artificial introduction of semen into the reproductive system of a cow after collecting and processing from a bull.

Bull plus (BB+): A kind of sexing agents mixed with semen (either fresh or frozen) before insemination with the intention of producing only bull calves.

Conception rates (CR): A reproductive performance measure that calculates the ratio between total numbers of conceptions confirmed to the total number of cows and/ or heifers inseminated.

Crossbreed: This refers to offspring resulting from parents of different cattle breed lines

Dual-purpose breed: Animals that have the potential of producing both milk and meat for subsistence and / or commercial purposes.

Heifer plus (AH+): A type of sexing agents mixed with semen (either fresh or frozen) before insemination with the intention of producing only heifers as calves.

Indicator: Is a variable or a qualitative or quantitative factor that provides a simple and reliable means to measure achievement or to reflect the changes connected to a programs intervention

Low input systems: Is a kind of pastoral system entailing low provision of nutrients and other husbandry measures or interventions for production or reproduction purposes

Mating: Is a farm breeding intervention that comprise the pairing of female and male animals for farm reproduction through natural methods and/ or using artificial insemination.

Nomadic pastoralism: Entails pastoralism based on random / erratic and long-range movement of cattle in search of pasture and water

Optimal herd practices: Is a husbandry practice that involves the maximum provision of nutrients and other measures as per individual animal requirement.

Outcome: The medium-term results of an operation's output. It relates to the purpose level of the log frame hierarchy.

Pastoralism: Is a livestock production system characterised by continuous movement of livestock from one place to another in search of pasture and water.

Payback period: Is the period required to recoup the funds expended in an investment

Pay-off period: This is the amount of time taken to break even on an intended investment and considers the time value of money and cash flows.

Program: Is a grouping of similar projects and/ or services performed by an individual, group, organization or government to achieve a specific objective.

Pregnancy diagnosis: This important reproductive management procedure done to measure the pregnancy success of dairy herd

Productive life: The interval between first calving and disposal for cows either by death, culling or sold-off

Pure breed: This refers to offspring resulting from parents of the same breed.

Ranching: Entails rearing of pastoral herd under confinement/ enclosed by either individual or community owned.

Rangeland: Is a land carrying natural or semi-natural vegetation, which provides a habitat suitable for herds comprising of wild or domestic grazers and browsers.

Repeat breeding: Is the failure to conceive from successive breeding services.

Return on investment: Is the ratio between the net profit and cost of investment resulting from an investment of some resources. A high ROI means the investment gains favourably to its cost.

Stocking rate: Refers to the optimal number of animals allowed into a given area of pasture and at a given time.

Sensitivity analysis: A type of analysis performed to determine the effect changes of an independent variable towards the response variable.

Sustainability: In the context of the study, this refers to the continuation of benefits from an intervention after completion from a major assistance.

Upgrading: In reference to this study, entails changes in cattle production and management process to increase herd performance through targeted breeding interventions.

1.8 Organization of the thesis

This thesis is organized in seven chapters. **Chapter one** discusses the general introduction comprising the background information of the study, statement of the problem, objectives of the study, research questions, justification and scope or limitations of the study. It further provides definitions of the terms as operationalised in this thesis to bring a common understanding within the context of the study. **Chapter two** presents the literature review informing the objectives of the thesis. The review has covered extensive production systems, utilization OvSynch and fixed TAI, Sahiwal cattle breed characteristics, distribution, multiplication performance, constraints and possible opportunities for improved productivity in pastoral rangelands found in Kenya. The chapter presents the concept of willingness to pay for agricultural technologies and its application under pastoral set up system; conception rates and associated factors affecting conception rates in pastoral herd within rangelands; uses of bull calves in pastoral herd; and overview of benefit-cost analysis that relates to the study background and theoretical basis. The chapter ends with a summary of identified research gaps from the literature review that formed the basis of this research study.

In **Chapter three,** the thesis presents methods and results that highlight the willingness to pay for OvSynch and fixed TAI utilization within their pastoral herds. This chapter provides insights on sustainable use of the technology post subsidy period when support is withdrawn and herd owners have to meet the direct costs of service delivery within the rangeland production conditions. **Chapter four** presents the influence of cattle evaluation procedures and associated mating decisions; on reproductive performance of Sahiwal herd. It highlights the effects of field evaluation procedures and bull-cow mating criteria often undertaken within breeding programs and their ultimate impact on the conception success rates within pastoral herd. **Chapter five** presents the perceived preferential use of progeny bull calves obtained from OvSynch and fixed TAI use within the pastoral herds. It highlights the various uses as perceived by the herd owners regarding the ultimate use of bull calves within the pastoral herd. **Chapter six** highlights the viability of using OvSynch protocol and fixed TAI in improving herd performance and producing superior calves. It presents two pastoral hypothetical case scenarios based on analysed financial indicators to assess the economic feasibility of OvSynch and fixed TAI use in pastoral rangelands. **Chapter seven** integrates the findings of all the previous results from other chapters, proposes implications, issues that need future considerations, proposed breeding framework, opportunities and challenges, conclusions and recommendations for effective and sustainable utilization of OvSynch and fixed TAI in Kenya.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Livestock sector directly or indirectly play a key role in addressing global challenges involving poverty reduction, undernourishment, unemployment, biodiversity loss and climate change (FAO, 2018a). In Kenya, livestock sector contributes 12% towards the national GDP (approximately USD 4 billion annually), 43% towards the Agricultural GDP and over 40% of farm gate value of agricultural commodities (KMT, 2019). Various livestock species including and not limited to 15.8 million cattle, 19.3 million sheep, 28.0 million goats, 38.8 million chicken, 4.6 million camels, 1.2 million donkeys and 0.44 million pigs (Figure 2.1) support the livestock sector in Kenya (KNBS, 2019).

The projected numbers of livestock will increase in future to accommodate the high demand of livestock products by increased population growth within the country. It is approximated that about one third of the total area of Kenya is arable with the remaining land area being semi-arid to arid lands characterised by low, unreliable and poorly distributed rainfall (Kamiti, 2015; MoA, 2009). These vast lands provide sources for extensive livestock production systems that support various livestock species including cattle, camels, sheep, goats, donkeys and chicken, which provide various livelihood sources to the many pastoral communities living within the ASALs.

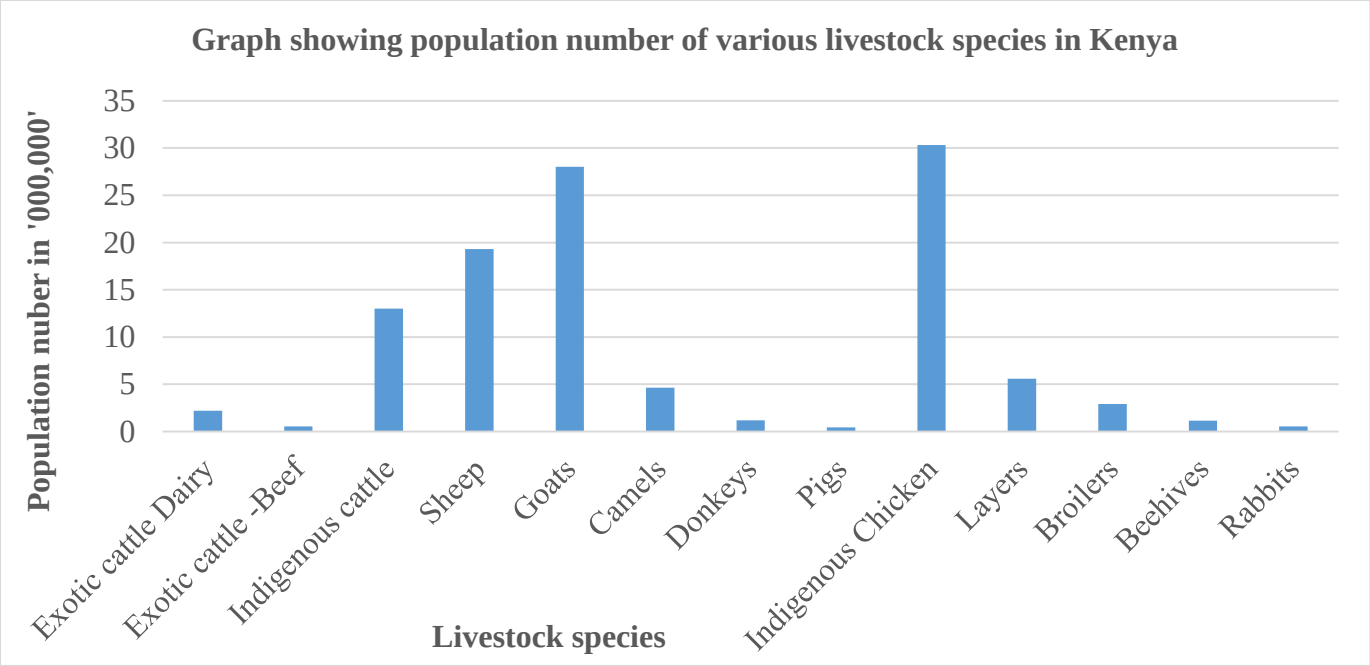


Figure 2.1: Population of various livestock species supporting Kenyan livestock sector

Source: KNBS (2019)

2.2 Cattle Production in Arid and Semi-Arid Lands (ASALs)

Sixty per cent (60%) of the livestock herd are estimated to be within Arid and Semi-Arid Lands (ASALs) mainly rangelands, which constitutes about 70% of the country's landmass and has an approximate population of 10 million Kenyans (Nyariki & Amwata, (2019). Arid and semi-arid lands are predominated by extensive production systems of which livestock offers great importance to the communities that inhabit pastoral rangelands. Of importance, the livestock sub sector within the ASALs provides direct and indirect employment to nearly 90% of the total rural population (Ketere-Lelgut, 2021). These pastoral communities within these ASALs mainly derive their livelihood sources largely from cattle through tangible (meat, milk and other products) and non-tangible benefits that are estimated to be worth over USD 1,000 million annually (Ketere-Lelgut *et al*., 2018).

Despite the unfavourable weather conditions experienced in ASALs, the bulk of beef consumed within and exported out of the country are produced within the ASALs through either large-scale dairy-meat commercial ranching or small-scale dairy-meat production (Kahi *et al*., 2006). Seventy five per cent of cattle herd in Kenya are found in pastoral rangelands that produce approximately 90 per cent of meat consumed in East Africa (Nyariki & Amwata, 2019). This outlines the greater importance attached to cattle within the pastoral communities, counties, Country and the region in general. The pastoral rangelands are characterized by seasonality and annual variability in environmental and climate parameters especially temperatures and rainfall. Despite these unfavourable conditions, the rangelands provide home to most pastoralists who form 20 percent of the Kenyan population (Nyariki *et al*., 2009).

Though livestock production predominates as the major livelihood strategy to most households within the rangelands, some have diversified income sources including owning businesses, practicing rain-fed agriculture while others undertake irrigated agriculture in effectively drained wetlands as in the case of Lielerai, Kimana and Ormakau swamps in Kajiado county (Boone *et al*., 2006; Mustaphi *et al.*, 2014). Cattle rearing is of great importance to most pastoral household and provide greater preferences with various additional benefits compared to other livestock species. Cattle populations within pastoral areas account for approximately 44% of the total national cattle population in Kenya and contribute significantly to the overall economic returns (Nyariki & Amwata 2019). Figure 2.2 presents a graphical presentation of the cattle populations within the national and pastoral regions in Kenya between the year 2010 to 2015. The trendline depicts a flactuating population size relative to the national population.

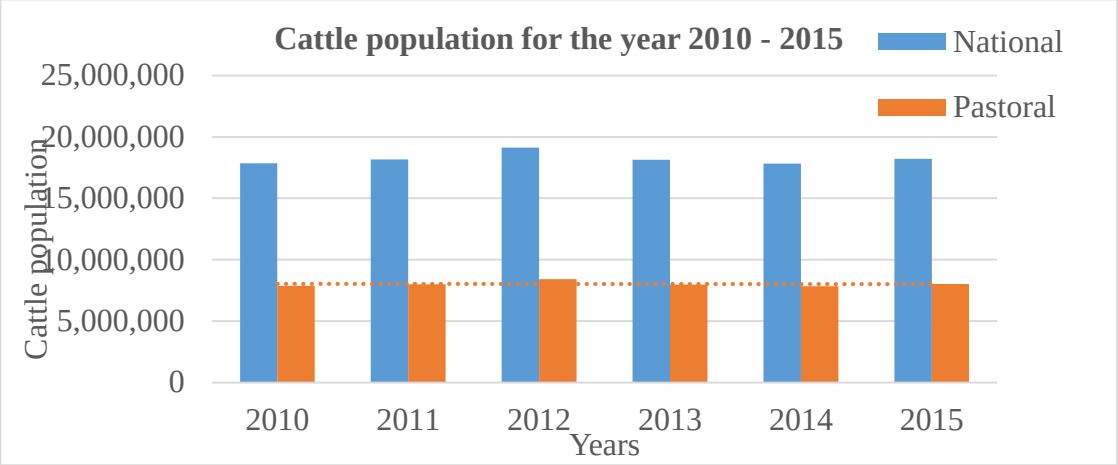


Figure 2.2: National and pastoral cattle population for the year 2010 - 2015
Source: Nyariki and Amwata (2019)

The main cattle breeds kept by most of the pastoral households include the Small East African Zebu, Orma Boran, Sahiwal and the Kenya Boran (Kosgey *et al*., 2011). Preferences have been high for the most adaptable to the pastoral environmental conditions and tolerance to pests and diseases compared to exotic cattle breeds. Of importance was the introduction of Sahiwal dual-purpose breed, which is still being used to improve the local indigenous breeds for improved milk and meat production. Compared to indigenous breeds, Sahiwal cattle breed is highly regarded by pastoralists based on production and fertility traits (Ilatsia *et al.*, 2011; Roessler *et al*., 2010). Furthermore, while introduction of Sahiwal and Boran breeds in pastoral rangelands aimed at increased beef production, exotic breeds especially Ayrshire, Friesian and their crosses were being encouraged for increased milk production in wetter areas with low temperatures and low disease prevalence (Nyariki *et al*., 2009).

2.3 Sahiwal breed characteristics and conservation in Kenya

The Sahiwal, a dual purpose breed has been bred in Kenya since 1939 when it was first introduced for upgrading the indigenous cattle breeds for increased herd productivity and growth performance (Ilatsia *et al.*, 2011; Muhuyi *et al*., 1999). Initially, imported Sahiwal bulls from India and Pakistan and best SEAZ cows selected from the pastoral rangelands were brought together to initiate a breeding program that formed the National Sahiwal Stud (NSS) in Naivasha (Kamiti, 2015). The selected indigenous zebu cows were used as foundation stock in the upgrading and multiplication of Sahiwal cattle through systematic crossing with the imported purebred Sahiwal bulls (Muhuyi *et al*., 1999). The imported Sahiwal bulls were later spread, maintained and used for upgrading indigenous cattle in twelve counties (Mailu *et al*., 2013). These Counties with their corresponding livestock improvement centres include;

Kajiado (Ngong), Kericho (Kabianga), Nandi (Baraton), Kisumu (Maseno), Kakamega (Sang'alo), Elgeyo-Maraket (Cheborорwa), Machakos (Machakos and Katumani), Kirinyaga (Ndomba), Baringo (Chemeron), Kwale (Mariakani), Nakuru (Naivasha) and Nairobi (Marimba).

These centres later became multiple grounds where pastoral herd owners would access superior Sahiwal bulls for further community or individual herd insemination programs. Besides the use of Sahiwal bulls, several doses of extracted Sahiwal semen were also imported from Pakistan to aid in the upgrading process through artificial insemination of the indigenous cows and heifers within the multiplication centres (Kamiti, 2015). The long term upgrading of the selected indigenous breeds (especially the local Zebu and Boran) with the imported Sahiwal bulls and semen resulted in the Kenya Sahiwal cattle breed that has supported improved herd performance at pastoral herd level, income and revenue generation at both county and Country level (Muhuyi *et al*., 1999). The improved performances of the resulting offspring have increased the local demand for Kenya Sahiwal bulls by most pastoralists (Ilatsia *et al*., 2012).

Sahiwal breed carries unique adaptive features making it relatively competitive in terms of milk and meat production; and adaptation under low input production systems. In addition, many pastoralists use Sahiwal sires for crossbreeding with indigenous cattle breed to improve on the growth performance of resultant offspring calves (Ilatsia *et al.*, 2011; Kamiti, 2015). The breed is heavily built with their colour ranging from reddish brown to chestnut, a dark brown colour that is common around the well-developed hump and neck (Muhuyi *et al*., 1999). In males the colour darkens towards the extremities (head, legs and tails), while females maintain the reddish coat colour. Sahiwal's have long ears that are drooping, set behind and are at the level with the eyes. They are generally docile and of low temperament, easily handled, have good milking ability even in the absence of calves and have good mothering ability (Ilatsia *et al.*, 2011; Muhuyi *et al*., 1999). These characteristics enable them to be easily handled in diverse production systems within pastoral rangelands.

Conservation of Sahiwal genetic resources has been undertaken through both *in-situ* and *ex-situ* strategies. In Kenya, *in-situ* conservation units involve the government and privately owned nucleus herds that produce breeding animals for the pastoral herds (Muhuyi, 1997). The National Sahiwal Stud (NSS) in Naivasha and other privately owned commercial ranches have owned the pure Sahiwal cattle breed and its crosses for subsequent cross breeding with other cattle breeds. Three categories of Sahiwal are recognised by the Sahiwal Cattle Breeders Society (SCBS) of Kenya. These include the foundation stock (these have seventh-eighths Sahiwal ancestry and inspected); purebreds- those that have passed inspection, weight-

for age evaluations and are minimally the progeny of registered animals above foundation stock; and pedigree Sahiwal that are minimally the progeny of registered animals above foundation stock (Kamiti, 2015). These three categories mainly dominate the various Sahiwal populations in the country. Besides the enclosed conservation units, pastoral herds largely of Maasai communities especially within the rangelands have also provided conservation options for continued access and preservation of Sahiwal cattle breed (Ilatsia *et al.*, 2011).

2.4 Distribution and multiplication of Sahiwal cattle breed in Kenya

Ever since its introduction in Kenya, Sahiwal cattle breed have been widely distributed amongst the pastoral rangelands due to its improved performances and disease tolerance relative to the indigenous cattle breed (Ilatsia *et al.*, 2011). The initial multiplication and dissemination of breeding materials was undertaken through sale of live breeding stock from NSS in Naivasha and use of artificial insemination semen from KAGRC in Nairobi (Mailu *et al*., 2013). These have further aided in increased access of Sahiwal cattle within rangelands for subsequent distribution to rural communities and pastoralists where Sahiwal cattle have provided most livelihood sources. Seven (7) counties in Kenya act as main Sahiwal rearing and distribution sites comprising of government and commercial ranches and model farms as well as pastoral area (Figure 2.3).

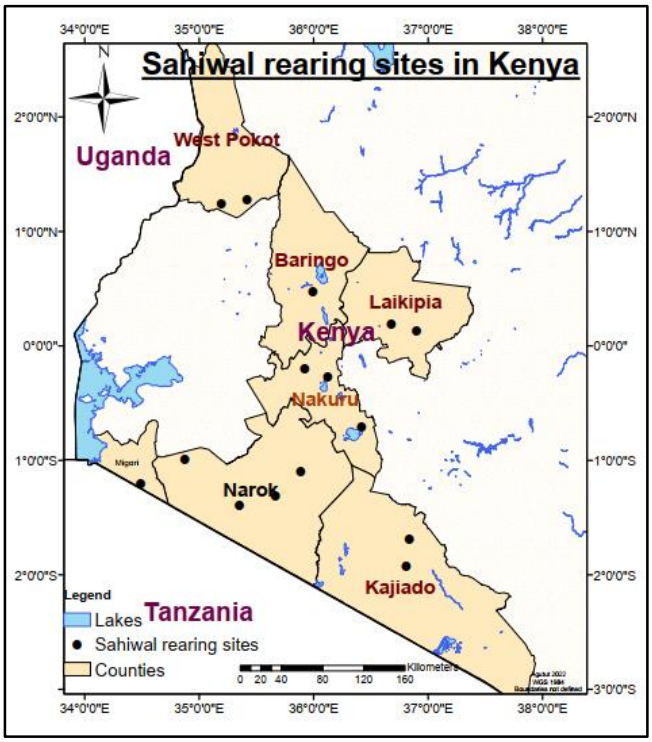


Figure 2.3: Sahiwal rearing sites and counties in Kenya

Source: Kamiti (2015)

These counties include Kajiado, Narok, Migori, Nakuru, Laikipia, Baringo and West Pokot, house several commercial ranches that deal with continuous multiplication of Sahiwal cattle breed to be used in other pastoral areas on demand basis. Table 2.1 presents an overview of the various counties, name of commercial ranches and estimated number of herd sizes.

Table 2.1: Major commercial ranches and Sahiwal herd sizes in Kenya

No.	County	Sub County	Name	Herd Size
1	Nakuru	Naivasha	National Sahiwal Stud	1,224
2	Laikipia	Laikipia	Elkarama ranch	900
3	Narok	Trans Mara West	Keiyan farm	450
4	Narok	Narok South	Ilikerin Loita	433
5	Kajiado	Kajiado North	Oloodo farm	333
6	Narok	Trans Mara West	Tunai farm	314
7	Narok	Trans Mara West	Ole sentu farm	306
8	Laikipia	Laikipia East	Ole Naishu/ Kamwaki	238
9	Kajiado	Kajiado Central	Olekejuado County Council (OCC)	195
10	Nakuru	Rongai	Dolerraine estates	180
11	Baringo	Baringo Central	KALRO Perkera	90
12	Narok	Trans Mara West	KALRO- Trans Mara	60
13	Nakuru	Nakuru East	KALRO- Lanet	58
14	Narok	Narok East	Narok PTC	58
15	Narok	Narok East	Olentutu farm	28

Source: Kamiti (2015)

Currently, research organizations such as Kenya Agricultural and Livestock Research Organizations (KALRO) are widely distributing Sahiwal semen for easy access and utilization of Sahiwal cattle genetic resources for improved herd productivity within the pastoral rangelands. Research centres in Naivasha, Lanet and Kiboko are capable of providing one hundred and eighty (180) bulls to pastoralist throughout the year, which are highly regarded by pastoral herd owners for bull inseminations (Gamba 2006). Despite these provision by the research centres, a higher and rising demand for superior Sahiwal bulls by most herd owners within the pastoral rangelands still exists.

To counteract the deficit, several commercial ranches and private farms have complemented the supply of Sahiwal breeding stock to the pastoral herd owners. Previous arrangements between government research centres and private farms incorporated in open

nucleus breeding programs have increased the capacity to supply the desired superior Sahiwal breeding stock to pastoral herd owners. The major breeding ranches in Kenya included El Karama ranch, Kilifi plantations, Cerdavale, Deloraine and Illkerin project, all of which sourced their foundation stock from NSS (Mailu *et al*., 2013).

Multiplication of Kenyan Sahiwal cattle breed has been achieved using two different breeding methods in Sahiwal breeding programs. These include pure breeding lines and cross breeding lines. Pure breeding (selection within breeds), is a breeding procedure that is done specifically to maintain certain traits or characteristics of interest. This breeding procedure practised in most established national research stations and commercial large ranches has aided in maintaining pure Sahiwal breed lines (Kamiti, 2015). However, care should be undertaken while practising pure breeding procedures in Sahiwal breeding programs so as to avoid inbreeding caused by mating animals with common lineage. Inbreeding depression has negative effect in cattle herd as it results to lower production performance relative to the parents (Mekonnen *et al*., 2020). This can be minimized by undertaking proper record keeping of all the breeding cows and bulls as well as their resulting offspring calves in breeding programs.

Besides pure breeding, crossbreeding has also been widely utilized in rapid dissemination of Sahiwal genetic resources within pastoral herd. This breeding procedure entails mating two or more unrelated cattle breeds with an objective of ensuring improved performance of the resultant offspring (Kamiti, 2015). Crossbreeding is often important in livestock production as it partly combines breed differences to make use of heterosis (hybrid vigour) to improve production and overall herd performances (Mekonnen *et al*., 2020). Within the pastoral rangelands, crossbreeding has been widely practiced to combine superior heat tolerance, disease resistance and environmental adaptability of local indigenous cattle breeds with superior milk yield, faster growth rates and early maturity of Sahiwal breed (Ilatsia *et al.*, 2011). The resultant offspring calves have recorded better performance (hybrid vigour) relative to their original parents. Crossbreeding contributes to higher livestock gross margins in the intensive areas as in the case of commercial ranches and model farms (Samdup *et al*., 2010). However, care should be undertaken to avoid indiscriminate crossbreeding during breeding programs that could lead to loss of genetic diversity among Sahiwal population (Kamiti, 2015).

2.5 Pastoral Production systems supporting Sahiwal cattle farming

In Kenya, pastoralists and ranchers mostly raise Sahiwal cattle genetic resources under optimal and low-input production systems in most pastoral rangelands (Ilatsia *et al.*, 2011). This mostly aims at achieving the high potential production (meat and milk) exhibited by

Sahiwal cattle relative to other indigenous cattle. The functions of Sahiwal cattle within these production systems relates to family subsistence and revenue generation through sale of surplus milk and live animals. Based on this relation, the systems supporting Sahiwal cattle farming can be classified under large and small-scale dairy-meat production systems (Kamiti, 2015).

2.5.1 Large scale dairy-meat production systems

This system occurs mostly in marginal areas and pastoral rangelands with vast land areas and includes the commercial large-scale ranching, pastoral ranching and intensive feedlot systems (Kahi *et al*., 2006). Ranching involves an enclosed extensive livestock production system which are either commercially oriented or community based (group ranches) and mostly characterised by large herd sizes (Muhuyi *et al*., 1999). In addition, ranching comprise labour-extensive enterprise that specializes in one or more livestock species produced mainly for slaughter (for meat, skins and hides), wool and milk; and generally commercialized with generation of cash income as the primary function of the livestock raised on them (Otte & Chilonda, 2002).

Commercial large-scale ranching has played a major role in the production of Sahiwal cattle and products destined for either local consumption or for international market. This constitutes the government and other commercial ranches where they use Sahiwal cattle for breeding and multiplication purposes. Ranches safeguards community land and promotes sustainable use of pasture and water as well as multiple resource use involving livestock-wildlife interactions (MoALF&I, 2019). Furthermore, they have supported growth and sale of pure and crossbred Sahiwal genetic resources intended for either breeding or sale for income. This has been achieved through improved herd, pasture and water management, adequate provision of animal feeds, water, minerals and disease control measures throughout the year. Besides this, exhibit proper record keeping, herding patterns closely adapted to the needs of different animal groups and higher intensification levels through more use of external inputs (labour, purchased feed, inputs for animal health) (Otte & Chilonda, 2002).

Based on livelihood pathways, Sahiwal cattle products from commercial ranches have targeted high-end markets where they fetch high economic returns from either live or product sales (Lind *et al*., 2020; Otieno *et al*., 2012). This has been made possible through the commercialized nature of operation, higher intensification and good resource access thereby enabling them to move up into high commercialization, undertake regional and export livestock trade and other high return economic activities (Figure 2.4).

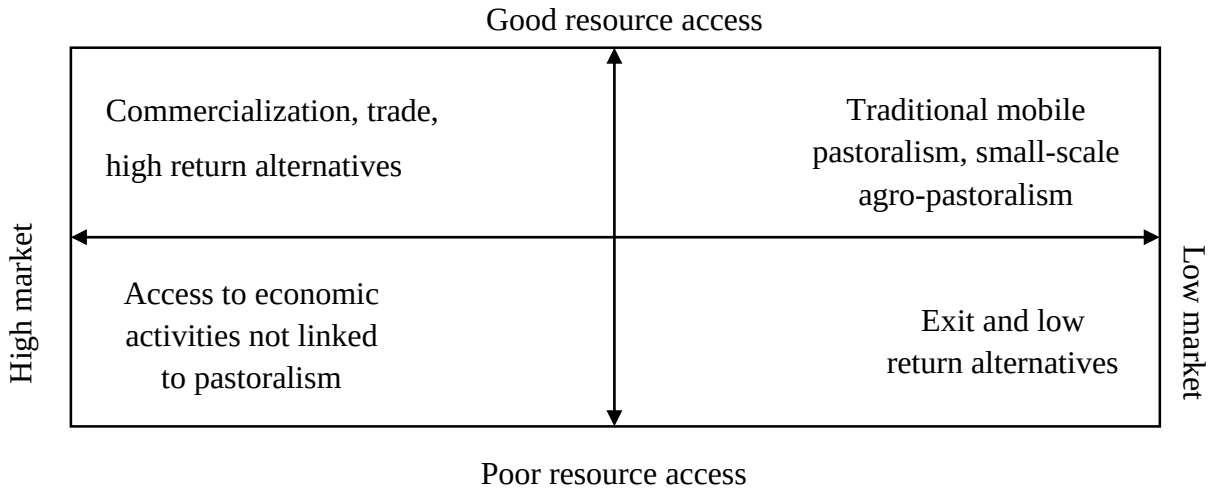


Figure 2.4: Livelihood pathways in pastoral rangelands

Source: Lind *et al*. (2020)

Controlled grazing within ranches are usually characterized by animals accessing natural and improved pastures through paddocks or strip grazing and supplemented with high quality fodder, mineral licks and commercial concentrates (FAO, 2018b). Within the ranches, water troughs are provide in strategic points for ease of reach by the cattle during and after pasture grazing. Ranches are purely commercial livestock enterprises with targeted market niches but may also grow a few crops for use as on-farm fodder or for sale (Otieno *et al*., 2012).

Within Narok County, Maasai communities still practice group ranches where members are allowed to graze animals without restrictions and this offers security of feed and water resources to the livestock in both dry and wet seasons for continued production throughout the year (Khainga, 2015). Despite the productive capabilities of ranches, group ranches in Kenya are decreasing in number and constrained by continuous land division and competition from other agricultural enterprises (MoALF&I, 2019). This has adversely affected the overall productivity of these ranches in terms of both milk and/ or meat production for commercial purposes.

Sahiwal bulls within established ranches have been selected for beef production and cows or heifers used in cross-breeding programs targeting other pastoralists (Rege *et al*., 1992). The ranches provide sources of young or mature culled Sahiwal breeding bulls and cows from where several nomads and agro-pastoralist access through purchases for breeding purposes. Sahiwal herd reared within these ranches and Government research farms, collectively form the nucleus herds and are further selected for breeding to improve the overall herd performances (Ilatsia *et al.*, 2011).

2.5.2 Small scale dairy- beef production system

These are mainly undertaken within pastoral rangelands where land size constrains the access of feed and water for optimal herd productivity. Most pastoral herd owners with small herd sizes, undertake Sahiwal cattle farming through strategic mobility in search of key resources such as pastures, nutrients and water for livestock (MoALF&I, 2019). The performances of these Sahiwal cattle are generally low compared to those from commercial ranches due constraints related to access to optimal farm input such feed, water and minerals. These constraints force them to lose more energy in search of feed and water thereby affecting their overall productivity. This system can further be divided into pastoralism and agro-pastoralism.

Pastoralism is a land use form involving adaptation to marginal environments characterized by climate uncertainty, low grade resources and continuous strategic mobility in search of key resources such as pastures, nutrients and water for livestock (Hatfield *et al.*, 2006: MoALF&I, 2019). Pastoral systems are further characterized by uncontrolled grazing in marginal and communal grazing lands; and often bull services that compromise the main breeding source (Mwacharo & Rege, 2002). Nomadic pastoralism is relatively unproductive and this could be attributed to the low level of management interventions offered to the animals during movements in search of pasture and water (Khainga, 2015). With average herd sizes of 50 cattle per household, the main breeds kept by most of these pastoralists for dairy and beef production include the Small East African Zebu, Borana, Orma, Sahiwal and the Kenya Boran (Kosgey *et al.*, 2011: Mbae *et al.*, 2020). Preferences are for the high adaptability towards the pastoral environmental conditions and high pest and disease tolerance as compared to other taurine cattle breeds.

Pastoralism is based mostly entirely on livestock production with little or no integration with crops and characterised by high animal mobility (Kimaro & Chibinga, 2013). Nomadic pastoralism within rangelands is being constrained by changes in land use systems leading to land sub-divisions and demarcations. The continuous sub-divisions of Maasai grazing areas from initial communally owned land has led to formation of group ranches and further sub-divisions to parcels owned by individuals (Boone *et al*., 2006). This has resulted in increased household settlement and loss of cattle herd mobility, land degradation and lower productivity for livestock rearing in these pastoral rangelands (Lind *et al*., 2020). In addition, subdivision has resulted in inadequate access of feeds and water resources to the pastoral herd due to the limited land sizes.

Besides these, uncontrolled grazing features characterised within these systems face the challenge of dwindling communal grazing fields as a result of increasing human settlement and development (FAO, 2018b). Traditionally, pastoralist designated grazing sites that were close to homestead as a coping strategy to counteract effects of feed shortages. This was achieved through herd splitting into core and satellite herd with the core comprising the breeding stock, young animals and old ones allowed to graze close to homestead. The satellite herd comprising the males and dry females were trekked into the emergency grazing sites away from the homesteads (Kibiro, 2007).

Agro-pastoralism entails the integration of crops and livestock in a complementary manner such that livestock benefits from feed source from plants while crops attain right nutrients and manure from animals' wastes. A large number of pastoralists within the pastoral environments, practice agro-pastoralism as ways of counteracting harsh environmental conditions as well as feed scarcity. Nomadic pastoralism is currently declining due to increase in population hence many pastoralists have adopted sedentary lifestyles and practicing agro-pastoralism for continued livestock production (Khainga, 2015).

2.6 Breeding programs while utilizing Sahiwal genetic resources

Breeding programs usually provide a means of improving the productivity of livestock and achieving genetic gains. In pastoral rangelands, well-designed breeding programs including natural mating through bull services (Awulachew, 2021) and ARTs, are necessary in achieving both long and short-term goals.

2.6.1 Natural mating

Within pastoral rangelands, herd owners have been using Sahiwal bulls from either National Sahiwal Stud, ranches or model farms for breeding with the indigenous cows for upgrading purposes (Ilatsia *et al.*, 2011). Within these rangelands, breeding bulls are allowed to roam within the female herds thereby mating with any female that show estrus signs. This has advantage, as the bulls are able to detect cows and heifers experiencing silent heat that do not present observable signs.

Cross breeding using Sahiwal bulls and local indigenous cows and heifers have been used to improve the cattle genotypes for higher genetic potentials in terms of both productive and reproductive performances. Over the years, this has been achieved through use of either superior community or individual Sahiwal bulls within pastoral herds in planned breeding programs within the rangelands (Khainga, 2015). Though community bulls provide cheap source of breeding service and social prestige amongst other cultural practices within Maasai

community, they also pose risks of uncontrolled mating, disease transmissions and injuries especially to young heifers during mating.

Plate 2.1 presents an illustration of Sahiwal bull and cows used within the pastoral rangelands for breeding purposes.

Plate 2.1: Illustration of a Sahiwal bull and cows used for breeding purposes within pastoral rangelands

2.7 Use of Assisted Reproductive Technologies (ART's)

Dairy intensification have led to drastic transformation towards utilization of reproductive technologies to increase productivity and herd genetic improvement (Ojango *et al*., 2016). Within pastoral areas, pooled efforts are being made by organizations such as KALRO, ILRI, Heifer Project International (HPI) and Kenya Livestock Breeders Association (KLBO) to disseminate high quality cattle breeds through existing technologies amongst cattle farmers, as ways of improving on the genetic merit of the low producing local breeds (Khainga, 2015; Mwai *et al*., 2020). Assisted Reproductive Technologies (ART's) play important breeding service role in genetic improvement programs aimed at increasing production and reproduction levels within dairy herds (Kebebe *et al*., 2017).

The use of ARTs being encouraged by development partners have the capability of; minimizing the risks of disease transmission and/ or injuries to young heifer, bringing about rapid genetic improvement and increasing conception rates especially in the pastoral herd (Saha *et al*., 2014). Though constrained by low awareness and adoption levels, these technologies

provide an avenue for increased access to superior Sahiwal semen for breeding purposes in the pastoral systems. Assisted Reproductive technologies are not only limited to increasing productivity, they also have the potential to shorten generation intervals, increase selection intensities (Gicheha *et al*., 2018) and identify quality sires for both fertility and milk yield for desired offspring (Khainga, 2015).

Assisted Reproductive technologies (ARTs) currently being used in dairy production systems include as AI, Multiple Ovulation and Embryo Transfer (MOET), estrus synchronization (ES), semen sexing, in vitro production of sexed embryos and their combinations (Lardner *et al.*, 2020; Mutembei *et al.*, 2015). These technologies provide an alternative to using bull services in various dairy production systems in Kenya. Despite the numerous attributes attached to the use of these reproductive technologies, their knowledge, dissemination, adoption and use especially in pastoral rangelands where indigenous cattle are predominant have remained low (Khainga, 2015; Kosgey *et al*., 2011; Lardner *et al.*, 2020). Arguably, low accessibility, high costs implications, infrastructural challenges involved for efficient service delivery attributes to this. Furthermore poor infrastructure especially bad roads have limited continuous access of these services to the most vast pastoral rural areas (Muia *et al*., 2011). This has opted for the continuous use of bull services that has a higher preference in pastoral rangelands for reproduction purposes (Gamba, 2006).

2.7.1 Estrus Synchronization

Synchronization of estrus (heat) is a reproductive management tool that involves artificial manipulation of the estrus cycle of dairy cows or heifers, so that they are inseminated at approximately the same time. Over the last years, hormonal manipulation of estrus cycle has been frequently used in dairy herds to improve AI submission rate, decrease intervals between AI, reduce days open, and improve overall reproductive performance (Bruno *et al*., 2013). This has led to improved herd performances and overall profitability of both smallholder and large scale dairy farms.

Synchronization involves hormonal injections using gonadotropin-releasing hormone and Prostaglandin F2α (GnRH and PGF2α) at specific times to induce estrus and contributes towards optimizing the use of time, labour, and financial resources by shortening the calving season, increasing calf uniformity and enhancing the possibilities of utilizing AI (Gebremichael, 2015). Furthermore, synchronization based on initiation of GnRH result in the release of Luteinizing Hormone (LH) and ovulation of the dominant follicle. Synchronization of ovulation can be achieved through administration of intra muscular injections of GnRH,

followed by PGF2α injection 7 days later and a second GnRH 2 days later resulting in ovulation approximately 30 hours later and allowing for timed AI 12 to 16 hours after second GnRH infection (Dewey *et al.*, 2010). The author further stated that the cows treated with GnRH between day 5 and day 9 of the estrus cycle, more likely ovulated, formed a new corpus luteum (CL), and developed a new follicular wave resulting in synchronized ovulation of a newly formed dominant follicle at the end of the synchronization protocol. Within pastoral herd, estrus synchronization induces a group of cows or heifers to come on heat at the same time for fixed insemination procedures.

Reproductive Tract Scoring (RTS) prior to insemination

Increased efficiency of dairy herd mostly depend on reproductive success in most cattle production systems (Binelli *et al.*, 2021). Replacement heifers' success will further depend on their maturity (how close they are at reaching puberty) and this can be measured by a method called "Reproductive Tract Score" or RTS (Anderson *et al.*, 1991). The RTS is an evaluation method that estimates the stage of development of the reproductive tract of a heifer (ovaries and uterus). When undertaken prior to the beginning of the breeding season, RTS is associated with heifers' reproductive performance measured at the end of the breeding season and involves rectal palpation of the reproductive tract and scoring the ovarian structures on a scale of 1 to 5 (Holm *et al.*, 2009).

Reproductive Tract Scoring is correlated with Age at Puberty (AP), response to synchronization, and pregnancy rate to synchronized estrus, and has an estimated heritability of 0.32 (Anderson *et al.*, 1991). Prior to breeding programs, it gives an overview of the ovarian structures to guide on subsequent hormonal injections and inseminations. The RTS evaluation needs to be undertaken by a trained specialist via rectal palpation of the reproductive tract followed by trans rectal examination of the ovaries by B-mode ultrasonography (Binelli *et al.*, 2021). The authors further mentioned that the method involves a series of steps comprising estimation of the diameter and tone of the uterine horns, identification and measurement of the diameter of the main ovarian structures and integration of measurements using specific criteria, and that yields an RTS ranging from 1 to 5 (Table 2.2).

Table 2.2: Reproductive tract score (RTS) system

RTS	Uterine horns (diameter, mm)	Ovarian (mm)			Ovarian structures
		Length	Height	Width	
1	Immature, < 20 mm, no tone	15	10	8	No palpable follicles
2	20-25 mm, no tone	18	12	10	8 mm follicles
3	20-25 mm slight tone	22	15	10	8-10 mm follicles
4	30 mm good tone	30	16	12	> 10 mm follicles, CL possible
5	> 30 mm, good tone, erect	> 32	20	15	CL present

Source: Anderson *et al.* (1991)

Ten (10) day synchronization and fixed time AI program for Sahiwal breeding program was recommended for use within pastoral rangelands. The detailed procedures as presented in Table 2.3 provide an overview of the specific daily activities to undertake within the 10-day program.

Table 2.3: Estrus synchronization and fixed artificial insemination procedures

Day	What to do
0	• Selection of individual cows or heifers for synchronization • Perform pregnancy diagnosis (PD) and disqualify pregnant cows or heifers • Provide 1st injection involving 1ml of GnRH, tag injected cows or heifers for identification and separate from any available bull
7	• Perform second PD and disqualify any pregnant cow or heifer injected at Day 0 • To non-pregnant cows and heifers, inject 2 ml of PGF2α at about same time
9	• For each previously injected and non-pregnant cows or heifers, inject 1 ml of GnRH at around same time as Day 7
10	Inseminate each non-pregnant cow or heifer within 8 to 18 hours after day 9 injection

On the contrary, cows that fail to ovulate to the first GnRH injection indicate that the follicle induced to ovulate at the end of the synchronization protocol may have undergone prolonged dominance thereby leading to the ovulation of an older oocyte and consequently reduced embryo quality (Cerri *et al*., 2009; Dewey *et al*., 2010). There is improvement of herd fertility including heat manifestation by implementing a synchronization or resynchronization protocol that involves a series of hormonal injections (Bruno *et al*., 2013). Positive responses are achieved when selected cows and heifers are on average or above body conditions scores (at least 5 on an average of 1-9) and replacement heifers attain a pre breeding target weight

representing 65 percent of the projected mature weight (Patterson *et al*., 2005). Furthermore, adequate time has elapsed from calving to the time synchronization treatments are implemented (a minimum of 40 days postpartum at the beginning of treatment is suggested) and cows experience minimal calving problems.

2.7.2 Artificial Insemination (AI)

Artificial Insemination (AI) is a reproductive management tool for genetic improvement in farm animals (Khan *et al*., 2007). It involves the process by which sperm is collected from a healthy and proven bull, and artificially introduced into the female reproductive system for the purposes of conception (Gillespie *et al*., 2014). This reproductive technology has been used for upgrading local breeds at small and large scale farm levels; and has accelerated uptake of dairying by smallholder farmers in most parts of the world (FAO, 2011). Within developing countries, AI is the most adopted and widely utilized reproductive technology by small, medium and large scale dairy farmers because it introduces and disseminates desired characteristics in dairy populations (MoLD, 2010; Ojango *et al*., 2016).

Artificial Insemination undertaken in fixed time presents a simple reproductive technology that is cost effective and offers best option for improving the genetic merit of cattle herds (Mwai *et al*., 2020). As the name suggests, the time for insemination is predetermined, thereby removing the need of observing heat signs within the herd. In their study, Lardner *et al.* (2020) indicated that TAI programs can be favourable to beef producers as they reduce time and labor required for estrus detection and allow for integration of superior genetics within the herd.

In pastoral rangelands, where observation of heat signs could be limiting due to harsh environmental conditions, TAI program offers an opportunity for improving the overall reproductive performance of the herd through timely inseminations for increased conception and pregnancy rates. Furthermore, pastoral herd owners can be able to choose semen from proven sires to transmit desirable traits to the next generation for improved performances. This has been achieved through use of frozen thawed semen from high performing sires in national research stations and model farms in Kenya.

Within cattle breeding programs, TAI provides avenues where semen from one bull can be able to serve several cows and heifers (Ojango *et al*., 2016). This therefore aids in distributing desirable characteristics to a wider population within an area. Furthermore, tested and proven bull semen used in insemination, limits the possibilities of transferring reproductive diseases to the cows or heifers and injury to young cows and heifers as often witnessed during

bull mating. With proper confinement and AI record use, pastoralist are able to control inbreeding within their pastoral herd.

Advantages and disadvantages of OvSynch and artificial insemination (AI) in breeding programs

Combined use of OvSynch and fixed time AI helps breeding programs in improving on mating and calving time to correspond with ideal economic and environmental conditions. This enables the herd owner to adequately plan on the breeding calendar and programs to achieve optimal reproductive performance from a dairy herd. Moreover, OvSynch and timed AI assists in planning to enable offspring calves to be born during favourable environmental conditions when feed and water are in plenty to ensure higher survival rates within the pastoral herd. This limits the high calf mortality and morbidity rates that could be caused by heat stress and feed scarcity. Through OvSynch and timed AI, several calves can be born at a specific time hence making them to be uniform in terms of age thus easy to manage and select (Johnson & Jones, 2002).

In addition, the combined use of OvSynch and timed AI provides a good avenue for cows experiencing silent heat and other fertility challenges since insemination undertakes a fixed time. The associated hormonal injections, improve on heat manifestation and saves time and labor required for constant heat observation and monitoring. These injections followed by timed AI are capable of improving conception and prenancy rates of the cows or heifers as insemination is done within the recommended time after heat manifestation (Mwai *et al*., 2020). Moreover, the combined use of OvSynch and AI have notable advantages which includes; shortened calving season, increased calf uniformity, earlier births during the calving season, enhanced pre-weaning growth and heavier calves at weaning (Johnson & Jones, 2002). The authors further reported that, calves initially born through OvSynch and AI use, were 10 days older and gained an extra 9.1 kg relative to the other calves.

Despite the associated attributes of OvSynch and AI in the pastoral rangelands, their adoption are constrained several factors of which low awareness levels, inadequate access, low service delivery, poor infrastructure that limit access, high costs of technical labour and skills are most striking (Muia *et al*., 2011). Low adoption levels have previously been attributed to the low exposure and awareness on the availability and use of OvSynch and timed AI (Khainga, 2015). Furthermore, accessibility challenges especially to the remote areas of the pastoral rangelands have been contributed by the poor infrastructure including bad and inaccessible road networks that has in turn increased the overall production costs of accessing the services.

These factors limit adoption and use of ES and AI which are ideal especially in most pastoral rangelands that are characterised by unfavourable environmental conditions such as heat stress.

Constraints limiting the use OvSynch and AI in pastoral breeding programs

OvSynch and AI use are is constrained by high cost implications that tend to limit its use especially in smallholder farmers in pastoral rangelands (Khainga, 2015). Additional costs experienced along the supply chain (from the producers to the distributors, technicians and finally to the farmers), force the ultimate farmers to pay more to access AI semen and services. The high cost of AI semen and services have forced many pastoralists to opt for the continuous use of bull services that has a higher preference for insemination especially in most pastoral systems (Gamba, 2006). This is further accelerated by the strong cultural attachment towards having a bull especially by the Maasai community who predominates most pastoral rangelands (Ojango *et al*., 2016). Besides these, poor heat detection, inefficiencies of AI technicians and AI centres not equipped with appropriate inputs have led to poor conception rates from AI use.

Artificial insemination is not a convenient method for cows or heifers that experience silent heat as heat detection is key in ensuring correct insemination timing. Poor heat detection and improper timing of insemination and embryonic death have often been associated with low conception rates and repeat breeding which is expensive in cattle breeding programs. Furthermore, there is risk of introducing disease-causing agents into the uterus of the cow or heifer by the inseminator especially under un-hygienic conditions. The use of AI especially among pastoral herd owners have been further limited by infrastructural constraints, low reliance on the technique and the communities' preference to bull service (Gamba, 2006; Janssen-tapken *et al*., 2006; Khainga, 2015).

The inaccessibility of semen and service delivery have made AI unreliable especially in pastoral rangelands. Furthermore, a previous study by Kios *et al*. (2018) indicated that most smallholder farmers in Kenya use bulls or haphazardly apply AI thereby leading to inferior heifer off springs of low quality that cannot be used for milk production. This therefore means that combined use of OvSynch and AI requires adequate record keeping and monitoring mechanisms to minimize genetic loss within pastoral herd.

In addition, continuous use of OvSynch and AI is constrained by inadequate recording scheme, wrong selection of procedures and inadequate management of insemination bulls leading to poor performance and low conception rates.

2.7.3 Multiple ovulation embryo transfer (MOET)

Multiple ovulation embryo transfer (MOET) is a reproductive technology carried mostly in cattle and involves harvesting fertilized eggs from a female cow and transferring them in multiple genetically unrelated surrogate recipients (Faizah *et al*., 2018). This technology is preferred in cows with superior genotypes to produce breeding heifers at an accelerated rate to ensure the dairy farmers achieve optimal benefits. The number of off springs from superior cows can be increased by MOET compared to natural reproduction (Kios *et al*., 2018). This technology exploits the reproductive potential of cows that can produce up to 30 embryos if flushed every two months as compared to the normal production of one calf per year.

The donor cows are injected with reproductive hormones to enable them produce more eggs (super-ovulate), then artificially inseminated and embryos harvested before transferring to recipient cows for implantation and pregnancy. The recipient hormones are also treated with hormones to prime them up and make them ready to receive embryos from the donor cows (Kios *et al*., 2018). The technology has several advantages which include; increased reproduction rates of individual or groups of cows, receiving more number of off-springs calves from superior cows, increasing percentage of genetic improvement in the herd, treatment for infertile females and minimizing disease transmission from cow to calf (Faizah *et al*., 2018). Furthermore, embryos harvested from MOET application, can be stored fresh or frozen in laboratories for future use.

Despite the positive attributes associated to MOET, its adoption especially in pastoral rangelands remains low due to cost implications, accessibility and preference for bull service use by pastoralists (Khainga, 2015), that lead to production of inferior heifers which compromise production levels in the long run. Besides this, its application requires technical expertise that could be limiting in many pastoral areas. Furthermore, MOET technology have also been associated with complicated births especially when several embryos are transferred to a recipient cow or all fertilized eggs are not harvested from the donor cow (Kios *et al*., 2018).

2.7.4 In-vitro embryo production (IVEP)

In-vitro embryo production (IVEP) is a reproductive technology that involves harvesting of unfertilized eggs directly from the cow and fertilizing them in an incubator that has controlled temperatures, environment and media to mimic the host animal's uterus. The technology allows for cheaper production of predictable supply of embryos from ovaries of either live or slaughtered cows (Mutembei *et al*., 2015). It further results in sustainable

utilization of indigenous breeds as oocyte donors and surrogate mothers as well as continuous production and access to productive and adapted F_1 crossbred heifers (Lawrence *et al*., 2015). The successful use of IVEP in Boran cows has increased the supply of lower price heifers in low input systems in Kenya as in the case of Kapiti ranch in Kenya (Mutembei *et al.*, 2015).

2.8 Conception Rates in cattle herd following OvSynch and Artificial Insemination (AI)

Several intrinsic and extrinsic factors have deleterious effect on conception hence influencing the outcome of AI (Jemal & Lemma, 2015). Intrinsic factors are factors that arise from within the animals' body while extrinsic factors are factors arising outside the animal body that affects the overall conception rate. Conception success rate is the measure of cow's fertility at service and it indicates the number of animals' conceiving as a percent of number served. Within dairy farms, low conception rates have been attributed to the two major factors and they include management failures, nutritional status, postpartum reproductive health, semen quality hence reducing efficiency of AI services. Conception rates determines the overall profitability of the farm and is directly associated with the production attributes responsible for monitoring life time productivity of individual animals (Potdar *et al*., 2016).

2.8.1 Intrinsic Factors Affecting Conception Success

These include factors arising within the animals' body that have direct influence of the conception rates post insemination. Amongst identified intrinsic factors, breed, age and parity of the cow have significant contributions on conception success rates of dairy cows (Howlader *et al.,* 2019). In breed comparison, pure breeds had higher conception rates than cross breeds. The author further reported that younger cows had higher conception rates relative to older cows. This is justified by the increased CR from the pubertal age to 6 years and then gradual reduction with subsequent increase of age. Higher conception rates were also recorded in cows that had lower parity number up to parity 4 and then decreased gradually with subsequent parities. Similar results of higher conception rates within heifers than in other parity and which then decreased to last parity was also reported by Potdar *et al.* (2016) in their study on local and crossbred cows in India. Furthermore, health status of the animals at insemination time also has direct influence on the conception rates with healthier animals having higher conception rates as compared to sick animals.

2.8.2 Extrinsic Factors Affecting Conception Success Rates

These factors originate from outside the cows' body and have direct influence on the conception success rates post insemination. Most of these factors are either environmental

(season, time, nutrition, welfare), human (inseminator) or semen (sire quality) related and have significant contribution towards conception success rates in cows. Season directly affect conception rates with cool and rainy seasons having higher conception rates as compared to hot and dry seasons (Potdar *et al.*, 2016). Furthermore, changes in nutrition, environmental temperature, climate and photoperiod are environmental factors affecting the overall wellbeing and comfort of cows. In extreme cases, these factors will affect the overall reproduction potential of dairy cows leading to low conception and pregnancy rates.

Inseminators handling of semen can lead to conception success or failures within inseminated cows. Unnecessary handling (especially during semen thawing), poor timing and/ or over exposure of semen straws to direct sunlight tends to minimise the viability of semen hence ultimate low conception rates. Technique and site of semen deposition by inseminators, especially deposition within the uterine horn tend to give higher conception rates as opposed to deposition in the uterine body (Jemal & Lemma, 2015). Furthermore, cows showing true heat signs should be inseminated using frozen semen thawed at 37^0C for 30 seconds.

The quality of semen used for insemination has great influence on the conception rates and critical to a successful pregnancy in cows (Jemal & Lemma, 2015). Poor quality semen involving dead, deformed or low sperm motility reduces the rates of conception when used for insemination. Besides semen quality, significant differences have also been reported on various breeds of cattle to have significant effect on conception rates (Potdar *et al.*, 2016). For instance, the authors further reported exotic breeds to be having a higher conception rate relative to tropical breeds.

2.8.3 Semen sexing technology use in breeding programs

The desire to provide the most efficient cattle production has raised the demand for predetermination of sex in livestock offspring across livestock production systems (Chongsi *et al*., 2019). Application of sex pre-selection is widely used in cattle herds to achieve short and long-term goals thereby maintaining economic viability in the production systems. In their previous study, stated Semen sexing is a proven technology that is cost effective and could achieve 70 to 85% in identifying X-chromosome carrying spermatozoa (Ayalew & Dekeba, 2006). For instance, in beef cattle, there is the desire to have more male calves for lean meat production for sale as compared to dairy farming that desire more female calves for continuous milk production. Besides semen sexing, sexing agents are also products that are added to conventional bull semen (fresh or frozen) to obtain a particular sex ratio. Semen sexing have widely been used in both human and animals, for instance in genetic improvement of farm

animals, control of sex-linked disease in humans and repopulation of endangered species in wildlife (Maxwell *et al*., 2004).

The combination of sexing technologies and use of assisted reproductive technologies in dairy cattle, have resulted in the birth of desired offspring calves thereby meeting the immediate and long term production objectives. The only accurate way for achieving sex pre-selection especially in cattle production systems involve separating the X-chromosome and the Y-chromosome bearing sperm followed by its use in AI (Chongsi *et al*., 2019; Maxwell *et al*., 2004). Currently, the use of various sexing kits in combination with AI procedures is widely applied in cattle production to achieve a particular sex ratio. These commercially sperm sexing agents include Heifer plus (HH+) and Bull plus (BB+), that target heifer and bull calves respectively.

Mode of operation in sexing technologies

The sexing technology operates through separation of X and Y chromosome bearing spermatozoa before fertilization and inseminating the females with the desired semen portion (Turk *et al*., 2015). In cattle breeding programs, the use of Heifer plus (HH+) stimulates the sperm mortality of X chromosome bearing female while slowing the Y-chromosome bearing male thereby enabling fertilization by the female sperm before male to produce a heifer (Chongsi *et al*., 2019). The contrary occurs when Bull plus (BB+) is used where the sperm mortality of Y chromosome bearing male is stimulated while slowing the Y-chromosome bearing females hence a bull calve. For utilization within the pastoral rangelands, the semen sexing agents can either be mixed with conventional bull semen prior to insemination or pre-mixed in the laboratory with freshly collected semen before freezing.

Advantages and disadvantages of sexing agents in conventional semen prior to insemination

Semen sexing have greatly contributed to biasness towards higher female sex ratios in cattle and wildlife thereby assisting in maintaining socially cohesive groups and minimizing male-male aggression (O'Brien *et al*., 2009). Furthermore, the authors highlighted the importance of this technology in endangered animal species where preferential production of females could enable propagation of the species at a faster rate. Biasness towards a particular sex (especially female offspring) is important for the long-term management of a breeding population as in the case of pastoral herd. In a previous study by Chongsi *et al*. (2019) the authors recorded a higher ratio of female calves on cattle treated with Heifer plus relative to

non-treated cows. Compared to sexed semen, the sexing agents are relatively low in terms of costs for access and use.

Despite the various advantages associated with semen sexing, one major setback remains to be the short viable lifespan of sorted spermatozoa in the female genital tract (Maxwell *et al*., 2004). This therefore necessitates sperm deposition deep in the uterus of the animal under insemination. This could lead to wrong sperm deposition especially into the non-ovulating horn, injuries or complication in scenarios where we have inadequate technical skills (Chongsi *et al*., 2019). Besides this, sperm damage due to the separating procedure, increased embryonic death due to the usage of DNA dyes and high financial cost implications also constitute limitations in the use of sexing technologies among cattle herd (Turk *et al*., 2015).

2.8.4 Modelling Conception Rates with Bull and Cow Characteristics

Regression analysis aims at providing relationships between dependent and independent variables. Logistic regression is a predictive and appropriate regression analysis to conduct when the dependent variable is dichotomous (binary). It is often used to investigate the relationship between discrete responses (example success or failure) and a set of explanatory variables. Logistic regression is used to obtain odds ratio in the presence of more than one explanatory variable. The procedure is quite similar to multiple linear regression, with the exception that the response variable is binomial, you can use continuous explanatory variables and it is easier to handle more than two explanatory variables simultaneously (Sperandei, 2014). A logistic regression will model the chance of an outcome based on individual characteristics. Because chance is a ratio, what will be actually modelled is the logarithm of the chance given by:

$$\log\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_n x_n + e_{ij} \quad \text{.....(1)}$$

where π indicates the probability of an event (example, conception success or failure), and β_i are the regression coefficients associated with the reference group and the x_i are explanatory variables.

2.9 Willingness to Pay for Assisted Reproductive Technologies Post Support Period

Upgrading processes involving use of reproductive technologies aim at in increasing herd productivity within dairy farms. Over the years, pastoralist have been using bull services for upgrading their cattle and this pose risks of inbreeding and spread of reproductive diseases (Khainga, 2015). Through subsidies from development agencies, ranch and pastoral herd owners are able to access most of these reproductive technologies for upgrading to pure

Sahiwal breed as well minimizing inbreeding and spread of reproductive diseases. To ensure continuous and sustainable use of these technologies (which are either new, improvement or replacement of traditional methods), the beneficiaries (pastoralist) upon adoption in short run, must be willing to pay for accessing the technologies.

Willingness to Pay (WTP) can be defined as the maximum amount an individual is willing to offer/ pay for a product or service. Sirajuddin *et al.* (2018) further defined willingness to pay as the willingness of individuals to pay for an environmental condition or man assessment of natural resources and natural services in order to improve the quality of the environment. It is a powerful tool for assessing the perception and acceptability of a social service (Mukama, 2010). It calculates the ability of each individual or society in aggregate to pay or spend money in order to improve the environmental conditions to suit their desired conditions.

2.9.1 Factors Affecting Willingness to Pay (WTP) for Agricultural Technologies

Farmers ability to purchase new technologies depends on his/her disposable income given existing production cost outlay (Khainga, 2015). Various studies have reported several factors that affect the willingness of farmers to pay for a new technologies post support period. For instance, in a study on adoption of AI by pastoralists, Khainga (2015) reported that farmers' bidding decision was mostly informed by socio-economic factors. This included awareness of technology, access to credit facilities, herd size, age, education level, access to credit facilities and farm income. These factors are mostly related to the farmers' themselves and their perception towards the new technology. Furthermore, the amount expressed by farmers' implied price comparison between the cost of the bid and the cost of acquiring the bull.

2.9.2 Quantifying Willingness to Pay (WTP)

Valuation methods relating to willingness to pay can be divided in direct and indirect methods. In indirect valuation method, estimates are based on the observed behaviour of individuals in the market of a good or service while direct methods try to elicit information about the value of the good or service directly from the individual (Lopez-Feldman, 2012). Contingent Valuation (CV) is a direct method involving asking respondents about their WTP for the provision of a given good or service. The method is very flexible and one can not only obtain estimations for public policies or projects that have not been implemented but also to obtain estimates of non-use values (Lopez-Feldman, 2012). Willingness to Pay can be elicited using Contingent Valuation in three ways. First is through open-ended questions whereby respondents are asked how much they are willing to pay for a good or service. Second is

through payment card approach where respondents are presented with series of amounts for possible payment where they choose the one close to their individual valuation. Third, is through dichotomous choice questions where respondents are asked (after the description of a hypothetical scenario); will you be willing to pay "X" amount (based on series of bids).

Asking simple yes/no questions eases the burden on the respondent, decreases the number of protest answers, and the "would not vote/answer" option and allows protest answers to be submitted without introducing bias in estimates of WTP (Cawley, 2006). Questions asked during interviews with respondents have possible outcomes as indicated in Table 2.4.

Table 2.4: Possible Outcomes of Double Bounded Dichotomous Choice Questions on WTP

Inferences	**Description**
B_i	Initial bid price/ hypothesized cost for a good or service
$0 < WTP < B_i$	If the respondents answers no to the first bid
$B_i < WTP < \infty$	If the respondents answers yes to the first bid
$B_i < WTP < B_i^u$	If the respondent answers yes to the first bid and no to second
$B_i^u < WTP < \infty$	If the respondent answers yes to the first and second bids
$B_i^d < WTP < B_i$	If the respondent answers no to the first and yes to second
$0 < WTP < B_i^d$	If the respondent answers no to the first and second bids

B_i^u = Second higher if answer to initial bid was yes; B_i^d = Second higher if answer to initial bid price was no. Source: Lopez-Feldman (2012)

2.10 Performances of selected cattle breeds amongst pastoral herd

Genetic improvement programs in pastoral production systems usually aim at improving the overall performances of indigenous cattle breed as well as achieving production objectives of individual farms. Seventy percent of pastoral households mainly keep the indigenous breeds with the Small East African Zebu (SEAZ) being the most common breed as compared to Boran and Sahiwal (FAO, 2018b) . The Sahiwal breed have mostly been used in upgrading the Small East African Zebu (SEAZ) especially by the Maasai communities within the southern rangelands for improved milk and meat production and growth performances (Ilatsia *et al*., 2012). Through these upgrading processes, pastoralists have been able to access superior genetic breeds such as Sahiwal that have increased both milk, meat and overall farm income through sales.

2.10.1 Productive performances

Within the pastoral rangelands, various production systems aim at producing milk and/ or beef for utilization at farm level or sales for income. Breed improvement programs from local to exotic cattle, target improved herd productivity both at farm and national levels for food security, insurance, financing and income generations through sale. Crossbreds of local and exotic breeds produce more milk and meat relative to the local indigenous breeds. In their previous study, reported

Sahiwal cows experience longer lactation periods and increased milk production relative to small East African Zebu and Boran cows. Recorded milk estimates of up to 5 litres per day by Sahiwal cattle breed compared to 2 and 4 litres of SEAZ and Boran respectively, indicate an increased milk production level by pure and crossbred Sahiwal compared to the indigenous breeds (Ilatsia *et al*., 2012). Application of proper breed selections and optimal husbandry practices can improve the production levels especially within pastoral rangelands. The authors further reported mean estimates for milk production traits as 1368 kg (lactation milk yield), 282 days (lactation length) and 4.9 kg test-day milk yield. Table 2.5 presents comparative productive traits and their corresponding mean values of various cattle breeds found within pastoral production systems.

Table 2.5: Mean productive traits for different breeds of dairy cattle in Kenya

Breed	**N**	**MY (Kg)**	**LL (days)**	**TDMY (Kg)**	**BW (Kg)**	**References**
Sahiwal	6365	1368	282	4.9	-	Ilatsia *et al*. (2007)
Sahiwal	827	1226	305	4.0	-	FAO (2011)
Sahiwal	4837	1663	305	5.5	22.7	Rege *et al*. (1992)
Sahiwal	1805	1540	-	-	-	Muhuyi (1997)
Jersey	931	3785	305	12.4	-	FAO (2011)
Jersey	-	-	-	-	22.9	Lemma *et al*. (2010)
Zebu	-	-	-	2.3	-	Rege *et al*. (2001)
Zebu	430	-	235	1.6	-	Mwacharo and Rege (2002)
Zebu	-	-	-	-	18.35	Mulindwa *et al*. (2012)
S x Z	-	-	-	-	23.2	Babigumira *et al*. (2018)
Boran	-	2630	240	4.2	22.9	Haile *et al.* (2011)

N: Number of cows, MY: Milk yield, LL: Lactation Length, TDMY: Total Day Milk Yield, DP: Dry Period, BW: Birth weight, S x Z: Sahiwal –Zebu crosses

2.10.2 Reproductive performances

Reproductive performance covers traits that describe the animal's ability to conceive, calve down and successfully suckle the young one/ calf to weaning stage. These traits are of importance within dairy enterprises and have direct relationship with the herd size, overall profitability of the farm and offtake (Haile *et al.*, 2011). In both dairy and beef production systems, reproduction offers an indicator of reproductive efficiency and the rate of genetic progress in both selection and crossbreeding programs. High reproductive efficiency is necessary for efficient milk and meat production; and herd profitability, and is expressed by the extent of reduction to reproductive wastages (Pryce *et al*., 2004).

Reproductive performance is commonly measured through evaluating the female reproductive traits that includes age to puberty, age at first service, age at first calving (AFC), calving intervals (CI), conception rates, days to conception, services per conception, conception rates, estrus detection and pregnancy rates (Dayyani *et al*., 2013; Haile *et al.*, 2011). These measures of reproductive performances are key indicators of sustainability of which upon adequate intervention measures, ensures economic viability of dairy production systems (Wangdi *et al*., 2014). Age at first service (AFS) entails the age at which heifers attain body condition and sexual maturity for accepting service for the first time. This signals the beginning of heifers' reproduction and production performance, which has great influence on the reproductive life of the female and is influenced by genotype, nutrition and other environmental factors.

Age at first calving (AFC) involves the age at which heifers calve down for the first time. The latter marks the beginning of a cow's productive life, is closely related to generation interval and, therefore, influences response to selection (Dayyani *et al*., 2013). In pastoral production systems, AFC has been reported to be at four years mostly attributed to the unfavourable environmental conditions (Haile *et al.*, 2011). This therefore provides an opportunity for improvement through better selection and proper management practices.

Calving interval is a measure undertaken within individual cows and entails the amount of time (days or months) between the births of subsequent calves. Calving interval can be divided into three periods involving gestation, postpartum anestrus/ open days (from calving to first estrus) and the service period (first postpartum estrus to conception (Dayyani *et al*., 2013). The authors further reported that by improved herd management, the "days open" period is the part of the calving interval that can be shortened. Table 2.6 provides comparative reproductive performance traits and their corresponding mean values of various cattle breeds found within pastoral production systems in Kenya.

Table 2.6: Average values for reproductive traits in different dairy cattle breeds in Kenya

Breed	N	AFS	AFC (days)	CI (days)	No. of services per conception	References
Sahiwal	2238	-	1218	426.2	2.1	Rege *et al*. (1992)
Sahiwal	1805	-	1236	446	-	Muhuyi (1997)
Sahiwal	6365	-	1345	468	2.2	Ilatsia *et al*. (2007)
Sahiwal	-	-	1296	-	-	Ngigi (2005)
Sahiwal	-	-	1643	480	-	Mwacharo and Rege (2002)
Jersey	-	722	1035	450	1.8	Lemma *et al*. (2010)
Zebu	-	-	1606	417	-	Rege *et al*. (2001)
Zebu	-	-	1317	-	-	Ngigi (2005)
Boran	-	972	1092	421	-	Haile *et al*. (2011)

N: Number of cows, AFS: Age at First Service, AFC: Age at First calving, CI: Calving Interval

Effect of genotypes on growth characteristics of Sahiwal and crosses

Upgrading processes from indigenous to exotic cattle breeds have direct influence on the genetic composition of the pastoral cattle breeds. Changes in genetic constitution of these crossbreds have direct influences on the resulting calf weights as compared to the pure bred. A study by Mulindwa *et al*. (2012), reported comparable differences between calves of Zebu (pure) and cross-breeds in birth and weaning weights as well as pre-weaning average daily gain (ADG). The study recorded higher weights from the crossbreds compared to the pure breed indicating improved growth characteristics amongst the crossbreds (Table 2.7).

Table 2.7: Effect of genotypes on Performances of Kenyan Sahiwal cattle breed and crosses based on birth, weaning, yearling, pre-weaning ADG and mature weights in pastoral environments

Genotype	N	BW (Kg)			WW (Kg)			YW (Kg)			Pre-weaning	Mature weight			References
		M	F	Mean	M	F	Mean	M	F	Mean	ADG (g)	M	F	Mean	
Sahiwal	5,681	-	-	21.86	-	-	48.59	-	-	133.39	-	-	-	-	Ilatsia *et al.* (2011)
Sahiwal	-	21.4	21		56.29	56.25	-	-	-	-	300	500	425	-	Muhuyi *et al*. (1999)
Sahiwal	4837	-	-	22.70	-	-	-	-	-	-	-	-	-	-	Rege *et al*. (1992)
Sahiwal	12	-	-	-	-	-	-	-	-	113.67	381	-	-	-	Ketere-Lelgut (2021)
Zebu	47	-	-	18.35	-	-	-	-	-	79.52	-	-	-	-	Mulindwa *et al*. (2012)
Boran	-	-	-	23.30	-	-	54.0	-	-	111.2	438	-	-	368	Haile *et al.* (2011)
F_1(S x Z)	-	-	-	18.94	-	-	-	-	-	104.56	315.43	-	-	-	Mulindwa *et al*. (2012)
F_1(S X Fre)	12	-	-	-	-	-	-	-	-	156.91	571	-	-	-	Ketere-Lelgut (2021)
B_1 Sx(BxZ)	40	-	-	18.35	-	-	-	-	-	106.48	324.64	-	-	-	Mulindwa *et al*. (2012)
B_1 (SxZ)xZ	64	-	-	16.21	-	-	-	-	-	98.05	301.94	-	-	-	Mulindwa *et al*. (2012)

N: Number of cows, BW: Birth Weight, WW: Weaning Weight, YW: Yearling Weight, ADG: Average Daily Gain, F_1: First Filial generation, B: Boran, S: Sahiwal, Z: Zebu breeds of cattle, Fre: Friesian, M: Male, F: Female

2.11 Benefits of Sahiwal cattle breed amongst pastoral communities

Cattle products have significant contributions to most pastoral households in form of goods and services both marketed and for non-marketed or subsistence use (Behnke & Muthami, 2011; Nyariki & Amwata, 2019). The provision of multipurpose contributions by cattle including food security, agricultural production and socio-cultural obligations can be classified as either tangible or intangible benefits towards the pastoral communities.

2.11.1 Tangible benefits

Tangible benefits has direct positive influence on the livelihood status and offers provisions for food and nutritional security to most rural households living within pastoral rangelands. Sahiwal cattle breed provides main utility to most rural communities as seen in crossbreeding for dual-purpose production in the middle- to lower potential areas (Kamiti, 2015). Within the rangelands, Sahiwal cattle breed is mainly kept by pastoralists, private and government ranches for milk and meat production; and revenue generation through sale of live animals and surplus milk in excess of household requirements (Bebe *et al*., 2002; Ilatsia *et al*., 2011; Nyariki *et al*., 2009; Roessler *et al*., 2010). Increased milk and meat production not only ensured self-sufficiency, but also counteracted the limited access to diverse diets for both the calf and the family during home consumption (Mishkin *et al*., 2018). Cattle milk offers staple of Maasai diet and is either taken fresh or in sour form while babies are given ghee. This contributes towards the overall household food security for subsistence use (Alusi, 2014). Well-established ranches that are commercially oriented and offer adequate animal health management practices exhibits higher milk production levels.

Sales of cattle and cattle products are major sources of cash income in pastoral production systems (Tolera & Abebe, 2007). Majority of the pastoralist use the cash income from cattle sale for direct purchase of goods and services ranging from food items, clothing, medication and schooling; to purchase of replacement and breeding stock as well as livestock inputs for production. Through home slaughter during ceremonies, the cattle provide sources of hides and skins, hooves, horns and other ornamental products. The volumes of hides and skins are directly dependent on the number of animals available for slaughter. Hides are obtained from large ruminants like cows while skins are got from small ruminants like sheep and goats.

In pastoral rangelands, hide and skin production are essential for various sociocultural functions including bedding, decorations and clothing. Though production of hides and skins have limited financial value for pastoralists and local communities, it has untapped potential

that could aid it's use for livelihood roles especially in pastoral production systems (Jemal *et al*., 2016). Through proper collection treatment and preservations, hides and skins provide an avenue for income generation at household, county and country level for rural economic development.

Sahiwal cattle provide a cheap source of meat upon slaughter during specific occasions and functions such as weddings, funerals, religious and socio-cultural festivals involving rites of passages to offer cheap sources of meat. Compared to other indigenous breeds that are small, Sahiwal cattle are heavily built and have higher live body weight hence providing an increased quantity of meat to satisfy a community need. Previously, several herds of cattle could have been slaughtered to meet the demand of meat during these ceremonies. Besides being a source of meat, cattle also offer alternative source of manure for fodder production and crop production especially for agro-pastoralists. Ruminants produce faecal dry matter at 0.8% of body weight per day, which when well-managed, can provide sources of nutrients used in crop cultivation for increased yields (Lekasi *et al*., 2003). Furthermore, in extensive grazing systems, manure droppings in the fields provide sources of nutrients to the field pastures, grasses and fodder trees that are later used as animal feed.

2.11.2 Intangible benefits

Besides tangible benefits, Sahiwal cattle breed provide non-tangible profound implications on the livelihood of many rural households and the environment in general. Within the pastoral environments, Sahiwal cattle features as living "savings" that can be converted into cash upon need and as security assets in terms of accessing credit and loans in financial institution (Ouma *et al*., 2003). This is mostly useful during times of medical requirements, children education or even in accessing necessities. Large herd sizes within pastoral production systems are often directly correlated to social status (leadership), demonstrates wealth and economic status to the households (Khainga, 2015). They are also considered as a common means of cementing relationships through bride price payments and acts as social links in crises and in settling individual or village disputes.

In most pastoral communities, Sahiwal cattle perform insurance roles (self-insurances) because the capital invested form a guarantee for meeting future unexpected requirements (Bebe *et al*., 2002). Large herds of cattle within pastoral rangelands offer insurance against pests, animal diseases and harsh environmental conditions that would lead to higher mortality rates. The high numbers provide cushion against external shocks such that some cattle remain within the herd in cases of animal exists within the herd. Besides insurance, Sahiwal cattle also

perform financing roles is situations where banking is not developed or households are not fully integrated into credit markets (Ouma *et al*., 2003). Furthermore, cattle acts as living banks with ease conversion to cash for most pastoralists in rangelands (Nyariki *et al*., 2009).

2.12 Sahiwal Bull calves within pastoral herd

Pastoral mating has always depended upon superior individual or community bulls for mating within the herd. Pastoral herd owners have opted for several uses of bull calves they get from either bull or artificial insemination of their herd. Amongst identified uses include; sales for income, rearing within farm for future breeding, for farming activities, undertaking sacrifices during ceremonies and source of prestige and wealth. Retaining for future breeding stock involves the bull herd to act as parents of future generation. Within pastoral rangelands, pastoralists would prefer to retain "superior" bull calves within the herd for future breeding purposes. Under natural pasture grazing, selection of breeding bulls is widely practiced with most farmers preferring to use own bulls or neighbor's bulls for mating (Rege *et al.*, 2001). Furthermore, pastoralist have adopted ways of bull exchanges amongst themselves to disseminate genetic resources though this is prone to disease transmission and inbreeding (Khainga, 2015). It is conceptualized that retaining of improved Sahiwal bull calves from ARTs within pastoral herd would increases the number of superior breeding stock as opposed to selling for income that would reduce the overall herd size.

The immediate need for household cash usually prompt many pastoralists to sell live animals. The preference for income through sales involve conversion of bull calves to cash either for profit or in settling an immediate household demand. Commercial ranchers often target high market niches involving processors, institutions and retailers depending on market prices and season (Mwangi *et al*., 2020). They prefer selling lives animals in large numbers as opposed to few numbers sold by nomads and agro pastoralists. In most scenarios, pastoralists usually dispose off their live animals during dry seasons when there is less water and pastures. Though disposal of bull calves adds additional income to the owner, it ultimately reduces the overall number of cattle in the herd. Cultural practices involve projected use of bull calves live animals as sacrifices during traditional ceremonies, gift provision or in settling disputes between two parties or communities. This is mostly attributed to the intangible benefits associated with keeping the bull calves. These benefits include social status, sign of wealth, donations, gifts to others and paying dowry which contributes either positively or negatively towards the overall number of bull calves in the herd. Utilizing the bull calves during cultural

practices such as sacrifices and slaughter for meat production ultimately reduces the overall number of herd size within the farm.

2.12.1 Assessing preferential use of Sahiwal bull calves within pastoral herd utilizing OvSynch and fixed time artificial insemination

Choice Experiment method as derived from Lancaster model theory of consumer choice, adopts the provision for the attributes or characteristics of goods that provide people with utility rather than the goods themselves (Lancaster, 1966).The method largely reviews people's choices, decisions, preferences and judgements of a goods' worth, value or a number of similar attractiveness. As in the case of pastoral rangelands, the method would integrate well in assessing the preferential use of bull calves from OvSynch and FTAI use within pastoral herds.

2.13 Economic Valuations of new technologies or interventions

The Economic viability of a livestock enterprise depends upon the efficiency of production as well as returns from sales. Within cattle herds, economic viability is a key parameter that determines whether the management can accept or reject a proposed technology based on the benefits and costs it offers. Within the current study, economic valuation of utilizing ARTs was undertaken based on benefits versus costs projected to lifetime of individual cow.

2.13.1 Quantifying Economic Viability using Benefit-Cost Analysis

Benefit-Cost analysis (BCA) is an evaluation method for decision options that systematically compares the value of the outcomes against the value of resources used in achieving the outcomes (Lawrence *et al*., 2015). It is the broadest economic evaluation method and evaluates whether benefits (quantified in monetary values), outweighs the costs of resources used to produce them and also linked to the concept of allocation efficiency (Razzouk, 2017). In computation, all benefits and costs (direct and indirect) originating from technologies and programs are estimated and aggregated into monetary measures. Benefit-Cost analysis measures economic efficiency of a technology or project and provides useful information for making decisions in both tangible and intangible monetary values for informed reasoning behind the investment (Lawrence *et al*., 2015; Pearce *et al*., 2006). Benefit Cost Analysis can further include the value of benefits from goods and services that do not have market prices taking into account the opportunity costs (Razzouk, 2017).

Three key parameteres are normally considered in computing Benefit-Cost analysis. This include: the Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of

Return (IRR) (Pearce *et al*., 2006). Results obtained from these parameters are useful in computing decision rules as to whether the technology or project is economically viable.

Net Present Value (NPV) is the total present value (PV) of a time series and is a standard method for using a time value of money to appraise a long-term project.

Benefit Cost Ratio (BCR) is the ratio of the present value of the benefits to the present value of the costs (Lawrence *et al*., 2015).

Internal Rate of Return (IRR) is the annualized effective compounded return rate that can be earned on the invested capital.

Decision rule; A Benefit-Cost Analysis proceeds on the explicit basis that a project /innovation is deemed socially worth-while if the benefits it generates exceeds the costs. The necessary condition or decision for adoption of a technology or a project is when the discounted benefits exceeds discounted costs (Pearce *et al.,* 2006) . This decision rule can be stated as;

PV(B) > PV(C) or, NPV > 0

where; PV(B) refers to the (gross) present value of benefits, PV(C) refers to the gross present value of costs and NPV refers to the net present value (or present value of net benefits) so that: NPV = PV(B) – PV(C) with present values calculated at the social discount rate.

2.14 Opportunities and Challenges for Sahiwal farming within the rangelands

The general performance of current Sahiwal breed has great potential for increase based on targeted management interventions at farm, county and national level. Targeted breeding interventions is paramount at various levels to increase the number of top proven Sahiwal pure and crossbred cattle. In addition to the national research centres and commercial ranches, nomads and agro-pastoralist need to be sensitized and targeted, to act as multiplication centres for easy access of genetic materials. Herd owners keeping low-grade cattle, can enter into commercial contacts with pastoral breeding program implementers' to provide their cows as recipients for the improved semen for offspring upgrading purposes. This will aid in reducing the high demand versus low supply chain of superior Sahiwal bulls from the national research centres and model farms. Furthermore, targeted and well-planned Sahiwal breeding programs will aid at limiting cases of indiscriminate crossbreeding or inbreeding that can lead to loss of genetic diversity among Sahiwal population (Mbuku *et al.*, 2019). Indiscriminate breeding can further lead to crossbreds that are less adaptable to the prevailing environmental conditions thereby compromising their overall performance (MoA&I, 2018).

A collaborative stakeholder approach that aim at pooling joint efforts towards ensuring adequate extensive service delivery, disease control and continuous disease surveillance need

to be undertaken. Service delivery should focus mostly on adequate animal husbandry practices involving feeding and disease control measure to assure optimal production and good health are maintained. Furthermore, extension should address challenges related to animal feed resources and conservation measures for use during scarcity. Inadequate feed availability limit the optimal growth of Sahiwal weaner calves hence reduced productive life (Ketere-Lelgut, 2021). With adequate extension provision, pastoral herd owners would efficiently utilize available feed resources and practice feed conservation measures such as hay and silage making for use during the dry seasons of the year. This would reduce production and reproduction losses experienced during the dry seasons when there is feed scarcity and cattle have to migrate in search of pasture and water within the designated grazing patterns (Ilatsia *et al*., 2012).

Proper husbandry practices also need to target adequate disease control measures especially in areas where wildlife-livestock interaction are common. These interactions spread various parasites and diseases that affect the overall health of livestock within these areas. For instance, a study by Ketere-Lelgut *et al*. (2018) reported that Sahiwal calf mortalities are mostly associated with parasites and diseases within the Trans Mara rangelands. These parasites and diseases that mostly emanate from wildlife-livestock interactions, pose serious animal health issues on Sahiwal cattle breed that has relatively compromised immunity relative to Small East African Zebu and Boran cattle breeds. In addition, information on climatic and weather condition would aid in planning targeted intervention measures such as mass vaccinations and treatments to minimize calf mortalities and morbidities. In the end, this will reduce herd reproduction and production losses hence increased economic returns from Sahiwal cattle farming in the rangelands.

Commercialization of the Sahiwal cattle products (milk and meat) from subsistence farming to targeted markets is essential for optimal economic returns. With technologies and innovations in ICT, innovative communication pathways and platforms can aid in accessing superior genetic materials and high potential markets for increased economic returns at farm and national levels (Mbuku *et al.*, 2019). Access and use of OvSynch and TAI provide avenues for wider and easy access of top proven Sahiwal genetic materials. Though still limited by adoption challenges, pastoral herd owners need continuous sensitization for continuous use of ARTs to reduce overreliance on bull services. Innovation platforms in ICT aid in easy high potential market exploration and provide good avenues for negotiations, price assuarance and bargaining power for increased economic returns. Furthermore, market opportunities from these platforms can provide opportuities for income diversification through value added

Sahiwal products for increased income. In addition, these innovations can also aid in traceability of stolen Sahiwal cattle in cases of raised concern amongst pastoral communities.

Dairy innovations such as Assisted Reproductive Technologies (ART's) are aimed at improving the genetic makeups of the local breeds for increased production and reproduction levels. Within the dairy production systems, there are limited use of these reproductive technologies due to inadequate access and high costs attributed to their use thereby forcing farmers to resent to using bulls of inferior genetic potential that negatively affected performance of the offspring (Muia *et al.,* 2011).

2.15 General considerations and Conclusions

The current literature has shown that there is an increasing demand for superior top proven Sahiwal genetic for upgrading and increased herd productivity amongst the pastoral rangeland communities. Though use of bull services dominated amongst pastoral communities, there is need to explore alternative breeding interventions for instance use of ARTs such as OvSynch and TAI to resolve the problem of high demand of superior Sahiwal breeding bulls. However, sustainable use of these OvSynch and TAI post subsidy period remains unclear especially when herd owners have to meet direct costs. With superior quality cattle breed, associated system and managerial adjustments is paramount and this provides uncertainty on sustainable use on social, environmental and economic aspects. Evaluating use of OvSynch and TAI would offer insights to guide mating decisions that would assure improved reproductive performance is vital. This calls for viability analysis that guide proper use and ensures feasibility while utilizing these technologies. Combined use of OvSynch and TAI assures accessing and disseminating of superior Sahiwal genetic materials that guarantees improved genetic and herd performance (productive and reproductive) in pastoral rangelands.

2.16 Conceptual Framework

Figure 2.5 presents the conceptualized research framework illustrating elements and their interdependency in the use of OvSynch and TAI in pastoral and ranch herds. The ultimate goal is to realise improved livelihood in households through upgraded Sahiwal cattle. Presently, upscaling of OvSynch and TAI; and upgraded Sahiwal cattle are subsidized. It is hypothesized that sustainable use of the technologies beyond the subsidy period will require that herders bear the cost directly. Therefore, WTP estimates should inform the extent to which herders are willing to absorb the cost of the attributes associated with using OvSynch and TAI ($\mathbf{H_{01}}$) as opposed to using bull services for insemination. These associated OvSynch and TAI attributes include improved meat and milk production, superior breeding stock, drought a

disease tolerant, low feed and water requirements, low temperament, good coat colour, early maturity and high quality calves.

Utilizing OvSynch and TAI on defined bull-cow mating criteria aims at upgrading existing Sahiwal crossbred population towards pedigree level. The implemented criteria to match cow characteristics to top proven bull genetic quality aim at producing high quality offspring calves for improved herd performances and economic returns. Therefore, informed mating decision would benefit from establishing whether the bull and cow mating criteria significantly influences conception success rates and calf performances **(H_{02a}** and **H_{02b})**. It is expected that upgrading Sahiwal crossbreds towards high pedigree will demand high level of calf management practices, implying that calf performance will be dependent on good calf management practices (**H_{03}**). From the mating, both heifers and bull calves are born and there is the likelihood that pastoral herd owners would retain the upgraded bull calves for breeding services. In that case, they would compete with future AI services in ARTs to reduce cost of AI, earn money from fellow herders and retain prestige of owning high-grade bull. Estimating the tangible and intangible benefits of bull calves would therefore inform full value of bull calves in ranching and pastoral herds utilising ARTs (**H_{04}**).

In using OvSynch and TAI, herders invest resources with the hope of positive returns from the upgraded heifer and bull offspring, when their value is estimated over their productive life. The estimates on projected costs and benefits, should inform on the economic viability of producing heifers and bull calves with OvSynch and TAI under pastoral and ranching herds (**H_{05}**). This would further inform on future sustainability and utilisation of OvSynch and TAI especially for breeding purposes as compared to using bull services within pastoral production systems.

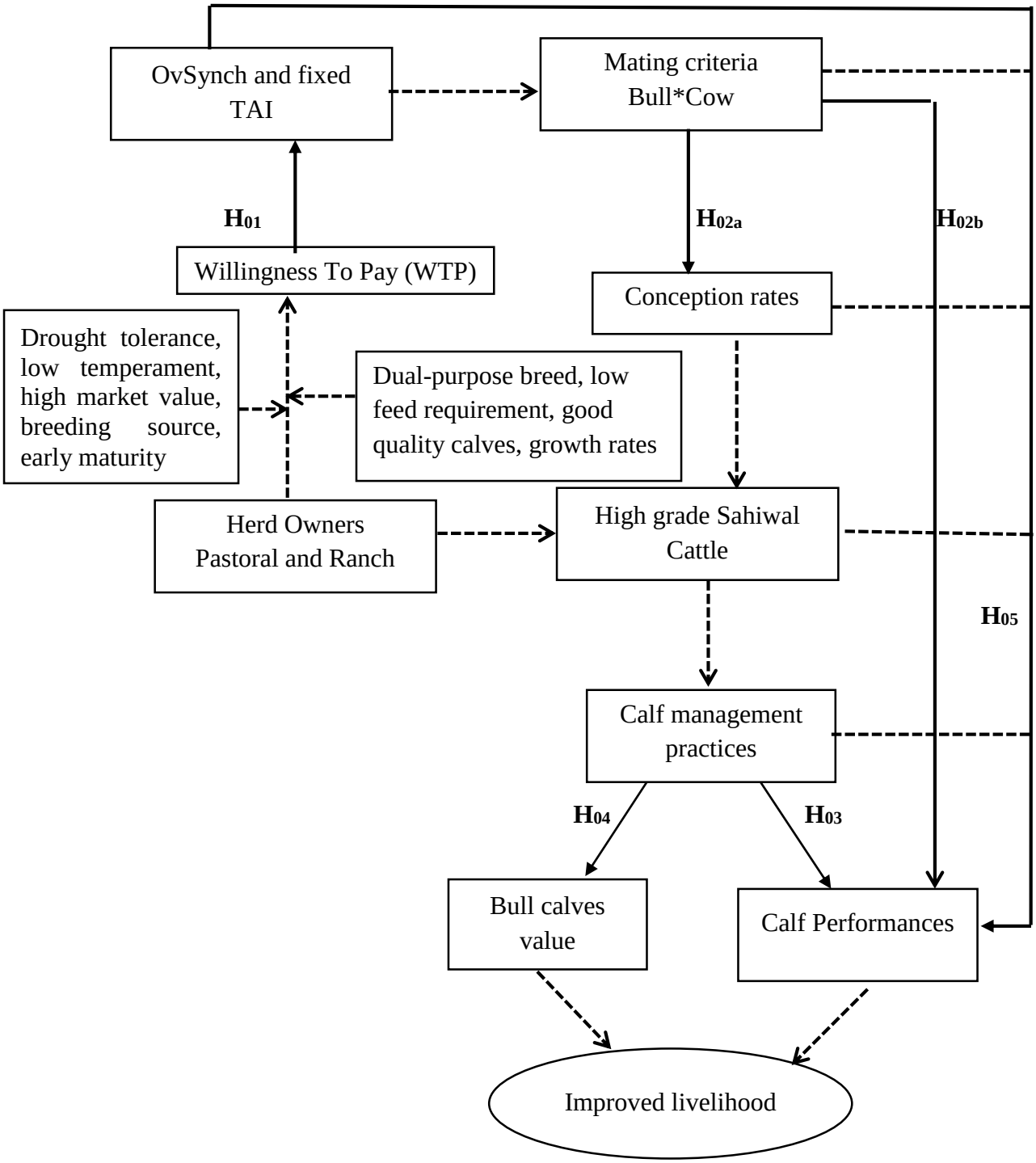


Figure 2.5: Research conceptual framework illustrating interacting hypothesized (H_{01} to H_{05}) elements in the use of OvSynch and fixed TAI in pastoral and ranch cattle herds with the goal of attaining improved livelihoods through upgraded Sahiwal cattle

CHAPTER THREE
WILLINGNESS TO PAY FOR OVSYNCH AND FIXED TIME ARTIFICIAL INSEMINATION AMONG PASTORAL HERD OWNERS IN SOUTHERN RANGELANDS OF KENYA

Abstract

Uptake of OvSynch and Fixed Time Artificial Insemination can widen and accelerate access to quality breeding stock under pastoral systems. However, access to OvSynch and fixed TAI is currently subsidised and it uncertain as to whether pastoral herd owners will be willing to meet direct cost for continuous access beyond the subsidy period. The willingness to pay (WTP) for the technology can provide insights on potential of sustained continued access especially when development agencies withdraw subsidies and private entrepreneurs take up the service delivery. This study estimated WTP for OvSynch and fixed TAI use without the subsidy among 126 pastoral herd owners in accessing superior genetic resources to upgrade Sahiwal cattle breed. The data was obtained from a sample of 130 herd owners participating in Sahiwal cattle breed upgrading program being implemented in Trans Mara West Sub County in the southern rangelands of Kenya. The WTP was estimated from double bounded dichotomous contingent valuation model and hypothesized bid levels. The average WTP was KES 3,643 (USD 33.4), equivalent to 21.4% premium with reference to base price (KES 3,000) (USD 27.5) of accessing OvSynch and fixed TAI. The findings indicate that seven in ten (67%) of the pastoral herd owners express the WTP above the hypothesized market price, twice more than those expressing WTP below the hypothesized market price (33%). For the pastoralists, animal attributes were important in influencing their WTP, which were high milk yield (62%), high value valves (37%), and high growth rates (1%). Gender was the only socioeconomic factor that significantly ($P<0.005$) influenced WTP, with men expressing higher WTP than women (KES 3,870 or USD 35.5 versus KES 3,223 or USD 26.6). The results indicate a high likelihood of pastoral herd owners continuing to access and use OvSynch and fixed TAI at market price. This is evidence of opportunities for private sector participation in extension service delivery and up scaling to increase access to superior Sahiwal genetic resources in pastoral herds. Therefore, policy interventions directed to enabling private sector to efficiently deliver OvSynch and fixed TAI, would be supportive to wider uptake of these reproductive technology among pastoral and ranching herds in the rangelands.

3.1 Introduction

Livestock production in the Arid and Semi-arid lands (ASALs) provide to pastoral communities' important livelihood benefits, both tangible (meat, milk) and non-tangible (financing, insurance against economic bottlenecks, dowry). Development agencies in Kenya prioritize investments towards increasing the tangible benefits through upgrading indigenous cattle to an adaptable and more productive Sahiwal cattle breed under rangelands where climate is increasingly variable and changing. These agencies include Kenya Agricultural and Livestock Research Organization (KALRO), International Livestock Research Institute (ILRI), Heifer Project International (HPI) and Kenya Livestock Breeders Association (KLBA) (Khainga, 2015).

The Sahiwal cattle breed is principally a dual-purpose (meat and milk) breed adaptable to Kenyan rangelands (Ilatsia *et al*., 2012). The demand for improved Sahiwal bulls and heifers has presently surpassed the supply. This situation emanates from multiple challenges limiting optimal utilization of the Sahiwal cattle as a livelihood improvement strategy. Supply of quality breeding stock is insufficient because of overreliance on a limited number of superior bulls initially provided by the progressive breeding farms, predominantly National Sahiwal Stud (NSS), private ranches and model farms (Mbuku *et al.*, 2019). These breeding farms largely utilize closed nucleus breeding schemes that deploy natural bull service. This breeding strategy has been associated with increasing inbreeding levels and loss of genetic diversity among Sahiwal cattle population in Kenya – and will be tragic, if remains unchecked (Ilatsia *et al.*, 2012).

Effective selection efforts for resilient and productive animals are required. Continued bull services could prove expensive as they are associated with risks of disease carriers, injurious to young heifers, increasing inbreeding levels and loss of genetic diversity with intensity of use. To increase access to high quality breeding stock, development agencies are supporting up scaling the use of a wide range of assisted reproductive technologies such as OvSynch and fixed TAI in the southern rangelands (Kebebe *et al*., 2017; Khainga, 2015).

These ARTs include artificial insemination (AI) using frozen semen, in vitro fertilization (IVF) and Multiple ovulation and embryo transfer (MOET) (Gicheha *et al*., 2018; Kios *et al*., 2018). Though use of these technologies offer comparative advantage over bull service in widening access to quality breeding stock for Sahiwal cattle upgrading, continued user participation without the subsidy from the government and development agencies is uncertain when the pastoral herd owners have to meet all the direct cost. For example, Khainga, (2015) reported higher level of awareness about AI services among pastoralists (70%), though

use of bull services as breeding method was still predominating within Narok County. Continued use of bull services was partly attributed to the preference for bull service by the herd owners based on cultural and societal related issues (Gamba, 2006; Janssen-tapken *et al*., 2006). Previous studies indicate that farmers often make decisions on adoption of new technologies based on awareness levels and enhanced efficiency in delivery, which is likely to influence their willingness to pay (WTP) for OvSynch and fixed TAI.

The WTP can be defined as the maximum amount an individual is willing to offer/ pay for a given product or service. It reflects the product's inherent value in monetary terms (Schmidt & Bijmolt, 2020), and is a powerful tool for assessing the perception and acceptability of a product or service for some livelihood benefits (Mukama, 2010; Sirajuddin *et al*., 2018). The WTP therefore, is an estimation of the ability of potential users to pay or spend money in a product or service for some desired livelihood benefits. Many studies estimating farmers' WTP for new technologies have used the contingent valuation method (CVM) which entails the use of hypothesized bid levels and asking a series of dichotomous choice questions until point estimate of WTP is reached (Hanemann *et al*., 1991).

Application of CVM draws its strength over the market-based techniques on the ability to assess use, option and non-use values (Christie *et al*., 2006). In the current scenario, use of OvSynch and fixed TAI for accessing superior genetic material for improving herd productivity could be an example of consumptive use value. On the other hand, products and services may also be valued for their potential future benefits, hence constituting an option value, which would be expressed in the WTP (Bett *et al*., 2009). In the case of OvSynch and fixed TAI, pastoral herd owners would present their WTP based on projected future benefits that could ensure improved herd productivity and performance in general.

The willingness to pay for OvSynch and fixed TAI expressed by pastoralists should provide insight into continued use when development agencies withdraw subsidy support, opening the service delivery to private entrepreneurs operating in a market system. The WTP would further inform on the societal sustainable use of the technology given that the pastoral communities pride more in the use of bull services. This information should interest development agencies and private service providers in the provision of sustainable breeding programs within pastoral production systems in Kenya. This study therefore estimated the WTP for OvSynch and fixed TAI to access superior genetic resources among pastoral herd owners.

3.2 Materials and methods

3.2.1 Description of the study area

The study was carried among the Maasai community practicing extensive cattle production in ranching, nomadic, or agro-pastoralism and utilizing a mix of pure and crossbreeds of Maasai zebu, Boran and Sahiwal breeds for livelihood benefits (Ilatsia *et al.*, 2011). Pastoral livelihood predominates in the southern Kenya rangelands in Trans Mara West sub-county, Narok County. All the study sites were in Narok County of Kenya, specifically in Lolgorian and Pusanki divisions in Trans Mara West Sub-county, located between Latitude 0^{o} 50' and 1^{o} 50' South and Longitude 34^{o}35' and 35^{o} 14' East (GoK, 2008) (Figure 3.1). The study sites were selected because of the ongoing community artificial insemination program involving the use of OvSynch and fixed TAI to upgrade Sahiwal cattle for increased milk production and develop efficient and sustainable heifer delivery model. To realise this, the Sahiwal upgrading breeding program prescribed selection criterion to promote the awareness and practical skills on the use of OvSynch and fixed TAI in the pastoral herds.

The distinct feature of these regions is variable altitude with the highlands between 2,200m and 2,500m above sea level, the plateau between 1,524m and 2200m above sea level and the lowlands below 1,524m above sea level. The lowland receives approximately 1,000 mm of rainfall per year (Magembe *et al.*, 2014). The herd owners indicated that they subjected the animals to similar husbandry and feeding practices in extensive grazing with mineral supplementation.

3.2.2 Sampling procedure and sample size

Sampling of the herds was in Lolgorian and Pusanki divisions in Trans Mara West Sub-county. These two divisions are beneficiaries of an ongoing Sahiwal community-upgrading program involving use of OvSynch and AI. Sahiwal is produced under ranching, pastoralism or agro pastoralism. In the two divisions, nine villages (Kirinkai, Oloirien, Ilokwaya, Pusanki, Meko, Olkilority, Enkiwancha, Entukai and Olosentu) were randomly selected to draw the needed sample size. The Kenya Agricultural and Livestock Research Organization (KALRO) program implementing the Sahiwal upgrading breeding program provided access to their database with list of beneficiary villages and farms, from where a sample of 150 herd owner beneficiaries were randomly selected.

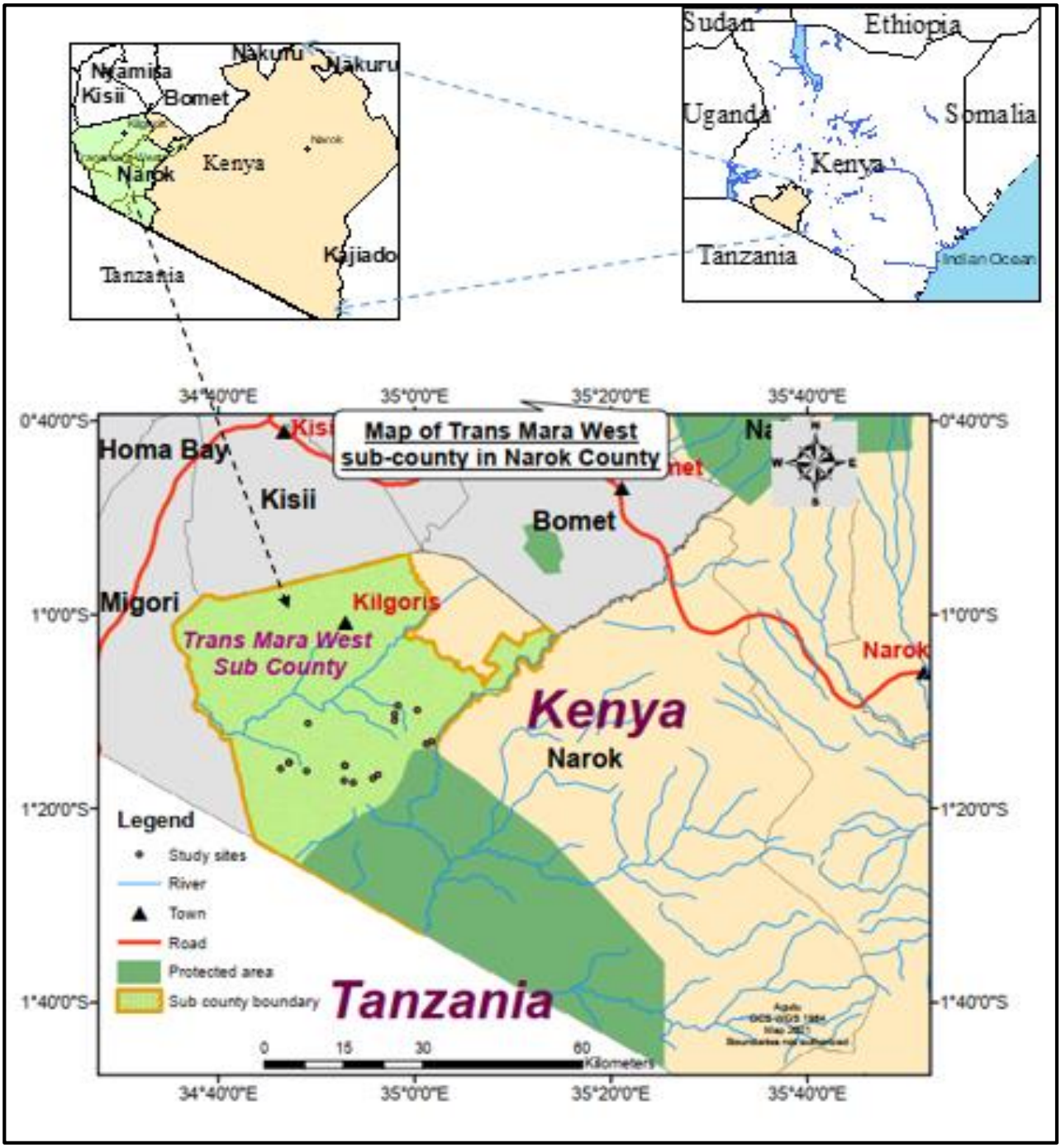


Figure 3.1: Map of Trans Mara West Sub County indicating the distribution of study areas and sampling sites**.** *Global Positioning System (GPS) data was collected using GPS essential software and used in ArcMap 10.8 application to produce the study map*

The sample size was determined with application of the Cochran's proportionate sample size formula (Mugenda & Mugenda, 2003):

$$\boldsymbol{n} = \frac{\boldsymbol{Z^2pq}}{\boldsymbol{e^2}} \quad \text{..... (2)}$$

where n = sample size, z is desired confidence interval level set at 1.96 for 95% confidence interval, p is the proportion of a characteristic of the population with Sahiwal cattle breed, q =

(1- p), and e is the error margin allowable for detecting a difference in the sample set at 0.05. In computation, the P was set to 0.051 being the proportion = $\left(\frac{2,573}{50,132}\right)$, of the total number of Lolgorian and Pusanki households to total households within Trans Mara West sub-county (KNBS, 2019) that have at least one Sahiwal cow (pure and/ or crossbred).

3.2.3 Techniques for data collection

The study incorporated the use of structured questionnaires and interview approaches to gather cross sectional primary data from pastoral herd owners rearing Sahiwal cattle in the rangelands. Prior to field data collection, a two-day training of the enumerators and pilot study were undertaken to equip the recruited enumerators with the knowledge and skills to solicit for appropriate answers in acceptable manner. The enumerators comprised Animal Health Assistants (AHAs) recruited from the local community for easy translation and recording of the responses from herd owners for analysis. Additional probing and follow-up questions were undertaken during field visits to give deeper insights and understanding of the responses.

The current study undertaken within the study sites incorporated the use of both primary and secondary data collection. Household visits and face-to-face interviews aided in administering the individual structured questionnaires to obtain primary data in qualitative and quantitative measurements directly from the field. The questionnaires were designed to capture household (socioeconomic characteristics), individual and herd characteristics, marketing and applied management husbandry practices. Secondary data were collected through desk reviews mainly sourced from the County reports, program database and broad bandwidth of online literature sources.

3.2.4 Analytical framework

The WTP was analysed using double bounded dichotomous choice contingent valuation model (CVM), applying the analytical framework of Hanemann *et al*. (1991). This model used hypothesized bid levels that reflected the cost of accessing the service as the basis for calculating the mean WTP and given that the herd owners were aware of the OvSynch and fixed TAI but unable to attach true value to its use. Close-ended questions approach was adopted. Though use of Contingent Valuation Model (CVM) in estimating farmers' valuation of technologies is not common, it is widely used in environmental studies, wildlife conservation as well as in evaluating WTP for new products and/ or services (Hanemann *et al*., 1991; Boyle, 2017).

This technique suited the case of OvSynch and fixed TAI whose market value was not yet fully developed in the study for pastoral rangelands. Furthermore, CVM accounted for dichotomous responses of 'yes' or 'no' simultaneously. The respondents were asked a second and subsequent bid, higher or lower depending on the response from the first question to ensure efficiency of the estimates. The herd owner was initially asked if he/she was willing to pay an amount say 'B_i' for the provision of OvSynch and fixed TAI services per animal served. The level of the second bid level was contingent upon the response to the first bid; "higher than the initial bid if the response was 'yes' and this assumed that the $B_i \leq WTP < \infty$", or "lower if the response was 'no' and this assumed that the $0 \leq WTP < B_i$". The subsequent bids played an important role in placing an upper and lower bound on the respondents' unobserved true WTP (Alberini & Cooper, 2000).

Four possible outcomes were obtained from the double bounded dichotomous model. These were presented as *yy*, *yn*, *ny* and *nn* where *yy* implied that both answers were 'yes' (WTP was higher than the upper bid) and *yn* implied first answer was 'yes' followed by 'no' (WTP was between initial bid and the upper bid). On the other hand, *ny* implied a 'no' answer followed by 'yes'(WTP was between lower bid and the initial bid) and *nn* implied 'no' answer in both (WTP was between zero and the lower bid) (Hanemann *et al*., 1991).

Table 3.1 presents the possible outcomes and inferences from double bounded dichotomous choice questions on WTP.

Table 3.1: Possible outcomes of double bounded dichotomous choice questions on WTP

Inferences	**Description**
B_i	Initial bid price/ hypothesized cost for a good or service
$0 < WTP < B_i$	If the respondents answers no to the first bid
$B_i < WTP < \infty$	If the respondents answers yes to the first bid
$B_i < WTP < B_i^u$	If the respondent answers yes to the first bid and no to second
$B_i^u < WTP < \infty$	If the respondent answers yes to the first and second bids
$B_i^d < WTP < B_i$	If the respondent answers no to the first and yes to second
$0 < WTP < B_i^d$	If the respondent answers no to the first and second bids

B_i^u = Second higher if answer to initial bid was yes; B_i^d = Second higher if answer to initial bid price was no. **Source:** Lopez-Feldman (2012)

The respondent was therefore assumed to make decisions following possible discrete outcomes that were;

WTP = 0 if $P \leq 0$; and WTP = 1 if $P > 0$

where WTP was 0 if the respondent was not willing to pay for the offered bid price and 1, if he/she was willing to pay the bid price for accessing OvSynch and fixed TAI. The dependent variable (WTP) was therefore hypothesized to be influenced by a set of socio-economic factors attributed to the respondent's choice of selection (Table 3.2). Regression analysis was further used in establishing the relationship between identified independent factors against the dependent factor using the equation 3;

$WTP_i = \alpha + \beta_1 Z_i + \cdots \ldots \ldots + \beta_n Z_n + \varepsilon_i$ and $i = 1 \ldots, n$……(3)

where, WTP_i is the probability of the *i*th respondent's willingness to pay the hypothesized bid price for accessing OvSynch and fixed TAI, $Z_{i \ldots n}$ are the set of socioeconomic variables of the respondent, ε_i is the random error term, while α and β are parameters of the model to be estimated.

Table 3.2: Various socioeconomic indicator variable definitions and their measurements

Variable	Definition	Measurement	Expected sign
Gender	Gender of herd owner	Categorical	+
Age	Age of respondent	Continuous	+/-
Education	Education level of herd owner	Categorical	+
Livelihood source	Main livelihood source for herd owner	Categorical	+
Production System	Production system for cattle keeping	Categorical	+
Grazing area	Number of acres for grazing livestock	Continuous	+/-
Farming Experience	Number of years keeping Cattle	Continuous	+/-
Market distance	Distance to main market for inputs	Continuous	+/-

3.2.5 Data analysis

The data collected with questionnaires was first processed in Microsoft Excel 2016 spreadsheet, serialized, sorted, edited, cleaned and checked for completeness before being transferred to Statistical Packages Social Sciences (SPSS) version 26 for statistical analysis. The analysis proceeded in two stages; firstly, descriptive statistics computation of frequencies, percentages and proportions. Secondly was logistic regression modeling with backward elimination procedures to retain only variables of significant influence on the WTP for OvSynch and fixed TAI out of all the hypothesized independent variables (Table 3.2).

3.3 Results

3.3.1 Characteristics of the herd owners

From a target of 150 respondents, 130 were reached in the survey with 126 providing complete responses for analysis. The four (4) excluded were incomplete or inconsistent responses on one or more variables. Table 3.3 provides descriptive statistics on mean scores of continuous variables describing the sample household characteristics. Results reveal that the herd owners' average age was 39.5 years with a range of 20 to 88 years and had been keeping livestock for the last 20 years. On average, a herd was 10 Sahiwal cattle on 40 acres of grazing land and had access to feeding and watering within about 1 km away. The average milk production per cow per day was at 2.5 Kg. The local market for inputs and outputs was accessed at about 10 Km way.

Table 3.3: Descriptive statistics of identified indicator variables in scale measurements

Variable	Min	Max	Mode	Median	Mean ± SD
Age of respondent	20	83	30	38	39.5 ±12.4
Livestock Farming experience	10	60	20	20	22.2 ± 10.3
Number of Sahiwal cattle genotypes	2	100	10	10	21.0 ± 20.7
Distance to feeding area (km)	1	20	1	1	2.9 ± 3.5
Distance to watering area (km)	1	20	1	1	2.8 ± 3.5
Grazing area (acres)	2	200	10	30	40.0 ± 37.5
Milk production/day/cow (Kg)	1	10	3	2	2.55 ± 1.2
Distance to market (km)	1	50	20	6	10.9 ± 11.3

Table 3.4 presents the summary descriptive characteristics relating to frequencies and percentages of the sample herd owners. Study findings indicate that males dominated females (65% versus 35%), with majority of the respondents' having attained basic primary education (89%). Their primary livelihood was livestock based (74%), with more than half practicing nomadic pastoralism, accessing less than 50 acres of grazing land and majority (68%) having kept livestock for less than 25 years

Table 3.4: Socioeconomic characteristics pastoral herd owners in frequencies

Variable	Level		Cattle Production Systems		
		n (%)	Ranching	Nomadic	Agro-pastoralism
			n (%)		
Gender	Male	82 (65)	5 (100)	69 (65)	8 (57)
	Female	44 (35)	0 (0)	38 (35)	6 (42)
Education level	None	14 (11)	0 (0)	12 (11)	2 (14)
	Primary	70 (56)	1 (20)	61 (57)	8 (57)
	Secondary	27 (21)	1 (20)	23 (22)	3 (21)
	Tertiary	15 (12)	3 (60)	11 (10)	1 (8)
Main livelihood source	Livestock	93 (74)	4 (80)	82 (77)	7 (50)
	Mixed	31 (24)	1 (20)	23 (21)	7 (50)
	Salaried	2 (2)	0 (0)	2 (2)	0 (0)
Grazing area (Acres)	<50	100 (79)	0 (0)	89 (83)	11 (79)
	51-100	16 (13)	1 (20)	15 (14)	0 (0)
	>100	10 (8)	4 (80)	3 (3)	3 (21)
Livestock keeping experience (years)	<25	86 (68)	3 (60)	70 (65)	13 (93)
	26-50	39 (31)	2 (40)	36 (34)	1 (7)
	>51	1 (1)	0 (0)	1 (1)	0 (0)

3.3.2 The willingness to pay for OvSynch and fixed TAI

Table 3.5 presents the estimated mean WTP by gender, production system and first choice attributes for using OvSynch and fixed TAI by pastoral herd owners. The mean WTP was KES 3,643.86 and was about 20% higher (P <0.05) among males (KES 3,870) than among females (KES 3,233). Within production systems, the mean WTP was 3% higher though insignificant (P >0.05), among agro-pastoralism than ranching (KES 3,657 vs KES 3,560). First choice attribute of utilizing for OvSynch and fixed TAI was high milk yield, which had a higher WTP compared to high growth rates (5%) or high value calves (3%).

Table 3.5: Estimated costs (KES)[a] on mean WTP values based on gender, production system, age and first choice attributes by pastoral herd owners

Factor	Level	Frequency (%)	Mean WTP ±SD	P-value
Gender	Male	82 (65)	3,870.37 ± 1139.67	0.04
	Female	44 (35)	3,233.33 ± 1218.42	
	Overall	**126 (100)**	**3,642.86 ± 1203.22**	
Production	Ranching	5 (4)	3,560.00 ± 1320.23	0.987
Systems	Nomadic Pastoralism	107 (85)	3,644.86 ± 1192.37	
	Agro-pastoralism	14 (11)	3,657.14 ± 1337.46	
	Overall	**126 (100)**	**3,642.86 ± 1203.22**	
Age	Below 30 years	37 (29)	3,586.49 ± 1164.80	0.716
	30 – 60 years	85 (68)	3,687.06 ± 1219.17	
	Above 61 years	4 (3)	3,225.00 ± 1447.70	
	Overall	**126 (100)**	**3,642.86 ± 1203.22**	
First	High milk yield	76 (60)	3,681.58 ± 1,225.80	0.905
Choice	High value calves	49 (39)	3,585.71 ± 1.190.06	
attributes	High growth rates	1 (1)	3,500.00 ± 0	
	Overall	**126 (100)**	**3,642.86± 1203.22**	

[a] One US dollar = KES 109 at the time of study

The value at which herd owners expressed WTP was above the base price: 71% for males and 29% for females (Table 3.6). However, an equal proportion (50%) of male and female herd owners declined the first bid with WTP below the bid price. Middle-aged herd owners (between 31-60 years) expressed a higher (69%) WTP above the bid prices relative to young (29%) and older herd owners (2%). For the first choice attributes, majority (62%) expressed WTP above the bid prices for high milk yield, which was 1.7 times more than for high value calves (37%) but 62 times more than for high growth rate (1%).

Table 3.6: Distribution by gender, age and 1st choice attributes that influence the willingness to pay (WTP) above or below the hypothesized market price of accessing for OvSynch and fixed TAI in pastoral rangelands

Variable	**Level**	**WTP above base price n (%)**	**WTP below base price n (%)**	**Pooled WTP n (%)**	**Chi Square stats**
Gender	Male	60 (71)	21 (50)	82 (65)	17.51 ^{NS}
	Female	24 (29)	21 (50)	44 (35)	
	Total	**84 (67)**	**42 (33)**	**126 (100)**	
Age	Below 30 years	24 (29)	13 (31)	37 (29)	27.09^{NS}
	31- 60 years	58 (69)	27 (64)	85 (68)	
	Above 61 years	2 (2)	2 (5)	4 (3)	
1st Choice attributes	High milk yield	52 (62)	24 (57)	76 (60)	17.70^{NS}
	High value calves	31 (37)	18 (43)	49 (39)	
	High growth rate	1 (1)	0 (0)	1 (1)	

^{NS}-Not Significant

Table 3.7 is a summary of the logistic regression coefficient estimates in full and reduced model of socio-economic factors influencing WTP for accessing OvSynch and fixed TAI within pastoral rangelands. Amongst the analyzed socio-economic factors, only gender was of significant (P <0.05) influence on the level of WTP.

Table 3.7: Logistic regression coefficient estimates for socio economic factors influencing WTP for OvSynch and fixed TAI

	Full model			Reduced model		
Variables	Estimate	P Value	Significance	Estimate	P Value	Significance
Intercept	5147.168	<0.0001	***	4507.407	<0.0001	***
Gender	-779.277	0.002	**	-637.037	0.004	**
Age	-14.112	0.301				
Education level	-53.802	0.674				
Main Livelihood	173.006	0.446				
Production System	-12.086	0.961				
Grazing Area	-0.929	0.608				
Farming Experience	0.146	0.991				
Distance to market	6.388	0.576				

** P <0.005, *** P <0.001

3.4 Discussion

Presently, pastoral herd owners in southern Kenyan rangelands are meeting the growing demand for quality breeding stock of Sahiwal heifers and bulls through subsidies provided by development agencies. This access to breeding technology is unsustainable because when subsidy is withdrawn, the access would have to revert to private sector delivery mechanism. The WTP for utilizing for OvSynch and fixed TAI was evaluated amongst pastoralists using double bounded contingent evaluation method based on hypothetical bid prices and subsequent follow-up bids of either above or below the bids depending on responses from initial bids (Bett *et al*., 2009; Drucker *et al*., 2001).

The findings indicate that seven in ten (67%) of the pastoral herd owners would be willing to pay above the initial bid price, which reflects a high likelihood of pastoral herd owners meeting direct cost on future access to OvSynch and fixed TAI. This suggests good prospects of continued access of Sahiwal semen for breeding purposes post subsidy support and participation of private sector in the delivery of OvSynch and fixed TAI to herd owners.

Higher WTP for accessing OvSynch and fixed TAI could mean that pastoral herd owners are satisfied with the progeny calves under their management conditions. This could be attributed to the continuous sensitization and practical demonstration forums that the programme implemented in the area. The findings corroborates those of Atsiaya *et al*. (2018) who reported that 66% of the herd owners expressed WTP above the bid prices. Furthermore, Khainga, (2015) also reported over half (52%) of the pastoral herd owners expressed WTP above the initial bid price for artificial insemination (AI) in Kajiado and Narok Counties.

In the study, the authors focused on perception of AI use by pastoralists as compared to the present study that had advantage of practical demonstrations and service delivery undertaken to enhance the community awareness levels on OvSynch and fixed TAI use. This therefore, implies that awareness and capacity building through trainings, practical demonstrations and extension service provision, is essential for successful introduction and adoption of OvSynch and fixed TAI use in pastoral production systems. This is in line with Dehinenet *et al*. (2014) who reported that awareness through livestock trainings and demonstrations, increase farmers' probability of adopting and paying for improved dairy technologies. This is a relevant matter for extension service when planning to upscale ARTs adoption in pastoral production systems.

The average WTP was an equivalent of 21.4% premium on the base price of meeting own cost for service delivery. The higher premium rate demonstrate the community desire to continue utilizing OvSynch and fixed TAI towards upgrading their herd. In this regard, the

agro-pastoralists expressed a 3% higher WTP than ranchers (KES 3,657 versus KES 3,560), which is contrary to expectations. The ranchers, being commercial oriented, would be expected to express higher WTP for OvSynch and fixed TAI than the agro and nomadic pastoralists. The awareness and farm-level demonstrations were directed to the agro and nomadic pastoralist, which could explain this observation. The premium rate reported in the study is in agreement with 25.4% WTP premium on AI by pastoralist from Kajiado and Narok counties (Khainga, 2015). The higher premium rate presents an opportunity to the private sector participation in OvSynch and fixed TAI delivery model. This will need supportive policy interventions that target delivering superior genetic materials to pastoral herd owners.

Gender was the only socioeconomic factor with significant (P <0.05) influence on WTP with men expressing 20% higher WTP than women (KES 3,870 versus KES 3,233). Partly, a higher proportion of males than females (65% versus 35%) in the sample partly explains this. When gender differences are differentiated by first choice attribute, males expressed higher preferences for superior progeny bull calves to use for future breeding. Males perceived that, accessing a bull calf and raising the calf on farm to breeding age, would be cheaper than buying one from the research stations, ranches or model farms. Furthermore, they argued that raising a bull calve on farm, ensures more adaptability to the local environment and diseases as compared to bulls sourced outside the locality.

On the other hand, females considered higher milk production as their initial reason for WTP for using OvSynch and fixed TAI. To explain this observation, women value milk to feed their families for food security and nutrition goals. This corroborates with reports of Kariuki *et al*. (2017) that women farmers express preferences for cows with higher milk potential. In other studies, female herders have been observed to trade some of the milk for family income to support other livelihood needs (Chawala *et al*., 2019). However, the result contradicts a study by Khainga, (2015) that reported insignificant influence of gender on the WTP for AI in Kajiado and Narok Counties.

3.5 Conclusion

About two-thirds of the herd owners expressed WTP above the base price, indicating a higher likelihood of pastoral herd owners adopting ARTs for upgrading Sahiwal cattle breed without reliance on subsidies. This presents an opportunity for private sector participation in ARTs delivery and up scaling in pastoral herds. This will need putting in place policy interventions supportive of efficient ARTs delivery mechanisms for pastoral herd owners.

CHAPTER FOUR

INFLUENCE OF MATING DECISIONS ON CONCEPTION RATES OF SAHIWAL COWS AND HEIFERS ON OVSYNCH AND FIXED TIME ARTIFICIAL INSEMINATION IN THE SOUTHERN RANGELANDS OF KENYA

Abstract

Conception rates of pure and crossbreed Sahiwal cows and heifers (n=414) on estrus synchronization protocol and fixed Time Artificial Insemination using frozen-thawed semen was assessed to determine the influence of bull- cow mating criteria. Cows and heifers were selected in four phases on the criteria of parity, percentage of true to type Sahiwal cattle breed, body condition score, ovarian structures and ovarian diameter. Selection of cows and heifers involved physical and record evaluation before hormonal injections and timed artificial insemination using frozen thawed semen. Sire selection was on the criteria of bull pedigree level, bull breed and semen type using either sexing agents or not. Semen was sourced from top proven Sahiwal bulls classified as either foundation, appendix or pedigree from the National Sahiwal Stud, private pastoral ranches or model farms. Conception rate averaged 61% and was higher among cows (P <0.05) than heifers (72% versus 54%), second parity cows (76%) than first parity (69%) or third parity cows (66%), and for sexing agents treated semen (94.7% for heifer-plus and 85.7% for bull-plus) than untreated semen (61.9%). However, conception rates decreased with increasing Sahiwal blood levels (66.9%, 67.2%, 61.0% and 52.3% for blood levels <25%, 50%, 75% and >75%) and with Sire upgrade class (69.3% at foundation, 72.7% at appendix and 47.2% at pedigree). These results imply that in Sahiwal upgrading breeding programs, higher conception rates can be attainable with early parity cows, sires of foundation and appendix upgrading classes and with sexed semen. Therefore, these are important mating criteria to mainstream in extension advisory service promoting estrus synchronization protocols and fixed Time Artificial Insemination in Sahiwal upgrading breeding program in the rangelands.

4.1 Introduction

In the pastoral rangelands, exposure of cattle to high environmental temperatures, high disease incidences, feed and water scarcity and seasonal rainfall should be important consideration in the choice of adaptable breeds. The indigenous cattle breeds predominating the pastoral rangelands and are utilized for livelihoods and incomes include Small East African zebu, Boran and Sahiwal cattle breeds. Though the indigenous cattle breeds are adapted to pastoral production systems, several studies have reported low reproductive performances in

Arid and Semi-Arid Lands (ASALs). This often lead to production and economic loses especially amongst pastoral households (Kanuya *et al*., 2006; Segura Correa *et al*., 2017). Sahiwal cattle utilised as pure or crossbreed has proven as exception. The breed is attracting greater preference as adaptive breed with potential for higher production (milk and meat), fertility, and higher tolerance for heat load, feed scarcity and disease infections. Theses stresses are prevalent in the pastoral rangelands (Ilatsia *et al.*, 2011; Mwacharo & Rege, 2002).

Because of their good adaptive capacities, Sahiwal breed has been used in cross breeding programs with the local small East African zebus to attain higher productive and reproductive performance. Cross breeding has been achieved either with the use of superior community Sahiwal bulls or with frozen-thawed semen in artificial insemination during planned breeding programs. Furthermore, development agencies are supporting the use of OvSynch and fixed TAI using frozen-thawed semen to increase access to superior genetic resources in the southern rangelands of Kenya (Kebebe *et al*., 2017). Combined use of estrus synchronization and artificial insemination is a reproductive technology that can accelerate genetic improvement for in the cattle herd (Saha *et al*., 2014).

There are several indicators to measure success rates of reproductive performances of dairy herds of which conception rates (CR), estrus detection and pregnancy loss are more informative (Chebel *et al*., 2004). Conception rate is a reproductive performance measure of the fertility of cattle at service and indicates the number that conceives successfully out of those that were served and conception status ascertained (Potdar *et al*., 2016). Several intrinsic and extrinsic factors have deleterious effects on successful conception of cows upon artificial insemination. These include the reproductive health of the cow, semen quality, animal husbandry (proper nutrition, disease control measures and housing); and efficient use of reproductive technologies. These factors either individually or in combination with poor heat detection skills and timing of insemination among farmers, have considerable influence on the success of AI programs (Jemal & Lemma, 2015).

Attaining high conception rates in pastoral herd is an important factor for uptake of assisted reproductive technologies, especially when investing in OvSynch and fixed TAI. Successful conception with this technology has implications for sustainable utilisation of Sahiwal genetic resources under pastoral production systems. Conception successes of cows and heifers may be enhanced with evaluations of the physical characteristics and performance history of the animals before insemination. This evaluation is a precaution to ascertain health status, pedigree level, body condition and ovarian activity, to inform matching of best bulls and cows that would produce best performing offspring calves. However, the extent to which the

bull-cow mating criteria influences conception rates is a knowledge gap because literature on this is scanty especially while undertaking Sahiwal cattle upgrading programs in pastoral herds. This necessitates generating empirical evidence to better inform mating decisions in Sahiwal breeding programs that delivers best bull-cow combinations to produce superior progeny calves.

Towards bridging this knowledge gap, the study sought to evaluate the influence of bull-cow mating criteria on conception success rates in Sahiwal cows and heifers under OvSynch and fixed TAI using frozen thawed semen in pastoral production systems. In this study, Sahiwal cows and heifers were of both pure and crossbreds.

4.2 Materials and methods

4.2.1 Study area and data source

Section 3.2.1 and Figure 3.1 of this thesis presents a detailed description of the study area and a map of the location in the Southern rangelands of Kenya. The study herds were participants in Sahiwal cattle upgrading breeding program utilizing OvSynch and fixed TAI, implemented in a 5-year community insemination program. The implementation was under Dairy Genetics Project supported by the Government of Kenya through National Research Fund (NRF/1/MMC/370) and led by Kenya Agricultural and Livestock Research Organization (KALRO). The program database complemented with individual cattle records from the field provided the data relating to bull-cow mating criteria and conceptions success rates observed in pastoral herds.

4.2.2 Evaluation of cows and heifers for mating decisions

The insemination program identified six hundred and ten (610) cattle comprising 336 heifers and 274 cows available for upgrading breeding using top proven bull semen. Prior to insemination, these cows and heifers were evaluated on physical characteristics and historical performance basing on herd owners recall data. The evaluation criteria ensured that a selected cow or heifer was from clinically healthy, of good body condition score (BCS); known percentage of Sahiwal blood level; and of known parity, normal reproductive organs as well as clear estrus signs at the time of estrus event (Plate 4.1a). Body condition score described by Hady *et al*. (1994) was adopted in which scoring is on a 5-point scale (1= emaciated to 5=obese).

Animals with body condition scores of 2 to 4, qualified for being mated while those scoring 1 or 5 were disqualified from the insemination program on the account that their general

nutritional and health status would influence the ultimate conception and pregnancy rates. This is on the basis that under poor nutrition, suckling cows tend to sacrifice their energy requirements to feed their calves leading to a poor body condition score (Segura Correa *et al*., 2017). On the contrary, over conditioned cows and heifers tend to have more fat deposits that affect their normal estrus and reproductive performance.

Cows within first to third parity were preferred over those that were above four, for possibilities of low conception rates. This was based on the hypothesis that cows in earlier parity has a higher likelihood of achieving higher conception rates than those in later parity above 5, majority of which could be culling candidates. Besides this, cows and heifers that had higher percentage of Sahiwal blood from visual evaluation were preferred for upgrading to produce pure Sahiwal breed off-springs.

4.2.3 Estrus synchronization

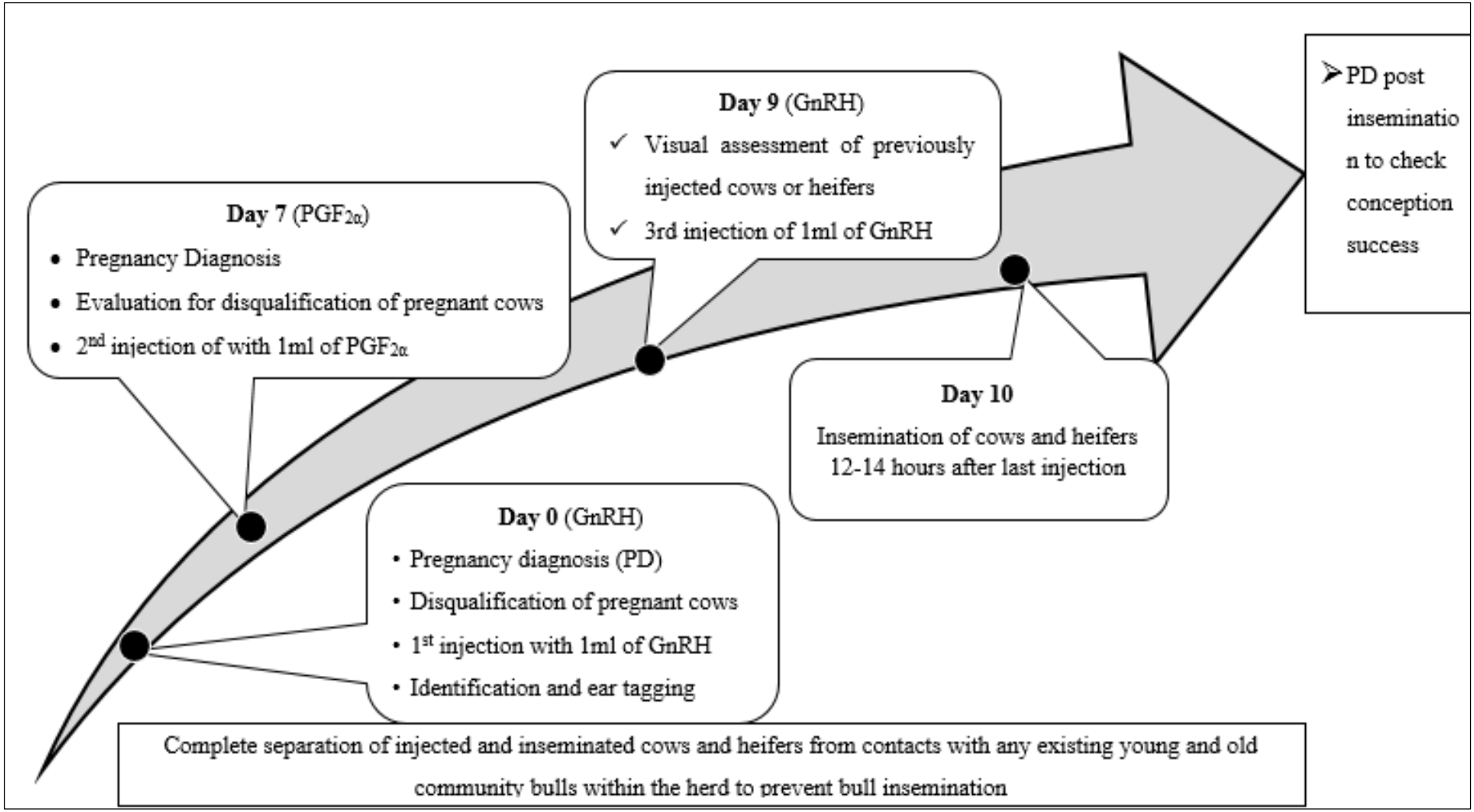
Selected cows and heifers were confined in community cattle crushes (Plate 4.1b) within the study areas prior to initial pregnancy diagnosis by rectal palpation. Experienced veterinarian undertook the pregnancy diagnosis to ascertain the reproductive physiological status. The veterinarian identified, marked and disqualified cows and heifers with reproductive disorders. Prior to this, visual assessment and body scoring ensured selection of only healthy cows and heifers with no reproductive disorders underwent pregnancy diagnosis. Results of the pregnancy diagnosis on ovarian structures and ovarian diameters were recorded for each selected cow and heifer for further reference and analysis. At this point, the program disqualified cows and heifers that were pregnant or did not meet the set requirements while retained successful ones for subsequent hormonal injections.

From pregnancy diagnosis results, retained cows and heifers were later subjected to reproductive hormonal injections for observable estrus manifestation prior to insemination. Initial hormonal injection on day 0 involved 1 ml of Gonadotrophin Releasing Hormone (GnRH) presented as gonabreed injection (Plate 4.1c) containing sodium cloprostenol 25 µg/ML (Papich, 2016). Individual cow or heifer identification by ear tagging immediately followed the initial injection and subsequent recording done in the program database. Day 7 comprised a second follow up injection using 2 ml of prostaglandin ($PGF_{2\alpha}$) at almost the same time as the first injection. Each dose of $PGF_{2\alpha}$ presented as estroplan injection, contained sodium cloprostenol at 500g/ML (Papich, 2016). Again, identified pregnant cows and heifers from bull inseminations were disqualified from further hormonal injections. Day 9 comprised

a third and final injection of 1ml of GnRH to the initially injected cows and heifers prior to artificial insemination.

Plate 4.1: Illustration of; (a) pastoral herd selection of cows and heifers for insemination; (b) confinement of cows/ heifers in cattle crush for hormonal injections; and (c) types of hormonal injections (GnRH and PGF2α) used during the breeding program for synchronization processes

After each subsequent injection, the herd owners ensured complete separation of the treated cows and heifers from any existing community or individual bulls for fear of bull insemination. Figure 4.1 describes detailed procedure of the synchronization process as undertaken during the community based upgrading program using frozen thawed Sahiwal semen. Each injection comprised 1 ml of GnRH and 2 ml of prostaglandin $PGF_{2\alpha}$ on subsequent days.



PD- Pregnancy Diagnosis, GnRH- Gonadotrophin Releasing Hormone, $PGF_{2\alpha}$- prostaglandin

Figure 4.1: Field procedures undertaken on selected cows and heifers during the OvSynch and fixed TAI in Trans Mara West sub-county

4.2.4 Artificial insemination of synchronized cows and heifers

The community insemination program was undertaken in four phases covering various years and months as indicated in Table 4.1.

Table 4.1: Summary of the insemination period and number of cattle inseminated

Program Phase	Year	Month	Dates	Number of cattle inseminated
1	2018	May	18^{th} - 21^{st}	146
2	2018	September	17^{th} – 20^{th}	82
3	2019	April	26^{th} – 28^{th}	99
4	2020	December	10^{th} – 15^{th}	162
Total				489

The program used two types of semen (untreated ordinary and treated semen), sourced from the National Sahiwal Stud herd, private ranches and model farms; and comprised different types of bull semen (differing in ejaculate sources and batch numbers). The untreated ordinary semen comprised of frozen thawed semen previously extracted from top proven superior bulls, preserved in liquid nitrogen and inseminated without any additive (commercial sexing agents). The treated semen comprised frozen thawed bull semen with added commercial sexing agents - heifer plus (AH+) or bull plus (BB+), targeting heifers and bull calves respectively.

The selected breeding program used the sexing agents to mimic the attributes associated with use of sexed semen. The study did not use sexed semen because of being expensive relative to the cost of accessing sexing agents. Of importance was the ability to skew the sex ratio of the entire calves towards a particular sex compared to use of untreated semen. The underlying hypothesis was that using sexed semen during insemination would result to a 25% increased chance of getting a male or female calf than when unsexed semen was used.

The confined synchronized cows and heifers not previously inseminated by any community bull were presented for artificial insemination using thawed frozen semen within 12- 14 hours after the last hormonal injection. The mating was based on an evaluation criterion designed such that better performing sires from performance records were mated to good body conditioned, higher Sahiwal blood, younger cows and heifers in order to obtain high genetic quality offspring calves. The AI program disqualified cows and heifers exposed to community or individual bull insemination prior to the set AI date and their records noted in the database. In addition, further elimination involved cows or heifers that failed the physical and historical record evaluation criteria. These animals had abnormal virginal discharges and signs, hence

not selected for hormonal injections and subsequent AI. Insemination was by four experienced inseminators. Cows and heifers were inseminated using frozen-thawed semen of 15 sires differing in levels of upgrading (Foundation, Appendix, and Pedigree) obtained from either nucleus Sahiwal herds in National Sahiwal Stud (NSS) or commercial private ranches. Frozen semen from Sahiwal bulls preserved in liquid nitrogen at -195°C, was thawed at 35°C -37°C and some mixed with sexing agents (heifer plus and bull plus) warmed at 35°C -37°C to prevent cold shock to the semen.

Inseminators used recto-vaginal AI technique to inseminate qualified cows and heifers confined in community cattle crushes 12 to 14 hours after the last hormonal injection (Plate 4.2). Information corresponding to insemination (cow tag number, bull semen type, and upgrading level), was recorded against individual cow or heifer details within the database. An experienced veterinarian undertook pregnancy diagnosis using rectal palpation method 90 days post insemination to ascertain conception status (success or failure) and the outcomes recorded against corresponding cow or heifer details.

Plate 4.2: Semen thawed artificial insemination process in selected cows confined in community crushes in the view of pastoral herd owner

4.2.5 Conception outcomes

Data on conception success status following first service insemination were approximated using foetal age and those coming back to heat recorded from results of the pregnancy diagnosis (PD) 90 days post insemination. Through rectal palpation, an experienced veterinarian undertook pregnancy diagnosis, to ascertain the reproductive status of the inseminated cows and heifers based on cyclic activity, pregnancy, possible reproductive diseases and infections. Compared to other pregnancy diagnosis procedures, rectal palpation was preferred in this case due to its convenience at field level (pastoral rangelands), relatively

cheap, wide use and vast experience in protocol by the veterinarian. The data clerk recorded PD results of each cow or heifer against corresponding entry for identification. The veterinarian further rechecked non-pregnant cow(s) for complications and later rescheduled them for subsequent hormonal injections and inseminations. The program considered inseminated cows or heifers that did not conceive after second and successive inseminations as repeat breeders, and therefore disqualified from the breeding program.

4.2.6 Data analysis

Table 4.2 provides a summary of the number of heifers and cows used during the insemination program. Six hundred and ten (610) cattle comprising 336 heifers and 274 cows, were selected for mating to upgrade Sahiwal of which 489/610; 80.2% comprising 269 heifers, 220 cows) were inseminated and conception status for 414 (238 heifers, 176 cows) ascertained. A large part of the inseminated cows and heifers could not be accounted for, 121 (31 heifers, 44 cows), the exits being death, theft, loss or sale during subsequent herd monitoring.

Table 4.2: Summary of cattle insemination data available for analysis

	Heifers	**Cows**	**Total**
Number selected for insemination	336	274	610
Number inseminated	269	220	489
Number unaccounted for	31	44	121
Conception status ascertained	238	176	414

The collected field data was edited, sorted and cleaned in Microsoft Excel spreadsheet. The data was then transferred to Statistical Packages Social Sciences (SPSS) version 26 for subsequent descriptive analysis. Conception rate (CR) was calculated as a ratio of total number of confirmed conceptions against total number of conceptions ascertained by rectal palpations 90 days' post-insemination using frozen-thawed semen as presented in equation 4.

$$Conception\ rate\ (CR) = \left(\frac{Total\ number\ concieved}{Total\ number\ of\ conceptions\ \ ascertained} \times 100\right) \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Significant relationship between conception rates and mating criteria was investigated in logistic regression fitted in generalized linear model procedure in Statistical Analysis Systems version 9.0 (SAS, 2009). The statistical model considered conception status as a binary dependent variable (0= Not conceived, 1=conceived,) with the mating criteria being the predictors. The cow mating criteria were parity, % Sahiwal blood, body condition score, ovarian structures and ovarian diameter while sire mating criteria were bull pedigree and semen

type. Multicollinearity was examined on the basis of the magnitude of correlation coefficients (≥ ± 0.7) to retain only non-correlated variables in the model specified in the form;

$$Conception\ Rate = \beta_0 + \beta_1 Parity + \beta_2 \%Sahiwal + \beta_3 BCS + \beta_4 Ovarstructures + \beta_5 OvariDiameter + \beta_6 Pediglevel + \beta_7 Semen\ Type \ldots\ldots(5)$$

4.3 Results

Overall conception rates

Table 4.3 presents the frequency outcomes for conception rates (%). The average conception rate (CR) was 61% and was higher among cows (*P* <0.05) than heifers (72% versus 54%), second parity cows (76%) than first parity (69%) or third parity cows (66%), and for sexing agents treated semen (94.7% for heifer-plus and 85.7% for bull-plus) than untreated semen (61.9%). However, CR decreased with increasing Sahiwal blood levels (66.9%, 67.2%, 61.0% and 52.3% for blood levels <25%, 50%, 75% and >75%) and among those with body condition score of 2 and 3 compared to those scoring 4 (towards being over conditioned). Higher conception rates was recorded among foundation (69%) and appendix (73%) sire upgrade classes relative to pedigree upgrading class.

Table 4.3: Frequency outcomes for conception rates (%)

Factor	Level	Conceived n (%)	Not conceived n (%)	Pooled n (%)
Dam class	Heifers	128 (53.8)	110 (46.2)	238 (57.5)
	Cows	126 (71.6)	50 (28.4)	176 (42.5)
	Overall	254 (61.4)	160 (38.6)	414 (100)
Production System	Nomadic	169 (63.3)	98 (36.7)	267 (64.5)
	Agro-pastoralism	51 (70.8)	21 (29.2)	72 (17.4)
	Ranching	34 (45.3)	41 (54.7)	75 (18.1)
Parity	Heifers	128 (53.8)	110 (46.2)	238 (57.5)
	First calvers	59 (69.4)	26 (30.6)	85 (20.5)
	Second calvers	51 (76.1)	16 (23.9)	67 (16.2)
	Third calvers	16 (66.7)	8 (33.3)	24 (5.8)
Body Condition Score (BCS)	2	45 (75.0)	15(25.0)	60 (14.5)
	3	208 (60.1)	138 (39.9)	346 (83.6)
	4	1(12.5)	7 (87.5)	8 (1.9)
	<25	99 (66.9)	49 (33.1)	148 (35.7)

Sahiwal blood level (%)	26-50	41 (67.2)	20 (32.8)	61 (14.7)
	51-75	47 (61.0)	30 (39.0)	77 (18.6)
	>75	67 (52.3)	61 (47.7)	128 (30.9)
Sire upgrade class	Foundation	192 (69.3)	85 (30.7)	277 (67.1)
	Appendix	8 (72.7)	3 (27.3)	11 (2.7)
	Pedigree	59 (47.2)	66 (52.8)	125 (30.3)
Semen type	Ordinary	236 (61.9)	145 (38.1)	381 (93.6)
	AH+	18 (94.7)	1 (5.3)	19 (4.7)
	BB+	6 (85.7	1 (14.3)	7 (1.7)

Of the analysed cow characteristics, significant differences (P <0.005) observed with conception success rates were parity number and body condition score. The pedigree of the Sahiwal, the ovarian structure and diameter showed insignificant influence (P >0.005) (Table 4.4).

Table 4.4: Summary results of cow characteristics on the insemination conception rates

Cow criteria	**No. of animals (n)**	**1st insemination CR (n) %**	**Chi Square statistics**
Parity number			14.529***
Heifers	238	98 (41.1)	
First calvers	85	59 (69.4)	
Second calvers	67	51 (76.1)	
Third calvers	24	16 (66.7)	
(%) Sahiwal blood level			7.183 NS
<25	148	99 (66.9)	
26-50	61	41 (67.2)	
51-75	77	47 (61.0)	
>75	128	67 (52.3)	
Body Condition Score			12.988***
2	60	45 (75.0)	
3	346	208 (60.1)	
4	8	1 (12.5)	
Ovarian structures			6.917NS
Corpus Albicans	99	63 (63.6)	

Corpus Luteum	52	32 (61.5)	
Corpus Hemorrhagicum	1	1 (100)	
Cyclic	3	0 (0.0)	
Follicles	257	156 (60.7)	
Not cyclic	2	2 (100)	
Ovarian diameter (cm)			5.500 NS
0.5	33	19 (57.6)	
1.0	116	75 (64.7)	
1.5	39	21 (53.8)	
2.0	112	64 (57.1)	
2.5	62	42 (67.7)	
3.0	27	19 (70.4)	
3.5	18	11 (61.1)	
4.0	7	3 (42.9)	

NS- not significant, * P <0.05, ** P <0.005, *** P <0.001

Of the examined sire mating criteria, only sire upgrade class and semen type had significant differences on the CR (P <0.005). Foundation and appendix upgrade classes recorded 22% and 26% higher CR respectively than the pedigree classes. Semen types treated with sexing agents ((Heifer plus (AH+) and Bull plus (BB+)) had a 33% and 24% higher CR than the ordinary (untreated) semen (Table 4.5).

Table 4.5: Effect of sire characteristics on 1st insemination conception rates of pastoral herd

Sire criteria	**No. of animals (n)**	**1st insemination CR (n) %**	**Chi Square statistics**
Sire pedigree class			18.498***
Foundation	277	192 (69.3)	
Appendix	11	8 (72.7)	
Pedigree	125	59 (47.2)	
Semen type			9.907**
Ordinary	381	236 (61.9)	
AH+	19	18 (94.7)	
BB+	7	6 (85.7)	

NS- not significant, ** P <0.005, *** P <0.001

In Table 4.6, the logistic regression results show that cow parity, pedigree level and sire semen type had significant influence on conception outcome (P <0.05). Insignificant contributions were recorded from body condition score, ovarian diameter, ovarian structures and % true to type Sahiwal cattle amongst the cow characteristics while bull breed was insignificant amongst the analysed sire characteristics.

Table 4.6: Logistic regression results showing cow and bull influence on conception rates

Mating criteria	**Parameter estimate**	**Chi Square statistic**
Intercept	-1.2266	0.53
Cow Characteristics		
Parity	0.3517	5.62*
Body Condition Score	-0.4577	1.65^{NS}
Ovarian Diameter	0.1418	0.96^{NS}
Ovarian Structures	0.1397	1.21^{NS}
% Sahiwal Blood	0.1115	1.18^{NS}
Bull Characteristics		
Bull Pedigree level	0.4610	12.41**
Semen Type	1.2478	4.33*

NS- Not significant, *P <0.05, ** P <0.005, *** P <0.001

4.4 Discussion

Conception rate is a key indicator of fertility in a dairy herd relating to the potential for sustainable herd replacement, profitability and progress in breeding improvement (Segura Correa *et al*., 2017). The present study assessed conception success of Sahiwal cows and heifers subjected to OvSynch and fixed TAI using thawed frozen semen. Pregnancy diagnosis through rectal palpation 90 days post insemination indicated that an average conception rate attainable was moderately high (61%) but with a large variation; 53.8% to 72%. The large variation was observed despite cows and heifers inseminated having been subjected to similar husbandry in feeding practices in extensive pasture grazing with mineral supplementation on offer. Possibly, this could be partly explained by intrinsic cattle related factors including differences in physiological and vital functions such as maintenance, growth and production within the animal's body that have direct influence on estrus manifestation. Arguably, the use of OvSynch and fixed TAI aided in improving fertility status of cows through proper estrus manifestation and timed AI for increased conception rates among the cows and heifers.

This level of conception is very comparable to 62% that Saha *et al*. (2014) obtained, and is within range (67% to 72%) previously obtained from AI insemination in cattle (Bhattacharyya *et al*., 2010; Howlader *et al*., 2019; Sharifuzzaman *et al*., 2015). While these authors reported conception rates obtained from cows confined in research centres with functional adequate follow up mechanisms, the present study was in a pastoral set up where a follow up of all the inseminated cows was challenging. Evidence of a challenge also in this study is a large part (121/414; 29.2%) of inseminated cows and heifers that could not be accounted for in the subsequent herd monitoring.

The observed higher conception rate demonstrates that hormonal synchronization (gonadotropin-releasing hormone and Prostaglandin F2α (GnRH and PGF2α)) prior to fixed TAI, can improve fertility performance amongst pastoral cattle herds. The findings corroborates observations of Bruno *et al*. (2013) and Dewey *et al*. (2010) who also reported increased fertility status among lactating dairy cows. With OvSynch and fixed TAI, 16% more conceptions were realised relative to bull insemination (61% versus 45%). In pastoral herds, bull insemination is the practice due to accessibility and affordability (Segura Correa *et al*., 2017). This result has practical implications for breeding improvement targeting Sahiwal upgrading programs within pastoral rangelands of Kenya. Cattle upgrading programs utilizing OvSynch and fixed TAI, provides a technology option for increasing accessibility to superior Sahiwal bull semen and improved conceptions and pregnancy rates amongst pastoral herds. This can therefore be used in increasing the herd sizes and improving the genetic potential of pastoral herd.

In addition to improved accessibility and reproductive performances, enhancing capacity in effective estrus detection and AI timing is needed to realise high reproductive performance for producing quality replacement stock and potentially improving herd profitability while accelerating genetic improvement (Ojango *et al*., 2016). Higher conception rates through use of OvSynch and fixed TAI, opens up opportunities for private sector participation in service and input delivery to pastoral herd owners in the rangelands. This opportunity will be realised with supportive policy interventions to attract private investments and to ensure quality standards in the service delivery.

Results show that parity of the cow is an important criterion in mating decision to consider for attaining high conception success. Conception rates were higher at early parity (first and second: 69% to 76%) than at later parity (third: 66%). This phenomenon has been observed, for instance Bhattacharyya *et al*. (2010), Gebremichael (2015), Miah *et al*. (2004), and Segura Correa *et al*. (2017), have all reported a pattern of recorded increased conception

rates as heifers transited to second and subsequent advanced parity. This has been explained as differences between heifers and cows in vital functions for maintenance and growth, which are likely more pronounced under pastoral production system (Bodmer *et al*., 2005). Managerial intervention may improve conception success in heifers through coordinated service delivery that ensures improved sensitization and good husbandry practices

Evidence in this study suggest that while parity is important criterion in cow mating decision, for sire it is the upgrading level and semen type that are of importance. Knowledge of sire pedigree require good record keeping while AI with treated semen require investment in relevant infrastructures. These are conditions to support uptake of record keeping and AI services, if such breeding intervention is to benefit pastoral herds. It should as well be acknowledged that unique identification of progenies is critical. This is so as to accurately trace their respective pedigrees and link the performance of individual animals to their progenies and relatives through known genetic relationships. Combining performance and pedigree records, enable more accurate computation of breeding values for the herds and used for making selection and mating decisions.

Interests in upgrading towards pure Sahiwal is increasing among pastoral herd owners for increased herd productivity. Sustaining this breeding practice will need reliable supply of quality breeding stock, of which improving the delivery of reproductive technologies will be of importance in pastoral herds. In this study, higher conception rates was obtained with the foundation upgrade level (69%) relative to pedigree upgrade level (47%). The findings corroborates with those of Gebremichael (2015) in Northern Ethiopia that bull pedigree has influence on conception success, but are contrasting to those of Bhattacharyya *et al*. (2010), Miah *et al*. (2004), and Saha *et al*. (2014), that bull pedigree has insignificant influence on conception rates.

Chongsi *et al*. (2019) reported insignificant influences of the sexing agent on conception rates with heifer plus (AH+) on tropical dairy breeds grazed on pastures in Cameroon. This is a departure from the present findings that are indicating 24% and 33% higher conception rates compared to untreated ordinary semen. For the current study, a likely explanation is the flow cytometer principle that triggers increased mortality rate of spermatozoa bearing either X or Y chromosome to achieve a particular sex. This therefore, indicates the usefulness of using either heifer plus AH+ or bull plus BB+ in cattle breeding programs. This is what has been observed with beef cows and heifers on treated semen with fixed TAI in the United States of America (Perry *et al*., 2020). It has implications that fertility status of Sahiwal cows and heifers could be increased by utilizing sexing technologies and improving on animal

husbandry practices. In genetic improvement (selection) programs, this means that cattle upgrading need to be bundled with capacity building of herd owners, enhanced last mile extension service delivery and greater private sector participation in artificial semen delivery for efficiency.

4.5 Conclusion

The analysis sheds lights into possible application of OvSynch and fixed TAI using frozen-thawed semen in Sahiwal upgrading breeding programme. Cows and heifers achieve good conception rates particularly when mating cows of second and third parity with sexed semen from bulls in foundation upgrading class. These results imply that in Sahiwal upgrading, higher conception rates can be attainable with early parity cows, sires of foundation and appendix upgrading classes and with sexed semen. Therefore, these are important mating criteria to mainstream in extension advisory service promoting OvSynch and fixed Time artificial insemination in Sahiwal upgrading breeding program in the rangelands.

CHAPTER FIVE

PREFERENTIAL USE OF SAHIWAL BULL CALVES BY BENEFICIARIES OF OVSYNCH AND FIXED TIME ARTIFICIAL INSEMINATION IN SOUTHERN RANGELANDS OF KENYA

Abstract

Bull service is the most common insemination method in pastoral herds grazing in the rangelands. To accelerate multiplication, distribution and access to high quality Sahiwal genetics to pastoral communities, development agencies have promoted the use of estrus synchronization protocol and fixed time artificial insemination in the Kenyan rangelands. However, sustainable use of this breeding technology is uncertain because pastoral herd owners attach high value to progeny bull calves of high genetic merits for breeding, which is a potential barrier to technology adoption. This study assessed preferential use of progeny bull calves among beneficiaries of the Sahiwal cattle upgrading breeding program utilizing OvSynch and fixed time artificial insemination in the southern rangelands of Kenya. Preferential use of bull calves was assessed in a choice experiment basing on attributes associated with potential use of bull calves. Overall, the first-choice preference was to retain the bull calves for future breeding (54%) compared to immediate selling for income (44%). This was the first-choice preference for pastoralists and agro pastoralists unlike ranchers who preferred selling bull calves for income compared to retaining for future breeding (80% versus 20%). The preference of retaining progeny bull calves for future breeding was higher among women compared to male respondents (59% versus 51%). Second choice preferences were sales for income (58%), breeding (29%), draft power (5%), meat production and cultural practices (3% each) and prestige (2%). Socio-economic factors had no significant influence on preferential use of progeny bull calves. The results indicate that high genetic merit bull calves are preferred for breeding, implying that bull calves would be retained within the pastoral herds for bull service. This presents a possible barrier to adoption of OvSynch and fixed time artificial insemination in pastoral herds for upgrading of Sahiwal cattle breed. Policy direction is to invest in Sahiwal multiplication and distribution of bull calves to pastoralists and agro pastoralists. Ranchers have low preference for retaining bull calves for breeding, so it would be best to capacitate them to invest in OvSynch and fixed time artificial insemination to multiply breeding bulls and supply to pastoralists and agro pastoralists.

5.1 Introduction

Pastoralism is a land use based livelihood oriented to securing livestock assets. It entails adapting to marginal environments characterized by climatic variability and uncertainty, degraded resources and continuous strategic mobility in search of pastures, water and mineral licks while confronting insecurity and conflict (Hatfield *et al.*, 2006; MoALF&I, 2019; Sarzana et al., 2022). Bull service is the traditional breeding method in these pastoral cattle herds, communally grazed extensively in marginal lands (Rege *et al.*, 2001). Sahiwal cattle is a popular dual purpose breed and herd owners use bulls sourced from either National Sahiwal Stud in Naivasha, private ranches or model farms for mating (Mbuku *et al.*, 2019).

However, these sources of breeding bulls are unable to meet the increasing high demand for quality Sahiwal bulls. Alternative sources of Sahiwal breeding bulls include community bulls, purchased culled bulls from other cattle ranches and model farms, but these sources have been disappointing to pastoral herd owners (Muhuyi *et al.*, 1999). The disappointments include low conception rates, transmission of diseases, injuries to young heifers and cows and limited selection choices. Confronted with unviable options, pastoral herd owners have continued to mate with own or community breeding bulls mostly while open grazing in the vast rangelands pastures (Rege *et al*., 2001).

In responding to the high demand for quality breeding Sahiwal bulls, development agencies are promoting OvSynch and fixed TAI, to accelerate multiplication and distribution of quality proven Sahiwal bulls (Khainga, 2015; Kebebe *et al.*, 2017). The objective is to multiply and distribute high quality Sahiwal genetics using OvSynch (hormonal injections) and fixed time artificial insemination through use of frozen-thawed semen. In a previous study, Khainga (2015) and the cross-sectional survey respondents demonstrated the willingness of pastoral herd owners to pay for AI as opposed to use of bull services, to continue accessing superior Sahiwal genetic materials for upgrading purposes. Though willingness to pay indicates acceptance and adoption of OvSynch and fixed TAI by herd owners, it is uncertain whether the technology can replace use of bull services. The Maasai community traditionally have a strong cultural and social prestige and preference for use of bull calves, especially progenies of high genetic merit Sahiwal cattle could impede uptake of OvSynch and fixed TAI. This a potential adoption barrier to the technology which can accelerate multiplication and distribution of -and access to- high quality Sahiwal genetics. Assessing the preferential use of progeny bull calves amongst project beneficiaries utilizing OvSynch and fixed TAI is necessary to provide insights and inform targeted breeding and conservation programs, development projects and policy interventions suited to pastoral circumstances.

Rearing on-farm breeding bulls has costs implications, which require that herd owners make informed economic decision in the transition from bull service to use of OvSynch and fixed TAI in pastoral breeding programs. Preferences of progeny bull calves can be assessed using choice experiment method. Amongst the various preference approaches, choice experiment method is widely advocated for. It enables evaluations of tradeoffs for various components (attribute level) of a good or service rather than the good or service *per se*. This is achieved by allowing the respondents to express preferences over a variety of attribute levels (Hanley *et al.,* 2001; Otieno *et al.,* 2011).

Previous studies have used choice experiment methods in evaluating farmers' preferences. For instance; in assessing livestock population control policy (Pan *et al.,* 2016), livestock pollution control policies (Schulz *et al*., 2014) and type of disease free zones (Otieno *et al*., 2011). Though farmers adopt new technologies based on expected economic returns (Adenuga *et al.,* 2020), pastoralists in contrast have other intangible benefits important to them that need consideration. These include social status, insurance during harsh economic times, wealth, cultural practices amongst others. When using bull calves, these intangible benefits could be of substantial value of as well as the value of tangible benefits from products (meat, milk), and income. In this case, evidence based information on preferences (tangible or intangible), is of importance in management decisions to adopt or not to adopt OvSynch and fixed TAI for own-herd breeding or multiplication purposes when delivery of quality Sahiwal genetics is the goal. This study assessed preferential use of progeny bull calves among beneficiaries of the Sahiwal cattle upgrading breeding program already utilizing OvSynch and fixed TAI in the southern rangelands of Kenya.

5.2 Materials and methods

5.2.1 Study area

The description of the study area and the map is presented in Section 3.2.1 and Figure 3.1 of this thesis. The agro ecology of the area is variable, from highlands, lowland to grasslands inhabited by the Maasai community, who were the beneficiaries of the breeding program. The selected study area had 5-year beneficiaries of the Sahiwal cattle upgrading breeding program that were utilizing OvSynch and fixed TAI in Lolgorian and Pusanki divisions. These divisions have large number of Sahiwal cattle populations that were subjected to OvSynch and fixed TAI for upgrading to superior genetics.

Livestock is the primary source of livelihood for Maasai community (Otieno *et al.,* 2011). Livestock may be reared solely under pastoralism system, integrated with cropping

under agro pastoralism or under ranching. The nomadic pastoralists seasonally migrate with their cattle herds in search of pasture, water and minerals. Overnight, cattle are restrained in cattle bomas or kraals to offer security from theft. Unlike pastoralists, the agro pastoralists integrate cattle keeping with cropping systems and frequently source external inputs from the market. Both pastoral and agro-pastoral herds graze communal pasture fields and sometimes confront insecurity and conflicts over resource use land, water, crops when they encroach private or public-protected land (Otieno *et al.,* 2011).

Ranches practice closed controlled grazing. Ranchers operate purely commercial livestock enterprises and integrate fodder crops for livestock feeding. Surplus fodder may be sold in some seasons. Ranch herds are either for both breeding and growing stock or fattening stock (Otte & Chilonda, 2002). Pastoral, agro pastoral and ranches are likely to differ in their preferential use of ARTs bull calves.

5.2.2 Analytical framework

The analytical framework for Choice Experiment method followed the Lancaster model theory of consumer choice. It adopted the provision for the attributes or characteristics of goods that provide people with utility rather than the goods themselves (Lancaster, 1966). The analysis followed the behavioral framework of random utility theory, which describes choices in a utility maximizing framework (McFadden & Train, 2000; Otieno *et al.*, 2011). Furthermore, it is concerned with people's choices, decisions, preferences and judgments of a goods' worth, value or a number of similar attractiveness. The theory is based on individual's preference –indifference relation for a given set X of choices x, y and z usually interpreted as decision alternatives (Khainga, 2015). For instance, if x is preferred to y, and y is preferred to z, then x is preferred to z hence the pastoral herd owner's preferential use of progeny bull calve can be explored within utility context.

The analysis deployed the random parameter logit (RPL) model. Each respondent (pastoral herd owner), was presented with a series of choices on probable use of progeny bull calves from which they had choose from. Thus, the alternative that the respondent faced in a particular choice comprised the probable use based on key design attributes. The attribute of alternative i in a particular preferential choice occasion t faced by the respondent n are collectively labelled as vector X_{int}. Therefore, the utility obtained by individual n from alternative i in choice situation t is expressed as;

$$U_{int} = \beta_n X_{int} + \varepsilon_{int} \quad \text{.....(6)}$$

where; the coefficient vector for each respondent β_n is unobserved and varies in the population with a density function $f(\beta_n \mid \theta)$, whereby θ are the parameters of this distribution. ε_{int} is an unobserved random term assumed to be identically independently distributed type I extreme value. Conditional on β_n, the probability that individual n chooses alternative i in choice situation t is given by the standard MNL model (Otieno *et al.,* 2011).

5.2.3 Experimental design and statistical description

Choice attributes and level settings

This study aimed at identifying pastoral herd owners' preferences for use of progeny bull calves from OvSynch and fixed TAI utilization within their herds. The first step of this investigation was therefore to define the possible uses of bull calves within pastoral herd in terms of the associated attributes (tangible or intangible). In reference to extensive review of published and gray literature, the study identified six possible attributes associated with the use of bull calves in pastoral herd as presented in Table 5.1. The review was complemented with extensive discussions during the field interviews to obtain additional insights and clarity on possible range of choices about use of bull calves.

Table 5.1: Variables indicating possible uses and description of bull calves in pastoral herd

Variable	Description	Measurement	Sign
Breeding stock	Rearing bull calves for future mating	Categorical	+
Sales for income	Rearing bull calves to sell for income	Categorical	+
Draft use in Farming	Rearing bull calves to use as draft in farming	Categorical	+
Cultural practices	Rearing bull calves for cultural practices; sacrifices, gifts, settling disputes	Categorical	+
Meat production	Rearing bull calves, castrating and fattening to sale to butcheries	Categorical	+
Prestige	Rearing bull calves to attain social class and sign of wealth in the community	Categorical	+

5.2.4 Conceptualized framework for preferential use of bull calves

Figure 5.1 outlines the conceptualized interrelationships in preferential use of progeny bull calves from OvSynch and fixed TAI utilization by pastoral herd owners. It illustrates that the herd owners make choices among the available alternatives, and the choice of each herd owner is his or her most preferred use among the possible choices (Table 5.1).

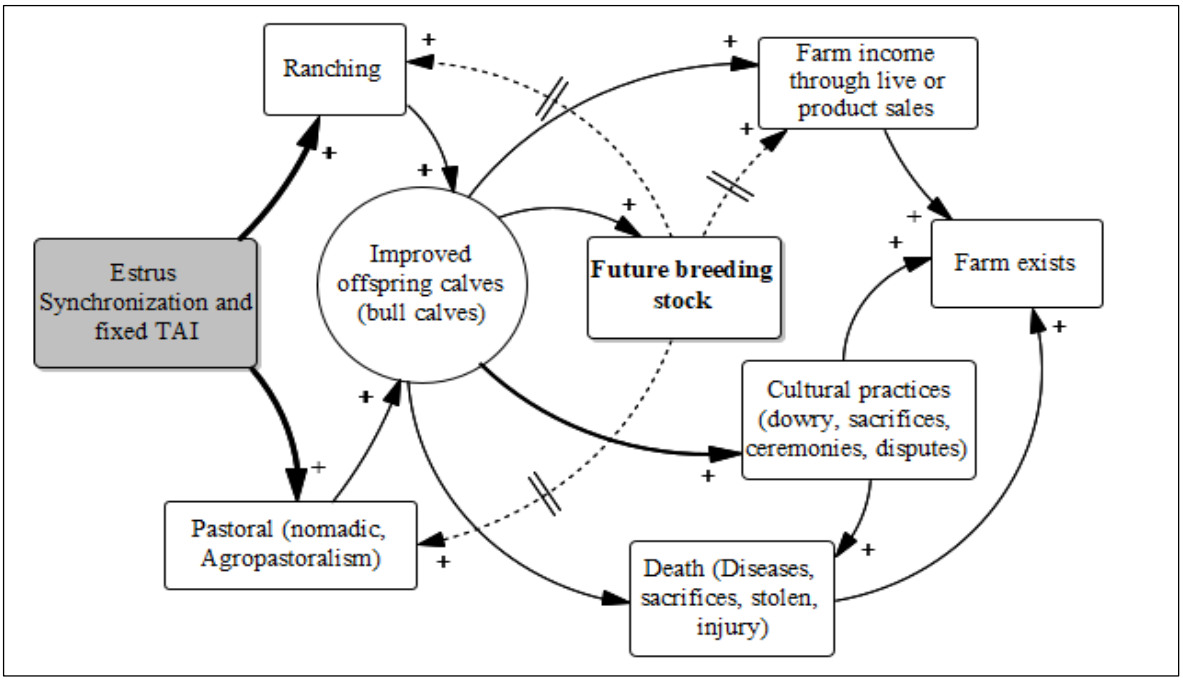


Figure 5.1: Conceptualized illustration of the probable use of progeny bull calves within pastoral herd

It is hypothesized that pastoralists prefer to retain "superior" bull calves within the herd for future breeding purposes. Under natural pasture grazing, farmers prefer to select breeding bulls among own bulls or among neighbor's bulls (Rege *et al.*, 2001). Pastoralist have adopted ways of bull exchanges amongst themselves to disseminate superior genetic resources though the strategy has a challenge of possible disease transmission and increasing inbreeding levels (Khainga, 2015). It is conceptualized that retaining improved Sahiwal progeny bull calves within pastoral herd would increase the number of superior breeding stock while selling for income would reduce the herd size through higher number of animal exits.

The immediate need for household cash usually prompt many pastoralists to sell live animals. The preference for income through sales involve conversion of progeny bull calves to cash either for profit or in settling an immediate household cash need. Commercial ranchers mostly target cattle sales to butchers, processors, institutions and retailers depending on market prices and season (Mwangi *et al.*, 2020). Selling is by auctioning in large numbers, contrasting selling just a few as practiced by pastoralists and agro pastoralists. Pastoralists usually dispose of their cattle during dry seasons when pastures and water are scarce. Though disposal of bull calves is an additional income to the owner, it ultimately reduces the overall number of cattle in the herd. Agro pastoralists practicing crop farming often use bulls as draft for farming purposes. They offer cheap sources of power for ploughing during land preparation and transporting farm inputs and products to the farms and markets. Relative to the use of

machineries and tractors, bull draft power offer cheap and reliable source that is convenient to the agro pastoralists. Use of bull calves for cultural practices may be for sacrifices during traditional ceremonies, gift to others or in settling disputes between two parties or communities. Other cultural uses are social status, sign of wealth, donations and paying dowry. Cultural uses are considered intangible benefits associated with keeping the bull calves. They contribute either positively or negatively to change in herd size and the number of bull calves in the herd.

Sampling and data collection

A full detailed description of the sample size determination and procedure are presented in section 3.2.2 of this thesis. Respondents were categorized by their production systems (nomadic, agro pastoralism and ranching) to obtain diverse views from theses differing production systems. The study incorporated the use of both primary and secondary data collection methodologies. Primary data in qualitative and quantitative measurements were obtained directly from the field using individual structured questionnaires administered through household visits and face-to-face interviews. Secondary data were collected through desk reviews mainly sourced from the County reports, program database and from internet. Prior to field data collection, a two-day enumerator training and pilot study was undertaken to equip the selected enumerators with the knowledge and skills on the contents of questions to ask. The questionnaires were designed to capture household (socioeconomic characteristics), individual and herd characteristics. The enumerators comprised Animal Health Assistants (AHAs) recruited from the local community for easy translation and recording of the responses from herd owners for analysis. Where possible, additional probing and follow-up questions were undertaken during the field visits to give deeper insights and understanding of the responses.

5.2.5 Data analysis

Both quantitative and qualitative data were subjected to cleaning in Microsoft Excel 2016 for analysis-readiness. In total 130 respondents participated in the survey. Out of these, 4 responses provided incomplete or inconsistent responses on at least one variable; the other 126 respondents provided complete and consistent responses, so these proceeded to data analysis. Statistical analysis was in two levels, descriptive and inferential. The descriptive statistics was in cross tabulations to generate frequencies subsequently subjected to chi square tests for associations. Additionally, random parameter logit (RPL) model for the choice experiment method was fitted to estimate coefficients associated with preferential use of progeny bull calves basing on attributes.

5.3 Results

Household demographics

Table 5.2 provides the characteristics of the sample herd owners. Among these herd owners, male dominated their female counterparts (65% versus 35%) with majority being middle aged (65%) and having attained basic primary education (77%). Land ownership by pastoralists and agro pastoralists was less than 50 acres for the majority (79%) while a majority of the ranchers (80%) owned over 100 acres of land. The primary livelihood source was livestock assets (74%), but livestock-keeping experience was indicated as less than 25 years. Secondary livelihood sources were mixed crop-livestock farming (24%) while opportunities in formal salaried employment were unavailable (2%).

Table 5.2: Demographic characteristics of interviewed pastoral herd owners in relation to the various production systems within the study area

			Cattle Production Systems		
			Ranching	**Nomadic**	**Agro-pastoralism**
Variable	**Level**	**n (%)**	**n (%)**		
Gender	Male	82 (65)	5 (100)	69 (65)	8 (57)
	Female	44 (35)	0 (0)	38 (35)	6 (42)
Age (years)	≤ 30	40 (32)	0 (0)	32 (30)	8 (57)
	31-60	82 (65)	4 (80)	72 (67)	6 (43)
	≥ 61	4 (3)	1 (20)	3 (3)	0 (0)
Education level	None	14 (11)	0 (0)	12 (11)	2 (14)
	Primary	70 (56)	1 (20)	61 (57)	8 (57)
	Secondary	27 (21)	1 (20)	23 (22)	3 (21)
	Tertiary	15 (12)	3 (60)	11 (10)	1 (8)
Main livelihood source	Livestock	93 (74)	4 (80)	82 (77)	7 (50)
	Mixed	31 (24)	1 (20)	23 (21)	7 (50)
	Salaried	2 (2)	0 (0)	2 (2)	0 (0)
Grazing area (Acres)	≤ 50	100 (79)	0 (0)	89 (83)	11 (79)
	51-100	16 (13)	1 (20)	15 (14)	0 (0)
	≥ 100	10 (8)	4 (80)	3 (3)	3 (21)
Livestock keeping experience (years)	≤ 25	86 (68)	3 (60)	70 (65)	13 (93)
	26-50	39 (31)	2 (40)	36 (34)	1(7)
	≥ 51	1 (1)	0 (0)	1(1)	0 (0)

Choice preferences on the perceived functions of bull calves

Figure 5.2 summarizes the first and second choices of stated preferential use of Sahiwal progeny bull calves from OvSynch and fixed TAI utilization by pastoral herd owners. For more than half (54%) of the herd owners, the stated preference was to retain the bull calves within their herds for future breeding relative to selling for income (44%) while rearing for draught power was very unpopular (2%). The stated second choice preference for the progeny bull calves was to sell for income (58%) relative to rearing for future breeding (29%), draught power (5%), meat production (3%), cultural practices (3%) or expressing prestige (2%).

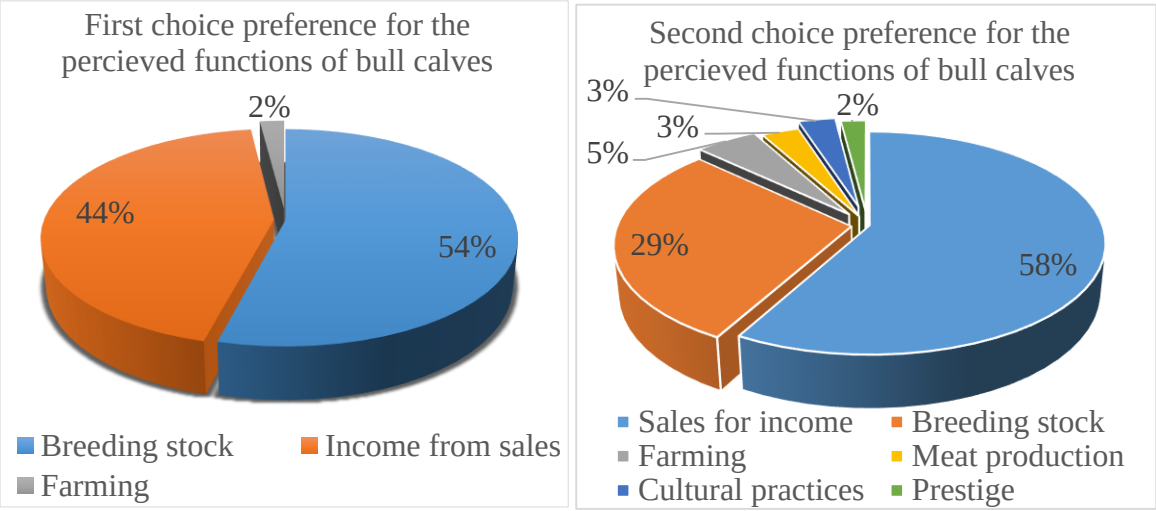


Figure 5.2: Overall results for first and second choice preferences on functions of progeny bull calves as perceived by pastoral herd owners utilizing OvSynch and fixed TAI

Table 5.3 presents the frequency distribution of stated preferences for use of ARTs bull calves by socioeconomic characteristics of pastoral herd owners in the rangelands. Female herd owners stated a higher preference to retain bull calves for future breeding as their first choice compared to their male counterparts (59% versus 51%). Retaining bull calves for future breeding was a preference for majority of herd owners who were young, under 30 years (65%) and those with secondary level education (63%). Primary livelihood sources showed no influence (P >0.05) on the preference for retaining progeny bull calves for future breeding that had a higher preference than selling bull calves for income among both pastoral and agro pastoral herd owners (50 to 56% vs 36% to 44%). Rearing progeny bull calves for draught power use in farming was unpopular among agro pastoral herd owners (14%). For ranchers, majority (80%) preferred rearing progeny bull calves for income relative to rearing for future breeding (20%).

Table 5.3: Frequency distribution for function of progeny bull calves in pastoral rangelands by socioeconomic characteristics of herd owners

Variable	Level	Perceived function of bull calves			n (%)	Chi Square statistics
		Breeding stock	Sales for income	Farming	Pooled	
Gender	Male	42 (51)	39 (48)	1 (1)	82 (65)	0.594 ^{NS}
	Female	26 (59)	17 (39)	1 (2)	44 (35)	
	Total	68 (54)	56 (44)	2 (2)	126 (100)	
Age (years)	≤ 30	26 (65)	13 (33)	1 (2)	40 (32)	0.471^{NS}
	31- 60	40 (49)	41 (40)	1 (1)	82 (65)	
	≥ 61	2 (50)	2 (50)	0 (0)	4 (3)	
	Total	68 (54)	56 (44)	2 (2)	126 (100)	
Education	None	5 (36)	9 (64)	0 (0)	14 (11)	0.100 ^{NS}
level	Primary	42 (60)	26 (37)	2 (3)	70 (57)	
	Secondary	17 (63)	10 (37)	0 (0)	27 (21)	
	Tertiary	4 (27)	11 (73)	0 (0)	15 (12)	
	Total	68 (54)	56 (44)	2 (2)	126 (100)	
Main	Livestock	51 (55)	41 (44)	1 (1)	93 (74)	0.518 ^{NS}
Livelihood	Crop-livestock	17 (55)	13 (42)	1 (3)	31 (24)	
source	Salaried employed	0 (0)	2 (100)	0 (0)	2 (2)	
	Total	68	56	2	126 (100)	
Cattle	Ranching	1 (20)	4 (80)	0 (0)	5 (4)	0.01**
production	Nomadic	60 (56)	47 (44)	0 (0)	107 (85)	
Systems	Agro pastoralism	7 (50)	5 (36)	2 (14)	14 (11)	
	Total	68 (54)	56 (44)	2 (2)	126 (100)	
Grazing area	≤ 50	57 (57)	41 (41)	2 (2)	100 (79)	0.614 ^{NS}
(acres)	51- 100	7 (44)	9 (56)	0 (0)	16 (13)	
	≥ 101	4 (40)	6 (60)	0 (0)	10 (8)	
	Total	68 (54)	56 (44)	2 (2)	126 (100)	
Farming	≤ 25	47 (55)	38 (44)	1 (1)	86 (68)	2.261^{NS}
experience	26-50	20 (51)	18 (46)	1 (3)	39 (31)	
	≥ 51	1 (100)	0 (0)	0 (0)	1 (1)	

**P <0.01, NS- Not Significant

Table 5.4 is a summary of the logistic regression coefficient estimates for socio economic factors influencing preference for use of progeny bull calves from OvSynch and fixed TAI utilization. Of the examined factors, none showed significance (P >0.05) influence on preference use of the progeny bull calves.

Table 5.4: Logistic regression coefficient estimates for socio economic factors influencing preference for functions of progeny bull calves

Variables	**Full model estimate**	***P*- Value**
Intercept	-0.492	0.706 ^{NS}
Gender	-0.052	0.847 ^{NS}
Age	0.312	0.278 ^{NS}
Education level	0.112	0.493 ^{NS}
Main Livelihood	0.159	0.489 ^{NS}
Production System	0.659	0.056 ^{NS}
Grazing Area	0.112	0.597 ^{NS}
Farming Experience	0.551	0.864 ^{NS}

^{NS} - Not Significant

5.4 Discussion

Adoption of OvSynch and fixed TAI in pastoral and ranch herds can accelerate multiplication and distribution of -and access to- high quality Sahiwal genetics. However, a potential adoption barrier is high cultural attachment to progeny bull calves of high genetic merits for breeding naturally in these herds. This study assessed preferential use of these progeny bull calves among beneficiaries of the Sahiwal cattle upgrading breeding program. Preferential use of bull calves was assessed in a choice experiment method that examined associated attributes of bull calves. The design assumed that the utility function follows a strict additive form in choosing a particular use attribute of bull calve.

Despite expressing a higher willingness to pay amount for accessing OvSynch and fixed TAI services, the survey respondents' first-choice preference was to retain bull calves for future breeding (54%) relative to selling for income (44%). Pastoralists and agro pastoralists prefer retaining bull calves for future breeding compared to selling for income (54% versus 44%) while ranchers prefer selling bull calves for income compared to retaining for future breeding (80% versus 20%). These results reveal differences between pastoralists and ranchers in values they attach to progeny bull calves. For pastoralists, progeny bull calves are for upgrading the

herd while for ranchers, they are for commercial value use. This points to pastoralists and ranchers attaching different values to progeny bull calves attributes.

The pastoralists consider owning own breeding bull, probably this is more reliable than the delivery of the OvSynch and fixed TAI services to them. This corroborates findings of Mbuku *et al.* (2019) and Mailu *et al*. (2013) that supply of breeding bulls are scarce and surpassed by the high demand of pastoralists. It could be argued that for pastoralists, reliable delivery of high-quality breeding bulls is of importance for adoption decision than paying for the cost of breeding technology. That high genetic merit bull calves are preferred for breeding implies that bull calves would be retained for bull service. This is a barrier to adoption of OvSynch and fixed TAI in pastoral herds for upgrading of Sahiwal cattle breed. For this, a relevant policy direction is to ranchers invest in Sahiwal multiplication and distribution of progeny bull calves to pastoralists and agro pastoralists. Ranchers have low preference for retaining bull calves for breeding, so when capacitated to invest in OvSynch and fixed TAI, would be to multiply breeding bulls and supply to pastoralists and agro pastoralists.

Female herd owners showed higher preference to using progeny bull calves for breeding relative to their male counterparts (59% versus 51%) who preferred selling bull calves for income earning. This reveals gender difference in value attached to progeny bull calves and their functional roles in pastoral systems. Women have higher need for milk to feed the family and high genetic merit calves are associated with higher milk yield potential (Mwangi *et al*., 2020). Men could be oriented to earning large sum of money, which sale of high merit bull calve would bring. However, both female and male herd owners' show that they are inclined to using progeny bulls for breeding or selling to earn income. Their preferred use of progeny bulls would be best served with multiplication centers supplying them with high quality Sahiwal bulls. Themselves, they are less likely to sustain uptake of the technology delivered through market mechanisms.

Rearing progeny bull calves for draught power use in farming (2%) was very unpopular among the pastoralists. In the study sample, few agro-pastoralists (11%) or herd owners whose primary livelihood was mixed crop-livestock farming (24%) may explain this. Draught power with oxen cattle is preferred for East African zebu cattle breed and not Sahiwal cattle breed, which herd owners may be associating with high production potential and delicate for draught power use in farming.

Second choice preference reveals the alternative function of progeny bull calves by the pastoral herd owners. Second choice may be also when there are surplus bull calves than are required for the primary use. Results do indicate that the alternative use is to earn income (58%)

while unpopular alternative uses are draught power, meat production, prestige and cultural practices. For these, herd owners stating a preference was two to three percent (2 to 3%), an observation that concurs with that of Rutherford *et al.* (2021), who reported that surplus bull calves are marketed. Sahiwal cattle is classified a dual-purpose breed- meat and milk, so the preference relates to utilizing Sahiwal for milk and meat.

On average, younger herd owners of below 30 years of age and had attained secondary level education had higher preference to use progeny bull calves for future breeding. The educated herd owners are christened the millennial dairy actors, expected to drive dairy modernization and operations. They have the potential to grow the benefit of meat and milk output and enhance the total factor productivity across the meat and milk value chains. It had been expected that these millennial dairy actors would express maximal use of the progeny bull calves, because they value innovation (Genius *et al.,* 2006), so would retain the bull calves for future breeding.

Ranchers are commercial oriented and value strategies that maximize profitability, which explains their preference to commercialize use of the high-quality genetics bull calves. This results corroborates with Mwangi *et al*. (2020) and Otieno *et al.* (2011) that ranchers attain higher income through live animals sales and products compared to nomads and agro pastoralists. To ranchers, sale of high genetic merit bull calves either for breeding or for meat slaughter fetches higher income for the enterprise compared to rearing for future breeding. This assumption requires validating with a directed study to determine the most profitable use of progeny bull calves under pastoral and ranching production systems. Ranchers' source breeding bulls from the stud herd, they can afford the price even of importing semen. Sale of bulls for meat is on weight basis and mostly in auction bidding for the highest, not at negotiated market price in local markets where pastoralists and agro pastoralist trade their stock (Mwangi *et al*., 2020).

In this study, half (50%) of the ranchers stated preference to retain progeny bull calves only as a second choice after sales for income. Most of the ranches have organized management and breeding systems, and can easily access OvSynch and fixed TAI services despite the cost implications or utilizing similar superior own farm reared bulls for breeding. However, half (50%) of the ranchers still chose to retain the superior bull calves obtained from OvSynch and fixed TAI within their herd as second choice after sales for income. Ranchers can invest in breeding service viably given their large herd size and off-takes.

The regression of socioeconomic indicators on the preference use of progeny bull calves including gender, education level, primary livelihood source, production system and

grazing area as well as years of experience in farming had no significant influence (P >0.05). Indeed, gender differences was just an eight percent margin (59% vs 51%) for first choice being to retain bull calves for future breeding. The marginal differences between production systems for first choice being to retain bull calves for future breeding was a six percent margin: 50% to 56%.

5.5 Conclusion

The study has demonstrated the application of choice experiment in projecting the preferential use of progeny bull calves from OvSynch and fixed TAI utilization within pastoral herds. Pastoral herd owners prefer to retain the progeny bull calves from OvSynch and fixed TAI utilization within their herd as future breeding stock. This presents a potential barrier to future adoption of OvSynch and fixed TAI in pastoral herds for upgrading of Sahiwal cattle breed.

CHAPTER SIX
ECONOMIC VIABILITY OF USING OVSYNCH AND FIXED TIMED ARTIFICIAL INSEMINATION IN BREEDING IMPROVEMENT OF SAHIWAL HERDS IN THE RANGELANDS

Abstract

Though using Assisted Reproductive Technologies (ARTs) can improve oestrus detection, conception and pregnancy success, thus benefit breeding program implementation, empirical evidence of their economic viability is lacking to inform investment decisions in pastoral herds. This study assessed economic viability of using OvSynch and fixed Timed Artificial Insemination (TAI) in Sahiwal upgrading breeding program under two hypothetical cases of best and worst in activity-based money allocations when pastoral herds deploy either optimal or low input husbandry practices. From herd owners' assessment of milk production, best-case scenarios attain on average 10 litres/cow/day with optimal husbandry and 5 litres/cow/day with low input husbandry. The worst-case scenarios attain 5 litres/cow/day with optimal husbandry and 1 litre/cow/day with low input husbandry. Benefit- Cost Analysis estimated Net Present Value, Benefit-Cost ratio and Internal Rate of Return to establish economic viability of using OvSynch and fixed time artificial insemination in pastoral breeding programs. Both best-case scenarios retuned positive Net Present Values (82,028 and 6,912), Benefit Cost Ratio values (1.68 and 1.08) and Internal Rate of Return (27.46% and 8.08%) while worst-case scenarios returned negative Net Present Values (-135,855 and -141,025), Benefit Cost Ratio values of below 1 (0.87 and 0.66) and Internal Rate of Return values below the minimum rate of returns. These economic parameters were sensitive to price changes in inputs and outputs, under both optimal and low input husbandry practices. Results indicate that using OvSynch and fixed time artificial insemination is a profitable and economically viable investment under optimal husbandry practices but not under low input husbandry practices. By implications, use of OvSynch and fixed time artificial insemination in Sahiwal upgrading breeding programs need be accompanied with improved husbandry practices and de-risking pastoral herd owners from price changes in input and output markets.

6.1 Introduction

Breeding programs are interventions designed to improve genetic merit of the target cattle herd. Reproductive performance, quality of breeding stock and level of husbandry practices are important components of realising improvement in the genetic merit of cattle herd. However, interventions targeting cattle herd improvement has to be economically viable to

support breeding programs. The level of husbandry practices influence the reproductive performance that is attainable. Herd fertility management is challenging in pastoral systems due to cows experiencing silent heat or their heat go undetected. These can be attributed to delay, failure or challenges in estrus detection, subsequently resulting in low conception and pregnancy rates and poor success of breeding programs (Roelofs *et al.*, 2005). In pastoral herd management, estrus detection is by visual observations of cows standing immobile while being mounted, vaginal discharges, continuous bellowing and reduced feeding frequencies (Adenuga *et al.*, 2020). These are characterise to low input husbandry practices but could be open to high risk of mis-informing management decisions and inefficiencies (Lawrence *et al*., 2015).

Assisted Reproductive Technologies (ARTs) have demonstrated enhanced efficiency of estrus detection in dairy herds, so potentially would benefit implementation of breeding programs in pastoral herds. Use of OvSynch and TAI protocol have the potential to overcome some of the limitations associated with low input husbandry practices. They enhance efficiencies in estrus detection, conception success and accelerate genetic improvement (Adenuga *et al*., 2020). For instance, automated estrus and mount detectors, activity monitors and estrus synchronization (OvSynch) procedures when used, improves estrus detection and determining optimal time to perform insemination for successful conception (Hojo *et al*., 2018; Roelofs *et al.*, 2005). These are indications that using OvSynch and TAI protocol in pastoral herds can enhance mating success, shorten calving time and accelerate multiplication of quality breeding bulls (Janssen-tapken *et al.*, 2006; Rodgers *et al.*, 2012; Sprott, 2000).

Already, use of OvSynch and fixed TAI in breeding programs has been introduced in pastoral herds (Khainga, 2015). However, economic viability of utilizing OvSynch and fixed TAI has not been determined for adoption and/ or technology improvement. This is important to inform investment decisions in the breeding program intervention. Adoption of ARTs especially artificial insemination remains low (Khainga, 2015), which necessitates assessing whether the technical successes return economic efficiency of cow-calf enterprise, especially in the pastoral rangelands (Adenuga *et al.*, 2020). Previous studies have indicated that farmers tend to be risk averse especially when they lack information to support major decision making. This applies to the case of adoption of new innovations, such as the use of OvSynch and fixed TAI in pastoral rangelands. An economic evaluation becomes relevant for making management and investment decisions as whether to shift to OvSynch and fixed TAI from natural bull service practice in pastoral herds (Mwacharo & Rege, 2002). Adopting OvSynch and fixed TAI suites to production objectives of Maasai pastoralism which is to breed with high genetic merit bulls that increase milk production for home consumption (Grandin, 1988).

Economic viability of technology investment can be assessed using Benefit-Cost analysis (BCA). This analysis compares the value of outcomes or benefits against the value of resources used in achieving the outcomes (Lawrence *et al.,* 2015). As explained by Razzouk (2017), BCA is a broad economic evaluation method that evaluates whether benefits (quantified in monetary terms), outweighs the cost of resources used to produce them. This is suited to obtaining evidence for decision making on adoption of a technology because expected economic returns is a criteria that would indicate to herd owners viability of adopting and using new technologies (Adenuga *et al.,* 2020). The application of Benefit-Cost analysis (BCA) economic valuations can be found in dairy cattle breeding improvement (Okeno *et al.,* 2010), usage of sexed in-vitro fertilization embryo transfer (Lawrence *et al.,* 2015), developing models for low-input dairy systems (Marshall, 2018), foot and mouth vaccination (Truong *et al.,* 2018) and adoption of automated estrus detection technologies (Adenuga *et al.,* 2020). In computation, all benefits and costs originating from using technologies and programs are estimated, aggregated into monetary measures and appraised using financial indicators. It allows for inclusion of the value of benefits from goods and services that do not have market prices taking into account the associated opportunity costs. It can be applied in projecting the benefits and associated costs in breeding programs. These makes BCA a good indicator when integrating the concept of allocation efficiency, accounting for both tangible and intangible benefits valued by pastoralist. As an economic measure, BCA measures in monetary values reveal economic efficiency of a technology, so is informative for making decisions (Lawrence *et al.,* 2015; Pearce *et al.,* 2006).

Some studies have applied BCA in evaluating Sexed In-vitro Fertilization Embryo Transfer (SIFET) technology in Kenya (Lawrence *et al.,* 2015; Mutembei *et al.,* 2016). However, none of these studies applied BCA to assess economic viability of investing OvSynch and TAI in pastoral herds. This study assessed economic viability of using OvSynch and fixed Time Artificial Insemination in Sahiwal upgrading breeding program under two hypothetical cases of best and worst in activity-based money allocations when pastoral herds deploy either optimal or low input husbandry practices.

6.2 Materials and methods

6.2.1 Study area

The study area was Lolgorian and Pusanki sub-divisions, Trans Mara West Sub-county, Narok County (GoK, 2008; KNBS, 2019) in the southern rangelands of Kenya (Figure 1). The ecology is diverse and can be classified into three distinct landscapes based on altitude: the

highlands (2,200m to 2,500m above sea level), the plateau (1,524m to 2200m) and the lowlands (≤ 1,524m above sea level) (Magembe *et al.*, 2014). Cattle grazing entailed extensive system characterized by full or partial grazing on natural pastures with limited purchase of dairy inputs such as mineral supplements (Chawala *et al.*, 2019). Inhabitants in the area were Maasai community practicing extensive cattle production through ranching, nomadic, or agro-pastoral systems. They keep either pure and/ or crossbreds of local (Maasai zebu and Boran) and Sahiwal breeds; cattle being a primary livelihood source (Ilatsia *et al.*, 2011).

6.2.2 Sampling procedure and data collection

Section 3.2.2 and equation 2 provides a detailed overview of the sampling procedure and estimation of the sample size. The data used in estimating benefits and costs were obtained through direct interviews in cross-sectional survey of pastoral herd owners. These herd owners were direct beneficiaries of OvSynch and fixed TAI Sahiwal upgrading breeding program, which was at community level.

Semi-structured questionnaires were administered in direct face-to face interviews (Plate 6.1a) complemented with direct farm observations and small group discussions (Plate 6.1c). Further probing on associated benefits and costs related to Sahiwal cattle farming such as feeding, disease control, mineral provision and Sahiwal product marketing were also undertaken during the interviews (Plate 6.1b). The questions captured aspects of (i) cattle production dynamics and products (ii) use of OvSynch and fixed TAI and (iii) livestock marketing. Estimates of benefits and costs were through direct measurement and recall data for the last three months. Two hypothetical case scenarios of best and worst cases were evaluated. The case scenarios were derived from previous records of milk and live sales; and different levels of husbandry practices obtained from herd owners.

6.2.3 Production system scenarios

Pastoral production systems were classified on the basis of the level of input resources as optimal and low input husbandry practices (Table 6.1). This was to reflect improved husbandry and traditional husbandry practices in pastoral rangelands. Optimal husbandry is commercially oriented, is high input-output, using supplemental minerals and concentrates frequently for cattle grazing on roughages in open fields. The low input husbandry practices are subsistence oriented with traditional husbandry practices characterized by extensive movement of Sahiwal cattle in search of natural pasture and water for production.

Plate 6.1: Direct (individual and joint) interviews with pastoral herd owners (a and c) and pooled mineral licking by pastoral herd (b)

In both optimal and low input husbandry systems, Sahiwal cattle breed was important for milk and meat supply for home consumption and surplus for sale. OvSynch and fixed TAI were used in both systems and surplus calves sold at a mean estimated price after weaning. Female calves are retained within the herd, reared, selected and used as replacements for culled cows after fifth lactation (Table 6.1).

Table 6.1: Production and reproduction indicators for herds with optimal and low input husbandry levels

Variables	Husbandry practices	
	Optimal	**Low input**
Calf birth weight (kg)[1]	19.75	18.86
Weaning age (days)[2]	120	120
Pre weaning survival rates (%)[4]	78	78
Survival rate to age at first calving (%)[3]	88	81
Conception rates (%)[1]	61	61
Calving rates (%)[2, 3]	77	67
Age at first calving (days)[3]	892	1,123
Age at culling (days) [3]	2880	3,424
Mature live weight (kg)[1,4]	400	300
Milk yield per cow per day[1]	10	5
Lactation length for Sahiwal cattle (days)[4]	293	293
Gestation length (days)[4]	287	287
Calving interval (days) [4]	437	437
Inflation rates (%)[5]	5.18	5.18

[1]Cross sectional survey data of pastoral herd undertaken in 2021
[2] Kahi and Nitter (2004)
[3] Wahinya *et al*. (2022)
[4] Muhuyi *et al*. (1999)
[5] Central Bank of Kenya (2021)

Feed intake for heifer calves and cows are calculated based on energy requirement for maintenance, growth, production and reproduction. Cattle meet their energy requirement from roughage pasture in the low input husbandry practices while in optimal husbandry practices energy is met from both roughage pastures and limited feeding of concentrate diets. The dry matter intake ranged between 2 and 4% of the body weight depending on the growth and physiological stages of cattle (NRC, 2001). Water was provided at *ad lib* basis. Cost of water was computed to account for the expenses if it were to be bought and accessed to meet the animal daily requirements. Calves are fed on milk equivalent to 15% of their birth weight for 7 weeks, 10% for the next 4 weeks and 1 litre twice a day until weaning time at 120 days (Lukuyu *et al.*, 2012; Rosenberger *et al.*, 2017; Wahinya *et al.*, 2022). Calves are introduced

to solid and good quality feeds after two weeks and to concentrate feed in the optimal husbandry system.

Animal health practices including treatment, parasite and disease control varied depending on the level of input resource in husbandry practices. Herd size was fixed in both low and optimal input husbandry practices as cows that attained the culling age were disposed of and replaced by heifers reared on farm while the surplus were sold. The culling age for Sahiwal cows varied within the optimal and low input husbandry practices (Table 6.1) and was sold mainly for slaughter based on live weight at the time of culling. An additional marketing cost accounted for marketing levies and transportation cost based on prevailing market prices of milk and live animal sales (Kahi & Nitter, 2004). The prices of milk, reproductive technologies, concentrates and fixed costs were same in the two husbandry practice scenarios (Wahinya *et al.*, 2022).

6.2.4 Model description

Economic models for money allocations followed activity based costing method for low input production systems as adopted by Marshall (2018), which provides financial appraisal of smallholder dairy cattle enterprises. A conceptual model (Figure 6.1), illustrates pastoral herd utilizing estrus synchronization and artificial insemination in producing superior progeny calves. The study defined productive herd life as the interval between first calving and disposal (culling and sale) of cows. It was hypothesized that using OvSynch and fixed TAI would increase returns from improved genetics, uniformity of offspring calves' age and production of superior and heavier claves concentrated in a calving season (Rodgers *et al.*, 2012). Benefits were computed from projected revenues obtainable from sales of milk, live animals and manure on yearly basis. Household and calf milk consumption was valued as an opportunity cost for buying milk from retailers. Live animal sales were valued at young stock (surplus yearlings, heifers or steers) and mature stock (cull for aged cows) at disposal time.

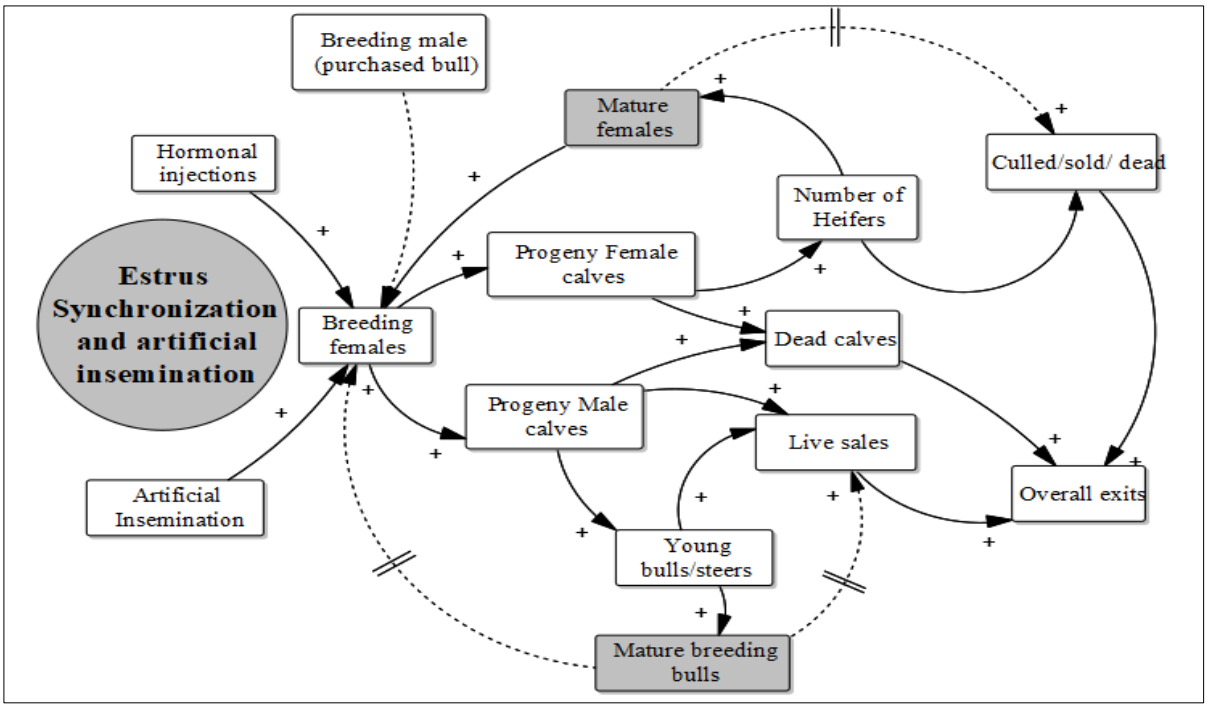


Figure 6.1: Conceptual model of the pastoral herd model utilizing OvSynch and fixed TAI
Source: Marshall (2018)

Benefits

Benefits value were estimated for lactation milk yield, sale of calves, value of manure and disposal value of individual animal. For cows and/ or heifer, total discounted benefits were computed from formula as suggested by Marshall, (2018);

$$B_{cow/heifer} = DR(LMY\ X\ P_m) + DV + (N_c\ X\ P_c) + (Manure\ Cost) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where $B_{cow/heifer}$ is the total lifetime benefits of the cow or heifer, DR is the discounting rate, LMY is the lifetime milk yield in Kg, P_m is the price of milk per Kg , DV is the disposal value in KES, N_c is the number of calves born in life time of the cow and P_c is the price per calf.

Costs

Associated costs were computed based on projected herd management practices related to animal health care, feeding and watering, labour (household labour valued as per hired labour), marketing and reproductive costs as per the two husbandry practice scenarios. In estimating the costs for achieving projected benefits, associated animal husbandry practices were valued depending on the age of individual animal. The valuations accounted for feeding, animal health, disease control, labour, breeding (cost of accessing OvSynch and fixed TAI for insemination purposes) and associated marketing costs (milk and live animals). These variable

costs were estimated from measurements and recall data obtained during the interviews with the pastoral herd owners, service providers and market prices as at the time of study.

Feeding cost is grouped into three classes depending on the age of individual animal (calves, yearlings or mature stock). Though pastoral set up entails mostly grazing, the opportunity cost of buying pasture or milk for the calves was used in calculation based on dry matter requirement for cattle optimal feeding (NRC, 2001). Calf feeding costs comprised estimated costs from birth until weaning time; heifer-feeding costs comprised costs incurred from weaning time until age at first calving while mature animal feeding costs comprised estimated feeding costs from first calving until disposal time based on the productive lifetime as perceived by the respondent. This was computed using the formula suggested by Marshall, (2018):

$F_c = \sum_{i=1}^{2}[(Calf_c \times T_i) + (Heifer_c \times T_i) + (Mature_c \times T_i)]$ .....(8)

where F_c is the total feeding costs projected to productive life time, $Calf_c$ = estimated cost of calf feeding per month, $Heifer_c$ = estimated cost of calf feeding per month, $Mature_c$ = estimated cost of calf feeding per month, T_i = the time taken in months for feeding within the category.

Health costs comprised estimations in ensuring proper attainment of animal health within the productive life of the animal. These involved both treatment and disease control measures undertaken within the pastoral herd to ensure optimum production levels are attained. Overall variable cost related to health was computed as follows;

$H_c = \sum_{i=1}^{2}[(T_c \times F_i) + (V_c \times F_i) + (S_c \times F_i) + (D_c \times F_i)]$ .....(9)

where H_c = the estimated average health costs per animal, T_c= treatment costs, V_c= vaccination costs, S_c = spraying costs, D_c = deworming costs and F_i = frequency of activity within one year.

Reproductive cost was estimated as an average amount for accessing OvSynch and fixed TAI. This comprised the cost of service delivery, bull semen, pharmaceutical products (hormonal injections) and supplies (syringes, needles, plastic sleeves, gloves, lubricant and pipettes).

Labour cost (L_c) was quantified based on prevailing average casual-workers' hiring rate, regardless of whether it was hired or family. This followed the argument that the time allocation of family labour to undertake Sahiwal farming reduces the overall time and amount that could have otherwise been used on other enterprises. For analysis, family labour cost was

estimated as an opportunity cost that comprised the amount the labourer would earn if it were to be hired in the same production scenario.

Marketing costs comprised of related charges incurred during sale of either milk or live animal. This was computed as;

$M_c = \sum_{i=1}^{2}[N_i \times f_i \times (T_c + Lv_c)]$……(10)

where M_c is the marketing cost, T_c = cost of transport of live animal to market, Lv_c = cost of levies charged per animal (auction fee, slaughter fee, meat inspection and carcass transport).

For cows/ heifers, total costs were computed as;

$C_{cow} = DR\ [F_c + H_c + RC + L_c + (LMY\ X\ MC_{milk}) + M_c +]$……(11)

where C_{cow} = the total productive life costs for cow, DR = the discounting rate, F_c = the estimated feed costs, H_c = animal health costs, RC is the reproductive costs, L_c is the labour costs, LMY is the lifetime milk yield in Kg, MC_{milk} is the cost incurred for marketed milk and M_c is the marketing costs for cows disposal for sale. The computed benefits and costs in monetary values were discounted based on prevailing market rates as at the study time to derive adjusted values for future economic returns.

6.2.5 Data analysis

Collected field data were sorted, edited and cleaned in Microsoft Excel spreadsheet and incorrect, incomplete or inconsistent data removed. In analysis, three key financial parameters were considered; the Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR).

Net Present Value (NPV*)*

This includes the total present value (PV) of a time series and is a standard method for using a time value of money to appraise a long-term project. Within the current study, NPV was calculated using the formula;

$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t}$……(12)

where NPV = Net Present Value, R_t= the net cash inflow – outflows during a single period t, i = discounting rate and t = number of time (years). In interpretation, positive NPV indicates economic viability and hence advisable to undertake the investment as it would lead to profits. On the contrary, negative NPVs indicate that the investment is not economically viable, hence the investment is not worth undertaking as it would lead to losses from invested capital.

Benefit Cost Ratio (BCR)

This is the ratio of the present value of the benefits to the present value of the costs. BCR was undertaken using the formula:

$$BCR = \left. \sum \frac{B^n}{(1+r)^n} \right/ \sum \frac{C^n}{(1+r)^n} \quad \text{.....(13)}$$

where B = Benefits, C = Costs, r= the discounting rate and n = number of years. For interpretation, BCR values above 1 would indicate economic viability as the benefits outweigh the costs and hence advisable to undertake an intervention. When BCR is less than 1 then the investment is not economically viable as the costs outweigh the benefits and hence advisable not to proceed with the intervention.

Internal Rate of Return (IRR)

This comprises the annualized effective compounded return rate that can be earned on the invested capital. Furthermore, it gives the interest rate at which the costs of the investment lead to the benefits of the investment. This was computed using the formula;

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0 \quad \text{.....(14)}$$

where NPV= the net present value, C_n= the period cash flows n is a positive integer, N= the total number of periods, r= the internal rate of return. In interpretation, IRR values greater than the minimum required rate of return indicate economic viability and hence the investment should be pursued. On the contrary, when the IRR values are below the minimum required rate of return, then the investment is not economically viable and hence should not be pursued.

6.2.6 Sensitivity analysis

A sensitivity analysis was carried out to assess the effect of changing input parameters on the analyzed financial appraisal indicators. Sensitivity analysis was undertaken through increasing or decreasing input and output prices related to milk, feeding and reproductive costs; and prevailing inflation rates, to reflect future changes while comparing the two case scenarios based on hypothesized probabilities. The cost of milk price was varied at 10%, inflation rate varied at 3%, cost of accessing OvSynch and fixed TAI varied at 20% and cost of feeding and watering varied at 10%. The analysis was undertaken at individual indicator variables while holding other factors constant (Tegemeo, 2021). The underlying assumption was that the herd owners would continue accessing OvSynch and fixed TAI despite the effect changes in milk prices, inflation rates, reproductive, feeding and watering costs. Table 6.2 presents the

estimated unit costs in each production system obtained from literature, respondents recall data and prevailing market prices as at the time of study.

Table 6.2: Estimated unit cost of economic variables (in Kenya Shillings)[a] as used in pastoral herd applying optimal and low input base scenarios

Variables	**Production system (KES)**	
	Optimal	**Low input**
Price of milk per Kg[1,2]	40	40
Price of weaned calf [1]	40,000	30,000
Price of manure per year [2]	1,500	1,500
Price of culled cow[1]	80,000	60,000
Price of culled bull[1]	120,000	120,000
Cost of feeding until AFC (per month)[1]	2,500	2,500
Cost of feeding (mature animal per month)	3,750	2,900
Average cost of dairy concentrates per 50 Kg bag[1]	2,000	-
Cost of mineral or salt licks per animal[1,2]	400	400
Watering costs per animal per month[1]	500	500
Vaccination costs per animal[1]	50	50
Treatment (health) cost per cow per day[3]	8.22	2.74
Parasite (ticks, worms) control per animal month[1]	800	400
Costs of labour per animal per month[1,4]	700	300
Reproductive costs per animal[1]	3,643	3,643
Cost of marketing per Kg of milk[1]	3	3
Cost of live sale marketing per cow[1]	300	300
Fixed cost per day [3,5]	1.05	1.05

[a] One US dollar = KES 108.7 at the time of study (Central Bank of Kenya, 2021)

[1]Cross sectional survey data undertaken in 2021

[2] Kashangaki and Ericksen (2018)

[3] Wahinya *et al*. (2022)

[4] Lawrence *et al*. (2015)

[5] Kahi and Nitter (2004)

The estimated benefits and costs of the best and worst case scenarios, were calculated for both the optimal and low input husbandry practices (Table 6.3). Benefits quantified from

primary and / or recall data, were based on income received from sales, consumption or utilization of cow products while costs reflected projected expenditure used in realizing the benefits within optimal and low input systems. Best-case scenarios represented attaining an average 10 litres/cow/day of milk and 5 litres/cow/day of milk while worst-case scenarios were attaining an average of 5 litres/cow/day and 1 litre/cow/day within optimal and low input husbandry respectively. The value for manure in the optimal scenarios included the cost implications if it were to be collected and sold on annual basis (Kashangaki & Ericksen, 2018). The feeds used in the scenarios include free grazing pasture, concentrates, minerals, other feed supplements and water.

6.3 Results

Table 6.4 presents results of the various economic analysis parameters of the two (best and worst) case scenarios in pastoral herd applying optimal and low input practices. Overall benefits were more in pastoral herd applying optimal husbandry practices relative to low input husbandry practices. Best-case scenarios (10 litres/cow/day and 5 litres/cow/day) recorded positive NPVs of 82,028 and 6,912; BCR values of 1.68 and 1.08; and IRR of 27.46% and 8.08%, compared to worst-case scenarios that recorded negative NPVs, BCR values below 1 and IRR values below the minimum required rate of return.

Table 6.3: Annual estimates comparing best and worst case scenarios under optimal herd practices within pastoral systems

Item	Particulars	Case Scenarios (husbandry practices)							
		Optimal input				Low input			
		Best		Worst		Best		Worst	
		KES	%	KES	%	KES	%	KES	%
Benefits	Milk sales	122,000	73	61,000	64	61,000	64	12,200	26
	Calf sales	32,000	19	24,000	25	24,000	25	24,000	52
	Manure	1,500	1	1,500	2	1,500	2	1,500	3
	Disposal value	11,429	7	8,571	9	8,571	9	8,751	19
	Total	166,929	100	95,071	100	95,071	100	46,271	100
Costs	Feeding and watering	79,800	66	69,600	67	50,550	69	42,150	71
	Labour	8,400	7	7,200	7	6,000	8	3,600	6
	Animal health	12,650	10	12,650	12	5,945	8	5,850	10
	OvSynch and TAI	3,643	3	3,643	3	3,643	5	3,643	6
	Marketing	9,390	8	4,815	5	4,815	6	1,155	2
	Operating costs	5,760	5	5,760	5	2,400	3	2,400	4
	Fixed costs	383	1	383	1	383	1	383	1
	Total	120,026	100	104,052	100	73,736	100	59,181	100

One US dollar = Kenya Shillings (KES) 108.7 at the time of study (Central Bank of Kenya, 2021)

Table 6.4: Economic analysis of the various production systems using identified financial indicators

Husbandry practices	Case scenarios	Average litres/ cow	NPV	BCR	IRR (%)
Optimal	Best	10	82,028.24	1.68	27.46
	Worst	5	(135,855.02)	0.38	-
Low input	Best	5	6,912.35	1.08	8.08
	Worst	1	(141,025.01)	0.66	-

NPV = Net Present Value; BCR = Benefit Cost Ratios; IRR = Internal Rate of Return

Sensitivity analysis assessed the effect of changes in prices and costs (milk sales, inflation rates, reproductive and feeding) on the NPV (Figure 6.3), BCR (Figure 6.4) and IRR values. Results indicate that a ten percent (10%) decrease in milk prices would render investment in low input system unviable with negative NPV (-19,366.57), BCR below 1 (0.77) and marginal IRR of 3.55%. Increase in inflation rates by 3% would render investment unviable, with -217.42 NPV, 0.98 BCR and 8.08% IRR. A twenty percent (20%) increase in reproductive costs would still be economically viable with positive NPVs, BCR values above 1and IRR above the minimum rate of returns in all the systems. However, a ten percent (10%) increase in feeding and watering costs would render investment unviable with -12,473.74 NPV, 0.85 BCR and 0.32% IRR in low input husbandry practices (Table 6.5).

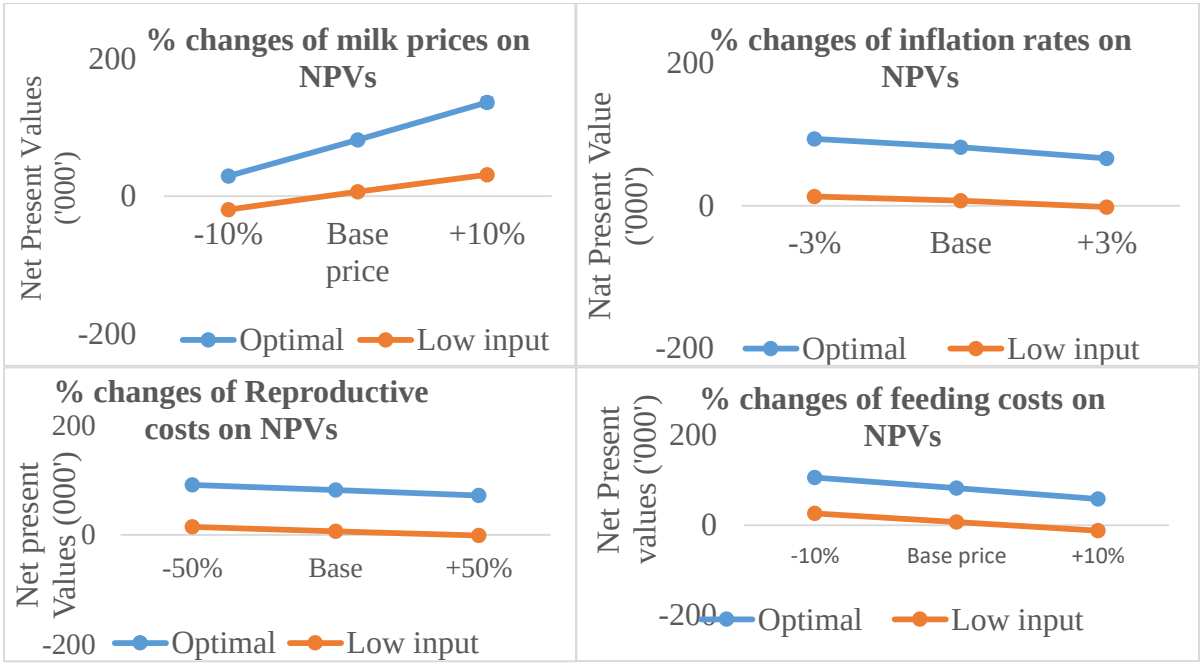


Figure 6.2: Sensitivity analysis of % changes in input parameters on the Net Present values

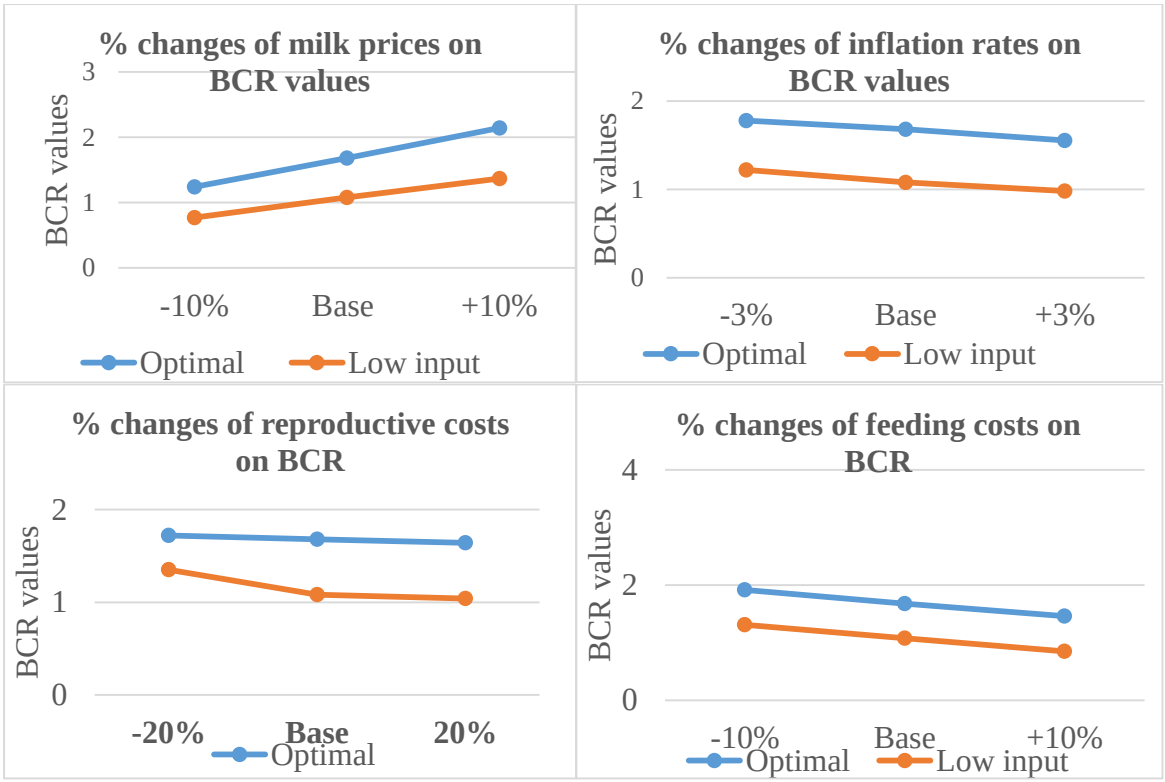


Figure 6.3: Sensitivity analysis of % changes in input parameters on BCR values

Table 6.5: Sensitivity analysis of percentage (%) change in selected variable values on financial appraisal indicators

Variable	Husbandry practices	% Change	Value	Financial indicators			
				NPV	BCR	IRR (%)	Payback Period (Years)
Milk price (KES)	Optimal	+10	44	136,620.36	2.14	40.70	2.0
		Base	40	82,028.24	1.68	27.46	3.8
		-10	36	29,470.41	1.24	13.69	
	Low input	+10	44	31,281.61	1.37	17.69	4.0
		Base	40	6,912.35	1.08	8.08	4.0
		-10	36	-19,366.57	0.77	3.55	-
Inflation rate (%)	Optimal	+3	8.18	66,354.56	1.86	27.46	5.2
		Base	5.18	82,028.24	1.68	27.46	3.8
		-3	2.18	93,671.48	1.78	27.46	4.4
	Low input	+3	8.18	-217.42	0.98	8.08	5.4
		Base	5.18	6,912.35	1.08	8.08	4.0
		-3	2.18	12,960.77	1.22	7.29	4.5

Reproductive Cost (KES)	Optimal	+20	4,372	78,160.81	1.64	26.37	3.8
		Base	3,643	82,028.24	1.68	27.46	3.8
		-20	2,914	85,896.66	1.72	28.55	3.8
	Low input	+20	4,372	3,773.53	1.04	6.78	-
		Base	3,643	6,912.35	1.08	8.08	4.0
		-20	2,914	11,542.61	1.35	10.06	4.0
Feeding cost (KES)	Optimal	+10	4,125	58,142.15	1.46	20.83	
		Base	3,750	82,028.24	1.68	27.46	3.8
		-10	3,375	105,914.32	1.92	34.32	
	Low input	+10	4,125	-12,473.74	0.85	0.32	
		Base	3,750	6,912.35	1.08	8.08	4.0
		-10	3,375	26.298.43	1.31	15.79	

KES = Kenya Shillings; NPV = Net Present Value; BCR = Benefit Cost Ratios; IRR = Internal Rate of Return

6.4 Discussion

OvSynch and fixed TAI can be used in disseminating high genetic merit breeding stock within the pastoral rangelands. Based on two hypothetical husbandry practices applied in the pastoral rangelands (optimal and low input), the study assessed the economic viability of using OvSynch and fixed TAI for economic returns. The study recorded a 1.76-fold benefit difference between best-case scenarios applying optimal relative to low input husbandry practices, meaning significant livelihood gains could be made by optimizing pastoral husbandry practices. Benefit-cost analysis further ascertains that using OvSynch and TAI protocol in pastoral rangelands is economically feasible when husbandry practices are optimal. The financial indicators were positive NPVs, BCRs estimates above 1 and large values of IRR under best-case scenarios applying optimal husbandry practices. This implies that herd owners would benefit more investing in OvSynch and fixed TAI while practicing optimal husbandry practices. The observation agrees with those of Lawrence *et al.* (2015) and Mutembei *et al.* (2016) on the feasible use of reproductive technologies in increasing profitability of cattle farming.

The study recorded positive responses in best-case scenarios in all systems applying either optimal or low-input husbandry practices for targeted output products. Best-case scenario in system applying optimal husbandry practices and producing an average of 10 litres or 5 litres of milk per cow per day recorded the highest NPVs (82,028 versus 6,912.35), BCR

(1.68 versus 1.08) and IRR (27.46% versus 8.08%) relative to system applying low input system. The positive NPVs, BCR values above 1 and IRR above the base minimum rate of returns of 5.18% (Central Bank of Kenya 2021), are indicators that could inform herd owners on possible investment decision for use in pastoral herds. The use of OvSynch and fixed TAI on Sahiwal, a dual-purpose breed, can be directed towards improving milk and beef production traits in upgrading programs. The higher economic returns as observed in system applying optimal husbandry practices agrees with Agutu *et al.* (2019); Wahinya *et al.* (2020) and Wahinya *et al.* (2022) who reported increased intensification level through use of higher dairy inputs and superior genetics as having direct influence on the overall farm productivity and economic returns.

Higher contribution to total benefits from milk sales well corroborates 61% to 78% contribution of milk sales from dairy production systems towards overall farm benefits in Senegal and Kenya (Marshall *et al.*, 2020; Ngigi, 2005;Wahinya *et al.*, 2022). This implies the need for an efficient milk pricing system that ensures profitability and thus sustainability of pastoral farms. One option could be through improving the milk prices for economic sustainability of the pastoral herd. Alternatively, herd owners could also venture in quality-based milk marketing that promotes nutritive value (fat and protein content) rather than liquid volumes. Pastoral herd owners therefore, need more sensitization on selection indexes that balances milk and meat traits especially while considering Sahiwal cattle- a dual-purpose breed. The variations as observed in milk incomes, can also influence herd owners motivation to improve the milk yield per cow and / or the contents of milk components and milk quality for increased economic returns (Michaličková *et al.*, 2017). Besides this, the estimated value for manure in the optimal case scenario included the benefit implications if it were to be collected and sold on annual basis (Kashangaki & Ericksen, 2018).

Higher costs were observed in optimal husbandry practices due to the additional input costs to support the high nutritive demands for production (milk and meat) to achieve higher returns (Wahinya *et al.,* 2020; Wahinya *et al.,* 2022). Feeding and watering costs were estimated accounting for daily nutrient requirement for maintenance, growth, milk production, pregnancy and other physiological activities of individual animals. Water and feed account for a larger part of production cost, implying that husbandry practices need prioritise efficiency in water and feed use to maximize economic returns. This calls for exploring alternative feed resources in meeting the nutrient requirements of pastoral herd. This would increase feed access and reduce the overall costs of production in pastoral herd.

The best-case scenarios in systems applying optimal and low input husbandry practice were viable economically, evidence being positive NPVs (82,028.24 versus 6,912.35), BCR values above 1 (1.68 versus 1.08) and IRR above the minimum rate of returns (27.46 versus 8.08). Sensitivity analysis simulated the costs effects of different indicator variables on the financial indicators based on likelihood scenarios. While holding the other costs constant, analysed financial indicators were sensitive to changes in hypothesized input and output prices that had notable effects on the economic parameters of systems applying either optimal or low input husbandry practices.

Sensitivity analysis indicated effect on overall economic returns, with use of OvSynch and fixed TAI proving not a viable investment in systems applying low input husbandry practices when milk prices decrease (10%), inflation rate increases (3%) and feeding and watering costs increase (10%). This is an economic signal to pastoral herd owners that investing in OvSynch and fixed TAI needs implementing optimal husbandry practices. For this, development agencies are advised to support actions that would de-risk pastoral herd owners from market and climate related shocks.

6.5 Conclusion

Based on the study results, using OvSynch and fixed TAI would be profitable, economically viable investment under optimal husbandry practices but not under low input husbandry practices. By implications, adoption of OvSynch and fixed TAI in Sahiwal upgrading breeding programs need be accompanied with improved husbandry practices to achieve higher economic returns and de-risking pastoral herd owners from price changes in input and output markets. De-risking strategies need to consider capacity building, access and provision of quality feeds and animal health services to mitigate against high production costs.

CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1 General discussions

Pastoralism in the rangelands is a livestock resource-based livelihood providing both tangible and intangible benefits for the households. Pastoral herd owners express high preference for Sahiwal cattle breed because of being adaptable dual-purpose in the harsh environmental conditions. Sahiwal cattle breed is considered more productive relative to the other indigenous breeds (Small East African Zebu, Boran) found in the rangelands. Over the years, pastoral herd owners have often relied on individual or community Sahiwal bulls for mating their cows and heifers. This has overtime proved unsustainable as the demand for Sahiwal bulls have outstripped the current supply from National research stations, ranches and other model farms (Mailu *et al*., 2013). This necessitated an intervention with OvSynch and fixed TAI to accelerate access, multiplication and distribution of superior Sahiwal genetics, which when adopted successfully would improve productive and reproductive herd performance in the rangelands. The performance of Sahiwal cattle herds utilizing rangeland resources can be enhanced with profitable deployment of OvSynch and fixed TAI, upgrading improved animal husbandry practices and supporting informed investments decisions. Enhanced productive performance of Sahiwal cattle herds would in turn contribute to improved livelihoods of pastoral communities.

This section discusses sustainability concerns related to the use of OvSynch and fixed TAI in pastoral rangelands. It describes the research issues addressed, methodological approaches, results and implications of the study towards addressing the sustainability concerns.

7.1.1 Research issues addressed

Inadequate supply of quality Sahiwal genetic resources have limited the scope of cattle upgrading programs in pastoral rangelands. Development agencies have promoted the use of OvSynch and fixed TAI, to provide alternative access and wider dissemination of top proven Sahiwal semen for improving the pastoral herds. Previous studies were biased towards use of reproductive technologies in exotic breeds kept under intensive and semi-intensive systems in the highlands. This excluded potential use of OvSynch and fixed TAI in pastoral extensive systems. Introduction of this technology in pastoral herds has occurred through subsidies, thus posing social and economic sustainability concerns especially when donor withdraws subsidy or ends as with any other project supported intervention. This study was conceptualised in

response to these sustainability issues to inform profitable use of OvSynch and fixed TAI in upgrading indigenous cattle breed, good animal husbandry practices and informed investments decisions for improved livelihoods of pastoral communities.

The study sought to answer the following research questions;

i. To what extent would, ranch and pastoral herd owners be willing to pay for the attributes from OvSynch and fixed TAI use without subsidy support?
ii. Does the sire and dam mating criteria significantly influence conception rates in pastoral and ranching herds utilizing OvSynch and fixed TAI?
iii. What are the tangible and intangible benefits of progeny bull calves from OvSynch and fixed TAI use in pastoral and ranching herds?
iv. What is the economic viability of producing progeny heifers and bull calves with application of OvSynch and fixed TAI under pastoral and ranching herds?

The study results and outputs provided empirical evidence informative to pastoral herd owners, development partners, national and county government; and livestock extension agents on sustainable utilization of OvSynch and fixed TAI, upgraded Sahiwal breed, required animal husbandry practices and de risking actions in pastoral production systems. These are preconditions to attaining improved herd productivity for household food security, nutrition and income security amongst pastoral households reliant on Sahiwal cattle breed for livelihoods.

7.1.2 Methodological approaches

The study was among Maasai pastoral community whose primary livelihood is livestock keeping in Lolgorian and Pusanki in Trans Mara West sub-county, Narok County (Khainga, 2015). The areas selected has high population of Sahiwal cattle herd utilizing OvSynch and fixed TAI in an upgrading program. The respondent herd owners practicing ranching, pastoral and agro-pastoral production systems, were beneficiaries of a Sahiwal upgrading program that was implemented by the Kenya Agricultural and Livestock Research Organization (KALRO).

Data collection and measurements

The study combined the use of semi-structured questionnaires administered through cross-sectional survey interview approaches. Prior to field data collection, a two-day enumerator training and pilot study was undertaken to equip the recruited enumerators with the knowledge and skills to solicit for appropriate answers in acceptable manner. The enumerators

comprised Animal Health Assistants (AHAs) recruited from the local community for easy translation and recording of the responses from herd owners for analysis.

Primary data in qualitative and quantitative measurements were obtained directly from the field using individual structured questionnaires administered through household visits and face-to-face interviews. Secondary data were collected through desk reviews mainly sourced from the County reports, program database and from internet. The designed questionnaires captured household (socioeconomic characteristics), individual and herd production dynamics, marketing and applied management practices. Where possible, additional probing and follow-up questions were undertaken during field visits to give deeper insights and understanding of the responses. Computational data was obtained through projections to reflect either monthly or annually for ease of comparison and analysis. Semi-structured questionnaire was administered in direct face-to face interviews complemented with direct farm observations. In cases where estimated data were missing due to inadequate herd data recording, information from group discussions and recall data was used with limits to the past three to twelve months as the recall period depending on the research question to be answered.

The study was accomplished using a combination of analytical methodological approaches. The willingness to pay (WTP) was analysed using double bounded dichotomous choice contingent valuation model, applying the model using the analytical framework (Hanemann *et al*.,1991). This model uses hypothesized bid levels that reflect the cost of accessing the service as the basis for calculating the mean WTP (Chapter three). The maximum bid prices on WTP from individual respondents were established. Backward elimination procedures in logistic regression model was selected to retain only predictor variables significantly influencing WTP for accessing OvSynch and fixed TAI. Choice experiment method and random parameter logit (RPL) model was used in assessing pastoral herd owners' preferences for use of progeny bull calves within their herd (Chapter five). Initially, the study identified six attributes on possible uses of progeny bull calves that were complemented by extensive discussions during field interviews. The respondents were presented with series of attribute-based choices on preferential use of progeny bull calves. The underlying assumption was that a particular choice comprised the probable use based on key design attributes associated with the respondents' choice. Four identified attributes associated with potential use of progeny bull calves (breeding stock, income from sales, cultural practices and source of draft power), were analysed as parameters for possible first choice preferences by pastoral herd owners.

Benefit – Cost Analysis (BCA) based on analysed financial indicators (NPV, BCR, IRR) was used to assess the economic feasibility of utilizing OvSynch and fixed TAI in producing superior off-spring Sahiwal calves amongst pastoral herd in Southern rangelands in Kenya. Two hypothetical base scenarios of optimal and low input husbandry practices in pastoral system were used in estimating the projected benefits and corresponding costs for analysis. Sensitivity analysis was further performed to determine the effect of changes in milk prices, inflation rates, reproduction cost and feeding costs based on likelihood circumstances on the NPV, IRR and BCR of the two case scenarios within the pastoral systems. This was undertaken to understand the variations in percentage changes of indicator variables on overall benefits and costs. Variables relating to milk price and feeding costs were varied by 10%, inflation rate varied by 3% while reproduction cost was varied by 20% based on probable endpoint scenarios. The decrease in milk prices and increase in inflation rates, reproduction and feeding costs were based on the hypothesis that herd owners would still be using OvSynch and fixed TAI as future breeding intervention as opposed to use of bull calves.

7.1.3 Willingness to pay (WTP) for OvSynch and fixed TAI among ranch and pastoral herd owners in southern rangelands of Kenya

The study established the willingness of pastoral herd owners to pay for OvSynch and fixed TAI assuming market price to gain insights into continuous and sustainable use when subsidies are withdrawn. Study findings indicate a higher likelihood of pastoral herd owners meeting direct service delivery cost at market price beyond subsidy period. This is evident based on the higher WTP by value above the premium amount (Chapter Three). This implies a possible ownership and guarantees continued use of OvSynch and fixed TAI in pastoral breeding programs post subsidy period. The willingness to meet individual costs exposes the untapped opportunities in reproductive technology supply and delivery chain that entrepreneurs and private sector can venture in especially within the pastoral rangelands. This calls for an efficient and effective delivery model that ensures quality service delivery is maintained along the supply chain.

The higher WTP value recorded by pastoralist and agro pastoralist relative to ranchers implies the desire for superior genetic resources for breeding within the pastoral herds. Specifically, OvSynch and fixed TAI provide an avenue in which pastoral herds could be upgraded through use of superior dual-purpose cattle genes for improved livelihoods. The herd owners' WTP for service delivery cost, would ensure increased access to Sahiwal genetics for herd improvement and ultimate livelihood roles through provision of milk and meat. For cattle

breeders, this implies an opportunity for increasing the Sahiwal effective population size which has been declining within the pastoral rangelands (Kamiti *et al.*, 2016). In the end, this would aid in reducing the already existing and high demand of Sahiwal breed from NSS, ranches and model farms. In addition, the higher WTP for OvSynch and fixed TAI provide an avenue for reducing in breeding incidences through efficient record keeping procedures hence limiting mating animals with common lineage (Mailu *et al*., 2013).

The herd owners' WTP implies the need for institutional support targeting knowledge and skill dissemination for sustainable use of OvSynch and fixed TAI in pastoral rangelands. This calls for targeted collaborations between the national, county and private sector in ensuring effective and efficient extension service delivery. Knowledge dissemination at pastoral level, would ensure right choices on breed and technology use are made while meeting own costs for service delivery. Besides this, coordination between the various stakeholders could offer targeted support in supply chain for easy access and utilization of superior genetic resources. To the pastoral breeding programs, this would imply increasing access and use of various Sahiwal genetic materials for sustainable upgrading within the rangelands.

The WTP provide insights where herd owners would need economic support to meet individual cost. This calls for the need to easily access credit facilities from both public and private financial institutions. National and county governments should strive at providing an enabling environment for innovative financial technologies where pastoral herd owners can easily access credit facilities aimed at improving herd performance. Innovative financial technologies such as mobile money should be spearheaded especially in pastoral remote areas including the rangelands where financial institutions such as banks could be limiting.

Finally, herd owners willingness to meet own costs would trigger policy discussions aimed at providing enabling environment for maintaining quality of input and service delivery during supply chain. Policy interventions directed to enabling private sector to efficiently deliver OvSynch and fixed TAI, would be supportive to wider uptake of these reproductive technologies among pastoral and ranching herds in the rangelands. Policy regulations that target and guide quality of products (hormonal injections, drugs, syringes) and service delivery need to be in place. Policies that also support herd owners easy access to credit facilities targeting use of OvSynch and fixed TAI for improved productivity also need to be reviewed. Policy makers at national and county governments should endeavour to provide enabling environment where innovative financial technology companies could venture in. Public and private institutions should be actively involved in setting up breeding policies, programs and

continuous monitoring of dairy inputs, costs and service delivery for sustainability. This would aid in limiting exploitation by scrupulous service providers.

7.1.4 Influence of sire and dam mating criteria on conception success and calf performance

Pastoral rangelands are characterized by harsh environmental conditions of which high temperatures, repeat breeding, poor estrus detection, low conception and pregnancy rates are outstanding. This leaves adaptable breeds such as the Sahiwal dual-purpose breeds as the best choice towards improving pastoral livelihood support strategy over other livestock species (Mwangi & Ilatsia, 2021). Though adaptable to pastoral rangelands, Sahiwal herd owners' are still constrained by access to superior genetic resources for herd improvement. This has compelled the use of OvSynch and fixed TAI, for faster multiplication and distribution of proven Sahiwal genetic resources for increased herd performances in pastoral rangelands. The study therefore, sought to evaluate the influence of bull-cow mating criteria on conception success rates of Sahiwal cows and heifers under OvSynch and fixed TAI using frozen thawed semen.

Study findings indicate a 16% increase in conceptions while using OvSynch and fixed TAI relative to bull insemination frequently used in pastoral rangelands (61% versus 45%) (Segura Correa *et al*., 2017). This implies the need for pastoral herd owners to adopt reproductive technology use in Sahiwal breeding programs to improve the overall fertility performance of the herd. As evident from the study, use of OvSynch and fixed TAI assures improved conception rates that translate to increased superior herd sizes and production of progeny calves with genetic potential for higher yields and economic returns for improved livelihood roles at household level. The higher conception rates further reveals the untapped potential for entrepreneurs and private sector participation in service and input delivery to the pastoral herds. The results provide insights that could guide investment decision in breeding programs towards adoption and use of OvSynch and fixed TAI by pastoral herd owners.

Increased conception rates by use of OvSynch and fixed TAI as reported in the study also implies the need by both national and county governments to prioritize building infrastructural facilities that promote use of reproductive technologies in pastoral rangelands. This would aid in improving pastoral herd owners' awareness, understanding and perception through demonstrations, field visits and knowledge sharing at different levels within the pastoral rangelands. High conception rates were observed with first time calvers relative to heifers and high parity cows. Arguably, this could have been contributed by high energy

demands for various physiological functions such as maintenance, growth, reproduction and production within the categories. To Sahiwal breeders and pastoral herd owners, this implies the need to prioritize low parity cows during breeding programs for optimal conception results in pastoral herds. For policy makers, the results could guide adequate legislations that support pastoral breeding programs for improved livelihood.

Study results indicated upgrading level and semen type amongst sire characteristics as having significant influence on conception rates of pastoral herds. Higher performance by foundation upgrade level provide insights that livestock breeders and herd owners' could prioritize while venturing in pastoral herd upgrading practice. Research and breeding institutions could also utilize the information while preparing breeding programs and interventions that target increased accessibility to superior offspring calves. This calls for continuous capacity building and sensitizations of herd owners on herd upgrading and improvement interventions for maximum performance and livelihood roles.

Higher conception rates recorded through use of sexed semen point towards the usefulness of using either heifer plus (AH+) or bull plus (BB+) in cattle breeding programs. Using semen-sexing technologies has implications towards improving the overall fertility status of Sahiwal cows and heifers for enhanced reproductive performances. In genetic improvement (selection) and breeding programs targeting specific calf sexes in meeting productive or reproductive pastoral herd objectives for increased economic returns. This further means that pastoral herd upgrading need be bundled with capacity building of herd owners, enhanced last mile extension service delivery and greater private sector participation in artificial semen delivery for efficiency.

7.1.5 Preferential use of bull calves in pastoral herd utilizing OvSynch and fixed TAI

Pastoral herd owners are accessing subsidized superior quality Sahiwal semen through OvSynch and fixed TAI in a community based insemination program. This breeding intervention being encouraged by development partners, can provide avenues for increasing access and distribution of top proven material with higher performance within pastoral herds. The strong social and cultural ties that pastoral communities have with Sahiwal bulls offering tangible and intangible benefits could limit uptake of OvSynch and fixed TAI use especially within the rangelands. Though survey respondents' expressed a high WTP for service delivery costs, uncertainty lies on the future use of bull calves especially when they fully adopt OvSynch and fixed TAI for own-herd breeding or multiplication purposes within their pastoral herds. Therefore, the study sought to assess preferential use of progeny bull calves among

beneficiaries of the Sahiwal cattle upgrading breeding program utilizing OvSynch and fixed TAI in the southern rangelands of Kenya.

Study findings indicate that more than half (54%) of the pastoralists and agro pastoralist would prefer to retain bull calves for breeding as overall first-choice preference relative to selling for income (44%). Retaining superior progeny bull calves for breeding purposes implies pastoralists' desire for superior genetic resources for upgrading within pastoral herd despite the limited Sahiwal breeding bull supply from research stations and model farms (Mbuku *et al.*, 2019). Breeding using progeny bull calves would ensure high-valued herd size with improved performances and higher economic returns for livelihood support. Through their high-value status, progeny bull calves act as easy collaterals for obtaining loans where either formal credit services are unavailable or when available, they are mostly informal and unfordable due to high interest rates (Kaumbata *et al.*, 2020). This aids in meeting immediate household or family needs such as medical expenses, school fees and purchase of dairy inputs (mineral salt licks, drugs and feed supplements). Retaining the progeny bull-calves preference could also imply the existing uncertainty in meeting future cost implications for continuous access to OvSynch and fixed TAI service delivery by pastoral herd owners beyond subsidy period. This calls for a collaborative approach between the public and private institutions in providing an enabling environment for easy access and use of the reproductive technology within the rangelands.

Study results indicate that female herd owners showed higher preference to using progeny bull calves relative to their male counterparts (59% versus 51%). This implies gender equality and differences in value attached to the bull calves and their functional roles in pastoral systems. Breeding option by women could signify their desire for increased milk production from superior offspring calves with high genetic potential to sustain home consumption and surplus sale for income (Mwangi *et al.*, 2020). This would in turn improve the overall nutrition status of the family thereby assuring good health and wellbeing. Their preferred use of the progeny bull calves, would be best served with a multiplication center supplying them with high quality Sahiwal bulls. Themselves, they are less likely to sustain uptake of OvSynch and fixed TAI delivered through market mechanisms. This implies the need for continuous capacity building through extension service delivery on the use of OvSynch and fixed TAI; and potential benefits that involves upgrading the pastoral herd for increased milk and meat production.

Study findings indicate that ranchers prefer income from sale of progeny bull calves relative to breeding. This preference ratifies their commercialized nature of operation based on organized management, marketing and breeding systems that could easily access top proven semen for insemination despite the cost implications as opposed to use of progeny bulls. The

preferential choice for income implies untapped potential using OvSynch and fixed TAI that ranchers can capitalize in multiplying high quality Sahiwal breeding bulls for increased supply to the pastoralists and agro pastoralists. To the ranchers, superior progeny bull calves have high genetic potential for breeding and/ or meat production, and could fetch more income as opposed to rearing for breeding. This calls for continuous capacity building and breeding programs targeting high quality Sahiwal offspring calves for breeding purposes. For this, relevant policy directions should aim ranchers investing in Sahiwal multiplication and distribution of progeny bull calves to limit exploitation during the supply chain.

7.1.6 Benefit-Cost of utilizing OvSynch and fixed TAI in producing heifer and bull calves in pastoral herd

Economic viability of an intervention has direct contributions towards the overall profitability and is crucial in decision making of adopting and using new farm technologies (Adenuga *et al.,* 2020). Within pastoral rangelands, shortage of quality Sahiwal breeding stock has necessitated an alternative breeding tool; the use of Assisted Reproductive Technologies (ARTs) especially OvSynch and fixed TAI. However, economic viability of utilizing ARTs as an alternative breeding tool remains to be uncertain. Therefore, the study assessed the economic viability of using OvSynch and fixed Time Artificial Insemination (TAI) for economic returns in pastoral rangelands. With two assessed hypothetical case scenarios (optimal and low input), estimations on benefits and costs were activity based and projected to productive life.

Study findings through Benefit-Cost analysis show the use of OvSynch and fixed TAI as an economically viable breeding option for use in the pastoral rangelands. Higher benefits are realised especially when pastoral herd owners apply optimal husbandry practices. This implies that pastoral herd owners would benefit investing in OvSynch and fixed TAI while practicing optimal husbandry practices. This findings agrees with Lawrence *et al.* (2015) and Mutembei *et al.* (2016), who reported economic feasibility of using reproductive technologies in increasing profitability of cattle farming. Viability results presents an opportunity for pastoral herd owners to increase their economic returns through investing in OvSynch and fixed TAI and practicing optimal husbandry practices. This calls for a collaborative approach involving public and private institutions to ensure an efficient extension service delivery is in place for capacity building and dissemination of optimal husbandry practices.

All best-case scenarios recorded positive responses in all systems (optimal or low-input husbandry practices) for targeted output products as indicated in the study. Higher economic implications are realized with high milk production while undertaking optimal husbandry

practices in either of the case scenarios. This implies that use of OvSynch and fixed TAI in pastoral upgrading programs can be effective on traits that target improving milk and beef production for higher economic returns. Pastoral herd owners therefore, need more sensitization on selection indexes that balances milk and meat traits especially while considering Sahiwal cattle- a dual-purpose breed. For breeders, this implies the need to capitalize milk trait on adaptable cattle breed that ensures maximum economic returns. This calls for an institutional support through adequate research that focuses on best cattle breed with high milk potential and effective extension dissemination mechanisms and service delivery within the pastoral rangelands.

Besides proper adaptable cattle breed with higher milk potential, efficient milk pricing system is essential to ensure higher economic implications and sustainability of pastoral farms. This could be achieved through either improving the milk prices or venturing in quality-based milk-marketing systems that promotes nutritive value (fat and protein content) rather than liquid volumes for increased economic returns (Michaličková *et al.*, 2017). This calls for continuous capacity building and sensitization that focus on milk quality through collaborative extension service provision by public and private sectors. To the policy makers, this further implies the need for regulations that target milk prices and those limiting exploitation of pastoral herd owners by dairy entrepreneurs.

All best-case scenarios recorded positive responses in all systems (optimal or low-input husbandry practices) for targeted output products. This implies the need for pastoral herd owners to apply best practices for increased production and economic returns. Study findings recorded feeding costs as contributing the highest (66%) towards the total costs of production. Higher feeding costs implies the need for targeted interventions that reduces the overall production costs for improved economic returns. One intervention could involve exploiting own-farm livestock feed production that assures quality and quantity of available fodder. Additionally, national and county governments could offer alternatives for increased animal feed resources where pastoral herd owners would easily access at low costs. This would ensure easy access to adequate feed resources for continued herd production within the rangelands throughout the year.

Finally, through sensitivity analysis the study recorded notable effects on analysed economic parameters upon deviations in input and output prices while applying either optimal or low input husbandry practices. This has economic implication and provides signal that pastoral herd owners investing in OvSynch and fixed TAI, need implementing optimal husbandry practices. This calls for institutional support actions that provides enabling

environment and aids in de-risking pastoral herd owners from market and climate related shocks.

7.2 Proposed breeding framework

To achieve a faster and wider access to quality genetic resources, a combined and efficient delivery model is paramount for ensuring sustainability in pastoral breeding programs. With one of the governments' priority agenda being to increase household productivity and income, herd owners can capitalize on the use of OvSynch and fixed TAI as a way of improving access to quality Sahiwal breed for increased herd performance. Therefore, the study proposes a community based breeding program approach that enables wider access and dissemination of top proven Sahiwal genetics through OvSynch and fixed TAI utilization within the rangelands. In the context of the study, community based breeding programs (CBBP) include initiatives spearheaded by herd owners in a pastoral community with a common objective of improving livestock production through appropriate use of animal genetic resources (Kahi *et al*., 2005). Herd owners can therefore, either individually or in a group, effect these community based breeding programs in cooperation with stakeholders to effect genetic improvement within their pastoral herds (Karnuah & Dunga, 2018). Community based breeding programs offer viable approach to systematic breeding in low-input smallholder scenarios (Wurzinger *et al.*, 2021), as in the case of pastoral rangeland. Through these breeding programs, herd owners could initiate interventions that would ensure sustainable upgrading from a less to a more performing cattle herd for improved performance and economic status. To be efficient, these programs need adequate awareness during extension service provisions and efficient genetic evaluation systems to minimize negative effects such as in-breeding incidences within the cattle herd (Kahi *et al.*, 2005; Kosgey *et al.*, 2011).

To achieve optimal results within the CBBPs, emphasis should target designed participatory approaches including adequate capacity building on proper breed selection and animal husbandry practices. Initial breed selection that is well adaptable is key for successful breeding programs in the pastoral rangelands. Adequate selection of indigenous breeds or genotypes is crucial for sustainability of genetic improvement initiatives as in the case of rangelands (Kosgey & Okeyo, 2007). Sahiwal dual purpose breed thus offers a good choice for improved milk and meat production in pastoral production systems. For instance, top proven Sahiwal bull semen, can be mated to selected cows or heifer (pure or Sahiwal crosses) to produce the first filial (F_1) generation. The resulting F_1 females could further be mated with unrelated high quality top proven bulls to get superior F_2, F_3, and F_4 generations (pedigree level)

subsequently for optimal performances within the cattle herd (Mwangi *et al*., 2020).. Continuous upgrading processes provides options for hybrid vigour within the offspring and improved maternal performance. Despite the positive attributes associated with CBBP, their successful establishment and sustainability in pastoral rangelands require a strong internal and external support through continuous collaboration with stakeholders in the livestock sector. This is achievable through continuous awareness and capacity building of herd owners to guarantee ownership and taking over the operations of the CBBP especially when donors withdraw support (Kahi *et al.*, 2005).

Increasing pastoral herd performances cannot be achieved exclusively by genetic improvement, but rather on a holistic approach, that involves both genetic and environmental improvement. Through capacity building, environmental contributions involving adequate husbandry measures related to feeding, housing, disease control and animal welfare, would ensure full genetic potential expression by the superior Sahiwal cattle from OvSynch and fixed TAI utilization. This further leads to increased production of quality products and improved productivity from Sahiwal pastoral herd. Therefore, harnessing the full potential of Sahiwal cattle within the rangelands can optimize their contributions towards reduction of rural poverty and hunger. In the end, this assures improved livelihood at household level and significant contributions towards pastoral economy in general. Based on these, the study envisages financing and scaling up of CBBPs coupled by OvSynch and fixed TAI utilization as a sustainable working model for improved access, multiplication and dissemination of top proven Sahiwal genetics targeting pastoralists within the rangelands. In addition, application of adequate husbandry will guarantee increased herd productivity and improved livelihood status.

7.3 Conclusions

i. Pastoral herd owners are willing to pay for OvSynch and fixed timed Artificial Insemination, implying they would be able to continue accessing Sahiwal semen for breeding purposes within their pastoral herd without subsidies.
ii. OvSynch and fixed Time Artificial Insemination (TAI) protocol using frozen-thawed semen can be applied in Sahiwal cows and heifers to achieve higher CR for improved reproductive performances.
iii. Pastoral herd owners prefer to retain the progeny bull calves within their herd as future breeding stock.
iv. Utilizing OvSynch and fixed TAI in producing progeny heifers and bull calves is economically viable in pastoral rangelands while applying optimal husbandry practices.

7.4 Recommendations

(i) Well-coordinated extension service delivery, policy provisions and enabling environment that ensures increased awareness and use of OvSynch and fixed TAI while maintaining quality supply chain.

(ii) Implementation of proper sire-dam selection procedures in Sahiwal breeding programs to ensure improved herd productive and reproductive performances.

(iii) Training and capacity building of pastoral herd owners on rearing superior progeny bull calves for optimal performances during future breeding programs.

(iv) Continuous sensitization on application of optimal husbandry practices that ensures maximum productivity and economic returns.

7.5 Areas for further research

Areas that need to be prioritized for further research include;

i. Assessing the possible use of other assisted reproductive technologies such as SIFET, MOET and IVEP that can be applied in pastoral herd for increasing access superior Sahiwal genetic resources.

ii. Assessing the temporal trends overtime in the continuous and sustainable utilization of OvSynch and fixed TAI within pastoral herds and their livelihood impacts.

iii. Impact of extension service provision in disseminating breeding technologies and service delivery within pastoral rangelands.

iv. In-depth and follow up longitudinal studies on the obtained progeny heifer and bull calves from OvSynch and fixed TAI utilization in pastoral herd to assess their overall performances.

REFERENCES

Adenuga, A. H., Jack, C., Olagunju, K. O., & Ashfield, A. (2020). Economic viability of adoption of automated oestrus detection technologies on dairy farms: A review. *Animals*, *10*(7), 1–14. https://doi.org/10.3390/ani10071241

Agutu, F. O., Ondiek, J. O., & Bebe, B. O. (2019). Associations between intensification interventions and herd productivity in smallholder dairy farms in the Kenyan Highlands. *African Journal of Rural Development*, *4*(3), 1–9.

Alberini, A., & Cooper, J. (2000). *Applications of the contingent valuation method in developing countries: A survey, FAO Economic and Social Development Paper No. 146, Rome.*

Alusi, P. M. (2014). *Socio-cultural and economic risk factors for human Brucellosis in Lolgorian Division, Transmara District.* Master's thesis in Anthropology, University of Nairobi. http://erepository.uonbi.ac.ke

Anderson, K. J., LeFever, D. G., Brinks, J. S., & Odde, K. G. (1991). The use of reproductive tract scoring in beef heifers. *Agri- Practice*, *12*(4), 19–26.

Atsiaya, G. O., Wati, L. N., Ingasia, O. A., & Lagat, J. K. (2018). Smallholder Farmers ' Willingness to Pay for Insurance Against Climate Variability Effects in Arid Land Areas of Kenya. *Journal of Environment and Earth Science*, *8*(11), 52–59. https://www.iiste.org/Journals/index.php/JEES/article/view/45049

Awulachew, M. (2021). Assessment on Cattle Breeding Practice and Production System Associated with Their Environmental Implication in Ethiopia. *Animal and Veterinary Sciences*, *9*(4), 99- 106. https://doi.org/10.11648/j.avs.20210904.13

Ayalew, W., & Dekeba, A. (2006). Organization and performance of government-owned cattle breeding ranches in the supply of genetically improved breeding stock in Ethiopia. *Proceedings of the 14th Annual Conference of the Ethiopian Society of Animal Production (ESAP) Held in Addis Ababa, Ethiopia, September 5–7, 2006 Part I: Plenary Session. Tadelle Dessie (Ed). 116 Pp*.

Babigumira, B., Nabukalu, R., Masaba, J., Egadu, G., Mulindwa, H., Oluka, J., & Kugonza, D. (2018). Growth Characteristics of Sahiwal x Zebu F1 Crossbred Cattle in Uganda. *International Journal of Livestock Research*, *8*(6), 1–7. https://doi.org/10.5455/ijlr.2018 0226064352

Bebe, B. O., Udo, H. M., & Thorpe, W. (2002). Development of smallholder dairy systems in the Kenya highlands. *Outlook on Agriculture*, *31*(2), 113–120. https://doi.org/10.5367/ 000000002101293958

Behnke, R., & Muthami, D. (2011). *The contribution of livestock to the Kenyan economy. IGAD Livestock Policy Initiative Working Paper No. 03–11. Intergovernmental authority for development in Eastern Africa. Ababa: IGAD LPI Communications Office; 2011.* (Issue 03). https://cgspace.cgiar.org/bitstream/handle/10568/24972/IGAD_LPI_WP_03-11.pdf?sequence=1

Bett, R. C., Bett, H. K., Kahi, A. K., & Peters, K. J. (2009). Evaluation and effectiveness of breeding and production services for dairy goat farmers in Kenya. *Ecological Economics, 68*(8-9), 2451–2460. https://doi.org/10.1016/j.ecolecon.2009.04.014

Bhattacharyya, H. K., Fazili, M. . R. R., Khan, I., & Bhat, F. A. A. A. (2010). Fertility Status of Artificially Inseminated Crossbred Cows of Kashmir Valley. *Asian Journal of Animal Sciences*, *4*(2), 56–63. https://doi.org/10.3923/ajas.2010.56.63

Binelli, M., Martins, T., Rocha, C. C., Silva, F. A. C. C., Bittar, J., Moriel, P., Gonella-Diaza, A., Butler, L., & Sanders, C. (2021). *Reproductive Tract Score: A Tool for Evaluating Beef Heifer Reproductive Potential. Extension Manual*. https://doi.org/10.32473/edis-an370-2021

Bodmer, M., Janett, F., Hässig, M., Den Daas, N., Reichert, P., & Thun, R. (2005). Fertility in heifers and cows after low dose insemination with sex-sorted and non-sorted sperm under field conditions. *Theriogenology*, *64*(7), 1647–1655. https://doi.org/10.1016/j.theriogenology.2005.04.011

Boone, R. B., BurnSilver, S. B., & Thornton, P. K. (2006). *Optimizing aspects of land use intensification in Southern Kajiado District, Kenya. Final report to the International Livestock Research Institute, Nairobi, Kenya. Reto-o-Reto Project, DGIC.*

Boyle, K. J. (2017). Contingent Valuation in Practice. In P. A. Champ, K. J. Boyle, & T. C. Brown (Eds.), *A Primer on Nonmarket Valuation. The Economics of Non-Market Goods and Resources* (Vol. 13, pp. 89–131). Springer. https://doi.org/10.1007/978-94-007-7104-8

Bruno, R. G. S., Farias, A. M., Hernández-Rivera, J. A., Navarrette, A. E., Hawkins, D. E., & Bilby, T. R. (2013). Effect of gonadotropin-releasing hormone or prostaglandin F2α-based estrus synchronization programs for first or subsequent artificial insemination in lactating dairy cows. *Journal of Dairy Science*, *96*(3), 1556–1567. https://doi.org/10.3168/jds.2012-5885

Cawley, J. (2006). *Contigent Valuation analysis of Willingness to pay to reduce childhood obesity*. *NBER Working Paper No. 12510*. https://doi.org/10.1017/CBO9781107415324.004

Central Bank of Kenya (C.B.K). (2021). *Annual report and Financial Statement 2020/2021. Central Bank of Kenya, Nairobi, Kenya.* https://www.centralbank.go.ke/uploads/cbk_annual_reports/569264497_Annual Report 2020-2021.pdf

Cerri, R. L. A., Rutigliano, H. M., Bruno, R. G. S., & Santos, J. E. P. (2009). Progesterone concentration, follicular development and induction of cyclicity in dairy cows receiving intravaginal progesterone inserts. *Animal Reproduction Science*, *110*(1-2), 56–70. https://doi.org/10.1016/j.anireprosci.2007.12.005

Chawala, A. R., Banos, G., Peters, A., & Chagunda, M. G. G. (2019). Farmer-preferred traits in smallholder dairy farming systems in Tanzania. *Tropical Animal Health and Production*, *51*(6), 1337–1344. https://doi.org/10.1007/s11250-018-01796-9

Chebel, R. C., Santos, J. E. P., Reynolds, J. P., Cerri, R. L. A., Juchem, S. O., & Overton, M. (2004). Factors affecting conception rate after artificial insemination and pregnancy loss in lactating dairy cows. *Animal Reproduction Science*, *84*(3-4), 239–255. https://doi.org/10.1016/j.anireprosci.2003.12.012

Chongsi, M. M. M., Ngoula, F., Bessong, O. W., Kenfack, A., Moumpou, E., Vemo Bertin, N., & Tchoumboue, J. (2019). Effects of Semen Sexing Agent (Heiferplus) on Sperm Characteristics and Fertility in Cows. *EC Veterinary Science*, *4*(9), 42–52. https://www.ecronicon.com/ecve/pdf/ECVE-04-00175.pdf

Christie, M., Hanley, N., Warren, J., Murphy, K., Wright, R., & Hyde, T. (2006). Valuing the diversity of biodiversity. *Ecological Economics*, *58*(2), 304–317. https://doi.org/10.1016/j.ecolecon.2005.07.034

Dayyani, N., Karkudi, K., & Bakhtiari, H. (2013). Reproductive performance definition in dairy cattle: affective factors. *International Journal of Advanced Biological and Biomedical Research*, *1*(11), 1392–1396. www.ijabbr.com/article_7965_96709d83657e3e6595ce068efdce6fb0.pdf%0A

Dehinenet, G., Mekonnen, H., Kidoido, M., Ashenafi, M., & Bleich, E. G. (2014). The impact of dairy technology adoption on small holder dairy farmers livelihoods in selected zones of Amhara and Oromiya National Rgional States, Ethiopia. *Global Journal of Agricultural Economics and Econometrics*, *2*(5), 126–135.

Dewey, S. T., Mendonça, L. G. D., Lopes, G., Rivera, F. A., Guagnini, F., Chebel, R. C., & Bilby, T. R. (2010). Resynchronization strategies to improve fertility in lactating dairy cows utilizing a presynchronization injection of GnRH or supplemental progesterone: I. Pregnancy rates and ovarian responses. *Journal of Dairy Science*, *93*(9), 4086–4095. https://doi.org/10.3168/jds.2010-3233

Drucker, A. G., Gomez, V., & Anderson, S. (2001). The economic valuation of farm animal genetic resources: A survey of available methods. *Ecological Economics*, *36*(1), 1–18. https://doi.org/10.1016/S0921-8009(00)00242-1

Faizah, H. M. S., Richard, F., Meena, P., Stanley, K. L., Amriana, H., Yadav, S. B., Marie, L., Crouch, B., & Saipul, B. A. R. (2018). Multiple ovulation embryo transfer (MOET) in dairy cattle in Gatton. *Malaysian Journal of Veterinary Research*, *9*(2), 109–116. www.dvs.gov.my/dvs/resources/user_16/.../MJVR-V9N2-p109-116.pdf

FAO. (2011). *Dairy development in Kenya, by H.G. Muriuki. Rome. 52 pp*. http://www.fao.org

FAO. (2018a). *Africa Sustainable Livestock 2050. Livestock and Livelihoods spotlight Kenya: Cattle and poultry sectors*. www.fao.org/3/I8978EN/i8978en.pdf

FAO. (2018b). *Africa Sustainable Livestock 2050. Livestock production systems spotlight: Cattle and poultry sectors in Kenya*. www.fao.org/3/i8270en/I8270EN.pdf%0A

Gamba, P. (2006). *Beef and dairy cattle improvement services: A policy perspective. Working paper No. 23, Tegemeo Institute of Agricultural Policy and Development, Egerton University. Pp 33*. http://41.89.96.81/handle/123456789/2272

Gebremichael, D. (2015). *Breeding practice and estrus synchronization evaluation of dairy cattle in Central zone of Tigray, Nothern Ethiopia.* Master's Thesis. Jimma University, Ethiopia. https://cgspace.cgiar.org/bitstream/handle/10568/76171/thesis_gebremichael_jun2015.pdf?sequence=1

Genius, M., Pantzios, C. J., & Tzouvelekas, V. (2006). Information acquisition and adoption of organic farming practices. *Journal of Agricultural and Resource Economics*, *31*(1), 93–113. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.483.6999&rep=rep1&type=pdf

Gicheha, M. G., Akidiva, I. C., & Cheruiyot, R. Y. (2018). Genetic and economic efficiency of integrating reproductive technologies in cattle breeding programme in Kenya. *Tropical Animal Health and Production*, *51*(2), 473–475. https://doi.org/10.1007/s11250-018-1689-1

Gillespie, J., Nehring, R., & Sitienei, I. (2014). The adoption of technologies, management practices, and production systems in U.S. milk production. *Agricultural and Food Economics*, *2*(1), 1–24. https://doi.org/10.1186/s40100-014-0017-y

Government of Kenya (GoK). (2008). *Trans Mara District Development Plan (2002-2008). Effective Management For Sustainable Economic Growth and Poverty Reduction. Ministry of Planning and National Development, Nairobi: Government Printers.* https://repository.kippra.or.ke/xmlui/bitstream/handle/123456789/1822/TransMaraDistri

ctDevelopmentPlan2002-2008.pdf?sequence=1&isAllowed=y

Grandin, B. E. (1988). Wealth and pastoral dairy production: A case study from Maasailand. *Human Ecology*, *16*(1), 1–21. https://doi.org/10.1007/BF01262023

Hady, P. J., Domecq, J. J., & Kaneene, J. B. (1994). Frequency and Precision of Body Condition Scoring in Dairy Cattle. *Journal of Dairy Science*, *77*(6), 1543–1547. https://doi.org/10.3168/jds.S0022-0302(94)77095-8

Haile, A., Ayalew, W., Kebede, N., Dessie, T., & Tegegne, A. (2011). *Breeding strategy to improve Ethiopian Boran cattle for meat and milk production. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 26. Nairobi, Kenya, ILRI. 26*, 56. http://mahider.ilri.org/bitstream/handle/10568/3141/WP_26.pdf?sequence=1

Hanemann, M., Loomis, J., & Kanninen, B. (1991). Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation. *American Journal of Agricultural Economics, 73*(4), 1255–1263. https://doi.org/10.2307/1242453

Hanley, N., Mourato, S., & Wright, R. E. (2001). Choice modelling approaches: A superior alternative for environmental valuation? *Journal of Economic Surveys*, *15*(3), 435–462. https://doi.org/10.1111/1467-6419.00145

Hatfield, R., Davies, J., Wane, A., Kerven, C., Dutilly-Diane, C., Biber, J. P., Merega, J. L., Odhiambo, M. O., Behnke, R., & Gura, S. (2006). *Global Review of the Economics of Pastoralism. The World Initiative for Sustainable Pastoralism*. www.iucn.org/wisp

Hojo, T., Sakatani, M., & Takenouchi, N. (2018). Efficiency of a pedometer device for detecting estrus in standing heat and silent heat in Japanese Black cattle. *Animal Science Journal*, *89*(8), 1067–1072. https://doi.org/10.1111/asj.13023

Holm, D. E., Thompson, P. N., & Irons, P. C. (2009). The value of reproductive tract scoring as a predictor of fertility and production outcomes in beef heifers. *Journal of Animal Science*, *87*(6), 1934–1940. https://doi.org/10.2527/jas.2008-1579

Howlader, M. M. R., Rahman, M. M., Hossain, M. G., & Hai, M. A. (2019). Factors Affecting Conception Rate of Dairy Cows Following Artificial Insemination in Selected Area at Sirajgonj District of Bangladesh. *Biomedical Journal of Scientific & Technical Research*, *13*(2), 9907–9914. https://doi.org/10.26717/BJSTR.2019.13.002386

Ilatsia, E. D., Migose, S. A., Muhuyi, W. B., & Kahi, A. K. (2011). Sahiwal cattle in semi-arid Kenya: Genetic aspects of growth and survival traits and their relationship to milk production and fertility. *Tropical Animal Health and Production*, *43*(8), 1575–1582. https://doi.org/10.1007/s11250-011-9845-x

Ilatsia, E. D., Muasya, T. K., Muhuyi, W. B., & Kahi, A. K. (2007). Milk production and reproductive performance of Sahiwal cattle in semi-arid Kenya. *Tropical Science*, *47*(3), 120–127. https://doi.org/10.1002/ts.205

Ilatsia, E. D., Roessler, R., Kahi, A. K., Piepho, H.-P., & Zárate, V. (2012). Production objectives and breeding goals of Sahiwal cattle keepers in Kenya and implications for a breeding programme. *Tropical Animal Health and Production*, *44*(3), 519–530. https://doi.org/10.1007/s11250-011-9928-8

Janssen-tapken, U., Kadarmideen, H. N., & Rohr, P. Von. (2006). Cattle breeding strategies using genetic markers as a pathway for improving competitiveness of pastoral systems in Kenya. *Paper Contributed to the Conference on Pastoralism and Poverty Reduction in East Africa: A Policy Research Conference, Nairobi, Kenya, June 27-28.*, 31. https://hdl.handle.net/10568/2514

Jemal, H., & Lemma, A. (2015). Review on Major Factors Affecting the Successful Conception Rates on Biotechnological Application (AI) in Cattle. *Global Journal of Medical Research*, *15*(3), 19–27. https://www.researchgate.net/publication/303675297

Jemal, K., Ahmed, A., Atlaw, H., Abdi, N., Mohammed, H., Jibril, S. M., & Ibrahim, M. (2016). *The Contribution of Hides and Skins To the Pastoralist Economy in the Ethiopian Somali Regional State : Findings From Jarrar and Shebelle Zones. Feed the Future Initiative - USAID & AKLDP Project Report*. www.agrilearningethiopia.org/wpcontent/.../Jemal-et-al-TEV-skin-hide-report.pdf

Johnson, S., & Jones, R. (2002). Costs and comparisons of estrous synchronization systems. *In Applied Reproductive Strategies in Beef Cattle Workshop, September 5-6, 2002, Manhattan, Kansas*, 138–151.

Kahi, A. K., & Nitter, G. (2004). Developing breeding schemes for pasture based dairy production systems in Kenya. I. Derivation of economic values using profit functions. *Livestock Production Science*, *88*(1-2), 161–177. https://doi.org/10.1016/j.livprodsci.2003.10.008

Kahi, A. K., Rewe, T. O., & Kosgey, I. S. (2005). Sustainable community-based organizations for the genetic improvement of livestock in developing countries. *Outlook on Agriculture*, *34*(4), 261–270. https://doi.org/10.5367/000000005775454706

Kahi, A. K., Wasike, C. B., & Rewe, T. O. (2006). Beef production in the arid and semi-arid lands of Kenya: Constraints and prospects for research and development. *Outlook on Agriculture*, *35*(3), 217–225. https://doi.org/10.5367/000000006778536800

Kamiti, D. N. (2015). *Evaluation of genetic diversity of Sahiwal cattle in Kenya.* Master's

Thesis in Animal Production (Animal Breeding option), Egerton University. www.egerton.ac.ke

Kamiti, D. N., Ilatsia, E. D., Bett, R., & Kahi, A. K. (2016). Population structure and demographic trends of the registered Sahiwal cattle in Kenya. *Tropical Animal Health and Production*, *48*(5), 1029–1036. https://doi.org/10.1007/s11250-016-1055-0

Kanuya, N. L., Matiko, M. K., Kessy, B. M., Mgongo, F. O., Ropstad, E., & Reksen, O. (2006). A study on reproductive performance and related factors of zebu cows in pastoral herds in a semi-arid area of Tanzania. *Theriogenology*, *65*(9), 1859–1874. https://doi.org/10.1016/j.theriogenology.2005.10.016

Kariuki, C., Van Arendonk, J., Kahi, A. K., & Komen, H. (2017). Multiple criteria decision-making process to derive consensus desired genetic gains for a dairy cattle breeding objective for diverse production systems. *Journal of Dairy Science, 100*, 4671–4682. https://doi.org/10.3168/jds.2016-11454

Karnuah, A. B., & Dunga, G. (2018). Community based breeding program for improve goat production in Liberia. *MOJ Current Research & Reviews*, *1*(5), 216–221. https://doi.org/10.15406/mojcrr.2018.01.00036

Kashangaki, J., & Ericksen, P. (2018). *Cost–benefit analysis of fodder production as a low emissions development strategy for the Kenyan dairy sector. ILRI Project Report. Nairobi, Kenya: ILRI.* cgspace.cgiar.org/rest/bitstreams/158438/retrieve

Kaumbata, W., Banda, L., Mészáros, G., Gondwe, T., Woodward-Greene, M. J., Rosen, B. D., Van Tassell, C. P., Sölkner, J., & Wurzinger, M. (2020). Tangible and intangible benefits of local goats rearing in smallholder farms in Malawi. *Small Ruminant Research*, *187*(March), 106095. https://doi.org/10.1016/j.smallrumres.2020.106095

Kebebe, E. G., Oosting, S. J., Baltenweck, I., & Duncan, A. J. (2017). Characterisation of adopters and non-adopters of dairy technologies in Ethiopia and Kenya. *Tropical Animal Health and Production*, *49*(4), 681–690. https://doi.org/10.1007/s11250-017-1241-8

Kenya Market Trust. (2019). *Contextualizing Pathways to Resilience in Kenya's ASALs under the Big Four Agenda. Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) Project Report. Pp 40*. http://www.kenyamarkets.org/wpcontent/uploads /2019/06/PRISE-Synthesis-Report_Final.pdf

Kenya National Bureau of Statistics (KNBS). (2019). *2019 Kenya Population and Housing Census: Volume IV: Distribution of Population by Socio-Economic Characteristics. Government Printers, Nairobi, Kenya*.

Ketere-Lelgut, J. N. (2021). *Growth of Sahiwal and their crossbred weaner calves fed on*

pasture with supplementation under pastoral system. Master's Thesis in Animal Production, University of Eldoret. http://erepository.uoeld.ac.ke/bitstream/handle/123456789/672/Ketere.pdf?sequence=1&isAllowed=y

Ketere-Lelgut, J. N., Muia, J. M. K., Oliech, G. O., & Kitilit, J. K. (2018). Current Livestock Production Challenges and Opportunities in Transmara Sub-County: Diagnostic Survey Report. *African Journal of Education, Science and Technology*, *4*(4), 38–47. http://www.ajest.info/index.php/ajest/article/view/311/320

Khainga, D. N. (2015). *Adoption of assisted reproductive technologies and Sahiwal cattle breed and their impact on household farm income in Narok and Kajiado Counties of Kenya.* Master's Thesis in Agricultural and Applied Economics, Egerton University. www.egerton.ac.ke

Khan, M. S., Bhatti, A. A., Bhatti, S. A., & Ashiq, M. (2007). Semen production and productive life of Sahiwal bulls: relationship with genetic worth. *Pakistan Veterinary Journal*, *27*(1), 20–24.

Kibiro, S. K. (2007). *Calf Health and Production Under Maasai Pastoral System in Kajiado District of Kenya.* Doctoral Dissertation. Department of Public Health, Pharmacology and Toxicology, University of Nairobi. http://erepository.uonbi.ac.ke/handle/11295/6430

Kimaro, E. G., & Chibinga, O. C. (2013). Potential impact of climate change on livestock production and health in East Africa: A review. *Livestock Research for Rural Development*, *25*(7) 1-7. http://www.lrrd.org/lrrd25/7/kima25116.htm

Kios, D. K., Tsuma, V., & Mutembei, H. M. (2018). Factors Affecting Adoption Of Embryo Transfer Technology In Dairy Cattle In Kenya. *Advances in Social Sciences Research Journal*, *5*(8), 456–463. https://doi.org/10.14738/assrj.58.5047

Kosgey, I. S., Mbuku, S. M., Okeyo, A. M., Amimo, J., Philipsson, J., & Ojango, J. M. K. (2011). Institutional and organizational frameworks for dairy and beef cattle recording in Kenya: a review and opportunities for improvement. *Animal Genetic Resources/Ressources Génétiques animales/Recursos Genéticos Animales*, *48*, 1–11. https://doi.org/10.1017/S2078633610001220

Kosgey, I. S., & Okeyo, A. M. (2007). Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues. *Small Ruminant Research*, *70*(1), 76–88. https://doi.org/10.1016/j.smallrumres.2007.01.007

Lancaster, K. (1966). A New Approach to Consumer Theory. *Journal of Political Economy*, *74*(2), 132–157. https://www.journals.uchicago.edu/doi/abs/10.1086/259131

Lardner, H., Damiran, D., & Larson, K. (2020). Comparison of FTAI and Natural Service

Breeding Programs on Beef Cow Reproductive Performance, Program Cost and Partial Budget Evaluation. *Journal of Agricultural Science*, *12*(9), 1–13. https://doi.org/10.5539/jas.v12n9p1

Lawrence, F. G., Mutembei, H. M., Lagat, J., Mburu, J., & Mwai, O. (2015). A Cost-Benefit Analysis of Usage of Sexed in-vitro Fertilization Embryo Transfer Technology in Kenya. *Journal of Agricultural Science and Food Technology*, *1*(4), 53–58. https://profiles.uonbi.ac.ke/hmutembei/files/cost_benefit_paper_2015.pdf%0A

Lekasi, J. K., Tanner, J. C., Kimani, S. K., & Harris, P. J. C. (2003). Cattle manure quality in Maragua District, Central Kenya: Effect of management practices and development of simple methods of assessment. *Agriculture, Ecosystems and Environment*, *94*(3), 289–298. https://doi.org/10.1016/S0167-8809(02)00037-3

Lemma, H., Belihu, K., Sheferaw, D., Sodo, W., Science, R., & Sodo, W. (2010). Study on the reproductive performance of Jersey cows at Wolaita Sodo dairy farm, Southern Ethiopia. *Ethiopian Veterinary Journal*, *14*(1), 53–70. https://www.ajol.info/index.php/evj/article/download/63869/51682

Lind, J., Sabates-Wheeler, R., Caravani, M., Kuol, L. B. D., & Nightingale, D. M. (2020). Newly evolving pastoral and post-pastoral rangelands of Eastern Africa. *Pastoralism*, *10*(1), 1–24. https://doi.org/10.1186/s13570-020-00179-w

Lopez-Feldman, A. (2012). *Introduction to contingent valuation using Stata. MPRA Paper No. 41018*. http://mpra.ub.uni-muenchen.de/41018/

Lukuyu, B., Gachuiri, C. K., Lukuyu, M. N., Lusweti, C., & Mwendia, S. (eds). (2012). *Feeding dairy cattle in East Africa. East Africa Dairy Development Project Report, Nairobi, Kenya*. https://scholar.google.com/scholar?cluster=8864360012852157201&hl=en&as_sdt=2005&sciodt=0,5

Magembe, E. M., Bebe, B. O., & Lagat, J. K. (2014). Evaluation of Livestock- Crop Enterprise Diversity Associated with Shift from Pastoral to Agro-Pastoral Farming Systems in Transmara West District of Narok County- Kenya. *Greener Journal of Agricultural Sciences*, *4*(3), 101–109. https://doi.org/10.15580/GJAS.2014.3.020514093

Mailu, S. K., Ndambiri, H. K., Ritho, C., Nganga, S. I., Miyancha, S. O., Omboto, P. I., Gudeta, S., & Kibowon, P. C. (2013). A demand analysis for Sahiwal breeding animals from the national sahiwal stud (NSS) between 1971 and 2007. *International Journal of Economics and Management Sciences*, *1*(12), 29–43. https://mpra.ub.uni-muenchen.de/49688/MPRA

Marshall, K. (2018). *Description of cost: benefit model developed for low-input dairy systems*

typical of developing countries. ILRI Manual 29. Nairobi, Kenya: International Livestock Research Institute (ILRI). https://hdl.handle.net/10568/101404

Marshall, K., Salmon, G. R., Tebug, S., Juga, J., MacLeod, M., Poole, J., Baltenweck, I., & Missohou, A. (2020). Net benefits of smallholder dairy cattle farms in Senegal can be significantly increased through the use of better dairy cattle breeds and improved management practices. *Journal of Dairy Science*, *103*(9), 8197–8217. https://doi.org/10.3168/jds.2019-17334

Maxwell, W. M. C., Evans, G., Hollinshead, F. K., Bathgate, R., De Graaf, S. P., Eriksson, B. M., Gillan, L., Morton, K. M., & O'Brien, J. K. (2004). Integration of sperm sexing technology into the ART toolbox. *Animal Reproduction Science*, *82*(2004), 79–95. https://doi.org/10.1016/j.anireprosci.2004.04.013

Mbae, R., Kimoro, B., Kibor, B., Wilkes, A., Odhong, C., van Dijk, S., Wassie, S., & Khobondo, J. O. (2020). *The Livestock Sub-sector in Kenya's NDC: A scoping of gaps and priorities. UNIQUE Livestocksub-sector NDC report. Global Research Alliance on Agricultural Greenhouse Gases (GRA) & CGIAR Research Program on Climate Change Agriculture and Food Security*. https://hdl.handle.net/10568/110439

Mbuku, S. M., Magothe, T. M., Mwangi, D., Egesa, P., & Kihurani, D. (2019). Smallholder Farmers Access to Improved Sahiwal Cattle Genetics in Kenya: The Long Shadow. *In Innovations to Harness the Potential of African Animal Agriculture in a Globalizing World. Paper Presented at the Proceedings of the 7th All Africa Conference on AnimaL Agriculture Held on July 29 to August 2, 2019 at Accra International Conference Cen*.

McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. *Journal of Applied Econometrics*, *15*(5), 447–470. https://doi.org/10.1002/1099-1255(200009/10)15:5<447::AID-JAE570>3.0.CO;2-1

Mekonnen, T., Tadesse, Y., & Meseret, S. (2020). Genetic Improvement Strategy of Indigenous Cattle Breeds: Effect of Cattle Crossbreeding Program in Production Performances. *Journal of Applied Life Sciences International*, *23*(1), 23–40. https://doi.org/10.9734/jalsi/2020/v23i130140

Miah, A. G., Salma, U. M. M. A. Y., & Hossain, M. M. (2004). Factors influencing conception rate of local and crossbred cows in Bangladesh. *International Journal of Agriculture and Biology*, *6*(5), 797–801. http://www.ijab.org

Michaličková, M., Krupová, Z., & Krupa, E. (2017). Economics of dual-purpose dairy cattle under various milk pricing systems. *Bulgarian Journal of Agricultural Science*, *23*(2), 183–188. https://www.agrojournal.org/23/02-02.pdf

Ministry of Agriculture (MoA). (2009). *Economic Review of Agriculture, Government printers, Nairobi Kenya*. https://statistics.kilimo.go.ke/files/bookpage/ECONOMIC_REVIEW_OF_AGRICULTURE__2009.pdf

Ministry of Agriculture and Irrigation (MoA&I). (2018). *Ministry of Agriculture and Irrigation. National Strategy and Action Plan on Animal Genetic Resources for Kenya. Ministry of Agriculture and Irrigation, Nairobi, Kenya. pp 58.*

Ministry of Agriculture Livestock Fisheries and Irrigation (MoALF&I). (2019). *Draft National Livestock Policy Kenya*. http://www.kilimo.go.ke/wp-content/uploads/2019/02/Draft-reviewed-National-Livestock-Policy-February-2019.pdf

Ministry of Livestock Development (MoLD). (2010). *Kenya National Dairy Master Plan 2010. Government printers, Nairobi, Kenya.*

Mishkin, K., Raskind, I., Dominguez - Salas, P., Baltenweck, I., Omore, A., & Webb Girard, A. (2018). The effect of participation in a pro-poor dairy development project on milk consumption among reproductive age women in rural Tanzania. *African Journal of Food, Agriculture, Nutrition and Development*, *18*(01), 12992–13008. https://doi.org/10.18697/ajfand.81.17200

Mugenda, O. M., & Mugenda, A. G. (2003). *Research Methods: Quantitative and Qualitative Approaches, ACTS Press, Nairobi, Kenya.*

Muhuyi, W. B. (1997). *A Comparison of the Productivity of Kenya Sahiwal and their Crosses in Large Scale Dairy Dual Purpose and Beef Production Systems.* Doctoral Dissertation, University of Nairobi.

Muhuyi, W. B., Lokwaleput, I., & Sinkeet, S. N. O. (1999). Conservation and utilisation of the Sahiwal cattle in Kenya Conservation of the Kenya Sahiwal Cattle. *Animal Genetic Resources Information, 26,* 35–46.

Muia, J. M. K., Kariuki, J. N., Mbugua, P. N., Gachuiri, C. K., Lukibisi, L. B., Ayako, W. O., & Ngunjiri, W. V. (2011). Smallholder dairy production in high altitude Nyandarua milk-shed in Kenya: Status, challenges and opportunities. *Livestock Research for Rural Development, 23*(108). http://www.lrrd.org/lrrd23/5/muia23108.htm

Mukama, C. P. (2010). *Economic benefit and willingness to pay for improved rangelands in Uganda.* Master's Thesis, Makerere University. https://www.mak.ac.ug/documents/Makfiles/theses/Mukama_P_C.pdf

Mukhopadhyay, C. S., Gupta, A. K., Yadav, B. R., Khate, K., Raina, V. S., Mohanty, T. K., & Dubey, P. P. (2010). Subfertility in males: An important cause of bull disposal in Bovines. *Asian-Australasian Journal of Animal Sciences*, *23*(4), 450–455. https://doi.org/10.5713

/ajas.2010.90298

Mulindwa, H. E., Kifaro, G. C., & Ssewannyana, E. (2012). Comparative pre-weaning growth of Zebu cattle and their crosses with Sahiwaland Boran. *Uganda Journal of Agricultural Sciences*, *13*(1), 35–44. https://www.ajol.info/index.php/ujas/article/view/126112/115640

Mustaphi, C. J. C., Githumbi, E. N., Shoemaker, A., Degefa, A. Z., Petek, N., Plas, G. Van Der, Muthoni, R., Rucina, S. M., & Marchant, R. (2014). *Ongoing sedimentological and palaeoecological investigations at Lielerai Kimana and Ormakau Swamps , Kajiado District , Kenya. A report to the local authorities of Kimana and Namelok, Olive Branch Mission Africa Operations, and the National Museums of Ken*. https://doi.org/10.13140/RG.2.1.4296.9449

Mutembei, H. M., Mulei, C. M., & Mbithi, P. (2016). A Kenyan Economic Analysis on Utilization of Ovum Pick Up, In vitro Embryo Production and Embryo Transfer Technologies in Cattle. *International Journal of Veterinary Science*, *5*(2), 64–68. http://www.ijvets.com/volume-5-no-2-2016/

Mutembei, H. M., Tsuma, V. T., Muasa, B. T., Muraya, J., & Erastus, R. M. (2015). Bovine in-vitro embryo production and its contribution towards improved food security in Kenya. *African Journal of Food Agriculture Nutrition and Development*, *15*(1), 9722–9743. http://ajfand.net/AJFAND/copyrightstatement.html

Mwacharo, J. M., & Rege, J. E. O. (2002). On-farm characterization of the indigenous small East African Shorthorn Zebu cattle (SEAZ) in the Southeast rangelands of Kenya. *Animal Genetic Resources Information*, *32(1)*, 73–86. https://doi.org/10.1017/S1014233900001577

Mwai, O. A., Tsuma, V., Owino, J. O., Ochieng., L., & Rao, E. J. O. (2020). *Accelerating genetic improvement in emerging smallholder dairy systems through fixed-time and conventional artificial insemination technologies: organizational and operational experiences from Kenya. ILRI Project Report.* https://cgspace.cgiar.org/bitstream/handle/10568/111149/GeneticImporvement_Kenya_pr.pdf?sequence=1

Mwangi, S. I., & Ilatsia, E. D. (2021). Sahiwal Breed in Pastoral Production Systems in Kenya : Future Roles and Existing Gaps in Knowledge and Supportive Technical Logistics ; A Review. *In the XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) Held Virtually from 25 - 29 October 2021.*, 5. https://uknowledge.uky.edu/igc/24/3-2/18

Mwangi, V., Owuor, S., Kiteme, B., & Giger, M. (2020). Beef Production in the Rangelands: A Comparative Assessment between Pastoralism and Large-Scale Ranching in Laikipia County, Kenya. *Agriculture*, *10*(9), 399–414. https://doi.org/10.3390/agriculture10090399

National Research Council (NRC). (2001). *Nutrient Requirements of Dairy Cattle*. National Academies Press. https://doi.org/10.17226/9825

Ngigi, M. (2005). *The case of smallholder dairying in Eastern Africa. Environment and Production Technology Discussion Paper No 131. International Food Policy Research Institute (IFPRI), Washington DC, USA*. https://doi.org/10.2139/ssrn.695481

Nyariki, D. M., & Amwata, D. A. (2019). The value of pastoralism in Kenya: Application of total economic value approach. *Pastoralism*, *9*(1), 1–13. https://doi.org/10.1186/s13570-019-0144-x

Nyariki, D. M., Mwang'ombe, A. W., & Thompson, D. M. (2009). Land-Use Change and Livestock Production Challenges in an Integrated System: The Masai-Mara Ecosystem, Kenya. *Journal of Human Ecology*, *26*(3), 163–173. https://doi.org/10.1080/09709274.2009.11906178

O'Brien, J. K., Steinman, K. J., & Robeck, T. R. (2009). Application of sperm sorting and associated reproductive technology for wildlife management and conservation. *Theriogenology*, *71*(1), 98–107. https://doi.org/10.1016/j.theriogenology.2008.09.052

Ojango, J. M. K., Wasike, C. B., Enahoro, D. K., & Okeyo, A. M. (2016). Dairy production systems and the adoption of genetic and breeding technologies in Tanzania, Kenya, India and Nicaragua. *Animal Genetic Resources/Ressources Génétiques animales/Recursos Genéticos Animales*, *59*, 81–95. https://doi.org/10.1017/S2078633616000096

Okeno, T. O., Kosgey, I. S., & Kahi, A. K. (2010). Economic evaluation of breeding strategies for improvement of dairy cattle in Kenya. *Tropical Animal Health and Production*, *42*(6), 1081–1086. https://doi.org/10.1007/s11250-010-9567-5

Otieno, D. J., Hubbard, L. J., & Ruto, E. (2012). Determinants of technical efficiency in beef cattle production in Kenya. *Selected Paper Prepared for Presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz Do Iguacu, Brazil, 18-24 August, 2012*. https://pdfs.semanticscholar.org/99bb/15e8967251796eacba2a5a4690f64cf3d87e.pdf

Otieno, D. J., Ruto, E., & Hubbard, L. (2011). Cattle Farmers' Preferences for Disease-Free Zones in Kenya: An application of the Choice Experiment Method. *Journal of Agricultural Economics*, *62*(1), 207–224. https://doi.org/10.1111/j.14779552.2010.00280

.x

Otte, M. J., & Chilonda, P. (2002). *Cattle and small ruminant production systems in sub-Saharan Africa: A systematic review. Rome: Livestock Information Sector Analysis and Policy Branch, Food and Agriculture organization of the United Nations.* https://www.fao.org/3/y4176e/y4176e07.htm

Ouma, E. A., Obare, G. A., & Staal, S. J. (2003). Cattle as assets: Assessment of non-market benefits from cattle in Smallholder Kenyan crop-Livestock Systems. *Proceedings of the 25th International Conference of Agricultural Economists (IAAE). 16 – 22 August 2003, Durban, South Africa*, 328–334. https://doi.org/10.22004/ag.econ.25895

Pan, D., Zhou, G., Zhang, N., & Zhang, L. (2016). Farmers' preferences for livestock pollution control policy in China: A choice experiment method. *Journal of Cleaner Production*, *131*, 572–582. https://doi.org/10.1016/j.jclepro.2016.04.133

Papich, M. G. (2016). Cloprostenol Sodium. In M. G. Papich (Ed.), *Saunders Handbook of Veterinary Drugs - Small and large Animals* (4th ed., pp. 178–180). Elsevier. https://doi.org/10.1016/B978-0-323-24485-5.00172-8

Patterson, D. J., Schafer, D. J., & Smith, M. F. (2005). Review of Estrus Synchronization Systems: Mga. *In Proceedings of Applied Reproductive Strategies in Beef Cattle Held on November 12 and 13, 2005, Texas A&M University, College Station*, 53–90 Pp. https://beefrepro.unl.edu/proceedings/2005collegestation/04_tamu_mga_patterson.pdf%0A

Pearce, D., Atkinson, G., & Mourato, S. (2006). *Cost-Benefit Analysis and the Environment: Recent developments. Organisation for Economic Co-operation and Development (OECD), Paris, France.* https://rockethics.psu.edu/documents/nsf-modules/unit-4/oecd-environmental-bca/at_download/file

Perry, G. A., Walker, J. A., Rich, J. J. J., Northrop, E. J., Perkins, S. D., Beck, E. E., Sandbulte, M. D., & Mokry, F. B. (2020). Influence of Sexcel^{TM} (gender ablation technology) gender-ablated semen in fixed-time artificial insemination of beef cows and heifers. *Theriogenology*, *146*, 140–144. https://doi.org/10.1016/j.theriogenology.2019.11.030

Potdar, V., Bhave, K., Gaundare, Y., Awasthi, H. R., & Khadse, J. R. (2016). Factors Influencing Conception Rate of Local and Crossbred Cows. *IOSR Journal of Agriculture and Veterinary Science*, *09*(10), 51–54. https://doi.org/10.9790/2380-0910015154

Pryce, J. E., Royal, M. D., Garnsworthy, P. C., & Mao, I. L. (2004). Fertility in the high-producing dairy cow. *Livestock Production Science*, *86*(3), 125–135. https://doi.org/10.1016/S0301-6226(03)00145-3

Razzouk, D. (2017). Cost-Benefit Analysis. In D. Razzouk (Ed.), *Mental Health Economics* (pp. 55–70). Springer International Publishing. https://doi.org/10.1007/978-3-319-55266-8_4

Rege, J. E. O., Kahi, A. K., Okomo-Adhiambo, M., Mwacharo, J. M., & Hanotte, O. (2001). *Zebu cattle of Kenya: Uses, performance, farmer preferences, measures of genetic diversity and options for improved use. International Livestock Research Institute, Nairobi, Kenya.*

Rege, J. E. O., Lomole, M. A., & Wakhungu, J. W. (1992). An evaluation of a long-term breeding programme in a closed Sahiwal herd in Kenya. I. Effects of non-genetic factors on performance and genetic parameter estimates By. *Journal of Animal Breeding and Genetics*, *109*(1-6), 374–384. https://doi.org/10.1111/j.1439-0388.1992.tb00417.x

Rodgers, J. C., Bird, S. L., Larson, J. E., Dilorenzo, N., Dahlen, C. R., Dicostanzo, A., & Lamb, G. C. (2012). An economic evaluation of estrous synchronization and timed artificial insemination in suckled beef cows. *Journal of Animal Science*, *90*(11), 4055–4062. https://doi.org/10.2527/jas.2011-4836

Roelofs, J. B., Van Eerdenburg, F. J. C. M., Soede, N. M., & Kemp, B. (2005). Pedometer readings for estrous detection and as predictor for time of ovulation in dairy cattle. *Theriogenology*, *64*(8), 1690–1703. https://doi.org/10.1016/j.theriogenology.2005.04.004

Roessler, R., Ilatsia, E. D., & Valle Zárate, A. (2010). . *Optimized breeding strategies for the local Sahiwal cattle in Kenya: use values and impor- tant breeding traits. In: Fifth All African Conference on Animal Agriculture, 25–28 October 2010, Addis Ababa, Ethiopia. Singh,.*

Rosenberger, K., Costa, J. H. C., Neave, H. W., von Keyserlingk, M. A. G., & Weary, D. M. (2017). The effect of milk allowance on behavior and weight gains in dairy calves. *Journal of Dairy Science*, *100*(1), 504–512. https://doi.org/10.3168/jds.2016-11195

Rutherford, N. H., Lively, F. O., & Arnott, G. (2021). A Review of Beef Production Systems for the Sustainable Use of Surplus Male Dairy-Origin Calves Within the UK. *Frontiers in Veterinary Science*, *8*(4), 1–12. https://doi.org/10.3389/fvets.2021.635497

Saha, R., Ashraf, A., & Rahman, Z. (2014). Comparative Study on Conception Rate of Cow in Using Frozen and Liquid Semen Comparative Study on Conception Rate of Cow in Using Frozen and Liquid Semen. *Journal of Animal Science Advances*, *4*(3), 749–772.

Samdup, T., Udo, H. M., Eilers, C. H., Ibrahim, M. N., & Zijpp, A. J. V. Der. (2010). Crossbreeding and intensi fi cation of smallholder crop – cattle farming systems in Bhutan. *Livestock Science*, *132*(1-3), 126–134. https://doi.org/10.1016/j.livsci.2010.05.01

Sarzana, C., Melgar, A., Laderach, P., & Pacillo, G. (2022). *Piloting the Climate Security Sensitiveness Scoring Tool: A case study assessing the climate security sensitiveness of Climate-Smart Villages (CSV) in Nyando, Kenya. CGIAR Focus Climate Security Report*. https://hdl.handle.net/10568/127046

SAS Institute Inc. (2009). *SAS/STAT ® 9.2 User's Guide, Second Edition. Cary, NC: SAS Institute Inc.* SAS Institute Inc. https://support.sas.com/documentation/cdl/en/statugmcmc/63125/PDF/default/statugmcmc.pdf

Schmidt, J., & Bijmolt, T. H. A. (2020). Accurately measuring willingness to pay for consumer goods: a meta-analysis of the hypothetical bias. *Journal of the Academy of Marketing Science*, *48*(3), 499–518. https://doi.org/10.1007/s11747-019-00666-6

Schulz, N., Breustedt, G., & Latacz-Lohmann, U. (2014). Assessing Farmers' Willingness to Accept "Greening": Insights from a Discrete Choice Experiment in Germany. *Journal of Agricultural Economics*, *65*(1), 26–48. https://doi.org/10.1111/1477-9552.12044

Segura Correa, J. C., Magaña Monforte, J. G., Ake Lopez, J. R., & Segura Correa, V. M. (2017). Season and parity number influence the conception rate of zebu breed cows in south-eastern Mexico. *Livestock Research for Rural Development*, *29*(11). 1-6 http://www.lrrd.org/lrrd29/11/jose29215.html

Sharifuzzaman, J. M., Barman, S. C., Matin, M. A., Rokonuzzaman, M. D., & Haque, M. A. (2015). Comparative study on conception rate in indigenous and crossbred cows after artificial insemination. *International Journal of Natural and Social Sciences*, *2*(23), 9–12. http://ijnss.org/wp-content/uploads/2015/03/IJNSS-V2I3-03-pp-9-12.pdf

Sirajuddin, S. N., Sudirman, I., Bahar, L. D., & Al-Tawaha, A. R. (2018). Social economic factors that affect cattle farmer's willingness to pay for artificial insemination programs. *Bulgarian Journal of Agricultural Science*, *24*(4), 574–580.

Sperandei, S. (2014). Understanding logistic regression analysis. *Biochemia Medica*, *24*(1), 12–18. https://doi.org/10.11613/BM.2014.003

Sprott, L. R. (2000). Management and financial considerations affecting the decision to synchronize estrus in beef females. *Journal of Animal Science*, *77*, 1–10. https://doi.org/10.2527/jas2000.00218812007700ES0041x

Tegemeo Institute of Agricultural Policy and Development. (2021). *Report on a study on cost of milk production in Kenya*. https://www.kdb.go.ke/wp-content/uploads/2021/06/Cost-of-milk-production-report..pdf

Tolera, A., & Abebe, A. (2007). Livestock production in pastoral and agro-pastoral production

systems of southern Ethiopia. *Livestock Research for Rural Development*, *19*(177), 1–16. www.lrrd.org/lrrd19/12/tole19177.htm

Truong, D. B., Goutard, F. L., Bertagnoli, S., Delabouglise, A., Grosbois, V., & Peyre, M. (2018). Benefit–Cost Analysis of Foot-and-Mouth Disease Vaccination at the Farm-Level in South Vietnam. *Frontiers in Veterinary Science*, *5*, 1–11. https://doi.org/10.3389/fvets.2018.00026

Turk, G., Yuksel, M., Sonmez, M., Gur, S., Ozer Kaya, S., & Demirci, E. (2015). Effects of semen sexing kits (Heiferplus^{TM} and Bullplus^{TM}) supplemented to frozen-thawed bull semen on pregnancy rates, foetal sex ratios and selected reproductive parameters in cows. *Veterinarni Medicina*, *60*(6), 309–313. https://doi.org/10.17221/8245-VETMED

Wahinya, P. K., Jeyaruban, G., Swan, A., & Magothe, T. (2020). Estimation of genetic parameters for milk and fertility traits within and between low, medium and high dairy production systems in Kenya to account for genotype-by-environment interaction. *Journal of Animal Breeding and Genetics*, *137*(5), 495–509. https://doi.org/10.1111/jbg.12473

Wahinya, P. K., Jeyaruban, M. G., Swan, A. A., & van der Werf, J. H. J. (2022). Breeding objectives for dairy cattle under low, medium and high production systems in the tropics. *Animal*, *16*(5), 1–13. https://doi.org/10.1016/j.animal.2022.100513

Wangdi, J., Mindu, Bhujel, P., Karma, & Wangchuk, S. (2014). Productive and reproductive performance of dairy cattle and their crossbreds in Bhutan. *Livestock Research for Rural Development*, *26*(10), 1-13. http://www.lrrd.org/lrrd26/10/wang26181.html

Wurzinger, M., Gutiérrez, G. A., Sölkner, J., & Probst, L. (2021). Community-Based Livestock Breeding: Coordinated Action or Relational Process? *Frontiers in Veterinary Science*, *8*(5), 1–9. https://doi.org/10.3389/fvets.2021.613505

APPENDICES

Appendix A: Questionnaire for field data collection

Assisted Reproductive Technologies (ART's) and Sahiwal Genetic Resources in Ranching and Pastoral Production Systems in Kenya

INTRODUCTION

This survey is part of an educational study undertaken by a PhD student from the Department of Animal Sciences, Egerton University and done in collaboration with the Kenya Agricultural and Livestock Research Organization (KALRO). Contributions and information provided will be used for academic work only and will be treated with ultimate confidentiality. Thank you in advance

A: GENERAL INFORMATION

Serial number_____Date_____County: **Narok** ***Sub-county:*** **Trans Mara West**

Division _____ Location: _____Ward

A: HOUSE HOLD INFORMATION		
Name of respondent		*Mobile Phone Number:*
Gender of Respondent	[___]	1=Male, 2=Female
Respondent Age (years)	[___]	Years
Respondent Education level	[___]	1=None, 2=Primary, 3=Secondary, 4=Tertiary
Source of livelihood	[___]	1=Livestock farming, 2=Mixed farming, 3=Cash and food crops; 4=Salaried employment; 4=Business,
Cattle production system	[___]	1=Ranching, 2=Nomadic pastoralism, 3=Agro-
Total grazing area (acres)	[___]	
Livestock Farming experience	[___]	

B: CATTLE GENOTYPES ON THE FARM

Provide information on type of cattle breeds kept & by the number

Breed	**Number of animals**	**Years kept**	**Rank primary objective of keeping breed in preference order**
Small East African Zebu (Maasai Zebu)	[___]	[___]	1st [___] 2nd [___] 3rd [___]
Sahiwal	[___]	[___]	1st [___] 2nd [___] 3rd [___]
Crosses (Sahiwal)	[___]	[___]	1st [___] 2nd [___] 3rd [___]
Boran	[___]	[___]	1st [___] 2nd [___] 3rd [___]
Others (Specify)	[___]	[___]	1st [___] 2nd [___] 3rd [___]

Primary objective - 1: Live sales 2: Meat production 3: Milk production 4: Meat and milk production 5: Wealth stock 6: Dowry payment 7: Keeping to tradition of owning cattle.

If not keeping Sahiwal Cattle/ crosses now, have you ever kept Sahiwal cattle breed in the past?

1: Yes [ ] 2: No [ ]

If Yes in above:

For how long did you keep the cattle breed? [……]

Why did you stop keeping Sahiwal cattle?

Factor	*Response*	*Factor*	*Response*
It is expensive to buy	[__]	Low growth and survival rates	[__]
Low breed availability	[__]	Low milk and meat production	[__]
Has increased feed and water requirement	[__]	Low pest and parasite tolerance	[___]
Has increased watering frequency	[__]	Low drought tolerance	[__]
High susceptibility to diseases	[__]	Late maturity	[__]
	[__]	Others (specify)	[__]

In relation to your preference for Sahiwal (pure and/ or crossbreds) (now or then)		
What is your upgrading level of preference?	[__]	1: Foundation Stock, 2: Intermediate level, 3: Appendix, 4: Pedigree level

C: ASSISTED REPRODUCTIVE TECHNOLOGIES (ARTs)

Have you ever used any Assisted Reproductive Technology (ART) before? Yes [ ] No [ ]

If Yes, which of the following Reproductive technologies have you used?

ART	*Response*	*If yes, years ART used*	*No. of cows so far served with ART*
Artificial Insemination	1: Yes [__] 2: No [__]	[__]	[__]
Multiple ovulation and embryo Transfer (MOEST)	1: Yes [__] 2: No [__]	[__]	[__]
Estrus Synchronization	1: Yes [__] 2: No [__]	[__]	[__]
Sexed Semen	1: Yes [__] 2: No [__]	[__]	[__]
In vitro Embryo Production (IVEP)	1: Yes [__] 2: No [__]	[__]	[__]
Pregnancy Diagnosis	1: Yes [__] 2: No [__]	[__]	[__]
Others (Specify)	1: Yes [__] 2: No [__]	[__]	[__]

If no, why have you not used these technologies before? Please rank in order of preference

Not Accessible [ ] It is expensive [ ] Have no idea [ ]

Lack of skilled technician [ ] Others (Specify) [ ] ……

Would you be willing to pay for the attributes associated with use of Assisted Reproductive Technologies within your cattle herd? 1: Yes [ ] 2: No [ ]

If yes, which of these attributes would you be willing to pay for?

ART attributes	*Response*	*ART attributes*	*Response*
High milk production	1: Yes [__] 2: No [__]	Quality breeding stock	1: Yes [__] 2: No [__]
High meat production	1: Yes [__] 2: No [__]	Coat colour	1: Yes [__] 2: No [__]
Early maturity	1: Yes [__] 2: No [__]	Pests and Disease tolerance	1: Yes [__] 2: No [__]
High growth rates	1: Yes [__] 2: No [__]	Heat & drought tolerance	1: Yes [__] 2: No [__]
Parasite resistance	1: Yes [__] 2: No [__]	Low temperament	1: Yes [__] 2: No [__]

Superior calves	1: Yes [__] 2: No [__]	High mature live weight	1: Yes [__] 2: No [__]
Others (specify)	1: Yes [__] 2: No [__]	Environmental adaptability	1: Yes [__] 2: No [__]

The current market price of hiring a bull is KES..... are you willing to pay more or an equivalent amount for accessing Assisted Reproductive Technologies for it's associated attributes? 1: Yes [ ] 2: No [ ]

Suppose the cost of accessing future ARTs increases above the current market prices, would you still be willing to pay more? 1: Yes [__] 2: No [__]

If Yes or No in question above, then provide the following bid levels at increasing or decreasing prices to the herd owner and tick either Yes or No depending on the response

Bid price (premium price) if answered "Yes" above	***Yes***	***No***	***Bid price (discount price) if answered "No" above***	***Yes***	***No***
KES 3,200	[___]	[___]	**KES 3,100**	[___]	[___]
" 3,500	[___]	[___]	**" 2,800**	[___]	[___]
" 3,800	[___]	[___]	**" 2,500**	[___]	[___]
" 4,100	[___]	[___]	**" 2,200**	[___]	[___]
" 4,400	[___]	[___]	**" 1,900**	[___]	[___]
" 4,700	[___]	[___]	**" 1,600**	[___]	[___]
" 5,000	[___]	[___]	**" 1,300**	[___]	[___]

What is your future plans for the number of Sahiwals and crosses within your herd?
1: To increase [___], 2: To maintain the number [___], 3: To reduce the number [___]

D: SAHIWAL CATTLE PERFORMANCES

Please provide the following information in relation to the cows from ARTs use in the farm
General: For the past 1 year give the following information in relation to cows from post ARTs

No. of cows inseminated	***No. of Cows that calved down***	***No. of cows that aborted***	***Reason for abortion***
[_____]	[_____]	[_____]	[_____]

Abortion reasons 1: Diseases, 2: Injury/ accident, 3: Drought, 4: Poisoning 5: Predation 6: Others (specify)

Provide the following information in relation to calves obtained from ARTs use for the past 1 year

No. born alive	***No. born dead***	***Reason for death***	***No. dead before weaning***	***Reason for death***	***No. dead after weaning***	***Reason for death***
[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]

Reason for death- 1: Diseases, 2: Injury/ accident, 3: Drought, 4: Poisoning 5: Predation 6: Others (specify)

For individual calves from ARTs, please provide the following information

No.	*Cross Breed*	*Sex*	*Age (Months)*	*Birth weight (Kg)*	*Weaning weight (Kg)*	*Current weight*	*Body score*
1	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
2	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
3	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
4	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
5	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
6	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
7	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
8	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
9	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
10	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
11	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
12	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
13	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
14	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
15	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
16	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
17	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
18	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
19	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
20	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]

Crosses: 1-ZebuXSahiwal, 2: Zebu X Boran, 3: Sahiwal X Boran 4: Others (specify) Sex: 1= Male, 2= Female. Body scores: scale of 1-5 with 5 being the best and 1 being the worst

E: MANAGEMENT PRACTICES FOR IMPROVED CALVES FROM ARTs

Provide information on the management practices performed on the Sahiwal calf breeds

Practice	**Variables**	**Response**		**Quantity**	**Costs/Kg**
Feeding	***Colostrum***	1:Yes [ ] 2: No [ ]		[_____]	[_____]
	Roughage (grass)	1:Yes [ ] 2: No [ ]		[_____]	[_____]
	Mineral licks/salts	1:Yes [ ] 2: No [ ]		[_____]	[_____]
	Others (specify)	1:Yes [ ] 2: No [ ]		[_____]	[_____]
		Response	**Source**	**Frequency**	**Costs (KES)**
Disease control	***Treatments***	[_____]	[_____]	[_____]	[_____]
	Ectoparasite	[_____]	[_____]	[_____]	[_____]
	Endoparasite	[_____]	[_____]	[_____]	[_____]
	Vaccination	[_____]	[_____]	[_____]	[_____]
Housing	***Walls***	[_____]	[_____]	[_____]	[_____]
	Roof	[_____]	[_____]	[_____]	[_____]

Source of health care: 1= Own, 2= Community health Assistant (CHA), 3= Veterinary (Private/public), Response rate: 1= Fast, 2= Slow; Temperament: 1= Dorsile, 2= Aggressive, 3= Others (Specify)

D2: BULL CALVES

Please provide general information (numbers)of bull calves from ART use in the farm

No. born alive	*No. born dead*	*Reason for death*	*No. alive at weaning time*	*Currently on farm*	*No. that have exited*	*Reason for farm exit*
[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]

Reasons for exit: 1=Sales for income, 2=Death, 3=Donations/gifts

For individual bull calves, provide information on the various functions within your farm

No.	*Bull ID*	*Cross Breed*	*Birth weight (Kg)*	*Weaning weight (Kg)*	*Age (Months)*	*Current weight (Kg)*	*Function*
1	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
2	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
3	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
4	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
5	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
6	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
7	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
8	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
9	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
10	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]

Crosses: 1-Zebu X Sahiwal, 2: Zebu X Boran, 3: Sahiwal X Boran 4: Others (specify)
Functions: 1=Breeding stock, 2=Meat production, 3=Sales for income, 4=Insurance and financing roles, 5= Cultural practices, 6=Prestige, 7=Dowry, 8= Settling disputes, 9= Others

E: INPUT AND OUTPUT MARKET

E1: (Please give information on the inputs and milk market experienced by the herd owner

Type of inputs	*Source of input supply*	*Distance to input supply (Km)*	*Cost of transporting inputs to farm*	*Distance to feeding area (Km)*	*Distance to watering area (Km)*	*Cost (if any) incurred in feeding and watering*
[ ]	[_____]	[_____]	[_____]	[ ]	[ ]	[ ]
[ ]	[_____]	[_____]	[_____]			
[ ]	[_____]	[_____]	[_____]			
[ ]	[_____]	[_____]	[_____]			

Input type: 1: dairy meal 2: Minerals 3: Drugs (dewormers) 4: Vaccines
Input supply source; 1=Agrovet 2= Shop 3= Market 4= Own 5= Others

E2: Output Market

(Please provide information in relation to products from ART utilization on the farm)

Product	*Market Choice*	*Distance to market (Km)*	*Reason for market choice*	*Frequency of sales*	*Price/unit or cost (KES)*

Live animals	[_____]	[_____]	[_____]	[_____]	[_____]
Meat	[_____]	[_____]	[_____]	[_____]	[_____]
Hides	[_____]	[_____]	[_____]	[_____]	[_____]
Others (Specify)	[_____]	[_____]	[_____]	[_____]	[_____]

Market choice*; 1= Own consumption, 2=Neighbour, 3= Hawker, 4= Local market, 5= Cooperative, 6= Others (Specify)* ***Reason for choice:*** *1= Convenience, 2= Better price, 3= Guaranteed market, 4= Support services, 5= Good neighbourliness, 6= Others (specify)*
Frequency of sales: *1= daily, 2= Weekly, 3= Fortnight, 4= Monthly, 5= Occasionally, 6= Others (Specify)*

F: ECONOMIC EVALUATION

For how long do you intend to keep the following Sahiwal(s) and crosses within your herd
1: Bull calves [___], 2: Steers [___], 3: Heifers, [___], 4: Cows [___], 5: Mature bulls [___]

For individual variables, please provide estimate projections on costs and benefits of the following cattle groups in your herd

Farm Benefits					
Variables	**No. of animals**	**Quantity per animal**	**Total Production**	**Unit Price (KES)**	**Total Benefit (KES)**
Milk	[_____]	[_____]	[_____]	[_____]	[_____]
Animals for slaughter					
Calves	[_____]	[_____]	[_____]	[_____]	[_____]
Steers/heifers	[_____]	[_____]	[_____]	[_____]	[_____]
Cows	[_____]	[_____]	[_____]	[_____]	[_____]
Bulls	[_____]	[_____]	[_____]	[_____]	[_____]
Animals for breeding/ sales					
Calves	[_____]	[_____]	[_____]	[_____]	[_____]
Heifers	[_____]	[_____]	[_____]	[_____]	[_____]
Cows	[_____]	[_____]	[_____]	[_____]	[_____]
Bulls for servicing	[_____]	[_____]	[_____]	[_____]	[_____]
Hides and skins from slaughter					
Young stock	[_____]	[_____]	[_____]	[_____]	[_____]
Mature stock	[_____]	[_____]	[_____]	[_____]	[_____]
Manure Production					
Young stock	[_____]	[_____]	[_____]	[_____]	[_____]
Mature stock	[_____]	[_____]	[_____]	[_____]	[_____]
Financing and Insurance					
Young stock	[_____]	[_____]	[_____]	[_____]	[_____]
Mature stock	[_____]	[_____]	[_____]	[_____]	[_____]

Farm Costs					
Variables	**Source**	**Frequency**	**Units/ quantity**	**Unit Price (KES)**	**Total Cost (KES)**
Animal feeding					
Pasture /roughages					
Young stock	[_____]	[_____]	[_____]	[_____]	[_____]
Mature stock	[_____]	[_____]	[_____]	[_____]	[_____]
Concentrates	[_____]	[_____]	[_____]	[_____]	[_____]
Mineral licks	[_____]	[_____]	[_____]	[_____]	[_____]
Water	[_____]	[_____]	[_____]	[_____]	[_____]
Animal Health management		Source: 1= *Own, 2= CHA, 3= Veterinary (Private/public*			
Treatment	[_____]	[_____]	[_____]	[_____]	[_____]
Vaccination	[_____]	[_____]	[_____]	[_____]	[_____]
Spraying/dipping	[_____]	[_____]	[_____]	[_____]	[_____]
Deworming	[_____]	[_____]	[_____]	[_____]	[_____]
Farm Labour	*Source: 1= Family, 2= Hired labour*				
Young stock	[_____]	[_____]	[_____]	[_____]	[_____]
Mature stock	[_____]	[_____]	[_____]	[_____]	[_____]
Reproductive Costs					
Hormonal Injections	[_____]	[_____]	[_____]	[_____]	[_____]
Artificial Insemination	[_____]	[_____]	[_____]	[_____]	[_____]
Combined ARTs	[_____]	[_____]	[_____]	[_____]	[_____]
Bull services	[_____]	[_____]	[_____]	[_____]	[_____]
Marketing related Costs					
Milk sales	[_____]	[_____]	[_____]	[_____]	[_____]
Live animals	[_____]	[_____]	[_____]	[_____]	[_____]
Levy charges	[_____]	[_____]	[_____]	[_____]	[_____]
Other variable costs					
Machinery	[_____]	[_____]	[_____]	[_____]	[_____]
Electricity	[_____]	[_____]	[_____]	[_____]	[_____]
Other operations	[_____]	[_____]	[_____]	[_____]	[_____]
Farm fixed costs					
Housing					
Young stock	[_____]	[_____]	[_____]	[_____]	[_____]
Mature stock	[_____]	[_____]	[_____]	[_____]	[_____]

Source: 1=Own farm, 2=Off farm, 3=Agrovet,
Frequency: 1=Daily, 2=Weekly, 3=Fortnight, 4=Monthly, 5=After 3 months, 6=Yearly,7=Others

Other general comments…….
……
……
……
……

Thank you

Confidentiality agreement form for research team during data collection

The objective of this research is to assess the sustainable utilization of ARTs in ranching and pastoral herd in Southern rangelands of Kenya. This research study will be carried out through direct observations and face-to-face interviews with pastoral herd owners who are either beneficiaries or non-beneficiaries of the on-going Sahiwal upgrading program within Trans Mara Sub-county of Narok County. Mr. Fredrick Agutu from Egerton University- Njoro campus leads the study in collaboration with other researchers from KALRO. The information, perceptions and experiences shared by the pastoral herd owners during the interviews, direct observations and status of cows, farms and households are confidential and must not be shared with anyone outside the research team. Furthermore, the identities of the study participants and their location must not be shared outside the research team.

I have read the above text, understood and agree to confidentiality.

SN	**Name**	**Telephone and email**	**Signature**
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

Appendix B: Photos of offspring calves from OvSynch and fixed Time Artificial Insemination protocol in Trans Mara Sub-county, Narok County

Appendix C: Published paper on objective one

International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2022; 7(1): 26-31

www.veterinarypaper.com
Received: 18-09-2021
Accepted: 05-12-2021

Fredrick Odiwuor Agutu
Department of Animal Sciences, Egerton University, P.O. Box 536, 20115 Egerton, Kenya

James Ombiro Ondiek
Department of Animal Sciences, Egerton University, P.O. Box 536, 20115 Egerton, Kenya

Samuel Mwanzia Mbuku
Kenya Agricultural and Livestock Research Organization, Veterinary Science Research Institute, Muguga North, P.O. Box. 32, 00902 Kikuyu, Kenya

Bockline Omedo Bebe
Department of Animal Sciences, Egerton University, P.O. Box 536, 20115 Egerton, Kenya

Corresponding Author:
Fredrick Odiwuor Agutu
Department of Animal Sciences, Egerton University, P.O. Box 536, 20115 Egerton, Kenya

Willingness to pay for assisted reproductive technologies by pastoral herd owners in southern Rangelands of Kenya

Fredrick Odiwuor Agutu, James Ombiro Ondiek, Samuel Mwanzia Mbuku and Bockline Omedo Bebe

Abstract
Uptake of Assisted Reproductive Technologies (ARTs) can widen and accelerate access to quality breeding stock under pastoral systems, but user participation without subsidy is uncertain when the herders have to meet the direct cost. Analysing willingness to pay (WTP) for ARTs may provide insights into potential uptake of ARTs when development agencies withdraw subsidies and private entrepreneurs take up the service delivery. This study estimated WTP for ARTs among 130 pastoral herd owners participating in Sahiwal cattle breed upgrading program implemented in Transmara Sub County in the southern rangelands of Kenya. The average WTP was KES 3,643 (USD 33.4), equivalent to 21.4% premium with reference to base price (KES 3,000) (USD 27.5). Sixty-seven percent of the pastoral herd owners expressed WTP above the hypothesized market price, twice more than those expressing WTP below the hypothesized market price (33%). The first choice attributes influencing the WTP for ARTs were high milk yield (62%), high value calves (37%), and high growth rates (1%). Gender was the only socioeconomic factor significantly ($P< 0.005$) influencing WTP, with men expressing higher WTP than women (KES 3,870 (USD 35.5) versus KES 3,223 (USD 26.6). The results indicate a high likelihood of pastoral herd owners continuing to access and use ARTs at own cost, which provides opportunities for private sector participation in ARTs delivery and upscaling to increase access to superior Sahiwal genetic resources in pastoral herds. This will need putting in place policy interventions supportive of efficient ARTs delivery mechanisms.

Keywords: Assisted reproductive technologies, willingness to pay, pastoral herd owners, double bounded dichotomous choice, contingent valuation

1. Introduction
Livestock production in the Arid and Semi-arid lands (ASALs) provide pastoral communities with important livelihood benefits, both tangible (meat, milk) and non-tangible (financing, insurance and dowry) [1]. Development agencies in Kenya prioritize investments towards increasing the tangible benefits through upgrading indigenous cattle to an adaptable and more productive Sahiwal cattle breed under rangelands where climate is increasingly variable and changing. The Sahiwal cattle breed is principally a dual-purpose (meat and milk) breed adaptable to the Kenyan pastoral rangelands [2]. Here, the demand for improved Sahiwal bulls and heifers outstrip the supply [3]. This situation emanates from multiple challenges limiting optimal utilization of the Sahiwal cattle as a livelihood improvement strategy. Supply of quality breeding stock is insufficient because of overreliance on a limited number of superior bulls initially provided by progressive breeding farms, predominantly the National Sahiwal Stud (NSS) and private ranches [3]. These breeding farms largely utilize closed nucleus breeding schemes that deploy natural bull service. This breeding strategy has been associated with increasing inbreeding levels and loss of genetic diversity among Sahiwal cattle population in Kenya – and will be tragic, if remains unchecked [4, 5].
Effective selection efforts for resilient and productive animals are required. Continued bull services could prove expensive as they are associated with risks of disease carriers, injurious to young heifers, increasing inbreeding levels and loss of genetic diversity with intense use [6]. To increase access to high quality breeding stock, development agencies are supporting upscaling the use of a wide range of ARTs in the southern rangelands of Kenya [4, 5].

Appendix D: Published paper on objective three

European Journal of Agriculture and Food Sciences
www.ejfood.org

Preferential Use of Sahiwal Bull Calves by Beneficiaries of Assisted Reproductive Technologies in Southern Rangelands of Kenya

Fredrick O. Aguru, Samuel M. Mbuku, James O. Ondiek, and Bockline O. Bebe

ABSTRACT

Bull service is the most common insemination method in pastoral herds grazing in the rangelands. To accelerate multiplication and distribution of and access to high quality Sahiwal genetics to pastoral communities, development agencies have promoted the use of Assisted Reproductive Technologies (ARTs) in the Kenyan rangelands. However, sustainable use of ARTs is uncertain because pastoral herd owners attach high value to bull calves of high genetic merits for breeding, which is a potential barrier to technology adoption. This study assessed preferential use of ART- bull calves among beneficiaries of the Sahiwal cattle upgrading breeding program that were utilizing OvSynch and TAI protocol in the southern rangelands of Kenya. Preferential use of bull calves was assessed in a choice experiment basing on attributes associated with potential use of bull calves. Overall, the first-choice preference was to retain the bull calves for future breeding (54%) compared to immediate selling for income (44%). This was the first-choice of pastoralists and agro pastoralists preferred unlike ranchers who preferred selling bull calves for income compared to retaining for future breeding (80% versus 20%). The preference of retaining bull calves for future breeding was higher among women compared to male respondents (59% versus 51%). Second choice preferences were sales for income (58%), breeding (29%), draft power (5%), meat production and cultural practices (3% each) and prestige (2%). Socioeconomic factors had no significant influence on preferential use of ARTs bull calves. The results indicate that high genetic merit bull calves are preferred for breeding, implying that bull calves would be retained within the pastoral herds for bull service. This presents a possible barrier to adoption of ARTs in pastoral herds for upgrading of Sahiwal cattle breed. Policy direction need to invest in Sahiwal multiplication and distribution of bull calves to pastoralists and agro pastoralists. Ranchers have low preference for retaining bull calves for breeding, so it would be best to capacitate them to invest in ARTs to multiply breeding bulls and supply to pastoralists and agro pastoralists.

Keywords: Assisted Reproductive Technologies, Bull calves, Bull service, Rangelands, Sahiwal.

Submitted : May 11, 2023

Published : June 28, 2023

ISSN: 2684-1827

DOI: 10.24018/ejfood.2023.5.3.686

F. O. Aguru*
Department of Animal Sciences, Egerton University, P.O. Box 536, 20115 Egerton, Kenya.
(e-mail: agurufredrick@gmail.com)
S. M. Mbuku
Kenya Agricultural and Livestock Research Organization, Veterinary Science Research Institute, Muguga North, P.O. Box. 32, 00902 Kikuyu, Kenya
J. O. Ondiek
Department of Animal Sciences, Egerton University, P.O. Box 536, 20115 Egerton, Kenya.
B. O. Bebe
Department of Animal Sciences, Egerton University, P.O. Box 536, 20115 Egerton, Kenya.

*Corresponding Author

I. Introduction

Pastoralism is a land use based livelihood oriented to securing livestock assets. It entails adapting to marginal environments characterized by climatic variability and uncertainty, degraded resources and continuous strategic mobility in search of pastures, water and mineral licks while confronting insecurity and conflict [1]-[3]. Bull service is the traditional breeding method in these pastoral cattle herds, communally grazed extensively in marginal lands [4]. Sahiwal cattle is a popular dual purpose breed and herd owners use bulls sourced from either National Sahiwal Stud in Naivasha, private ranches or model farms for mating [5].

However, these sources of breeding bulls are unable to meet the increasing high demand for quality Sahiwal bulls. Alternative sources of Sahiwal breeding bulls include community bulls, purchased culled bulls from other cattle ranches and model farms, but these sources that have been disappointing to pastoral herd owners [6]. The disappointments include low conception rates, transmission of diseases, injuries to young heifers and cows and limited selection choices. Confronted with unviable options, pastoral herd owners have continued to mate with own or community breeding bulls mostly while open grazing in the vast rangelands pastures [4].

In responding to the high demand for quality breeding Sahiwal bulls, development agencies are promoting Assisted Reproductive Technologies (ARTs), to accelerate multiplication and distribution of quality proven Sahiwal bulls [7], [8]. The ARTs breeding intervention is to multiply and distribute high quality Sahiwal genetics obtained using OvSynch (hormonal injections) and fixed time artificial insemination (TAI). The semen is frozen thawed. In previous studies, [9] and. [10] demonstrated the willingness of pastoral herd owners to pay for AI as opposed to use of bull services, to continue accessing superior Sahiwal genetic materials for upgrading purposes. Though willingness to pay indicates acceptance and adoption of ARTs by herd owners, it is

Appendix E: Published manuscript on objective four

Tropical Animal Health and Production (2024) 56:68
https://doi.org/10.1007/s11250-024-03907-1

REGULAR ARTICLES

Economic viability of using OvSynch and fixed timed artificial insemination protocol in breeding improvement of pastoral herds in the rangelands

Fredrick Odiwuor Agutu[1] · Samuel Mwanzia Mbuku[2] · James Ombiro Ondiek[1] · Bockline Omedo Bebe[1]

Received: 5 June 2023 / Accepted: 17 January 2024

Abstract

Though using Assisted Reproductive Technologies (ARTs) can improve oestrus detection, conception and pregnancy success, thus benefit breeding program implementation, empirical evidence of their economic viability is lacking to inform investment decisions in pastoral herds. This study assessed economic viability of using OvSynch and fixed Timed Artificial Insemination (TAI) protocol in Sahiwal upgrading breeding program under two hypothetical cases of best and worst in activity-based money allocations when pastoral herds deploy either optimal or low input husbandry practices. From herd owners' assessment of milk production, best-case scenarios attain on average 10 L/cow/day with optimal husbandry and 5 L/cow/day with low input husbandry. The worst-case scenarios attain 5 L/cow/day with optimal husbandry and 1 L/cow/day with low input husbandry. Benefit- Cost Analysis (BCA) estimated Net Present Value (NPV), Benefit–Cost ratio (BCR) and Internal Rate of Return (IRR) to establish economic viability of using OvSynch and TAI Protocol in pastoral breeding programs. Both best-case scenarios returned positive NPVs (82,028 and 6,912), BCR values (1.68 and 1.08) and IRR (27.46% and 8.08%) while worst-case scenarios returned negative NPVs (-135,855 and -141,025), BCR values of below 1 (0.87 and 0.66) and IRR values below the minimum rate of returns. These economic parameters were sensitive to price changes in inputs and outputs, under both optimal and low input husbandry practices. Results indicate that using OvSynch and TAI Protocol is a profitable and economically viable investment under optimal husbandry practices but not under low input husbandry practices. By implications, use of OvSynch and TAI Protocol in Sahiwal upgrading breeding programs need be accompanied with improved husbandry practices and de-risking pastoral herd owners from price changes in input and output markets.

Keywords Assisted Reproductive technologies · Breeding program · Economic viability · Husbandry practices · Pastoral systems · Sahiwal

Introduction

Breeding programs are interventions designed to improve genetic merit of the target cattle herd. Reproductive performance, quality of breeding stock and level of husbandry practices are important components of realising improvement in the genetic merit of cattle herd. However, interventions targeting cattle herd improvement has to be economically viable to support breeding programs. The level of husbandry practices influence the reproductive performance that is attainable. Herd fertility management is challenging in pastoral systems due to cows experiencing silent heat or their heat go undetected. These can be attributed to delay, failure or challenges in estrus detection, subsequently resulting in low conception and pregnancy rates and poor success of breeding programs (Roelofs et al., 2005). In pastoral herd

✉ Fredrick Odiwuor Agutu
agutufredricks@gmail.com

Samuel Mwanzia Mbuku
Samuel.Mbuku@icalro.org

James Ombiro Ondiek
james.ondiek@egerton.ac.ke

Bockline Omedo Bebe
bbebe@egerton.ac.ke

[1] Department of Animal Sciences, Egerton University, P.O. Box 536, Egerton 20115, Kenya

[2] Kenya Agricultural and Livestock Research Organization, Dairy Research Institute, P.O. Box 25, Naivasha 20117, Kenya

Published online: 06 February 2024

Manuscript under Review on Objective two of this Thesis

Agutu, F. O., Ondiek, J. O., Mbuku, S. M., & Bebe, B. O. (2022). Association of mating decisions with conception rates among Sahiwal cows and heifers on OvSynch and fixed time artificial insemination in the southern rangelands of Kenya.

Conference presentations

i. **Agutu, F.O., Mbuku, S.M., Ondiek, J.O., Bebe, B.O. 2024**. Preferential Use of Sahiwal Bull Calves by Beneficiaries of Assisted Reproductive Technologies in Southern Rangelands of Kenya. In a paper prepared for the 15th Biennial International Conference. 'Research for Innovative Solutions in the 21st Century'. 19th – 21st March, 2024. Egerton University.

ii. **Agutu, F.O., Mbuku, S.M., Ondiek, J.O., Bebe, B.O. 2022.** "Influence of mating decisions on conception rates among Sahiwal Cows and Heifers on OvSynch and Fixed Time Artificial Insemination in the Southern Rangelands of Kenya". In a paper presented at the National Innovation System for Resilience and Sustainable Development in Africa, 5th AfricaLics Conference. November 9th - 11th, 2022 IRIC Campus, Yaounde', Cameroon

Correct citations of research papers from this PhD Thesis

Agutu, F. O., J. O. Ondiek, S. M. Mbuku, and B. O. Bebe. 2024. "Economic viability of using OvSynch and fixed timed artificial insemination protocol in breeding improvement of pastoral herds in the rangelands". *Tropical Animal Health and Production* **56**, 68 (2024). https://doi.org/10.1007/s11250-024-03907-1

Agutu, F. O., J. O. Ondiek, S. M. Mbuku, and B. O. Bebe. 2022. "Preferential Use of Sahiwal Bull Calves by Beneficiaries of Assisted Reproductive Technologies in Southern Rangelands of Kenya" *European Journal of Agriculture and Food Sciences* 5(3): *http://www.ejfood.org/index.php/ejfood/article/view/686*

Agutu, F. O., J. O. Ondiek, S. M. Mbuku, and B. O. Bebe. 2022. "Willingness to Pay for Assisted Reproductive Technologies by Pastoral Herd Owners in Southern Rangelands of Kenya." *International Journal of Veterinary Sciences and Animal Husbandry* 7 (1): 26–31. https://www.veterinarypaper.com/archives/2022/7/1/A/6-6-5

Appendix F: Selected analyzed result outputs for various objectives in this thesis

Cross-tabulations

			Cattle Production System			
			Ranching	Nomadic Pastoralism	Agro pastoralism	Total
WTP category	<3000	Count	3	34	5	42
		% within WTP category	7.1%	81.0%	11.9%	100.0%
		% within Cattle Production System	60.0%	31.8%	35.7%	33.3%
		% of Total	2.4%	27.0%	4.0%	33.3%
	>3001	Count	2	73	9	84
		% within WTP category	2.4%	86.9%	10.7%	100.0%
		% within Cattle Production System	40.0%	68.2%	64.3%	66.7%
		% of Total	1.6%	57.9%	7.1%	66.7%
Total		Count	5	107	14	126
		% within WTP category	4.0%	84.9%	11.1%	100.0%
		% within Cattle Production System	100.0%	100.0%	100.0%	100.0%
		% of Total	4.0%	84.9%	11.1%	100.0%

Max/Min Amount

Cattle Production System	Mean	N	Std. Deviation
Ranching	3560.00	5	1320.227
Nomadic Pastoralism	3644.86	107	1192.368
Agro pastoralism	3657.14	14	1337.457
Total	3642.86	126	1203.224

Selected results for objective two of this thesis

The SAS System 14:46 Monday, February 14, 2022

The GENMOD Procedure

Model Information

Data Set	WORK.CONC
Distribution	Binomial
Link Function	Logit
Dependent Variable	Conc
Observations Used	403
Missing Values	214

Response Profile

Ordered Value	Conc	Total Frequency
1	1	257
2	0	146

PROC GENMOD is modeling the probability that Conc='1'.

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	395	491.9475	1.2454
Scaled Deviance	395	491.9475	1.2454

Pearson Chi-Square	395	404.3699	1.0237
Scaled Pearson X2	395	404.3699	1.0237
Log Likelihood		-245.9737	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter	DF	Standard Estimate	Error	Likelihood Ratio 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	1	-1.6893	1.3200	-4.3417	0.8734	1.64	0.2006
Parity	1	0.3556	0.1482	0.0706	0.6531	5.76	0.0164
BCS	1	-0.4224	0.3453	-1.1207	0.2408	1.50	0.2212
OvarDiameter	1	0.1491	0.1436	-0.1304	0.4343	1.08	0.2991
OvarStucture		0.1439	0.1265	-0.0997	0.3983	1.29	0.2555
SahiBlood	1	0.1170	0.1016	-0.0812	0.3180	1.33	0.2495
PedLevel	1	0.4772	0.1258	0.2320	0.7260	14.39	0.0001
SemenType	1	1.2594	0.6002	0.2606	2.6915	4.40	0.0359
Scale	0	1.0000	0.0000	1.0000	1.0000		

NOTE: The scale parameter was held fixed.

The GENMOD Procedure

LR Statistics For Type 3 Analysis

Source	DF	Chi-Square	Pr > ChiSq
Parity	1	6.03	0.0141
BCS	1	1.54	0.2147
Ovary Diameter	1	1.09	0.2970
Ovarian Stucture	1	1.32	0.2499
SahiBlood	1	1.34	0.2479
PedLevel	1	14.61	0.0001
SemenType	1	6.65	0.0099

Selected results for objective four of this thesis

Perceived Function of bull calves

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Breeding stock	67	53.2	53.2	53.2
	Sales for income	57	45.2	45.2	98.4
	Farming	2	1.6	1.6	100.0
	Total	126	100.0	100.0	

Appendix G: NACOSTI approval permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 895287

Date of Issue: 09/June/2022

RESEARCH LICENSE

This is to Certify that Mr.. Fredrick Odiwuor Agutu of Egerton University, has been licensed to conduct research in Narok on the topic: Evaluating Sustainable use of Reproductive Technologies and Sahiwal Cattle Genetic Resources in Pastoral Production Systems in Semi-Arid Kenya for the period ending : 09/June/2023.

License No: NACOSTI/P/22/18103

895287

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Animal Production Society of Kenya
Secretariat: State Department for Livestock
P.O. Box 34188, Hill Plaza Building, Nairobi, KENYA
Email: info@apsk.or.ke or apskkenya@gmail.com; Website: www.apsk.or.ke

Our ref: APSK/ADM/SYMP/22/23 September 25, 2022

Fredrick Odiwuor Agutu,
Egerton University,
P.O. Box 536, 20115
Njoro, Kenya

Dear Sir,

RE: ACCEPTANCE OF YOUR PAPER AND INVITATION TO THE ANIMAL PRODUCTION SOCIETY OF KENYA (APSK) 2022 ANNUAL SCIENTIFIC SYMPOSIUM

The Animal Production Society of Kenya (APSK) 2022 Annual Scientific Symposium will be held at Bamburi Beach Hotel, Mombasa on 25th – 28th October 2022 and the theme is ***"Sustainable Food Systems Transformation Agenda: Making Climate Smart Livestock Production Real"***. The symposium will provide a platform for stakeholders to share their work and help shape the emerging national agenda on a wide range of livestock development and transformation issues.

We are pleased to inform you that your paper entitled ***'Influence of Mating Decisions on Conception Rates among Sahiwal Cows and Heifers on OvSynch and Fixed Time Artificial Insemination in the Southern Rangelands of Kenya'*** has been evaluated and accepted for presentation at the upcoming APSK scientific symposium.

We regret that APSK is not able to provide support for participation in the symposium. In addition, funding for travel and other related expenses is the responsibility of the symposium participants. The symposium participation fee is KES 24,000/-.

We look forward to seeing you in Mombasa.

Yours faithfully,

Samuel M. Mbuku, PhD
CHAIRMAN, APSK