ASSESSING SUSTAINABILITY OF SMALLHOLDER DAIRY AND TRADITIONAL CATTLE MILK PRODUCTION SYSTEMS IN TANZANIA

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ABSTRACT

Sustainability of smallholder dairy and traditional cattle milk production systems in developing countries, including Tanzania, is limited by a number of constraints such as low cow productivity, shortage of feed, limited access to inputs and outputs markets and degradation of natural resources. Efforts have been made to improve the sustainability, but the improvement is hindered by lack of knowledge on how to ensure sustainability of the production systems particularly at the farm level. To contribute to the efforts being made to address these issues, this study aimed at assessing sustainability of smallholder dairy and traditional cattle milk production systems in Tanzania. The study was conducted in four districts located in Morogoro and Tanga Regions. In the context of this study, a smallholder dairy production system refers to a system with dairy farms which have up to five dairy cows, where majority are crossbreeds of local and pure exotic breeds and milk is considered the main source of income. Meanwhile, a traditional cattle milk production system consists of cattle farms keeping mainly indigenous cattle and milk is not considered the main source of income.

The first step of the study involved identifying relevant indicators for assessing sustainability of smallholder dairy as well as traditional cattle milk producing farms. The systems were further categorised into Rural production to Rural consumption (R-to-R) and Rural production to Urban consumption (R-to-U) systems. Whereby R-to-R refer to rural farmers sold milk to rural consumers and R-to-U to rural producers predominantly selling milk to urban consumers. A two-round Delphi approach involving 44 diverse experts and stakeholders was used in identifying the sustainability indicators. The second step involved developing a milk production farm sustainability assessment tool based on a set of fifteen most relevant of the identified indicators. The indicators were selected from the

previously identified indicators according to data availability and cost. The tool was used to assess sustainability of 431 randomly selected farms in the study districts. The data were collected through interview of the farmers using a pre-tested questionnaire administered to the selected farms. Individual indicators of sustainability were measured, normalized using mini-max approach, weighted using factor analysis and aggregated into economic, social, environmental and overall sustainability indices using linear aggregation. The sustainability performance indicator and index scores were ranked from 0 to 1 and grouped into three categories of sustainability indicator / index scores namely weak (< 0.33), medium (0.33 ≤ and < 0.66) and high (≥ 0.66). Then, the sustainability mean performance indicators and indices were compared between the R-to-R systems and the R-to-U systems using a two-tailed Student's t-test. The third step involved analysis of the relationships between the farm and milk producers' organisations (POs) sustainability performances. The differences between farm sustainability mean performance indicators and indices for PO-member farmers and non-PO-member farmers were analysed using a two-tailed Student's t-test. The sustainability of POs was assessed using an existing tool, "Producers' Organisation Sustainability Assessment tool (POSA)", which is based on a set of six economic and organizational dimensions. The relationships between farm and PO sustainability performance indicators were established using Pearson correlation analysis. The correlation coefficients (r) were categorized as weak (r < 0.3), moderate (0.3 ≤ r < 0.5) and strong (r ≥ 0. 5). Lastly, the study analysed the determinants of smallholder dairy and traditional cattle milk production farm sustainability. Descriptive statistics were analysed to understand the socio-economic characteristics of milk production farms. Then the socio-economic characteristics were compared between R-to-R systems and R-to-U systems using two-tailed Student's t-test and chi-square for the means and proportions respectively. The double censored Tobit regression model was applied to analyse the determinants of farm sustainability.

The Delphi technique refined an initial set of 57 indicators to a final set of 29 relevant indicators. The relevant indicators included 18 economic, seven environmental and four social indicators. Specifically, the key economic indicators were milk hygiene, cow productivity, income per litre of milk and access to milk market. Social indicators included participation in organizations, women's empowerment and the education level of the farm manager; while environmental indicators were water conservation and access to water. Results from the farm sustainability assessment show that the economic mean score (0.27 ± 0.20), social mean score (0.32 ± 0.27), environmental mean score (0.31 ± 0.22) and overall mean score (0.30 ± 0.15) of farm sustainability indices were weak. The economic, social and overall sustainability mean performance index scores were significantly higher in the R-to-U systems than in the R-to-R systems ($p < 0.05$), implying better sustainability of R-to-U systems than R-to-R systems. The overall farm sustainability mean performance index, and its economic and social dimensions scores were significantly higher ($p < 0.05$) in PO-member farmers than in non-PO-member farmers. The "access to dairy production inputs and services" dimension of POs presented strong positive correlations with the overall farm sustainability performance index and its economic dimension (r = 0.58 and 0.67 respectively; $p < 0.01$). Similarly, the "access to dairy production inputs and services" of POs showed strong correlations (r = 0.70; $p < 0.01$) with cow productivity performance indicator. The farmers in R-to-U systems had significantly ($p < 0.05$) smaller land and herd size than in R-to-R system. Stall feeding system was the determinant factor ($\beta = 0.256$; $p < 0.01$) of economic sustainability. The determinant factors for social sustainability were stall feeding system ($\beta = 0.165$; $p < 0.01$), age of household head ($\beta = 0.003$; $p < 0.05$) and acquiring credit ($\beta = 0.190$; $p < 0.01$). The factor influencing environmental sustainability was stall feeding system ($\beta = 0.098$; $p < 0.01$). The factors influencing the overall sustainability were stall feeding system ($\beta = 0.161$; $p < 0.01$), the age of the household head ($\beta = 0.001$; $p < 0.01$) and acquiring credit ($\beta = 0.081$; $p < 0.01$).

From the results of the study, it is concluded that a large number of existing indicators like greenhouse gas emissions could be considered less relevant in the context of Tanzania's smallholder dairy and traditional cattle system than in other contexts. The study showed that 29 out of 57 sustainability indicators assessed were relevant to the studied system. The indicators identified here demonstrate the importance of matching any set of indicators to the characteristics of the specific production system being examined. The study provided a tool and framework for assessing sustainability of milk production farms in smallholder dairy and traditional cattle milk production systems in Tanzania using a set of 15 most relevant sustainability indicators out of the selected 29 indicators. The most relevant economic indicators were milk hygiene and cow productivity; social indicators were participation in organizations and women's empowerment; environmental indicators were access to water and water conservation. Regarding the level of sustainability of the milk production farms, the results showed that the sustainability performances of smallholder dairy and traditional cattle milk production farms in the selected districts were weak, particularly in R-to-R system. Producers' organisation sustainability performances, particularly its provision of dairy inputs, have strong positive relationship with farm sustainability performances, particularly the farm economic dimension. Indeed, stall feeding and access to credit tend to improve farm sustainability.

From the results of the study, continued private and public investments in the non-traditional dairy areas and promotion of market linkages to urban areas where milk demand is stronger, is recommended not only for immediate improvement of livelihoods but also for sustainability considerations. Indeed, intensive dairy systems should be encouraged for higher sustainability of milk production and this could be possible by improving access to inputs and embedded services. The developed framework can be used by farmers, policy and decision makers to enable them identify key strengths and weaknesses and make respective decision towards sustainable milk production during implementation of dairy improvement programs.

DECLARATION

I, **CELESTIN MUNYANEZA,** do hereby declare to the Senate of Sokoine University of Agriculture that, this thesis is my own original work done within the period of registration and that it has neither been submitted nor is being concurrently submitted for a degree award in any other institution.

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LIST OF ABBREVIATIONS AND SYMBOLS

CAP	Common Agricultural Policy
CAP	Common Agricultural Policy of the EU
EAAE	European Association of Agricultural Economists
EADD	East African Dairy Development
ESA	Economic and Social Affairs
EU	European Union
FADN	Farm Accountancy Data Network
FAO	Food and Agriculture Organization
IDEA	Indicateurs de Durabilité des Exploitations Agricoles
IDF	International Dairy Federation
IFSA	International Farming System Association
ILRI	International Livestock Research Institute
INRA	Institut Nationale de la Recherche Agronomique
LITA	Livestock Training Agencies
NGO	Non-Governmental Organization
^{o}C	Degree Centigrade
OECD	Organisation for Economic Cooperation and Development
Pg	Page
PO	Milk Producers’ Organization
POSA	Producers’ Organizations Sustainability Assessment tool
RISE	Response-Inducing Sustainability Evaluation
R-to-R	Rural Production to Rural Consumption
R-to-U	Rural Production to Urban Consumption
SHG	Self-Help Group

SUA	Sokoine University of Agriculture
TALIRI	Tanzania Livestock Research Institute
TZS	Tanzanian Shilings
URT	United Republic of Tanzania
USAID	United States Agency for International Development
WP	World Population

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The dairy sector plays an important role not only in human nutrition, but also as a source of livelihoods for poor farmers and other stakeholders in developing countries, including Tanzania. Milk and other dairy products have a great potential in contributing to human nutrition and health due to their high nutritional value (Dugdill *et al.,* 2013). Milk production, particularly when practiced as a business generates income and employment for a large number of poor families, which contribute to poverty reduction. Furthermore, the milk sector promotes the economic and social roles of women in communities (Bayer and Kapunda, 2006). When integrated with crop farming, dairying provides organic manure which positively contributes to soil fertility as well as better crop yield. The use of organic fertilizer contributes to reduction of excessive use of chemical fertilizers which could lead to several environmental problems including water pollution (Rasul and Thapa, 2004).

The demand for milk and other dairy products is expected to increase. The demand will be driven by the expected increase in world human population, urbanization and income (Gerosa and Skoet, 2012). Projections have shown that the world population is expected to rise to 9.1 billion by 2050 (Godfray *et al.,* 2010). In Tanzania, it is projected that the human population will rise up to 138 million and 303 million in 2050 and 2100, respectively (United Nations, Department of Economic and Social Affairs, Population Division, 2017). The increase in population will be associated with increased food consumption including milk and other dairy products (Gerosa and Skoet, 2012).

Concomitant to the increase in human population, income and urbanization in developing countries will be associated with high purchasing power and preference for food of higher quality including milk and meat, which will catalyse the increase in milk and dairy products demand (Gerosa and Skoet, 2012). Hence, the world milk production will need to grow by 2% per year in order to meet the increased demand (Hemme *et al.*, 2010).

Extensive efforts have been made to increase milk production including upgrading the genetic potential of milk production cattle and better animal nutrition (FAO-IDF, 2011; Hume *et al.*, 2011). Meanwhile, cattle rearing could have negative effects on the environment such as the degradation of natural resources and contribution to greenhouse gas emissions (Steinfeld, 2006; Gerosa and Skoet, 2012). Moreover, socio-economic negative effects of dairy sector have been reported. For example, dairy cows could transmit some diseases to human when hygienic standards are not met (Lupindu *et al.*, 2012; Dhanashekar *et al.*, 2013). The search for pasture and water could generate competition between cattle and crop farming activities which could result into severe conflicts between livestock farmers and crop farmers, which sometimes result in economic and human losses (Benjaminsen *et al.*, 2009). In addition to the aforementioned constraints, Zvinorova *et al.* (2013) report that some dairy farms are not economically viable as their revenue does not cover the cost of their activities. Green (2012) argues that when the farm is not profitable, its sustainability is compromised since the farmers likely leave dairy production to another activity which is more profitable, particularly when the farm is not financed by off-farm income. Hence, sustainable agriculture, including milk production, is among the priorities for the policy makers and other stakeholders in order to feed the growing world population within finite means, particularly land (Herrero and Thornton, 2013; Miller and Auestad, 2013).

Despite the efforts which has been made, there is no agreement on the practical definition of sustainable agriculture. The World Commission on Environment and Development (1987) defines sustainability as a "development which meets the needs for the present without compromising the ability of future generations to meet their own needs". This definition is not precise enough as it does not provide clear information on the practical and specific form of sustainability. As a consequence, the concept of sustainability has many practical meanings which differ across space and time, and among individuals (Robinson, 2004; White, 2013). This vagueness has resulted into a large number of sustainability definitions (Rigby and Cáceres, 2001; Diazabakana *et al.,* 2014). In spite of this large number of definitions, it is generally agreed that sustainability is manifested in three interlinked dimensions, "economic, social and environment" (European Commission, 2001; van Calker *et al.,* 2005; van Cauwenbergh *et al.,* 2007; Fauzi *et al.,* 2010) whereby sustainability is the intersection of the three dimensions (Fig. 1).

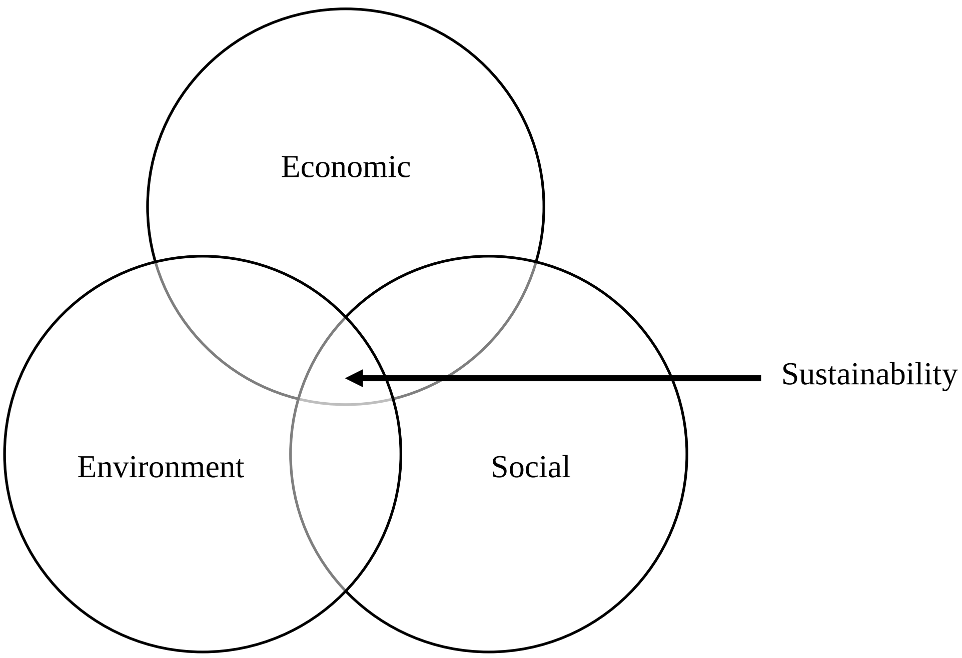


Figure 1: Sustainability Dimensions

(Source: Fauzi *et al.,* 2010)

Sustainability should be measured in order to be operational. Sustainability assessment using the indicators is suggested as the pathway towards operationalization of the sustainability concept. Waas *et al.* (2014) define sustainability assessment as any process aiming to: "contribute to a better understanding of the meaning of sustainability and its contextual interpretation (interpretation challenge)"; "integrate sustainability issues into decision-making by identifying and assessing (past and / or future) sustainability impacts (information-structuring challenge)"; "foster sustainability objectives (influence challenge)".

Participating in farmers' organizations has been suggested to be among the best mechanisms for improving farm sustainability performances, particularly in developing countries (Mojo *et al.,* 2015; Iyabano *et al.,* 2016). This is mainly due to the fact that a large number of the rural farming households are geographically scattered in remote rural areas with limited access to infrastructure and information which constrains access to services, inputs and outputs markets at individual farm level. Farmers' organizations could alleviate the constraints by improving bargaining power which enables easy access to production inputs and embedded services, including more efficient extension services, to enhance productivity and participating in more valuable output markets (Salokhe, 2016). Indeed, farmers' organizations provide a platform where farmers could discuss their challenges and opportunities, share skills, knowledge and experience on good farming practices (Verhofstadt and Maertens, 2015).

Farm level sustainability performances could be influenced by a number of social-economic factors such as household characteristics (Manda *et al.,* 2016; Gómez-Limón and Sanchez-Fernandez, 2010; Umanath, 2015). Understanding the factors is therefore crucial to guide any intervention toward sustainability improvement (OECD, 2008; Dabkienė, 2015). Moreover, factors which influence sustainability could vary from one place / farm type to another (Gómez-Limón and Sanchez-Fernandez, 2010; Umanath and Rajasekar, 2015; Li *et al.,* 2016).

1.2 Problem Statement and Justification of the Research

Smallholder dairy and traditional cattle milk production systems have potential role in alleviating poverty and improving the livelihoods of the poor farmers in developing countries, including Tanzania (Urassa and Raphael, 2002; Bayer and Kapunda, 2006). The long-term viability of these systems in the future, in the competitive context requires that these smallholder dairy production and traditional cattle milk production systems are sustainable in environmental, social, and economic terms (Fadul-Pacheco *et al.,* 2013). However, various studies have shown that, in Tanzania, smallholder dairy and traditional cattle milk production farms face a large number of issues, classified into economic, social and environmental, which hinder their sustainability (Leonard *et al.,* 2016; Ogle, 2001; Benjaminsen *et al.,* 2001; Lupindu *et al.,* 2012; Nkya *et al.,* 2005).

Some examples of the issues which could constrain sustainability of smallholder dairy and traditional cattle milk production systems in Tanzania have been reported. Regarding the economic aspects, Tanzania's milk production is mainly for subsistence. A large proportion (90%) of produced milk is consumed at the point of the production while only 10% is sold (Rural Livelihood Development Company, 2010). The subsistence form of production is driven by many factors such as low yield of milk due to poor genetic potential of the dominant indigenous cattle, scarcity of forage and water, poor knowledge on dairy husbandry and limited access to inputs as well as milk markets, which are more pronounced in traditional cattle keeping than in smallholder dairy systems (Urassa and Raphael, 2002; Nkya *et al.,* 2007; Nell *et al.,* 2014; Leonard *et al.,* 2016). This is consistent with Green (2012) who argues that some farmers in Tanzania exit dairy farm activities due to low profitability, searching for other activities which are more profitable. In addition to that, the subsistence nature of milk production has repercussions on milk availability where the estimated consumption of milk per annum per capita is still low (43 litres) compared to 200 litres as recommended by the FAO (URT, 2010).

Besides, social issues which could constraint Tanzania's milk production sustainability have been reported. Some examples are marginalization of women (Kimaro *et al.,* 2013), low education level among the cattle farmers (Baker *et al.,* 2015), recurrent conflicts between livestock keepers and crop farmers which sometimes result in loss of wealth and lives (Benjaminsen *et al.,* 2009; Mwamfupe, 2015). Issues related to environmental sustainability like land degradation and insecure land tenure have been also reported to constrain sustainability of milk production systems in Tanzania (Ogle, 2001; Lugoe, 2011; Mwamfupe, 2015). The constraints need to be systematically addressed in order to have sustainable smallholder dairy and traditional cattle milk production systems in Tanzania.

Tanzania's livestock vision aims to transform milk production from subsistence to a modern and sustainable level (URT, 2015). To meet the national vision, an assessment of the progress made in improving the sustainability of dairy production systems is necessary. In this regard, a number of measurable indicators to monitor the interventions towards modernization and sustainability of Tanzania's milk production have been established (URT, 2010). These indicators include "the number of staff trained" and "number of communities allocated land for grazing" among others. The indicators are set at a higher level, particularly at country level. Hence, they could have limitations since aggregation at country level could hide large difference between farms (Gómez-Limón and Sanchez-Fernandez, 2010).

Numerous tools for assessing sustainability of milk production farm level have been developed. Many of the tools have been developed specifically for the European context (Van Calker *et al.,* 2005; Zahm *et al.,* 2008; Paracchini *et al.,* 2015), while others are specific for the Asian context, particularly in India (Chand *et al.,* 2015; Singh *et al.,* 2016). The existing tools might not be adaptable to Tanzania's context. For instance, van Calker *et al*. (2005) developed a dairy farm sustainability assessment model in Germany which covered the three aspects of sustainability, but they attached less importance on the economic aspect, which is important for Tanzania's context. Some tools are deemed to be universal (Urutyan and Thalmann, 2011; FAO, 2013). In this case, Urutyan and Thalmann (2011) in Kenya and China used Response Induced Sustainability Evaluation (RISE) developped in Switzerland. Another option is to adapt the existing tools to the context being studied. For instence, the tool IDEA (Indicateur de durabilite des exploitations agricoles) was developed in France and adapted to the Mexican context (Salas-Reyes *et al.,* 2015). However, evidence from a large number of studies including the study by Fadul-Pacheco *et al.* (2013) in Mexico, among others, have shown that using the tool in other contexts different from the original one could provide misleading results since some indicators are deemed out of the context being evaluated. For example, Fadul-Pacheco *et al.* (2013) used IDEA tool, developed in France, in Mexico; however, they removed some indicators like "Enhancement of landscape" refering to European Common Agricultural Policy (CAP) of the Eurropean Union which are not applicable in Mexico.

According to de Olde *et al*. (2016), developers of sustainability assessment tools make judgment during the stages of tool development namely defining sustainability and selecting, measuring, weighting and aggregating indicators depending on the context being considered, and this judgement could be different for the adopter of the tools. For example, Kamalia *et al*. (2017) found that perception of the relative importance of sustainability indicators and dimensions of an agricultural system by the stakeholders varied significantly between Argentina and Brazil. This mismatch implies that using a predetermined tool without adaptation to the prevailing system could be misleading. The adaptation should be performed on almost all stages of sustainability assessment tool development, namely, the sustainability definition and indicators selection, measurement, weighting and aggregation. Meanwhile, Frater and Franks (2013) suggest assessing sustainability according to the context being studied by involving key stakeholders.

Some works on milk production sustainability assessment using locally identified indicators have been done in Tanzania including HADO (Dodoma Soil Conservation) (Ogle, 2001). However, the assessments did not provide good results due to overlooking some local aspects such as involving all key stakeholders, particularly the farmers in the key stages of sustainability assessment namely the selection and monitoring of indicators, and resulted in failure of environmental conservation program (Ogle, 2001). Currently, the literature shows that there is no appropriate tool for assessing sustainability of milk production farms in Tanzania. Thus, it is necessary to develop a tool for assessing sustainability of milk production farms in Tanzania, using rigorously selected sustainability indicators.

Farmers' organizations could be among the solutions for the problems encountered by poor farmers, especially in relation to access to milk markets and inputs and services in developing countries, including in Tanzania (Ogutu *et al.*, 2014). However, the available literature shows that Tanzania's farmers' organizations present some weaknesses. For example, the organizations members do not have business and marketing skills, which prevent them from efficiently exploiting the collective action (Uliwa and Fischer, 2004). In addition, Ogutu *et al.* (2014) report that a large number of formed milk producers' organization, particularly through projects interventions, are not sustainable since they likely collapse as soon as the projects phase out. Currently, little has been done on the assessment of milk producers' organization sustainability performances and their relationships with farm sustainability performances. This shows a need for assessing sustainability performance of farmers' organizations in Tanzania, and also analyse the relationships between the producers organisations' sustainability performances and the sustainability performances of milk production at the farm level.

Milk production farm sustainability in Tanzania could be influenced by numerous factors. One obvious instance is the number of cattle per unit area which could be the source of land degradation caused by overgrazing. Currently, there are no empirical studies on factors which could influence the economic, social and environmental sustainability performance indices in Tanzania. Thus, this study was set to analyse key factors influencing the sustainability of milk production farms in Tanzania.

The assessment of sustainability of milk production farms using rigorously selected indicators could enable the farmers and the other stakeholders in the milk value chain to monitor progress of their interventions towards sustainability. Knowledge of the relationships between sustainability indicators at farm level and at POs level will provides insights on how the POs could be leveraged to improve farm level sustainability. In addition, the insights on factors influencing sustainability could be used to direct public and private interventions towards improving farm and PO sustainability.

1.3 Study Objectives

1.3.1 Overall objectives

To assess the sustainability of smallholder dairy and traditional cattle milk production systems in Tanzania.

1.3.2 Specific objective

Specific objectives were to:

i. Establish relevant indicators for assessing the sustainability of smallholder dairy and traditional cattle milk producer farms in the selected areas of Tanzania;
ii. Assess sustainability of smallholder dairy and traditional cattle milk producer farms;
iii. Establish the relationships between the sustainability indicators relevant at smallholder dairy and traditional cattle milk producer farm level and those relevant at milk producers' organization level in Tanzania;
iv. Analyse the factors influencing the sustainability performances of smallholder dairy and traditional cattle milk producer farms in Tanzania.

1.4 Research Questions

i. What are the relevant sustainability indicators of smallholder dairy and traditional cattle milk producer farms in the study area?
ii. What are sustainability performances of smallholder dairy and traditional cattle milk producer farms in the selected districts?

iii. What are the relationships between sustainability indicators relevant at smallholder dairy and traditional cattle milk production farm level and those relevant at producers' organization level in the study area?

iv. What are the factors influencing specific sustainability performances of smallholder dairy and traditional cattle milk producer farms in the study area?

1.5 Research Hypothesis

i. There is no relationship between sustainability indicators relevant at smallholder dairy and traditional cattle milk production farm level and those relevant at producers' organization level in the study area.

ii. Socio-economic characteristics do not significantly influence specific sustainability performances of smallholder dairy and traditional cattle milk producer farms in the study area.

1.6 Organization of the Thesis

This thesis is divided into five chapters. Chapter One consists of the introduction which includes the background describing the context in which the problem was observed, problem statement and justification of the study. It also includes the objectives of the study and respective research questions and hypotheses. Chapter Two covers the literature review relating to the study. Chapter Three covers the research methodology used to answer the research questions. Particularly, it describes the location and geographical description of the study area, the sampling procedures and sample size, data collection approaches used in the study and data processing and analysis. Chapter Four presents results. Chapter Five discusses the results. Chapter Six presents the major conclusions drawn from the results obtained and presented with respect to the four research questions and the hypothesis. It also provides recommendations to improve milk production farm sustainability.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Sustainability Concept

2.1.1 Sustainability definitions

A clear understanding of the operational definition of "sustainability concept" is the starting point for any sustainability program (Zahm *et al.*, 2008; Urutyan and Thalmann, 2011). Although the essence of the concept of sustainability is clear, its practical definition is still subjective among individuals (Seghezzo, 2009). The word sustainable has its roots in Latin word *subtenir*, meaning 'to hold up' or 'to support from below'. Indeed, the term "sustainability" is considered a synonym of "sustainable development"; and its widely known definition as provided by the World Commission on Environment and Development (1987) is "the development which meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition has been criticised for its vagueness and subjectivity by many individuals. For example, the major difficulty is defining the term "need" since what some individuals consider to be "needs", others may consider it as other things like simply "desires" (Robinson, 2004; Cox and Ziv, 2005). This ambiguity implies that what is considered as sustainable to one individual could be considered as moderately or non-sustainable to another individual. Meanwhile, Seghezzo (2009) shows other weaknesses of the sustainability definition provided by the World Commission on Environment and Development such as being more essentially anthropocentric, over estimating the importance of the economy, neglecting the space and time aspects and disregarding personal aspects.

2.1.2 Sustainability dimensions

Sustainability is represented by dimensions also called aspects, domains or pillars (van Cauwenbergh *et al*., 2007; Bausch *et al*., 2014; van Calker *et al*., 2007, respectively).

Three basic dimensions commonly known as the ‘triple bottom line’ of economy, environment, and society are the mostly used to represent sustainability. Besides the three basic dimensions of sustainability, other dimensions have been added. One example is good “governance” or “institutional” dimension which is added in the framework for Sustainability Assessment of Food and Agriculture systems (SAFA) which is deemed to be universal as suggested by FAO (2013). Meanwhile, Seghezzo (2009) proposes an alternative sustainability triangle formed by ‘Place’, ‘Permanence’, and ‘Persons’ (the new three Ps) in order to better understand the sustainability concept.

Graphical representations of sustainability dimensions have been used to help to communicate the integration of sustainability dimensions and make the sustainability concept more tangible (Lozano, 2008). Two of the most used sustainability representations are: (1) the *Venn diagram* where the union created by the overlap among the three components of economy, environment and society are designed to represent sustainability as presented in Fig. 2 (Lozano, 2008); (2) the three concentric circles where the inner, middle and outer circles represent the economic, social and the environmental aspects, respectively as presented in Fig. 3 (Waney *et al.,* 2014; Gary *et al.,* 2005 cited by Nguyen (2012)). The concentric graphical representation implies that the environment is ultimate setting within which societal structures are built, and society itself is more fundamental than the economic constructions that humans design and implement (Gary *et al.,* 2005) cited by Nguyen (2012). Some authors propose other graphical representations such as the one with embedded circles but no concentricity or common middle point (Mebratu, 1998).

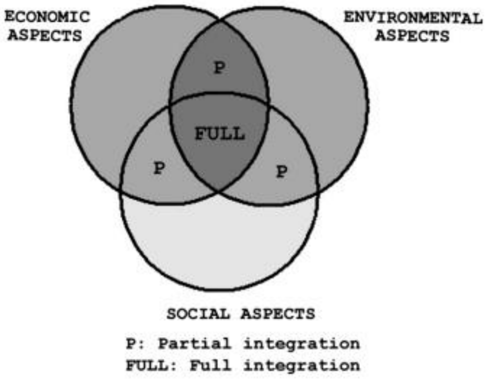


Figure 2: Graphical representation of sustainability using a Venn diagram.
(Source: Lozano (2008)

Figure 3: Graphical representation of sustainability using concentric circles
(Source: Source: Lozano (2008)

2.1.3 Sustainability of milk production system

An agriculture which continually provides food and other resources to a growing world population is of crucial importance for human existence and hence for any human activity. However, there are a great number of social, economic and environmental problems that threaten this ability of agriculture to fulfil human needs now and in the future. These problems include climate change, high rate of biodiversity loss, land degradation through soil erosion, compaction, salinization and pollution, depletion and pollution of water resources, side effects on human and animal health (Steinfeld, 2006; Swai, 2011; Gerber et al., 2013; Velten *et al.*, 2015). Therefore, there is growing emphasis on sustainable agriculture in concerning with the adverse social, environmental and economic impacts of conventional agriculture (Hansen, 1996).

The idea of a sustainable agriculture has gained importance since the publication of the Brundtland Report in 1987. Yet, similarly to the concept of sustainability, the definition of of sustainable agriculture is still very vague and ambiguous in its meaning (Lichtfouse *et al.,* 2010), which renders its practical use difficult (Velten *et al.,* 2015). Many definitions of sustainable agriculture exist with different focusses: at least 70 definitions can be identified in the literature (Zhen and Routray, 2003). Landais (1998) and Lichtfouse *et al.* (2009) suggest that a sustainable agricultural system should sustain itself (in three dimensions) over a long period of time; this is possible if it is economically viable, environmentally safe and socially fair. For a farm, the contribution to sustainable agriculture often involves three functions namely: (1) the production of goods and services (economic function); (2) the management of natural resources (ecological function); and (3) the contribution to rural dynamics (social function) (Latruffe *et al*., 2016). The American Society of Agronomy defines sustainable agriculture as a system that, "over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fibre needs; is economically viable; and enhances the quality of life for farmers and society as a whole" (American Society of Agronomy, 1989).

More specifically, Devendra (2001) described sustainable milk production farming system as the one which is efficient in resources management without negative impact on the environment, profitable, contributes to employment creation and improving livelihood of the poor. Nguyen (2012) argues that most definitions of sustainable agriculture are fundamentally similar. According to Weil (1990), a sustainability definition should be general enough in order to accommodate the wide range of agricultural situations in which it will be applied, yet specific enough to provide criteria by which the sustainability of alternative systems may be judged.

The concept of sustainable agriculture emphasizes on different aspects of agriculture in the context of different countries and regions. For example, in developed countries, the main sustainability issues are diversification away from a limited range of commodities and the satisfaction of environmental pressure groups, particularly with respect to large losses of nutrients and the quantities of pesticides currently used (Zhen and Routray, 2003). In developing countries, the imperative is to maintain food production, while preserving the underlying resource base (Zhen and Routray, 2003).

2.2 Sustainability Assessment and Sustainability Indicators

2.2.1 Sustainability assessment

Sustainability should be assessed in order to know the situation and guide interventions for its improvement (Häni *et al.,* 2003; Urutyan and Thalmann, 2011; Bond *et al.,* 2012). Sustainability assessment enables decision-makers and other stakeholders decide what actions they should take and should not take in an attempt to improve sustainability (Devuyst, 2001).

Nguyen (2012) suggests that in the field, especially in farming systems, sustainability is an extremely complex measure. Therefore, operationalizing sustainability on the ground involves considering numerous aspects, variously identified as physical, environmental, social, cultural and / or economic. This complexity leads to the need for integrated and interdisciplinary assessments that can consider the sum of its parts. According to Poveda and Lipsett (2011), sustainability assessments are practical undertakings in evaluation and decision making with expected participation by stakeholders.

2.2.2 Sustainability indicators

Sustainability assessment is made possible by using the most relevant indicators which cover the economic, social and environmental aspects of sustainability (Zahm *et al.*, 2008;

FAO, 2013; Chand *et al.,* 2015). Practically, sustainability assessment consists of dividing the economic, social and environmental sustainability dimensions into relevant attributes, which could be termed “issues” / “principles” / “criteria”, then monitor the attributes using measurable indicators (de Boer and Cornelissen, 2002; van Calker *et al.,* 2005; van Cauwenbergh *et al.,* 2007). An attribute is described as a feature that can either negatively (constraints) or positively (opportunities) influence the respective dimension of sustainability (van Calker *et al.*, 2005).

The indicators provide information on other variables which are difficult to access and serve as a tool for decision making by showing whether the process is not deviating from the desired situation (Gras *et al.,* 1989). When specific indicators are selected, it is possible to say whether certain trends are steady, going up or going down (Pretty, 1995). An indicator could have many meanings such as a variable, a parameter, a measure, a value, metrics, a measuring instrument, an index, a piece of information, representation, a proxy (Waas *et al.*, 2014). An indicator can also be defined from “system” and “technical” perspectives. From a system perspective, Bell and Morse (2003) define an indicator as “an operational representation of an attribute (quality, characteristic and property) of a system”. From a technical perspective, Gallopin, (1997) cited by Borin *et al.* (2006) defines an indicator as a “variable” or an aggregation / function of a number of variables. Therefore, the integrative definition of an indicator becomes: “the operational representation of an attribute (quality, characteristic and property) of a given system, by a quantitative or qualitative variable (for example numbers, graphics, colours, symbols) (or function of variables), including its value, related to a reference value (Waas *et al.,* 2014). Fig. 4 shows the schematic presentation of an indicator’s integrative definition.

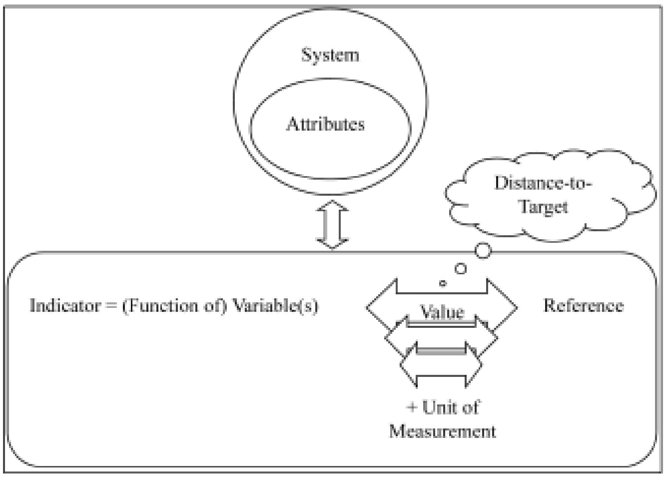


Figure 4: Schematic presentation of an indicator's integrative definition.
Source: Waas *et al*. (2014)

An indicator shows, among others, the extent to which the value of interest is close to the reference or desired value (Sauvenier *et al.*, 2005; Waas *et al.*, 2014). The indicator should be compared to the reference value in order to be meaningful (Waas *et al.*, 2014). According to van Cauwenbergh *et al.* (2007), the reference values could be either relative or absolute. The absolute reference values include threshold value and target value while the relative reference values include the regional average, between sector comparison and trend.

2.2.3 Rationale for the choice of sustainable indicators

Selection of a set of relevant indicators is among the most critical stages of sustainability assessment. It influences the conclusion from the sustainability assessment as well as the results from its intervention (Ogle, 2001). A large number of indicators for assessing sustainability have emerged (Rigby and Cáceres, 2001; de Olde *et al.,* 2016). Due to the lack of specific meaning of the concept of sustainability, the indicators could be viewed as relevant or otherwise depending on the individuals (Hayati *et al.*, 2010; Frater and Franks, 2013). Indeed, an indicator could change its dimension according to the context. One example is the animal welfare which is considered more economic for the farmer and more social for the consumer (Atanasov and Popova, 2010).

There exist several methodologies for sustainability indicators selection. The two widely known methodologies for selecting sustainability indicators are “top-down” / “expert-driven” and “bottom-up” / “stakeholder-driven” and these methodologies are also referred to “reductionist” and “conversational”, respectively (Bell *et al*., 2001). Top-down approaches are characterized by quantitative indicators, which are developed by a group of experts and with explicit, clearly stated methodologies (Singh *et al*., 2012). On the contrary, bottom-up approaches use qualitative indicators which are developed by (local) stakeholders and with implicit, no clearly defined methodologies (Bell *et al*., 2001; Singh *et al*., 2012). Top-down sustainability indicators are developed by experts and are “scientifically rigorous” but such methodologies fail to engage local stakeholders, whereas the opposite is true for bottom-up methodologies (Ogle, 2001; Reed, 2006).

Various examples of approaches have been used during the selection of the relevant indicators. During the selection of relevant indicators, some studies use participatory methods while others use hierarchical methods (van Cauwenbergh *et al*., 2007; van Calker, 2005; Zahm, 2008; Majewsk, 2013). For example, Arandia et *al.* (2011) proposed establishing indicators using several phases during selection of indicators: Literature review search, drafting initial list of specific indicators and valuation of the information by the experts. Indicators can also be identified by farmers, advisors and teachers of agriculture schools using questionnaires (Elsaesser *et al*., 2013). Alternatively, Ghozlane (2006) and Fadul-Pacheco *et al.* (2013) suggested an adaptation of existing indicators to the context being considered.

Selection of sustainability indicators using participatory approach should assure that all opinions from the respondents are properly integrated. Hence, the Delphi technique has been suggested as among the most objective approaches (Parent *et al*., 2010; Bélanger *et al.,* 2012). The Delphi technique is used to generate the most reliable agreement on a subjective topic by extracting and integrating a group of diverse opinions from different individuals through a series of questionnaires with controlled feedbacks (Linstone and Turoff, 2002; Grisham, 2009). The Delphi technique can be conducted remotely and is characterized by four main features: "anonymity, iteration, controlled feedback and statistical aggregation of group response". These features enable respondents to provide their opinions without bias due to the fear from social pressure by peers or society which could occur during face to face meetings.

The indicators to be selected should have a certain number of criteria. They should be "(i) relevant; this is related to the appropriateness of the indicator to the context and scale, and also includes a quality / accuracy aspect; (ii) practicable, which consists of measurability, quantification and compatibility of the data with the selected aggregation method, and transferability to other farm types; (iii) valuable for the end user; this relates to the appropriateness of the indicator to stakeholders' expectations in terms of clarity, comprehension and policy relevance" (Lebacq *et al.,* 2013).

2.2.4 Indicators' presentation

Indicators should be presented as a set instead of single indicators (Latruffe *et al*., 2016). Lebacq *et al.* (2013) suggest three criteria for selecting a set of indicators: (1) parsimony, i.e. indicators should be as few as possible and not redundant; (2) consistency, i.e. all necessary indicators are in the set; and (3) sufficiency i.e. that is to say that the set is exhaustive in the sense that it embraces all sustainability objectives. Atanasov and Popova (2010) suggest that the indicators must not be too many so as to simplify the interpretation specifically for those who are not experts, particularly the farmers. Although they provide more detail, too many indicators are difficult to handle, confusing and some of the indicators could be redundant (van Cauwenbergh *et al.,* 2007). When oversimplified, the set of indicators could fail to measure what they are supposed to measure (Dale and Beyeler, 2001). Hence, the choice of the number of indicators depends on the objective of the end user and the capacity of handling these indicators (Marchand *et al.,* 2014).

Indicators may be difficult to interpret when they are presented separately. Therefore, the indicators could be aggregated into indices (Chand 2015; Latruffe *et al*., 2016; Paracchini *et al*., 2016). The individual indicators are constructed from raw data. Then, the composite indicators are the result of aggregation of individual indicators. The composite indicators enable to simplify the information, hence, be understood while the individual indicators and the data enable to better understand the details. On contrary, the non-aggregators question the aggregation since it could be dangerous due to mixing apple and oranges (Latruffe *et al*., 2016). Fig. 5 shows, with examples, how composite indicators are made from raw data.

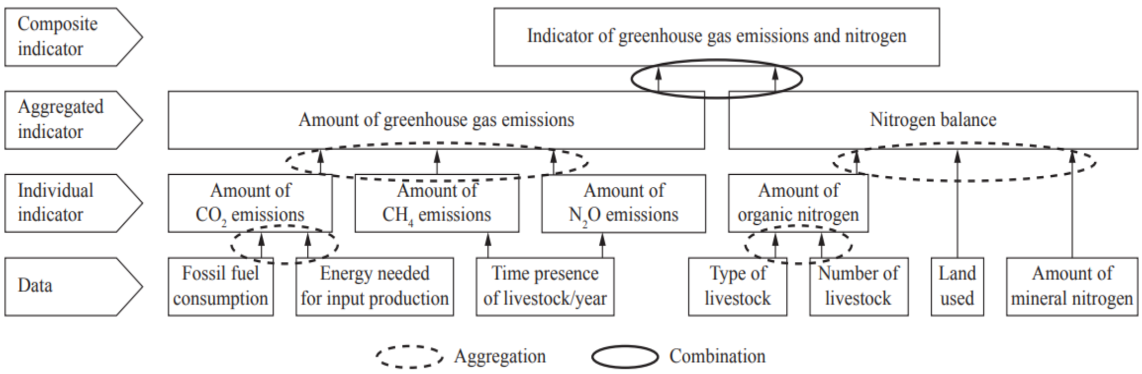


Figure 5: From raw data to composite indicators: an illustration

Source: Latruffe *et al*. (2016)

The preference of level of aggregation varies with the group of individuals (Fig. 6). Policy-makers and the public are more interested in the highest aggregation level while the scientists are mostly interested in the details at the bottom and up to the data. Farmers are interested in the moderate aggregation level (Sauvenier *et al.*, 2005; Bélanger *et al.*, 2015).

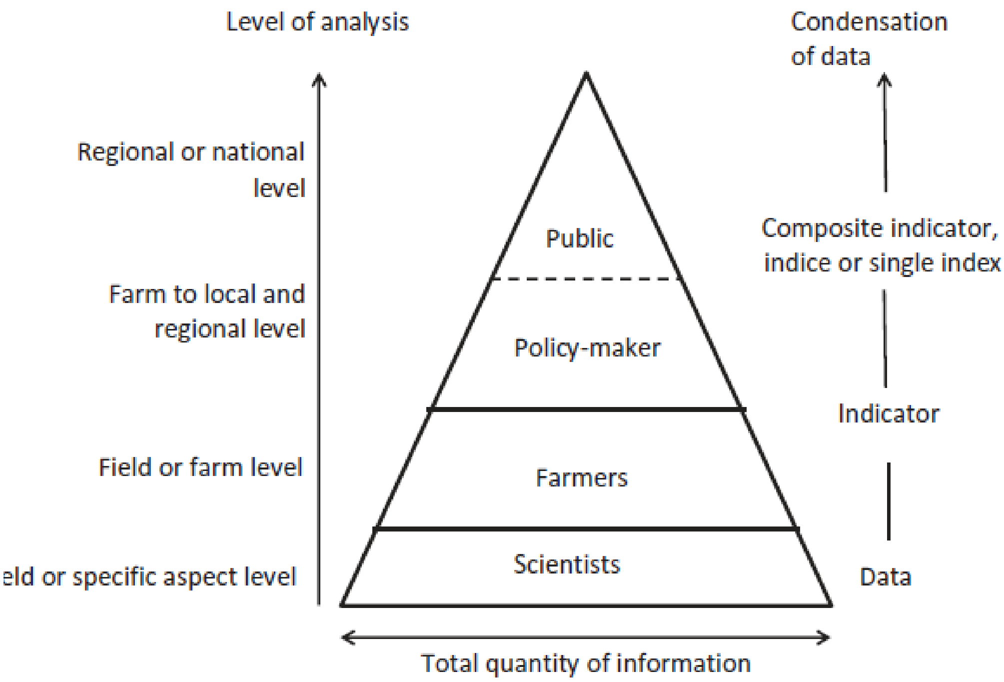


Figure 6: Relationships between Indicators, Users and the Level of Analysis

Source: Bélanger *et al.* (2015)

The indicators and indices could be graphically presented in different forms. These include the amoeba / spider diagram form. This form enables the end users to easily visualize the strengths and weaknesses of an indicator where the intervention is needed (Grenz, 2012; Bélanger *et al.,* 2012).

2.2.5 Sustainability assessment tools

There are a large number of available sustainability assessment tools, and classifying them can be a challenge. Among others, indicator-based sustainability assessment tools are generally structured following three or four hierarchical levels as suggested by de Olde *et al.* (2016) in Fig. 7. A dimension is the highest and most general level in the structure of a tool. On the intermediate level, universal sustainability goals are translated into themes and, in some cases, made more explicit in sub-themes. Finally, indicators are measurable variables used to evaluate the sustainability performance for the (sub) theme (FAO, 2013). The stages of sustainability assessment index construction are mostly subjective. Therefore, the framework for construction of sustainability assessment index should be done carefully in order not to lose valuable information or provide wrong answer (OECD, 2008; Frater and Franks, 2013; de Olde *et al.*, 2016).

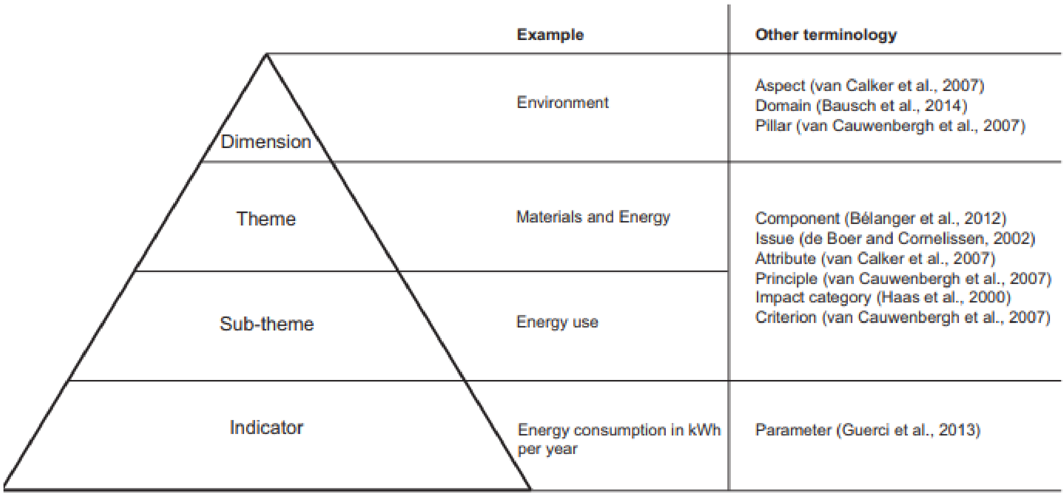


Figure 7: Hierarchical levels in sustainability assessment and terminology used

Source: de Olde *et al.* (2016)

Marchand *et al.* (2014) identify two types of indicator-based sustainability assessment tools: full sustainability assessment (FSA) tools and rapid sustainability assessment (RSA) tools. The RSA tools are quick and more oriented toward communicating and learning. They are therefore more suitable for use by a larger group of farmers. The RSA tools can help to raise awareness, trigger farmers to become interested in sustainable farming, and highlight areas of good or bad performance. If and when farmers increase their commitment to on-farm sustainability, they can gain additional insight by using a FSA tool which provides more details.

2.2.6 Test and validation of sustainability assessment tool

The developed tool must be tested and adjusted before application. A tool might work theoretically but faces difficulties during its application. For example, de Odle *et al.* (2016) in Denmark reported that the farmers expressed a hesitation to apply the outcomes of some existing tools, even the tool "Response-Inducing Sustainability Evaluation" (RISE) which is deemed to be universal, in their decision making and management. Therefore, a sustainability assessment tool needs to be tested and validated before being used. van Der Werf and Petit (2002) suggest some reasons for validating a sustainability assessment tool: the first reason is that a tool may provide wrong information due to the objective not appropriate with respect to the purpose. The second is that the tool may be difficult to use due to a very complicated method, too expensive or requires data that cannot be available. Therefore Bockstaller *et al.* (2009) and Bélanger *et al.* (2012) propose a methodology for validation of sustainability assessment tool which takes into account scientific soundness, feasibility and utility of the tool. Meanwhile, Bockstaller and Girardin (2003) suggest three types of validation: design validation, output validation and end user validation as described in Fig. 8. After the test and validation, the indicators which do not comply with the requirements (if any) should be adapted or removed to come up with the refined tools which are easy to use and comprehended.

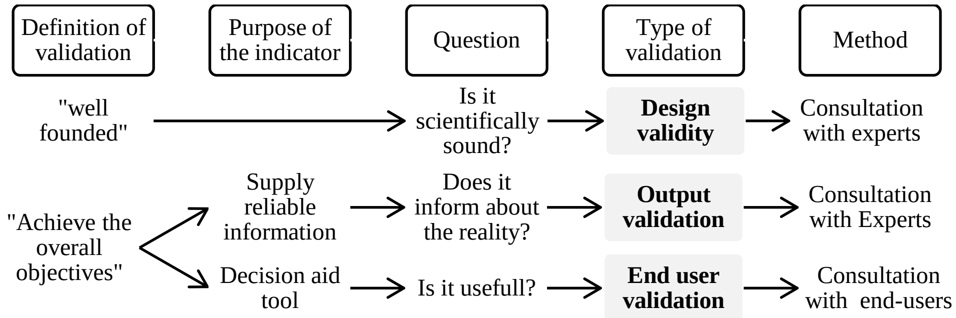


Figure 8: Flowchart for framework of indicators validation

Source: Adapted from Bockstaller and Girardin (2003).

2.3 Assessment of Sustainability of Smallholder Dairy and Traditional Cattle Milk Production Farms in Tanzania

2.3.1 Sustainability issues in smallholder and traditional cattle milk production systems in Tanzania

Assessing sustainability of Tanzania's smallholder dairy and traditional cattle milk production systems is crucial in order to maintain their existence. In the context of Tanzania, smallholder dairy farms are relatively small in size having 1 – 5 cows per household under zero grazing while in the traditional system, milk is mainly produced by indigenous cattle which are kept for multiple objectives (meat and milk especially) (Njombe *et al*., 2011). The traditional system is characterised by low productivity (Leonard *et al*., 2016); and due to the remoteness and poor infrastructure, inadequate collection of milk and marketing constitute the largest bottlenecks (Njombe *et al*., 2011). Other issues like conflicts between crop farmers and cattle farmers, shortage of feed and water have been reported in the traditional cattle keeping systems (Benjaminsen *et al*., 2009; Leonard *et al*., 2016). Meanwhile, issues like land degradation and shortage of feed have been reported in smallholder dairy systems (Ogle, 2001; Nkya *et al*., 2005; Benjaminsen *et al.,* 2009). In this regard, it is important to determine the level of sustainability and formulate respective policy and advice in order to improve the sustainability of smallholder dairy and traditional cattle milk production farms in Tanzania.

2.3.2 Indicators of Sustainability at Smallholder Milk Producer Farm Level in Tanzania

Smallholder milk producer and traditional cattle milk producer farms in Tanzania require specific sustainability indicators to monitor their performance. Many indicators for sustainability at dairy farm level have been identified, particularly for smallholder dairy farms. In smallholder milk production systems, Devendra (2001) identified a set of sustainability indicators such as education level and return on asset, among others. In India, Chand *et al*. (2015) provided attributes and indicators for sustainability assessment of smallholder dairy farms. They include, for example, cost of milk production and capital productivity for the economic dimension, women empowerment measure for social dimension and enteric methane emissions for the environmental dimension. However, the choice of appropriate indicators for smallholder dairy and traditional cattle milk production farms is still a challenge as some of the indicators are specific to the context, the same as the sustainability concept (Hayati *et al*., 2010). For example, proportion of dung production used for fuel indicator used by Chand *et al*. (2015) for assessing sustainability of smallholder dairy farm is not relevant in the context of Tanzania since dung is not commonly used as fuel. In Tanzania, Ogle (2001) also reports a set of indicators which were used to monitor degraded ecosystem rehabilitation in Dodoma Region in order to lead to its sustainability. Those are namely biophysical indicators (cow performance data, feed supply and feeding strategies, crop yields and manure utilization), socio-economic indicators (labor inputs, economic indicators like net profits from the sale of milk, changes in wealth distribution, nutritional status of children and gender issues). However, the set of indicators presents some incompleteness for holistically assessing sustainability of milk production farm since it overlooks the environmental indicators. Indeed, the indicators selection procedure did not include the opinions from all stakeholders including the farmers (Ogle, 2001).

2.3.3 Tools for Assessing Sustainability at Smallholder Farm Lever in Tanzania

Several studies aiming to address issues which hinder milk production sustainability have been conducted in Tanzania. However, issues related to economic, social and environmental sustainability of milk production systems have been addressed in separate studies. Some examples are the studies which dealt with feed and manure management, water pollution, milk quality, farm profitability and conflicts between livestock keepers and crop farmers (Lupindu *et al.*, 2015; Morris *et al*., 2015; Leonard *et al*., 2016; Mdegela *et al*., 2009). However, the studies are not sufficient as they do not perform holistic assessment which covers the three dimensions of sustainability.

A large number of integrated sustainability assessment tools involving milk producer farmers exist in developed countries and less so in developing countries. These tools could be used in other areas including Tanzanian smallholder dairy and traditional cattle milk production farms. However, the tools may manifest some incompatibilities as the farming systems and interests by the stakeholders are not the same. This could be explained by many factors like the indicators not being adapted to the context, scoring and aggregation method, time requirement and data input (de Olde *et al.,* 2016). Fadul-Pacheco (2014) suggest adapting the tool to the context being studied by excluding / modifying the indicators which are not compatible with the context. Therefore, the developers of the sustainability assessment tools should pay attention on all stages since they are the ones make value judgements and assumptions about the working definition of sustainability, sustainability level to be considered, the indicators to be selected, how the indicators are measured and aggregated, etc.(Gasparatos, 2010; De Olde *et al.,* 2016). For this reason, developing an accurate sustainability assessment tool requires specific weight and reference values adapted to Tanzania's context using experts and stakeholders' involvement, instead of using the existing tools with predetermined indicators and weights.

2.4 Relationships between Indicators of Sustainability Relevant to Milk Producers' Organizations and Farm Level

2.4.1 Effect of farmers' organization membership on farm sustainability performances

Farmers' organizations are an effective mechanism to improve sustainable performances among farmers through improving some key indicators of farm sustainability. Organized farmers can carry out many activities together such as milk collection and marketing, having easy access to credit, inputs and services. According to Rahman and Jancy (2015), farmers' organizations improve socio-economic status of the members and positively influence knowledge gain and adoption of technologies in the farms**.** Yadav *et al.* (2016) show that at individual level, farmers' organizations are capable of improving the capacity building of members in terms of enhancing confidence, participation in training programmes and extension activities. In economic terms, farmer groups are able to increase income, enhance saving habits, improve repayment of loan and facilitate capital formation (Yadav *et al*., 2016; Agbonlahor *et al*., 2012). In Nigeria, Agbonlahor *et al.* (2012) showed that farmers' organizations are attractive since they enhance access to farm inputs procurements and access to market information, cooperative credits and thrift, social networking and multipurpose commercial activities.

Although it is known that farmers' organization improve some of the farm sustainability indicators, they could also have negative effects on other parameters / indicators of farm sustainability. For example, Francesconi (2012) in Ethiopia showed that cooperative membership has a positive impact on milk production and productivity, but have also a negative impact on milk quality in terms of butter fat. In fact, cooperatives promote high yielding crossbred cows which produce larger volumes of milk with lower fat and protein content compared to the indigenous zebus, characterised by the production of small volumes of milk with high density of nutrients. Indeed, Mojo *et al.* (2015) suggests that famers' organizations negatively affect environmental performances, contrary to the expectation, particularly in coffee farming. This is due to the fact farmers intensify production activities to comply with the urge made to reverse the low productivity of coffee and respond to the impeding market demands of cooperatives, which actually propel the process of resource degradation.

Other issues related to poor performances at farmers' organizations level which have negative impact on farm performances have been reported. For example, Shiferaw (2009) argues that that poor performances such as lag to payment for deliveries makes farmers' organizations less attractive marketing channels for the poor. Mujawamariya *et al*. (2013) in Rwanda shows that despite their possible opportunities offered by the farmers' organizations, the members prefer to sell their produce to traders rather than to their organization because of their long-standing relationship with the traders. In fact, the personal contacts of farmers with traders reduce certain transaction costs such as payment in time and easy provision of credit. This seems to secure the farmers' commitment to the traders rather than to the cooperatives which show less flexibility towards the farmers' daily needs.

2.4.2 Sustainability of farmers' organization

A farmers' organization should be sustainable in order to continue to exist while helping its members. However, a large number of producers' organizations in developing countries, including Tanzania, are not sustainable since they either stay static for a long time without helping their members or dissolve, particularly the ones created through mobilization by donors (Bayer and Kapunda, 2006; Ogutu *et al.*, 2014). Some of the major reasons for the failure include poor management, conflicts among members, lack of funds, dependence on external support and poor marketing skills (Holloway *et al.*, 2000; van der Walt, 2005; Nyang *et al.*, 2010). According to Joseph and Coblentz (2002), "organizational sustainability represents an ongoing process rather than a state of perfection. It is like a plant: it will grow and prosper if watered and cared for, but wither quickly if it is not". "Furthermore, organizations are like a body: if one part is ill, the rest will not function like it should. If too many parts fail at once or in quick succession, the body dies". Therefore, farmers' organizations need to be sustainable in order to efficiently continue supporting their members without merely depending on external support which are mostly ephemeral.

2.4.3 Assessing sustainability of milk producers organization

Sustainability of milk producers' organization should be assessed in order to guide the interventions towards its improvement. In India, Rahman (2011) analysed sustainability of dairy farmers' organizations using organizational and financial sustainability indicators. The organisational sustainability indicators were the frequency of meeting, attendance in group meeting, books maintained by the groups, drop-out rates and the reasons for such dropouts. The financial sustainability indicators were the rate and periodicity of savings, utilization of savings, credit-deposit ratio and repayment performance. However, Hubbard *et al*. (2006) and Terry (2013) suggest that a framework for assessing sustainability of an organization should not be primarily economic, but it should also consider the impact on the society and environment so as it could continue to exist. Therefore, the Triple Bottom Line (TBL) approach is more improved during the assessment of organization's sustainability since it adds the social and environment measures to the economic measures (Hubbard, 2006; Cella-De-Oliveira 2013). Similarly, Baumgartner and Ebner (2010) use the three sustainability dimensions for assessing organizational sustainability: Economic Organizational Sustainability (EcOS), Environmental Organizational Sustainability (EnOS), and Social Organizational Sustainability (SOS) as presented in Fig. 9. The theory behind the TBL is that an organization should take into account its performance in relation to that wider group of stakeholders (such as communities and governments) who are affected by the organization's activities, rather than just the narrower group of stakeholders (such as employees, suppliers and customers) who are directly impacted through transactional relationships (Hubbard *et al*., 2006).

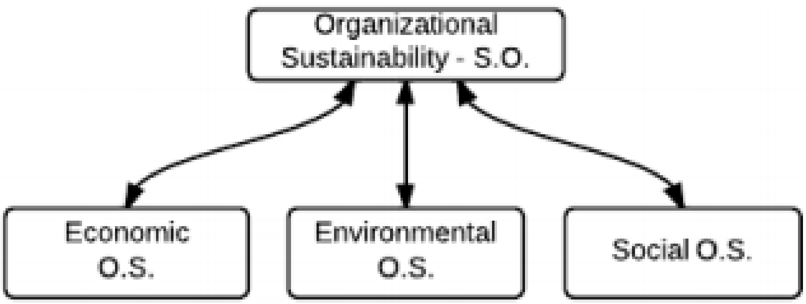


Figure 9: Organizational Sustainability framework

Source: adapted from Cella-de-oliveira (2013)

In order to assess sustainability of an organization using TBL, Cella-de-Oliveira (2013) proposes an extensive list of 19 economic, 32 social and 23 environmental indicators for assessing organizational sustainability. Some examples are generation of adequate capital pay outs to the shareholders and not gaining economic advantage by illicit means for the economic organizational sustainability dimension; the organization possesses environmental policies tied to its strategic planning, management and processes and monitoring programs of environmental performance exist and its results are considered in the future planning for the environmental organizational sustainability dimension; frequent training opportunities and other activities that promote the development of its collaborators and conducts satisfaction surveys among its collaborators, and its results are considered for changes for the social organizational sustainability dimension.

According to Santos *et al.* (2013), improving sustainability using financial, environmental and social dimensions according to the TBL approach does not guarantee itself an effective sustainability of organizations. Therefore, DPOBE Model was suggested for assessing organizational sustainability (Fig.10). This model suggests that organizational sustainability is represented by five pillars that are considered as the most important to assure the organizational sustainability. Those are direction, posture, organization, behaviour and evaluation. Trying to upgrade this theoretical model and its empirical applications, some of authors have proposed a quantitative application in order to determine the global sustainability robustness of organizations with the measure of the sustainability strength in each one of the pillars (Santos *et al.*, 2012).

Figure 10: The DPOBE Model for Organizational Sustainability

Source: López *et al.* (2010; 2011) cited by Santos *et al.* (2013)

Sustainability assessment approach for an organization should be specific to the context, particularly for milk production systems which vary extremely from one to another. In this regard, the East African Dairy Development Project (EADD) has developed a tool, "the Producers Organisation Sustainability Assessment tool (POSA)", to assess producers' organisation sustainability (Mutinda *et al*., 2015; Baltenweck *et al*., 2016). The EADD is a regional industry development program which has the goal of helping families living on small 1-5 acre farms lift themselves out of poverty through more profitable production and marketing of milk. The tool was used in Kenya and Uganda. The tool considers an organization to be sustainable "if it can adjust its business practices to respond to external shocks (such as a changing milk price) and internal shocks (such as corruption among the leadership)" (Baltenweck *et al*., 2016). The POSA tool covers organizational and economic dimensions and suggests that sustainability is represented by six dimensions. The assessment produces a score on each dimension: the higher the score, the more sustainable the organization. The tool enables to classify the organizations into five stages according to their sustainability scores. Where; Stage I implies that a PO may have an interim board, have not held elections, have no staff, etc. while Stage V implies that a PO has a well-established board with regular and documented meetings; it is profitable and the financial management is in order; it is able to handle fluctuations in milk supply, etc. (Baltenweck *et al*., 2016).

A large number of empirical studies suggesting the importance of farmers' organizations in improving farm performances which result into their sustainability include the studies by Mojo *et al.* (2015) and Chagwiza *et al.* (2016). Other studies including the study by Baltenweck *et al*. (2016) enable to analyse the sustainability performances at PO level. However, there is no empirical study on to the relationship between sustainability indicators available at farm level and those relevant at producers' organizations level. Hence, there is a need for information on how sustainability of farmers' organizations influences sustainability of smallholder milk production farm.

2.5 Factors Influencing Sustainability

The sustainability performance indices could have relationships with other factors like social and economic factors (Haileslassie *et al.*, 2016; Li *et al*., 2016). For example, Gómez-Limón and Sanchez-Fernandez (2010) in Spain, using double censored Tobit regression, suggest that farm sustainability has a positive relationship with farm size, proportion of the farmer's income derived from agriculture and participation in cooperatives; but negative relationship with the age of the farm owner. Similarly, Dabkiene (2015), using multivariate regression analysis, show that the overall farm sustainability has negative relationship with farmer's age. Using Anova, Dabkienė (2015) suggests that the economic and social sub-indices values were greater in farmer's age category under 35 years old and the value of environmental sub-index was greater in the age category of farmer's over 65 years old. In China, Li *et al*. (2015) show that non-farming income has a positive relationship with economic dimension of farm sustainability and negative relationship with social dimension of farm sustainability. The distance to market shows a negative relationship with the social farm sustainability dimension. Indeed, Li *et al*. (2015) show the age of the head of household has significant positive effects on the economic and environmental farm sustainability dimensions, but a negative effect on the social farm sustainability dimension. Education attainment, information sources, attitude, and awareness were the major determinants of use of sustainable agricultural land management practices in Nigeria (Simon *et al*., 2013). Education, number of training and extension contact had positive and significant contribution towards sustainability of a dairy farm in India (Rahman, 2011). Since sustainability is context specific, the factors influencing sustainability might be contextual as well. This implies that it is crucial to analyse the determinant of farm sustainability in the context being studied.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Study Location

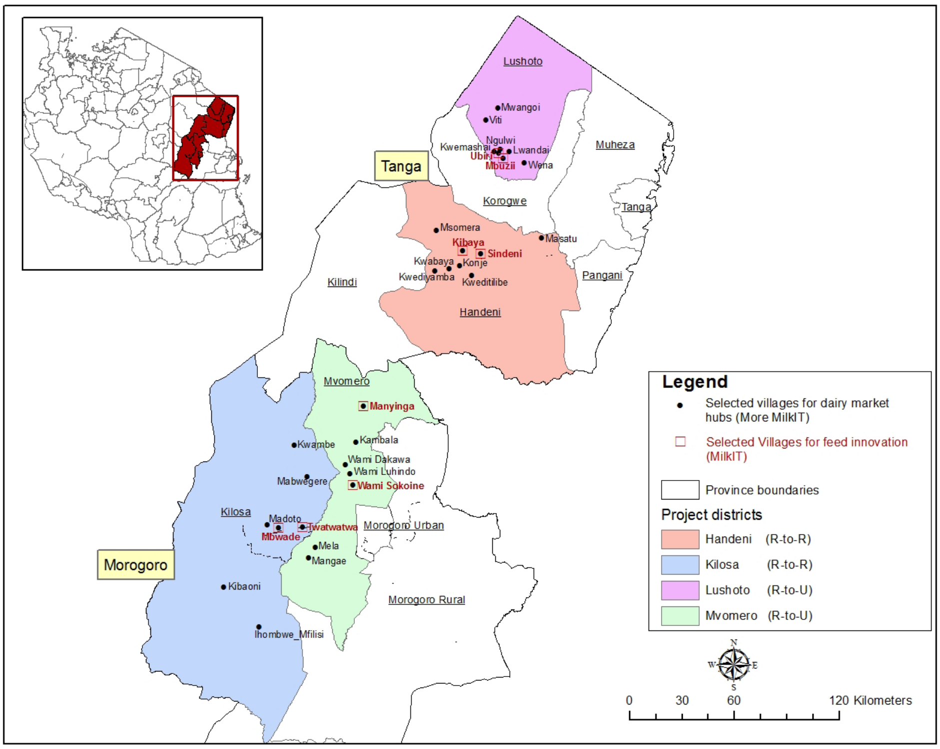
The study was conducted in Kilosa and Mvomero districts of Morogoro Region and Handeni and Lushoto districts of Tanga Region. Morogoro Region is located between latitude 5^{o} 58’ and 10^{o} 00’ to the South of the Equator and longitude 35^{o} 25’ and 35^{o} 30’ to the East, and covers a total area of 72 939 km^2 (URT, 1997a). Tanga Region is located between 4^{o} and 6 ^{o} Southern of the Equator and 37^{o}-39^{o} 10' East and occupies an area of 27 348 km^2 (URT, 1997b). The annual rainfall varies from 600 mm to 1 200 mm for Morogoro Region. In Tanga Region, the amount of rainfall is above 750 mm in most districts. The average temperature is almost regularly around 25^{o}C in most parts of Morogoro Region. In Tanga, the temperature varies from 20^{o}C to 28^{o}C during cool months and from 26^{o} to 32^{o} in the hot months. In the two regions, cattle keeping is the second most important economic activity after crop production.

Cattle keeping in Kilosa and Handeni districts are dominated by pastoralists and agro pastoralists who raised indigenous cattle and less than 1% improved dairy breeds is kept by smallholder dairy farmers. These production systems represent “mostly pre-commercial rural production for rural consumption systems (R-to-R)” (ILRI, 2014a) due to the remoteness and bad status of infrastructure. Indeed, a large proportion of the produced milk is consumed locally and often excess left for the calves due to lack of market access, especially during the rainy season. In Mvomero and Lushoto districts, zero-grazing systems with improved dairy breeds make up 5% and 24% of production respectively and represent more “commercial rural production for urban consumption systems (R-to-U)” (ILRI, 2014a).

The study area covered the villages piloted by the project “More milk by and for the poor: Adapting dairy market hubs for pro-poor smallholder value chains in Tanzania (More Milk in Tanzania). In the context of the project, a dairy market hub is a connection point for all agents in a dairy value chain; and it is formed by creating mutually beneficial business linkages between a group of farmers and dairy value chain actors. The linkages should ease farmers’ access to inputs and output markets to increased milk supply. The project aimed to achieve inclusive growth, reduced poverty and vulnerability among people with dairy-dependent livelihoods in the selected rural areas in Tanzania. The project was primarily targeted at pre-commercial, marginalized smallholder cattle-keeping men and women who do not currently participate fully in dairy value chains. For this purpose, 30 milk producers’ organisations (POs) were established and monitored in the 30 randomly selected villages (one PO per village) in order to help the farmers to better access dairy inputs, outputs markets, and other embedded services (ILRI, 2014b).

The pro-poor approach that was central to the project is a departure from most development efforts to date in Tanzanian dairy. Following a national dairy sector situation study, sites that show potential for the pro-poor approach were screened through GIS-based spatial mapping of various socio-economic and bio-physical data, followed by consultation with stakeholders. The GIS-based spatial mapping mainly relied on the following data: socio-economic data (human population and poverty, market access and consumption), livestock density and livestock production systems. Other criteria also mapped and considered were: biomass use / feed requirements, production (represented by bovine milk production and surplus – deficit areas), spatial distribution of bovine nitrogen excretion, distribution of bovine CO_2 emissions, length of pasture and crop growing period, and relevant trends (projections of consumption of different animal products, feed surplus / deficits, and growth in livestock numbers) (ILRI, 2014b).

The following districts were selected since they have the potential for the pro-poor approach: Kilosa and Handeni districts that represent mostly pre-commercial rural production for rural consumption; and Mvomero and Lushoto districts that represent relatively more commercial rural production for urban consumption. Urban consumption centres have been defined as those markets with over 50 000 inhabitants (ILRI, 2014b). The study districts with their respective milk production systems are shown in Fig. 11.



Key:
R-to-R = Rural production milk sales mostly to rural consumers (pre-commercial)
R-to-U = Rural production milk sales mostly to urban consumers (more commercial)

Figure 11: Livestock farming systems in Morogoro and Tanga Region

Source: ILRI (2014a)

3.2 Sampling Procedures and Sample Size

3.2.1 Selection of household

The households were randomly selected from the intervention villages of the project More Milk in Tanzania in Kilosa and Mvomero districts of Morogoro Region and Handeni and Lushoto districts of Tanga Region. District (Handeni, Kilosa, Lushoto and Mvomero) and Hub Type (chilling plant / milk trader) were used as the two main stratification factors to ensure sufficient households in each District x Hub Type combination. Therefore, 8 'types' of households, plus cattle-keeping households in non-project villages were obtained (Appendix 1).

The project evaluated and compared changes in indicators according to the level of participation of households in the hub, in terms of: sales of milk to the hub, access of inputs and services from the hub and membership of producers' organisations (PO). At the start of the project, milk sales to hub and access of inputs and services from the hub were zero as an initial project activity is creation of the hub. However, producers' organisations (PO) were already in existence in some project villages and hence this is the only factor which was used to stratify the sample. In stratifying by PO membership we ensure sufficient and equal (most efficient) replication to enable comparisons of indicators for members versus non-members of POs is ensured. To provide the counter-factual group of households who have no access or opportunity to participate in the project, non-project villages have been identified and were included in the survey. There was one 'control' village representing each district.

The sample size was calculated using More Milk in Tanzania project (MoreMilkIT) baseline survey data as detailed in ILRI (2014a). Key variable to be considered was the gross margin from dairy per household per year (USD). The following formula was used to calculate sample size per household type:

$$N = 2 \times \frac{\left(Z_{\frac{\alpha}{2}} + Z_{\beta}\right)^2 \delta^2}{d^2} \qquad \text{Equation 1}$$

Where: n (sample size per type of household) = 5, $Z_{\alpha/2}$ (number of units of standard deviation at significance level α) = 1.96, Z_{β} (number of units of standard deviation related to a desired power) = 0.84, σ (A priori estimate of population standard deviation of gross margin per household per year) = USD 874.71/year and d = (change / difference in gross margin from mean from current) = USD 1600/ year. The sample was adjusted using the Equation 2:

$$DEFF = 1 + \delta\,(n-1) = 1.1;\ \text{adjusted } n = \text{Unadjusted } n \times Deff = 6 \qquad \text{Equation 2}$$

Where; DEFF (Design effect) = 1.1, δ (Intra-class correlation for the statistic in question) = 0,099 and n (Average size of the cluster) = 2.

A sample size of 461 households cattle farmers' households were randomly selected in four districts (154, 105, 98 and 104 households in Lushoto, Handeni, Mvomero and Kilosa districts respectively). The households were randomly selected from 30 project villages and 4 non project villages in the selected districts. Within each district, a stratified random sampling (based on farmer group membership) was used to ensure we minimum number households of group members is obtained. The household lists for all villages were combined into one list of group members and one of non-members of group. Finally, the required number of households was randomly selected from each list. Among the selected households, 158 were members of the project POs while 303 were not member of the project POs. The number of farm households per type of village is presented in Table 1.

Table 1: Number of farm household per village type

District	Village type		Group membership			Total number of cattle
	Village type	**Number of villages**	**Group members**	**Non-group members**	**Total households**	
Lushoto	Project villages	8	47	87	134	1 326
	Non-project village	1		20	20	
Lushoto Total		9	47	107	154	1 326
Handeni	Project villages	8	41	46	87	1 343
	Non-project village	1		18	18	
Handeni Total		9		64	105	1 343
Mvomero	Project villages	7	39	39	78	3 424
	Non-project village	1		20	20	
Mvomero Total		8		59	98	3 424
Kilosa	Project villages	7	31	53	84	538
	Non-project village	1		20	20	
Kilosa Total		**8**		**73**	**104**	**538**
Overall Total		**34**	**158**	**303**	**461**	**6 631**

Although the study targeted a sample of 461 households, only 431 households participated. The rest of the households did not respond. According to milk market channel, the households that participated include 191 and 240 households in rural production to rural consumption (R-to-R) and rural production to urban consumption (R-to-U) systems, respectively; while according to the number of graded breeds, the farms include 275 traditional cattle farms and 156 smallholder dairy farms in order to know whether dairy systems which have been promoted through milk production intensification are more sustainable than traditional systems. Some households moved between levels of a factor during the period between the households' recruitment and survey. For example, households might join or leave a PO. Indeed, some farmers in non-project villages participated in other organizations while others (28 respondents) did not provide information about PO membership during the data collection period. Among the 423 households of which the PO-membership status was known, 181 households were members of POs while 242 households were not members of any PO. Among the household members of POs, 136 households were members of the project POs.

3.2.2 Selection of the respondents for the Delphi survey

The study used the Delphi approach to identify relevant indicators for assessing sustainability in the study context. The Delphi approach is used to generate the most reliable agreement on a subjective topic by extracting and integrating a group of opinions from different individuals through a series of questionnaires with controlled feedbacks (Linstone and Turoff, 2002). The Delphi approach was preceded by selection of key respondents from the study area. Unlike in household surveys, there is no conventional sample size for the Delphi technique. Okoli and Pawlowski (2004) suggest that 10-18 respondents are necessary for credible results. This study used a sample of 44 respondents. In each sector of respondents, a list of potential candidates for the Delphi survey was developed, then the respondents were randomly selected from the list. The respondents were selected based on their background and experience in dairy sector, their availability and willingness to participate in the survey and provide information when needed. The respondents included academic experts from Sokoine University of Agriculture (SUA) in all departments dealing with the dairy production; researchers from Tanzania Livestock Research Institute (TALIRI-Tanga); Livestock extension officers at Ward, District, Regional and Ministry levels in the study area; NGO workers (Heifer International and FAIDA-Mali); farmers (Extensive, semi-intensive and intensive systems); farmer trainers from Livestock Training Agencies (LITA Buhuri, Morogoro and Dar es Salam).

3.3 Data Collection

The data were collected at three levels in order to achieve the study objectives. The levels are namely the expert and stakeholder level, household level and PO level.

3.4 Data Collection at Experts Level

To address the first objective "Establish relevant indicators for assessing sustainability of smallholder dairy and traditional cattle milk producer farms in the selected areas of Tanzania", literature review and consultation with experts and stakeholders, including the local farmers in each selected district and system, using the Delphi approach were used as presented in Fig. 12.

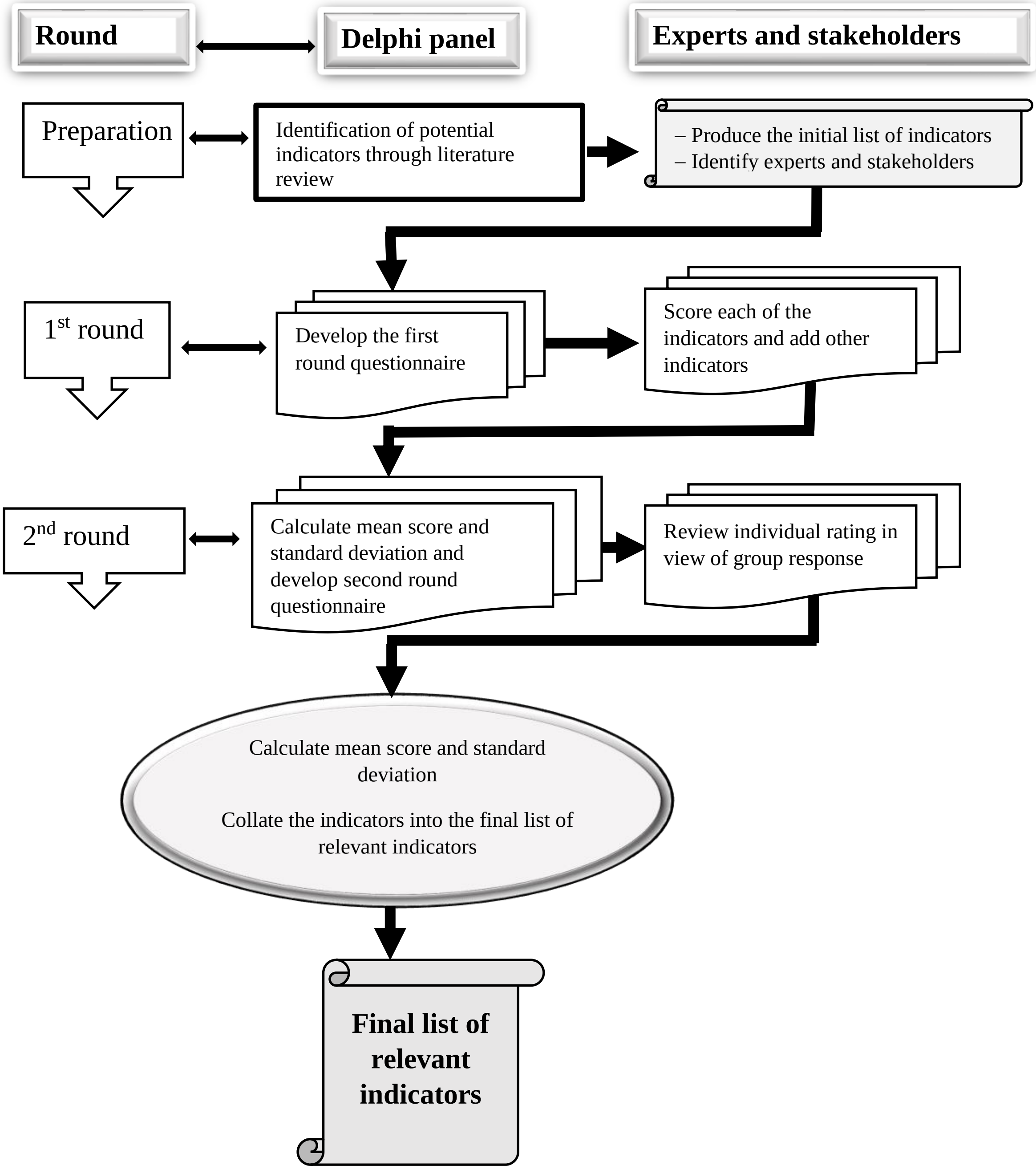


Figure 12: A two Round Delphi Survey Technique

Source: Adapted from Harmsen *et al*. (2015)

3.4.1 Selection of initial set of indicators

An initial list of sustainability indicators was developed through literature review and discussion with experts. Literature review was conducted to identify the key attributes within economic, social and environmental dimensions of sustainability, an attribute being a feature that can influence negatively (constraints) or positively (opportunities) each aspect of sustainability (van Calker *et al.,* 2005). Then, measurable indicators were identified for each attribute. The literature review was coupled with discussions with 15 individual experts, mostly academic personnel, on the identified attributes and indicators, whereby they proposed additional attributes and indicators. The exercise generated a long list of indicators which were termed as “initial set”. Then, a two round Delphi approach with key experts and stakeholders from the study area was used to identify relevant indicators for assessing sustainability.

3.4.2 Delphi survey

The Delphi survey was conducted in two rounds, each with a specific questionnaire. The first round questionnaire was developed based on the initial set of indicators. The questionnaire included two types of questions namely close-ended questions and open-ended questions (Appendix 2): (1) in close-ended questions where the respondent was requested to score the indicators in the “initial set” according to their relevance using 5-point Likert scale (1 = indicator is not important and 5 = indicator is highly important); (2) in open-ended questions the respondent was requested to add other indicators he / she thought were relevant and score them using the same scale as in the first set of questions. Thereafter, the first round questionnaire was pre-tested and refined. During the first round survey, the respondents were consulted to judge the relevance of all possible indicators through the pre-tested questionnaire. After filling and returning the first round questionnaires, the “initial set” and added indicators were compiled; thereafter, the mean and standard deviation scores were calculated for each indicator. Indicators which did not meet the criteria of a “good indicator” such as measurability, as previously defined were excluded from the list, while indicators with similar meanings were merged. The first round survey yielded a long list of all possible indicators applicable in the study area, which was used for the subsequent second round.

The second round aimed to confirm the responses from the first round in order to get a consensus. An individual questionnaire was constructed for each respondent who participated in the first round (Appendix 3). Each questionnaire for the second round included the results from the first round (the individual, group mean and standard deviation scores). The respondents were requested to reassign the scores to all the indicators according to their relevance using the same scale as in the first round. After collecting the filled questionnaires, the mean and standard deviation scores were calculated. The standard deviation was used to measure the consensus. Thus, the survey was terminated as there was at least reasonable consensus (standard deviation score of each indicator $\leq$ 1.49) on the relevance of all indicators as described by Henning and Jordaan (2016). The cut-off point was chosen in order to have a reasonable number of indicators. The threshold score was subjectively set at 4 in order to have a reasonable number of relevant indicators. The indicators which scored more than 4 points were accepted.

3.5 Data Collection at Farm Level

The indicators and indices were calculated using both primary and secondary data. The primary data were collected through a survey at the household level using a pre-tested structured questionnaire administered by the researcher (Fig. 13 and Appendix 4). The primary data consisted of socio-economic and environmental data. Secondary data were collected to complement primary data in order to calculate sustainability indicators and indices. Secondary data mostly consisted of the data on women’s empowerment indicator collected from a survey conducted by the International Livestock Research Institute (ILRI) project and the reference values from the literature, particularly for risk to water quality indicator.

Figure 13: Interview with typical smallholder farmer in Lushoto District, 2016

3.6 Data Collection at PO Level

The data at PO level were collected through interview with PO key informants and consultation of important PO documents using Producers' organizations sustainability assessment tool (POSA). The necessary PO documents were, for example, PO organogram / structure, copies of strategic plans, business plans, annual operating plans and / or other documents related to vision, mission and plan of activities, policy documents, PO constitution / bylaws, documents relating to key dairy production, services and inputs access and market access strategies, plans and projected sustainability performance (breeding, feed, animal health, milk quality, other), up to date progress records/ reports and previous assessment reports.

3.7 Data Analysis

3.7.1 Procedure for sustainability assessment

The study focused on developing and testing a milk production sustainability assessment tool. The tool was developed using guidelines of OECD (OECD, 2008) for constructing a composite indicator and tested it on milk production farms in the study area. Five main stages were as follows (Fig. 14): 1. Selection of relevant indicators, 2. Measurement of indicators, 3. Normalization of indicators, 4. Aggregation of indicators into sustainability indices and 5. Testing the developed tool.

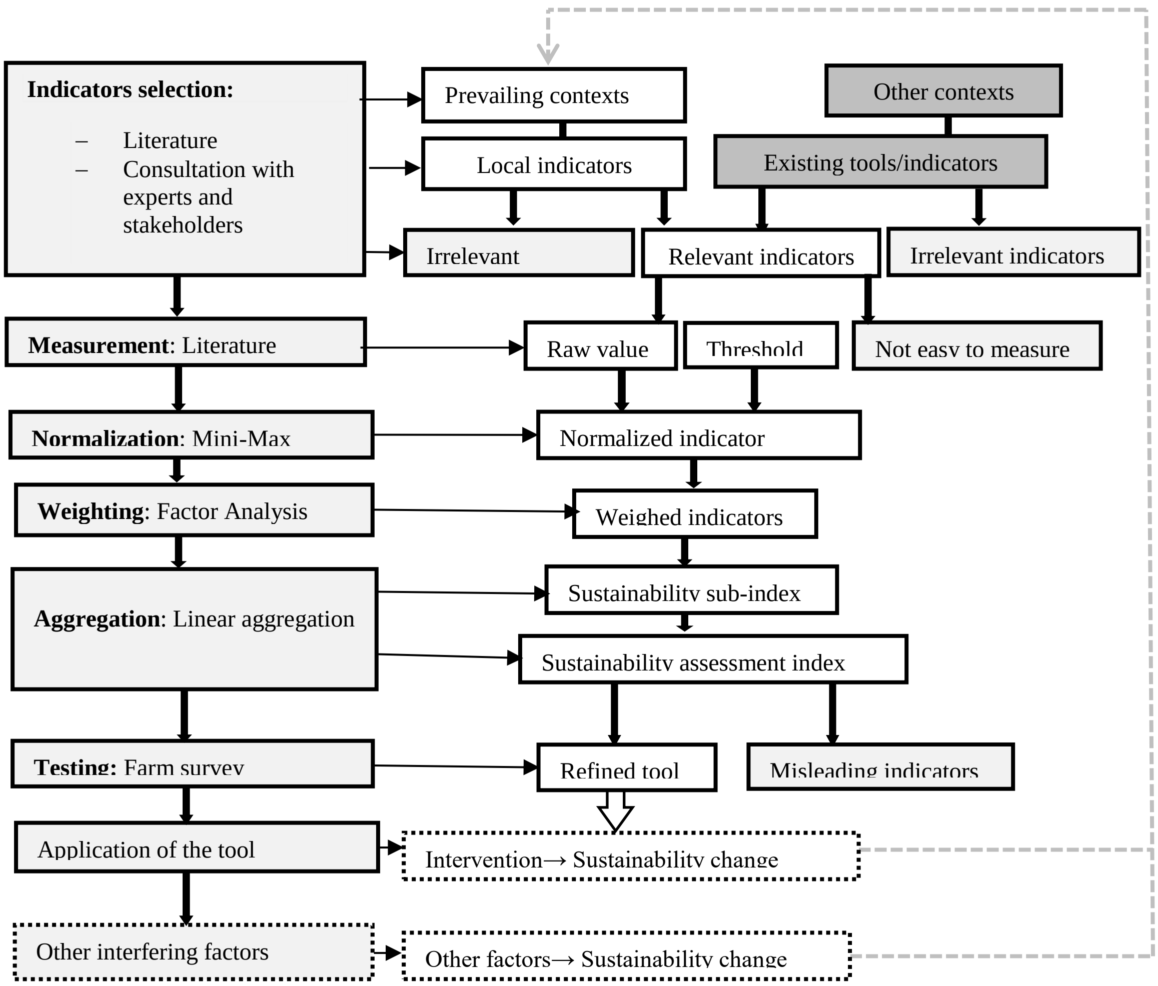


Figure 14: Framework for milk production farm sustainability assessment

Source: Adapted from Gómez-Limón and Sanchez-Fernandez (2010); Vitunskiene and Dabkiene (2016)

3.7.1.1. Rationale for indicators selection

A set of relevant indicators was derived from literature review, and consultation with experts and stakeholders using the Delphi technique. The relevant indicators previously obtained through the Delphi technique (the first objective) were thoroughly screened so as to remain with 15 that satisfy the main criteria of a good indicator, namely, easy to implement, relevant for end user, comprehensibility and data availability as described by Parent *et al.* (2010). The selected indicators and their respective attributes are shown in Table 2.

Table 2: Selected indicators for assessing sustainability of milk production farms in Tanzania

Dimension	Attribute/Issue	Measurable Indicator
Economic	Profitability	1. Income per litre of milk
	Productivity	2. Cow productivity 3. Labour productivity
	Feed availability	4. Feed conservation
	Animal health	5. Animal diseases control (Vaccination and parasite control)
	Animal genetics	6. Breeding system
	Forage self-sufficiency	*7.* Forage self-sufficiency
Social	Knowledge	1. Participation in farmer trainings 2. Education level of the farm manager
	Farmers' organization	3. Participation in organizations
	Gender equality	4. Women's empowerment
Environment	Land ownership	1. Land ownership
	Water quantity	2. Access to water
	Water quality	3. Distance between manure disposal and water source/way
	Land degradation	4. Erosion control

(a) Economic indicators

Income from milk was used to assess profitability as it ought to be among the major farm outputs in the studied systems. The income should be generated efficiently through better use of factors of production. Therefore, two indicators, "**labour productivity**" and "cow productivity", were used to determine the farm productivity. Use of **artificial insemination technology** was used as economic indicator since it is among the most effective way for upgrading the genetics of predominant indigenous cattle in the study area, thus, increased **cow productivity**. Sustainable increase in milk production through improved genetics cannot be made possible without feed being available the whole year round and at low cost. Therefore, "**feed conservation**" and "**forage self-sufficiency**" indicators were used to assess the seasonal feed fluctuation and dependence on external forage supply. **Animal health** was used as economic indicator, due to the economic loss that it could create if animals suffered ill-health.

(b) Social indicators

Farmers need knowledge and skills for a good management of farm activities. The farmer could get this knowledge through formal or informal education and training. Hence, two indicators "**participation in training**" and "**education level**" were used to assess knowledge acquisition. "**Participation in organizations**" was selected as it allows the farmers to have a bargaining power, which enable them to easily get input and services, especially in the case of the remote area. In the study area, women are among the main actors of dairy value chain. However, they do not have enough access to the main resources and decision making over use of income. This situation made "**women's empowerment**" an important social indicator.

(c) Environmental indicators

Livestock keeping activity is land demanding. Therefore, **land ownership** was used as a relevant indicator. Milk production farming could have negative impact on soil, including soil erosion. We used "**erosion control**" as a relevant indicator. **Availability of water was** used as crucial environmental indicator as farming is not possible without available water the whole year. On the other hand, the cattle can contaminate water by manure, especially when the manure is stored near the water way. Therefore, the **distance between manure store and water way** was used as proxy for assessing water quality.

3.7.1.2 Framework for measuring indicators

The most relevant indicators were assigned respective measurements. The measurements were designed considering their data availability and cost as suggested by Parent *et al.* (2010). Some indicators were measured directly while others were measured indirectly using a proxy or an adapted index. Moreover, some indicators were measured using the existing indices which were adapted to the study context. The indicators whose data were difficult to obtain were removed and eventually remain with 15 indicators instead of 29 previously selected (the first objective).

(a) Economic indicators

Income from milk production was measured through gross margin (GM) per litre of milk (l) as a proxy. The gross income was calculated by deducting the variable costs (VC) related to milk production from the milk revenues (MR) over the quantity of milk (QM) during the study period. The main variable costs in the studied systems include feed, labour, drugs and vet service cost:

$$Gross\ Margin\ per\ litre\ of\ milk\ (Tsh/l) = \frac{\sum(MR-VC)}{QM} \qquad \text{Equation 3}$$

Where, QM (l) = Sum of all quantity of milk produced; MR (TZS) =$\sum$ QM $\times$ milk price; VC=$\sum$ Variable costs (Cost of feed, labour, drugs and cost ofvet service)

Cow productivity was calculated by dividing the average quantity of milk produced per day (QM/d) by the average number of milking cows over one year (NC):

$$Cow\ productivity\ (l/cow/day) = \frac{QM/Study\ period}{NC} \qquad \text{Equation 4}$$

Labour productivity was computed by dividing the average quantity of milk produced per day (QM/d) by the number of mandays used in adult equivalent. The labour includes the hired and family labour:

$$Labour\ productivity\ (l/day/manday) = \frac{QM/Study\ period}{Mandays} \qquad \text{Equation 5}$$

Forage self-sufficiency was determined on the basis of the ratio of the total quantity of forage produced by the farmer (FP) to the total quantity of forage used (FU) by the farmer in dry matter. The quantity in dry mater was obtained using feed conversion table specific to the local feedstuffs by Doto *et al.* (2004):

$$Forage\ self-sufficiency\ (\%) = \frac{FP_1+FP_2+\cdots+FP_n}{FU_1+FU_2+\cdots+FU_n} \qquad \text{Equation 6}$$

Where, FP: forage produced by the farmer, FU: forage used and $_{1,\ 2 \ldots n}$ refer to forage type

Feed conservation: a value 1 was assigned when feed conservation practice was used; and when it is not used a value 0 was assigned.

Animal health was measured using animal health control as proxy variables. The variables considered are control of parasites (external and internal) and control of diseases (vaccination). A value 1 was assigned if the practice was used while a value 0 was assigned if the practice was not used. The overall score was computed by the average of the three practice scores:

$$Farm\ disease\ control = \frac{X_1+X_2+X_3}{3} \qquad \text{Equation 7}$$

Where;

X_1=Vaccination,

X_2=deworming and

X_3=Spraying/dipping and for each X_i, 1=Yes, 0=No

Breeding system was captured by the use of technology of artificial insemination. A value 1 was attributed to the farm which uses artificial insemination while 0 was assigned to the farm which did not use artificial insemination as suggested by Mohamed and Temu (2008).

(b) Social indicators

Education level was determined by the number of years of formal education of the farm manager.

Participation in training was captured by assigning a value 1 if the household has a family member who attended training at least once while those who have not attend one were assigned a value 0.

For **Participation in organizations, a** value 1 was assigned to the farm where the farm manager is a member of an organization and 0 was assigned to the farm where the farm manager is not a member of any organization.

Women's empowerment was examined by constructing an index adapted from Alkire *et al.* (2013) and Chand (2011), which focus on six components:

1) Ownership of resources;
2) Decision making over income and expenditures;
3) Time allocation;
4) Participation in trainings;
5) Access to information;
6) Participation in organizations

The women's empowerment indicator was computed by the mean average of all components scorers by adapting procedure by Chand (2011) and Yasmin and Ikemoto (2015):

$$Women's\ empowerment = \frac{X_1+X_2+X_3+X_4+X_5+X_6}{Cn} \qquad \text{Equation 8}$$

Where;

X_1= Ownership of resources,
X_2= decision making over income and expenditures,
X_3= time allocation
X_4= participation in training,
X_5=access to information,
X_6= participation in organizations and
C_n= number of components.

Each component was quantified as follows:

- ***Ownership of resources***: It was computed by averaging land ownership, cattle ownership and access to credit. Where, access to credit was determined by giving a value 1 if the woman has access to credit and a value 0 if the woman did not have access to credit. Livestock ownership and land ownership was calculated by the ratio of quantity of item owned by the women either alone or jointly to all respective quantity of items owned by the household.
- ***Decision making over income and expenditures*** was determined by four sub-components: decision in using income from livestock and crops, and decision making in major and minor expenditure. Decision making was measured by giving a value 1 if the women decide alone, 0.5 if women decide conjointly with men and 0 if they are not consulted in the decision making. The overall decision was measured by the average for the four sub-components.
- ***Time allocation productive and domestic workload:*** a value 1 was assigned if a woman worked less than 10.5 hours the day before the survey, and 0 value was

assigned if a woman worked more than 10.5 hours as suggested by Alkire *et al*. (2013).

- ***Participation in trainings*** was captured by assigning a value 1 if at least one woman member of household has attended at least one training and 0 value if no woman has not attended any training.
- ***Access to information:*** a value 1 was assigned if the woman had access to livestock information and a value 0 was assigned to those without access to information.
- ***Participation in organizations:*** A value 1 was assigned to the farm of which at least one woman is a member of any organization and 0 was assigned to the farm where there is no woman participating in organizations.

(c) Environmental indicators

Soil erosion control was captured by assigning a value 1 if the farmer used erosion control method and a value 0 when he/she did not use.

Water availability: a value 1 was assigned to a farm with access to water throughout the year and 0 was assigned to a farm that experienced a shortage of water at least once.

Water quality was determined using the distance between manure storage and water way as proxy for quality.

Land ownership was measured by attributing a value 1 if the household owned a land with title and a value 0 was assigned to the farms without land or with land without title.

3.7.1.2 Normalization of indicators

The normalization of indicators aimed at generating dimensionless indicators to enable their aggregation into sub-indices and an overall index. Mini-max procedure was used as described by the OECD (2008). The approach consists of subtracting the minimum value from the observed value, and dividing by the difference between the maximum and minimum values. Minimum and maximum thresholds were either obtained from the literature, computed from the sample, or assigned by experts depending on the availability of information. For the thresholds computed from the sample, the maximum was the average of the top 10% highest value while the minimum was the average of the lowest 10% as suggested by Chand *et al.* (2015). For indicators with positive association with sustainability, the following formula was used:

$$I_{ij} = \frac{X_{ij} - MinX_{ij}}{MaxX_{ij} - MinX_{ij}} \quad \text{Equation 9}$$

Where;

I_{ij} = Normalized value of the indicator;

X_{ij}= Actual value of the indicator I in sub-Index j;

$MinX_{ij}$ = The minimum (lowest) value of the indicator X_{ij};

Max = the maximum (highest) value of the indicatorX_{ij}.

For the indicators which have negative association with sustainability, the formula (1- I_{ij}) was used. The Table 3 shows the reference values for the selected indicators.

Table 3: Reference values for the selected indicators

Dimension	Selected indicator	Reference values
Economic	1. Income per litre of milk	Min: Average of the 10% lowest values Max: Average of the 10% highest values
	2. Cow productivity	Min: Average of the 10% lowest values Max: Average of the 10% highest values
	3. Labour productivity	Min: Average of the 10% lowest values Max: Average of the 10% highest values
	4. Forage self sufficiency	Min=0 Max=1
	5. Animal genetics	Min=0 Max=1
	6. Feed conservation	Min=0 Max=1
	7. Animal health	Min=0 Max=1
Social	1. Participation in farmer trainings	Min=0 Max=1
	2. Education level of the farm manager	Min=0 Max=7
	3. Participation in organizations	Min=0 Max=1
	4. Women's empowerment	Max=1 Min=0
Environment	1. Land ownership	Min=0 Max=1
	2. Water availability	Min=0 Max=1
	3. Distance between manure disposal and water /way	Min=0m Max=10m
	4. Erosion control	Min=0 Max=1

3.7.1.3 Weighting and aggregation of indicators into sustainability indices

The normalized indicators were aggregated into sub-indices (Economic, social and environmental sub-indices), and the sub-indices were aggregated into one overall sustainability index (SI). The individual indicators were assigned weights using Factor Analysis as suggested by (OECD, 2008). In fact, the individual indicators with the highest factor loading were grouped into intermediate composites and were aggregated by attributing a weight of each equals the proportion of explained variance in the data set (Appendix 5). The economic, social and environmental dimensions were assigned equal weight (1/3) by assuming that the sustainability dimensions are equally important as suggested by Meul *et al.* (2008). The weight for each indicator according to the results from factor analysis is given in Table 4.

Table 4: Weight of sustainability indicators

Dimension	Weight	Indicator	Weight
Economic	1/3	1. Income from milk production	0.13
		2. Cow productivity	0.31
		3. Labour productivity	0.11
		4. Percentage of grown fodder	0.16
		5. Animal health	0.11
		6. Use of artificial insemination technology	0.03
		7. Feed conservation program	0.15
Social	1/3	1. Education level	0.14
		2. Participation in trainings	0.35
		3. Participation in farmers' organizations	0.37
		4. Women's empowerment	0.14
Environment	1/3	1. Erosion control	0.01
		2. Distance between manure storage/disposal and the	0.43
		water way	0.18
		3. Water availability through the year 4. Land ownership	0.38

The linear aggregation was used to consolidate individual indicators into respective sub-indices and the overall index. The aggregation was performed as follows:

– $\text{Sub-Index}_j = \sum_{j=1}^{n} W_{ij} I_{ij}$ and Equation 10

For i=1, 2, 3…..n; j=1, 2 and 3

– $\text{SI} = \sum_{j=1}^{n=3} 0.33\,\text{Sub} - \text{Index}_j$. Equation 11

Where;

Sub-Index_j: sustainability sub-index for dimension j (1=economic, 2=social and 3=environmental Sub-Index);

I_{ij} Normalized value of indicator I in sub-index j;

W_{ij} denotes the weight of the indicator i for the sub index j and with $\sum_{=j}^{n} W_j = 1$;

SI= overall sustainability index.

3.7.1.4 Test of the developed sustainability assessment tool

The tool was tested on 431 households sampled in the study area. The farms were classified according to milk marketing channel and the number of graded cattle. The sustainability performance indicator and index scores were ranked from 0 to 1 and grouped into three categories of sustainability indicator / index scores namely weak (< 0.33), medium ($0.33 \leq$ and < 0.66) and high (≥ 0.66) as suggested by Vitunskiene and Dabkiene (2016).

3.7.2 Framework for assessing farm sustainability

The framework for assessing sustainability was developed based on the most relevant and representative set of indicators, out of the set of the indicators generated by the consultation with experts and stakeholders. The most relevant indicators were selected based on the criteria of an ideal indicator namely practicality (easy to implement and comprehensible immediately) and usefulness (adapted to the objectives and relevant for users) as suggested by Parent *et al.* (2010). The indicators which are difficult to measure at farm level, expensive in terms of their measurability or whose data are difficult to get were dropped out. The set of indicators was checked for parsimony: selected indicators are not redundant and are few in number to ensure readability and manageability as proposed by Bossel (1999) and Binder (2010). Indeed, the sustainability indicators were narrowed down in order to perform a rapid sustainability assessment (RSA) as suggested by Marchand *et al.* (2014). The RSA suggests that the data for calculating the selected indicators are easily available at low cost. Therefore, the indicators which are difficult to measure and / or of which the data are difficult to obtain or time consuming were withdrawn from the set of indicators to be used in the framework. More details on how the indicators considered as relevant by experts and stakeholders were narrowed down to have the manageable set and the respective questionnaire on farm data collection are presented in Appendices 6 and 7, respectively.

3.7.3 Assessment of PO sustainability performances

Producers' organization (PO) sustainability assessment was carried out using milk Producers' Organisation Sustainability Assessment tool (POSA). The tool, developed by ILRI and partners within the EADD project (Mutinda *et al.*, 2015; Baltenweck *et al.*, 2016), has six dimensions which cover production and business/marketing aspects. Each dimension is made of basic sub-dimensions and each sub-dimension is also an aggregation of measurable indicators (Table 5).

Table 5: Dimensions and sub-dimensions for producers' organizations sustainability assessment tool (POSA)

PO sustainability performance	
Dimension	**Sub-dimension**
Financial health	Net Profit Margin
	Business units lost
	Liquidity
	Capital structure
Engagement with output buyers	Milk quality
	Market reliability
	Suppliers
Effective and transparent leadership and management	Representation participation
	Effective supervision
	Effective management
Access to dairy production inputs and services	Feed and feeding
	Genetics
	Health
	Extension
	Financial services
Relations with external environment	Partnership actors
	Social responsibility
Member loyalty	Patronage
	Member investment
	Ownership
	Member loyalty programs

Source: adapted from Mutinda *et al.* (2015)

The results for indicator and index scores were ranked from zero to one, where 0 is the lowest performance and 1 is the highest performance. The overall PO sustainability performance scores were categorized into four stages namely stage I (0 - 0.19), stage II (0.2 - 0.39) stage III (0.4 - 0.59) and stage IV (≥ 0.6). The POs at stage I may have an interim board, have not held elections, have no staff, etc. while the POs at stage IV are regarded as on the way to independence (Baltenweck *et al*., 2016). The details on indicators scoring, aggregation, presentation and interpretations are provided in Appendix 8. Fig. 15 shows the PO-members discussing the results of their PO after sustainability assessment exercise.

Figure 15: Farmers discussing the results from PO sustainability assessment in Kilosa District, 2016

3.7.4 Descriptive statistics

Descriptive statistics were computed to determine the means, standard deviations, frequencies and percentages depending on the nature of the data being used for each objective. For the first objective, means and frequencies were used to analyse the respondents' characteristics. In addition, the mean and standard deviation scores for each indicator were computed to analyse the relevance of indicators and measure the consensus between the respondents on the relevance of the indicators, respectively. The indicators were considered relevant if the mean score is equal or above 4 points. The consensus was considered reasonable if the standard deviation score of each of the indicators ≤ 1.49 as described by Henning and Jordaan (2016).

For the second objective, the mean and standard deviation scores were used to describe farm sustainability performances.

For the third objective, means and frequencies were used to understand the producers' organization (PO) characteristics. The mean scores were used to understand farm sustainability performances within PO members and non-PO members. In order to achieve the fourth objective, descriptive statistics were computed using frequencies and means to describe farm socio-economic characteristics.

3.7.5 Comparison of different production systems

The sustainability mean performance scores (indicators, dimensions and sustainability indices) for all dimensions (Economic, social and environmental dimensions) were compared between the farming systems (Rural production to rural consumption and Rural production to urban consumption systems; traditional cattle system and smallholder dairy farms) / PO-member farmers and non-PO-member farmers using two-tailed Student's t-test. The socio-economic characteristics were compared between R-to-R system and R-to-U system using two-tailed Student's t-test and chi-square for the means and proportions respectively. The difference between means / frequencies was considered significant for *p* Value < 0.05.

3.7.6 Relationship between PO and farm sustainability

Correlation analysis was used to establish the relationships between PO and farm sustainability performance indicators and indices. The purpose of the relationships was to understand whether farm and PO sustainability performances vary together. Pearson's correlation coefficient (r) was used to analyse the strength of the relationships. The relationships were grouped into three categories depending on their strengths namely weak ($0 \leq r < 0.3$), moderate ($0.3 \leq r < 0.5$) and strong ($0.5 \leq r \leq 1$). The correlations were considered statistically significant if *p-value* < 0.05.

3.7.7 Determinants of farm sustainability

The double censored Tobit regression model was employed to identify the determinants of farm sustainability. The model was used since the sustainability indices (dependent variable) can vary from 0 to 1. Two analysis were performed: the analysis of the influence of PO dimension performances on farm sustainability and socio-economic determinants of farm sustainability for the third and the fourth objectives, respectively. For each objective, we used four separate Tobit regressions models respectively for the economic, social, environmental and overall sustainability performance indices. Each model in these cases can be expressed as follows (Tobin, 1958):

$y_i^* = \beta X_i + \varepsilon_i$ i=1, 2, 3 ...N,

$$y_i = \begin{cases} y_i^* & 0 < y_i^* \leq 1 \\ 0 & 0 > y_i^* \ or \ \ y_i^* > 1 \end{cases}$$

Where, N is the number of observations, y_i is the dependent variable (economic, social, environmental and overall sustainability indices), x_i is a vector of independent variables, β is a vector of estimable parameters, and ε_i is a normally and independently distributed error term with zero mean and constant variance σ^2 and y_i^* is the latent variable.

The social economic independent variables used in the model are x_1 = CREDIT, x_2 = SEX, x_3 = AGE, x_4 = FARMSIZE, x_5= HERDSIZE, x_6=HHSIZE, x_7=FEEDING, x_8= DISTANCE, x_9=MARITAL. The PO independent variables used in the model are x_1 = FH, x_2 = EOB, x_3 = ET, x_4 = ADPIS, x_5= REE, x_6= ML.

The age of the household head was used as explanatory variable since it is associated with experience and endowment of resources which enable to adopt new technology towards sustainable agriculture (Arellanes and Lee 2003). On the other hand, the more advanced age is associated with lag in new technology implementation (Dabkienė 2015). It was hypothesised that women lag behind in implementing new technology and other sustainable practices compared to men, as they have lower access to information and resources. Landholding is important since the farmers with a large parcel of land may be able to spare a portion for feed cultivation which improve economic sustainability (by the definition used here). A large herd could have negative effect on sustainability especially when the farmer does not have enough land. Household size is crucial in terms of labour availability. Access to credit could influence the adoption of new technology and access to production factors such as inputs and services, especially for the poor farmers who are resource constrained. Grazing could have negative impact on natural resources, low adoption of new technology and social impact like conflicts with crop farmers especially in the case of land scarcity. It was hypothesized that the unmarried, especially widows are marginalized, which could have negative impact on farm sustainability. The independent and dependant variables are described in Table 6.

Table 6: Description and measurement of socio-economic independent and dependent variables

Variables	Description	Measurement	Expected sign
Independent variables			
AGE	Age of household head	Years	+/-
SEX	Gender of household head	Binary variable (Binary:1 = female; 0 = male)	-
FARMSIZE	Size of land owned by household	Acres	+
HERDSIZE	Number of cattle owned by household	Number of heads of cattle	-
MARITAL	Marital status of household head	Binary variable (1 = Married; 0 = Otherwise)	+
HHSIZE	Number of people in a household	Adult equivalent	+
FEEDING	Type of cattle feeding system	Binary variable (1 = Intensive; 0 = Extensive)	+
CREDIT	Household received credit in last 6 months	Binary variable (1 = Yes; 0 = No)	+
DISTANCE	Distance of household from nearest trading centre	Km	-
Dependant variables			
ECONOMIC	The farm is economical viable	Index	N/A
SOCIAL	The farm is socially acceptable	Index	N/A
ENVIRONMENT	The farm is environmental friendly	Index	N/A
OVERALL SUSTAINABILITY	The farm is sustainable	Index	N/A

N/A: Not applicable

For the PO sustainability dimensions, we used all sustainability dimensions at PO as dependant variables. We assumed that all variables would have a positive effect on farm sustainability performance indices. The Description of PO level independent and dependent variables is shown in Table 7.

Table 7: Description and measurement of PO level independent and dependent variables

Independent variable	Description	Expected sign
FH	Financial health	+
EOB	Engagement with output buyers	+
ET	Effective and transparent leadership and management	+
ADPIS	Access to dairy production inputs and services	+
REE	Relations with external environment	+
ML	Member loyalty	+
Dependant variables		
ECONOMIC	The farm is economical viable	N/A
SOCIAL	The farm is socially acceptable	N/A
ENVIRONMENT	The farm is environmental friendly	N/A
OVERALL SUSTAINABILITY	The farm is sustainable	N/A

N/A: Not applicable

For both farm level and PO level studies, two statistics software were used for data analysis depending on the type of analysis. For descriptive statistics, comparison of means and correlations were computed using IBM-SPSS-statistics 20 computer software package. The both social economic determinant of farm sustainability and effect of producers' organization sustainability dimensions on far sustainability performance indices were analysed using Stata software (Stata version 13, Lakeway Drive College, Texas, USA).

CHAPTER FOUR

4.0 RESULTS

4.1 Indicators for Assessing Sustainability of Milk Production Farms in Tanzania

4.1.1 Characteristics of respondents

This study used 44 respondents to develop a more robust set of indicators. The categorical distribution of the respondents is shown in Table 8. The respondents comprised academic experts from Sokoine University of Agriculture (SUA), researchers from Tanzania Livestock Research Institute (TALIRI-Tanga), livestock extension officers at Ward, District, Regional and Ministry levels in the study area, NGO workers (Heifer International and FAIDA-Mali), farmers from the study area (extensive, semi-intensive and intensive systems) and farmer trainers from Livestock Training Agencies (LITA Buhuri, Morogoro and Dar es Salam). The majority of respondents were livestock officers, followed by the academic staff members. One quarter were female. The experience of the respondents was reasonably evenly distributed except the small proportion of respondents that had above 30 years of experience within dairy sector.

Table 8: Categorical distribution of respondents (n=44)

Category	Frequency
Sector	
Academic department staff member	11
LITA instructor and trainer	5
Farmer (extensive, semi-intensive and intensive systems)	8
Government livestock field officers	14
NGO (FAIDA-MALI and Heifer International)	2
Researcher	4
Gender	
Male	32
Female	12
Experience in dairy production (Years)	
Below 10	14
11 to 20	11
21 to30	14
Over 30	5

4.1.2 Sustainability indicators

Results of literature review and discussions with individual experts are summarized in Table 9. The exercise generated a long list of indicators termed "initial set" of 57 indicators which comprised 28 economic, 13 social and 16 environmental indicators.

Table 9: "Initial set" of indicators for assessing sustainability in Morogoro and Tanga Regions

Economic (n=28)	Environmental (n=16)	Social (n=13)
(1) Source of capital [1]	(1) Proportion of manure used [5]	(1) Age of the farm manager [18]
(2) income per litre of milk[2]	(2) Type of floor surface for manure storage [10]	(2) Working time [11]
(3) Benefit-cost ratio [4]	(3) Covering manure store [10]	(3) Off days from work [12]
(4) Cost of milk production [5]	(4) Runoff flowing into the manure storage area [10]	(4) Workload distribution [5]
(5) Capital productivity[5]	(5) Manure storage runoff [10]	(5) Gender equality [13]
(6) Labour productivity [8]	(6) Greenhouse Gas emission [5]	(6) Work sharing [5]
(7) Feed productivity [5]	(7) Livestock stocking density [11]	(7) Participation in farmer' training [17]
(8) Cow productivity [19]	(8) Land ownership[3]	(8) Participation in farmers' organization [13]
(9) Source of feed [11]	(9) Distance from water source/way*	(9) Ownership of the farm *
(10) Source of labour [12]	(10) Animal access to water body*	10) Benefit from farmers' organization*
(11) Access to credit [13]	(11) Soil conservation and erosion*	11) Cattle bandits control*
(12) Off-farm income [11]	(12) Percentage of improved breeds	12) Distance between living house and manure disposal*
(13) Access to milk Markets [13]	(13) Water conservation/ Harvesting*	13) Protection during manure handling*
(14) Keeping written records [14]	(14) Grazing on formally demarcated land*	
(15) Access to input market*	(15) Animal farm/Backyard production*	
(16) Access to milk storage and logistics*	(16) Water Use Efficiency*	
(17) Access to value addition*		
(18) Cost of hired labour*		
(19) Vaccination program [14]		
(20) Prophylactic treatment program [14]		
(21) Prevention measures of entry of disease [14]		
(22) Animal living environment [15]		
(23) Animal-Based welfare [16]		
(24) Education level of the farm manager[11]		
(25) Milk hygiene [11]		
(26) Breeding system[5]		
(27) Percentage of improved breeds in the farm*		
(28) Breeding facilities*		

[1](Van Cauwenbergh *et al*., 2007); [2](Elsaesser *et al*., 2013); [3](Atanga *et al*., 2013); [4](Roy and Chan, 2012); [5](Chand *et al*., 2015); [6](Meul *et al*., 2008); [7](Sauvenier *et al*., 2005); [8](van Der Meulen *et al*., 2013); [9](Slavickiene and Slavickiene, 2014); [10](Rufino *et al*., 2007); [11] (Lebacq *et al*., 2013); [12](Arandia *et al*., 2011); [13](Smith *et al*., 2015); [14](FAO-IDF, 2011); [15](Bekhouche-Guendouz, 2011); [16](Meul *et al.,* 2012); [17](Majewski, 2013);[18](Danttsis *et al*., 2010); [19](van Calker *et al*., 2005); [20](Alkire *et al*., 2013); * Indicators proposed by academic experts.

The Delphi exercise yielded a final set of 29 considered most relevant indicators, which comprised 18 economic, four (4) social and seven (7) environmental indicators. The most relevant indicators were also grouped into 16 attributes which consist of nine (9) economic, three (3) social and four (4) environmental attributes. The response rate was 98.7% for the first round and 88.4 % for the second round. The mode of highest standard deviation score used to measure the consensus decreased from 1.5 for the first round to 1.4 for the second round. The results for the first and second rounds for indicators which scored 4 and above in the second round are presented in Table 10, while the results for all the indicators are presented in Appendix 9.

Table 10: List of accepted indicators for assessing sustainability of milk production farm in Morogoro and Tanga

Aspect	Attribute/Issue (n=16)	Measurable Indicator(n=29)	1st round SD	1st round $\bar{X}$	2nd round SD	2nd round $\bar{X}$
Economic	Profitability	(1) Income per litre of milk	1.0	4.4	0.8	4.5
		(2) Cow productivity	1.0	4.4	0.6	4.6
	Efficiency	(3) Feed productivity	1.2	4.1	0.8	4.3
		(4) Labour productivity	0.9	3.9	0.7	4.0
	Feed availability	(5) Feed conservation*	0.0	5	0.9	4.1
	Access to market	(6) Access to milk market	0.9	4.5	0.6	4.7
		(7) Access to input market	1.2	4.1	0.8	4.3
	Keeping farm record	(8) Farm record keeping	1.2	4.1	1.1	4.3
	Milk quality and safety	(9) Milk hygiene	0.9	4.5	0.5	4.8
	Animal health and welfare	(10) Vaccination as recommended	1.0	4.4	0.8	4.5
		(11) Prophylactic treatment as recommended	0.8	4.3	0.6	4.4
		(12) Prevention measures of entry of disease onto the farm	1.0	4.1	0.8	4.4
		(13) Use of drugs as recommended*	0.9	4.1	0.8	4.2
		(14) Animal living environment condition	0.9	4.1	0.8	4.2
		(15) Availability of vet service*	0.8	4.1	0.7	4.3
	Animal genetics	(16) Breeding system	0.7	4.1	0.8	4.3
	Independence	(17) Source of capital	1.1	3.9	1.0	4.1
		(18) Source of feed	1.1	4.0	1.0	4.1
Social	Knowledge	(1) Participation in farmer training	1.2	3.8	1.0	4.1
		(2) Education level of the farm manager	1.2	3.9	1.0	4.0
	Farmers' organization	(3) Participation in organization	1.1	4.0	0.9	4.0
	Gender equality	(4) Women empowerment	1.0	4.1	0.9	4.1
Environment	Land ownership	(1) Land ownership	1.0	4.3	0.7	4.5
	Water quantity	(2) Water conservation/ Harvesting	1.1	4.3	0.8	4.6
		(3) Access to water*	0.0	5	0.7	4.6
	Water quality	(4) Animal access to water body	1.4	4.0	0.7	4.4
		(5) Distance between manure disposal and water source/way	1.1	4.1	0.8	4.3
	Land degradation	(6) Livestock stocking density	1.5	3.9	1.1	4.1
		(7) Soil conservation and erosion	1.3	4.0	1.3	4.0

*Indicators added by the respondents; Cut-off point: Mean ≥ 4.0; $\bar{X}$: Mean; SD: Standard deviation

The relevance of some indicators was higher than others. For economic aspects, milk hygiene (4.8 points) was the most relevant indicator followed by access to milk markets (4.7 points), cow productivity (4.6 points) and income per litre of milk (4.5 points). For environmental indicators, the most relevant indicators were access to water (4.6 points), water conservation (4.6 points) and land ownership (4.5 points). For social indicators, the most relevant indicators were participation in farmer training (4.1 points), women's empowerment (4.1 points) and education level (4.0 points). However, some indicators like age of the farmer, day-off from work, greenhouse gas emissions, manure management and protection during manure handling among others were scored at very low or zero importance by the respondents.

Results from the second round show that the relevance of some indicators varies among the respondents' categories. The indicators which were considered relevant by at least one group of respondents, per each indicator, were 40. Most of the economic indicators were accepted by all groups of respondents. For social aspects, the farmers accepted more indicators than other groups (six social indicators). The groups of technical personnel (livestock officers and trainers) accepted only women's empowerment and participation in organization as relevant social indicators while the group of academics and researchers accepted education level of the farm manager and participation in farmers' training as relevant. For environment aspects, farmers selected fewer indicators compared to other groups. The accepted indicators according to respondents' categories are presented in Table 11.

Table 11: List of accepted indicators for assessing sustainability of milk production farm in Morogoro and Tanga, according to respondents' groups

Aspect	Indicator (40)	Ac+Re		Farmer		Lo+Tr	
		X̄	SD	X̄	SD	X̄	SD
Economic	(1) Net income per litre of milk	4.4	0.8	4.7	0.8	4.3	1.1
	(2) Capital productivity	4.1	0.9	4.3	0.8	3.9	0.9
	(3) Labour productivity	4.0	0.6	4.0	0.6	4.2	0.8
	(4) Feed productivity	4.1	1.0	4.7	0.5	4.3	0.7
	(5) Cow productivity	4.8	0.6	4.7	0.5	4.7	0.5
	(6) Source of Capital (Own capital/Total capital)	4.2	0.9	3.9	1.3	4.0	1.2
	(7) Source of feed (Feed from own farm/Total feed used)	4.1	1.2	4.1	0.9	3.8	0.9
	(8) Access to input market (Feed, vet drug, etc…)	4.2	0.7	4.9	0.4	4.3	1.0
	(9) Access to milk Markets	4.9	0.4	4.9	0.4	4.3	0.8
	(10) Access to milk storage and logistics	4.0	1.1	4.6	0.8	4.2	0.9
	(11) Access to value addition	4.0	1.0	3.3	1.0	3.7	1.3
	(12) Access to credit (Dairy)	4.1	1.0	4.3	0.5	4.0	1.1
	(13) Proportion of income from off-farm activities	3.9	1.0	4.0	0.6	3.6	1.1
	(14) Having a vaccination programme as recommended	4.3	1.0	4.9	0.4	4.6	0.8
	(15) Prophylactic treatment program in place	4.3	0.8	4.9	0.4	4.4	0.7
	(16) Prevention measures of entry of disease onto the farm	4.3	1.0	4.6	0.5	4.4	0.8
	(17) Animal welfare	3.9	1.0	4.3	0.8	4.5	0.7
	(18) Breeding system (AI/ Natural breeding)	4.1	1.0	4.0	0.6	4.6	0.7
	(19) Conservation of feed during the dry season	4.6	0.7	4.8	0.4	4.2	0.8
	(20) Farm record keeping	4.2	1.0	4.2	1.3	4.3	1.3
	(21) Separation of seek animals in the farm	3.5	0.8	4.4	0.8	3.8	0.5
	(22) Use of drugs as recommended	3.8	1.0	4.6	0.5	4.1	1.0
	(23) Observation of withdrawal period	3.9	1.0	4.4	0.5	3.9	1.1
	(24) Availability of vet service	4.2	0.6	4.4	0.8	4.3	0.9
	(25) Milk hygiene	4.8	0.4	4.6	0.8	4.8	0.6
Social	(1) Education level of the farm manager	4.3	0.8	4.1	0.9	3.3	1.2
	(2) Working time (number of hours/day)	3.9	0.8	4.6	0.8	3.5	1.2
	(3) Workload distribution	3.7	0.9	4.3	1.0	3.6	1.4
	(4) Women's Empowerment index	3.8	1.2	4.4	0.8	4.3	0.8
	(5) Work sharing (Share between male and female)	3.8	1.3	4.4	0.8	3.6	1.2
	(6) Participation in farmer' training	4.3	0.9	4.3	0.8	3.6	1.2
	(7) Participation in farmers organization	3.7	0.9	4.4	0.8	4.0	1.0
Environment	(1) Distance from water source/way	4.2	0.9	4.3	0.8	4.3	0.9
	(2) Animal access to water source (river. pound etc.)	4.5	0.8	4.3	0.8	4.6	0.5
	(3) Livestock stocking density	4.4	0.8	3.6	1.5	4.2	1.1
	(4) Soil conservation and erosion	3.9	1.2	3.3	1.9	4.4	0.8
	(5) Access to water	4.7	0.6	5.0	0.0	4.3	0.7
	(6) Land ownership	4.5	0.7	4.4	0.5	4.4	1.0
	(7) Water conservation/ Harvesting	4.7	0.9	4.3	0.5	4.5	0.9
	(8) Animal farm/Backyard production (Existence of real farm)	4.2	0.8	3.6	1.3	3.7	1.4

Where, X̄: mean score; SD: Standard deviation; Ac: Academic, Re: Researcher, Lo: Livestock officer; Tr: Farmer trainer

4.2 Sustainability Performances of Smallholder Dairy and Traditional Cattle Milk Producer Farms

4.2.1 Sustainability index and sub-indices

Results for the overall sustainability performance index and sub-index scores are summarized in Table 12. The sustainability performance indicator and index scores were ranked from 0 to 1 and grouped into three categories namely weak (< 0.33), medium (0.33 ≤ and < 0.66) and high (≥ 0.66) sustainability indicator / index scores. The overall sustainability mean score shows weak sustainability (0.30±0.15). The social sub-index presented the highest mean score (0.32 ± 0.27), followed by the environmental (0.31 ± 0.22), and the economic was the lowest (0.27 ± 0.20).

The overall sustainability mean score was moderate (0.35 ± 0.16) in R-to-U system and significantly higher ($p < 0.05$) than in R-to-R system which was in non-sustainable range (0.24 ± 0.12). Indeed, the overall sustainability mean score was moderately sustainable in smallholder dairy system and significantly higher ($p < 0.05$) than in traditional cattle keeping system (0.40 ± 0.15 and 0.24 ± 0.12 respectively). All sustainability sub-index mean scores were in the weak range in R-to-R system and moderately sustainable range in R-to-U system. The economic and social mean scores were significantly higher ($p < 0.05$) in R-to-U system than in R-to-R system. The economic, social and environmental sustainability mean scores were in moderate range in smallholder dairy system and significantly higher ($p<0.05$) than in traditional cattle keeping system which was in weak range.

Table 12: Farm sustainability index and sub-index performances

System	Economic		Social		Environment		Overall	
	Mean±SD	N	Mean±SD	N	Mean±SD	N	Mean±SD	N
Milk market channel								
R-to-R	0.15±0.11	191	0.26±0.26	191	0.29±0.23	191	0.24±0.12	191
R-to-U	0.37±0.20	240	0.36±0.27	240	0.33±0.20	240	0.35±0.16	240
Significance	***		***		ns			***
Number of improved cattle								
TCS	0.18±0.13	275	0.26±0.25	275	0.28±0.23	275	0.24±0.12	275
SHD	0.43±0.19	156	0.41±0.28	156	0.37±0.18	156	0.40±0.15	156
Significance	***		***		***			***
Total	0.27±0.20	431	0.32±0.27	431	0.31±0.22	431	0.30±0.15	431

*p < 0.05; **p < 0.01; ***p < 0.001; ns not significant; R-to-R: Rural production to rural consumption (pre-commercial); R-to-U: Rural production to urban consumption (more commercial); TCS: Traditional cattle system; SHD: Smallholder dairy system

4.2.2 Economic indicators

Table 13 shows the results for economic sustainability mean scores in each milk production system. The majority of economic indicators (four out of seven) presented mean scores below 0.33 (weak). Income presented the highest mean score (0.35±0.29), followed by feed conservation (0.34±0.47) while forage self-sufficiency indicator presented the lowest score (0.17±0.37).

Table 13: Economic sustainability performances by milk market channel

System	Income		Cow productivity		Labour productivity		Forage self sufficiency		Animal health		Breeding system		Feed conservation	
	Mean±SD	**N**	**Mean±SD**	**N**	**Mean±SD**	**N**	**Mean±SD**	**N**	**Mean±SD**	**N**	**Mean±SD**	**N**	**Mean±SD**	**N**
Milk market channel														
R-to-R	0.27±0.26	97	0.16±0.14	162	0.21±0.24	191	0.00±0.00	191	0.35±0.30	191	0.15±0.36	191	0.14±0.34	191
R-to-U	0.41±0.30	121	0.41±0.31	155	0.24±0.30	240	0.30±0.45	240	0.32±0.28	240	0.35±0.48	240	0.50±0.50	240
Significance	***		***		ns		***		ns		***		***	
Number of improved cattle														
TCS	0.30±0.28	145	0.18±0.19	230	0.26±0.29	275	0.02±0.15	275	0.35±0.31	275	0.13±0.33	275	0.17±0.38	275
SHD	0.44±0.30	73	0.53±0.28	87	0.17±0.25	156	0.42±0.49	156	0.30±0.26	156	0.50±0.50	156	0.64±0.48	156
Significance	***		***		***		***		ns		***		***	
Total	**0.35±0.29**	**218**	**0.28±0.27**	**317**	**0.23±0.28**	**431**	**0.17±0.37**	**431**	**0.33±0.29**	**431**	**0.26±0.44**	**431**	**0.34±0.47**	**431**

*p < 0.05; **p < 0.01; ***p < 0.001; ns not significant; R-to-R: Rural production to rural consumption (pre-commercial); R-to-U: Rural production to urban consumption (more commercial); TCS: Traditional cattle system; SHD: Smallholder dairy system

Economic performance indicators varied with production systems. More than one half (four) of the economic indicator mean scores were moderate in R-to-U system against one indicator (animal health) in R-to-R system. Indeed, five economic indicator mean scores were moderate in smallholder dairy system while only the animal health mean score was moderate in traditional cattle keeping system. The majority (four of seven) of economic indicator mean scores were significantly higher ($p < 0.05$) in R-to-U system than in R-to-R. Feed conservation, use of artificial insemination, percentage of grown fodder indicator mean scores were more than two times higher in R-to-U system than in R-to-R system. Indeed, the results showed that the farmers in R-to-R system do not use forage from their own farms. Animal health indicator mean score was slightly higher in R-to-R system (0.35±0.30) than R-to-U system (0.32 ± 0.28). Fig. 16 and Fig. 17 show feed conservation in Lushoto and death of calves due do shortage of feed and water during the dry season in Mvomero District respectively.

Figure 16: Feed conservation in Lushoto District

Figure 17: Death of calves due do shortage of feed and water during the dry season in Mvomero District

Five indicators mean scores in smallholder dairy system were significantly higher ($p < 0.05$) than in traditional cattle system. However, labour productivity mean score was significantly higher ($p < 0.05$) in traditional cattle system than in smallholder dairy system (0.26 ± 0.29 and 0.17 ± 0.25, respectively).

4.2.3 Social indicators

Table 14 presents the results for social sustainability performances. The education level, participation in organization and women's empowerment mean scores were moderately sustainable. The participation in farmer groups presented the highest mean score (0.43 ± 0.50), while participation in trainings presented the lowest mean score (0.16 ± 0.36). R-to-U system presented significantly higher ($p < 0.05$) mean scores than R-to-R system for all indicators, except participation in training where the mean score was higher as well, but the difference was not significant ($p > 0.05$). Indeed, all social indicator mean scores were significantly higher ($p < 0.05$) in smallholder dairy system than in traditional cattle system.

Table 14: Social sustainability performances

System	Education level		Participation in trainings		Participation in farmer groups		Women's empowerment	
	Mean±SD	N	Mean±SD	N	Mean±SD	N	Mean±SD	N
Milk market channel								
R-to-R	0.33±0.29	191	0.15±0.35	191	0.33±0.47	185	0.31±0.17	143
R-to-U	0.45±0.27	240	0.17±0.37	240	0.50±0.50	238	0.41±0.18	204
Significance	***		ns		***		***	
Number of improved cattle								
TCS	0.34±0.31	275	0.12±0.33	275	0.36±0.48	267	0.32±0.17	212
SHD	0.51±0.22	156	0.22±0.42	156	0.54±0.50	156	0.45±0.18	135
Significance	***		**		***		***	
Total	**0.40±0.29**	**431**	**0.16±0.36**	**431**	**0.43±0.50**	**423**	**0.37±0.18**	**347**

*p < 0.05; **p < 0.01; ***p < 0.001; ns not significant; R-to-R: Rural production to rural consumption (pre-commercial); R-to-U: Rural production to urban consumption (more commercial); TCS: Traditional cattle system; SHD: Smallholder dairy system

4.2.4 Environmental indicators

The results for environmental performances are presented in Table 15. One half of the indicators presented average scores higher than 0.33 (moderately to highly sustainable).

Availability of water presented the highest mean score (highly sustainable), followed by the distance between manure storage/disposal and water way (moderately sustainable). Land ownership presented the lowest mean score in environmental indicators (weak). Rural Production to Urban consumption (R-to-U) system presented far higher mean score with significant difference ($p < 0.05$) than R-to-R system in erosion control mechanism. Indeed, erosion control, risk to water quality and water quantity indicator mean scores were significantly higher ($p < 0.05$) in smallholder dairy system than in traditional cattle system.

Table 15: Environmental performances

Category	Erosion control		Risk to water quality		Water quantity		Land ownership	
	Mean±SD	**N**	**Mean±SD**	**N**	**Mean±SD**	**N**	**Mean±SD**	**N**
Milk market channel								
R-to-R	0.08±0.29	12	0.61±0.37	9	0.73±0.44	191	0.08±0.27	191
R-to-U	0.49±0.51	49	0.66±0.37	51	0.80±0.40	240	0.05±0.23	240
Significance	**		ns		ns		ns	
Improved cattle								
TCS	0.22±0.42	32	0.49±0.37	29	0.68±0.47	275	0.08±0.27	275
SHD	0.62±0.49	29	0.81±0.29	31	0.92±0.27	156	0.04±0.21	156
Significance	**		***		***		ns	
Total	0.41±0.50	61	0.65±0.36	60	0.77±0.42	431	0.06±0.25	431

*p < 0.05; **p < 0.01; ***p < 0.001; ns not significant; R-to-R: Rural production to rural consumption (pre-commercial); R-to-U: Rural production to urban consumption (more commercial); TCS: Traditional cattle system; SHD: Smallholder dairy system

4.2.5 Framework for assessing farm sustainability in Tanzania

The study generated a framework for assessing sustainability of smallholder dairy and traditional cattle milk production farm in the context of Tanzania. The framework is composed of a set of fifteen most relevant and representative indicators. These indicators were selected out of the 29 identified relevant indicators based mainly on their measurability and data availability. The indicators were grouped in three dimensions: seven indicators for the economic dimension, four indicators for the social dimension and four indicators for the environmental dimension. The economic, social and environmental dimensions are aggregated into the overall farm sustainability index. Fig. 18 illustrates the structure of the framework.

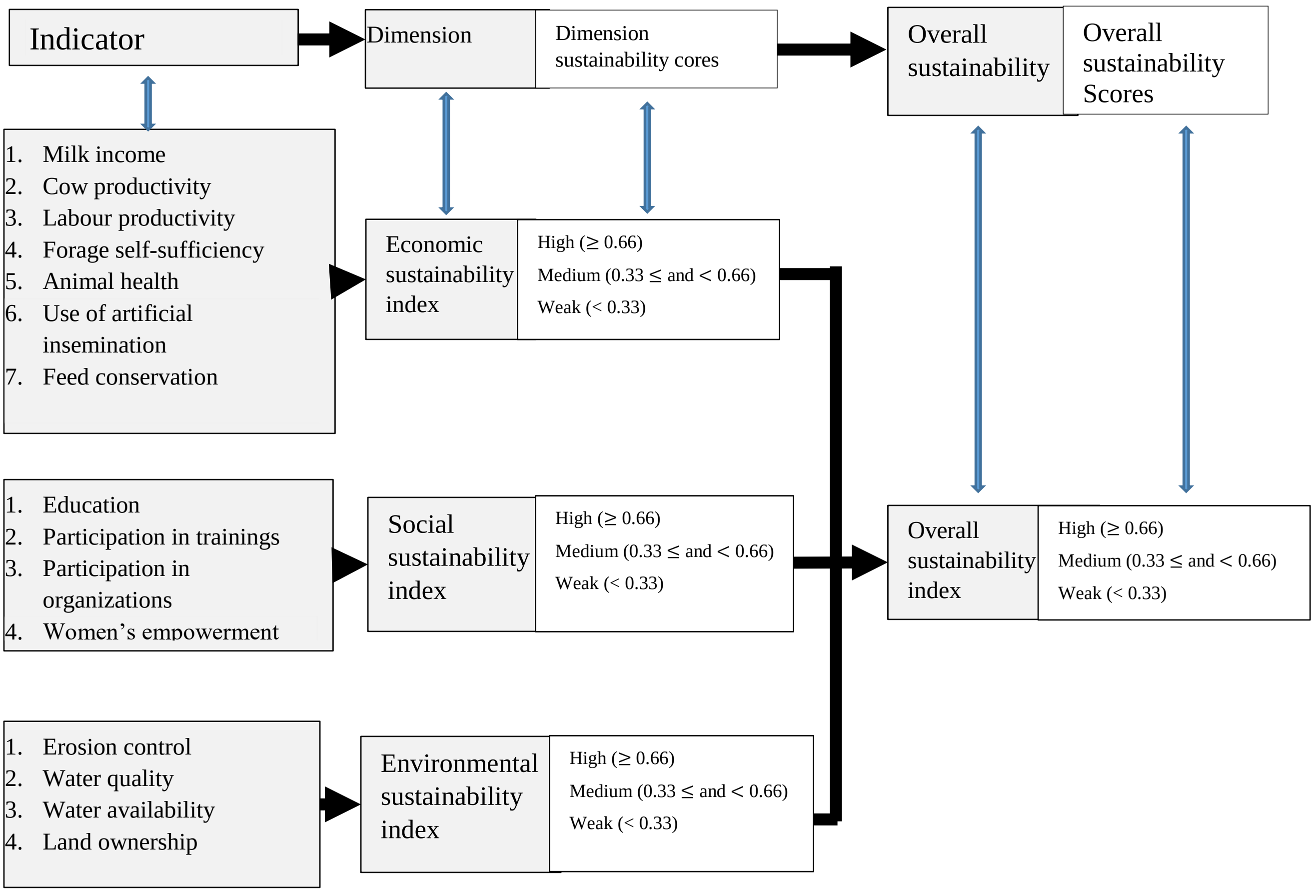


Figure 18: Framework for assessing sustainability of smallholder dairy and traditional cattle milk production systems using a set of 15 indicators

4.3 Relationship between Farm Level Milk Production Sustainability Performances and Producers' Organization Sustainability Dimensions

4.3.1 Farm sustainability performances in PO-Members and non-PO-Members

Table 16 shows farm sustainability performances mean scores in PO-member farmers and non-PO-member farmers. The overall farm sustainability mean performance index score as well as economic and social mean performance dimension scores were significantly ($p < 0.05$) higher in PO-members than in non-PO-members. Similarly, a number of indicators showed significantly higher mean performance scores in PO-member farmers than non-PO-member farmers; these indicators include cow productivity, forage self-sufficiency, use of artificial insemination for the economic dimension; women's empowerment and participation in trainings for social dimension, and erosion control for environmental dimension.

Table 16: Farm sustainability performances in PO-members and non-PO-members (normalized values)

Dimension	Farm indicator	Non-PO-Member		PO-Member		Total	
		N	Mean±SD	N	Mean±SD	N	Mean±SD
Economic	Milk income	106	0.34±0.28	107	0.38±0.30	213	0.36±0.29 ^{ns}
	Cow productivity	179	0.24±0.26	131	0.33±0.29	423	0.28±0.27**
	Labour productivity	242	0.22±0.27	181	0.24±0.29	423	0.23±0.28 ^{ns}
	Forage self-sufficiency	242	0.10±0.30	181	0.26±0.43	423	0.17±0.37***
	Animal health	242	0.32±0.30	181	0.34±0.29	423	0.33±0.29 ^{ns}
	Use of artificial insemination	242	0.22±0.41	181	0.33±0.47	423	0.27±0.44**
	Feed conservation	242	0.35±0.48	181	0.34±0.48	423	0.35±0.48 ^{ns}
	Sub-Total	**242**	**0.25±0.18**	**181**	**0.32±0.21**	**423**	**0.28±0.20*****
Social	Education	242	0.38±0.29	181	0.43±0.28	423	0.40±0.29 ^{ns}
	Participation in trainings	242	0.07±0.25	181	0.29±0.45	423	0.16±0.37***
	Participation in organizations	242	0±0	181	1±0	243	0.43±0.50 ^{NA}
	Women's empowerment	187	0.35±0.19	154	0.40±0.18	341	0.37±0.18*
	Sub-total	**242**	**0.12±0.10**	**181**	**0.59±0.17**	**423**	**0.32±0.27*****
Environment	Erosion control	30	0.27±0.45	29	0.59±0.50	59	0.42±0.50*
	Water quality	27	0.60±0.39	31	0.72±0.32	58	0.66±0.36 ^{ns}
	Water availability	242	0.76±0.43	181	0.79±0.41	423	0.77±0.42 ^{ns}
	Land ownership	242	0.08±0.28	181	0.04±0.21	423	0.07±0.25 ^{ns}
	Sub-total	**242**	**0.31±0.23**	**181**	**0.32±0.20**	**423**	**0.31±0.22** ^{ns}
Overall sustainability		**242**	**0.22±0.11**	**181**	**0.41±0.14**	**423**	**0.30±0.15*****

*p < 0.05; **p < 0.01; ***p < 0.001; ^{ns} not significant; ^{NA} not applicable

4.3.2 PO characteristics

Table 17 shows the PO characteristics. The POs had on average 60 members. POs in Lushoto District had the highest average number of members per PO while Mvomero District had the lowest number of members per PO (90.63 ± 32.82 and 43.29 ± 12.05

members per PO respectively). The proportion of women was 47.54%. The highest proportion of women was observed in Mvomero District POs (54.13%) while the lowest proportion was observed in Lushoto District (44.41%). The average age of POs after registration was two years (2.16 ± 0.78). POs in Mvomero District showed the smallest average age after registration which was less than two years (1.77 ± 0.15) while POs in Lushoto District showed the highest average age after registration (2.44 ± 1.30 years).

Table 17: PO characteristics

Characteristics	District				Total (n=30)
	Lushoto (n=8)	Handeni (n=8)	Kilosa (n=7)	Mvomero (n=7)	
Member per group					
Mean±SD	90.63±32.82	53.38±23.27	50.57±16.47	43.29±12.05	60.30±28.92
Minimum	54	26	36	30	26
Maximum	156	82	77	59	156
Sex					
Proportion of men (%)	55.59	52.93	51.13	45.87	52.46
Proportion of women (%)	44.41	47.07	48.87	54.13	47.54
Age of the PO (years after registration)					
Mean±SD	2.44±1.30	2.15±0.39	2.12±0.61	1.77±0.15	2.16 ±0.78
Minimum	1.73	1.76	1.61	1.62	1.61
Maximum	5.64	3.01	3.38	1.98	5.64

4.3.3 Producers' organization sustainability performances

PO sustainability means performances scores are shown in Table 18. The overall PO sustainability mean performance index score was 0.22 ± 0.17. The relations with external environment dimension of PO had the highest mean performance score (0.46±0.41) of all the dimensions, followed by member loyalty (0.33 ± 0.21) and "effective and transparent leadership and management" (0.29 ± 0.17) dimensions while the engagement with outputs buyers and the financial health dimension had the lowest mean scores (0.06 ± 0.21 and 0.13 ± 0.26 respectively). The member investment and partnership with actors PO sustainability performance sub-dimension had the highest mean score (0.55 ± 0.55 and 0.53 ± 0.51 respectively), while all sub-dimensions for the engagement with outputs buyers and profit (number of business units lost) sub-dimensions for financial health had the lowest mean scores (< 0.1). Lushoto District had the best overall sustainability mean performance index score (0.41 ± 0.18), followed by Handeni District (0.20 ± 0.10) whereas Mvomero District (0.10 ± 0.05) had the worst followed by Kilosa District (0.20 ± 0.12). Lushoto District had the highest mean score for financial health performance dimension (0.20 ± 0.37) whereas Mvomero and Handeni districts had the worst mean scores (0).

Table 18: PO sustainability performances (scores)

PO sustainability performance		District									
Dimension	Sub-dimension	Handeni (n=8)		Kilosa (n=7)		Lushoto (n=8)		Mvomero (n=7)		Total (n=30)	
		Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
Financial health	Net Profit Margin	0.00	0.00	0.19	0.26	0.33	0.47	0.00	0.00	0.13	0.30
	Business units lost	0.00	0.00	0.29	0.49	0.00	0.00	0.00	0.00	0.07	0.25
	Liquidity	0.00	0.00	0.00	0.00	0.38	0.52	0.00	0.00	0.10	0.31
	Capital structure	0.00	0.00	0.43	0.53	0.29	0.42	0.00	0.00	0.18	0.37
	Sub Total	**0.00**	**0.00**	**0.24**	**0.32**	**0.26**	**0.37**	**0.00**	**0.00**	**0.13**	**0.26**
Engagement with output buyers	Milk quality	0.00	0.00	0.00	0.00	0.25	0.46	0.00	0.00	0.07	0.25
	Market reliability	0.00	0.00	0.02	0.05	0.18	0.33	0.00	0.00	0.05	0.18
	Suppliers	0.00	0.00	0.04	0.09	0.20	0.38	0.00	0.00	0.06	0.21
	Sub Total	**0.00**	**0.00**	**0.02**	**0.06**	**0.20**	**0.37**	**0.00**	**0.00**	**0.06**	**0.21**
Effective and transparent leadership and management	Representation participation	0.45	0.39	0.55	0.24	0.66	0.22	0.45	0.15	0.53	0.27
	Effective supervision	0.05	0.07	0.06	0.16	0.07	0.08	0.04	0.07	0.06	0.10
	Effective management	0.26	0.24	0.11	0.16	0.65	0.23	0.00	0.00	0.27	0.31
	Sub Total	**0.25**	**0.23**	**0.26**	**0.14**	**0.44**	**0.09**	**0.18**	**0.07**	**0.29**	**0.17**
Access to dairy production inputs and services	Feed and feeding	0.10	0.15	0.03	0.08	0.58	0.27	0.17	0.14	0.23	0.28
	Genetics	0.25	0.27	0.00	0.00	0.66	0.35	0.00	0.00	0.24	0.35
	Health	0.38	0.44	0.07	0.19	0.75	0.27	0.14	0.38	0.35	0.42
	Extension	0.75	0.35	0.05	0.13	0.96	0.12	0.24	0.37	0.52	0.45
	Financial services	0.00	0.00	0.07	0.12	0.31	0.28	0.04	0.09	0.11	0.20
	Sub Total	**0.25**	**0.13**	**0.04**	**0.05**	**0.61**	**0.21**	**0.13**	**0.14**	**0.27**	**0.26**
Relations with external environment	Partnership actors	0.88	0.35	0.29	0.49	0.88	0.35	0.00	0.00	0.53	0.51
	Social responsibility	0.38	0.52	0.43	0.53	0.50	0.53	0.14	0.38	0.37	0.49
	Sub Total	**0.66**	**0.34**	**0.35**	**0.38**	**0.71**	**0.36**	**0.06**	**0.16**	**0.46**	**0.41**
Member loyalty	Patronage	0.27	0.23	0.00	0.00	0.50	0.33	0.00	0.00	0.21	0.29
	Member investment	0.63	0.32	0.52	0.42	0.59	0.33	0.45	0.39	0.55	0.35
	Ownership	0.38	0.35	0.29	0.39	0.13	0.23	0.14	0.24	0.23	0.31
	Member loyalty programs	0.31	0.37	0.14	0.38	0.56	0.32	0.14	0.38	0.30	0.39
	Sub Total	**0.41**	**0.19**	**0.24**	**0.22**	**0.46**	**0.20**	**0.19**	**0.10**	**0.33**	**0.21**
PO overall sustainability		**0.20**	**0.10**	**0.16**	**0.12**	**0.41**	**0.18**	**0.10**	**0.05**	**0.22**	**0.17**

4.3.4 Correlations between overall farm and PO sustainability performance indicators

The correlations between PO and overall farm sustainability performance indicators are shown in Table 19. The overall farm sustainability performance index showed a moderate positive correlation (r = 0.49; p < 0.01) with the PO overall sustainability performance index. Similarly, all of the PO sustainability performance dimensions and the majority of their sub-dimensions had weak to strong positive correlations ($0 < r < 1$; $p < 0.05$) with the overall farm sustainability performance index. The overall farm sustainability performance index had strong correlations with "access to dairy production inputs and services" and "effective and transparent leadership and management" ($r = 0.58$ and 0.51 respectively; $p < 0.01$) sustainability performance dimensions of POs. All sub-dimensions of "access to dairy production inputs and services" sustainability performance (excluding the financial service) and effective management for "effective and transparent leadership and management" dimensions of POs showed strong positive correlations ($r > 0.5$; $p \leq 0.01$) with the overall farm sustainability performance index.

Table 19: Correlations between PO overall sustainability performance index and farm sustainability performance indicators

PO sustainability performance Dimension	Sub-dimension	Overall farm sustainability
Financial health	1. Profit-Net Profit Margin	0.38**
	2. Business units lost	-0.16
	3. Liquidity	0.43**
	4. Capital structure	0.24**
	Sub Total	**0.32****
Engagement with output buyers	1. Milk quality	0.31**
	2. Market reliability	0.31**
	3. Suppliers	0.30**
	Sub Total	**0.30****
Effective and transparent leadership and management	1. Representation participation	0.25**
	2. Effective supervision	0.15
	3. Effective management	0.54**
	Sub Total	**0.51****
Access to dairy production inputs and services	1. Feed and feeding	0.52**
	2. Genetics	0.50**
	3. Health	0.54**
	4. Extension	0.51**
	5. Financial services	0.42**
	Sub Total	**0.58****
Relations with external environment	1. Partnership actors	0.31**
	2. Social responsibility	0.10
	Sub Total	**0.26****
Member loyalty	1. Patronage	0.28**
	2. Member investment	0.01
	3. Ownership	-0.16
	4. Member loyalty programs	0.22*
	Sub Total	**0.17***
PO overall sustainability		**0.49****

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

4.3.5 Correlations between farm economic and PO sustainability indicators

Table 20 shows the relationships between farm economic performance dimension and its indicators and PO sustainability performance dimensions and their sub-dimensions. The farm economic dimension had strong correlations (r = 0.67; $p < 0.05$) with “access to dairy inputs and services sustainability performance dimension of PO”. Furthermore, all sub-dimensions of “access to dairy production inputs and services” sustainability performance dimension, except “the extension sub-dimension”, and the “effective management” sub-dimension of the “effective and transparent leadership and management” sustainability performance dimension of PO had strong positive correlations (r > 0.5; $p < 0.01$) with "farm economic sustainability" performance dimension. On the contrary, PO "business units lost" sub-dimension of "financial health sustainability" performance dimension showed a weak negative correlation with the "farm economic" sustainability performance dimension (r = -0.23; $p < 0.01$).

Table 20: Correlation between farm economic and PO sustainability performance indicators

PO sustainability performances		Farm economic performance							
Dimensions	**Sub-dimension**	**Income**	**Animal health**	**Cow productivity**	**Labour productivity**	**Forage self-sufficiency**	**Use of artificial insemination**	**Feed conservation**	**Economic**
Financial health	Profit-Net Profit Margin	-.099	-0.08	0.25*	-0.22*	0.44**	0.17*	0.38**	0.36**
	Business units lost	-0.06	0.02	-0.21*	-0.14	-.17	-0.20*	-0.06	-0.23**
	Liquidity	-0.12	-0.05	0.36**	-0.19*	0.50**	0.25**	0.42**	0.45**
	Capital structure	-0.08	-0.07	0.10	-0.23**	0.30**	0.06	0.29**	0.21*
	Sub Total	**-0.10**	**-0.06**	**0.18**	**-0.24****	**0.38****	**0.12**	**0.35****	**0.29****
Engagement with output buyers	Milk quality	-0.12	-0.03	0.35**	-0.16	0.41**	0.21*	0.35**	0.37**
	Market reliability	-0.13	-0.02	0.33**	-0.16	0.40**	0.19*	0.35**	0.36**
	Suppliers	-0.14	-0.01	0.32**	-0.17*	0.38**	0.18*	0.35**	0.35**
	Sub Total	**-0.13**	**-0.02**	**0.33****	**-0.17**	**0.40****	**0.19***	**0.35****	**0.36****
Effective and transparent leadership and management	Representation participation	0.27	-0.15	0.16	-0.13	0.18*	0.10	0.19*	0.21*
	Effective supervision	0.00	0.14	0.01	-0.13	.08	0.07	0.24**	0.16
	Effective management	-0.06	-0.15	0.43**	-0.34**	0.58**	0.34**	0.48**	0.50**
	Sub Total	**0.12**	**-0.15**	**0.34****	**-0.31****	**0.47****	**0.28****	**0.46****	**0.46****
Access to dairy production inputs and services	Feed and feeding	0.20	-0.12	0.68**	-0.16	0.53**	0.37**	0.51**	0.66**
	Genetics	0.01	-0.17*	0.58**	-0.24**	0.53**	0.40**	0.43**	0.56**
	Health	0.27	-0.09	0.71**	-0.16	0.49**	0.35**	0.44**	0.65**
	Extension	0.10	-0.08	0.48**	-0.27**	0.44**	0.35**	0.39**	0.48**
	Financial services	-0.054	-0.09	0.54**	-0.17	0.50**	0.30**	0.39**	0.50**
	Sub Total	**0.13**	**-0.13**	**0.70****	**-0.23****	**0.58****	**0.41****	**0.51****	**0.67****
Relations with external environment	Partnership actors	-0.10	-0.09	0.18	-0.35**	0.32**	0.33**	0.17*	0.18*
	Social responsibility	-0.13	-0.13	0.04	-0.24**	0.21*	0.18*	0.16	0.08
	Sub Total	**-0.14**	**-0.13**	**0.14**	**-0.36****	**0.32****	**0.31****	**0.20***	**0.16**
Member loyalty	Patronage	0.01	-0.18*	0.36**	-0.23**	0.28**	0.35**	0.25**	0.29**
	Member investment	0.22*	-0.08	0.13	-0.10	-.06	0.18*	-0.11	-0.02
	Ownership	0.11	-0.07	0.03	0.12	-0.21*	-0.10	-0.17*	-0.14
	Member loyalty programs	-0.06	-0.15	0.18	-0.19*	0.26**	0.26**	0.27**	0.22*
	Sub Total	**0.10**	**-0.20***	**0.29****	**-0.19***	**0.13**	**0.32****	**0.12**	**0.17**
PO overall sustainability		**0.00**	**-0.12**	**0.49****	**-0.29****	**0.53****	**0.34****	**0.47****	**0.51****

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

Some farm sustainability performance indicators namely cow productivity, forage self-sufficiency, use of artificial insemination and feed conservation had moderate to strong correlations (0.3 < r < 1; $p < 0.05$) with the overall sustainability performance index of PO. Moreover, cow productivity, forage self-sufficiency and feed conservation showed moderate to strong correlations (0.5 < r < 1; $p < 0.05$) with "access to dairy production inputs and services" performance dimension of PO.

Cow productivity was strongly positively correlated ($0.5 < r < 1$; $p < 0.01$) with all sub-dimensions for "access to dairy production inputs and services" dimension of PO. Similarly, forage self-sufficiency farm sustainability performance indicator was strongly positively correlated ($0.5 < r < 1$; $p < 0.01$) with feed and feeding, genetics and financial service sub-dimensions for "access to dairy production inputs and services", liquidity sub-dimension for financial health and effective management sub-dimension for "effective and transparent leadership and management" dimension. Farm feed conservation sustainability performance dimension was strongly positively correlated ($r > 0.5$; $p < 0.01$) with feed and feeding sub-dimension for "access to dairy production inputs and services" dimension of PO sustainability performance. On the other hand, the farm use of artificial insemination and cow productivity sustainability indicators were weakly and negatively (r = -0.20 and -0.21 respectively; $p < 0.05$) correlated with PO business units lost sub-dimension for financial health of PO performance dimension.

Income and animal health performance indicators showed non-significant correlations ($p > 0.05$) with the PO overall sustainability performance index and the majority of its dimensions and sub-dimensions. Indeed, labour productivity indicated weak negative correlations ($-0.3 < r < 0$; $p < 0.5$) with PO overall sustainability performance index and most of its dimensions and sub-dimensions.

4.3.6 Correlation between social farm and PO sustainability performance indicators

Table 21 shows the correlations between PO sustainability performance and social farm sustainability indicators. There was no significant correlation between farmer social sustainability performance dimension and overall farm sustainability ($r = 0.06$, $p > 0.05$). Farmer education performance indicator showed moderate positive and weak positive correlation ($r= 0.33$ $p < 0.01$) with the overall PO sustainability performance index.

Similarly, education presented weak to moderate positive correlation ($0 < r < 0.3$; $p < 0.05$) with engagement with output buyers, "access to dairy production inputs and services", "relations with external environment" and "effective and transparent leadership and management" PO performance dimensions and most of their sub-dimensions.

Table 21: Correlations between farm social and PO sustainability indicators

PO performance indicator		Farm social performance indicator			
Dimensions	**Sub-dimension**	**Education**	**Training**	**Women's empowerment**	**Social**
Financial health	Profit-Net Profit Margin	0.22*	-0.07	0.06	0.00
	Business units loss	-0.17	0.00	-0.12	-0.04
	Liquidity	0.28**	-0.07	0.12	0.03
	Capital structure	0.11	-0.10	0.03	-0.05
	Sub Total	**0.17**	**-0.08**	**0.05**	**-0.02**
Engagement with output buyers	Milk quality	0.26**	-0.17*	0.15	-0.07
	Market reliability	0.25**	-0.16	0.14	-0.07
	Suppliers	0.24**	-0.16	0.15	-0.06
	Sub Total	**0.25****	**-0.16**	**0.15**	**-0.07**
Effective and transparent leadership and management	Representation participation	0.10	0.10	0.10	0.15
	Effective supervision	0.17*	-0.03	-0.01	0.01
	Effective management	0.33**	0.06	0.23*	0.18*
	Sub Total	**0.29****	**0.09**	**0.19***	**0.20***
Access to dairy production inputs and services	Feed and feeding	0.31**	-0.02	0.31**	0.08
	Genetics	0.30**	0.05	0.21*	0.14
	Health	0.33**	-0.02	0.33**	0.09
	Extension	0.37**	0.11	0.24*	0.22*
	Financial services	0.28**	-0.14	0.21*	-0.03
	Sub Total	**0.37****	**0.00**	**0.31****	**0.12**
Relations with external environment	Partnership actors	0.21*	0.15	0.06	0.19*
	Social responsibility	0.19*	-0.16	0.06	-0.08
	Sub Total	**0.24****	**0.01**	**0.07**	**0.09**
Member loyalty	Patronage	0.16	0.05	0.25**	0.14
	Member investment	0.08	-0.04	0.00	-0.01
	Ownership	-0.06	-0.01	0.04	-0.02
	Member loyalty programs	0.14	-0.12	0.12	-0.03
	Sub Total	**0.15**	**-0.05**	**0.17**	**0.04**
PO overall sustainability		**0.33****	**-0.06**	**0.22***	**0.06**

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

Women's empowerment indicator was correlated with PO sustainability performance index ($r = 0.22$, $p < 0.05$). Indeed, women's empowerment indicator showed weak positive correlations with "access to dairy production inputs and services" sustainability PO performance dimension and its sub-dimensions and effective management sub-dimension for "effective and transparent leadership and management" PO performance dimension. However, training and social dimensions show non-significant correlations ($p > 0.05$) with PO sustainability performance index and most of its dimensions and sub-dimensions.

4.3.7 Correlation between farm environmental and PO sustainability indicators

The correlations between environmental performance indicators and PO components are shown in Table 22. The environmental farm sustainability performance dimension showed moderate and positive correlations ($0 < r < 0.5$; $p < 0.05$) with PO overall sustainability performance index and all its dimensions and the majority of their sub-dimensions, except member loyalty. Similarly, water availability and land ownership farm sustainability performance indicators showed weak positive correlations ($r = 0.26$ and 0.18 respectively; $p \leq 0.05$) with overall PO sustainability performance index. Moreover, water quality showed strong correlations with the overall PO sustainability performance index and the majority of its dimensions and sub-dimensions ($r > 0.5$; $p < 0.01$).

Table 22: Correlation between farm environmental and PO sustainability performance indicators

PO dimensions and sub-dimensions		**Farm environmental performance**				
Dimensions	**Sub-dimension**	**Erosion control**	**Water quality**	**Water availability**	**Land ownership**	**Environment**
Financial health	Profit-Net Profit Margin	0.14	0.59**	0.13	0.16	0.38**
	Business units reported loss	.[c]	.[c]	0.10	-0.07	-0.04
	Liquidity	0.15	0.60**	0.11	0.15	0.37**
	Capital structure	0.05	0.58**	0.15	0.13	0.30**
	Sub Total	**0.12**	**0.60****	**0.15**	**0.14**	**0.34****
Engagement with output buyers	Milk quality	-0.11	0.44*	0.09	0.18*	0.31**
	Market reliability	-0.11	0.44*	0.10	0.18*	0.31**
	Suppliers	-0.09	0.43*	0.11	0.15	0.29**
	Sub Total	**-0.10**	**0.44***	**0.10**	**0.17**	**0.30****
Effective and transparent leadership and management	Representation participation	0.29	0.00	0.25**	-0.01	0.14
	Effective supervision	-0.09	0.08	0.06	0.07	0.13
	Effective management	0.13	0.59**	0.28**	0.17	0.41**
	Sub Total	**0.24**	**0.42***	**0.32****	**0.11**	**0.36****
Access to dairy production inputs and services	Feed and feeding	0.08	0.40*	0.12	0.14	0.28**
	Genetics	0.06	0.55**	0.15	0.17	0.30**
	Health	0.07	0.55**	0.27**	0.15	0.32**
	Extension	0.23	0.52**	0.35**	0.11	0.32**
	Financial services	-0.17	0.43*	0.14	0.25**	0.34**
	Sub Total	**0.07**	**0.52****	**0.24****	**0.187***	**0.36****
Relations with external environment	Partnership actors	0.15	0.60**	0.29**	0.12	0.25**
	Social responsibility	-0.11	0.44*	0.15	0.13	0.19*
	Sub Total	**0.05**	**0.57****	**0.27****	**0.15**	**0.26****
Member loyalty	Patronage	0.30	0.44*	0.19*	-0.01	0.14
	Member investment	0.04	-0.20	0.24**	0.06	0.06
	Ownership	0.09	-0.136	0.15	-0.18*	-0.15
	Member loyalty programs	0.04	0.65**	0.16	0.04	0.24**
	Sub Total	**0.31**	**0.52****	**0.30****	**-0.02**	**0.14**
PO overall sustainability		**0.07**	**0.55****	**0.26****	**0.18***	**0.39****

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level
[c]Can not be computed because at least one of the variables is constant

4.3.8 Producers' organization level factors influencing farm sustainability

The results from regression show that PO financial health sustainability performance dimension had a positive and significant effect on the overall farm sustainability performance index (β = 0.116; $p < 0.05$). Access to dairy production inputs and services PO sustainability performance had a positive and significant effect on the economic (β =0.636; $p < 0.001$) and the environmental (β = 0.223; $p < 0.05$) farm sustainability performance dimension. However, the engagement with output buyers had a negative effect on the economic (β = -0.242; $p < 0.05$) and social farm sustainability performance dimensions (β = -0.235; $p < 0.05$). Indeed, relations with external environment had a negative effect on the economic sustainability (β =-0.107; $p < 0.05$); member loyalty had a negative influence on the overall farm sustainability (β =-0.129; $p < 0.05$). Table 23 presents the results from regression.

Table 23: Producers' organization level factors influencing farm sustainability

Explanatory variables	Dependent variables							
	Overall		Economic		Social		Environment	
	B	SE	B	SE	B	SE	β	SE
Financial health	0.116*	2.94	0.144^{ns}	0.08	0.012^{ns}	0.10	0.188^{ns}	0.12
Engagement with output buyers	-0.204**	1.21	-0.242*	0.09	-0.235*	0.12	-0.127^{ns}	0.14
Effective and transparent leadership and management	0.152^{ns}	2.57	0.121^{ns}	0.13	0.231^{ns}	0.17	0.167^{ns}	0.21
Access to dairy production inputs and services	0.339***	1.45	0.636***	0.07	0.170^{ns}	0.10	0.223*	0.12
Relations with external environment	-0.006^{ns}	0.59	-0.107*	0.05	0.058^{ns}	0.05	0.0152^{ns}	0.07
Member loyalty	-0.129*	0.79	-0.135^{ns}	0.07	-0.175^{ns}	0.11	-0.060^{ns}	0.13
CONSTANT	0.318**	2.31	0.171***	0.03	0.548***	0.04	0.206***	0.05
Observation	330		136		136			136
LR Chi^2	77.12		102.40		14.38			25.79
Prob. > chi$^{2(9)}$	***		***		***			***
Log Likelihood	120.45		66.08		44.82			-6.42
Pseudo R^2	-0.4708		-3.44		-0.19			0.67

*p < 0.05; **p < 0.01; ***p < 0.001; ^{ns} not significant

4.4 Determinants of Smallholder Dairy and Traditional Cattle Milk Producer Farm Sustainability

4.4.1 Socio-economic characteristics of the households

Socio-economic characteristics of the sample households are shown in Table 24. The average household size was 4 persons (in adult equivalent) and ranked from 1 to 9 persons. The average age of the household heads was 49 years and varied from 20 to 87 years, mostly men (89%) and married (88%). The households owned, on average, 12 acres of land which varied from 0.25 to 160.5 acres. The farmers owned on average 25.8 heads of cattle which varied from 1 to 271 heads of cattle. More than a half of the total number of households (63 %) exclusively practised grazing system while the reminders either stall-fed their cattle with or without some grazing. The average distance from household to trading centre was 3.3 Km and varied from 0.01 to 40 Km. A small number of surveyed households acquired credit (8%).

The farmers in R-to-R system had significantly ($p < 0.05$) larger land than in R-to-U system (15.34 ± 18.47 and 9.88 ± 22.34 acres respectively). Similarly, the farmers in R-to-R system had significantly ($p < 0.05$) larger herd than in R-to-U system (31.56 ± 38.48 and 21.10 ± 45.17 heads of cattle respectively). The proportion of farmers practicing either stall feeding system or stall feeding system with some grazing was significantly ($p < 0.05$) higher in R-to-U system than in R-to-R system (66.30% and 0.67% respectively).

Table 24: Socio-economic characteristics of the households

Variable		**Milk market channel**						**Total (N=330)**			**Sig**
		R-to-R (n=149)			**R-to-U (n=181)**						
Mean ± SD, Min and Max		**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	
AGE (Year)		49.91±14.09	22.00	87.00	49.11±12.20	20.00	80.00	49.47±13.07	20.00	87.00	ns
FARMSIZE (Acre)		15.34±18.47	0.25	113.00	9.88±22.34	0.25	160.50	12.35±20.83	0.25	160.50	*
HERDSIZE(Head of cattle)		31.56±38.48	1.00	230.00	21.10±45.17	1.00	271.00	25.82±42.54	1.00	271.00	*
HHSIZE (Adult equivalent)		4.32±1.50	0.80	9.10	4.11±1.37	1.00	9.40	4.20±1.43	0.80	9.40	ns
DISTANCE (Km)		3.59±5.43	0.01	40.00	2.93±3.17	0.01	15.00	3.23±4.34	0.01	40.00	ns
Frequency											
CREDIT	No	136(91.3%)			169(93.37%)			305(92.42%)			ns
	Yes	13(8.7%)			12(6.63%)			25(7.58%)			
SEX	Male	137(91.95%)			158(87.29%)			295(89.39%)			ns
	Female	12(8.05%)			23(12.71%)			35 (10.61%)			
FEEDING	Grazing	148(99.33%)			61(33.70%)			209(63.33%)			***
	Stall feeding	1(0.67%)			120(66.30%)			121(36.67%)			
MARITAL	Married	15(10.07%)			24(13.26%)			291(88.18%)			ns
	Otherwise	134(89.93)%			157(86.74%)			39(11.82%)			

*p < 0.05; **p < 0.01; ***p < 0.001; ns not significant; R-to-R: Rural production to rural consumption (pre-commercial); R-to-U: Rural production to urban consumption (more commercial)

4.4.2 Determinants of farm sustainability

Table 25 shows the determinants of sustainability of milk production farm in the study area. Six variables out of nine, namely, sex, feeding system, farm size, distance between the household and the nearest trading centre, age of the household head and acquisition of credit showed significant effects on at least one of the economic, social, environment and overall sustainability performance indices. The feeding system showed positive effects on the farm economic (β = 0.256; $p < 0.01$), social (β = 0.165; $p < 0.01$), environmental (β = 0.098; $p < 0.01$) sustainability and overall farm sustainability (β = 0.161; $p < 0.01$) as well. Similarly, acquiring credit exhibited positive effects on the social sustainability (β = 0.190; $p < 0.01$) and overall farm sustainability performances (β =0.081; $p< 0.01$). Farm size showed positive effect on the economic (β = 0.001; $p < 0.1$) and environmental (β = 0.01; $p < 0.1$) sustainability. The age of the household head showed a positive effect on the overall farm sustainability (β = 0.01; $p < 0.05$) as well as the social (β = 0.05; $p < 0.1$) and environmental (β = 0.003; $p < 0.1$) sustainability. Indeed, sex of the household head showed a positive effect on environmental sustainability (β = 0.143; p < 0.1). However, the distance between farm and the nearest trading centre showed a negative effect on farm economic sustainability performance (β = -0.004; p < 0.1).

Table 25: Tobit regression analysis results of the determinants of sustainability

Explanatory variables	Dependent variables							
	Overall		Economic		Social		Environment	
	β	SE	β	SE	β	SE	β	SE
CREDIT	0.081***	0.03	0.018 ns	0.03	0.190***	0.06	0.060 ns	0.05
SEX	0.054 ns	0.04	0.072 ns	0.05	-0.043 ns	0.09	0.143*	0.09
AGE	0.001**	0.00	0.001 ns	0.00	0.003**	0.00	0.002*	0.00
FARMSIZE	0.001 ns	0.00	0.001*	0.00	0.000 ns	0.00	0.001*	0.00
HERDSIZE	0.000 ns	0.00	0.000 ns	0.00	0.001 ns	0.00	0.000 ns	0.00
HHSIZE	0.004 ns	0.01	0.000 ns	0.01	0.012 ns	0.01	0.001 ns	0.01
FEEDING	0.161***	0.02	0.256***	0.02	0.165***	0.03	0.098***	0.03
DISTANCE	-0.002 ns	0.00	-0.004*	0.00	-0.002 ns	0.09	-0.002 ns	0.08
MARITAL	0.016 ns	0.04	0.041 ns	0.05	-0.062 ns	0.00	0.075 ns	0.00
CONSTANT	0.122**	0.05	0.097 ns	0.06	0.116 ns	0.11	**0.061** ns	0.10
Observation	330		330		330			330
LR Chi^2	111.25		168.24		39.98			25.75
Prob. > $chi^{2(9)}$	***		***		***			***
Log Likelihood	201.30		131.81		-55.47			-73.18
Pseudo R^2	-0.3818		-1.7638		0.2649			0.1496

*p < 0.1; **p < 0.05; ***p < 0.01; ns not significant; β: coefficient; SE: Standard error

CHAPTER FIVE

5.0 DISCUSSION

5.1 Indicators for Assessing Sustainability of Milk Production Farms in Tanzania

In the context of this research, sustainability was defined using three components: economic, social and environmental. A preliminary survey generated a comprehensive list of 57 potential indicators of all aspects of sustainability from which, after a second survey using a Delphi technique, a refined set of 29 emerged. Comparison with previous literature (Chand *et al*., 2015; Meul *et al.,* 2008; Sauvenier *et al.,* 2005; Van Der Meulen *et al.,* 2013), the indicators identified in this research fall into three categories: those which are common across multiple comparable analyses; those which, though common, are viewed in a different light in the Tanzanian responses reported here and those which are uncommon or unique to this analysis. These comparisons provide a picture of the current milk value chain in Tanzania and may point towards its future.

Hugé *et al*. (2010) suggest that the Delphi technique is not a tool for decision making or deducing definitive answers but it is of assistance in identifying all possible factors and potential solutions. In this regard, some authors use focus group discussions to complement Delphi technique (Roy *et al.,* 2013). A number of other limitations are important in interpreting the results of this analysis. The validity of the Delphi technique depends on the expertise of the contributors. For the current research, the spread of experience of the respondents within the dairy sector was diverse and fairly evenly distributed from those relatively new to the sector to others with more than 30 years' experience. Gender bias of the sample was significant, three quarters of the respondents being male although women are major actors in the milk production chain. Eight of 44 respondents were farmers, while the remainder had academic or more technical backgrounds.

The selection of indicators using a participatory approach generates a set of indicators suitable for the prevailing situation. Meanwhile, it can generate a large number of highly correlated indicators. Although these issues were taken into account during the selection process by merging the indicators with possible correlation to avoid biases, inconsistences could persist. Authors like Paracchini *et al*. (2015) and Vitunskiene and Dabkiene (2016) have suggested further correlation analysis to exclude strongly correlated indicators while Yigitcanlar and Dur (2010) suggested weighting indicators to correct overlapping biases before using them.

Finally, the Delphi technique rejects opinions offered by a small proportion of participants even if they are relevant (Chu and Hwang 2008). Such rejected indicators could be important in the future, particularly with factors such as environmental sustainability which gain importance with time (Hai *et al.*, 2009) as society becomes more sensitive to environmental issues.

The results from stakeholder's opinions showed that most relevant indicators were economic (18 economic indicators against 4 social and 7 environmental indicators). The proportion of economic indicators is higher than in integrated sets used by Paracchini *et al*. (2015) and Zahm *et al*. (2008) among others. Prioritization of economic indicators could be justified by the subsistence nature of milk production systems in the study area, where milk is produced in low quantity and difficult to access the market (Leonard *et al.*, 2016). Income per litre of milk was among the most relevant profitability indicators. This is in agreement with Roy *et al*. (2014) who argue that income is a fundamental indicator for measuring farm viability. In fact, to be viable milk production farm must cover the cost of production and produce surplus to economically sustain itself (Zahm *et al.*, 2008). Moreover, the alternative, the use of off-farm resources to finance farm activities, is not possible for those farmers with limited resources (Zvinorova *et al.,* 2010). Green (2012) reported that in Tanzania some farmers exit dairy farm activities due to low of profitability, searching for other activities which are more profitable.

A number of key indicators, though present both in our results and in the published literature, were nevertheless viewed differently. Atanasov and Popova (2010) categorized milk quality as social, van Calker *et al*. (2005) viewed animal health and welfare as social while Chand *et al*. (2015) considered animal genetics as environmental. In the Tanzanian results, although the respondents considered animal health and welfare, milk quality and animal genetics as important, they were all regarded as economic criteria. This perception of the overwhelming importance of economic criteria can be explained by the current nature of milk production in Tanzania which is dominated by the subsistence farming systems (Rural Livelihood Development Company, 2010). Most milk is consumed by its producers or local communities and only 10% is sold in commercial markets, that is, production is largely pre-commercial. Milk production in Tanzania is constrained by poor genetic quality of dominant livestock which result in low milk yield, animal diseases responsible for economic loss and low milk quality which hinder its commercialization (URT, 2006). Thus animal genetics, milk quality and animal health and welfare are all seen primarily through the potential economic benefits their improvement could deliver.

Similarly milk hygiene was considered the most important economic indicator (4.8 points). Poor milk quality could have a negative impact on public health (Atanasov and

Popova 2010). In Tanzania, poor microbiological quality and presence of drug residues have been reported (Mdegela *et al.,* 2009; Ngasala *et al.,* 2015). A farm with milk of low quality is less likely to be economically sustainable as such milk is rejected by the market (Ndungu *et al.,* 2016). This was probably the reason that milk quality was regarded as primarily an economic factor.

Women's empowerment is a common indicator of social sustainability (Chand *et al.,* 2015). For example, Moses *et al*. (2016) reported that in Kenya, women's access to dairy income, control of dairy assets, knowledge and technology have a significant positive impact on household commercial activity and thus its sustainability. Our results confirm this assessment. Unfortunately, URT (2010) reported that women do not have enough access to resources and decision making on the use of income, even though they are the main actors of milk value chain. This situation makes women's empowerment indicators more relevant in the context of this study compared to others where gender was not considered as an issue.

The existence of farmers' organisations and participation in training are other commonly used social indicators. Participation in training was identified among the most relevant social factors as it was by Sharghi *et al*. (2010) in Iran and Roy *et al*. (2014) in Bangladesh. Farmers need appropriate knowledge and skills in farm management to efficiently use farm resources (Smith and McDonald, 1998), particularly in the study context dominated by traditional cattle farmers, with limited knowledge in dairy management. Only 55% of the farmers received extension services (URT, 2012). Training was not taken into account in some other sets of sustainability indicators as in Chand *et al*. (2015) in India. The respondents' consensus indicated that participation in farmers' organizations is an important indicator of farm sustainability as suggested in Tanzania by Tumusiime and Matotay (2014). Farmers' organizations can be a way to reduce constraints which hinder sustainable milk production in developing countries. It is difficult to get access to inputs and other services individually but by joining farmers' organizations, farmers gain bargaining power which enables them to get inputs at lower cost, and access credit and other services; moreover, the organizations are also important for social networking (Kalra *et al*., 2013), which is the case in our study.

It is striking that, of the five top ranked indicators of environmental sustainability, four are to do with water availability and quality. Milk production is not sustainable without access to water the whole year round. Poor yield is expected during shortage of water specifically in the dry season as has been reported in Tanzania (Morris *et al.,* 2015). Respondents identified water conservation among the most relevant environmental indicators. Ideally, the farmer could ensure that the water is available throughout the year by conserving the rainy season water (Devendra, 2001). The use of rain water as an alternative water source was proposed by Meul *et al*. (2008) as relevant indicator. The practicability of such approaches would have to be assessed under local conditions. For an increase in milk production to be genuinely sustainable, it should have little or no negative effects on water quality. Livestock can contaminate water with pharmaceutical products, parasites, viruses and biochemical oxygen demanding organic substances (Burkholder *et al.*, 2007; Strokal *et al.,* 2016). Nitrate (Calker *et al.*, 2005) and bacteriological count have been suggested as indicators of water quality (Smith *et al.,* 2015). Although more precise, these indicators are difficult to measure. The most relevant current indicators which could influence the water quality were "distance between the manure storage and water way/source" and "direct access of animal to water source". Morris *et al*. (2015) reported a case in Tanzania where the farmers were urged to water cattle using troughs instead of letting them access the water source directly, to avoid water contamination.

Given the importance attached to economic factors, it is curious that access to land was identified as the most important indicator of environmental sustainability, rather than an economic one. Baker *et al*. (2015) reported that access to land is among the major constraints to milk production in Tanzania. Few farmers allocate land for livestock pasture while other farmers depend on public grazing land; indeed, some farmers practise grazing in urban against the by-laws of the city (Gillah *et al.,* 2013). Lack of ownership in using communal land was also reported to be a source of conflicts between crop and livestock farmers and negatively affects incentives to sustainable land use, which results in land degradation in Tanzania (Lugoe, 2011).

In the list of environmental indicators, some were noticeable by their absence. Indicators considered relevant by other studies such as greenhouse gas emissions and manure use (Chand *et al.*, 2015) were rejected by the respondents as not relevant in this study context. Our finding is in agreement with Nuntapanich (2011) in Thailand who also did not include greenhouse gas emissions in sustainability indicators milk production. Indeed, Lopez-Ridaura *et al*. (2005) argue that indicators relevant in one context may not be relevant in another context. Some indicators ranked surprisingly low. The two indicators of land degradation, namely stocking density and soil conservation were ranked sixth and seventh in the list. This variation in relevance could be explained by the local context of sustainability indicators (Gafsi and Favreau, 2010). Alternatively, it may be that given the current nature of the milk supply chain in Tanzania, environmental factors are simply seen as less pressing than expansion of production.

Some indicators were viewed differently among different groups of respondents. Most of economic indicators were accepted by all the groups of respondents. For social indicators, the farmers expressed more interest than the other groups that accepted only two of the seven indicators for each. For environmental indicators, the farmers showed less interest than other groups where they considered only four out of seven indicators. van Calker (2005) has suggested selection of indicators of concern to individual groups of respondents. Although perceptions of sustainability vary among individuals, a compromise among the diversity of experts and stakeholders is necessary to avoid failure in sustainability improvement such as was observed by Ogle (2001).

5.2 Framework for Assessing Sustainability of Smallholder Dairy and Traditional Cattle Milk Producer Farms

5.2.1 Framework development

The framework was developed to assess sustainability of milk production farms in the context of smallholder dairy and traditional cattle production farms in Tanzania. The developed tool provided a framework for assessing sustainability of smallholder dairy and traditional cattle milk production farms. It is unique and more locally adapted compared to the existing ones. The developed framework may be used to assess milk production farm sustainability in Tanzania more objectively compared to the existing performance measurements. Besides measuring, the framework synthesizes the sustainability performances to express them into more meaningful forms through normalization and aggregation of individual indicators into indices contrary to the simple presentation of raw sustainability indicator performances as reported by Ogle (2001) in Tanzania.

The developed framework differs from the existing frameworks found in the literature, such as the one used by chand *et al.* (2016) and FAO (2013), in terms of the nature and number of individual indicators, the number of dimensions, and distribution of indicators within dimensions and weights of indicators. These differences are explained by the context specific of sustainability concept. Hence, using a framework which is not adapted to the study contexts could results into failure in sustainability improvement program.

The number of indicators used in this framework is fewer than the number of indicators provided by the experts and stakeholders. This could be explained by the fact that the developed framework is for rapid sustainability assessment (RSA) on contrary to full sustainability assessment (FSA) which provides more details with a large number of indicators as suggested by Marchand (2014). If and when framework users increase their commitment to on-farm sustainability, they can gain additional insight by using an FSA tool.

5.2.2 Sustainability performances of smallholder dairy and traditional cattle milk producer farms

5.2.2.1 Overall farm sustainability

The results showed that the overall sustainability mean score was low and significantly higher in R-to-U system than in R-to-R system. These findings reflect the current situation of sustainability as it has been reported through a series of studies about milk production issues in Tanzania (Nkya *et al.*, 2007; Baker *et al.*, 2015). The difference could be explained by the dominance of traditional cattle keeping system in R-to-R system compared to R-to-U system. In fact, the traditional cattle keeping system is less developed and characterised by a larger number of constraints to its sustainability compared to the smallholder dairy farming system in the study area. Some of the constraints are shortage of water, conflict between pastoralists and crop farmers, low cow productivity and inefficient milk marketing system (Leonard *et al.,* 2016).

5.2.2.2 Economic sustainability

The results showed that the income mean score was moderate and the situation was significantly more severe in R-to-R system than in R-to-U system. The results could be attributed to various up and downstream factors like inefficiency of milk market system, low cow productivity and farm management. The farmers usually sell their milk to the nearest buyers (vendors and local consumers) who pay more than other buyers along the marketing channel like milk processors and collection centres but the nearest buyers have a limited buying capacity which could be overloaded during the rainy season; hence, the remaining milk is either sold at low price to the other milk buyers or consumed at home (ILRI, 2014b; Leonard *et al.,* 2016; Cadilhon *et al.,* 2016). Indeed, the potential buyers are the ones who make decision on milk price (Cadilhon *et al.,* 2016). The limited milk market affects more R-to-R system due to the remoteness vs. the potential milk buyer; and this remoteness could explain the significant difference between the two systems.

A number of farmers did not use artificial insemination. Moreover, the use of artificial insemination was lower in R-to-R system compared to R-to-U system. Previous studies show that the main reasons for not using artificial insemination are, among others, the high cost of artificial insemination service, low pregnancy rate, the unavailability of the service (Mangesho *et al.,* 2013; ILRI, 2014b). Indeed, a number of traditional cattle farmers prefer a large number of indigenous cattle as asset (Sikira *et al.,* 2013). This preference could justify the significant mean difference between the two studied systems.

A large number of the farmers strongly depend on external inputs in terms of forage and did not conserve feed. The situation was poorer in R-to-R system where the forage is exclusively from off-farm supply. The dependence on external forage supply could be the result of low adoption of forage cultivation and conservation technology. The reasons for not cultivating fodder are, among others, lack of knowledge of fodder cultivation technology, large number of cattle specifically for pastoralists (Sikira *et al.,* 2013; ILRI, 2014b) and mainly because off farm feed is available and at low cost (only cost of person in charge of grazing the animals).

5.2.2.3 Social indicators

Participation in farmers' organizations was moderate. The reason could be attributed to lack of farmers' organization in the study area as reported by (Nkya *et al.,* 2007; Sikira *et al.,* 2013). Participation in organisations was significantly higher in R-to-U system than R-to-R system. A number of reasons could explain the difference in participation in organisations. The farmers' organisations in R-to-U system are strong and linked with a number of actors of the milk value chain (Cadilhon *et al.*, 2016) which is an incentive for the farmers to join them compared to the organisations in R-to-R particularly in Mvomero which are weak and can not influence prices (Leonard *et al.,* 2016). In addition, the farmers' organizations could be less active due to the mobility of the pastoralists in R-to-R system compared to R-to-U system.

The results showed that some women were disempowered. The situation was significantly more pronounced in R-to-R system than in R-to-U system. These findings are supported by Sikira *et al*. (2013) and Baker *et al*. (2015) who reported that women make the decision over only milk. Meanwhile, other decisions on more important activities and assets (livestock and crops) are mostly made by men in extensive systems especially pastoralists;

contrary to the intensive system, where the decision over all activities on all production assets is mostly made jointly by men and women.

5.2.2.4 Environmental indicators

Long term land ownership is among the determinant for sustainable land use (Shrestha and Ligonja, 2015). However, land ownership showed the lowest score among environmental indicators. Similarly, the issue of land shortage or tenure insecurity was reported by Baker *et al.* (2015) and is also among the main sources of conflicts between cattle farmers and farmers in Tanzania (Lugoe, 2011).

The results showed that a number of farmers do not control erosion, especially in R-to-R system. Results from this study corroborate with the results of Morris *et al.* (2015) who reported the case of erosion in Tanga region especially in farmers who do not use methods against erosion like establishing terraces. The predisposition to erosion risk and the farming system could be the reason of the difference in two studied systems. R-to-U system includes high risk zones like Lushoto, which motivate the farmers to adopt erosion control practices. Indeed, pastoralists in R-to-R system are less involved in crop farming, thus, soil prevention practices like establishing terraces is not frequent as they are not needed.

Surprisingly, availability of water was good in both R-to-R system and R-to-U system in spite of several reports on water shortage in Tanzania such as by Forbes and Kepe (2014). The situation could be explained by the fact that the study was conducted in the period which covers the pick rainfall period.

5.3 Relationship between Farm Level Milk Production Sustainability Performances and Producers' Organization Sustainability Dimensions

5.3.1 Farm sustainability Performances in PO-members and non-PO-members

The overall farm sustainability mean performance index score and most of its dimensions and mean performance indicators were significantly higher in PO-members than non-members. These findings also confirm the finding of the studies by Mojo *et al.* (2015) and Chagwiza *et al.* (2016) that organization facilitate access to production inputs and output markets and other services which result in improved farm economic viability with socially acceptable and environmentally friendly practices.

5.3.2 Producers' organization characteristics

POs in Lushoto District were the oldest and presented the highest average number of member per PO. This could be explained by the presence of high proportion of smallholder dairy farmers, which motivates the farmers to join and build strong POs, unlike the other districts with high proportion of traditional cattle and some transhumance,. POs in Mvomero District presented the highest proportion of women. This could be explained by the fact that Mvomero District is dominated by traditional cattle keeping where women are in charge of milk. Thus, they join POs in order to sell their milk.

5.3.3 Producers' organization sustainability performances

The overall PO sustainability mean performance index was ranked in Stage II. This implies that a number of POs did not reach the stage of maturity to graduate (Stage IV). Results from this study are in line with findings by Tumusiime and Matotay (2014) who also reported poor performances of POs in Tanzania. Similarly, the engagement with output buyer and financial health PO sustainability performance dimensions were among the weakest PO sustainability performance dimensions. This situation could be due to the low knowledge on business and marketing as it has been reported in Tanzania by Uliwa and Fischer (2004). Although a number of trainings has been conducted during the PO monitoring, Barham and Chitemi (2009) disclosed that low level of education of the members in the study area does not allow absorbing and implementing the outcomes from the trainings fully. Indeed, Trebbin (2014) in Ethiopia suggests that most of the organizations promoted by NGOs lack business skills to develop reliable market linkages. A number of POs were newly established. However, Kaganzi *et al*. (2009) and Kamdem (2012) in Cameroon and Uganda, respectively, suggest two up to five years of monitoring to achieve sustainability especially in strengthening management and leadership and in establishing market linkages. The business unit made loss could be explained by the fact that during the early stage, the POs were overambitious by conducting many activities which are beyond their capacity, hence, they had to give up some in order to be efficient. The weak financial health sustainability performance is probably due to the fact that the farmers were expecting to get external supports from the donors/government instead of generating their own financial resources.

5.3.4 Correlations between overall farm and PO sustainability performance indicators

The overall PO sustainability performance index showed a significant moderate positive correlation with the overall farm sustainability performance index. This result confirms that an effective PO could be a vehicle of sustainable agriculture practice at farm level as reported by Iyabano *et al*. (2016) and Mojo *et al*. (2017). Moreover, the overall farm sustainability performance index showed strong positive correlations with PO “access to dairy production inputs and services" dimension and most of its sub-dimensions and effective management of "effective and transparent leadership and management". This strong correlation implies that a good provision of inputs and services to the PO members, together with a good effective management could influence positively the overall farm sustainability performance. The overall farm sustainability performance indices are aggregation of indicators. Therefore, their lower level of aggregation is crucial to understand more precisely the relationships.

5.3.5 Economic dimension

The farm economic sustainability performance dimension showed a strong positive correlation with overall sustainability performance index and access to dairy production inputs and service sustainability performance dimension of PO. The strong positive correlations could explain the importance of PO in alleviating the economic challenges of milk production in the study area, namely, low productivity due to poor genetic potential of the dominant indigenous cattle breeds, shortage of feed, shortage of outputs market and poor farm management skills which have been reported in the study area (Nkya *et al.,* 2007; Baker *et al.,* 2015; Leonard *et al.,* 2016).

There were positive correlations between "access to dairy production inputs and services" PO sustainability performance dimension and most of its sub-dimensions and cow productivity, forage self-sufficiency, feed conservation and use of artificial insemination. This implies that POs could play an important role in improving cow productivity by facilitating access to artificial insemination to improve the genetic potential of cattle breed, inputs and health services and provide training, extension and information for better farm management including forage cultivation and feed conservation technologies. Similar results have been reported by Chagwiza *et al*. (2016) in Ethiopia who found that PO has a positive impact on the similar farm performance indicators and suggested that PO could be a pathway that leads to intensification through using improved cows and their associated requirements as facilitated by PO.

The inputs and services provided by PO supports increased output, which requires better market. This could explain the positive correlations between engagements with outputs buyers dimension and all its sub-dimensions and farm economic performance dimension and cow productivity and feed conservation farm sustainability performance indicator. Results from this study are in line with Jera and Ajayi (2008) in Zimbabwe who found that access to dairy output market is a driver for the adoption of feed technology namely forage cultivation and conservation. Evidence in Uganda showed that increase in production without access to market does not provide incentive for the PO-members due to the fact that it generates oversupply at the farm level (Kaganzi *et al.*, 2009).

Activities of PO such as linking the organization to market and provision of inputs which result in increased farm performances need mobilization of financial resources to make them more readily available. This could explain the number of positive correlations between PO financial health and its sub-dimensions and economic dimension and almost the entire set of cow productivity, feed conservation, and use of artificial insemination and forage self-sufficiency indicators. Results of the study are supported by Sonam and Martwanna (2011) who suggest that a sustainable PO should be profitable and have liquidity instead of depending on external support.

Efficient inputs and services supply and creation of linkages with milk buyers require good management, which could explain the correlations between PO “effective and transparent leadership and management" dimension and mostly effective management sub-dimension and cow productivity, feed conservation, forage self-sufficiency and use of artificial insemination indicators as well as the economic dimension of PO sustainability performances. Leadership is important to link the members with better markets, especially higher markets which need a lot of attention and good management of resources (Kaganzi *et al.,* 2009). Moreover, some PO can go far successfully but end up collapsing due to poor financial management (Kaganzi *et al.,* 2009).

Surprisingly, there were non-significant correlations between income (gross margin per litre of sold milk) and almost all PO performance dimensions and their sub-dimensions. The lack of significant correlation could be due to the fact that the milk processors linked to PO provide reliable market but low price and delay in payment compared to middlemen and neighbours as reported by the farmers during the survey and Cadilhon *et al*. (2016); Leonard *et al*. (2016).

There was a negative relationship between labour productivity and the overall PO sustainability. This could be explained by the fact that POs favour intensification which is labour demanding (Chagwiza *et al.,* 2016). Moreover, the study was conducted in the rainy season where feed and water are available at very low cost, especially, in predominantly traditional systems with poor performing POs compared to the predominantly smallholder dairy system with better performing POs.

5.3.6 Social dimension

There was a positive correlation between social sustainability farm performance dimension and overall PO sustainability performance index. Similarly, evidence in Tanzania shows that education has a positive effect on PO marketing due to the fact that the farmers with good education level are more responsive to trainings (Barham *et al.*, 2009). Also Kamdem (2012) in Cameroun suggest that education level is crucial for PO success in business.

Women's empowerment was positively correlated with PO overall sustainability, "access to dairy production inputs and services" PO sustainability performance dimension and all its sub-dimensions. These positive correlations could be explained by the fact that women are in charge of milk, especially in extensive systems.

5.3.7 Environmental dimension

The organization was mostly meant for marketing purpose. However, there were a number of positive correlations between environmental performance dimension and its indicators and PO overall performance, most of its dimensions and their sub-dimensions. These correlations imply that there are positive associations between farm environmental and PO sustainability performances. This could be explained by the fact that PO favour intensification which in the study area has positive impact on the environment. Our results corroborate with results by Iyabano *et al.* (2016) who observed that farmers in organization had practices which are environmental friendly in their farm. Meanwhile, Mojo *et al*. (2015) in Ethiopia found that PO could have negative impact on the environment due to the benefit it provides which results in overexploitation of natural resources.

5.3.8 Producers' organization level factors influencing farm sustainability

The results from the regression show that PO financial health sustainability performance dimension had a positive and significant effect on the overall farm sustainability performance index. This positive effect could be explained by the fact that financial means enable the organization to run its activities, thus better help its member than the organization with less financial means. Access to dairy production inputs and services PO sustainability performance had a positive and significant effect on the economic and the environmental farm sustainability performance dimension. This could be explained by the fact that the more the farmers get access to inputs and services, the more the economic sustainability of their farms is improved. However, the engagement with output buyers showed a negative effect on the economic. The negative effect could due to the fact that the milk processors linked to PO provide reliable market but low price and delay in payment compared to middlemen and neighbours as reported by the farmers during the survey, Cadilhon *et al*. (2016) and Leonard *et al*. (2016).

5.4 Determinants of Smallholder Dairy and Traditional Cattle Milk Producer Farm Sustainability

5.4.1 Socio-economic characteristics of the households

The farmers in R-to-U system had significantly smaller land and herd size than in R-to-R system. This difference could be explained by the fact that R-to-U system included a large number of smallholder dairy farmers particularly in Lushoto District while the R-to-R system encompass a large number of traditional cattle farmers with a large proportion of indigenous cattle herd particularly in Kilosa District (Leonard *et al.*, 2016).

5.4.2 Determinants of farm sustainability

Feeding system showed a positive influence on the economic, social, environment and overall farm sustainability performance indices. This implies that stall feeding is associated with improved economic, social, environmental and overall sustainability. This could be due to the fact that stall feeding is associated with a number of practices which could improve a number of the economic, social and environmental sustainability performance indicators. In fact, stall feeding is among the strategy to improve productivity, especially in smallholder dairy farming systems compared to the extensive systems in the study area. Improved milk yield generated by stall feeding is associated with the need for milk and input markets as well as other embedded services which could be incentives for participation in organizations. In stall feeding, the feed must be available the whole year round, which is an incentive to forage cultivation. Furthermore, the forage cultivation is important in soil and water conservation (Lebacq *et al.,* 2015).

The economic and environmental sustainability increased with farm size. This could be due to the fact that the farmers with adequate land more likely spare land for fodder cultivation and use crop residues from their own farms which also could result in increased milk (Lanyasunya *et al.,* 2006). Similarly in Zimbabwe, Chakoma (2012) reports that land shortage is a constraint for adopting sustainable forage production. Therefore, the farmers with inadequate or without land will likely get feed from off-farm sources or practice grazing system which faces more economic sustainability issues like low cow productivity and responsible for environmental sustainability issues like overuse of natural resources compared to the stall feeding systems. Moreover, possession of large land implies that farmers have financial means which enable them adoption of economically and environmentally sustainable agriculture.

Acquiring credit had a significant positive influence on the social sustainability performances. The positive influence of credit on social sustainability performances implies that acquiring credit enhances social sustainability indicators such as participation in organization, education level of the household head and women’s empowerment. Our results corroborate with results by Asante *et al.* (2011) in Ghana and Tolno *et al*. (2015); Olila (2014) in Kenya who found that access to credit is an incentive to social integration like participation in organizations. Taj *et al*. (2012) in India suggest that acquiring credit enables increased milk production and improve education. Indeed, Mani (2015) in India observed that acquiring credit has a positive influence on women's empowerment.

The results showed positive and significant effect of sex of household head on the environmental sustainability. This implies that female headed household are more likely to practice environmentally friendly farming practice. Similarly, Kizza *et al.* (2016) in Uganda found that women are more involved in water and soil conservation activities than their male counterparts. However, our results differ from the results of Atinkut *et al.* (2017) who report that in Ethiopia men use sustainable agriculture practice as they have more access to land than women. This difference could be explained by the fact that, in spite of scarce resources including land, the women are mostly attracted by smallholder dairy farming and adopt stall feeding practice which is more environmentally friendly compared to grazing system in the study area (Kaliba *et al.*, 1997). Indeed, women have less managerial skills on large cattle herd rearing than men.

Age of household head had significant effect of overall, social and environmental sustainability. This implies that the older the household head, the more sustainable is the farm. These findings corroborate with Li *et al.* (2016) in China who suggest that older farmers have more assets compared to the younger farmers which enable them to use environmentally and social sustainable practices. Similarly, Atinkut *et al.* (2017) argue that the old farmers are likely to use sustainable agriculture practices due to their experience. Mgbada (2016) in Nigeria found that the older farmers are conservative and do not introduce new technology which is not environmentally friendly. For the social sustainability, these results are in line with those of Francesconi and Ruben (2012) and

Chagwiza *et al.*, 2016) in Ethiopia who found that older farmers are more likely to join farmers' organizations, which is among key indicators of farm social sustainability. However, these results differ from what was reported by Gómez-Limón and Sanchez-Fernandez (2010) in Spain who found a negative effect of the household manager age on the overall farm sustainability due to the fact that the young are not likely to abandon the farm, and use more sustainable practices. Li *et al.* (2016) in China suggest that in spite more assets possession and experience, the older farmers have shorter life expectancy compared to young, which has a negative effect on social sustainability. This discrepancy could be more explained by Van Passel *et al*. (2006) who suggest that sustainability increases with age but decreases at the advanced age. This effect of age on social sustainability performances could vary with the context of farming systems the same way as sustainability is context specific.

Distance to trading centre showed a negative impact on the economic sustainability. Similar results were reported in China (Li *et al.*, 2016). This could be due to the fact that households dwelling near the trading centre have more access to inputs and outputs markets and other services, which result in increased economic sustainability performances, including productivity and income compared to the farmers in the remote areas.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The first objective was to identify indicators for assessing sustainability of smallholder dairy and traditional cattle milk production farm. The study showed that a large number of existing indicators like greenhouse gas emissions could be considered less relevant in the context of Tanzania's smallholder dairy and traditional cattle system than in other contexts. Therefore, the study showed that the set of only 29 out of 57 sustainability indicators were relevant to the studied system. The most relevant economic indicators were milk hygiene and cow productivity; social indicators were participation in organizations and women's empowerment; environmental indicators were access to water and water conservation. The indicators identified here demonstrate the importance of matching any set of indicators to the characteristics of the specific production system being examined.

Regarding the level of sustainability of the milk production farms, the results showed that the overall farm sustainability performances and its economic, social and environmental dimensions were in weak range. The economic, social and overall sustainability performances were moderate in rural production to urban consumption systems and non-sustainable in rural production to rural consumption system.

Regarding the third objective "to establish the relationships between farm and PO sustainability", it is concluded that participating in POs has a positive effect on farm sustainability performances, especially the economic and social sustainability performance dimensions. Access to dairy production inputs and services at PO level has strong positive relationships with the farm economic sustainability dimension performance and related "cow productivity, forage self-sufficiency and feed conservation" indicators.

The fourth objective aimed to analyse the factors influencing milk production farm sustainability. The results showed that the key factors of milk production farm sustainability were the stall feeding system, acquiring credit, distance to trading centre and farm size.

6.2 Recommendations

6.2.1 Promoting use of the milk production sustainability assessment tool

Sustainability is dynamic and varies among individuals, which implies that the developed tool is not static. Therefore, the tool may be improved based on the objectives and the dynamics of sustainability in order to stay adapted to the context being studied. Indeed, the framework used in this study should be easily applied to other milk production farming systems by modifying some of its components especially in developing countries where farming systems are heterogeneous.

6.2.2 Improvement of economic, social and environmental sustainability

The overall PO sustainability performance and its "dairy production inputs and service provision" dimension significantly vary with the farm economic sustainability. Therefore, building sustainable POs should be used as a strategy to improve farm sustainability especially in case of dairy inputs and services (eg. training, artificial insemination, credit and feed) provision which are difficult to access at individual level.

The stall feeding system showed a positive effect on farm economic, social and environmental sustainability. Therefore, the stall feeding system should be encouraged where applicable in order to improve economic, social and environmental sustainability. This is possible by supporting farmers in access to graded cows, training the farmers on dairy cow management, facilitate access to inputs and service provision and access to reliable milk market.

Access to credit has a positive effect on social and economic farm sustainability. Therefore, access to credit through POs should be improved in order to enhance social and economic sustainability and alleviate the issue of collateral.

The more the distance to trading centre increase, the more the economic sustainability is likely to decrease. Hence, active POs should be used to alleviate issues like access to inputs and services and limited markets which are encountered by the farmers in the remote areas.

The older household heads are likely to have more socially sustainable farms than younger. Therefore, there should be a specific program targeting the younger farmers such as providing them with dairy services such as credit and training in order to make dairy farming attractive within young generations.

Women household heads are likely to have more environmental sustainable farms than men. Hence, women should be encouraged to practice dairy farming, which is possible through facilitating access to capital especially graded breeds and embedded inputs and services including credit. Moreover, a program should be implemented to sensitise male headed households on environmentally sustainable farming practices.

6.2.5 Improvement of PO sustainability

The results showed that a number of POs were weak. Therefore, the POs in the study area should be strengthened in order to be sustainable, particularly in inputs and service provision and effective transparent leadership and management. The transparent leadership and management could be acquired via PO training on organisational skills. Indeed, the PO could be assisted in making strong linkages with inputs suppliers and reliable milk markets, and generating their own income.

6.2.6 Contribution of the Study and Suggestions for Further Research

Improving sustainability of Tanzania's milk production needs a good understanding of its sustainability status. This study contributes to the existing knowledge on sustainability assessment by developing a locally adapted tool and framework for assessing economic, environmental and social sustainability at individual milk producer farm level and sustainability at the level of producer organization. However, in this study only a rapid sustainability assessment was undertaken at the farm level using indicators with data readily available, while indicators, such as milk hygiene and use of drugs as recommended, which are difficult to measure due to their cost and data availability were dropped out. Therefore, a detailed study for complete sustainability assessment that would provide more insight on the sustainability of milk production in smallholder dairy and traditional cattle production systems in Tanzania is recommended. Moreover, further studies need to be conducted at higher level, especially at village and country levels in order to properly cover the features which are not covered at the farm level, like overgrazing and allocation of land for livestock in traditional cattle keeping systems.

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APPENDICES

Appendix 1: Monitored Household 'Types'

Location	Milk Sales to hub?	Access of inputs & services from the hub?	Membership of PO?	Household 'type'
Project Villages	No	No	No	1
	Yes	No	No	2
	No	Yes	No	3
	No	No	Yes	4
	Yes	Yes	No	5
	Yes	No	Yes	6
	No	Yes	Yes	7
	Yes	Yes	Yes	8
Non-project villages	No	No	Yes / No	9

Appendix 2: Questionnaire for Selection of Relevant On-Farm Milk Production Sustainability Assessment Indicators (1st Round)

QUESTIONNAIRE FOR SELECTION OF RELEVANT ON-FARM MILK PRODUCTION SUSTAINABILITY ASSESSMENT INDICATORS

SOKOINE UNIVERSITY OF AGRICULTURE

SURVEY ON IDENTIFICATION OF SUSTAINABILITY INDICATORS FOR SMALLHOLDER MILK PRODUCTION FARM IN MOROGORO AND TANGA REGIONS

Dear Participant,

I have the honour to invite you to participate in the survey of identifying sustainability indicators for smallholder milk production farm in Morogoro and Tanga regions. The aim of this survey is to identify and select relevant indicators that will be used to assess the sustainability of smallholder milk production farms. The identified indicators will help farmers and other stakeholders identify strengths and weaknesses to improve their practices towards sustainability in terms of economic, social and environmental dimensions.

I kindly ask you, as an expert to help me by giving your opinion on the relevant indicators that could be used to assess sustainability of smallholder milk production farms. The participation is voluntary and anonymous. I appreciate your willingness to participate in this initiative.

Instructions:

- *1st: The initial list of indicators was identified through literature review. Attribute scores to the listed indicators (From 1 to 5) according to the level of importance for sustainability of smallholder milk production farm in the study area.*

- *2nd: Propose and score additional sustainability indicators that you think could be relevant for smallholder milk production farm in the study area.*

- ***Definition**: An indicator is defined as **"a variable which supplies information on other variables which are difficult to access and can be used as a benchmark to make a decision"**.*
- ***Criteria of indicator:** An indicator must be **practicable** (easy to use, comprehensible immediately and reproducible) and **useful** (sensitive to variation, adapted to the context and relevant for end-user).*

A. PERSONAL INFORMATION

Highest education level:_______1.Primary, 2. Secondary, 3. Diploma, 4.Bachelors, 5.Masters, 6.PhD and above, 7. Other (Specify________________),

Occupation:_________ 1.Academician, 2.Livestock officer, 3.Non Government Organization, 4.Researcher, 5.Independent consultant, 6.Farmer, 7.Other (Specify___________________),

Years of experience in dairy sector:_______________________

B. IDENTIFICATION OF RELEVANT INDICATORS

- Please, rate the listed indicators using a 5-point Likert Scale:
  - **5. Highly important,**
  - **4. Important,**
  - **3. Moderately important,**
  - **2. Least important and**
  - **1. Not important**
- You may add to the bottom of each table other indicators that have not been mentioned in this table that might also be relevant.

I. ECONOMIC INDICATORS

Attribute	**Measurable Indicator**	**Importance**				
		1	**2**	**3**	**4**	**5**
Profitability	1. Net farm income from milk production per household man day					
	2. Net income per litre of milk					
	3. Benefit-cost ratio					
Production cost	4. Cost of milk production					
	5. Cost of hired labour					
Efficiency	6. Capital productivity					
	7. Labour productivity					
	8. Feed productivity					
	9. Cow productivity					
	10. Water Use Efficiency (On-Farm and irrigation of fodder crop)					
Independence (source of input)	11. Source of Capital (Own capital/Total capital)					
	12. Source of feed (Feed from own farm/Total feed used)					
	13. Source of labour (Use of own labour)					
Access to market	14. Access to input market (Feed, vet drug, etc…)					
	15. Access to milk Markets					
	16. Access to milk storage and logistics					
	17. Access to value addition					
Access to capital(dairy)	18. Access to credit					
Off-farm income	19. Proportion of income from off-farm activities					
Animal health	20. Having a vaccination programme as recommended					
	21. Prophylactic treatment program in place: Deworming and Dipping					
	22. Prevention measures of entry of disease onto the farm (eg. Quarantine)					
	23. Keep written health records					
Animal welfare	24. Animal living environment condition					
	25. Animal-Based welfare (Health, Physical appearance and behaviour)					
Genetic	26. Number of improved breeds in the farm/Total animal					
	27. Breeding system (AI/ Natural breeding)					
	28. Breeding facilities					
Add and rate other indicators you think are relevant		**1**	**2**	**3**	**4**	**5**

II. SOCIAL INDICATORS

Attribute	Measurable Indicator	Importance				
		1	2	3	4	5
Education	1. Education level of the farm manager					
Age of the farmer	2. Age of the farm manager					
Working conditions	3. Working time (number of hours/day)					
	4. Off days from work (number of days/year)					
	5. Workload distribution (sharing in Feeding, cleaning and milking)					
Gender equality	6. Women's Empowerment					
	7. Work sharing (Share between male and female)					
Knowledge and skills	8. Participation to farmer' training (Number of training attended/ year)					
Linkage to milk producers' organization	9. Participation to farmers organization					
	10. Benefit from farmers' organization					
Ownership	11. Ownership of the farm					
Milk quality and safety	12. Milk hygiene					
Farmer commitment	13. Farmer commitment to dairy keeping					
Theft	14. Cattle bandits control					
Add and rate other indicators you think are relevant		**1**	**2**	**3**	**4**	**5**

III. ENVIRONMENTAL INDICATORS

Attribute	Measurable Indicator (Unit)		Importance				
			1	2	3	4	5
Manure management	1. Proportion of manure used (Manure used as fertilizer/Biogas)						
	2. Manure storage period (Months)						
	3. Solid-liquid separation						
	Risk to water quality	4. Distance from water source/way					
		5. Type of floor surface for manure storage					
		6. Covering manure store					
		7. Runoff flowing into the manure storage area					
		8. Manure storage runoff					
		9. Animal access to water source (river, pound etc...)					
Health and safety	10. Distance between living house and manure disposal (m)						
	11. Protection during manure handling (eg. Wearing gloves)						
Global warming	12. Green house Gas emission (From rumen fermentation and manure)						
Land degradation	13. Grazing on formally demarcated grazing communal land						
	14. Livestock stocking density (Overstocking)						
	15. Soil conservation and erosion						
Land ownership	16. Land ownership (having own land for livestock)						
Water quantity	17. Water conservation/ Harvesting (water to be used in dry season)						
Existence of animal farm	18. Animal farm/Backyard production (Existence of real farm)						
Add and rate other indicators you think are relevant			**1**	**2**	**3**	**4**	**5**

C. General comment:

....

Appendix 3: Questionnaire for Selection of Relevant On-Farm Milk Production Sustainability Assessment Indicators (2nd Round)

QUESTIONNAIRE FOR SELECTION OF RELEVANT ON-FARM MILK PRODUCTION SUSTAINABILITY ASSESSMENT INDICATORS

SOKOINE UNIVERSITY OF AGRICULTURE
SURVEY ON IDENTIFICATION OF SUSTAINABILITY INDICATORS FOR SMALLHOLDER MILK PRODUCTION FARM IN MOROGORO AND TANGA REGIONS (2nd Round)

Dear Expert,

I have the honour to invite you to participate in the second round of the survey for ***identifying sustainability indicators for smallholder milk production farm in Morogoro and Tanga regions***. The aim of this survey is to identify and select relevant indicators that will be used to assess the sustainability of smallholder milk production farms. The identified indicators will help farmers and other stakeholders identify strengths and weaknesses to improve their practices towards sustainability in terms of economic, social and environmental dimensions.

Instructions:

As you will notice, this round 2 is similar to round 1. Here is how it will proceed:

1. You are asked to review and rate the exact same as you did in round 1.
2. For each indicator, you are provided with your individual round one rating. You will then compare your round 1 rating with the rating assigned by the group. To perform this comparison, you will use from round 1, two statistical tendency (Median: Me and mean: $\bar{X}$) and statistical dispersion (Standard deviation: SD).
3. You are invited to either keep the same rating by indicating your previous choice in this new round, or revise your previous rating by choosing a new response after comparing your rating with the rating of the group.
4. You are also requested to rate the indicators proposed by experts according to their importance, the same as you did in the first round.

   Thank you again for your participation

- ***Definition****: An indicator is defined as* ***"a variable which supplies information on other variables which are difficult to access and can be used as a benchmark to make a decision"****.*
- ***Criteria of indicator:*** *An indicator must be* **practicable** *(easy to use, comprehensible immediately and reproducible) and* **useful** *(sensitive to variation, adapted to the context and relevant for end-user).*

A. PERSONAL INFORMATION

Participant number	

B. IDENTIFICATION OF RELEVANT INDICATORS

Use 5-point Likert Scale to re-rate each indicator after comparison between your rating and the rating of the group from round 1:

- **5. Highly important.**
- **4. Important.**
- **3. Moderately important.**
- **2. Least important and**
- **1. Not important.**

I. ECONOMIC INDICATORS

		Standard deviation	Group Median	Group mean	Your rating in round 1	Importance				
Attribute/Issue	**Measurable Indicator**	**SD**	**Me**	**x̄**	**Xi**	**1**	**2**	**3**	**4**	**5**
Profitability	1. Net farm income from milk production per household man day	0.7	4.5	**4.1**	**3**					
	2. Net income per litre of milk	1.0	5.0	**4.4**	**5**					
	3. Benefit-cost ratio	1.1	4.0	**4.1**	**4**					
Production cost	4. Cost of milk production	1.0	4.5	**4.3**	**4**					
	5. Cost of hired labour	1.1	4.0	**3.8**	**2**					
Efficiency	6. Capital productivity	0.9	4.0	**4.1**	**5**					
	7. Labour productivity	0.9	4.0	**3.9**	**4**					
	8. Feed productivity	1.2	4.5	**4.1**	**2**					
	9. Cow productivity	1.0	5.0	**4.4**	**5**					
	10. Water Use Efficiency (On-Farm and irrigation of fodder crop)	1.4	3.5	**3.5**	**2**					
Independence (source of input)	11. Source of Capital (Own capital/Total capital)	1.1	4.0	**3.9**	**3**					
	12. Source of feed (Feed from own farm/Total feed used)	1.1	4.0	**4.0**	**3**					
	13. Source of labour (Use of own labour)	0.9	4.0	**3.7**	**2**					
Access to market	14. Access to input market (Feed, vet drug. etc…)	1.2	4.0	**4.1**	**4**					
	15. Access to milk Markets	0.9	5.0	**4.5**	**5**					
	16. Access to milk storage and logistics	1.0	4.5	**4.2**	**5**					
	17. Access to value addition	1.3	4.0	**3.7**	**5**					
Access to capital	18. Access to credit (Dairy)	1.1	4.0	**4.0**	**5**					
Off-farm income	19. Proportion of income from off-farm activities	1.0	3.0	**3.6**	**2**					
Animal health	20. Having a vaccination programme as recommended	1.0	5.0	**4.4**						
	21. Prophylactic treatment program in place: Deworming and Dipping	0.8	5.0	**4.3**	**2**					
	22. Prevention measures of entry of disease onto the farm	1.0	4.5	**4.1**	**3**					
	23. Keep written health records	1.2	4.0	**4.1**	**3**					
Animal welfare	24. Animal living environment condition	0.9	4.0	**4.1**	**2**					
	25. Animal-Based welfare (Health. Physical appearance and behaviour)	0.9	4.0	**3.9**	**2**					
Genetic	26. Number of improved breeds in the farm/Total animal	0.9	4.0	**4.1**	**3**					
	27. Breeding system (AI/ Natural breeding)	1.1	4.0	**4.1**	**3**					
	28. Breeding facilities	1.1	4.0	**3.6**	**3**					
Proposed indicators[1]	29. Access to water									
	30. Identification of animals (Ear tags)									
	31. Conservation of feed during the dry season									
	32. Ability to invest									
	33. Calf mortality									
	34. Farm record keeping									
	35. Seasonal feeding programs									
	36. Separation of seek animals in the farm									
	37. Use of drugs as recommended by Tanzania food and drug authority									
	38. Observation of withdrawal period									
	39. Availability of vet service									

[1] The indicators were proposed by experts during the first round. You are requested to score them according to their importance. the same as you did in the first round.

II. SOCIAL INDICATORS

Attribute/Issue	Measurable Indicator	Standard deviation SD	Group Median Me	Group mean x̄	Your rating in round 1 Xi	Importance 1	2	3	4	5
Education	1. Education level of the farm manager	1.2	3.5	**3.9**	**3**					
Age	2. Age of the farm manager	1.3	3.0	**3.3**	**4**					
Working conditions	3. Working time (number of hours/day)	1.2	4.0	**3.8**						
	4. Off days from work (number of days/year)	1.2	4.0	**3.4**	**1**					
	5. Workload distribution	1.2	3.5	**3.8**	**2**					
Gender equality	6. Women's Empowerment index[2]	1.0	4.0	**4.1**						
	7. Work sharing (Share between male and female)	1.2	4.0	**3.9**	**3**					
Knowledge and skills	8. Participation to farmer' training	1.2	4.0	**3.8**						
Linkage to milk producers' organization	9. Participation to farmers organization	1.1	4.0	**4.0**	**3**					
	10. Benefit from farmers' organization	1.2	4.5	**3.9**	**3**					
Ownership	11. Ownership of the farm	0.9	4.0	**4.1**	**4**					
Milk quality and safety	12. Milk hygiene	0.9	5.0	**4.5**	**4**					
Farmer commitment	13. Farmer commitment to dairy keeping	1.0	5.0	**4.4**	**5**					
Theft	14. Cattle bandits control	1.0	5.0	**4.1**	**5**					
Proposed indicator[3]	**15. Reliable and trustworthy worker**	-	-	-	-					

III. ENVIRONMENTAL INDICATORS

Attribute		Measurable Indicator	Standard deviation SD	Group Median Me	Group mean x̄	Your rating Xi	Importance 1	2	3	4	5
Waste management		19. Proportion of manure used (fertilizer/Biogas)	1.2	4.0	**3.7**	**3**					
		20. Manure storage period (Months)	1.2	3.0	**3.3**	**3**					
		21. Solid-liquid separation	1.3	3.0	**2.8**						
	Risk to water quality	1. Distance from water source/way	1.1	4.0	**4.1**	**5**					
		2. Type of floor surface for manure storage	1.2	4.0	**3.3**	**2**					
		3. Covering manure store	1.2	4.0	**3.2**						
		4. Runoff flowing into the manure store	1.2	3.0	**3.3**	**2**					
		5. Manure storage runoff	1.3	4.0	**3.5**	**1**					
		6. Animal access to water source (river. pound etc.)	1.4	4.0	**4.0**	**5**					
Health and safety		7. Distance between living house and manure disposal (m)	1.2	4.0	**3.7**	**3**					
		8. Protection during manure handling (eg. Wearing gloves)	1.2	4.0	**3.3**	**1**					
Global warming		9. Green house Gas emission	1.2	3.0	**3.2**						
Land degradation		10. Grazing on formally demarcated grazing communal land	1.4	3.5	**3.6**	**3**					
		11. Livestock stocking density (Overstocking)	1.5	5.0	**3.9**	**3**					
		12. Soil conservation and erosion	1.3	5.0	**4.0**						
Land ownership		13. Land ownership (having own land for livestock)	1.0	4.0	**4.3**	**5**					
Water quantity		14. Water conservation/ Harvesting	1.1	5.0	**4.3**	**5**					
Existence of farm		15. Animal farm/Backyard production (Existence of real farm)	1.3	4.0	**3.7**	**5**					
Proposed indicator[4]		**16. Topographic manoeuvre**	-	-		-					

[2] Production. resources. income leadership and time

[3] and [4]. The indicators were proposed by experts during the first round. You are requested to score them according to their importance. the same as you did in the first round.

General comment:

Appendix 4: Farm questionnaire

1. Farm level sustainability

More Milk in Tanzania (MoreMilkiT)
Project Monitoring Survey – August2016
Household Monitoring Questionnaire (Jan-July2016)
International Livestock Research Institute (ILRI)
Sokoine University of Agriculture (SUA)

A. General Identification

A.1 Household ID (to be used in subsequent surveys)	
GPS Coordinates	Latitude (N/S): Longitude (W/E):
Distance of household from nearest trading center (km)	
A.2Date of interview (DD/MM/YY)	
A.3Enumerator name	
A.4Respondent name	
A.5 Respondent sex (0= Male; 1 = Female)	
A.6Relationship to household head (1 = Head; 2 = Spouse; 3 = Son; 4 = Daughter; 5 = Other (specify)	
A.7Village	
A.8 Farmer group name (if any)	
A.9District	

B. Household composition and demographics

A household includes all members of a common decision making unit (usually within one residence) that share income and resources. Include workers or servants as members of the households.

B.1 Household Register									
ID code	Name	Sex 0 = Male 1 = Female	Age in Years	Relation to head See code below	Marital status See code below	Years of schooling	Months living at home in last 12 months	Occupation (*more than one occupation allowed*)	Is the household member knowledgeable about the household's production activities and resources 0=No, 1=Yes
B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**

Code for B5: 1 = Head; 2 = Spouse; 3 = Son; 4 = Daughter; 5 = Other (specify)
Code for B6: 1 = Single; 2 = Married; 3 = Separated; 4 = Divorced; 5 = Widowed
Code for B9: 1 = Crop farming; 2 = Livestock & poultry keeping (incl. sales); 3 = Trading in livestock and livestock products (not own); 4 = Trading in agricultural products (excluding livestock!) (not own produce); 5 = Formal Salaried employee (e.g. civil servant, domestic work); 6 = Business – trade / services (non-agric.); 7 = Not working / unemployed; 8 = Old/Retired; 9 = Infant (<6 years) 10 = Student/ pupil; 11 = Disabled; 12 = Other (specify)

C. Agricultural Assets: Value, Ownership and Access

a. Land

Plot ID	Plot Description / Name	Size of this plot (acres)	Tenure system (code)	If plot **is *owned,*****who owns (code**)**	If rented, rent value (TZS/year)
1					
2					
3					
4					

Plot description code	**Tenure system**	**Plot owner**
1. = Homestead 2. = Cash crop 3. = Food crop 4. = Fodder crop 5. = Grazing land	1. = Owned with title 2. = Owned without title 3. = Communal/public 4. = Rented in 5. = Rented out	1. = HH head 2. = Spouse 3. = Joint (HH head & spouse) 4. = Other male 5. = Other female 6= Others (specify) ________________

** Ownership means the one who decides on how the land is used

a. Livestock

6. How have the numbers of cattle changed over the last six months (increased, static, decreased)
7. Why have these changes in numbers taken place?
8. **Cattle owned -** *enter details for each cattle separately*

Cattle type (codes)	Breed (0 = local; 1 = exotic/cross)	Number owned by male	Number owned by female	Number owned jointly	Total number owned by household

Cattle type code		
1. Bulls (> 3 years) 2. Castrated adult males (oxen> 3 years) 3. Immature males (<3 years)	4. Cows (calved at least once) 5. Heifers(female ≥1yr,have not calved) 6. Female calves (between 8 weeks &<1yr)	7. Male calves (between 8 weeks &<1yr) 8. Pre weaning males (<8 weeks) 9. Pre weaning males (<8 weeks)

** Ownership means the one who decides on purchase and sale of respective animal and the use of proceeds from that animal

b. Cattle Exit: Has any cattle exited the household in the last six (6) months? (0=No, 1=Yes)

If yes, enter details for each cattle exit in last six (6) months - enter details for each cattle separately

Months Cattle Exit	Type of Exit	Cattle type (code)	Breed (0 = local; 1 = exotic/cross)	**If Sold**	
				Average price of cattle	Who decided on how the money was used?
Months	**Type of Exit**	**Cattle type codes**			**Who receives and decides how money is used**
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 2016 6.Jun 2016	1.Sale 2.Death 3.Given as a gift 4.Stolen 5.Slauthered for home consumption 6.Culling 7.TemporaryTransfered	1. Bulls (> 3 years) 2. Castrated adult males (oxen> 3 years) 3. Immature males (<3 years) 4. Cows (calved at least once) 5. Heifers(female ≥1yr,have not calved) 6. Female calves (between 8 weeks &<1yr) 7. Male calves (between 8 weeks &<1yr) 8. Pre weaning males (<8 weeks) 9. Pre weaning males (<8 weeks)			1. HH male 2. HH female 3. Joint HH (male & female) 4. Non-household member 5. Other (specify)_____ ____________ ________

i. Cattle Entry: Have you added any cattle to your herd in the last six (6) months? (0=No, 1=Yes)

If yes, enter details for each cattle purchased in last six (6) months – *enter details for each cattle separately*

Month cattle added	Type of entry	Cattle type (code)	Breed (0 = local; 1 = exotic/cross)	If purchased		
				Average price of cattle (TZS)	Number purchased	Who contributed the money used?

Months	**Entry**	**Cattle type codes**	**Who contributed the money is used to purchase cattle**
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	1.Purchase 2.Gift 3.Birth	1. Bulls (> 3 years) 2. Castrated adult males (oxen> 3 years) 3. Immature males (<3 years) 4. Cows (calved at least once) 5. Heifers(female ≥1yr,have not calved) 6. Female calves (between 8 weeks &<1yr) 7. Male calves (between 8 weeks &<1yr) 8. Pre weaning males (<8 weeks) 9. Pre weaning males (<8 weeks)	1. HH male 2. HH female 3. Joint HH (male & female) 4. Non-household member 5. Other (specify)____________

i. **Other livestock owned**

Livestock Species		Number owned by male	Number owned by female	Number owned jointly	Number owned by the household (total)
Goats	Local				
	Cross/ exotic				
Sheep	Local				
	Cross/ exotic				
Poultry	Local				
	Exotic				
Pigs	Local				
	Cross/ exotic				
Donkeys/Horses					
Rabbits					
Other, specify					

** Ownership means the one who decides on when to sell or purchase the livestock and how and for what the respective livestock is used

ii. **Sale of other livestock: Have you sold any other livestock (other than cattle) in the last six (6) months? (0=No, 1=Yes)**

If yes, enter details of other livestock sold in last six (6) months

Livestock Species	Number sold	Sales value	Who decided on how money was used (code)
Goats			
Sheep			
Poultry			
Pigs			
Donkeys/Horses			
Rabbits			
Other, specify			

Who received and decided how money was used?	
1. HH male 2. HH female 3. Joint HH (male & female)	4. Non-household member 5. Other (specify)__________________________

iii. **Purchase of other livestock: Have you purchased any other livestock (other than cattle) in the last six (6) months? (0=No, 1=Yes)**

iv. (Enter details of other livestock purchased in last six (6) months - *enter details for each cattle separately*)

Livestock Species	Number purchased	Sales value (TZS)	Who contributed the money used (code)
Goats			
Sheep			
Poultry			
Pigs			
Donkeys/Horses			
Rabbits			
Other, specify			
Who contributed the money used to purchase livestock?			
1. HH male 2. HH female 3. Joint HH (male & female)			4. Non-household member 5. Other (specify)_______________________

D. Milk Production: Supply, Input use and Technology Adoption

d. Milk production

a. Have you been milking any cows in the last six months? [__] 1=Yes; 0 = No

b. If yes, please enter details for average milk production for**10cows milked** during the **last six (6) months**.

	cow 1	**cow 2**	**cow 3**
Average milk production per day (AMD)			
Milk production at calving (*morning and evening milk*)			
Milk production at peak (if known) (*morning and evening milk*)			
Milk production yesterday (*morning and evening milk*)			
Milk production at late lactation (*morning and evening milk*)			
Lactation length (**number of months** cow is milked between 2 calvings)			
When did the cow calve down (give birth)? *(MM/YY)*			
Breeding method used for the last calving [1=Own bull 2=Other bull 3= AI]			
Number of services (repeats) before conception for this service			

Months when milk was *produced* in the last six (6) months (*please tick*)					
Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	Dec 2014

c. Milk production

Month milk produced	Number of cows milked	Average volume produced per day	Average selling price
Months			
1. Jan 2016 2. Feb 2016	3. Mar 2016 4. Apr 2016	5. May 016 6. Jun 2016	

d. Use of milk for yesterday's/last milk production

Months milk utilized	**Category of yesterday milk production**	**Quantity (liters)**
	Liters used/consumed by household	
	Liters of fresh milk sold (morning and evening milk)	
	Liters lost due to spoilage/spillage on farm	
Months		
1. Jan 2016 2. Feb 2016	3. Mar 2016 4. Apr 2016	5. May 016 6. Jun 2016

e. Sale of fresh milk for yesterday's/last sale milk production(if litres sold~=0)

	Morning milk			**Evening milk**		
	Buyer 1	**Buyer 2**	**Buyer 3**	**Buyer 1**	**Buyer 2**	**Buyer 3**
Type of buyer (code)						
Name of buyer						
Gender of buyer 1 = |Female; 0 = Male						
Quantity sold to buyer (liters)						
Price received (TZS/liter)						
Who decides on how money from buyer is used?						
Inputs/goods/services received from buyer						
Distance to buying point						
Who transports						
Transport cost if any						
Payment method						

Months when milk was *sold* in the last six (6) months (*please tick*)

Jan 2016	Feb 2016	Mar 2016	April 2016	May 2016	June 2016

Buyer	**Who receives and decides how money is used?**	**Inputs or goods on credit**	**Who transports**	**Payment**
1. = Individual consumers 2. = Private milk-traders 3. = Dairy co-op/ group with chilling plants 4. = Dairy co-op/ group without chilling plants 5. = Privatively owned chilling plants 6. = Other (specify)_______	1. HH male 2. HH female 3. Joint HH (male & female) 4. Non-household member 5. Other (specify)________	1. = None 2. = Buyer provided access to feed on credit 3. = Buyer provided access to animal health services on credit 4. = Buyer provided access to breeding services on credit 5. = Buyer provided access to household goods on credit 6. = Other (specify) ______	1. = Farmer 2. = Hired transport, organised by farmer **3.** = Hired transport, organised by Coop/ FG/trader **4.** = other, (specify)__________	1. = cash, no delay in payment 2. = at end of month, no delay 3. = at end of month, has experienced delay 4. =Bank/Mobile banking 5. =SACCO 6. =Other (specify)_______

f. Sale of fermented milk yesterday/last sale if aside by household for **fermentation is ~=0**

	Morning milk			**Evening milk**		
	Buyer 1	**Buyer 2**	**Buyer 3**	**Buyer 1**	**Buyer 2**	**Buyer 3**
Buyer (code)						
Buyer name						
Quantity sold to buyer (liters)						
Price received (TZS/liter)						
Who receives and decides how money is used						
Inputs/goods/services received from buyer						
Distance to buying point						
Who transports						
Transport cost if any						

Payment method						

Months when milk was *sold* in the last six (6) months (*please tick*)

Jan 2016	Feb 2016	Mar 2016	April 2016	May 2016	June 2016

Buyer	**Who receives and decides how money is used?**	**Inputs or goods on credit**	**Who transports**	**Payment**
1. = Individual consumers 2. = Private milk-traders 3. = Dairy co-op/ group with chilling plants 4. = Dairy co-op/ group without chilling plants 5. = Privatively owned chilling plants 6. = Other (specify)_______	1. = HH male 2. = HH female 3. = Joint HH (male & female) 4. = non-household member 5. = Other (specify)__________	1. = None 2. = Buyer provided access to feed on credit 3. = Buyer provided access to animal health services on credit 4. = Buyer provided access to breeding services on credit 5. = Buyer provided access to household goods on credit 6. = Other (specify) ______	1. = Farmer 2. = Hired transport, organised by farmer **3.** = Hired transport, organised by Coop/ FG/trader **4.** = other, (specify)__________	1. = cash, no delay in payment 2. = at end of month, no delay 3. = at end of month, has experienced delay 4. =Bank/Mobile banking 5. =SACCO 6. =Other (specify)_______

E. Input Use, Costs and Technology Adoption

e. Feeding system

Type of cattle	**Rainy season (code)**	**Dry season (code)**
Local (if breed in C2=Local)		
Cross and/or grade (if breed in C2=Cross)		

Feeding system code	
1. = Only grazing (free-range or tethered) 2. = Mainly grazing with some stall feeding 3. = Mainly stall feeding with some grazing	4. = Only stall feeding (zero grazing) 5. = On transhumance, some animals 6. = On transhumance, all animals

f. Water for cattle

Watering point	For off farm watering **distance** to watering point	For on-farm watering; **source of water**	Do you have enough water for your animals throughout the year [1=yes; 0=No]	If surface water, do you let animals access to water source (river) directly[1=yes; 0=No]
Watering point	**Distance to watering point**	**Source of water**		

1. Off-farm 2. On-farm 3. Both	1. <1 kms 2. 1-2 kms 3. 3-4 kms 4. 5-7 kms 5. 8+ kms	1. = No irrigation 2. = Ground water 3. = Surface water, i.e. dam, river or lake 4. = Piped water 5. = other _____

g. Grown fodder

1. Besides grazing/harvested grass from forest/roadside/farm, do you currently grow any improved fodder? [__] 1= Yes; No =0

2. If yes, please provide the following details for each fodder type grown.

Months fed	Grown fodder type fed	Quantity fed per day in last (6) months			Any treatment before feeding? (code)
		Cattle fed (code)	Unit	Quantity	

Months	**Fodder type/pasture**	**Cattle fed**
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	1. = Napier grass 2. = Planted grasses e.g. Rhodes grass 3. = Fodder maize 4. = Fodder shrubs (Calliandra, Sesbania, Lucaenia) 5. = Other fodder legumes (Desmodium, lucern, vetch) = Other (specify) [__]	1. = All 2. = Cows only 3. = Lactating cows only 4. = Calves only 5. = Other (specify) ___________

Measurement unit	**Treatment**
1. Kg 2. Tones 3. Bales 4. Handcart/wheelbarrow 5. Standar sack 6. Other (specify) __________________	1. = No treatment 2. = Stored standing 3. = Cut and stored loose 4. = Chopped using panga 5. = Hand chopped using chaff cutter 6. = Motorized chopping using a pulverizer 7. = Ensiled in situ without additives 8. = Chopped and ensiled with additives (urea, molasses etc.) 9. = Chemical treatment 10. = Other (specify) ______________________

3. If no, what are the possible reasons for not growing fodder? [__]; [__]; [__]

Reasons for not growing improved fodder	
1. = Lack of land 2. = Lack of knowledge on how to grow fodder 3. = I have enough forage for my cattle	4. = Lack of labour to undertake fodder production 5. = No reason 6. = Other (specify) ____________________

h. Purchased fodder

1. Have you been purchasing fodder to feed cattle in the last six months (since September last year to now)? [__] Yes = 1; No = 0

2. If yes, in which of the last six (6) months did you purchase fodder? *Tick accordingly*

3. For **each month selected** above please enter the following details.

Month when purchased	Fodder type	Cattle type fed?	Monthly cost during months when purchased	Where purchased?

			Unit	Qnty	Price/unit	(code)

	Fodder type	Cattle fed
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	1. = Napier grass 2. = Planted grasses e.g. Rhodes grass 3. = Fodder maize 4. = Fodder shrubs (Calliandra, Sesbania, Lucaenia) 5. = Other fodder legumes (Desmodium, lucern, vetch) 6. = Other (specify)___________________	1. = All 2. = Cows only 3. = Lactating cows only 4. = Calves only 5. = Other (specify) ____________
	Measurement unit	**Where purchased?**
1. Kg **2.** Tones **3.** Bales **4.** Handcart/wheelbarrow **5.** Standard sack **6.** Other (specify) __________________		1. = Other farmers 2. = Market, trader 3. = Supplier affiliated to farmer group 4. = Other (specify) ___________

i. Crop residues

1. Do you use crop residues? [__] Yes = 1; No = 0
2. If yes, in which of the last six (6) months did you use crop residues?
3. For every month selected above please enter the following details.

Month(s) used	Crop residue	Cattle type fed?	Source: 1=Own farm; 2=Other farm; 3=Purchased	If purchased			
				Monthly cost during months when purchased			Where purchased? (code)
				Unit	Qnty	Price/unit	

Months	Crop residues	Animal fed
1. Jan 2016 2. Feb 2016 3. Mar2016 4. Apr 2016 5. May 016 6. Jun 2016	1. = Green/dry maize stovers and thinning 2. = Cereal(wheat, barley, rice etc.) straws and millet, sorghum stalks 3. = Legumes (beans, cowpeas, soya etc.) 4. = Root and tubers peelings (potato, cassava, bananas etc) 5. = Crop by products (sweet potato vines, cassava leave etc.) 6. = Other (specify) _________________	0. = All 1. = Cows only 2. = Lactating cows only 3. = Calves only 4. = Other (specify) ____________
	Measurement unit	**Where purchased?**
1. Kg 2. Tones 3. Bales 4. Handcart/wheelbarrow 5. Standard sack 6. Other (specify) __________________		**1.** = Other farmers **2.** = Market, trader **3.** = Supplier affiliated to farmer group **4.** = Other (specify) ___________

j. Concentrates

1. Do you use concentrates? [__] Yes = 1; No = 0
2. If yes, in which of the last six (6) months did you use concentrates?
3. For every month selected above please enter the following details.

Month(s) used	Concentrate	Cattle type fed?	Source: 1=Own farm; 2=Other farm;	If purchased	
				Monthly cost during months when purchased	Where purchased?

			3=Purchased				(code)
				Unit	Qnty	Price/unit	

months	**Concentrate type**	**Cattle fed**
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	1. = Commercial dairy meal 2. = Mineral blocks 3. = Bran (Maize, wheat) 4. = Maize germ 5. = Oilseed by-product (Sesame seed, cotton seed, copra, sunflower etc.) 6. =Agro industrial byproducts (vegetable waste, brewer's waste etc.) 7. = Other (specify) _____________________	1. = All 2. = Cows only 3. = Lactating cows only 4. = Calves only 5. = Other (specify) ___________
Measurement unit		**Where purchased?**
1. Kg 2. Tones 3. Bales 4. Handcart/wheelbarrow 5. Standard sack 6. Other (specify) __________________		1. = Agro vet shop 2. = Other farmers 3. = Market, trader 4. = Posho mills (*Mashineyakusaga*

g. Have you experienced a shortage of feeds in the last six months [1=yes 0=No]

h. Do you practice feed conservation for the dry season [1=yes 0=No]

i. Is it enough to cover for the six months [1=yes 0=No]

7. Breeding services and expenses

Months		**Own bull service**	**Other bull service**	**AI service**
	How many times have you used this service			
	What is the average cost per service?			
	Which are your preferred breeding methods? (Tick as accordingly)			
	Reasons for preference	[___] [___]	[___] [___]	[___] [___]
	If you wanted to breed/serve your cow can you find and use this method? (0= NO; 1=YES)			
	If yes, How many times have you used this service in the last six (6) months?			
	Reasons for use /non-use of method ***	[___] [___]	[___] [___]	[___] [___]
	How many different service providers can you access for this type of service			
	Who are the providers that you can access			
	What is the distance from your farm to the service providers/bull owner?		Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]

	Which breeding method don't you like? (Tick accordingly)			
	Reasons for dislike ***	[___] [___] [___]	[___] [___] [___]	[___] [___] [___]
	Reasons for preference/use of method	**Service provider**		
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	1. Cheap 2. Easily accessible (provider can easily be reached) 3. Readily available when cow is one heat 4. Higher success rate 5. Offers calf with desirable traits 6. Offers access to wide variety of breeds 7. Frequently gives female calves 8. Offers access to sires with known history 9. Helps to avoid inbreeding 10. Other (specify) _____________ 11. 99 (N/A)	1. Other farmers 2. Community bull (bull scheme) 3. Private AI provider 4. Government/public AI provider 5. Project/NGO AI provider 6. Coop/AI provider 7. 99 (N/A) Other (specify) ________		
Reasons for non-use/dislike of method				
1. Expensive 2. Not easily accessible 3. Not readily available 4. Low success rate 5. Produces poor quality calf		6. Limited access to variety of reeds 7. Frequently gives male calves 8. Unknown sire history 9. Encourages inbreeding 10. Other (specify) _______________ 11. 99 (N/A)		

8. Animal health services and expenses

month		Anthelmintic (deworming)	Tick control (spraying/dipping)	Vaccination	Curative treatment	Other (specify)
	Is the service available? (0= NO; 1=YES)					
	How many times have used this service in this month					
	What was the average cost per service					
	Type of cattle treated/given the service in last six (6) months (code)					
	If lactating cow, for how l					
	Who provided the service?	Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]
Months	**Type of cattle**		**Service provider**			

1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	1. = All 2. = Cows only 3. = Lactating cows only 4. = Calves only 5. = Other (specify)___________	1. = Self/ Neighbour with professional advice 2. = Self/ Neighbour without professional advice 3. = Animal health service provider/para-vet 4. = Government veterinarian5= Project/ NGO staff 5. = Coop/ group staff 6. = Agro-vet shop 7. = Community dip 8. = Other (specify) __________________

F. Labour use and expenses

4. **Monthly labour: Have you employed any monthly labourer(s)**in the last six (6) months (between January and now)? (0=No 1=Yes), if yes, enter the following details

	Months	**Name of labourer**	**Gender of labourer 0 = Male 1 = Female**	**Average working hours per day on dairy**	**Monthly wage**
1					
2					
3					
Months					
1. Jan 2016 2. Feb 2016		3. Mar 2016 4. Apr 2016		5. May 016 6. Jun 2016	

5. **Casual labour: Have you employed any casual labourer(s)**in the last six (6) months (between January and now)? (0=No 1=Yes), if yes, enter the following details:-

	Months	**Name of labourer**	**Gender of labourer 0 = Male 1 = Female**	**Average working hours per day on dairy**	**Total Amount paid**
1					
2					
3					
Months					
1. Jan 2016 2. Feb 2016		3. Mar 2016 4. Apr 2016		5. May 016 6. Jun 2016	

6. **Household labour: Employed household labour** in the last six (6) months (since September to now)? (0=No 1=Yes), if yes, enter the following details:

Type of Activity	Household							Freq. (code)
	Adult Males		Adult Females		Children (< 15 yrs)			
	No. people	Hrs/person/day	No. people	Hrs/person/day	No. people	Gender M/F	Hrs/person/day	
1. Grazing								
2. Feeding (+								
3. Fodder/feed								
4. Providing water to								
5. Cleaning of animal								
6. Collection of Farm								
7. Milking and milk								
8. Selling milk								
9. Selling animals/								
10. Crop production								

11. Other: [								
Frequency of activity code								
1. [___] per day	2. [___] per week	3. [________] per	4. [_____] per year					

G. Participation in Farmer Group and Dairy Market Hub

a. **Do any household member belong to a Farmer Group?**: (0=No 1=Yes), if YES, Enter details below:-

Who is a member of a group	Group name	Type of group	When did the HH join the group? (mm/yyyy)	Two (2) main function that this group performs for you
HH male				
HH female				

Type of groups (main function)	**Main functions of group to HH member**
1. Social/ welfare & community development groups 2. Savings and credit groups/Sacco 3. Agricultural producer groups 4. Livestock producer groups 5. Agricultural marketing groups 6. Livestock marketing groups 7. Other (specify) ______________________	1. Provides access to milk market 2. Provides access to inputs and services for dairy 3. Provides training/ advisory for dairy 4. Provides access to market for crops 5. Provides access to inputs and services for crops 6. Provides training/ advisory for crops 7. Provides ways to save money and get credit 8. Social functions and networking 9. Other (specify) ________________

(include all household members who belong to a group. Membership in more than one group is possible)

b. For farmer group affiliated to the dairy management hub

a. Dairy management hub

Does household member hold position of responsibility in the group? 1=Yes; 0=No	
Gender of household member who holds position of responsibility in group 1=M; 0=F	
How did you learn about the group?	
How many times has the HH participated in group meetings in the last six months	

Learn about the group	
1. Other group member 2. Household member 3. Heifer/Faida Mali	4. District livestock officer 5. Local government representative 6. Other (specify) __________________

Dairy Training

a. Have you ever attended any training about dairying during the last six months (1=yes; 2=No)

If yes how many times in the last six months [______]

b. Participation in Dairy Market Hub

i. For each of the following services received, indicate the service provider, mode of engagement and the payment mode used. (*More than one service provider allowed for every service type; hence more than one type of engagement and payment mode also allowed).*

Service	Service provider (code)	Mode of engagement (code)	Payment mode (code)
1. Feed supply			
2. Other input supply			
3. Animal healthcare			
4. Breeding service			
5. Extension advice			
6. Milk purchase			

7. Milk transport			
8. Credit provision			
9. Savings services			
10. Other (specify) ________			

Service provider	Mode of engagement	Payment mode
1. Agro-vet/input supplier 2. Vet/AHA 3. Milk trader 4. Milk transporter 5. Chilling plant 6. Extension officer 7. SACCO 8. Microfinance 9. Bank 10. Community/NGO staff 11. Other (specify) _______________	1. Individually 2. Through group linked to BDS__________(Specify farmer group)	1. Cash 2. Credit 3. Check-off

ii. For each **serviceand service provider** selected above, please provide the frequency and value of transaction for the last six (6) months.

	Jul		Aug		Sep		Oct		Nov		Dec	
	Freq	TZS	Freq	TZS	Freq	TZS	Freq	TZS	Freq	TZS	Freq	TZS
Feed supply												
Other input supply												
Animal healthcare												
Breeding services												
Extension advice												
Milk purchase												
Milk transport												
Credit provision												
Savings												
Others (specify) __________												

H. Credit: Access and Utilization

a. Has any household member been in need of credit in the last 6 months? 0 = No; 1 = Yes [__]

b. Has any member of your household received credit in the last 6 months? 0 = No; 1 = Yes [__]

c. If yes, enter details for all loans/credit obtained by any household member in last six (6) months

Who received credit? (code)	Source of credit	Reason for credit	Amount received (TZS)	Repayment period (months). If period is not specified, use 99	Interest charged on loan	Did the loan require collateral? 0 = No; 1 = Yes	Type of collateral

Who received credit?	Source of credit	Reason for credit	Type of collateral
1. HH male 2. HH female 3. Joint HH (male & female) 4. Non-household member	1. Local micro-credit bank 2. Relative 3. Friend 4. Input supplier 5. Milk	1. HH expenditure (food, education, health etc.) 2. Investment in crop production 3. Investment in livestock production	1. Livestock 2. Land 3. HH item 4. Crop harvest 5. Milk sales

5. Other (specify)________	trader/transporter 6. Milk processor 7. Other (specify) _______	4. Purchase of fixed assets (e.g., land) 5. Repay another loan 6. Other (specify) _________	6. Other (specify) __________

I. Household Income

i. Crop income

1. **Crop revenue**: For all crops **harvested** in the last six (6) months, please enter the following details.

Crops	Total Output	Units (code)	Quantity consumed by household	Quantity sold	Average price/unit (TZS)
A. Potatoes					
B. Maize					
C. Beans					
D. Tomatoes					
E. Onions					
F. Vegetables					
G. Yams					
H. Tea					
I. Coffee					
J. Bananas					
K. Other (specify)					
Measurement units					
1. Kgs 2. Standard sack 3. Bunches			4. Pieces 5. Other (specify) __________________		

Cost of producing crops: For all crops **planted** in the last six (6) months, please enter the following details.

Crop	Land rent	Cost of inputs for all plots (TZS)					
		Seeds	Fertilizer	Manure	Pesticide	Machinery for land preparation	Other (specify) _____________
Potatoes							
Maize							
Beans							
Tomatoes							
Onions							
Vegetables							
Yams							
Tea							
Coffee							
Bananas							
Other							

ii. Income from cattle products (products other than milk) and services

1. Sale of cattle products other than dairy products: Do you sell cattle products other than milk and other dairy prducts? (0=No 1=Yes), if YES, enter details below:-

	Number sold in last six (6) months	Unit (code a)	Average price per unit*	Who received and decided how money was used? (code)
Manure				
Hides and Skins				
Others (specify)				
Units		**Who receives and decides how money is used**		

1. Piece 2. Kgs 3. Other (specify) _______________	1. HH male 2. HH female 3. Joint HH (male & female) 4. Non-household member 5. Other (specify)_____________________

2. Sale of cattle services: Do you sell cattle services? (0=No 1=Yes), if YES, enter details below:-

Services	No of services in last six (6) months	Revenue received	Who received and decided how money was used? (code)
Bull services			
Draft power			
Other (specify)			
Who receives and decides how money is used			
1. HH male 2. HH female 3. Joint HH (male & female)	4. Non-household member 5. Other (specify)_____________________		

3. **Other income sources: Any other income source(s) in the last 6 months?** (0=No 1=Yes), if YES, enter details below:-

Income Source	Did anyone in the household earn income from source in last six (6) months? (0 = no, 1 = yes)	Who mainly earns income from this source? (code)	Total HH income in last six (6) months
H. Trading in livestock and livestock products (**not own produce**)			
I. Trading in milk, feeds and other livestock products (**not own produced**)			
J. Trading in agricultural products (excluding livestock!) (**not own produce**)			
K. Formal salaried employment (non-farming, e.g. civil servant, private sector employee, domestic work in other home)			
L. Business – Trade or services (non-agricultural)			
M. Working on other farms (including herding)			
N. Sale of products of natural resources (forest and sea/rivers products)			
O. Pensions			
P. Rent out land / sharecropping (cash value of share crop or rent)			
Q. Remittances			
R. Other (specify) ________________________			
Who earns/controls money from this source			
1. HH male 2. HH female 3. Joint HH (male & female)	4. Non-household member 5. Other (specify)_____________________		

Appendix 5: Determination of indicator weights using principal components analysis

I. Economic sustainability

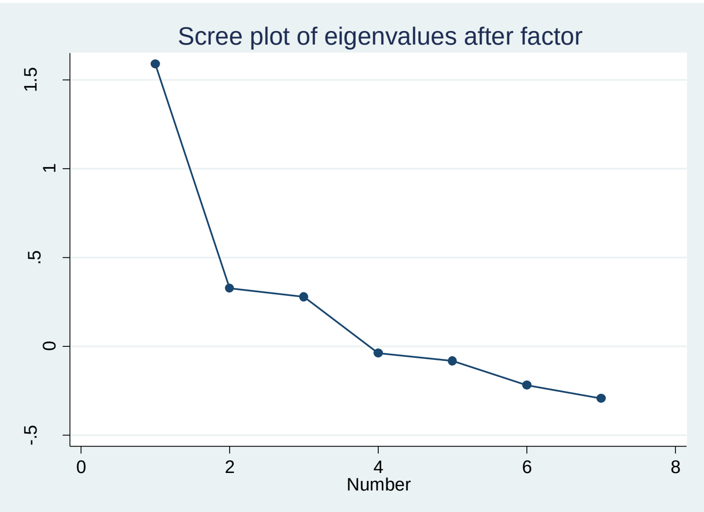
1. Rotated factor loadings

```
Factor analysis/correlation                    Number of obs    =      218
    Method: principal factors                  Retained factors =        3
    Rotation: orthogonal varimax (Kaiser off)       Number of params =       18

Rotated factor loadings (pattern matrix) and unique variances

    ---------------------------------------------------------
        Variable |  Factor1   Factor2   Factor3 |   Uniqueness
    -------------+-----------------------------+--------------
             Ec1 |   0.2740    0.4679    0.1287 |      0.6894
             Ec2 |   0.7313    0.1770    0.0383 |      0.4324
             Ec3 |   0.0119    0.0354    0.4433 |      0.8021
             Ec4 |   0.5280    0.0477   -0.1364 |      0.7004
             Ec6 |  -0.1566   -0.4425    0.1408 |      0.7598
             Ec7 |   0.4818    0.1637   -0.2288 |      0.6887
             Ec8 |   0.5143   -0.0070    0.0238 |      0.7349
    ---------------------------------------------------------
```

2. Eigenvalues



3. Calculation of indicator weights

Indicator	Squared factor loading			Squared factor loading/explained variability			Normalized weight
	Factor1	Factor2	Factor3	Factor1	Factor2	Factor3	
Income from milk production	0.08	0.22	0.02	0.05	**0.46**	0.05	0.13
Cow productivity	0.53	0.03	0.00	**0.36**	0.07	0.00	0.31
Labour productivity	0.00	0.00	0.20	0.00	0.00	**0.64**	0.11
Percentage of grown fodder	0.28	0.00	0.02	**0.19**	0.00	0.06	0.16
Animal health	0.08	0.20	0.02	0.05	**0.41**	0.06	0.11
Use of artificial insemination technology	0.23	0.03	0.05	0.16	0.06	**0.17**	0.03
Feed conservation program	0.26	0.00	0.00	**0.18**	0.00	0.00	0.15
Expl.Var	1.47	0.48	0.31	-	-	-	-
Expl./Tot	0.65	0.21	0.14	-	-	-	-

II. Social sustainability

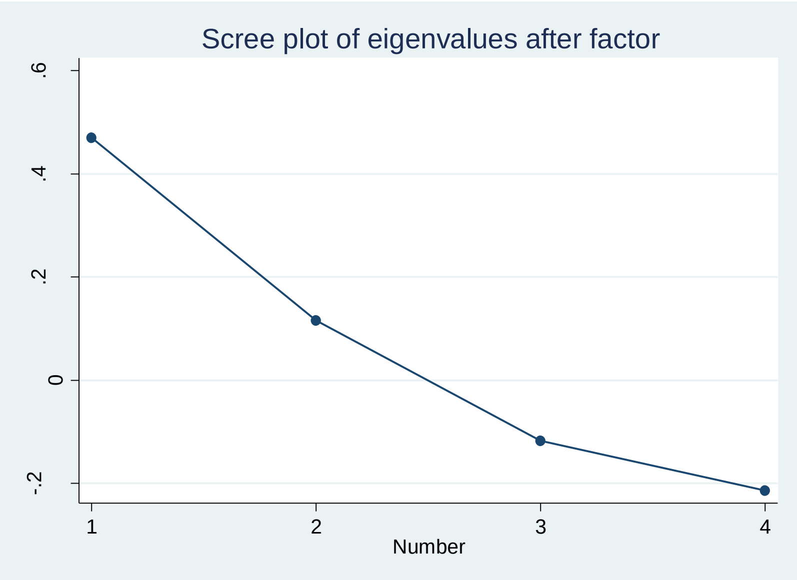
1. Rotated factor loadings

```
Factor analysis/correlation                Number of obs    =     341
    Method: principal factors              Retained factors =       2
    Rotation: orthogonal varimax (Kaiser off)     Number of params =       6

Rotated factor loadings (pattern matrix) and unique variances

    ------------------------------------------------
        Variable |  Factor1   Factor2 |   Uniqueness
    -------------+--------------------+--------------
            Soc1 |  0.0759    0.2755 |      0.9184
            Soc2 |  0.4349    0.0227 |      0.8104
            Soc3 |  0.4504    0.1125 |      0.7845
            Soc4 |  0.1490    0.2763 |      0.9015
```

2. Eigenvalues



1. Calculation of indicator weights

Indicator	Squared factor loading		Squared factor loading/explained variability		weight
	Factor1	Factor2	Factor1	Factor2	
Education level	0.01	0.08	0.01	0.46	0.14
Participation in training	0.19	0.00	0.45	0.00	0.35
Participation in farmer group	0.20	0.01	0.48	0.08	0.37
Women's empowerment	0.02	0.08	0.05	0.46	0.14
Education level	0.42	0.17			1.00
Expl.Var	0.42	0.17			
Expl./Tot	0.72	0.28			

III. Environmental sustainability

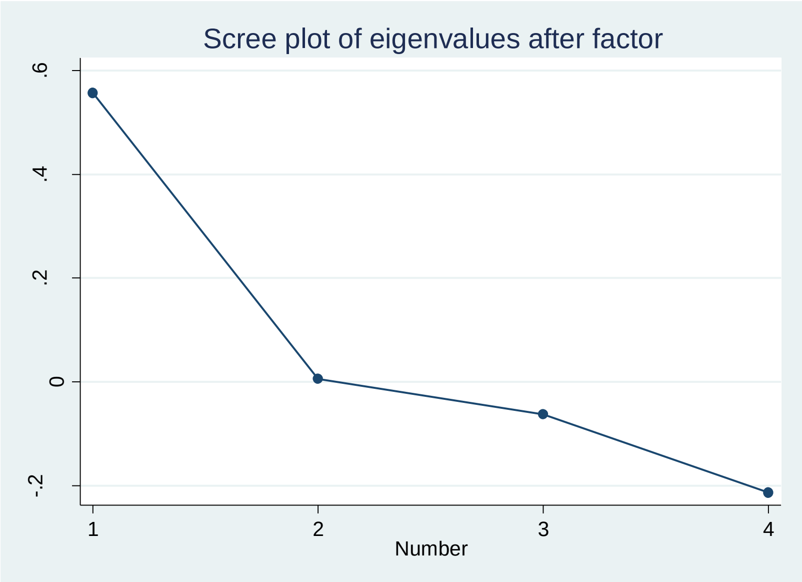
1. Rotated factor loadings

```
Factor analysis/correlation                  Number of obs    =      57
    Method: principal factors                Retained factors =       2
    Rotation: orthogonal varimax (Kaiser off)    Number of params =       6


Rotated factor loadings (pattern matrix) and unique variances

    -------------------------------------------------
        Variable |  Factor1   Factor2 |   Uniqueness
    -------------+--------------------+--------------
            Env1 |   0.0245    0.0725 |      0.9941
            Env2 |   0.4918    0.0022 |      0.7581
            Env3 |   0.3217    0.0183 |      0.8961
            Env4 |  -0.4593   -0.0102 |      0.7890
    -------------------------------------------------
```

1. Eigenvalues



1. Calculation of indicators

Indicator	Squared factor loading		Squared factor loading/explained variability		weight
	Factor1	**Factor 2**	**Factor1**	**Factor2**	
Erosion control	0.00	0.01	0.00	**0.92**	0.01
Distance between manure storage/disposal and the water way	0.24	0.00	**0.43**	0.00	0.43
Water availability through the year	0.10	0.00	0.19	0.06	0.18
Land owned with title	0.21	0.00	**0.38**	0.02	0.38
Expl.Var	0.56	0.01			1.00
Expl./Tot	0.99	0.01			

Appendix 6: Farm questionnaire for data collection measuring sustainability indicators

F. General Identification

A.1 Household ID (to be used in subsequent surveys)	
A.2 GPS Coordinates	Latitude (N/S): Longitude (W/E):
A.3Date of interview (DD/MM/YY)	
A.4 Respondent sex (0= Male; 1 = Female)	
A.5 Years of schooling	
A.6 Participation in farmer groups (Yes/No)	
A.7 Participation in farmer trainings (Yes/No)	
A.8 District	

G. Agricultural Assets: Value, Ownership and Access

b. Land

Plot ID	Plot Description / Name	Size of this plot (acres)	Tenure system (code)	If plot **is *owned,*****who owns (code**)**
1				
2				
3				
4				

Code		
Plot description code	**Tenure system**	**Plot owner**
6. = Homestead 7. = Cash crop 8. = Food crop 9. = Fodder crop 10. = Grazing land	6. = Owned with title 7. = Owned without title 8. = Communal/public 9. = Rented in 10. = Rented out	9. = HH head 10. = Spouse 11. = Joint (HH head & spouse) 12. = Other male 13. = Other female 6= Others (specify) _______________

** Ownership means the one who decides on how the land is used

c. Cattle owned - *enter details for each cattle separately*

Cattle type (codes)	Breed (0 = local; 1 = exotic/cross)	Number owned by male	Number owned by female	Number owned jointly	Total number owned by household

Code		
10. Bulls (> 3 years) 11. Castrated adult males (oxen> 3 years) 12. Immature males (<3 years)	13. Cows (calved at least once) 14. Heifers(female ≥1yr,have not calved) 15. Female calves (between 8 weeks &<1yr)	16. Male calves (between 8 weeks &<1yr) 17. Pre weaning males (<8 weeks) 18. Pre weaning males (<8 weeks)

** Ownership means the one who decides on purchase and sale of respective animal and the use of proceeds from that animal

H. Milk Production: Supply, Input use and Technology Adoption

a. Milk production

1. Have you been milking any cows in the last six months? [__] 1=Yes; 0 = No
2. If yes, please enter details for average milk production the **cows milked** during the **last six (6) months**.

Month milk produced	Number of cows milked	Average volume produced per day

Months		
1. Jan 2016 2. Feb 2016	3. Mar 2016 4. Apr 2016	5. May 016 6. Jun 2016

d. Use of milk

Months milk utilized	**Category milk production**	**Quantity (liters)**	Average price received (TZS/liter)
	Liters used/consumed by household		
	Liters of fresh milk sold (morning and evening milk)		

	Liters lost due to spoilage/spillage on farm		
Months			
1. Jan 2016 2. Feb 2016	3. Mar 2016 4. Apr 2016	5. May 016 6. Jun 2016	

I. **Input Use, Costs and Technology Adoption**

a. **Feeding system**

Type of cattle	**Rainy season (code)**	**Dry season (code)**
Local (if breed in C2=Local)		
Cross and/or grade (if breed in C2=Cross)		
Feeding system code		
7. = Only grazing (free-range or tethered) 8. = Mainly grazing with some stall feeding 9. = Mainly stall feeding with some grazing	10. = Only stall feeding (zero grazing) 11. = On transhumance, some animals 12. = On transhumance, all animals	

b. **Water for cattle and water pollution**

Watering point	For off farm watering **distance** to watering point	For on-farm watering; **source of water**	Do you have enough water for your animals throughout the year [1=yes; 0=No]	What is the distance between cattle house and water way? (In m)	If surface water, do you let animals access to water source (river) directly[1=yes; 0=No]
Watering point	**Distance to watering point**		**Source of water**		
4. Off-farm 5. On-farm 6. Both	6. <1 kms 7. 1-2 kms 8. 3-4 kms 9. 5-7 kms 10. 8+ kms	6.	7. = No irrigation 8. = Ground water 9. = Surface water, i.e. dam, river or lake 10. = Piped water 11. = other _____		

c. **Grown fodder**

1. Besides grazing/harvested grass from forest/roadside/farm, do you currently grow any improved fodder? [__] 1= Yes; No =0
2. If yes, please provide the following details for each fodder type grown.

Months fed	Grown fodder type fed	Quantity fed per day in last (6) months		
		Cattle fed (code)	Unit	Quantity

Months	**Fodder type/pasture**	**Cattle fed**
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	6. = Napier grass 7. = Planted grasses e.g. Rhodes grass 8. = Fodder maize 9. = Fodder shrubs (Calliandra, Sesbania, Lucaenia) 10. = Other fodder legumes (Desmodium, lucern, vetch) = Other (specify) [__]	6. = All 7. = Cows only 8. = Lactating cows only 9. = Calves only 10. = Other (specify) ____________
Measurement unit		
7. Kg 8. Tones 9. Bales 10. Handcart/wheelbarrow 11. Standar sack 12. Other (specify) __________________		11.

d. **Purchased fodder**

1. Have you been purchasing fodder to feed cattle in the last six months (since September last year to now)? [__] Yes = 1; No = 0
2. If yes, in which of the last six (6) months did you purchase fodder?
3. For **each month selected** please enter the following details.

Month when purchased	Fodder type	Cattle type fed?	Monthly cost during months when purchased		
			Unit	Qnty	Price/unit

Month	**Fodder type**
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	7. = Napier grass 8. = Planted grasses e.g. Rhodes grass 9. = Fodder maize 10. = Fodder shrubs (Calliandra, Sesbania, Lucaenia) 11. = Other fodder legumes (Desmodium, lucern, vetch) 12. = Other (specify:__________________)
Measurement unit	**Cattle fed**
1. Kg **2.** Tones **3.** Bales **4.** Handcart/wheelbarrow **5.** Standard sack **6.** Other (specify) __________________	**7.** = All **8.** = Cows only **9.** = Lactating cows only **10.** = Calves only **11.** = Other (specify

e. Crop residues

1. Do you use crop residues? [__] Yes = 1; No = 0
2. If yes, in which of the last six (6) months did you use crop residues?
3. For every month selected above please enter the following details.

Month(s) used	Crop residue	Cattle type fed?	Source: 1=Own farm; 2=Other farm; 3=Purchased	**If purchased** Monthly cost during months when purchased		
				Unit	Qnty	Price/unit

Months	**Crop residues**	**Measurement unit**	**Animal fed**
1. Jan 2016 2. Feb 2016 3. Mar2016 4. Apr 2016 5. May 016 6. Jun 2016	1. = Green/dry maize stovers and thinning 2. = Cereal(wheat, barley, rice etc.) straws and millet, sorghum stalks 3. = Legumes (beans, cowpeas, soya etc.) 4. = Root and tubers peelings (potato, cassava, bananas etc) 5. = Crop by products (sweet potato vines, cassava leave etc.) 6. = Other (specify)________	7. Kg 8. Tones 9. Bales 10. Handcart/wheelbarrow 11. Standard sack 12. Other (specify) __________________	5. = All 6. = Cows only 7. = Lactating cows only 8. = Calves only 9. = Other (specify) ___________

f. Concentrates

1.Do you use concentrates? [__] Yes = 1; No = 0
2.If yes, in which of the last six (6) months did you use concentrates?
3.For every month selected above please enter the following details.

Month(s) used	Concentrate	Cattle type fed?	Source: 1=Own farm; 2=Other farm; 3=Purchased	**If purchased** Monthly cost during months when purchased		
				Unit	Qnty	Price/unit

Months	**Concentrate type**	**Measurement unit**	**Cattle fed**
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	8. = Commercial dairy meal 9. = Mineral blocks 10. = Bran (Maize, wheat) 11. = Maize germ 12. = Oilseed by-product (Sesame seed, cotton seed, copra, sunflower etc.) 13. =Agro industrial byproducts (vegetable waste, brewer's waste etc.)	7. Kg 8. Tones 9. Bales 10. Handcart/wheelbarrow 11. Standard sack 12. Other (specify) _______________	6. = All 7. = Cows only 8. = Lactating cows only 9. = Calves only 10. = Other (specify) ___________

	14. = Other (specify)____________		

j. Do you practice feed conservation for the dry season …………[1=yes 0=No]

k. **Breeding services and expenses**

Months		**Own bull service**	**Other bull service**	**AI service**
	How many times have you used this service			
	What is the average cost per service?			

	Service provider
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016	8. Other farmers 9. Community bull (bull scheme) 10. Private AI provider 11. Government/public AI provider 12. Project/NGO AI provider 13. Coop/AI provider 14. 99 (N/A) Other (specify) ________

l. **Animal health services and expenses**

Month		Anthelmintic (deworming)	Tick control (spraying/dipping)	Vaccination	Curative treatment
	Is the service available? (0= NO; 1=YES)				
	How many times have used this service in this month				
	What was the average cost per service				

Months
1. Jan 2016 2. Feb 2016 3. Mar 2016 4. Apr 2016 5. May 016 6. Jun 2016

F. Labour use and expenses

7. **Monthly labour: Have you employed any monthly labourer(s)** in the last six (6) months (between January and now)? (0=No 1=Yes), if yes, enter the following details

	Months	**Name of labourer**	**Gender of labourer 0 = Male 1 = Female**	**Average working hours per day on dairy**	**Monthly wage**
1					
2					
3					

Months		
1. Jan 2016 2. Feb 2016	3. Mar 2016 4. Apr 2016	5. May 016 6. Jun 2016

8. **Casual labour: Have you employed any casual labourer(s)** in the last six (6) months (between January and now)? (0=No 1=Yes), if yes, enter the following details:-

	Months	**Name of labourer**	**Gender of labourer 0 = Male 1 = Female**	**Average working hours per day on dairy**	**Total Amount paid**
1					
2					
3					

Months		
1. Jan 2016 2. Feb 2016	3. Mar 2016 4. Apr 2016	5. May 016 6. Jun 2016

9. **Household labour: Employed household labour** in the last six (6) months (since September to now)? (0=No 1=Yes), if yes, enter the following details:

Type of Activity	Household							Freq. (code)
	Adult Males		Adult Females		Children (< 15 yrs)			
	No. people	Hrs/person/day	No. people	Hrs/person/day	No. people	Gender M/F	Hrs/person/day	

12. Grazing									
13. Feeding (+ collecting									
14. Fodder/feed									
15. Providing water to the									
16. Cleaning of animal									
17. Collection of Farm									
18. Milking and milk									
19. Selling milk									
20. Selling animals/									
21. Crop production									
22. Other: [									
Frequency of activity code									
1. [___] per day	2. [___] per week		3. [________] per month		4. [_____] per year				

G. Participation in Farmer Group

iii. **Do any household member belong to a Farmer Group?**: (0=No 1=Yes) [____________]

c. Have you ever attended any training about dairying during the last six months (0=No 1=Yes) [____________]

I. Soil conservation

e. Do you practice any erosion control ……….[1=yes 0=No]

J. Women's empowerment in livestock index

a. Daily time allocation

3.1: please record a log of the activities for the indivdual in the last typical week day. Identify a typical day be asking 'was yesterday a typical/usual day? If no, ask if the day before yeseterday was a typical day until you identify a typical day. Then ask 'at what time did you wake up? What did you do? For how long?' record all activities that take more than 15 minues in the right (1 hour) time intervals. More activities (maximum 4 activities) can be marked for each hour by checking the corresponding box. **"Now I'd like to ask you about how you spent your time during the (day that was identified at a 'typical day'). This will be a detailed accounting. We'll begin from the moment you woke up until the moment you went to sleep .**

Activity	**hours**									
Revenue generating activities	**4-5am**	**5-6am**	**6-7am**	**7-8am**	**…**	**11am-12pm**	**12pm-1pm**	**1pm-2pm**	**…**	**9pm-4am**
Work as employed										
Own business work (e.g. having a shop, work as daily labourer etc.)										
Livestock farming										
Crop farming										
Cooking (e.g. processing or cooking milk, meat or vegetables for sale)										
Marketing farm products										
Weaving, sewing, etc.										
Traveling (to sell)										
Social activity (e.g. Vicoba)										
Other										
Non-revenue generating activities										
Sleeping and resting										
Eating and drinking										
Personal care (e.g. bathing, dressing etc.)										
Education (e.g. school, trainings etc.)										
Livestock farming (e.g. milking, feeding, breeding, washing, watering etc)										
Crop farming (e.g. planting, weeding, harvesting, storing, hoeing, fertilizing										

etc)										
Shopping										
Getting services (e.g. banking, vet, doctor, paying bills, Mpesa services etc)										
Weaving, sewing etc.										
Cooking (e.g. processing or cooking milk, meat or vegetables for family consumption)										
Domestic work (e.g. fetching water, wood, cleaning house etc.)										
Care for children (e.g. feeding, supporting with homework, washing, preparing special food etc.)										
Care for adults or elderly (e.g. help sick, wash them, feed them, give them medicines, prepare special food etc.)										
Travelling and commuting										
Watching TV, listening to radio										
Exercising (e.g. sports)										
Social or religious activities (e.g. visiting friends and family, attending ceremonies etc.)										
Other										

b. Decision making on hh expenditure

"Now I have some questions about making decisions about various aspects of household life."

ACTIVITY		Who makes the following decisions? (Code below, multiple select)
C	Major household expenditures (such as a large sofa set, car etc)	
E	Minor household expenditures (such as oil for lamps, clothes for self and family)	

1=MYSELF
2=PARTNER/SPOUSE/HUSBAND
3=BOYS
4=GIRLS
5=OTHER MALE HOUSEHOLD MEMBERS
6=OTHER FEMALE HOUSEHOLD MEMBERS
7=A WOMAN OUTSIDE THE HOUSEHOLD
8=A MAN OUTSIDE THE HOUSEHOLD
9=SOCIETY

c. Decision MAKING ON HH INCOME

"Now I have some questions about making decisions about household management of income"

Income source(s)	Who decides how to manage the household income from the following sources? (Code below, multiple select)
Livestock	
Crop	

1=MYSELF
2=PARTNER/SPOUSE/HUSBAND
3=BOYS
4=GIRLS
5=OTHER MALE HOUSEHOLD MEMBERS
6=OTHER FEMALE HOUSEHOLD MEMBERS
7=A WOMAN OUTSIDE THE HOUSEHOLD
8=A MAN OUTSIDE THE HOUSEHOLD
9=SOCIETY
10=NOT APPLICABLE

d. Access to training and information

1. **ACCESS TO TRAINING**

   Did you take any training in the last year? (Y/N) [ ]

2. **ACCESS TO INFORMATION**

   Do you receive new information to improve your livestock work in the past year? (Y/N) [ ]

a. Group membership

Did you participate in any training in the last year? (Y/N) [ ]

Appendix 7: Reasons for including / including the indicators identified through the Delphi technics in the final set used in the framework for assessing sustainability

Aspect	Attribute/Issue (n=16)	Relevant indicators identified through the Delphi Technics (n=29)	Included in the framework	Reason for exclusion
Economic	Profitability	(1) Income per litre of milk	Yes	NA
	Efficiency	(2) Cow productivity	Yes	NA
		(3) Feed productivity	No	Difficult to be capture with accuracy since a large proportion of farmers practice grazing systems
		(4) Labour productivity	Yes	NA
	Feed availability	(5) Feed conservation*	Yes	NA
	Access to market	(6) Access to milk market	No	Difficult to be capture with accuracy
		(7) Access to input market	No	Difficult to be capture with accuracy
	Keeping farm record	(8) Farm record keeping	No	Removed in order to have few and representative indicators
	Milk quality and safety	(9) Milk hygiene	No	Difficult to capture with accuracy within short time at farm level using a questionnaire
	Animal health and welfare	(10) Vaccination as recommended	Yes	Used as a parameter of animal health
		(11) Prophylactic treatment as recommended	Yes	Used as a parameter of animal health
		(12) Prevention measures of entry of disease onto the farm	Yes	Used as a parameter of animal health
		(13) Use of drugs as recommended	No	Difficult to capture
		(14) Animal living environment condition	No	Difficult to capture
		(15) Availability of vet service	No	Difficult to capture
	Animal genetics	(16) Breeding system	Yes	NA
	Independence	(17) Source of capital	No	Removed in order to have few and representative indicators
		(18) Source of feed	Yes	NA
Social	Knowledge	(19) Participation in farmer training	Yes	NA
		(20) Education level of the farm manager	Yes	NA
	Farmers' organization	(21) Participation in organization	Yes	NA
	Gender equality	(22) Women empowerment	Yes	NA
Environment	Land ownership	(23) Land ownership	Yes	NA
	Water quantity	(24) Water conservation/ Harvesting	Yes	Represented by water availability throughout the year
		(25) Access to water*	Yes	NA
	Water quality	(26) Animal access to water body	No	Mostly for extensive system
		(27) Distance between manure disposal and water source/way	Yes	NA
	Land degradation	(28) Livestock stocking density	No	Difficult to measure at farm level
		(29) Soil conservation and erosion	Yes	NA

Appendix 8: Producers' Organization Sustainability Assessment Tool (POSA)

NB: Enter data in the white cells only!!

Note: this from only applies to farmers group with some 'business'. Farmers groups not doing any business are not assessed

Private businesses are assessed with the other form

SECTION I: BASIC DATA

			PO Type	
Country	*Tanzania*	*Tanzania*		Cooperative
Village	*Kwemashai*			
Name of farmer group				
Type of services provided	any two	*specify*		Association
Organisation form	Association			
Date of assessment (dd/mm/yyyy)				
Name & title of reviewer				
Name & title of data validator				

SECTION II:PO SUSTAINABILITY DATA

Dimension	*Sub-Dimension*	*Indicator*	*Enter Data Source*	*Maximum Score*	*Rating Scale*	*Scores*	*Enter/select PO Value*	*PO Score*	*Enter Comments/Notes*
Financial health	***Profitability***	What is the group Net Profit Margin (Net Profit after interest and tax/sales*100 %)?		3.0	>5%	3.0		0.0	No Milk bulking or any other Business
					2 to 5%	2.0			
					0 to 2%	1.0			
		How many individual business units reported losses for 2 consecutive years or more?		2.0	One or more	0.0		0.0	No Milk bulking or any other Business
					None	2.0			
	Liquidity	What is the group current Ratio (Current assets/current liabilities)?		2.0	>=1	2.0		0.0	
					<1	0.0			
	Capital structure	What proportion of stakeholders equity is used to finance the business? Debt Equity ratio = (Total liabilities/stakeholder equity*100%)		3.0	>=41%	0.0		0.0	
					31 to 40%	1.0			
					21 to 30%	2.0			
					<21%	3.0			
	Sub-Total			**10.0**				**0.0**	
Engagement with milk market- if farmers group is in milk business	***Suppliers***	What is the proportion of registered members marketing milk through the group (average monthly milk suppliers/total registered members*100 %)?		3.0	>50%	3.0		0	No Milk bulking or any other Business
					31-50%	2.0			
					21-30%	1.5			
					11-20%	1.0			
					<11%	0.0			
		What is the proportion of female suppliers supplying milk to the group (average monthly female suppliers/ average monthly milk		2.0	>=30 &<=70%	2.0		0.0	No Milk bulking or any other Business
					20-29%	1.5			
					10-19%	1.0			
					<10%	0.0			

		suppliers*100 %)?							
		What is the annual milk supply variance (average volumes of top three months less average volumes of bottom three months/average volumes of top three months*100%)?		3.0	<25% 26-40% 41-50% >50%	3.0 2.0 1.0 0.0		0	
	Milk quality	What is the proportion of milk rejected by the buyer(s) annually (total annual volume of milk rejected by buyers/ total annual amount of milk sold *100%)?		3.0	<1% 1-2% >2%	3.0 2.0 0.0		0.0	
	Market reliability	Group has signed contracts with buyers (Contracts specifies period, minimum volume and price)		3	All three Any two One None	3.0 2.0 1.0 0.0		0	
		Does the group consistently (at least 9 months in a year) meet minimum milk volume requirements as per the supply contract?		4.0	>=9 Months Between 6 and 9 months < 6months No contract	4.0 3.0 2.0 0.0		0.0	
	Sub-Total			**18.0**				**0.0**	
Effective and transparent leadership and management	***Representation and participation***	Does the group conduct Annual General Meeting (AGM) where: (i)elections are held if due, (ii)presentation of audited financial report, (iii) presentation of annual workplan and budget take place?		3.0	All three covered Any two covered None covered	3.0 2.0 0.0	Any two covered	2.0	elections held after four years, presentations of financial reports, work plans discussed
		What is the proportion of women in BOD (Number of women in BOD/ total BOD membership*100%)?		2.0	>=30 and <=70% <30 and >70%	2.0 0.0	36	2.0	four out of 11
		What is the proportion of youth (<=35 years) in BOD (Number of youth in BOD/ total BOD membership*100%)?		2.0	>=30 and <=70% <30 and >70%	2.0 0.0	36	2.0	
	Effective Group	Are internal		5.0	All four	5.0	None	0.0	

	supervision and control	audits conducted annually covering all internal management systems (HR, finance, procurement, quality) by either supervisory committee or internal auditor and the findings implemented?			covered Any three covered Two or less covered None covered	 3.0 1.0 0.0	covered		
		Have the current BoD members completed at least secondary level education (O-level)?		2.0	100% 50-99% <50%	2.0 1.0 0.0	0	0.0	none
	Effective Group management	Does the Group prepare and review **separate** annual and monthly financial reports for all its business units?		2.0	Annual and monthly Annual only None	2.0 1.0 0.0	Annual only	1.0	
		Has the Group hired key professional staff as per the organogram (e.g manager, production, finance, quality)?		1.5	100% filled At least 75% Below 75%	1.5 1.0 0.0	100% filled	1.5	
		What is the voluntary staff turnover ratio over the past 12 months (Number of staff who left the Group during the year divided by the total staff compliment at the beginning of the year *100%)?		1.5	>2 and >20% <=2 and <=20%	0.0 1.5		0.0	
	Sub-total			**19.0**				**8.5**	
Access to dairy inputs and services	***Dairy feeds and feeding***	Does the group operate a feed store(s) and/or has it contracted private supplier(s)?		1.0	Yes No	1.0 0.0	No	0.0	
		Does the group stock/contract private suppliers of quality (nutrition, viability e.t.c) fodder planting material (seeds, cuttings and splits)?		1.0	Yes No	1.0 0.0	No	0.0	
		Does the group promote feed processing, pasture improvement and water availability		1.0	Yes No	1.0 0.0	Yes	1.0	

		technologies (financial linkages, education and training, demonstration, production)?							
		Does the group contract or negotiate with feed suppliers for dry season feed?		1.0	Yes No	1.0 0.0	No	0.0	
		What is the proportion of members using group facilitated feed services (total members using group facilitated feed services/ total members*100 %)?		1.0	>=30% >10<30% <10%	1.0 0.5 0.0		0.0	
	Genetics	Does the group have a semen bank/ AI satellite centre or have a link with an external semen supplier?		1.0	Yes No	1.0 0.0	Yes	1.0	no semen bank at the group but linked to AI provider, the price is still high. The service provider is far
		What is the proportion of members using group facilitated AI services (total members using group facilitated AI services/ total members *100%)?		1.0	>=30% >10<30% <10%	1.0 0.5 0.0	0	0.0	
	Herd Health	Does the group operate drug store(s) or has it contracted a private dealer(s)?		1.0	Yes No	1.0 0.0	Yes	1.0	
		What is the proportion of members using group facilitated AH services (total members using group facilitated AH services/ total members *100%)?		1.0	>=30% >10<30% <10%	1.0 0.5 0.0		0.0	
	Extension structure	Does the group have an functional extension unit (internally or externally resourced)?		2.0	Yes No	2.0 0.0	Yes	2.0	
		Does the group conduct/collaborates on periodic on-farm surveys and are the findings used for decision making (covering dairy production and farmer satisfaction with group services)?		1.0	Yes No	1.0 0.0	Yes	1.0	
	Financial	Does the group		2.0	Four or more	2.0	Any	1.5	mainly on drugs and

	services	have a functional check off system for dairy inputs and services is in place offering: Feeds, breeding, animal health and dairy equipment?			Any Three 1 to 2 None	1.5 1.0 0.0	Three		Extension
		Does the group have FSA/SACCO or linkage with financial service provider(s) offering diversified and suitable financial services (Asset financing, savings, credit, livestock insurance, financial literacy e.t.c)?		2.0	Four or more Any Three One or Two None	2.0 1.5 1.0 0.0	None	0.0	
	Total			**16.0**				**7.5**	
Relationship with external environment	***Partnership with actors***	Does the group work (mutually beneficial partnerships) with other actors (public/private) to improve its business operating environment?		2.0	Yes No	2.0 0.0	Yes	2.0	during the site visits , the trainings we also invite the villagers to attend the traings
	Corporate social responsibility	Does the group have a functional corporate social responsibility (CSR) program for promotion of social cohesion?		1.5	Yes No	1.5 0.0	Yes	1.5	tey contribute to the community indirectly by contributing to the community
	Total			**3.5**				**3.5**	
Member loyalty	***Patronage***	What is the general trend of active milk suppliers or users of group services for the last three years?		1.5	Increasing Static Decreasing	1.5 1.0 0.0	Decreasing	0.0	started with 156 members, but the numbers have been decreasing due to misconception that they will get free cows from the project
		What is the proportion of active members using Group check off facility (total active suppliers using check off facility/ total active suppliers *100%)?		1.5	>60% 41-60% 21-40% 10-20% <10%	1.5 1.0 0.7 0.5 0.0		0.0	
	Member investment	What is the proportion of members who are fully paid up shareholders (fully paid up shareholders/ total members*100		1.0	>60% 41 to 60% 21 to 40% <=20%	1.0 0.7 0.5 0.0	55	0.7	intially 156 members thought they will get cows, and had joined to get cows only 65 left with an active base of 39

	%)?							
	What is the proportion of fully paid up shareholders who are women (fully paid up female shareholders/ total shareholders *100%)?		1.0	>=30 and <=70% <30 and >70%	1.0 0.0	43	1.0	17 out 39
	What is the proportion of fully paid up shareholders who are youth (fully paid up youth shareholders/ total shareholders*100%)?		1.0	>=30 and <=70% <30 and >70%	1.0 0.0	25	0.0	10 out the 39
Ownership	What is the average number of members offering themselves per elective post (number of interested candidates/number of vacant posts)?		1.0	Three or more Less than three	1.0 0.0	1.8	0.0	20 vied for posts
	What is the average number of female members offering themselves per elective post (number of interested female candidates/number of vacant posts)?		1.0	At least one None	1.0 0.0		0.0	four women
Member loyalty programs	Does the Group run social security programs (Medical schemes, food/household stuff, school fees, other agri-inputs)?		1.0	At least one None	1.0 0.0	1	1.0	
	Does the Group run environmental sustainability programs (solar, biogas, water tanks, water harvesting equipments)?		1.0	At least one None	1.0 0.0	0	0.0	none at the moment. But planning to train the members
Total			**10.0**				**2.7**	

Summary

NB: Do not enter any data in this tab!				
PO Summary data by dimension				
Dimension	**Maximum score**	**PO score**	**Percentage score**	
Financial health	10.00	-	**-**	
Engagement with milk market- if farmers group is in milk business	18.00	-	**-**	
Effective and transparent leadership and management	19.00	8.50	**44.74**	
Access to dairy inputs and services	16.00	7.50	**46.88**	
Relationship with external environment	3.50	3.50		

			100.00	
Member loyalty	10.00	2.70	**27.00**	
Total PO score	76.50	**22.20**	***29.02***	
Stage	***Stage II***			
Stage intervals				
Stage	**Score Range**	**PO Score**		
Stage I	0-20			
Stage II	21-40	**29.02**		
Stage III	41-60			
Stage IV	61-80			
Stage V	81-100			
PO Summary data by sub-dimension				
Dimension	**Sub-dimension**	**Maximum score**	**PO Score**	**Percent score**
Financial health	Profitability	3.00		
	Profitability	2.00		
	Liquidity	2.00		
	Capital structure	3.00		
Total		***10.00***		
Engagement with milk market- if farmers group is in milk business	Milk quality	3.00		
	Market reliability	7.00		
	Suppliers	8.00		
Total		**18.00**		
Effective and transparent leadership and management	Representation and participation	7.00	6.00	85.71
	Effective Group supervision and control	7.00		
	Effective Group management	5.00	2.50	50.00
Total		***19.00***	***8.50***	***44.74***
Access to dairy inputs and services	Dairy feeds and feeding	5.00	1.00	20.00
	Genetics	2.00	1.00	50.00
	Herd health	2.00	1.00	50.00
	Extension structure	3.00	3.00	100.00
	Financial services	4.00	1.50	37.50
Total		***16.00***	***7.50***	***46.88***
Relationship with external environment	Partnership with actors	2.00	2.00	100.00
	Corporate social responsibility	1.50	1.50	100.00
Total		***3.50***	***3.50***	***100.00***
Member loyalty	Patronage	3.00	-	-
	Member investment	3.00	1.70	56.67
	Ownership	2.00	-	-
	Member loyalty programs	2.00	1.00	50.00
Total		***10.00***	***2.70***	***27.00***
PO Total		**76.50**	**22.20**	***29.02***

Appendix 9: Relevant indicators for assessing sustainability of milk production farm in Morogoro and Tanga Regions

Aspect	Attribute/Issue (n=16)		Measurable Indicator (n=41)	1st round SD	1st round Mean	2nd round SD	2nd round Mean	Status	Consensus level
Economic	Profitability	(1)	Income per litre of milk	1.0	4.4	0.8	4.5	Accepted	High
	Efficiency	(2)	Cow productivity	1.0	4.4	0.6	4.6	Accepted	High
		(3)	Feed productivity	1.2	4.1	0.8	4.3	Accepted	High
		(4)	Labour productivity	0.9	3.9	0.7	4.0	Accepted	High
	Feed availability	(5)	Feed conservation*	0.0	5	0.9	4.1	Accepted	High
	Access to market	(6)	Access to input market	0.9	4.5	0.6	4.7	Accepted	High
		(7)	Access to milk market	1.2	4.1	0.8	4.3	Accepted	High
	Keeping farm record	(8)	Farm record keeping	1.2	4.1	1.1	4.3	Accepted	Reasonable
	Milk quality and safety	(9)	Milk hygiene	0.9	4.5	0.5	4.8	Accepted	High
	Animal health and welfare	(10)	Vaccination as recommended	1.0	4.4	0.8	4.5	Accepted	High
		(11)	Prophylactic treatment as recommended	0.8	4.3	0.6	4.4	Accepted	High
		(12)	Prevention measures of entry of disease onto the farm	1.0	4.1	0.8	4.4	Accepted	High
		(13)	Use of drugs as recommended*	0.9	4.1	0.8	4.2	Accepted	High
		(14)	Calf mortality*	0.9	3.9	0.9	3.9	Rejected	High
		(15)	Animal living environment condition	0.9	4.1	0.8	4.2	Accepted	High
		(16)	Availability of vet service*	0.8	4.1	0.7	4.3	Accepted	High
	Animal genetics	(17)	Breeding system	0.7	4.1	0.8	4.3	Accepted	High
	Independence	***(18)***	Source of capital	1.1	3.9	1.0	4.1	Accepted	High
		(19)	Source of feed	1.1	4.0	1.0	4.1	Accepted	High
		(20)	Source of labour	0.9	3.7	1.0	3.6	Rejected	High
	Off-farm income	(21)	Off-farm income	1.0	3.6	0.9	3.8	Rejected	High
	Identification of animals	(22)	Identification of animals *	1.4	4	0.9	3.9	Rejected	High
Social	Knowledge	(1)	Education level of the farm manager	1.2	3.9	1.0	4.0	Accepted	High
		(2)	Participation in farmer training	1.2	3.8	1.0	4.1	Accepted	High
	Working conditions	(3)	Working time	1.2	3.8	1.0	3.9	Rejected	High
		(4)	Workload distribution	1.2	3.8	1.1	3.8	Rejected	Reasonable
	Farmers' organization	(5)	Participation in organization	1.1	4.0	0.9	4.0	Accepted	High
	Gender equality	(6)	Women empowerment	1.0	4.1	0.9	4.1	Accepted	High
		(7)	Work sharing	1.2	3.9	1.1	3.8	Rejected	Reasonable
	Health and safety	(8)	Distance between living house and manure disposal*	1.2	3.7	1.2	3.7	Rejected	Reasonable
Environment	Land ownership	(1)	Land ownership	1.0	4.3	0.7	4.5	Accepted	High
	Water quantity	(2)	Water conservation/ Harvesting	1.1	4.3	0.8	4.6	Accepted	High
		(3)	Access to water*	0.0	5	0.7	4.6	Accepted	High
	Water quality	(4)	Animal access to water body	1.4	4.0	0.7	4.4	Accepted	High
		(5)	Distance from water source/way	1.1	4.1	0.8	4.3	Accepted	High
		(6)	Manure storage runoff	1.3	3.5	1.3	3.5	Rejected	Reasonable
	Land degradation	(7)	Livestock stocking density	1.5	3.9	1.1	4.1	Accepted	Reasonable
		(8)	Soil conservation and erosion	1.3	4.0	1.3	4.0	Accepted	Reasonable
		(9)	Grazing on formally demarcated land	1.4	3.6	1.4	3.5	Rejected	Reasonable
	Farm existence	(10)	Animal farm/Backyard production	1.3	3.7	1.1	3.8	Rejected	Reasonable
	Manure management	(11)	Proportion of manure used	1.2	3.7	1.2	3.7	Rejected	Reasonable

*Indicators added by the respondents; Cut-off point: Mean score ≥ 4.0; Indicators not listed in table those mean score was less than 3.5