Traditional livestock systems in Tanzania;
An application of the TEEB Framework

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Funded by the
European Union

Acknowledgements: We acknowledge the EU for funding this research and report and the EC commitments towards the sustainability development goals, Aichi targets and the agri-environmental schemes in the common agricultural policy.

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Table of Contents

Natural and capital valuation glossary

- Ecosystem services: Ecosystem services are "the direct and indirect contributions of ecosystems to human well-being" (De Groot et al., 2010). Examples of ecosystem services are food provisioning, carbon regulation and recreation.
- Natural capital: The naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity (SEEA definition). Natural capital can also be defined as "the stock of natural ecosystems on earth including air, land, soil, biodiversity and geological resources. This stock underpins our economy and society by producing value for people, both directly and indirectly" (NCC, 2014). Natural capital includes the extent and condition of ecosystems that provide ecosystem services.
- Externalities: An externality arises when the actions of one economic agent in society impose costs or benefits on other agent(s) in society, and these costs or benefits are not fully compensated for and thus do not factor into that agent's decision-making (Hussain and Miller, 2014). External costs and benefits are called negative and positive externalities, respectively.
- Invisible costs and benefits: Costs and benefits are considered invisible when not captured in financial transactions or cost-benefit analysis and therefore not taken into account in common decisions making. Examples of invisible costs and benefits relevant for livestock systems are greenhouse gas (GHG) emissions and landscape management.
- Visible costs and benefits: Costs and benefits captured in the market. Examples of visible benefits relevant for livestock systems are food provisioning and raw materials. Examples of visible costs are compound feed or medicines.
- Natural capital costs or impacts: Natural capital costs express in monetary terms the impacts on natural capital that are produced by livestock systems, as a result of resource use and pollutant emissions (units in $). Natural capital costs captured in this study are external to the market, thus are invisible costs.
- Income: The amount of earnings available to the household. For a household farm, this represents the profit after all costs have been deducted from revenues. Since labour mostly exists of family labour its value is not subtracted. Income can be derived from financial activities or from in-kind consumptions.
    - In-kind income: The income derived from sources other than monetary income. In the case of smallholder farms, it is what households save from consuming their own production. For pastoralism, this also includes materials such as animal skins.
    - Financial income: Share of the household income that is monetary, calculated as revenues from sales derived from economic activities minus the costs incurred for those activities. As such, it is equivalent to the profit of the household's economic activities.
- Financial revenue: The monetary revenue derived from sales of products.
- Full-time equivalent (FTE): A unit that indicates the workload of an employed person and is calculated as the ratio between the total paid hours during a period and standard full-time working hours in the same period. When not specified otherwise, 1 FTE refers to one person working full time for one year.
- Price mark-ups: The difference between the price of product purchased and the price of the product resold.

1 Introduction

1.1 Background

Tanzania's population is growing fast, as is the average income per capita (see Table 1.1). These factors are associated with increased demand for animal proteins (meat, fish, milk, milk products and eggs), a trend which is expected to continue (Cockx et al., 2017). Most animal products consumed in Tanzania are produced in the country, largely by traditional livestock systems that are characterised by low-input use and low yields.

Table 1.1: Key macroeconomic indicators Tanzania

	2008	2014	2015	2016	2017
Gross domestic product (GDP, current in million $)	27,368.4	48,219.7	45,623.5	47,388.4	52,090.3
GDP growth (annual %)	5.6	7.0	7.0	7.0	7.1
Agriculture as part of GDP (%)	24.8	25.8	26.7	27.4	24.8
GNI per capita, PPP (current int. $)	1,890	2,500	2,610	2,740	2,920
Population (in million)	43.3	52.2	53.9	55.6	57.3
Population growth (annual %)	3.2	3.1	3.1	3.1	3.1
Urban population (% of total)	26.8	30.9	31.6	32.3	33.1
Employment in agriculture (%)	71.4	68.1	67.8	67.5	66.9
Cattle (heads)	18,800,000	25,800,000	26,713,644	26,697,483	26,399,523
Chicken (heads)	32,500	36,000	36,389	37,113	37,146

Source: World Bank

An important question is how traditional livestock systems in Tanzania can benefit from the expected increase of demand for animal proteins while at the same time avoiding negative environmental and socio-economic impacts. These kind of questions need a 'holistic' or 'system thinking' approach that is offered by 'The Economics of Ecosystems and Biodiversity for Agriculture and Food' (TEEBAgriFood) valuation framework.[1] Former analysis of the livestock sector in Tanzania (such as Da Silva, Desta and Stapleton (2017), Nadonde, Gebru and Stapleton (2017) and Katjiuongua and Signe (2014)) are limited to economic and physical evaluations with a high risk that hidden costs for ecosystems or livelihoods are not taken into account. The TEEB framework illuminates how the components of a system – the social, the human, economic and natural dimensions – are interconnected.

1.2 Objective and scope of the evaluation

The study 'Valuation of livestock eco-agri-food systems: Poultry, beef and dairy' (Baltussen et al., 2017) describes externalities until the farm gate[2] of livestock systems for different developing countries, including Tanzania. The Economics of Ecosystem and Biodiversity (TEEB) requested to expand upon the previous study for Tanzania in terms of impacts and externalities to be analysed across the value chain. This study takes into account the entire value chain including supplying industries (e.g. feed industry), farmers, middlemen/traders, processors, retail and consumers.

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[1] Chapter 6 of the 'TEEB for agriculture & food; scientific and economic foundations report' (http://teebweb.org/agrifood/) presents the assessment framework in detail.

[2] Farm gate means the total food value chain until the produce leave the farm.

The objective of this study is to evaluate the socio-economic and environmental impacts of value chain activities related to three livestock sectors in Tanzania using the TEEBAgriFood evaluation framework. The aim is to improve decision-making in livestock production policies, to enhance its viability, not just economically but also socially and environmentally. The three different livestock production systems studied, are:

- The pastoral cattle system (Maasai);
- The backyard poultry system; and
- The smallholder dairy system.

By applying a mix of traditional techniques, these systems provide animal protein to a large section of Tanzania's population, both rural and urban. This TEEBAgriFood study (i) provides input for the synthesis of African case studies, (ii) quantifies the value of social and environmental externalities of livestock systems so they are accounted for in decision-making, and (iii) assesses the various types of interventions that might be used to capture these values, leading to sustainable food production and improved livelihoods.

1.3 Method

1.3.1 Framework

This evaluation follows the TEEBAgriFood framework, (see Figure 6.7 in the TEEB Foundations report, 2018). The TEEBAgriFood evaluation framework has been developed to better capture the value of natural, human and social capital that contribute to and are impacted by agricultural value chains. Value chain activities are mostly evaluated for their contribution to economic output. Sometimes social impacts are evaluated but their full impact on all the natural capital is often neglected. By highlighting all relevant components of the value chain and the non-market social and environmental impacts of food systems across that value chain, the TEEBAgriFood evaluation framework allows for a better understanding of and forecasting of the outcomes of policy and business decisions.

The framework seeks to review the interdependencies between human (economic and social) systems, agriculture and food systems, and biodiversity and ecosystems services and environment. In doing so, it addresses the economic invisibility of many of these links while exploring how biodiversity and key ecosystem services deliver benefits to the agriculture sector and beyond, itself being a key contributor to human health, livelihoods and well-being. In the framework the following capital dimensions are distinguished:

a. Produced and financial capital;
b. Natural capital (e.g. GHG emissions, biodiversity and ecosystems services);
c. Human capital; and
d. Social capital.

The descriptive use of the framework tends to focus on stocks, flows and outcomes, while the analytical use of the framework tends to focus on outcomes and impacts of agri-food systems on human wellbeing. In both uses, all stages of the agri-food value chain are intended to be covered, from production through to final consumption and human health. The figure below summarizes and visualizes the linkages between the stocks, flows, outcomes and impacts.

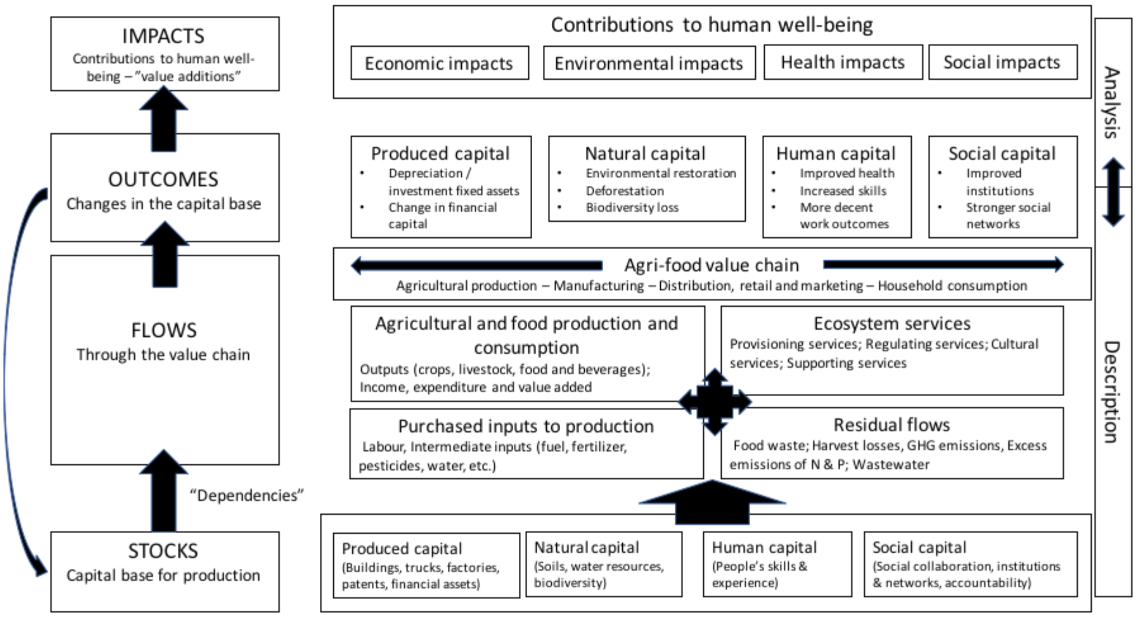


Figure 1.1: TEEBAgriFood schematic showing the eco-agri-food system nexus. Source: TEEB

1.3.2 Approach

For the initial assessment of the socio-economic and environmental impacts, we considered the current value chain of the three traditional livestock production systems. We do not compare the three systems with each other, but for each system, we evaluate an improved production scenario. This production scenario is hypothetical in the sense that the average farmer produces less efficiently, but there are already a few farmers who are able to produce conforming to the improved production scenario. Next to the initial assessment of the current impacts, we considered improved livestock systems based on small technical improvements that could contribute significantly to a more efficient livestock production system.

Effects on produced and financial capital

We will describe the flows of the stocks for each value chain, including change of the value in machinery and equipment, infrastructure, research and development, and finance. For all value chains, this will be evaluated in a qualitative way.

Effects on produced and financial capital are quantified by assessing the typical income of each value chain actor including financial and in-kind household income, price mark-up, cost of labour, purchased inputs and asset value of livestock. This was built upon by the addition of several data sources for both the calculation of contributions to the value chain and profit and loss (P&L) accounts for households. A more detailed overview of data sources used can be found towards the end of this section. The potential impact of improved scenarios is assessed looking at expected changes in household income and costs. All the results in Chapter 3 express changes in income based on changes in revenues and costs. Annex 2 gives detailed information of all the evaluated flows within the income changes.

Effects on natural capital

For the environmental modelling, the Global Livestock Environmental Assessment Model (GLEAM) was used to evaluate the effects of change in feed and herd dynamics on GHG emissions, covering the three major GHGs from agri-food chains, namely methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) (Gerber et al., 2013). The methods used in GLEAM to calculate the GHG emissions are mainly sourced from the Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 2006; IPCC, 2007).

The model is built on five modules (Gerber et al., 2013): the herd module, the manure module, the feed module, the system module and the allocation module. Once the herd structure (e.g. number of animals in each cohort) and animal characteristics (e.g. live weight, mortality rate etc.) are defined, energy requirements for each animal category are calculated in the system module. The model presumes that the energy requirements of animals are met, which is not necessarily the case in Tanzania. The user inputs the proportions of feed items used to feed the animals in the feed inventory containing data associated with the production of each feed ingredient. The information on herd structure, manure, animal and feed characteristics is used in the system module to calculate the amount of animal products produced per year. Subsequently, the emissions associated with manure management, enteric fermentation and feed production are estimated. Energy use on farm is added to the total emissions, which are then allocated to co-products and services in the allocation module. Allocation in this study was based on protein content. Emissions intensity i.e. emissions produced per unit of product are reported as a final output. Land-use change was not part of this assessment at farm level. However, for the system, the implications on pastoral land management and biodiversity in the context of regional land use change trends are presented in the landscape level assessment of ecosystem services of pastoralism (explained below).

We will describe other relevant positive and negative environmental externalities related to the following natural capital stocks for each value chain (for a complete overview of the flows see Figure 6.1 in TEEB (2018):

- Fresh water (incl. quality, quantity);
- Soil (incl. quality, quantity);
- Air;
- Vegetation cover and habitat quality;
- Biodiversity (quantitative by referring to Globio Model output as described in Baltussen et al., 2017[3]);
- Land use based on general land and agricultural statistics;

The ecosystem services of the pastoral livestock system have been assessed as part of the natural capital assessment. This assessment builds on the innovative natural capital analysis of the Maasai steppe that was developed in the previous TEEB global livestock study (Baltussen et al. 2017, explained in True Price, 2016) to quantify key positive externalities of grassland management carried out by pastoralists at the landscape level. The results presented in this report add one additional layer to the above-mentioned analysis, taking the perspective of the value chain of pastoral meat and, in particular, that of meat consumption in the region. Past research shows evidence that pastoral livestock systems maintain natural capital stocks better than sedentary farming, as farming in the region has shown to have two main negative effects on the environment: the decline of wildlife migratory corridors and land degradation (Msoffe, 2010; Msoffe et al., 2011; FAO, 2009).

[3]GLOBIO is a tool to assess past, present and future impacts of human activities on biodiversity. For our study we only used it to assess the present situation because we only considered livestock activities at farm level and not other human activities such as arable farming, mining, climate change.

The Maasai steppe is a biodiversity rich area, hosting some of the most visited National Parks in Tanzania. Grassland areas used by pastoralists for grazing act as migratory corridors that allow large mammals such as wildebeest, elephants and zebras to graze outside National Parks in the wet season. However, only five of the nine migratory corridors that existed in 1988 were still open in the 2000s, due to the expansion of sedentary farming and the shrinking of pastoralists rangeland (trends that are continuing today), leading to a steep decline of wildlife populations (Msoffe et al., 2011). In terms of ecosystem services, this can be translated into effects on the economic potential of the national parks. Besides the decline of wildlife corridors, another prominent effect of land use change in the region is land degradation. As land in the Maasai Steppe is generally arid and not particularly suited for farming or keeping concentrated livestock, agriculture is characterized by low productivity and declining soil fertility. Degraded land that can no longer be used for farming or grazing, is systematically abandoned (Msoffe, 2010; FAO, 2009). In terms of ecosystem services, this can be linked to lower food production and lower land carbon stocks stored in soil and biomass. Based on this research, we analyse natural capital effects of pastoralism looking at these three types of ecosystem services: contribution to tourism, carbon storage and land degradation prevention. These represent key flows from natural capital to human well-being in this region that are protected by pastoralism[4].

The following question is asked: *what is the value of landscape-level positive externalities of pastoralism compared to sedentary farming per unit of meat produced in that region?* To answer this question, we quantify tourism, carbon storage and land degradation prevention, as monetary benefits per kg of meat produced. These ecosystem services represent quantifiable positive impacts on natural capital of pastoral livestock systems compared to sedentary agriculture in the same region. The results can be compared to household income and the retail price of meat. The methodology used for each of the three ecosystem services is summarized below and presented in detail in Annex 3. The assessment of ecosystem services of the pastoral cattle system focusses on the baseline scenario, as it was outside the scope of this project to also gather the data required to assess the improved scenario.

Contribution to tourism. Tourism revenues, based on biodiversity, come from investments in tourism infrastructure and labour, but also from the existence of wildlife corridors and wet season grazing areas that are outside national parks and under pastoral management. These grazing areas are used by pastoralists for their herds and frequented by wildlife and as such increase the area of the habitat available to elephants, wildebeests, giraffes and other animals. Wildlife populations in turn, contribute to attract visitors in the two National Parks in the region. In other words, pastoralist rangelands allow to sustain larger wildlife populations than those that would be viable if sedentary farming would take the place of pastoral livestock herding. Contribution to tourism can therefore, be quantified as a side flow of economic benefits to pastoral food production.

Carbon storage. Potential carbon losses are very large if current land conversion trends continue. Up to 35% of the regional area could be converted to sedentary farming according to FAO (2009). As discussed in Baltussen et al. (2017), carbon is removed from agricultural land through crops and crop

[4] Contribution to tourism, carbon storage and land degradation prevention represent two of the three categories of ecosystem services of the TEEBAgriFood framework: cultural and regulating ecosystem services. The third type, provisioning services, had been quantified for Maasai pastoralism in Baltussen et al. (2017) through a range of animal products (meat, milk, skins and blood, which is in certain cases consumed by Maasai) and grassland products. In this case we consider beef as the denominator of the analysis (e.g. results are per kg of meat produced) while we exclude the other provisioning services, as these were found to be marginal compared to beef. Other ecosystem services of Maasai rangeland that may be important but could not be quantified are water cycle regulation and carbon sequestration.

residues. Additionally, ploughing the land increases soil micro-organism respiration and decreases soil carbon stocks. By managing grasslands to graze their livestock and by preventing land from being converted to cropland, the pastoral system allows for maintenance of soil carbon stocks. Carbon storage is quantified by looking at the difference between the original carbon stocks of grasslands and the final carbon stocks after land converted to cropland has become unfit for agricultural purposes, and dividing these by the total food output in this period.

Land degradation prevention. Beyond the loss of soil carbon stock, areas converted to agricultural land lose productivity over time. The prevention of land degradation is a positive externality of pastoral systems. Grassland converted to farmland in this region has been shown to become abandoned after only 20 years of farming, by which time it has become unfit for agricultural purposes (Msoffe, 2010). The value of preventing land degradation of pastoral grassland management is quantified as the difference in depreciation of the natural capital value of land of an average hectare of grassland and an average hectare of farmland over the respective amount of food produced in a period of 20 years. The natural capital value of land is defined as the present value of food provisioning ecosystem services over that time period with a discount rate of 2.5%. A more detailed explanation is provided in Annex 3.

Improved scenario

For each livestock system, a baseline value representing the current situation is compared to an improved scenario. The improved scenarios have been defined, based on the reference situation for each of the livestock systems studied, taking into account a realistic development scenario and the current enabling environment (e.g. education, infrastructure, agricultural policies). We also considered stocks and flows of the agricultural system, the social system and the ecosystem. As an improved scenario, we took a number of limited technical improvements within the existing farm structures. The reasons for this are the following:

- The ecosystem is sensitive to intensification for land use, for example due to changing the pastoral system into sedentary livestock farming that includes arable farming (see also Baltussen et al., 2017);
- 67% of the population still live in rural areas where alternative employment opportunities outside the agricultural sector are limited; and
- Past agricultural policies in Tanzania (e.g. Livestock Strategy (URT, 2010)) have been proven to be ineffective until now (see Chapter 6).

To increase food production and to improve the income position of the value chain actors without harming the social system and the ecosystem, we developed an improved scenario containing the following aspects:

- Improving management practices such as better-quality feed and use of medicines to improve animal health. For smallholder dairy, we also considered the use of artificial insemination to improve the output per unit of input of dairy cattle by introducing improved breeds.
- Improved knowledge by supporting a well-functioning extension service to support production and marketing practices without endangering the environment.
- We assume that no further investments in infrastructure are needed for the poultry and beef value chain. However, for the improved dairy chain it might be necessary to introduce an improved milk collection system to keep the milk cool and the process accordingly.

For each of the improved scenarios, specific changes in inputs are given in a footnote in the respective chapters.

Human and social capital
Human capital and social capital are assessed by describing for each value chain and the differences between the scenarios in a qualitative matter based on literature and some statistics. Different stocks are used for describing human capital: education, skills, health, working conditions. For social capital food security, opportunities for empowerment, social cooperation, institutions, law and regulations (child labour) are evaluated.

Data sources
For all assessments, we used different models to assess the change in the conditions of the capital dimensions and impacts. Overall, the background data on the economic dimensions of each system (including ecosystem services contributions) was drawn from the previous study (Baltussen et al., 2017), for example the number of livestock in each system, nutritional information as well as several of the outputs from each agricultural system for households. This was built upon using a large set of secondary data collected during a literature review and presented in the following Chapters. In Annex 2, an overview is given per stock or flow on what issue for what part of the value chain is taken into account and what type of information will be delivered. This is more or less the same for all three cases: the pastoral cattle system, the backyard poultry system and the smallholder dairy system. For backyard poultry, a majority of additional data was drawn from Queenan (2016) for both the value chain construction and P&L calculation, in-kind income, in terms of prices for sale and purchase, consumption rates of goods, as well as outputs from poultry. Further data was sourced for flock productivity for the P&L accounts (Alemayehu et al., 2018; Guni et al., 2013). For smallholder dairy, most data were sourced from IFAD (2016) for both the value chain and P&L, in terms of the pricing of cattle and goods produced, in-kind income, as well as input costs. Value chain data was supplemented with milk consumer prices from Katjiuongua and Signe (2014). For pastoralism, data for both the value chain and P&L were primarily sourced from Meshack (2015) as well as Chapters 1, 6, 8 and 9 from ILRI's 1991 book 'Maasai herding - An analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya'. The P&L account needed to be supplemented with further data on average meat prices (PINGO's Forum, 2016), total livestock units (ILRI, 1991), as well as outputs of sheep and cattle in pastoral herds in terms of milk and skins (Akliku, 2002; Mdoe and Mnenwa, 2007; Liljestrand, 2012; Tungu et al., 2016). All income figures were compared with benchmark minimum wages for agricultural services (WageIndicator, 2018), pastoral herder wages (FAO, 2007), and average rural household income (Lusambo, 2016).

1.3.3 Limitations

Our approach offers a high level of detail, but also has some limitations:

- The scope of the valuation is partial. Although the descriptions of the systems do cover a broad range of natural capital-livestock linkages, the impacts that could be quantified and monetized are limited. However, this does not influence the reliability of the results and it is important to keep in mind that other aspects (e.g. other income sources) should also be considered when drawing conclusions.
- The focus is on one type of benefit. Livestock is mainly kept for food provision, and therefore animal protein was chosen as the functional unit for this assessment. However, there are other benefits that humans derive from animal husbandry, which are overlooked if we limit our scope to the ratio between external costs and food output. Animal traction and the use of manure as fuel or as soil amendment could also be assessed monetarily from the bottom-up. The same holds for the quality of food produced, as contribution to human health could also

be included in the assessment of invisible benefits. Including into the picture these other benefits, in addition to the production of animal protein, would result in a more complete assessment but also introduce many methodological challenges related to the choice of a functional unit and system boundaries.

- Direct comparability is limited. The bottom-up valuation quantitatively assesses and compares the different livestock systems. The results are expressed in the same unit ($/kg of protein) and can be compared. However, the systems capture livestock systems in very different contexts, with their own economic and ecological constraints, and the systems do not necessarily substitute each other.
- System boundaries differ, and are not exactly the same for each natural capital aspect valued.

1.3.4 Reading guide

Based on the scope determined, the report is structured as follows:

- Chapter 2 describes the current value chain context of agri-food production systems for the three livestock systems;
- In Chapter 3, 4 and 5 we assess the impacts and dependencies between financial, natural, social and human capital systems for each livestock system;
- Chapter 6 provides a narrative on the Theory of Change, i.e. opportunities for policy interventions to capture the visible and invisible values of nature in decision-making, leading to better livelihood outcomes; and
- The report ends with the conclusions in Chapter 7.

2 Systems description

2.1 The pastoral cattle system

2.1.1 Introduction

Livestock production in Tanzania falls under three sub-systems namely commercial ranching, pastoralism and agro-pastoralism. Commercial ranching constitutes around 2% of all livestock activities in Tanzania. The remaining proportion is occupied by either pastoralism or agro-pastoralism. Pastoralism is practiced in areas characterized by poor soils and insufficient rainfall, which are areas that are normally unfit for crop cultivation. Therefore, livestock are mainly kept for subsistence, storage of wealth and cash earnings. The most popular livestock are cattle, goat, sheep and poultry. The United Nations Industrial Development Organization (UNIDO) defines ‘pastoralism’ as a traditional cattle production system, which relies entirely on natural pasture for animal rearing (UNIDO, 2012).

In Tanzania, about 50% of the households keep livestock and of these livestock-keeping households, 14% belongs to pastoral communities mainly living in the arid, semi-arid and dry regions (PINGO’s Forum, 2016). Pastoral communities in Tanzania are multi-ethnic in nature and Maasai is the dominating pastoral ethnic community. A study conducted in the North of Tanzania indicates that almost all pastoral households own cattle, goats and sheep (Mkonyi et al., 2017). More than 70% of the total cattle herd in the country are found in the eight regions namely; Arusha, Dodoma, Manyara, Mara, Mwanza, Shinyanga, Singida and Tabora (Figure 2.1) (URT, 2010).

Figure 2.1: Regions of Tanzania. More than 70% of the total cattle herd in the country are found in Arusha, Dodoma, Manyara, Mara, Mwanza, Shinyanga, Singida and Tabora. Source: URT (2010)

Over 95% of meat from cattle, sheep and goats in Tanzania comes from local breeds of animals mainly reared under extensive conditions in the pastoral, agro-pastoral and smallholder dairy systems (PINGO’s Forum, 2016; Trevor, 2015). It is estimated that over 90% of cattle herds in Tanzania are kept by pastoralists who supply the bulk of meat consumed in the country (Wakhungu et al., 2014).

Likewise, beef production in Tanzania is overwhelmingly the domain of small-scale traditional producers. It is estimated that up to 99% of red meat production is obtained from the traditional sector and there are prospects this situation will continue long into the future (Trevor, 2015).

2.1.2 Livestock genetic resources

The main cattle breeds kept by Maasai people and other pastoralists in the country are the Zebu and Ankole breeds (PINGO's Forum, 2016; Trevor, 2015). There have been efforts at breed modification through the promotion of the use of 'improved' Boran bulls mainly from Tanzania National Ranching Company (NARCO) and from few available private commercial ranches.

Tanzania has the third largest livestock population on the African continent comprising about 25 million cattle. A large share comprises of goats: 16-17 million, of which over 98% are indigenous goats belonging to the Small East African (SEA) breed. The SEA goats are widely distributed in all agro-ecological zones of the country and are kept mainly by pastoralists, agro-pastoralists and farmers engaged in mixed farming. According to Chenyambuga and Lekule (2014) the most important purpose for keeping goats in pastoral and agro-pastoral communities is provision of cash income obtained from sales of live animals and meat. Pastoralists also keep goats as savings to be drawn upon in times of need. Goats are also important for the production of meat for home consumption. They are also used for payment of dowry, to cater for traditional/cultural ceremonies and to provide skins, milk and manure (Chenyambuga and Lekule, 2014). In the pastoral community, goat milk is normally for home consumption.

2.1.3 Maasai pastoral herds and flock characteristics

Livestock numbers kept by pastoralists vary across households but consistently cattle is a dominant livestock species (Mkonyi et al., 2017). A group of households together typically own 300 head of cattle, 50 sheep and 60 goats (Baltussen et al., 2017). It is uncertain how many households would be in such a group of households because the characteristics of pastoral groups may not align with the regular understanding of a household. Based on sources about pastoral communities in Kenya and Tanzania, the number of households in the reference group of households is most likely within the range of 3-9, where the reported household size is around 14 people (Achiba, 2018; McCabe et al., 2010; Kaimba et al., 2011).

Table 2.1: Livestock per household group (herd size)

Animal Type	Animals
Cattle	300
Goat	60
Sheep	50

Source: Baltussen et al. (2017)

2.1.4 Pastoralists' meat and milk production

In addition to the production of meat (and milk, hides and skins), livestock have many other important outputs including their functions as draught animals, provision of manure, repositories of wealth, dowry payments, rituals and media of exchange (Trevor, 2015). Pastoral cattle grow slowly and in a classic gain-loss-gain pattern according to the rhythm of the seasons and the passage of the years. Male cattle may reach a maximum of 416 kg live weight (though the common range is between 240 and 270 kg) at slaughter age normally from 6 to 7 years (Baltussen et al., 2017; Trevor, 2015; URT, 2013). Females can reach a maximum of 320 kg, but 160—180 kg is a common range. Pastoralists' cattle produce little milk and meat but they are well adapted to the environment and long periods of harsh environments. In pastoral management systems, there are high mortality rates (8—10% in young and adult stock and around 25% in calves), coupled with an annual calving rate of less than 50%. These factors limit herd growth and more importantly commercial offtake. Dressing percentages[5] are generally about 46-47% in carcasses of 100—175 kg, whilst a few better-fed animals can give a carcass yield of 50% (Trevor, 2015; URT, 2013) (Table 2.2).

Table 2.2: Production parameters of cattle under pastoralist system in Tanzania

Production parameter	Estimate
Calving rate (%)	40-50
Calving interval (months)	18-24
Calf mortality rate (%)	25
Pre - weaning mortality (%)	25-40
Adult mortality (%)	8-10
Mature weight (kg)	320-416
Carcass weight (kg)	100 - 175
Offtake rate (%)	8-10
Age at first calving (months)	30
Lactation length (days)	400
Age at weaning (days)	180-210
Average milk production (litres/year/cow)	200
Age at slaughter (years)	6-7

Source: Baltussen et al. (2017); PINGO's Forum (2016) and URT (2013)

The average weight of a mature goat is 24 kg. These animals are good browsers, and are also somewhat prolific breeders and produce enough milk for twins (to which they often give birth) to grow at a reasonable growth rate and be ready for slaughter at an age of 8 to 12 months (URT, 2013). Pastoralists' goats are tolerant of harsh conditions and of some diseases, and obtain their nutrients from a variety of shrubs, herbs and grasses. Most goats slaughtered for meat are young males that normally yield a carcass of around 15 kg per animal (Table 2.3) (Trevor, 2015). There is insufficient information with regard to goat milk production among the pastoral community, which could be associated with the fact that pastoralists mainly keep local breeds of goats that are more suited for meat production.

Table 2.3: Production parameters of goat under the traditional sector in Tanzania

Production Parameter	Estimate
Kidding rate (%)	100-150
Age at slaughter (months)	8-12
Average live weight (kg/animal)	24
Off-take rate (%)	15
Average carcass weight (kg)	12-15
Average kid mortality (%)	20-40
Average adult mortality (%)	8-15

Source: PINGO's Forum (2016); Trevor (2015); URT (2013) and URT (2015)

[5] A dressing rate represents the meat and skeletal portion of an animal compared to its live weight.

The fat-tailed sheep reared by pastoralists are neither as hardy as goats nor as prolific (reproduction), as single births are typically the rule. The fat-tailed sheep are resistant to worms (helminths) that may be present in some other types of sheep. Mature live weights are almost the same as those of goats but growth rates are slow and carcass quality is not particularly good. Most sheep slaughters occur at the age approaching 12 months and provide a carcass of 10-12 kg, as can be seen in Table 2.4 (Trevor, 2015; URT, 2013).

Table 2.4: Production parameters of sheep under the traditional sector in Tanzania

Production Parameter	Estimate
Lambing rate (%)	100
Age at slaughter (months)	12
Average live weight (kg/animal)	24
Off-take rate (%)	25
Average carcass weight (kg)	10-12
Lamb mortality (%)	20-40

Source: URT (2013) Tanzania

Poultry, specifically chickens, are also raised by a large number of Maasai pastoralists, a practice that was not common in the Maasai land some decades ago. However, there is a tendency for Maasai men to say they do not have poultry, despite chickens running all around the *boma*. This is because poultry are largely owned by the women and are not considered livestock by the men. Likewise, there is a widespread perception among the Maasai men that chickens are the livestock for the poor and associate chickens with poverty (Kirwa et al., 2010). However, more and more households are developing an interest in chicken farming. Chicken raised by Maasai pastoralists often share the same production parameters as others raised in the traditional backyard system. The eggs laid by these chicken ranges from 12 to 15 per clutch and there are on average three clutches per hen per year.

2.1.5 Market structures and value chains for Maasai pastoralists' cattle

Tanzania mainland has in total 475 livestock markets countrywide, of which 464 are primary livestock markets and the rest are either secondary or terminal livestock markets (PINGO's Forum, 2016). The primary markets are normally characterized by sellers and buyers mainly from pastoralists themselves from within the market area; and a low price of livestock marketed. The buyer in the primary markets has higher bargaining power because the demand is lower than the supply, and the number of sellers is high compared to the number of buyers. In the secondary market there are more buyers so the seller and buyer share almost equal bargaining power due to higher demand. The terminal markets involve mostly livestock dealers that sell to local traders, international traders and slaughterhouses who buy and sell animal in bulk, and sometimes retail buyers can also be found here.

In this paragraph, we discuss the case of Arusha and surrounding regions in Northern Tanzania since this is the most important pastoral area in Tanzania (see Figure 2.2). Arusha Region ranks second in the total number of livestock unit in Tanzania. In terms of cattle only, it ranks number four after Shinyanga, Tabora and Mwanza regions. It also ranks first and second respectively in the number of goats and sheep (Allegretti et al., 2016). Arusha district and municipal council has one of the only modern public abattoirs in Tanzania which slaughters and processes meat for both internal and export markets. Its capacity is around 200 cattle and 200 other ruminants per day which is equivalent to 60,000 cattle and 60,000 other ruminants per year, respectively (PINGO's Forum, 2016).

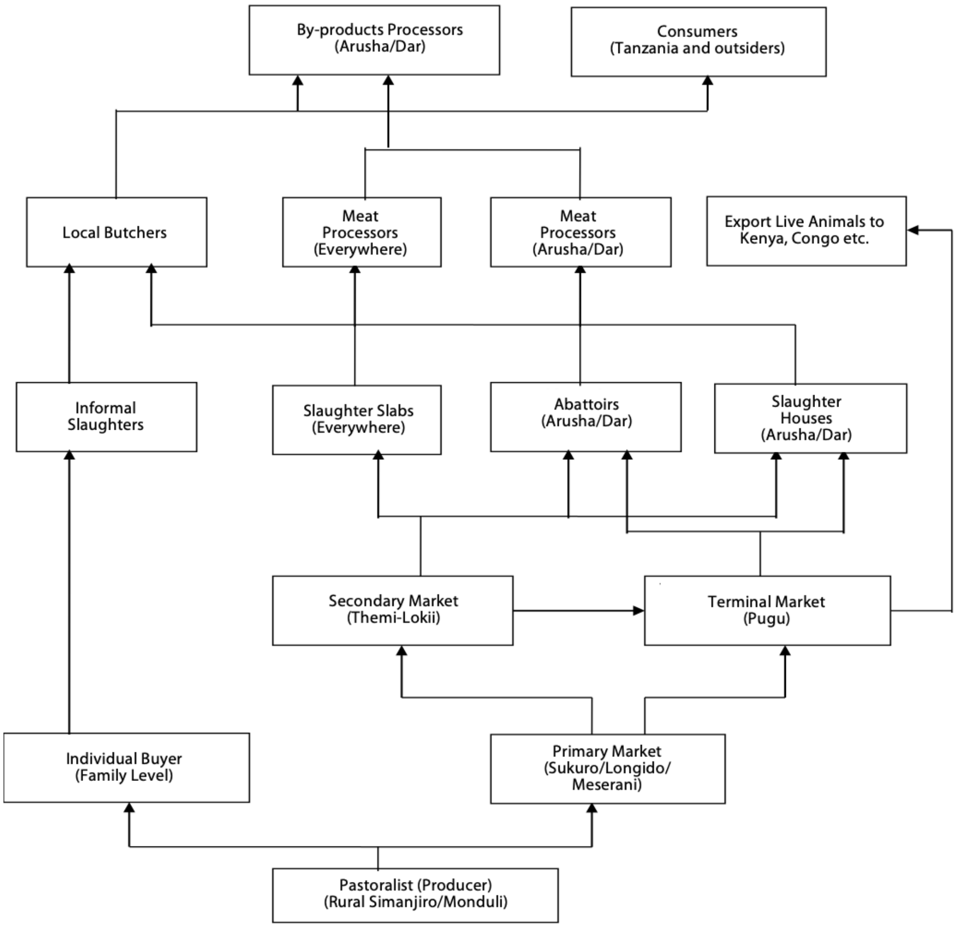


Figure 2.2: The livestock market in Arusha/Manyara regions. Source: PINGO's Forum (2016)

2.1.6 Value chain actors along the pastoral cattle value chain

Different actors exist in the pastoralists' cattle value chain in the Arusha region. The major actors in the chain are producers (farmers), middlemen (cattle traders), abattoirs, butchers, supermarkets, hotels and individual consumers (final consumers). However, middlemen have the greatest market power and are the primary source of market information. The characteristics of each of the actors are as follows:

Producers (Pastoralists): Pastoralists in Arusha (Monduli and Longido Districts) supply cattle to the primary markets around their districts and subsequently the animals are bought by traders who send them directly to Meserani secondary market or fatten some cattle that weigh too little, before re-selling them at higher prices.

Cattle traders: Pastoralists in the Monduli and Longido districts sell their animals to traders in the primary or secondary markets in their proximity. Markets are dominated by middlemen who contact pastoralists everywhere in the district, but only 10% of pastoralists manage to meet traders. In practice, most pastoralists (85%) sell their cattle to middlemen. Hence, in most cases traders buy the animals from middlemen at primary or secondary markets, and assemble and transport them to the terminal markets. Traders purchase four to eight animals or more in a given market day depending on the arrangement of a particular day and place. On average, cattle weighing about 200 kg cost about TZS 450,000. In most cases, they have the financial power to deal with their customers, including butchers, either for cash or on a credit basis. Cattle traders incur various costs, including market fees, labour costs (herder's wages), food, transport and cattle movement permits.

Butchers/meat shop operators: Owners and operators of butchers/meat shops are the category of actors who buy animals from the primary or secondary markets for immediate slaughter. These actors act as a bridge between traders and consumers. Some butchers go directly to livestock markets to buy live cattle but nonetheless often end up buying from traders. According to Meshack (2015), about 5% of pastoralists trade with butchers. They sell meat on a retail basis to restaurants, street vendors and the ultimate consumers. These also incur costs such as a holding pen fee, slaughtering fee, market fee, and costs for meat transportation and movement permits. Other butchers/meat shops operators are supplied by their beef suppliers under contracts. It should also be noted that butchers/meat shop operators play an important role as they link together producers, traders and final consumers. The Arusha region is reported to have about 260 butchers/meat shops.

Domestic abattoir: In the Monduli and Longido districts no abattoirs exist. There is a modern abattoir in Arusha City which is owned by the Arusha City Council and thus provides formal slaughter services to butcheries and the general public. This abattoir buys cattle directly from secondary markets, national ranches and livestock farmers. The designed capacity of the Arusha meat abattoir is to slaughter about 250 cattle per day, but due to inadequate infrastructure for handling cattle and the basic tools and equipment needed for slaughtering, the number of cattle slaughtered per day is only 200 (PINGO's Forum, 2016). Meat from the abattoir is sold to domestic markets (supermarkets, hotels and lodges, industries, institutions and final consumers) and some is exported to countries in the Middle East. Tanzania imports far more meat (especially from Kenya) than it exports. The exports of meat in dollars fluctuated from $40,000 to $3 million between 2014 and 2018, while imports fluctuated from $1.6 million to $4.6 million in the same period.

2.1.7 Consumption

Almost everyone in Tanzania consumes red meat, a large number of Tanzanian families own cattle, goats or sheep and approximately one third of the population are engaged to some degree in the production, processing and sale of red meat. Tanzania is currently unable to meet domestic demand for meat (Nadonde et al., 2017), which is also shown by the trade deficit shown above. Individual consumers buy meat from different sources such as butcheries and informal slaughterhouses, especially in villages.

- ***Supermarkets:*** Supermarkets mainly sell raw as well as processed beef and by-products directly to consumers for home consumption. These supermarkets are found in Arusha city and other urbanized areas whereby storage (chilling and cold chain systems) is maintained and therefore shelf life is extended. Supermarkets undertake further processing and packing activities at their premises. Since such processing and packing require special competencies, they need skilled and trained people (in processing and packing meat for retail outlets).
- ***Hotels and restaurants:*** These are other important actors because they act as intermediate consumers as they are supplied with carcasses by butchers. Meat is bought directly from butcheries or from the abattoir for those hotels in Arusha city and nearby villages.

2.1.8 Pastoral cattle feeding strategies

Herding is the main method used by Maasai pastoralists in supplying feed for their animals. Herding of older cattle is done by male children older than 11 years. Some Maasai pastoralists herd their animals collectively while others choose to do it individually. Maasai pastoralists inhabit marginal lands and therefore the availability and quality of the feed resource fluctuates throughout the year. Forage is abundant in the wet season, but is both scarce and poor in quality in the dry season. Various strategies are adopted by the Maasai pastoralists in overcoming feed shortage problems in the dry season. Of main importance is the grazing in the nearby crop fields after the harvest to utilise crop residues (Kitalyi and Kabatange, 1987). It is only when crop fields are exhausted that Maasai pastoralists will opt for other strategies including moving animals to distant grazing lands for varying periods of time depending on the severity of the dry periods.

The quality of forage determines the milk yield and libido of bulls. When animals graze good quality forage, milk production is high as well as the libido of bulls (Kavana et al., 2005). Pastoralists consider good quality grass during the rainy season to be grass with a height that is less than the animals' height. It is perceived that grasses with a height of 30-60 cm are suitable for grazing. However, this shows a dependency on natural capital since feed from some trees is also preferred by charcoal producers and they reduce the plant population very rapidly and consequently it affects dry season feed supply to livestock.

Kavana et al. (2005) point out several factors associated with the choice of grazing area and grazing range among the Maasai pastoralists. First, they regard body condition and milk yield to be the perfect reflection of the suitable range for grazing. Rumen-fill and milk yield determine the need to shift from one grazing area to another. Second, animals are shifted from a particular grazing area when their body condition worsens and they become weak and succumb to diseases easily, together with a deprived appetite while on grazing grounds. Third, the grazing area could be abandoned if the forage colour turns yellow from greenish together with too much trampling. According to Lindell (2013), other reasons for herd owners to graze their cattle in a specific area include the availability of good quality forage, lack of predators and tsetse flies, and the availability of open grazing areas.

The water sources for animals in Maasai pastoral areas include rivers, ponds and wells. Water is assessed based on colour, taste, turbidity, odour, and the occurrence of wild animals, parasites and algae. Kavana et al. (2005) noted that slightly coloured water is acceptable as a water source for livestock but milky coloured water is not preferred, while a salty taste is considered good for livestock in comparison to tasteless water. When referring to turbidity, muddy water is considered unsuitable for livestock. Likewise, the presence of healthy wild animals around water sources indicates availability of suitable water for livestock, while the presence of large numbers of swimming insects and the presence of floating algae leads to the rejection of water sources.

2.1.9 Extension services

The major objective of extension services is to assist farmers to increase agricultural production and productivity thus improving their socio-economic status. In Tanzania, the agricultural extension services have been allotted to local government authorities to ensure the effective participation of beneficiaries and to motivate private sector involvement in service delivery (Kimaro et al., 2010). Access to animal health care and production services are essential for livelihoods and the welfare of households that engage in livestock rearing and farming. The Tanzanian government has established a system of public village and ward level livestock providers to deliver basic animal health and husbandry services. However, while most rural wards have been assigned a public service provider, 80% of livestock rearing households report not having access to them. For example, data from the Tanzanian National Panel Survey shows that the majority of livestock farmers utilise rudimentary husbandry and production practices. 75% of livestock keepers do not adopt breeding or mating strategies, 60% do not vaccinate their animals and 65% do not treat their animals against parasites. This is because the agriculture extension services are severely constrained by a combination of factors including the shortage of qualified extension personnel, inadequate infrastructure and facilities, weak research-training extension- farmer linkages, and inadequate collaboration among stakeholders (RIU, 2011).

Gadner et al. (2012) reported that the accessibility of livestock extension officers and commercial medicines presented a challenge to the delivery of health care services to pastoralists. Pastoralists primarily travel by foot or bus, creating opportunity costs to obtaining health care. For instance, pastoralists travelled an average of three hours one-way to reach a livestock officer, and nearly five hours to reach a vendor selling medicine for their animals. Transportation therefore represents a significant drain on extension officers' time. In a recent survey conducted by the Tanzanian Ministry of Agriculture, Livestock and Fisheries, only 56% of officers reported having access to motorised transport, with essentially no support from the government (Chipman and Blum, 2016). Given this constraint, remote areas including those under pastoralists are less likely to be served. Pricing to cover the transport costs associated with livestock service delivery has been decentralised to service providers. This practice delivers an incentive for officers to perform their task and gives them the ability to balance the costs associated with travelling to remote areas. This suggests that extending animal health care services to smallholder livestock owners could produce significant productivity gains.

2.1.10 Scoping definition for the further evaluation

The current system is based on a herd of 300 cattle with almost no inputs. The labour is estimated at about six full-time equivalent (FTE); family labour. The improved system is the same as above in terms of animals and labour input, but adds improved access to knowledge, vaccines and medicines for veterinary care, and feed storage for the dry period. All other aspects of the livestock systems remain the same. Annex 1 gives an overview of all production and herd statistics used for the calculations for the pastoral livestock system assessed in this study.

Based on the system description we define the scope of the pastoral livestock system that we will use in the following chapter to evaluate the economic and produced capital, natural capital and the social and human capital. Table 2.5 provides an overview of the stages of the value chain and the different flows that we will take into account.

Table 2.5: Visible and invisible flows and value chain stages evaluated

	Production			Processing and distribution			Consumption	
	Land-scape	Infra-structure and manufac turing	Farm	Whole sale	Food and beverage	Retail	Industry/ household/ hospitality	Waste*
Captured by system of national accounts	N.A.	N.A.	XX	XX	N.A.	N.A.	XX	N.A.
Provisioning	XX	X	X	N.A.	N.A.	N.A.	X	N.A.
Regulation and maintenance	XX	N.A.	X	N.A.	N.A.	N.A.	N.A.	N.A.
Cultural	X	X	X	N.A.	N.A.	N.A.	X	N.A.
Human health		X	X	N.A.	N.A.	N.A.	X	N.A.
Pollution to air, soil and water	XX	XX	XX	XX.	N.A.	N.A.	N.A.	N.A.
GHG emissions to air, soil and water	XX	XX	XX	XX	N.A.	N.A.	N.A.	N.A.
Social values	N.A.	X	X	X	N.A.	N.A.	X	N.A.
Risks and uncertainties	X	X	X	X	N.A.	N.A.	X	N.A.

N.A. = not applicable
X = evaluated qualitatively
XX = evaluated quantitatively
* accounted for in the production stage

2.2 The backyard poultry system

2.2.1 Introduction

Backyard poultry production in Tanzania is a traditional sector at smallholder level, and has an important position in the rural household economy, supplying high quality meat and eggs, and increasing income for rural farmers (URT, 2016). The local chicken ecotypes are well adapted to local circumstances and are resistant to diseases. They are kept under free range and find their own feed. The birds often get leftovers or food that is unsuitable for human consumption. Housing is often limited to night shelters, and medical care is very limited. This low-input system for poultry also has a relatively low production level in terms of egg and meat production, with high death rates. The flock size per household generally varies from 10 to 30 (URT, 2012; Boki, 2000), but can occasionally be up to 150 chickens (Kisungwe, 2012). In the backyard, these chickens are generally kept in small scale traditional systems by the rural poor and managed by women and children. They play a vital role in households by providing an important source of high-quality nutrition, income, as well as quick cash to pay for medicine, food, transportation, school fees and manure. They supply over 70% of the poultry meat and eggs consumed in rural areas as well as about 20% in urban areas (URT, 2010). The demand for chickens in urban centres is high as most people in Tanzania prefer the taste of local chicken over the taste of exotic breeds that are perceived as relatively tasteless due to their rearing method. Local chickens are also considered free of antibiotics, hormones and other harmful chemicals (Mlozi et al., 2003).

Chickens drop their manure in the backyard, and only the manure in the night shelter can be collected as fertilizer for crop production. Greenhouse gases are estimated at 6.5 kg CO_2eq per kg carcass weight, based on regional figures (MacLeod et al*.,* 2013). Chickens also play a role in social activities, religious ceremonies and the traditional treatment of diseases (Knueppel et al., 2009). Poultry cohabit with humans and have free contact with potential reservoirs of Highly Pathogenic Avian Influenza (HPAI) viruses, salmonella and other zoonoses. The main constraints of the sector include weak producer organization, lack of knowledge on appropriate management practices, housing and feeding, disease control and prevention, inadequate extension services by public and private actors, inadequate supply of quality inputs and limited access to financial services and markets.

2.2.2 Chicken populations in Tanzania

The current chicken population in Tanzania is about 42 million chickens (URT, 2016). Within this number is about 39 million local village chicken kept predominantly in rural areas, and about 3 million commercial birds (broiler and layer chickens) kept by both smallholder farmers and large-scale farms. Based on the Annual Agriculture Sample Survey report (URT, 2016), Tabora region with 2,829,024 birds (7.3%) had the highest number of indigenous chickens, followed by Shinyanga with 2,332,826 and Singida with 2,184,743, while Njombe had the lowest number of 732,252. Other types of poultry kept in small numbers include ducks, turkeys, guinea fowls and pigeons.

Most chickens in the backyard system are local ecotypes that constitute various subpopulations which exist in different plumage forms and colours, showing a discrepancy in frequency of occurrence from one location to another. A study conducted by Guni, Katule and Mwakilembe (2013) has shown that location may have a significant effect on the performance of chickens with respect to egg production and other reproduction attributes as well as body weight and other body measurements. Chickens differ in weight depending on sex, age or ecotypes. Various studies in Tanzania have shown that cocks are heavier than hens at maturity and that the average body weight for male chickens fall within the ranges between 1.95 to 2.86 kg, whereas for female chickens ranges are between 1.03 and 1.52 kg (Katule, 1998; Msoffe et al., 2001; Mwalusanya et al., 2002; Guni et al., 2013). Egg production potential for most of these local chicken ecotypes is very low, around 40-60 eggs per year and most of these eggs are used for reproduction (Boki, 2000). Table 2.6 summarizes the production and reproduction traits of backyard chicken in Tanzania.

Table 2.6: Productive and reproductive traits of backyard chicken in Tanzania

Trait	Mean
Age at first egg (months)	7.5
Cock age at sexual maturity (months)	7.0
Clutch size per hen (number of eggs)	13.7
Clutch length (days)	17.8
Inter clutch duration (days)	14.0
Eggs incubated per hen per clutch (number)	11.3
Chicks hatched per hen per clutch (number)	9.9
Hatchability (%)	88.0
Weaning age (months)	2.59
Chick weaned (number)	6.9
Chick survival rate to weaning (%)	69.8
Cycles per hen per year (number)	3.3
Annual egg number per hen	45.2

Source: Guni et al. (2013)

2.2.3 Production

Table 2.7 exhibits the production of chicken meat and eggs from the periods 2005/2006 to 2014/2015. Total meat production increased from 69,420 tons in 2005/2006 to 99,540 tons in 2014/2015. During the same period, egg production has increased from 2.1 billion to 4.2 billion. Unfortunately, there is no up-to-date information available on more recent production figures.

Table 2.7: Production of chicken meat and eggs in Tanzania between 2005 and 2015

Year	Meat (tons)	Egg (billion)
2005/2006	69,420	2.1
2006/2007	77,280	2.2
2007/2008	77.250	2.7
2008/2009	78,168	2.8
2009/2010	80,916	2.8
2010/2011	93,534	3.3
2011/2012	84,524	3.5
2012/2013	87,400	3.7
2013/2014	91,700	3.9
2014/2015	99,540	4.2

Source: URT 2010; URT 2015

There is a generally scant literature on poultry marketing systems in Tanzania. However, the limited research shows that a large number of marketing agents are involved throughout the poultry marketing chain including chicken keepers, input suppliers, wholesalers, retailers, processors, and consumers. A study by Wilson (2011) identified two market chains from producers to consumers. The first chain started from producers through to local collectors at the farm gate. The local collectors, who also acted as traders at primary markets, sold the chickens to bulk suppliers who bought the chickens at primary markets. The bulk suppliers sold the chickens to hotels, restaurants and bars (retailers), and the latter sold to consumers. The second chain on the other hand, involved producers who sold the birds to wholesalers at primary markets; the primary market sold to bulk suppliers from cities who sold to hotels restaurants/bars (retailers). The retailers then sold to consumers. The local collectors and bulk suppliers are also regarded as middlemen in the poultry marketing chain. Queenan et al. (2016)

grouped the key marketing chain actors into producers, intermediaries, market traders and consumers.

Producers: These are chicken keepers and they undertake a number of roles in the value chain. They raise the chickens, process them at household level, and also sell live chickens to intermediaries, traders or to individual farmers for consumption. In most cases small flocks of local chickens are owned and managed by women, youth, and children who are at home most of the time. However, there is a tendency for men to dominate the poultry business as poultry flocks become larger and production becomes more commercial (Queenan et al., 2016; Mnenwa, 2010). Chicken production is both for selling and home consumption, although in most cases selling is much higher than for home consumption in village areas. A study by Queenan et al. (2016) revealed that producers in the villages sold twice as many chickens than they consumed in a year. This is different to urban and peri-urban areas where the local chickens are mainly kept for domestic consumption rather than for commercial purposes (Chingonikaya and Salehe, 2018). The majority of producers in the villages do not sell eggs but instead left the chickens to hatch their own eggs in order to increase the flock size (Queenan et al., 2016).

Intermediaries (middlemen) and market traders: Middlemen play a major role in the local chicken marketing chain as they benefited more and earned 65% of the total profit generated in the local chicken market chain (Mlozi et al., 2003). The quantities of chickens supplied and sold in the markets are elastic and varied significantly with sex, month of the year as well as seasons, and more cocks than hens are usually supplied in the markets. High profits are obtained by middlemen from September to December because farmers sell fewer chickens due to low chicken numbers in farmers flocks due to the occurrence of diseases such as Newcastle disease, which shows a seasonal occurrence pattern with a peak in the dry season (August - November). This creates a shortage of chickens to the markets and causes a high demand of local chickens which results in increased chicken prices (Mlozi et al., 2003).

Retailers who purchase chickens directly from producers benefited more in the market chain. For example, a retailer can purchase local chickens at an average price of TZS 8,000 from producers or a local market and sell to consumers for roughly TZS 15,000 per mature chicken (Peter, 2015). The majority of all retail chicken and egg sales in rural areas are carried out directly by household members. Women are normally involved in farm gate sales and the agreed prices are the basis for negotiations between the traders and poultry keepers. Retail trade for local chickens in markets and towns is normally managed by men, and men also normally dominate most wholesale trading activities that require travel and transportation. They tend to be more mobile and to have more outside contacts than women. A study by Queenan et al. (2016) has noted that women have less time available for marketing-related travel due to household and family responsibilities. As a result, men have more access to information related to the chicken production and sales than women.

Consumers: Chickens can be purchased as live birds and slaughtered at home or at the market place. The consumers preferences influence the type and quality of local chickens offered by keepers and traders. Some consumers prefer hens as they are perceived to be more tender while others prefer cocks due to bigger body size and better taste. Chicken prices are influenced by several factors among which are sex, body weight and the general health of the bird (Queenan et al., 2016).

2.2.4 Consumption

The per capita consumption levels in Tanzania are estimated based on per capita availability of poultry and eggs assuming that the poultry and eggs made available are actually consumed (Mnenwa, 2010).

The average consumption of chicken was reported to be about 0.7 kg of chicken meat and 13 eggs per capita per year in Tanzania in 2010, which was relatively low in comparison to other African countries and the rest of the world where the average consumption is about 6.8 kg and 108 eggs annually. For instance, consumption of chicken meat by chicken keepers in rural areas was often limited to periods of chicken disease while egg consumption was restricted to those that were damaged or those of less broody hens (Queenan et al*.,* 2016).

Income level is one of the main factors that influence the pattern of the consumption of poultry products, but consumer tastes and preferences play an even bigger role. Most of the poultry products are consumed in urban areas as opposed to rural areas (Mnenwa, 2010). It has to be noted that the consumption of poultry products also varies from one location to another. A baseline survey on backyard poultry production conducted by the African Chicken Genetic Gains (ACGG) in five zones of Tanzania has revealed differences in egg and meat consumption between zones (Alemayehu et al., 2018).

2.2.5 Poultry feeds

In contrast to the backyard chicken system in which chicken are kept under free range and find their own feed, the success of the poultry industry depends on the availability of quality feeds. Energy-rich feedstuffs such as grains of maize, sorghum, pearl-millet and their by-products, are the most important scavengeable feed resources and are also the most important crops grown for human consumption in Tanzania. Their availability is high during the dry season when they are harvested. These energy-rich feedstuffs are used mostly as basal feeds or as supplements to the diets scavenged by rural poultry in most rural households in the villages (Goromela et al., 2009). Supplementation with available feedstuffs is generally done by giving cereal grains, their by-products and household wastes in the morning or evening when chickens return from scavenging, depending on their availability in the households. However, supplementation of these feedstuffs decreases or sometimes disappears during the wet season in most households due to their scarcity. Protein-rich feedstuffs such as sunflower seeds, groundnut seeds, sesame seeds and sunflower seed cakes are also the most important poultry feeds in the villages.

Production of commercial feed in Tanzania is not well regulated; hence the quality of chicken feed is uncertain and may vary between batches as well as among manufacturers. Poor quality feed is therefore an issue for commercial farming in Tanzania. Most of the feeds are low quality and are lacking in nutritional content in terms of energy, protein, mineral and amino acid and crude fibre content. Based on the chemical composition of the feeds, the quality of almost all the feeds manufactured in Eastern and north-eastern Tanzania were lower than the requirements of the chickens (Msami, 2008). Crude protein and metabolisable energy contents of the feeds were below the recommended levels which contributed to the low performance of the chickens. Unfortunately, there is little institutional capacity to control the quality of chicken feeds produced and processed (Da Silva et al., 2017). The prices of poultry feed are still relatively high due to the fact that feed millers are competing with other millers for raw materials, which affects the price of the end-product (i.e. poultry meat and eggs). As a result, the feeds and poultry products become more expensive in Tanzania compared to other countries which use raw materials such as yellow maize, soya bean and by-products from meat processing and oil pressing industries for feed manufacturing.

2.2.6 Veterinary

Viral infections (such as infectious bursal disease, Newcastle disease and fowl pox), bacterial infections (such as coccidiosis and salmonellosis), internal and external parasites, and malnutrition have been mentioned as major causes of disease and death of village chickens in Tanzania (Sonaiya and Swan, 2004). Newcastle disease is usually mentioned by farmers as the major constraint inhibiting rural chicken development. The disease outbreak is usually accompanied by high mortality rates which discourages farmers from investing much time or money in their flocks. The disease shows a seasonal occurrence pattern with a peak in the dry season (August - November) with all age groups being equally affected, but this has been controlled to a large extent due to the development of a thermo stable vaccine known as I-2 produced by The Tanzania Veterinary Laboratory Agency (TVLA).

Disease prevention rates ranging from 77% to 100% have been reported for a vaccine which is administered as an eye-drop (Wambura et al., 2000; Illango et al., 2005). The vaccine is inexpensive and easily administered by trained villagers. Currently, a dropper vial of the I-2 vaccine, is enough to vaccinate around 500-1000 chickens and costs TZS 5,000 to 6,000 ($2.25-2.7).

In the villages, veterinary drugs (including antibiotics, dewormers, vitamins and vaccines) for local chickens, are purchased either from local village pharmacies or in nearby urban centres, despite its utilization by farmers being inconsistent due to the lack of technical skills, storage facilities and accessibility. Saleque et al. (2016) reported that only 18% of farmers had access to inputs including vaccines. As a result, some farmers utilise traditional herbs either to strengthen the immune system of the chickens or as treatment. Low cost, local availability and easiness of application were the main reasons for the use of local herbs (Sindiyo and Misinga 2018; Chingonikaya and Salehe, 2018).

Poultry production has a relatively high risk of zoonoses. This is the case for small-scale and large-scale production, but the mechanisms and risks are of a different nature. In small-scale systems people are more continuously in direct contact with animals, while industrial systems are more market oriented and are therefore likely to be better controlled. Preventive use of antimicrobials is quite common in medium and large-scale poultry production, posing the risk of increasing resistance against antibiotics. Zoonoses should be controlled without excessive and preventive use of antibiotics. Antibiotics are often relatively cheap and used in a preventive way to hide the defects of the production system, but there are also best practices where high productivity is possible without the preventive use of antibiotics. In that sense, the interaction between the type of animal/breed and the level of management in the poultry system is important (Baltussen et al., 2017).

2.2.7 Extension services

Delivery of quality agricultural extension services in Tanzania has been the centre of attention for quite a long time, given the fact that the majority of Tanzanians (more than two thirds) live in rural areas and depend on small-scale agriculture including chickens for their livelihood and employment (URT, 2006). The Government's efforts have been geared towards improving production and productivity so as to attain food security and sufficiency at both household and national level.

Agricultural extension services in Tanzania have been allotted to local government authorities to ensure the effective participation of beneficiaries and to motivate private sector involvement in service delivery (Kimaro et al., 2010). Various approaches including farmers field schools, farming systems approach, training and visit, contract farming, participatory extensions and farmer to farmer extensions have been proposed as methods to reach the farmers (Kimaro et al., 2010).

Nevertheless, the agriculture extension services are severely constrained by a combination of factors including a shortage of qualified extension personnel, inadequate infrastructure and facilities, weak research-training extension- farmer linkages, and inadequate collaboration among stakeholders (RIU, 2011). For example, a study on small scale poultry rearing in Tanzania by Saleque et al. (2016), revealed that only 36% of surveyed households had access to extension services, 24% had access to training, 18% had access to livestock inputs, whereas only 17% conducted farmer meetings. Moreover, a clear mechanism for monitoring and regulating the indigenous poultry industry in Tanzania has been largely missing, partly due to the backyard nature of the industry characterized by subsistence production, low productivity of chickens, lack of a functional value chain, and limited public and private sector interest and investments in the industry.

2.2.8 Scoping definition for the further evaluation

The current backyard chicken livestock system is based on a flock of 29 chickens with almost no inputs. The death rate for pullets is 50%, and 20% for adult females, while egg productivity is 50 eggs per year. The improved system is the same as above in terms of animals present at a certain moment, but improved access to knowledge, vaccines and medicines, will reduce the death rate of pullets and females (30% and 10%). In addition, the egg productivity will increase to 70 eggs per year. All other aspects of the livestock system remain the same. Annex 1 gives an overview of all production and herd statistics used for the calculations in this study.

Based on the system description we define the scope of the backyard chicken system that we will use in the following chapter to evaluate the financial and produced capital, natural capital, and social and human capital. Table 2.8 provides an overview of the stages of the value chain and the different flows that we will take into account. An evaluation of the landscape at production level is not applicable for the backyard poultry system since all chickens are kept in the backyard.

Table 2.8: Flows and value chain stages considered

	Production			**Processing and distribution**			**Consumption**	
	Landscape	Infrastructure and manufacturing	Farm	Wholesale	Food and beverage	Retail	Industry/ household/ hospitality	Waste*
Captured by system of national accounts	N.A.	N.A.	XX	XX	N.A.	N.A.	XX	N.A.
Provisioning	N.A.	X	X	N.A.	N.A.	N.A.	X	N.A.
Regulation and maintenance	N.A.	N.A.	X	N.A.	N.A.	N.A.	N.A.	N.A.
Cultural	N.A.	X	X	N.A.	N.A.	N.A.	X	N.A.
Human health	N.A.	X	X	N.A.	N.A.	N.A.	X	N.A.
Pollution to air, soil and water	N.A.	XX	XX	XX	N.A.	N.A.	N.A.	N.A.
GHG emissions to air, soil and water	N.A.	XX	XX	XX	N.A.	N.A.	N.A.	N.A.
Social values	N.A.	X	X	X	N.A.	N.A.	X	N.A.
Risks and uncertainties	N.A.	X	X	X	N.A.	N.A.	X	N.A.

N.A. = not applicable
X = evaluated qualitative
XX = evaluated quantitative
*accounted for in the production stage

2.3 The smallholder arable dairy system

2.3.1 Introduction

The livestock sector contributes to 4.6% to Tanzania's GDP; the dairy sub-sector contributes about one-third of the livestock sector's output (Njombe et al., 2011; URT, 2013). Despite the potential benefits of the dairy sub-sector, commercial dairy activities in the country are at an infancy stage. The bulk of milk produced originates from the traditional cattle that form over 90% of the cattle population and is consumed at household level, with only about 3% of the milk filtering through to the formal market (Urassa and Martin, 2013). Despite this, the dairy sub-sector contributes to the employment of over 2 million households working at different stages in the value chain i.e. the production, processing, marketing and consumer stages (Urassa and Martin, 2013). For that matter, the dairy sub-sector has greater potential for improving people's livelihoods through improved nutrition arising from milk consumption, increased employment and incomes raised from sales of milk and milk products, both in rural and urban areas. Nevertheless, its potential has not been fully unlocked.

The dairy sub sector is usually divided into two main categories; the traditional sector with local breeds and the modern sector with grade cattle (cross-breeds and pure-breeds). Sometimes milk produced on medium to large scale farms with grade cattle (crossbreeds and pure-breeds) are counted as a separate third category. The traditional systems are the largest category and consist of local zebu cattle where milk is one of the products besides meat, savings, draft, etc. The milk produced under this system is mainly used for home consumption and only excess can be marketed (Nell et al., 2014). Traditional systems include pastoralism, agro-pastoralism and smallholder mixed farmers (sedentary). Milk is an important product for home consumption and seasonal surpluses are available for marketing provided there are customers (Nell et al., 2014). With this system, owners of the cropland can benefit from cattle manure which has the potential to improve soil fertility. Likewise, milk produced by agro-pastoralists is used for home consumption and any seasonal surpluses may be marketed if there is an opportunity to sell. Smallholder mixed farming, also known as sedentary farming, is a production system mainly in the sub-humid areas of Tanzania (Nell et al., 2014). Under this system, cattle are mainly kept for manure purposes to improve soil fertility. Cattle density under this system is generally low, and milk production per unit area is low and consequently milk offtake per unit is also low with high collection costs.

Smallholder arable dairy systems based on grade dairy cattle are the second category of milk production in Tanzania. The cattle kept under this system are mainly crossbreds of exotic dairy breeds with either Tanzania Shorthorn Zebu or Boran. Milk production is the main aim and most of the milk is marketed as fresh milk (Nell et al., 2014). Dairy production systems with grade cattle are further categorized as rural smallholder dairy systems and urban-/peri-urban smallholder dairy systems (IFAD, 2016). Under rural smallholder arable dairy systems, farmers manage small mixed farms with crops and livestock in the rural areas. Farms have 1–5 dairy cows kept under semi-zero grazing systems based on cultivated crop residues, fodder and cut grasses from communal land (IFAD, 2016). Farmers use varying levels of inputs such as artificial insemination, bull services, veterinary care by Community Animal Health Workers (CAHW), feed conservation and supplementary feeds. Direct marketing of milk to consumers is limited as farmers sell the milk through middlemen or milk collecting centres. Farmers' use of the inputs depends on marketing opportunities for milk and also on their income from milk sales. Urban-/peri-urban smallholder arable dairy sub-systems are similar to rural smallholder dairy systems, but differ in their higher level uses of inputs such as animal health care services and feeds. Farmers applying this sub-system sell the milk through informal markets which are considered more profitable than the formal market.

Medium and large scale dairy farming sub-systems normally encompass private farms keeping crossbred and purebred dairy cattle (IFAD, 2016; Nell et al., 2014). This system requires a substantial amount of land for fodder production and conserving roughage (hay or silage) for use in the dry season. There is also a high level of usage of external inputs such as animal health care and supplementary feeds. Farmers sell the milk directly to milk plants, and sometimes the milk is processed on the farm and products sold in the cities.

2.3.2 Other livestock species in the smallholder arable dairy system beside cattle

While cattle are the most dominant species among smallholder dairy farmers, goats, sheep, pigs and chicken are also kept by a significant number of households. About 38% of the smallholder farmers keep goats, 14% keep sheep while 11% keep pigs (NBS, 2012b).

2.3.3 Crop production in the smallholder arable dairy system

Crop production is an integral part of the smallholder arable dairy farming system in Tanzania. About 39% of smallholder farm households engage in mixed crop-livestock (NBS, 2012a). On average, these households cultivate around 2 ha of land. The main types of crops grown in Tanzania are cereals (for example: maize, rice and sorghum) which occupy 67% of the land under annual crops, followed by pulses (11%), oil seeds and oil nuts (11%), root and tubers (3%), cash crops (tobacco, cotton, pyrethrum, jute and seaweed) (7%), and vegetables and fruits (1%) (NBS, 2012a). Taking an example of the Mbeya Region in the Southern Highland of Tanzania, maize is the dominant annual crop grown by smallholder households and it has a planted area 3.1 times greater than beans, which has the second largest planted area (URT, 2012c). Other crops grown in the region in order of their importance (based on area planted) are beans (15.2%), paddy (14.3%), and groundnuts (5.9%). Others though grown in a small area include sunflower, cassava, sweet potatoes, sesame, sorghum, finger millet, tobacco, wheat, Irish potatoes, field peas, tomatoes, pyrethrum and bulrush millet.

Land scarcity has contributed significantly to the high degree of dependence between the crop and livestock sub-systems (Mlay, 1985). Stall feeding is the rule, and crop by-products are extensively used as feed, while the manure from the livestock is in turn, used on the crop plots to maintain soil fertility. In the highland zones of the country, coffee intercropped with bananas are the main crops. Vegetables also grow in these zones. Maize and beans are the main crops in the lowland zone, either as pure stands or intercropped. Livestock also contributes to crop production through the provision of draft power for ploughing and packing for transportation. Livestock is an important part of the farming system considering the low availability of tractors and the virtual absence of artificial fertilizers used by smallholders in Tanzania (NBS, 2012b).

2.3.4 Breeding practices

The Zebu is the most widespread cattle breed in the nation and dominates milk production in the traditional sector. The grade cattle are mainly cross-breed of Friesian, Jersey and Ayrshire with the Zebu. Total grade cattle are estimated to be between 600,000 and 700,000 heads, about 3% of the cattle population in Tanzania (NBS, 2012b; Nell et al., 2014).

Most (over 60%) of the smallholder dairy farmers use bulls to mate their cows (Temba, 2011), while artificial insemination is only practiced by few farmers. Thus, the easy availability of bulls makes dairy farmers depend mostly on natural service rather than on AI. The drawback of depending on natural service is that the bulls available are not necessarily genetically superior. A continuous supply of artificial insemination services is essential to convince the farmers and to build their confidence about artificial insemination services. However, a study by (Temba, 2011) shows that the majority (62.2%) of smallholder dairy farmers indicated difficulties in receiving artificial insemination services. The dairy industry in Tanzania is facing a critical shortage of high producing dairy cows and therefore there is a need to expand the national dairy herd through efficient and cost-effective breeding strategies.

2.3.5 Milk production

Dairy production in Tanzania takes place principally in the highland areas such as the Northern highlands of Arusha and Kilimanjaro; the Southern Highlands regions of Iringa, Mbeya, Njombe and Ruvuma; the Coastal belt around Dar es Salaam and Tanga Regions; and the Lake Region of Kagera (IFAD, 2016). The concentration of dairy cattle in these areas is still very low. For example, the concentration of dairy cattle in Arusha and Tanga is around 1.5 head/km^2 and 1.0 head/km^2 respectively compared to 106 heads/km^2 in central Kenya (IFAD, 2016). Traditional breeds continue to play a major role in milk production, contributing about 70% of the total milk produced in the country (IFAD, 2016; Kurwijila, 2015; Nell et al., 2014; Njombe et al., 2011; Ogutu et al., 2014). Dairy (improved) breeds contribute to the remaining 30%. Cattle productivity remains low at an average of 5 to 7 litres per cow per day. Details on the performance of dairy cattle for both traditional and improved cattle are presented in Table 2.9.

Table 2.9: Performance of traditional versus improved dairy cows

Parameter	Unit	Traditional livestock	Smallholder dairy	Improved dairy
Lactation yield	Litres/lactation	160-250	1,500-2,000	2,800-3,500
Lactation length	Days	200	270-300	300
Milk yield	Litres/day	0.5-2	5-7	9-12
Raw milk price	TZS/litre[6]	650	650	650

Source: IFAD (2016); Kurwijila (2015)

The milk market in Tanzania is highly fragmented, with very weak or non-existent links between the various sub-markets. The annual flush of milk from the Zebu herd (indigenous herd) during the wet season poses a challenge as milk prices tend to crash, which affects those without long term contracts or commitments, and formal marketing channels can become saturated. Where there are contracts for milk supply that keep farm gate prices fairly constant over a long period, the contract is often between the farmer groups/primary cooperative and a processor rather than with individual smallholder farmers. Milk prices are relatively low when a farmer sells directly to neighbours or at the farm gate (Ogutu et al., 2014).

[6] Average weighted price of raw milk which takes all channels into account.

2.3.6 Labour

In most areas of the country, livestock is under men's control although almost 95% of the activities[7] related to the smallholder dairy sub-sector are performed by women. A study conducted by Mbillu (2015) indicates that on average, the management of smallholder dairy cows requires 131 man days per year equivalent to an annual value of TZS 449,299. The labour used in smallholder dairy farming is principally derived from family members but sometimes hired labour may be used (IFAD, 2016). Labour cost is the largest cost component which accounts for about 44% of overall variable costs incurred by smallholder dairy farmers.

2.3.7 Dairy value chain in Tanzania: the case of the Southern Highlands

The Southern Highlands' dairy value chain, like any other parts of Tanzania, is composed of different nodes which start from farmer to consumer, each with a slightly different degree of coordination and mode of transaction. Key players include traders, transporters, processors, wholesalers/distributors, retailers and other vendors, such as milk parlours and restaurants. Figure 2.3 adopted from TechnoServe (2012) illustrates these two distinct value chains. The study conducted by TechnoServe (2012) has shown that in reality the link of value chain nodes is not straight forward. There is much value addition that goes on in the informal sector such as basic bulk pasteurization, processing of *mtindi* (fermented milk), manufacturing of yoghurt, and direct retail sales of milk from the milk collection centre.

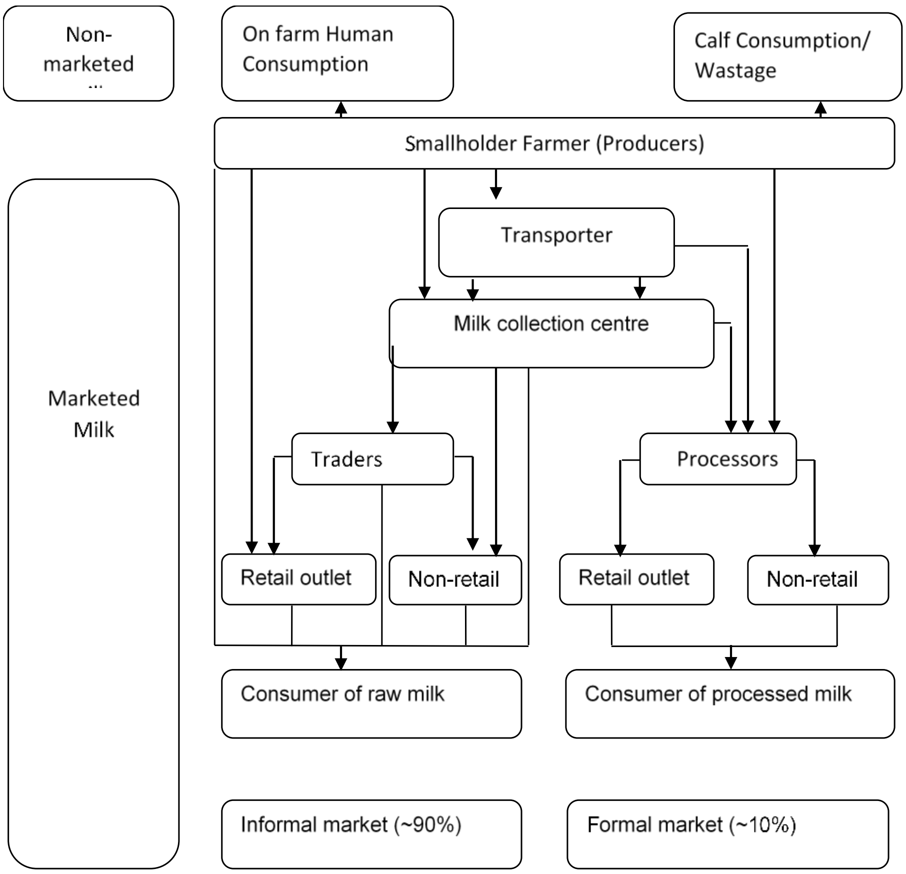


Figure 2.3: Dairy flow in Tanzania. Source: TechnoServe (2012)

[7] These activities include feeding cattle, cleaning cattle sheds, milking, and for a few, taking milk to the collection centre.

Typically, smallholder dairy farmers in the Southern Highlands sell fresh milk but may also sell other dairy products such as *mtindi*. Producers rely on informal markets and trust-based contracts for selling their milk. In most cases, payment is done right away and the only exception is when milk is sold directly to Milk Collection Centres (MCCs). In the MCC, the milk of many farmers is collected and is only sold at a later stage to a processer. The processer will pay after the milk quality has been checked, which delays the payment time.

Informal milk trading is dominated by so-called ‘milk hawkers’, who trade 67% of all milk produced. The remaining proportion is for on-farm consumption (30%) and 3% is sold through formal marketing channels (IFAD, 2016). These hawkers collect small quantities at the farm gate and offer good prices, especially when milk is scarce, but in practice, they are not a reliable sales outlet when there is surplus production. These informal traders usually focus on market imperfections as they often compete with MCCs and processors. They sometimes buy milk from MCCs and sell in urban centres where they can get good prices.

The bulking of milk normally occurs at the milk collection and cooling centres owned by dairy producer associations or processors (Njombe et al., 2011). Milk is transported by head, or on bicycles or vehicles depending on the quantity of milk and the distance to the collection centres. Milk collection is usually practiced in areas with surplus milk above the local market requirement and in areas which are connected to markets in peri and urban areas. Seasonal availability of milk, which is acute in the traditional sector, discourages the establishment of collection centres and processing plants. Milk Collection Centres are a key part of linking smallholder dairy farmers to processing units. The MCC purchases milk from farmers at prices ranging from TZS 550 to TZS 750, depending on the location. According to IFAD (2016), in 2015, Tanzania had around 183 MCCs of which about 55 had milk chilling facilities. The size of an MCC is determined by its bulking and cooling capacity, which generally ranged between 50 and 500 litres (IFAD, 2016). Ownership of MCCs is mixed ranging from the “processor-smallholder” model; the “NGO-facilitated” model; the “smallholder co-operative” model; and the “processor- large-holder model (IFAD, 2016). Likewise, A study by Njombe et al. (2011), showed that there are few dairy producer societies in Tanzania, mainly found in Northern Tanzania (Tanga and Kilimanjaro Regions). The nonexistence of producer societies in many parts of the country not only makes collection and marketing of raw milk difficult, but also discourages the introduction of innovations. The establishment of a coordinated milk collection network is important for successful milk processing and marketing.

A study commissioned by IFAD (2016) shows that the two largest dairy products processors in the Southern Highlands of Tanzania are the family-owned ASAS Dairies and Njombe Milk Factory. The ASAS Dairies has a capacity of 50,000 litres a day, although it currently handles up to 20,000 litres of milk a day. It collects milk from its milk cooling centres in Mbeya, Njombe and Iringa Regions. This signifies that processing capacity is indeed available at this moment for increased milk production.

2.3.8 Consumption

Tanzania has low per capita consumption of milk of about 45 litres per year – compared to the recommended 200 litres/year (IFAD, 2016; Ogutu et al., 2014). However, consumption data from milk-shed areas and from peri-urban areas reveals much higher consumption levels. For instance, milk producers in the central corridor of Tanzania are estimated to consume an average of 94 litres per capita per year, which is more than twice the national average. Likewise, rural dwellers outside milk-shed areas drink less than a quarter of the amount consumed by those living in milk-shed areas (Ogutu et al., 2014). In terms of the range of dairy products consumed, IPSOS (2015) cited in IFAD (2016), found that raw milk is by far the most regularly consumed dairy product, with *mtindi* coming at a distant second. Dairy products consumed by smallholder farmers in rural areas are characterized by low added-value because of the lack of reliable markets and the absence of milk processing facilities. Moreover, rural incomes have been reported to be fairly static, while transport is difficult and storage losses are high. The perishable nature of milk limits its storage and hence hinders farmers from taking advantage of seasonal price differences (Ogutu et al., 2014). The industry as a whole is extremely energy and transport intensive.

2.3.9 Smallholder dairy cattle feeding strategy

Milk production under smallholder dairy farming systems in Tanzania is seasonal due to fluctuations of feeds both in terms of quantity and quality. A dry season decline in milk production of over 40% due to feed scarcity is a common challenge (Katjiuongua and Signe, 2014).

Data on the quantity of pastures utilized in the traditional sector and zero-grazing systems are not readily available. However, according to Komwihangilo et al. (2009), the traditional sector is constrained by inadequacies in quantities and qualities of pasture. Smallholder dairy farmers graze their animals in crop fields when all the grains have been harvested. However, an increase in cattle and human population is continuously leading to shrinkages in grazing areas. The need for more pastures on the one hand, and demands for more areas for cropping, on the other hand, causes frequent conflicts between livestock keepers and arable farmers (Massawe and Urassa, 2016; Komwihangilo et al., 2009). As a result, pastoral rights activists, say a combination of recurrent drought, loss of grazing lands to wildlife reserves and large-scale agricultural investments have forced increasing numbers of Maasai to migrate to cities[8].

Some of the smallholder dairy farmers cope with pasture deficit during the dry season by conserving standing hay and some crop residues such as maize and millet stovers and groundnut haulms. Other stored crop residues for livestock include rice, sorghum and bean straws (Maleko et al., 2018). In many cases, the quantities of feeds stored at home are, however, not enough for the whole herd but only for calves, lactating cows and some sick animals. Likewise, the conserved crop residues are usually not properly stacked or covered but left under the sun as long as they lasted. This practice is not ideal in fodder conservation practices. For example, the maize stover materials tend to lose their nutritional quality when left under the sun for a long period of time (Bwire and Wiktorsson, 2002).

Only few smallholder dairy farmers provide energy, protein, vitamin and mineral supplements to lactating cows (Kavana et al., 2005; Kavana and Msangi, 2005; Komwihangilo et al., 2009). This is caused by underlying criticisms that commercial compounded dairy feeds in Tanzania are of unreliable quality, very expensive and with unguaranteed effects to the specified animal class (Laswai and Nandonde, 2013). This mistrust by smallholder dairy farmers and the high costs of dairy meals, has made the usage of commercial dairy meals in Tanzania almost non-existent.

2.3.10 Veterinary

Cattle diseases remain a major constraint to increasing dairy productivity in Tanzania, by killing or keeping cattle sick and under-producing. Recent studies report the overall mortality to be between 12 and 14% in smallholder dairy cattle across different regions of Tanzania (Alonso et al., 2015). Many of these diseases can also be transmitted to people, causing illness and/or even death. Existing

[8] https://www.reuters.com/article/us-tanzania-landrights-migration/as-grazing-land-shrinks-maasai-herders-make-unlikely-city-dwellers-idUSKBN18I22Z

information on the diseases affecting dairy cattle in Tanzania and their relative importance is limited and relies either on passive reporting by poorly resourced veterinary services, or on localised surveys focused on specific well-known diseases. The causes of cattle diseases are often unknown and differential diagnosis is not conducted leading to mistreatment or ineffective treatment.

The primary animal diseases affecting smallholder dairy cattle in Tanzania include *contagious bovine pleura pneumonia*, foot and mouth disease, *peste des petits ruminants*, east coast fever, Newcastle disease, rabies, avian flu, brucellosis and tick-borne diseases (Katjiuongua and Signe, 2014).

Animal healthcare infrastructure to support smallholder dairy farmers in Tanzania is inadequate. Disease diagnosis, surveillance, control and immunization against endemic diseases are key elements of preventive animal healthcare. However, smallholder dairy farmers rely mainly on the TVLA and Zonal Veterinary Centres to support these activities. The TVLA manages eight zonal centres that are responsible for laboratory work and diagnostics, while the department of veterinary services (under MLF) manages eight Zonal Veterinary Centres (ZVCs) responsible for disease surveillance, control and advisory services. Vaccine production is conducted at the TVLA in Dar es Salaam (Katjiuongua and Signe, 2014).

2.3.11 Extension services

In Tanzania, the agricultural and livestock extension services have been vested in local government authorities to foster effective participation of all stakeholders including smallholder arable dairy farmers, and to motivate private sector participation in service delivery (CUTS International, 2011; Kimaro et al., 2010). In 2015, Tanzania had 7,974 extension staff, which was just over half the national requirement of 15,082 for placement in every village and ward (URT, 2015). While insufficient human resources hinder efficient delivery of extension services (Tanzanian MAFS, 2013), it is argued that even the services offered by existing staff fall short in diagnosing smallholder dairy farmers' problems and transferring practical knowledge due to low capacity and/or limited understanding of the smallholder dairy farming environment by the extension officers. Consequently, extension services have not led to significant increases in production among smallholder dairy farmers (CUTS International, 2011). In addition, while the extension and technical services account for a substantial proportion of district spending on agriculture and livestock keeping activities, the Agriculture Sector Review-Public Expenditure Review (ASR-PER) of 2014, have shown that the total routine expenditure (central level plus district level recurrent and development spending) amounts to only 1.2% to 1.7% of agricultural GDP (URT, 2016). The proportion of funds allocated for agriculture (including livestock) from the national budget is inadequate to run the broad range of activities covered under the sector, including the extension service delivery.

2.3.12 Scoping definition for the further evaluation

The current smallholder dairy system is based on five dairy cows with almost no purchased inputs. Milk yield is estimated at 240 litres per year. The improved system is the same as above in terms of dairy cows. However, improved access to knowledge, vaccines and medicines and improved farm management practices may improve the milk yield to 2,400 litres per year. Annex 1 gives an overview of all production and herd statistics used for the calculations in this study.

Based on the system description we define the scope of the pastoral livestock system that we will use in the following chapter to evaluate the financial and produced capital, natural capital, and social and human capital. Table 2.10 provides an overview of the stages of the value chain and the different flows that we will take into account. At processing stage in the reference scenario, there is hardly any dairy processing. Since we have developed an improved scenario, we assume that the dairy processing requires more capacity and as such we included a qualitative evolution of the pollution and emissions flows, mainly related to waste water for cleaning processing facilities in the dairy factories.

Table 2.10: Flows and value chain stages considered

	Production			**Processing and distribution**			**Consumption**	
	Land-scape	Infra-structure & manufacturing	Farm	Wholesale	Food & beverage	Retail	Industry/ household/ hospitality	Waste*
Captured by system of national accounts	N.A.	N.A.	XX	XX	N.A.	N.A.	XX	N.A.
Provisioning	X	X	X	N.A.	N.A.	N.A.	X	N.A.
Regulation and maintenance	X	N.A.	X	N.A.	N.A.	N.A.	N.A.	N.A.
Cultural	X	X	X	N.A.	N.A.	N.A.	X	N.A.
Human health		X	X	N.A.	N.A.	N.A.	X	N.A.
Pollution to air, soil and water	XX	XX	XX	XX.	N.A. Only waste water in improved scenario	N.A.	N.A.	N.A.
GHG emissions to air, soil and water	XX	XX	XX	XX	N.A.	N.A.	N.A.	N.A.
Social values	N.A.	X	X	X	N.A.	N.A.	X	N.A.
Risks and uncertainties	X	X	X	X	N.A.	N.A.	X	N.A.

N.A. = not applicable
X = evaluated qualitative
XX = evaluated quantitative
*accounted for in the production stage

3 Produced and financial capital assessment

This chapter presents the results of a financial analysis of Maasai pastoralism, backyard poultry and smallholder dairy farming in Tanzania. For each of these three systems, the analysis looks at the distribution of benefits across typical value chains, at the income from livestock of a reference household and at the additional benefits that technical improvements could bring to these dimensions. The reference household is selected to represent a common household in the area. For most parameters average values per household are used.

3.1 Pastoral livestock systems

Pastoral livestock systems in Tanzania's Maasai steppe are the traditional way of life for many Maasai households who roam large areas to let cattle and small ruminants graze for the production of meat and marginally, milk. In recent years, pastoralism has been decreasing. People are moving to farming or to the city, and pastoral grazing areas are being converted into farmland both by the traditionally pastoral population and by immigrants from other regions. This trend can be explained by the search for a higher income and increased financial stability, as income from sedentary farming or city jobs is expected to be higher and less dependent on climate and other external sources of uncertainty (Bekure et al., 1991; Msoffe et al., 2011; Kimaro et al., 2018).[9] This chapter explores the economic dimension of this phenomenon from three angles: distribution of value in the pastoral beef value chain, pastoral household income and the consequences for pastoral households of potential technical improvements.

3.1.1 Pastoral beef value chain

For the pastoral cattle system, we analyse a local value chain consisting of four steps: the pastoral producer, the market trader, the butcher and the consumer. The cows are sold live by a pastoralist in the Monduli and Longido districts, from where they are transported by a market trader to markets in rural centres. From here the live cow is purchased by a butcher, who after slaughtering, sells it directly to the end consumers (see Table 3.1).

Table 3.1: Overview of the pastoral beef value chain by actor, price and location. For more detail, see Annex 2 Table A2.2

Sold by	Sold to	Price per head[10]	Location and transport
Pastoralist	Market trader	$220	Monduli and Longido districts
Market trader	Butcher	$259	To Meserani and Weruweru market
Butcher	Consumer	$313	From slaughter area to butchery

Figure 3.1 below shows that for pastoralists the profit per animal is relatively high ($107 per head sold), roughly equal to the costs (here including hired labour, dipping/spraying, medication, deworming and other variable costs per head of cattle). In absolute terms, profits for market traders and butchers are lower, but they will be able to process many more animals in a year. For a pastoral household, this profit constitutes household financial income.

[9] Although income from sedentary farming or city jobs is generally higher, it is also true that migration to the city often leads to unemployment and sedentary farming is often not sustainable over time because of soil degradation issues (described in chapter 4.2).

[10] Prices per head based on local meat market price in the Monduli and Longido districts as reported by (Meshack, 2015) and converted to US$.

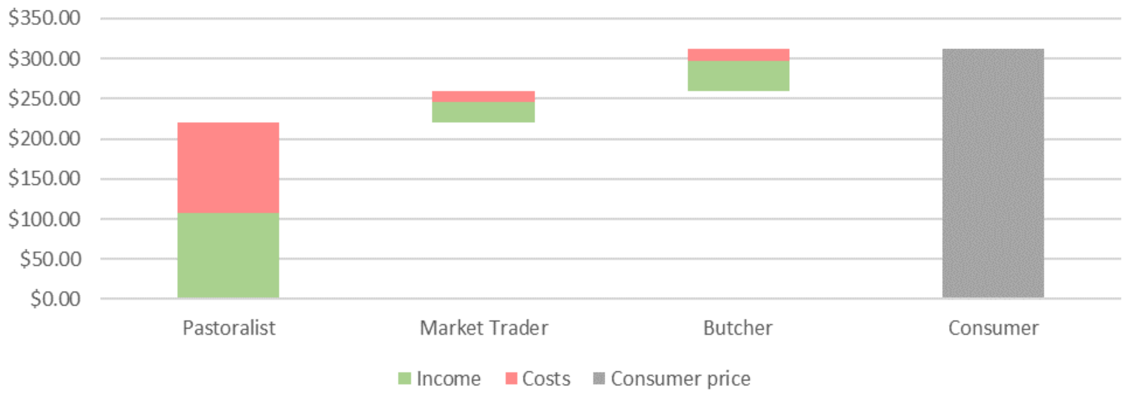


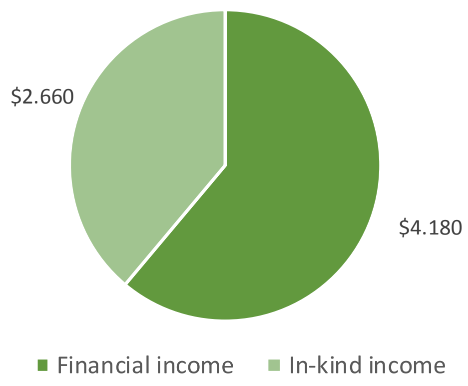
Figure 3.1: Profit, costs and consumer price per head of cattle in the pastoralist value chain ($/head of cattle). The sum of profit and costs gives the revenue in each step of the value chain

3.1.2 Pastoral household income

We analyse the household income of a reference pastoral herd of 300 cows, 60 goats and 50 sheep, based on the data presented in table 2.1. The herd is taken as a starting point for the analysis.

When interpreting the income from livestock for households it has to be noted that such a herd will belong to a group of households. Applying the concept of household in the context of pastoral communities is not without problems. The concept of household as it is generally used in reporting on household income, is not used as such for pastoral communities. Studies are usually conducted per herd, where a herd is run by what one could consider to be a group of households (groups of people who are related). As there is no unequivocal method to go from herds to households, the number of households that would own a herd of the reference size is uncertain. Based on a literature review, we estimate the number of households in the reference group to be within the range of 3-9 households (Achiba, 2018; McCabe et al., 2010; Kaimba et al., 2011). For reference, a pastoral household as documented by Kaimba et al. (2011) has on average 14 people and 65 heads of cattle. To illustrate the range, the minimum household size reported is 3, and the maximum is 36 (Kaimba et al., 2011).

The pastoral income before costs for a herd of the considered size is $11,120 of which $8,460 is livestock sales and $2,660 is in-kind income: household income generated as food (Figure 3.2). Yearly costs are $4,280 per year, giving a net financial income of $4,180 per year. Out of the total household income from livestock (both in-cash and in-kind), over 90% originates from keeping cattle, and primarily from the consumption of meat and the sale of live animals. The rest comes from consumption of small stock (goats and sheep) as food, and from the use of cow skins, hides and other materials (Figure 3.3). Cattle accounts for three quarters of the pastoral herd and, given the large weight difference between cattle and small stock (goats and sheep), such a percentage of income contribution is reasonable. Annex 2 provides a detailed breakdown of financial and in-kind income.



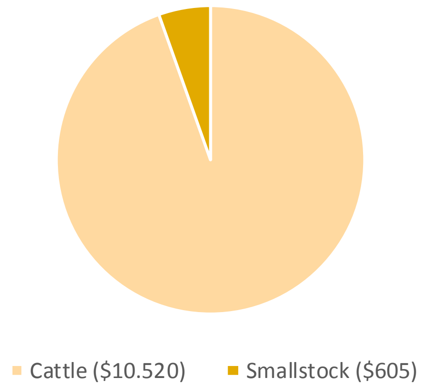


Figure 3.2: Pastoral income from livestock after costs and in-kind (per year)

Figure 3.3: Pastoral income from livestock before costs, by animal (per year)

Pastoral households seem to have reasonably high compensation for work, when considering the income per FTE. Labour input of pastoralism is difficult to define and therefore to determine. Based on the available evidence provided by Bekure et al. (1991) on time spent on livestock management however, we estimate the amount of labour for keeping livestock to be 5.6 FTE for a herd of the considered size[11]. This translates to an income of $1,222 per year per FTE, including financial and in-kind, and as such the reference pastoralist earns over two times the minimum rural agricultural wage ($570) in Tanzania. The compensation per year per FTE is significantly higher than a rural hired herder ($140) or a city housekeeper ($210), and is about one and a half times a city teacher's annual salary ($800), but over 50% less than a city bank clerk's ($2,290)[12]. In interpreting these results it is important to point out that the reference household, with a herd of 300 cattle heads, can be considered a comparatively rich pastoral household in the region, and that the definition of what constitutes a labour input is quite uncertain and there is limited availability of data on this aspect, directly influencing these comparisons between income per FTE.

Besides income, cattle have an important savings value. In fact, the herd performs the function of a savings account, or social security. In the pastoralist context, a herd can be considered a valuable alternative to a savings account, because currency devaluation and inflation are more of a threat to the security of cash deposits than the volatility of the market price of cattle is to the value of the herd (Siegmund-Schultze et al. 2011, Manoli et al. 2014). The monetary value of the herd of the reference pastoral group of households is estimated to be about $66,000 (note that this is a hypothetical value). If selling a whole herd at the same time, the value would likely be somewhat lower, since not all animals would be fit for slaughter at the same moment.

3.1.3 Improved scenario

In this paragraph, the reference pastoral system is compared to an alternative with better animal management[13].

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[11] Further explanation on time spent on livestock management is provided in section 5.2.1.1, where values are specified per wealth class. Due to the pastoralist herd size, our estimations refer to the rich family in Table 5.2.
[12] Wage data was taken from a variety of sources including: Africapay (2018) and World Bank (2003) and it refers to the financial wages exclusively.
[13] The rationale for the choice of the scenario is described in the Approach section: Improved scenario.

The pastoral system described in this chapter is taken as the baseline scenario. In the improved scenario, measures are taken to improve feed availability throughout the year. Additionally, basic bio-veterinary measures are implemented. This results in a higher use of inputs (more feed, medicine and labour), which causes a decline in mortality and an increase in fertility[14]. Compared to the baseline scenario, more cows are born and less decease, allowing pastoralists to sell more cattle without increasing herd size.

As figure 3.4 shows, improved feed availability means increased costs for feed, but this is outpaced by an increase in revenue. The cattle offtake rate will increase from 16% to 24% of the herd annually. As a result, the income of pastoralists increases from $4,180 to $6,125. This represents the difference between monetary revenues and costs, excluding the own labour costs. Consumption of beef (in-kind income) is assumed to stay stable, which means that relative to the baseline, a larger share of the herd is sold in the improved scenario.

Even with an increase in red meat supply, prices are unlikely to decrease. At present, domestic production is unable to cover the internal demand for red meat in Tanzania (Nadonde et al., 2017). Due to a projected increase in future income, population growth and urbanization, demand is expected to grow (Animalchange, 2012), even more than the expected increase of supply.

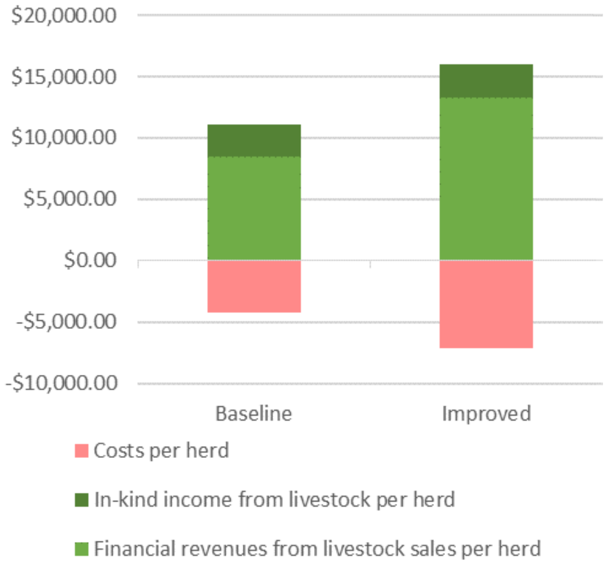

Figure 3.4: Household income in the two pastoral scenarios ($/herd/year)

3.1.4 Evaluation of the produced capital stocks

There is no effect on the produced capital stocks. Meat is mostly consumed in the community and only sometimes sold alive at rural markets. Small animals are mostly slaughtered at home, and the larger

[14] This was modelled with the following assumptions:

- Freshly cut grass in the ration increased from 90% to 95%. Crop residues in the ration reduced from 10% to 2%. Meal oil seeds and grain by-products were added by 2% and 1%, respectively;
- The calve mortality dropped from 21% to 15%;
- The mortality of adult reproductive females dropped from 7% to 5%;
- The age at first calving goes from 4 to 3 years;
- The fertility rate increases from 75 to 80%.

animals such as cattle are mostly bought at the regional markets by traders and then slaughtered. There is no cold chain available in this livestock system. There is no impact foreseen of the improved scenario since most of the equipment is currently underused (PINGO's Forum, 2016).

3.1.5 Summary

The income of the reference pastoral herd, which has size of 300 cattle heads and 110 between sheep and goats, is relatively high. As discussed earlier, household sizes vary greatly in pastoral communities and usually refer to a group of multiple families.

On top of the financial income through the sales of animals, a substantial share of income that is earned is in kind, as food for the household. Our estimate of pastoral labour income per FTE (in-kind and financial) is over two times higher than the rural agricultural minimum wage. This estimate points to a relatively high income compared to informal agricultural labourers in the region that very often earn much less than a formal minimum wage. It should be taken into account that this value is subject to high uncertainty, due to the difficulties in defining what constitutes a labour input for pastoralists, as well as the lack of data on this aspect.

The picture of pastoral income excludes two elements: such a pastoral group of households has about $66,000 in savings as herd value, and a pastoral livestock system has positive externalities in landscape management services such as contribution to tourism, carbon storage and land degradation prevention. Some of these positive externalities of pastoralism are quantified in section 4.2 Ecosystem services of pastoralism.

When reviewing an alternative system with higher inputs, economic results show that an increase in year-round feed availability and basic veterinary measures can increase financial income, primarily due to an increased offtake rate due to lower animal mortality, allowing pastoral households to sell more cattle while their herd remains the same size. A drawback can be that if additional animals are kept in the same area, negative environmental impacts could occur due to overgrazing. Careful consideration should be given to the possible loss of ecosystem services, and especially the carbon content of grasslands (see 4.2 for an analysis of the ecosystem services of pastoral livestock systems).

3.2 Backyard poultry systems

The economic importance of backyard poultry for rural households in Tanzania lies in its contribution to food consumption and monetary income, with low or no costs. This section quantifies how poultry is economically important from three perspectives:

- The distribution of value among value chain actors;
- The contribution to household income; and
- The economic consequences of potential technical improvements for households keeping poultry.

3.2.1 The backyard poultry value chain

A reference backyard poultry value chain consists of four actors: the producer (a household), a middle man, a market trader, and the consumer. In this value chain, the chickens are produced in rural areas and sold in a regional urban centre (in this case, Dodoma). Butchering occurs on the consumer side. This value chain is described by Queenan et al. (2016) as determined from interviews with households and all value chain actors. It can be observed that in this small-scale supply chain, the producers receive the highest share of the final price (Table 3.2). This can be explained because the buyers have to kill the animal and also provide cooling, whilst this is normally done by slaughter houses and other service providers.

Table 3.2: Overview of the backyard poultry value chain by actor, price and location

Sold by	Sold to	Price per chicken	Location
Producer	Middleman	$3.30	Farm gate (village)
Middleman	Market trader	$4.20	Area outside the market
Market trader	Consumer	$5.10	Regional market

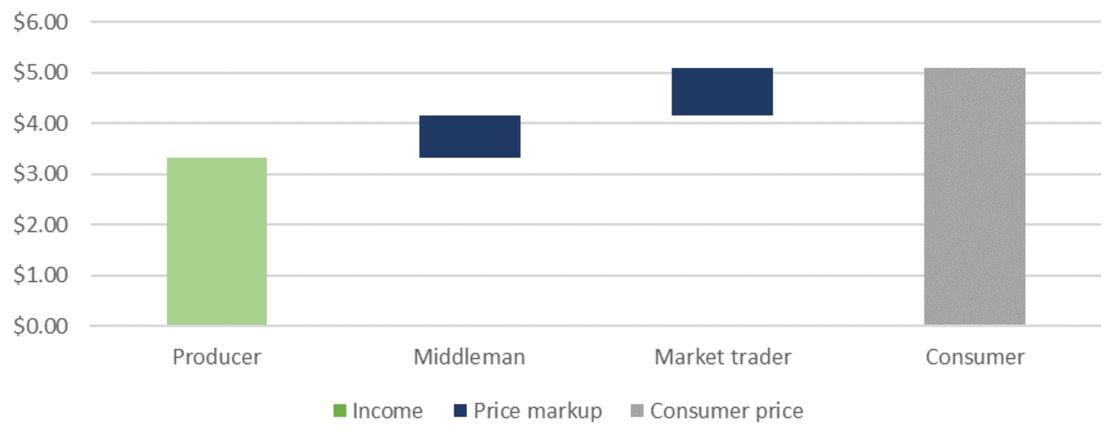

Figure 3.5: Income, price mark-up[15] and consumer price per chicken ($) for a reference poultry value chain, excluding eggs

The producer is the actor in the chain that earns the most, as there are generally no input costs. Chicks hatch naturally on the farm, consume only household waste and require minimal care. Because of this, all revenue constitutes income. The price mark-up per chicken for middle men and market traders are similar, as shown in Figure 3.5 above.

3.2.2 Contribution to household income

Backyard poultry contributes equally to nutrition and cash inflow of rural households. A large share of the total offtake of chicken kept by a household (around 30%), is used for own consumption rather than sold. Figure 3.6 shows the annual in-kind and financial income from backyard poultry for a reference household owning 29 chickens. The value of consumed poultry meat and eggs, in-kind income, amounts to $56 which is more than half of the financial income of $87 in sales. When a chicken is sold, owners earn a large profit margin as there are virtually no input costs. The $56 of in-kind income consists mainly of meat consumption and for a small part, $9 of the value of consumed eggs. The majority of eggs are hatched rather than consumed. A full overview of in-kind and financial income is provided in Annex 2.

[15] The term *price mark-up* represents the mark-up of the price that increases every intermediate step in the value chain e.g. the difference in the buying and selling price for a specific value chain actor. It is different from income as it does not take into account costs. *Income* refers to household income.

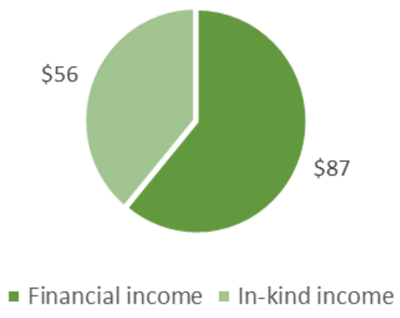

Figure 3.6: Annual in-kind and financial income from backyard poultry for a household ($/household/year)

The savings value of the flock of chicken kept by the reference household is around $100. As discussed elsewhere in this report, chickens are an important form of savings for low income households and are especially relevant for women who generally take care of the animals, in a context where women are often excluded from participation in other economic activities.

3.2.3 Improved scenario

In this paragraph, the system described in this chapter is compared to an alternative with improved management[16].

The backyard poultry system described here is taken as the baseline scenario. In the alternative scenario, feed quality and productivity (e.g. egg productivity and number of clutches) are improved. However, the number of birds remain the same. Additionally, basic bio-veterinary measures are implemented, resulting in better animal health and reduced mortality rates of both adult chickens and the pullets. We assume that the improved productivity is achieved through better feeding, but also improved fencing, which decreases the chances of birds being killed by predators or road traffic.

As Figure 3.7 shows, alternative production strategies have little potential to increase income. This is limited to an increase in in-kind income, a higher consumption of eggs. Because of the low market value of eggs, this amounts to about $3 yearly meaning that in-kind income per household per year increases from $9.50 to $13. Overall, the household does not achieve any significant increase in income, but the increase in costs is compensated.

[16] The rationale for the choice of the scenario is described in the Approach section: Improved scenario.

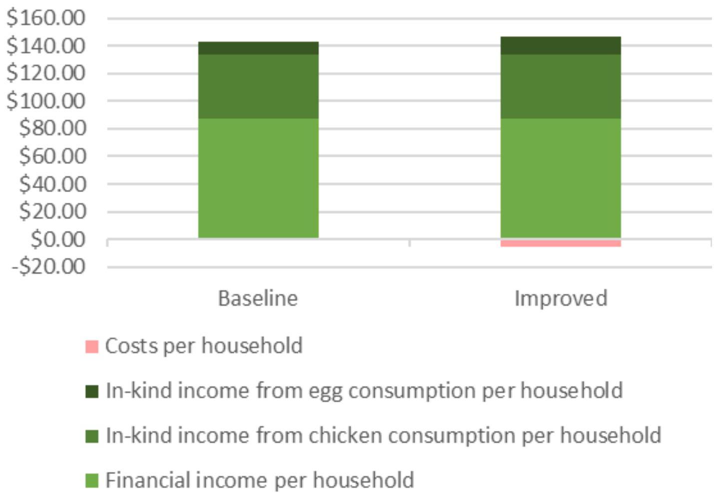

Figure 3.7: Household income in the two backyard poultry scenarios ($/year)

3.2.4 Evaluation of the produced capital stocks

There are a limited number of capital items in this value chain (night shelter, fencing, transport, a knife etc.), since chickens are mostly slaughtered at the farm or at home and no cold chain exists.

3.2.5 Summary

The socio-economic importance of backyard poultry is not in the absolute income generated, but rather in the ability for women to generate cash revenues and provide household nutrition at very low input costs. In the alternative scenario, the in-kind income increases slightly when feed quality is improved, but is offset by increased costs. The weight of animals is the same in two scenarios.

3.3 Smallholder dairy systems

This section discusses the economic dimension of a traditional smallholder dairy farm with dairy cows and arable products in the Southern Highlands region of Tanzania. The farm is mixed in the sense that it combines crops and livestock. However, the analysis focuses on milk. The economic analysis has two angles: the distribution of value among the actors in the milk chain and the household income from milk for smallholder dairy farming. Furthermore, a comparison is made between traditional and improved dairy farming in terms of the economic implications for smallholder farms.

3.3.1 The traditional dairy value chain

The value chain of the reference traditional farm with dairy and arable products is local and consists of three steps: the dairy farm, a trader and the consumer (IFAD, 2016). The milk produced at the farm is collected at the farm gate in the Southern Highlands region by a trader, after which it is transported to the local village where it is sold to the consumer and consumed raw. This is the most common chain in rural Tanzania as only 10% of the milk is found to be passing through a more formal chain that includes milk collection centres (IFAD, 2016).

Table 3.3: Overview of the value chain for milk from farms with dairy and arable products by actor, price, and locations

Sold by	Sold to	Price per kg milk	Location and transport
Smallholder dairy farmer	Trader	$0.42	Farm gate
Trader	Consumer	$0.54	Local village

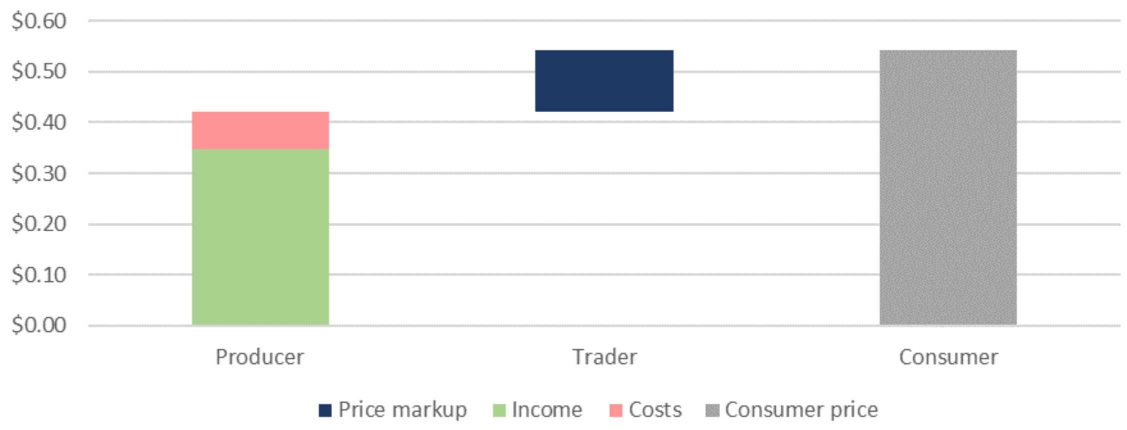

Figure 3.8: Income, costs, price mark-up and consumer price per kg of milk for a reference dairy value chain ($/Kg milk)

Figure 3.8 and Table 3.3 illustrate the distribution of financial benefits in this value chain. For the producer, more than 80% of the sales price is kept as income. The costs incurred by the farmer include the purchase of limited feed and water. The income depicted in Figure 3.9 is the revenue minus these costs. The labour mostly exists of family labour so it is not included as a production cost (IFAD, 2016). For the trader, the cost structure is unknown so a comparison cannot be made. Traders in rural regions often sell milk without cooling and travelling, on foot and by bike, but it is not possible to estimate how often this is the case. Annex 2 illustrates the costs faced by producers in detail.

3.3.2 Milk income

We analyse the income from livestock of a reference farm, owning 5 cows for milk. We look at a traditional farm, with low inputs and low outputs, as this is the most common system in Tanzania. The achieved milk yield on the reference farm is 240 litres per lactating cow per year. Most often, these are mixed farms, farms that have both crops and livestock. For the economic analysis we look primarily at milk production and only provide estimates for the other farm revenues (e.g. crops, slaughter meat production, other animals than cattle) due to a lack of accurate data on these parts of the system.

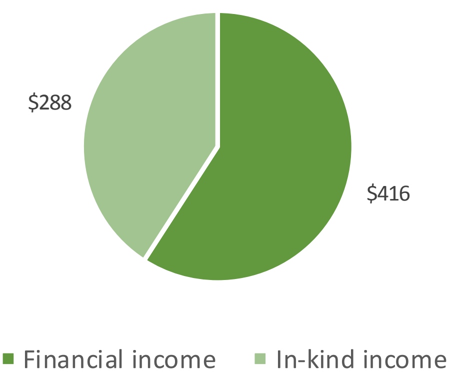

Figure 3.9: In-kind and financial household income from dairy production ($/household/year)

The annual income from milk is $704, of which $288 represented by milk consumed by the household. As the labour inputs for this system are unknown, this value represents household income from milk only, rather than income per FTE of the whole farm. This household income is higher than the annual income per FTE of a hired herder ($140), a city housekeeper's annual salary per FTE ($210), lower than a reference pastoral herd ($1,222/FTE), and higher than the minimum agricultural wage ($570)[17]. It is similar to the yearly salary of a city teacher ($800) and a city bank clerk earns over three times as much as a dairy smallholder household at $2,290 per FTE[18].

Dairy farmers can count on other income sources than milk, such as the income from selling the cattle no longer used to produce milk for meat and crops produced within their land that are not used to feed the animals. These sources of income are not included in the figures provided above, but they can be estimated based on the best available information. Based on the biophysical model of GLEAM we estimate that about two animals per year can be sold. The income before costs derived from this would be roughly $440. The selling price has been assumed equal to the price pastoralists earn per head of cattle sold, and used as a proxy for calculating the farmers' income since no better data is available. Regarding crops, the most commonly cultivated ones are maize and beans. It is not possible to determine the household income from crops as there is no local data on the costs, selling price, and the share of output sold. To give an indication of gross revenue, a farm of 1.8 hectares with maize and beans with average national yields and selling prices would have $875 gross revenues per year. For sources and more information on crop production see also section 2.3.3.

3.3.3 Improved scenario

In this paragraph, the dairy system described in this chapter is compared to an improved alternative with higher inputs[19].

The low-input traditional dairy system discussed in this chapter is compared to a specialized improved system. This has much higher inputs of feed and water and uses artificial insemination. These

[17] To be noticed the difference in units between farm income and other salaries. The latter are expressed per FTE whereas, due to data availability, milk income is provided per household and the income for a pastoral herd is per herd (owned by a group of households).

[18] Wage data was taken from a variety of sources including: Africapay (2018) and World Bank (2003).

[19] The rationale for the choice of the scenario is described in the Approach section: Improved scenario.

improvements require an increase in labour that can be either performed by the household or by hired workers. Compared to the traditional system, the amount of milk produced per lactating dairy cow is ten times higher (2,400 litres per year compared to 240 litres per year)[20]. Rather than presenting an incremental change, this is a comparison between the traditional and a high-input smallholder system. A transition from the baseline to the improved system would require collaboration between farms and government support. This system is modelled here to show the potential of policies to create an environment in which farmers could make this step.

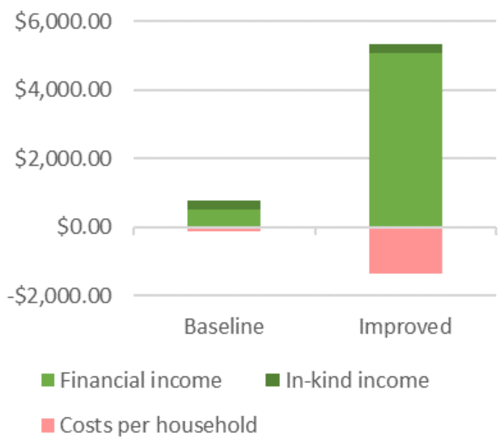

Figure 3.10: Household income in the two smallholder dairy scenarios ($/year)

The costs for the baseline scenario are very low. Costs for feed are $76 per year, whereas in the improved scenario, $940 per year would be spent on feed. In total, costs excluding labour[21] increase from $90 to $1,360. Figure 3.10 shows that although costs increase dramatically, it is well compensated by the income increase. In-kind income is likely to stay constant, as households are not expected to consume more milk when productivity increases. A detailed breakdown is presented in Annex 2. In the improved scenario the number of cows is higher, resulting also in a higher income from meat production. Due to scarcity of local data on beef production from dairy farms, this is not included in the figures. However, the estimated additional revenue from the sales of three slaughter animals per year is $660.

It is important to note that in comparison with the improvements analysed for pastoralism and backyard poultry, here the step to take from the baseline to this improved scenario is very large. The

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[20] The following adjustments were made to the baseline for the improvement scenario:

- Concerning feed rations, grazed grass increases from 24% to 0%, but instead freshly cut grass is introduced by 48%. The contribution of crop residues is reduced from 70% to 46%;
- Calf mortalities reduce from 20% to 15% and adult mortalities reduce from 7% to 5%;
- Age at first calving is reduced from 4 to 3 years;
- Fertility increases from 75% to 80%;
- Artificial insemination makes some of the bulls redundant, resulting in that the bull to cow ratio decreases from 0.69 to 0.10.

The milk production increases from 240 kg/cow per year to 2,400 kg/cow per year. This is a significant change, implying improved feed availability and quality during all seasons. The improvements would also need to allow for less (but healthier) cows in a given area, meaning fewer families with dairy cows or fewer cows per family, or it would imply that more land is dedicated to grass for the animals.

[21] Because labour inputs are unknown for the baseline scenario, these have been excluded for both scenarios.

improved scenario requires a radical improvement in management and an improvement in feed quality. This is not easily achieved by an individual smallholder dairy farmer. Rather, this can be seen as a scenario for a system that can be further promoted and facilitated through policy. The large income increase shows the potential for enabling these transitions.

3.3.4 Evaluation of the produced capital stocks

The dairy value chain is divided into informal and formal value chains (IFAD, 2016; TechnoServe, 2012). The informal value chain makes up 90% or more of total marketed milk in the Southern Highlands. The informal market chain is characterised by sales of raw milk from producer through trader/hawker to consumers, either directly or via a retail outlet/restaurant. The formal value chain makes up to 10% of milk sales and usually starts from the producer going either directly to the processor or, indirectly via a milk collection centre; and from the processor to a retailer/restaurant, and eventually to the consumer. In the informal chain there are almost no capital stocks involved. However, in the formal chain there are transport, milk processing factories and some cold chain transportation and storage, which requires capital investments in the entire value chain.

3.3.5 Summary

In the traditional value chain, about 80% of the sales price of milk is income for the dairy farmer. At farm level, the share of income that is in-kind is relatively low compared to the financial income, as the largest share of production is sold rather than consumed. The annual net income of smallholder dairy farmers, including the value of milk consumed at home, is $704. A limitation of the above is the exclusion of crop cultivation and other livestock (sheep, goats or chicken) in the economic analysis. Additionally, the potential meat produced from dairy cows and bulls sold for slaughtering, as well as sheep, goats and chicken has not been taken into account. Especially in the baseline scenario, this is expected to potentially add substantially to the basic income level of the household. For future research it is recommended to include crops and meat for a richer economic perspective. The alternative scenario included is much more profitable then the baseline, due to a radical increase in milk production per lactating cow, but it also requires a better equipped value chain with cold storage.

3.4 Synthesis

The table and graphs below summarize the findings of this chapter, providing estimations for both financial and in-kind income for traditional livestock systems in Tanzania. Financial income is valued based on farmgate and producer prices whereas in-kind income is based on market prices. The values in the table do not allow for a direct comparison, as the systems are very different in scale and scope. Households keeping backyard poultry generally also have other sources of income and pastoralists and smallholders are likely to keep backyard poultry as well. Furthermore, they are based on estimates for different regions. Finally, as the pastoral herd is kept by a group of households, the conversion to household-level results for this system has a high degree of uncertainty. The values in Table 3.4 are given per household under the assumption that a pastoral group of households with a herd of the considered size consists of 6 households, taken as the mid-point of the range of 3-9 households estimated based on the findings of Achiba (2018). Due to the uncertainty of this number, it is advised to rather focus on the values per herd than per household.

The dairy smallholder household income shown in Table 3.4 only includes income and in-kind consumption of milk for dairy farming. It does not include the revenue from meat and the arable part of the farm, which are roughly estimated for the baseline scenario at $440 (meat) and $875 (crops), before costs and $660 (meat) and $875 (crops) for the improved scenario.

Table 3.4: Household income for traditional livestock systems ($/household)

	Pastoral cattle		Backyard poultry		Dairy smallholder	
	Baseline	Improved	Baseline	Improved	Baseline	Improved
Financial income	8,465	13,290	85	85	505	5,060
In kind income	2,660	2,660	55	60	290	290
Costs	4,280	7,165	0	5	90	1,360
Net income from livestock per herd (as reported in chapter)	**6,845**	**8,785**	**140**	**140**	**705**	**3,990**
Estimate of pastoral household net income	**1,140**	**1,465**	**-**	**-**	**-**	**-**

The graph below shows the income and costs per kilogram of output. Income is both financial, through revenues from the sales of meat, milk and eggs, and in-kind, through household consumption of animal products valued at market prices. It shows that from this perspective, there are no large changes in income and costs between the baseline and improved scenarios, although the balance between financial and in-kind benefits changes slightly, since for cattle systems more output is produced but consumed output stays similar. For poultry, it is the other way around. The fact that the income per kg of output stays constant, while the household income increases (Table 3.4), shows the increased production of the improved scenarios.

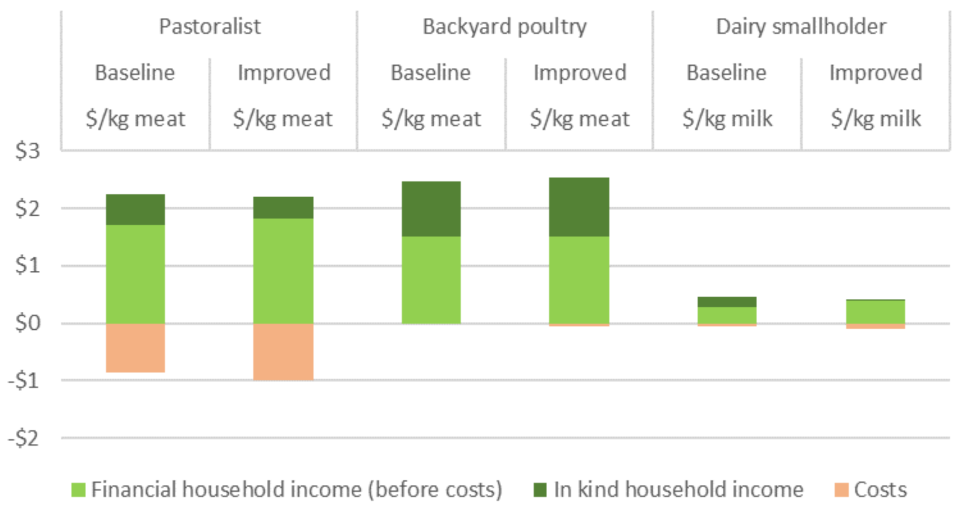

Figure 3.11: Household income for traditional livestock systems ($/kg of output)

4 Natural capital assessment

4.1 The pastoral cattle system

4.1.1 Assumptions

The assumptions for the economic and environmental assessment are based on the earlier TEEB study (Baltussen et al., 2017) and adjusted by critically reviewing the data from this paragraph in consultation with the livestock experts among the authors. The assumptions are used to calculate the environmental impacts by using GLEAM.

- The average total herd size of 300 was kept the same. It includes all young stock and replacement animals. Maximum animal weights were kept the same as in the earlier study (Baltussen et al., 2017). 60 goats and 50 sheep are also part of the herd. They are included in the economic assessment and not in the environmental assessment.
- The slaughter weight was lowered to 200 kg (female) and 260 kg (male) weights, similar to the data in 2.1.4. With a default dressing percentage of 50% in GLEAM, identical to data from 2.1.4, this results in a carcass weight on the conservative end of the range from 2.1.4. This lower slaughter weight is plausible, as feed requirements are not met regularly (each year) and growth rates are slower, so that older animals at a slaughter age are not fully grown. The slow growth is motivated in 2.1.4. The default growth rate within the GLEAM was a calculated value in the model in order to yield the defined slaughter weights. The energy required for maintenance was a function of metabolic body weight (e.g. live weight$^{0.75}$) and a coefficient defined by IPCC (2006) for different animal cohorts. Therefore, the estimated feed intake changed according to the live weight of the animals, reflecting lower feed intake for animals with lower live weight.
- The calf mortality was kept at 21%, consistent with the earlier TEEB study, which is slightly more optimistic than the 25% mentioned paragraph in 2.1.4. The pre-weaning mortality is included in calf mortality in GLEAM.
- The adult mortality was kept at 7%, consistent with the earlier TEEB study, which is slightly more optimistic than the 8-10% mentioned in 2.1.4.
- Fertility was kept at 75%, consistent with the earlier TEEB study. The low calving rate of 40-50% from 2.1.4 points at a lower fertility, as does the high calving interval.
- Age at first calving was kept at 4 years (48 months), consistent with the earlier TEEB study, which is more conservative than the 30 months listed in 2.1.4.
- Milk production was assumed to be negligible, see Chapter 2.3.8.
- The feed ratios are presented in Annex 1, in which the tables include the proportions of feed ingredients constituting the ration. The grass fed was assumed to be freshly cut and fed. For crop residues, wheat straw was used as an example.
- Based on the value chain description, no energy or mechanized transport is required in the rest of the chain, in both the baseline and the improved situation.

The combination of optimistic estimations of calf mortality, fertility rate and calving interval and a conservative age at first calving composes a realistic set of assumptions, reflecting a livestock system with its internal dynamics.

Positive externalities are included and are understood as ecosystem services such as contribution to tourism, carbon storage and land degradation prevention. Their size is compared to the consumer price of pastoral beef.

Based on separate calculations, other environmental indicators in this improved system show reductions in the surplus Nitrogen (N) and a negligible change in surplus Phosphorus (P). Nitrate leaching derived from N input was also lower in the improved system than in the baseline system.

4.1.2 Results

The results of the environmental assessment are shown in Figure 4.1. In graph A of this figure, the effects of the improved scenario with the lower mortalities are shown: the number of animals available for slaughter increase, while fewer animals need to be kept to generate young stock. The amount of feed (in kg dry matter) required by animals in the different groups is lowered slightly, because they can fulfil their requirements consuming less feed with better diet quality (graph B). The combined effect on the climate impact (graph C) is just a slight reduction, and minor shifts of the impact contributions from different animal groups. The same holds for land occupation required to grow the feed demand of animals (graph D). The number of animals slaughtered each year increases slightly in the improved scenario, reflecting the improvement in mortality rates. This results in a reduction of the climate impact per kg of meat of about a third (graph E). The major contributions to this impact are CH_4 originating mainly from enteric fermentation and manure management and N_2O from manure and soils (graph F).

However, it is likely that the land used to grow feed is probably overestimated because the model assumes that the feed required by the animals is produced on the land, therefore the animal requirements are met, which is unlikely to happen in practice. Lower emissions intensity in the improved case than the baseline means that the total impact is distributed over a larger amount of meat produced. Alternatively, the herd size could be reduced to a level on which the same amount of meat is produced, and the total environmental impacts would go down. Incentive structures for the Maasai pastoralists will determine if herd sizes will decrease, remain stable or increase. For example, a relation between the herd size and the subsidies should limit the number of animals per hectare. In summary, output could be increased considerably without significantly increasing the GHG emissions associated with the production of livestock.

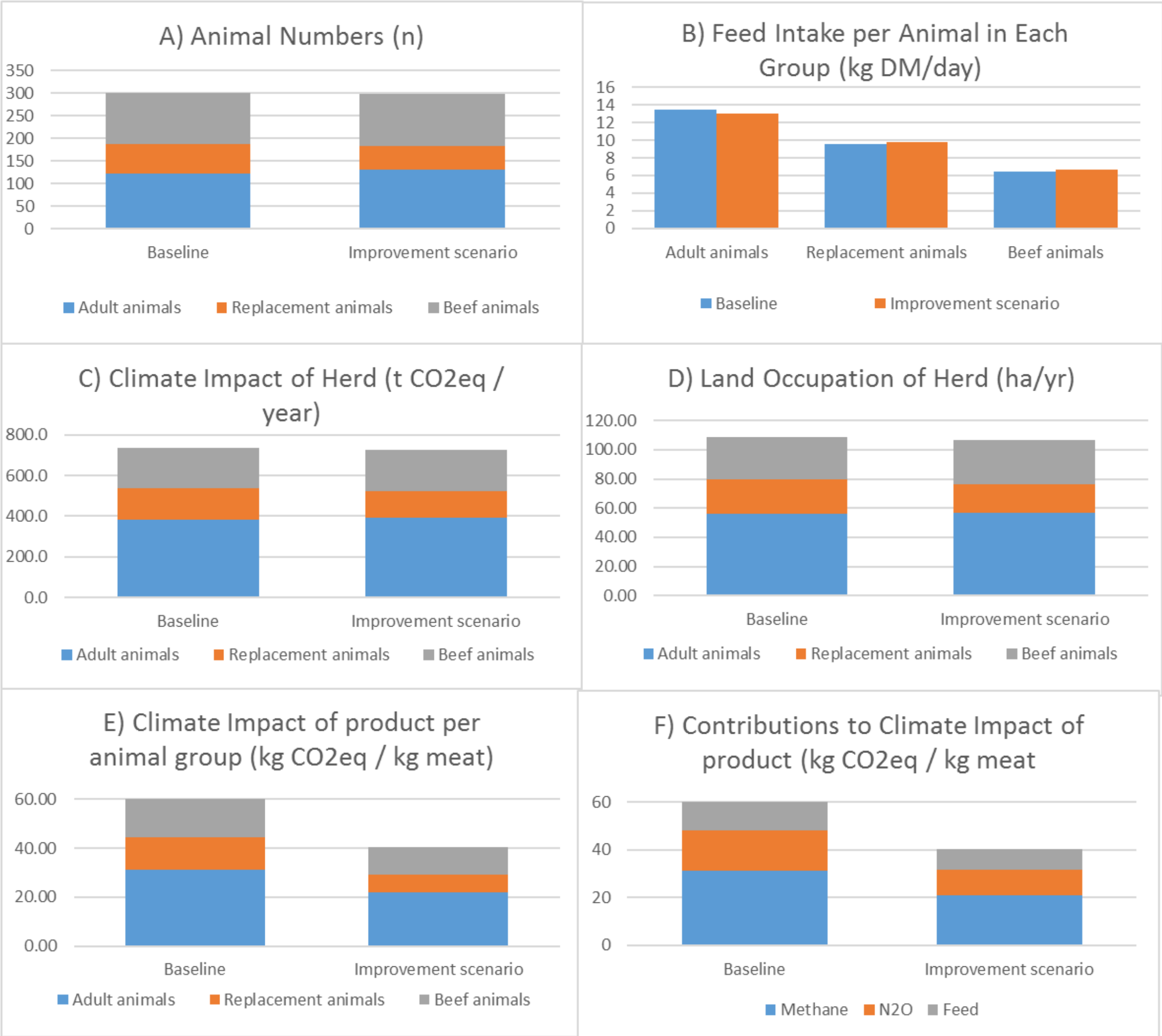

Figure 4.1: Natural capital assessment results for pastoral cattle: A) Animal numbers for each group; B) Feed intake for each group, per animal; C) Climate change Impact of entire herd; D) Land occupation of entire herd; E) Climate impact per unit of product, specified per animal group; F) Contributions to climate impact of products.

4.2 Ecosystem services of pastoralism

4.2.1 Context

Maintenance of natural capital value is a positive externality of pastoralism. In our previous study (Baltussen et al., 2017), the value of ecosystem services in the Maasai steppe were quantified for the whole region, including the two districts of Monduli and Simangiro and the two national parks of Lake Manyara and Tarangire (Figure 4.2). Here we analyse how the activities of pastoralists provide three ecosystem services: land degradation prevention, tourism, and carbon storage. The benefits are calculated per unit of food produced and compared to food produced by sedentary farming and ranching in the same region. The results give insight in the positive externalities of pastoral beef in the baseline scenario.

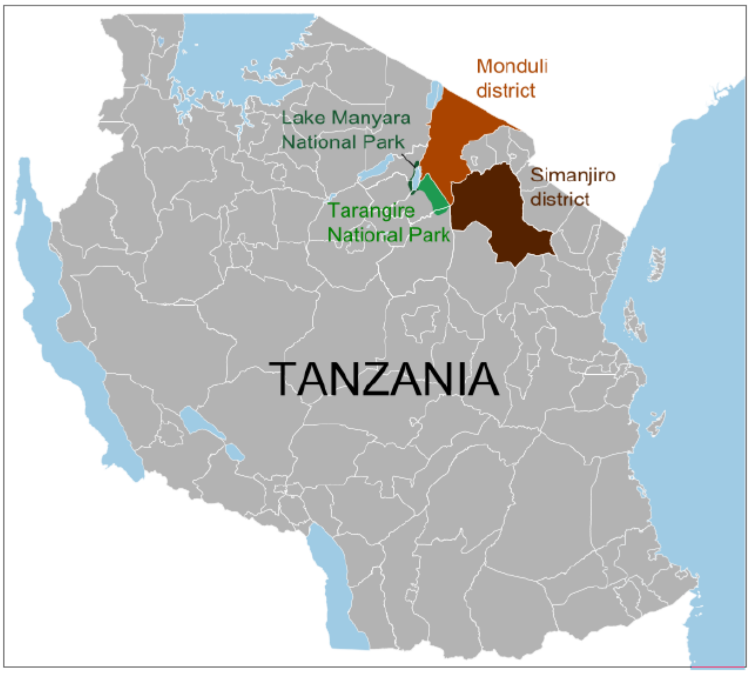

Figure 4.2: The Maasai steppe in Tanzania: boundaries of the area considered in the model (from Baltussen et al., 2017)

Pastoralism, as a traditional way of grassland management, is an economic process that maintains ecosystem quality. However, in the Maasai steppe in Tanzania the most fertile areas are being converted to farmland and fenced for sedentary grazing to produce beef and crops. Although this type of farming has higher output per hectare than pastoralism, research has shown these benefits to be short-lived. In the long-run, farming in this region leads to degradation of land, reduction in livestock densities, wildlife decline and loss of carbon stocks. Grassland converted to farmland has been shown to lose soil carbon over time, leading to abandonment after only 20 years of farming and resulting in a drop in the land's carrying capacity for livestock (Msoffe, 2010). Furthermore, sedentary farming leads to the closure of migratory corridors for wildlife which could seriously affect tourism in nearby National Parks (FAO 2009).

Sedentary farming is taken as a baseline because an analysis of ecosystem services must take a regional focus, and in the Maasai steppe that is the most likely alternative to pastoralism in the region to produce meat, as well as the most likely alternative form of land use.

4.2.2 Data sources

The quantification of ecosystem services provided by pastoralism is based on the natural capital model of the Maasai steppe presented in Baltussen et al. (2017). The model is used as the main data source for ecosystem benefits and services, land areas, human inputs, livestock input costs, and natural capital value of degraded land. It is built on an extensive literature review described in the 'Bottom up methodology TEEB Animal husbandry' report (True Price, 2016). Key sources for land degradation include, among others, Msoffe (2010) and FAO (2009). Average natural capital value per hectare of rangeland, farmland, and national parks given different usage intensities were based on a range of sources, put together into the model described in the True Price 2016 report (see Annex 3). Upper, medium and lower values are provided for carbon stocks, since these are subject to high uncertainty. In Baltussen et al. (2017), the value of carbon storage, the stocks of carbon stored in soil and biomass which is threatened by land degradation, was found to be the largest ecosystem service of the Maasai steppe. This led to the choice to expand the literature review in this study. The high estimate uses the same sources used in Baltussen et al. (2017), which are taken from a study specified for an area in South Africa with similar characteristics to the Maasai steppe (Petz et al., 2014). The lower bound estimate is based on a study of land degradation conducted in Kenya (FAO, 2004), and the medium estimate combines two studies conducted in Tanzania (Osei, 2015 for degraded land; Kempen et al., 2018 for grassland). Carbon stocks are monetized using a social cost of carbon of 133 \$/tCO_2 published by the US IAWG (2013), which represents the expected economic damage to the global economy resulting from climate change causing emissions. The US IAWG social cost of carbon of 133 \$/tCO_2 (95th percentile, 3% discount rate) was selected in line with the previous TEEB global livestock study (Baltussen et al., 2017) because it represents a middle value in the range of estimates that have been published. The social cost of carbon can range between less than \$30 to more than 200 \$/tCO_2 depending on the models used (True Price, 2016)[22].

4.2.3 Results

Through their customary way of managing the land, pastoralists create around \$4.90 in ecosystem services per kilogram of pastoral beef (Figure 4.3), sum of carbon storage, land degradation and contribution to tourism, using the medium estimate of carbon storage. The largest share of this positive impact (\$4.00) is the preservation of carbon stocks in grasslands, the rest in other values of land degradation prevention (\$0.52) and contribution to tourism (\$0.35) by allowing migratory corridors. For reference, one kg of meat costs \$2.93 to a Tanzanian consumer in the region. In other words, crop farming and paddock grazing reduce carbon storage, degraded land, and damaged tourism relative to pastoralism.

The carbon storage positive externality amounts to 70% to 260% of the consumer price of pastoral meat. Loss of soil carbon stocks is a side effect of conversion to settled farming as well as land degradation. Upper and lower bounds estimates are provided (Figure 4.3) as carbon storage loss is subject to a high degree of uncertainty. The review shows that carbon storage remains a very important externality although uncertainty is high and the former estimate was on the high end.

The value of land degradation prevention is a positive externality of pastoral meat, amounting to 18% of the consumer price. Finally, the contribution of pastoralism to tourism value of national parks is quantified to be 12% of the consumer price of pastoral beef. In interpreting these results, it is important to keep in mind that they are region-specific and they emerge from the comparison with the most likely alternative for the region, namely sedentary farming. This means that caution should be used when comparing these results with the natural capital externalities of other livestock systems used elsewhere.

It is interesting to notice that the benefit to the global population, carbon storage, is larger than the local economic benefits themselves (agriculture and tourism). This raises the question whether the global community could reward the positive climate externalities of pastoral grassland management through carbon finance, and in this way also help maintain habitats and land quality. From a financial perspective, such a mechanism would meet a much lower carbon price than the social cost of carbon considered in this study. Voluntary land and forestry offsets, for example, have an average value around 5 \$/tCO_2 (Ecosystem Marketplace 2017), meaning the *local* value of carbon storage benefits would be around 0.08-0.29 \$/kg of beef (0.15 using the medium estimate).

[22] There are other approaches to pricing carbon next to the social cost of carbon. In a business context it is possible for example to look at carbon taxes and traded allowances and (voluntary) offsets. These normally have a lower value, with reviews highlighting a range between 1\$ to around 130\$/tCO2 (World Bank, 2019; Ecosystem Marketplace, 2018).

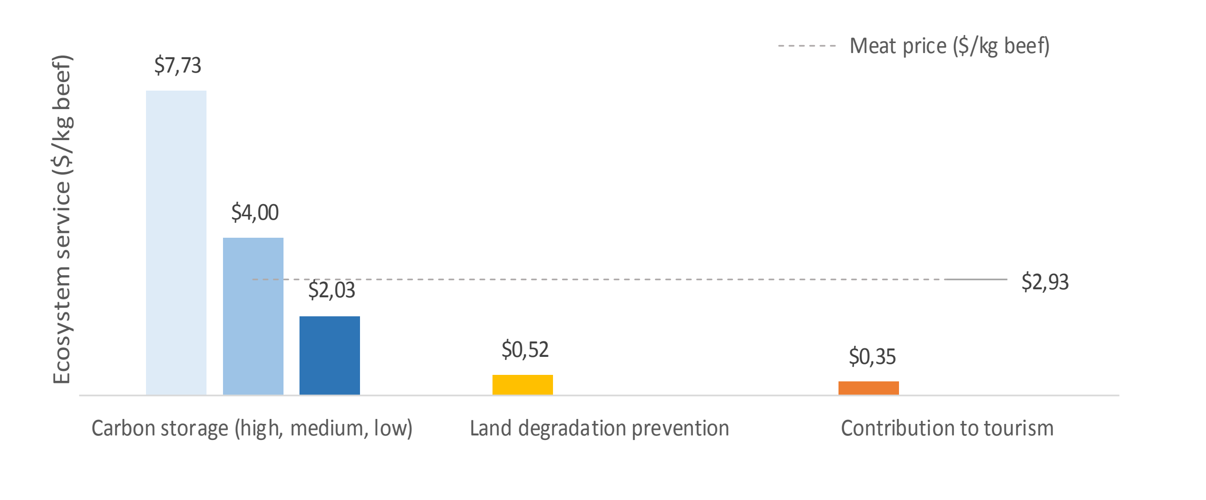

Figure 4.3: Positive externalities (ecosystem services) of pastoralism compared to the price of meat ($/kg beef)

The assessment of ecosystem services of the pastoral cattle system shows that this type of beef production has positive externalities both at the local and the global scale. Improvements of animal management practices should take this into account if they affect the way herd is managed in the landscape. This can be done for example by maintaining pastoralist landscape management or by avoiding overgrazing and preventing land degradation.

4.3 The backyard poultry system

4.3.1 Assumptions

The assumptions for the economic and natural capital assessment are based on the earlier TEEB study and adjusted by critically reviewing the data from this paragraph in consultation with the livestock experts among the authors.

- The average total chicken flock size was 29 based on more recent up-to date literature. This is smaller than the 100 heads than was reported in the earlier TEEB study by Baltussen et al. (2017). GLEAM estimated that on average 2.4 adult reproductive hens were required to reach a flock size of 29.
- Maximum animal weights (1.35 kg for females and 1.92 kg for males) were kept the same as in the report by Baltussen et al. (2017). These weights are on the low end of the range for roosters and in the middle of the range for chickens presented in this paragraph. The number of months it takes for adult females and fattening females to reach their slaughter weight an input in the GLEAM and the values were 926 and 250 days, respectively.
- The slaughter weight was different for different animals and for males kept for meat, the slaughter weight was lower than that of roosters because males kept for meat are slaughtered before they reach full maturity. See Annex 1.
- Mortalities were kept the same as in the earlier TEEB study. We used a death rate of 50% for pullets and 20% for adult females.
- Hatchability, egg productivity and rooster to hen ratio was kept the same as in the earlier study by Baltussen et al. (2017).

- The ration was kept the same in comparison with the earlier study (Baltussen et al., 2017), consisting of swill predominantly. It is mentioned in this paragraph that backyard chickens are fed food waste and no feed is purchased. However, chickens must be able to acquire valuable nutrients, from meal scraps, foodstuffs unfit for human consumption, growing crops or animal and crop waste. Otherwise, the chickens would be underweight and mortalities would be even higher. Therefore, shares of maize, meal oilseeds and grain byproducts are included (11% each) as a proxy for this nutrient rich ration component.

Based on the value chain description, no energy is required in the rest of the chain, neither in the baseline nor the improved situation. Some mechanized transport will occur to transport chickens to markets, but this was assumed to be negligible.

4.3.2 Results

The results of the environmental assessment are shown in Figure 4.4. In graph A of this figure, the effects of the lower mortalities are shown: less replacement hens and roosters are needed. The amount of feed (in kg dry mass) required by animals in the different groups is roughly the same, because the different rations in the baseline and the improvement scenario have similar energy contents (not shown in the graph, described in 2.2.10). Reduced mortality, increased egg productivity, in addition to better quality feed, contribute to the improvement of production efficiency and result in reduced emissions intensity both for egg and meat. The land occupation (graph C) increases because the protein crops introduced in the ration have a higher land occupation than the swill.

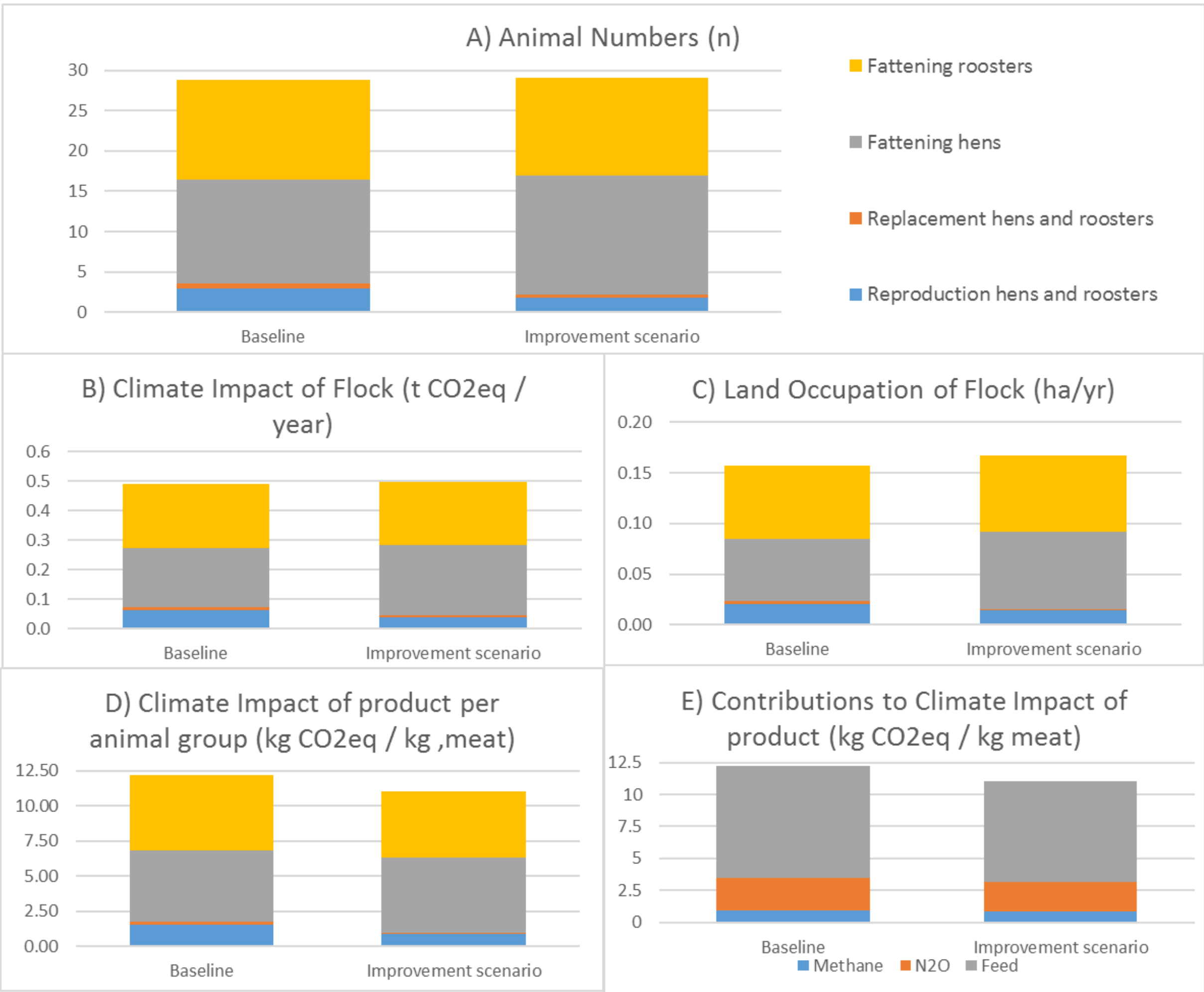

Figure 4.4: Natural capital assessment results for backyard poultry: A) Animal numbers for each group; B) Climate change impact of entire flock; C) Land occupation of entire flock; D) Climate impact per unit of product, specified per animal group; E) Contributions to climate impact of products

The impact per kg of meat decreases by about 10% (graph D). The egg productivity increases more strongly, resulting in a stronger reduction of the impact per egg (not shown in the graph). The major contribution to the emissions intensity is the N_2O from soils and manure, followed by CO_2 from energy use and enteric CH_4 emissions (Graph E).

The herd dynamics in a flock of 29 animals are variable. People may need to barter or trade chickens in order to balance their flock and match their flock with the feed availability, but this is not likely to happen. It should be determined what chicken smallholders will do most likely given their incentive structures in the context of the policy measures.

Other environmental indicators in this improved system show slight reductions in the surplus N and P. Nitrate leaching derived from N input was also lower in the improved system than in the baseline. Only if the feeding of backyard chickens changes more radically than in the current improvement scenario and across a very high share of the households, the feed cultivation will intensify, resulting in increased GHG emissions (mainly from CO_2 emissions associated with feed production and processing).

4.4 The smallholder dairy system

4.4.1 Assumptions

The assumptions for the economic and the externalities assessment are based on the earlier TEEB study and adjusted by critically reviewing the data from this paragraph in consultation with the livestock experts among the authors.

- The average size of five lactating adult cows was kept the same as in the baseline as defined in Baltussen et al. (2017). The number of adult reproductive females as well as mortality rates, age at first calving, and bull to cow ratio (for adult males only) determined the number of animals in each cohort.
- Maximum animal weights and mortalities were kept the same as in the study by Baltussen et al. (2017).
- The milk productivity was adjusted from 937.5 kg milk / lactating cow per year to 200 kg milk per lactating cow per year, in order to accommodate recent data found in this project (see Chapter 2.3.5). The original productivity (and growth rates) from the TEEB study was based on genetic potential of the livestock, and it was assumed that all feed requirements are fulfilled. However, in practice, feed availability is limited and quality is variable, and the milk productivity is a resultant.
- Fertility was kept at 75%, consistent with the earlier TEEB study. Age at first calving was kept at 4 years (48 months), consistent with the earlier TEEB study.
- The ration was kept the same in comparison with the earlier TEEB study, consisting of crop residues augmented with some grazed or freshly cut grass.
- Based on the value chain description, no energy or mechanized transport is required in the rest of the chain, in both the baseline and the improved situation.

4.4.2 Results

The results of the natural capital assessment of smallholder dairy systems are shown in Figure 4.5. In graph A of this figure, the reduced bull to cow ratio (i.e. increased use of artificial insemination) and the lower mortalities are shown. In order to maintain five lactating adult females, the other animal numbers can decrease. The amount of feed (in kg dry matter) required by animals in the different groups is lowered by about 10%, because they can take more energy from fresh cut grass than from crop residues. Lactating cows will increase their feed intake in order to produce ten times more milk. The combined effect of herd composition and feed intakes on the climate impact (Graph C) is a reduction of a third, and notable shifts of the impact contributions from different animal groups. The largest contribution to the reduction of emissions at herd level comes from the reduced number of adult and replacement males that are not needed to maintain the herd structure anymore (40.4 t versus 5.1 CO_2eq/year in baseline and improved case, respectively). Naturally, the reduced number of replacement females also contributes to this change. Land occupation (Graph D) decreases more strongly than the climate impact, because more feed can be taken from fresh cut grass than from grazed grassland and from land providing crop residues. The strong increase in milk productivity reduces the impact per kg of milk very strongly (Graph E). The meat impact is also reduced strongly, because the meat production increases and a larger share of impact is allocated to the milk instead of to the meat. The major contribution to this impact is methane (CH_4), mainly from enteric fermentation but also from manure (graph F).

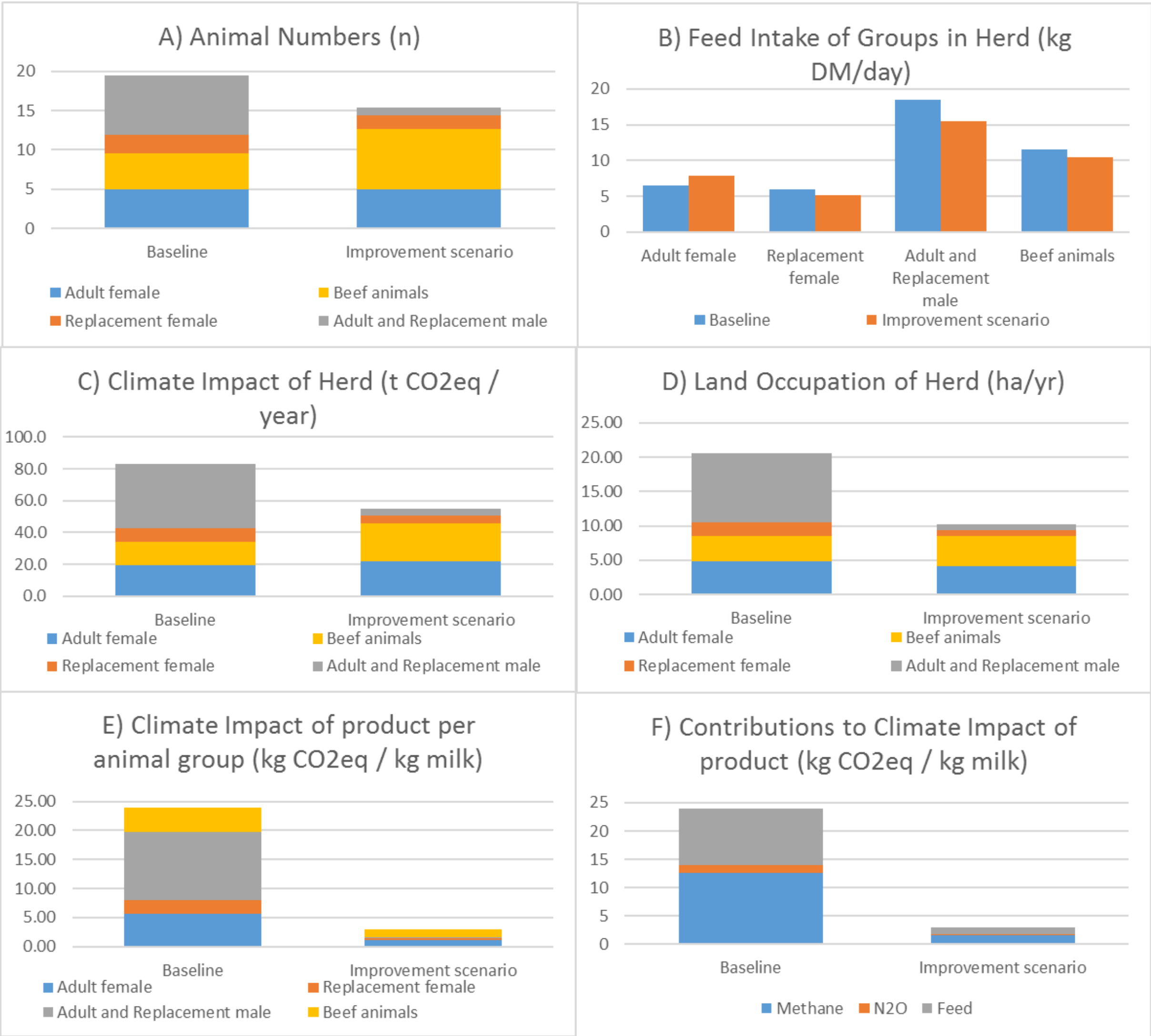

Figure 4.5: Natural capital assessment results for dairy smallholders: A) Animal numbers for each group; B) Feed intake for each group, per animal; C) Climate change impact of entire herd; D) Land occupation of entire herd; E) Climate Impact per unit of product, specified per animal group; F) Contributions to climate impact of products

Furthermore, it is likely that the yield of the grass is lower than the default values in GLEAM, so that land occupation is significantly higher and stocking density is lower. As indicated in 2.4.3, it is likely that more grazing land is required if numerous smallholders in the same area switch to this system. Since only roadside grazing would not provide a sufficient grazing area, it is questionable how this area will be made available. Some smallholders might stop cattle farming if they can get the services and manure that the cattle provide from their surroundings, but all changes depend on the incentive structures that vary across Tanzanian communities.

Other environmental indicators in this improved system show considerable reductions in the surplus N and P. Nitrate leaching derived from N input in the improved system is almost half the amount in the baseline, reflecting the ten-fold increase in milk production in the improved scenario.

4.5 Biodiversity assessment

Baltussen et al. (2017; Figure 4.17), provided the Mean Species Abundance (MSA) per ha per kg protein for the three livestock systems. This is based on detailed GLOBIO calculations. MSA is a relative indicator between 0 and 1 that relates population sizes of species occurring in allocation to the population sizes in those species that would have occurred in unaltered reference situations, which is often indicated as pre-industrial. Basically, it is an indicator for the naturalness (e.g. the situation without the human intervention) in a certain location.

For poultry the MSA per ha per kg is 0, while it equals 0.04 for pastoral, and 0.06 for the dairy systems. A value of 0.04 indicates that for the production of 1 kg of protein, the equivalent of 0.04 ha loses 100% of its biodiversity.

In the improved scenarios there will be no impact for the MSA per ha per kg for the poultry and the beef systems. For both systems the land use will not change, and the intensity of land use also remains the same. For the dairy system there is an increase in the intensity and less land use in the improved scenario compared to the present situation. It is unclear how this will influence the MSA per ha kg protein.

5 Human and social capital assessment

In this chapter we assess the social and human capital for the different livestock systems. This is based on the description of the systems (Chapter 2) and the outcomes of the economic and natural capital assessments. Table 5.1 and 5.3 summarise the findings of the assessment.

5.1 Human capital assessment

5.1.1 Education and skills

The delivery of quality agricultural extension services in Tanzania has been a centre of attention for a long time, given the fact that the majority of Tanzanians (more than two thirds) live in rural areas and depend on small-scale agriculture. In 2015, Tanzania had 7,974 extension staff, which was just over half the national requirement of 15,082 for placement in every village and ward (URT, 2015). While insufficient human resources hinder efficient delivery of extension services (MAFS, 2013), it is argued that even the services offered by existing staff fall short in diagnosing smallholder dairy farmers' problems and transferring practical knowledge due to low capacity and / or limited understanding of the smallholder dairy farming environment by the extension officers. Consequently, extension services have not led to significant increases in production among smallholder dairy farmers (CUTS International, 2011).

Recent levels of demand for education amongst pastoralist communities have been reported to be increasing (Bishop, 2007). However, Carr-Hills's study of six East African countries found the rates of primary school enrolment for children in pastoralist communities to be significantly below the national average in each country (Carr-Hill et al. 2005). Much of the literature on education for pastoralists has concentrated on the reasons for their low levels of participation and attainment in education. Many of the explanations suggested in literature, focus on the practical challenges of providing education to pastoralist populations. Pastoral areas generally have low population densities, resulting in long distances to schools, and varying degrees of mobility amongst pastoralists make it difficult for children to attend static schools. It has also been argued that pastoralists' dependence on the labour of children is not compatible with schooling. It has been noted by several authors that pastoralism in East Africa requires a much heavier commitment of labour by children than in cultivation (Bishop, 2007). Another explanation which has been put forward is that pastoralists are often amongst the poorest groups in the countries they inhabit, and consequently parents do not have access to cash to pay for schooling costs such as uniforms and contributions to schools. However, results in Chapter 3 show that income for pastoralists are higher than many wage earners in the country given the assumptions used (see section 3.1.2).

On the other hand, children carry most of the routine work of the Maasai household. They do almost all of the herding and much of the work around the *boma.* Children become involved from when they are 3 or 4 years old, helping with tasks such as carrying kids and lambs in or out of the house and watching animals around the *boma.* This fulfils three functions: it helps protect the animals from predators, it trains the children as future herders and it keeps the children occupied so their mothers can do other jobs. At 6 or 7 years old, a child becomes a full-time herder, beginning with herding goats and sheep. At 8 or 9 years old, children start herding calves, and by the age of 11, children, particularly boys, begin to herd older cattle, initially as apprentices to an older herder. Girls tend to mainly focus on goats, sheep and calf herding and less on cattle than boys. If girls herd calves, goats or sheep, they usually return to the *boma* in time to help with young-stock management, preparations for milking as well as domestic tasks.

All improved livestock farming systems require improved knowledge and skills on modern livestock farming practices that contribute to improved agricultural output such as improved knowledge on the correct application of inputs. Access to education remains low, but an improved pastoral system could increase income and make education more accessible.

5.1.2 Human health

This paragraph examines the impact of livestock products on human health. All assessed food systems show an increase in output that can be sold on the market or that is consumed by the household / communities contributing to better human health. Animal diseases can also impact human health via zoonosis (see https://www.wur.nl/en/Dossiers/file/Global-One-Health-5.htm). For backyard chicken that live in or around houses of people in particular, there is a potential risk of avian flu outbreaks. In addition, the use of antibiotics and medicines in animal production systems can also impact human health. Medicines should only be used to cure animals rather than to prevent them from contracting diseases, in order to stop viruses or bacteria from becoming resistant to certain medicines as well as contributing to antibiotic resistance among humans (see https://www.wur.nl/en/Research-Results/Research-Institutes/Economic-Research/show-wecr/Antibiotic-reduction-no-negative-effect-on-competitive-position-of-Dutch-farmers.htm).

5.1.3 Working conditions

The labour used in smallholder dairy farming is principally derived from family members but sometimes hired labour is used (IFAD, 2016). Working conditions in general are not affected by the improved scenarios, but in theory, jobs are generated mainly within the smallholder dairy system. However, the presented improvements require an increase in labour that can be either performed by the household or by hired workers. Also, further downstream in the value chain, opportunities are created considering the increased supply of meat that is processed for human consumption.

5.1.4 Conclusion

Below, Table 5.1 presents the results of the human capital assessment. If the improved policy is compared to the baseline scenario it is expected that the livestock systems ‘pastoral cattle’ and ‘smallholder dairy’ education and skills will be improved. With the expected income increase it would be possible to pay for more education for the children and to increase skills by using the extension service. The improvement for the ‘backyard chicken’ production system is small because of a small expected increase in income due to the new policy.

For all systems, an increase of human health is expected because more animal proteins are produced and used for own consumption. Since levels of animal protein are still low, human health is positively affected. The possible negative impacts such as zoonosis and antibiotic use are estimated to be low given the assumed levels of inputs in the improved policy scenario.

The impact of the improved policy scenario on the working conditions are estimated to be low to no impact. The systems are not changed radically and therefore also the working conditions do not change. In the smallholder dairy system some jobs may be created downstream in the value chain.

Table 5.1: Assessment of possible impacts on human capital

	Possible impact		
	Pastoral cattle	**Backyard poultry**	**Smallholder dairy**
Education and skills	Improved	Small improvement	Improved
Human health	Improved	Improved	Improved
Working conditions	No effect	No effect	Improved

5.2 Social capital assessment

5.2.1 Food security

The average consumption of chicken in Tanzania was relatively low in comparison to other countries. Consumption of eggs have great potential for improving maternal and child nutrition (Lutter and Morris, 2018). Most of the poultry products are consumed in urban areas as opposed to rural areas. It must be noted that the consumption of poultry products also varies from one location to another. However, the improved scenarios show a 30% increase in eggs that can be consumed by the household from 50 to 70 eggs per year, in addition to the additional meat supply.

As stated in Chapter 2, Tanzania has a low per capita consumption of milk. The improved smallholder dairy system will increase milk output so that the amount of milk produced per lactating dairy cow is ten times higher than the baseline scenario (2,400 litres per year compared to 240 litres per year). This will result in more milk available on the market suitable for human consumption and will contribute to increased food security. Also, the demand for milk is increasing (see also paragraph 1.1.). We assumed that the increased demand and the increased supply will result in stable prices.

The pastoral cattle system: in the improved scenario the communal consumption of beef is assumed to stay stable, which means that relative to the baseline, a larger share of the herd is sold on the market. The supply of beef from pastoral systems will increase and will contribute to food security.

A higher production of beef, milk, eggs and chicken meat in rural areas also has the advantage that the risk of a shortage of livestock products will decrease or that prices for livestock products will sharply increase if supply is lower because of natural conditions, as explained in Chapter 1.

5.2.1.1 Gender structure of three livestock sectors

The Maasai have strong, culturally prescribed norms for the division of responsibilities and labour between age groups and sexes. Adult married men are primarily managers and supervisors in the livestock keeping businesses. They are responsible for gathering all necessary information on range conditions, water availability and marketing. They also make decisions on residence location, herd movement, herd splitting, the daily orbit of grazing and the person in charge of the herding. In the evening, men inspect animals as they return home to ensure none are lost, to determine whether animals have grazed enough, whether any are about to give birth or are sick. Men are also responsible for veterinary drugs and perform castrations and other minor veterinary procedures. They decide at what time and which animal(s) should be slaughtered, sold or buffered, and may wish to consult other household members in order to do so. It is important to note that in pastoral communities, participation in political affairs are often at the discretion of the men (Kipuri and Ridgewell, 2008).

Women in pastoral communities are responsible for all major domestic household decisions, including those relating to taking care of children, collecting water and fuelwood, preparing food and house-building and/or maintenance (Kipuri and Ridgewell, 2008). In addition, women also take part in some livestock management activities including taking care of very young stock that usually spend the day around the *boma;* and inspecting the animals of their sub-household to ensure all have returned from grazing and are in good health. If any problems arise they will be reported to the household head. In addition, milking is done by women and they have the right to the milk of their animals (Kipuri and Ridgewell, 2008).

After circumcision girls will be ready for marriage, and their labour to their household will soon be lost. On the other hand, boys become *moran* (often referred to as warriors) and will then be nominally free from routine labour. However, they may be called upon to help with watering in severe dry seasons as well as herd-splitting. When herds are split, *moran* commonly manage the distant camps (Bekure et al., 1991). Table 5.2 below details the time spent on livestock management by adults and children in poor, medium and rich households.

Table 5.2: Overall time spent on livestock management by adults and children in different types of Maasai households

	Mean time spent on livestock management (hours/day)			
	Children		Adults	
Wealth class[1]	Male	Female	Male	Female
Poor	4.3	4.3	4.5	0.8
Medium	7.5	7.9	4.6	1.8
Rich	5.7	6.9	6.9	1.6

Source: Bekure et al. (1991) Kajiado District, Kenya

Backyard chickens are largely owned by the women and are not considered livestock by the men in Tanzania. The savings value in chicken kept by the reference household is around $100. As discussed elsewhere in this report, chickens are an important form of savings for low income households and are especially relevant for women, who generally take care of the animals, in a context where women are often excluded from participation in other economic activities. As such, the poultry sector enables a huge opportunity for the empowerment of women. At the individual level, when a woman starts to generate her own income, she improves her status and decision-making power in relation to household matters such as the children's upbringing and general expenditure. Moreover, she feels more confident and independent as she gains control over resources and no longer needs to consult her husband about the smallest economic matters. However, gender-based constraints remain present (Guèye, 2003) and there is a serious risk that this activity might be taken over by the men and for implementation of an improved scenario the social context should be considered by setting women owned groups or cooperatives or other support functions in order to empower gender based poultry systems.

Studies on female participation in dairy farming in Tanzania show that women contribute more labour force in dairy management than men (Kimaro et al., 2013). They are mainly involved in activities such as milking, fetching animal feeds, cleaning barns and marketing milk products. Specific female farmer groups or cooperatives enable women to gain control and access over income from dairy farming. Improving the smallholder dairy system will therefore empower women in the dairy sector.

5.2.2 Social cooperation

In general, the Maasai pastoral system enables good opportunities for social cooperation. A group of Maasai families together typically own 300 head of cattle and various other animals. Increasing the herd due to reduced mortality is likely to increase social cooperation. Also, there is a risk that if herding cattle is a lucrative activity, more cattle will be held by the communities, which would in turn increase the risk of overgrazing. Therefore, communities should not harvest more feed than they did before, otherwise overgrazing could become a problem for these vulnerable regions.

In the dairy system, social cooperation is essential to collect and sell the increased output of milk from smallholder farmers in Tanzania. Without proper collection, it is impossible to benefit from the increased milk production. The development of regional marketing cooperatives to organize milk collection is therefore very important.

5.2.3 Institutions, laws and regulations

In the improved dairy scenario, the increase in milk produced has to be transported to a central place for further processing. Collection of milk for processing requires significant investment in a collection grid as well as cooling and transportation equipment. Institutions such as farmers cooperatives, can also be established to facilitate the collection of milk of various farmers (van der Lee et al., 2014). In many regions, private milk collectors and vendors play a crucial role in the collection of raw milk. Their possibilities to meet quality standards and their attitude towards adding (sometimes harmful) additives to increase milk value, influences both the quality of milk and the costs dairy plants have to detect additives. Better milk quality testing and payment systems based on quality, will contribute to the awareness of quality at farmers' and collectors' level. MCCs (and cooperatives) can play a very positive role in the collection and selling of milk, based on quality standards. In Tanzania, ownership of MCCs is mixed ranging from the "Processor-smallholder" model; to the "NGO-facilitated" model. An institution like a MCC requires an effective board, fair quality standards and testing, logistics, cooling and much more.

5.2.4 Conclusion

Below Table 5.3 presents the results of the social capital assessment. The improvement on social cooperation, institutions, and food security for the production system 'smallholder dairy' is large because of the expected increase in milk output and the need to organize marketing, offtake, cooling and transportation. The expected impact for the improved scenarios compared to the baseline scenario for the livestock systems 'pastoral cattle' and 'backyard poultry', will be smaller.

Table 5.3: Assessment of possible impacts on social capital

	Expected impact		
	Pastoral cattle	**Poultry**	**Smallholder dairy**
Food security	Improved	Improved	Improved
Opportunities for empowerment	No effect	Positive	Positive
Social cooperation	Improved	No effect	Institutions like cooperation development
Institutions	No effect	No effect	Institutional development like MCCs

6 Policy options

6.1 Introduction

A Theory of Change serves as the backdrop to pathways to implementation (TEEB, 2018). To tackle the challenge of possible trade-offs between the goals of increasing yields and reducing negative externalities of agricultural practices, sustainable intensification, as presented in the various improved scenarios, is a concept that helps guide Tanzanian policy makers. It will contribute to public knowledge and will improve informed decision making. As such it is an important building block for a Theory of Change. In this chapter we will provide a narrative on the Theory of Change.

For policy makers in Tanzania we have developed several policy options that can be explored for further development leading to sustainable food production and improved livelihoods. In the debate on the options and the pros and cons of sustainable intensification for African agriculture, a group of international experts gathered in the Montpellier Panel, giving new meaning to the sustainable intensification-concept as a practical approach for African farmers to cope with food insecurity (Montpellier Panel Report, 2013). The panel defines sustainable intensification as "the goal of producing more food with less impact on the environment, intensifying food production while ensuring the natural resource base on which agriculture depends is sustained, and indeed improved, for future generations." This definition involves producing more crops, higher animal yields, better nutrition and higher rural incomes from the same set of inputs – such as land, water, credit and knowledge – while reducing environmental impacts on a sustained basis. The panel emphasized that none of the components of their paradigm for sustainable intensification are new. New in the report is the way in which they are combined as a framework towards appropriate solutions to Africa's food and nutrition challenges (see also Achterbosch et al., 2014 for a discussion of the framework).

An improved scenario has been defined, based on the reference situation, taking into account a realistic development scenario and the current enabling environment (education, infrastructure, agricultural policies). We also considered stocks and flows of the agricultural system, the social system and the ecosystem. We assessed improved livestock systems to determine if food production and incomes can be improved without harming the social system and the ecosystem. As a starting point we used the current policies (URT, 2016) which are mostly food production orientated and with limited attention on possible impacts on the human, social and natural ecosystems.

Efficiency and quality of the supply chains will be improved significantly as shown by the examples of alternative production parameters applied in the three systems considered. Assuming that due to these improvements, food supply will better be able to respond to increasing food demand, especially in urban regions (where due to increasing incomes and changing lifestyles, consumption of animal products tend to increase), rural production can expand without market prices falling so that farm household income rises. How then to achieve these improved production parameters – such as higher productivity and lower mortality rates? In the previous chapters, efficiency improvements are largely assumed to result from better management practices in combination with small technological and organisational innovations at farm and chain or sector level. Solid governmental policies could help support the sector in achieving these improvements. We suggest two key policy options that will enable this:

- Policies to develop infrastructures and institutions to improve farmers' access to various inputs including feed, medicines and vaccines to increase productivity of the food supply chain; and
- Policies to improve knowledge by training livestock farmers through improved extension services, to raise awareness on the importance of the utilization of improved inputs.

These policy options should be implemented by supporting the institutional change of food supply chains, including the structure and function of support services covering input supply and extension services. By improving livestock production systems with these two policy foci, rural livelihoods can be improved and people in the urban areas can be supplied with local animal products without increasing the negative externalities of their produce in total, while maintaining positive externalities of livestock production systems.

Intensifying production has two basic risks. The first is the overuse of inputs such as fertilisers, medicines and pesticides which will increase the negative externalities, such as water pollution and soil acidification. The second one is the increase of animals which can lead to overgrazing. Such negative environmental effects of more intensive use of external inputs or natural resources can be mitigated by policies. For example, in the EU cross compliance measures are positive incentives to farmers to avoid negative externalities of agricultural practices. Measures are in the form of direct income payments that are subject to a proof of ecological performance in terms of adopting environmentally friendly production methods that ensure the support payments. Also, the overuse of inputs can be regulated in industry standards such as Good Agricultural Practices (G.A.P.). Tanzania may not have the financial resources and institutional capacities to apply EU type of cross-compliance policies, and a more practical approach of sustainable intensification may seem more appropriate in the country's context. This approach is discussed in section 6.4.

6.2 Input provision

The use of productivity enhancing inputs in Tanzania's agricultural sector is among the lowest in the region, as is shown by figures related to fertilizer application and the sales of improved seeds (see ASDP2, 2016). The main reason is a lack of financial means in the sector and little public expenditure (via grants and subsidies) to provide inputs at affordable rates. Purchases of inputs show some positive trends since 2007/2008, when the government increased funding for its National Agricultural Input Voucher System (NAIVS). However, for the majority of farmers, inputs are still expensive and, even when used, the efficiency of used (i.e. return of) inputs is low (ASDP2, 2016). The government's strategy to stimulate investments in productivity enhancing inputs includes improved access to credit next to improved knowledge and extension on how to use the inputs efficiently.

The use of feed fodder is low in livestock. Moreover, fodder conservation is poorly practiced by the livestock farmers and this affects dry season animal feed availability and ultimately lowers the output of the food supply chain. There is a serious need to identify and promote the use of locally accessible fodder conservation technologies to ensure that harvested fodder crops are properly stored for use in the dry season. Policy can support this by (co-)investing in the required storage infrastructure and by promoting farmers' knowledge of the conservation of crops.

The animal healthcare infrastructure to support smallholder dairy farmers in Tanzania is inadequate. The government and other stakeholders should enhance the capacity of the existing veterinary laboratory systems in Tanzania to conduct disease surveillance and support the establishment of new animal healthcare infrastructures. This implies investment in veterinary laboratories and related equipment, milk quality control checkpoints and professional staff that are well-trained for the job (see also van der Lee et al. (2014) for examples from different emerging economies).

In order to monitor the quality of the feeds/ feed ingredients used in compounding the rations, there should be well equipped analytical laboratories in different agro ecological zones which can receive feed samples from both public and private sector organization for quality testing.

6.3 Extension service development

As stated before, in a recent survey conducted by the Tanzanian Ministry of Agriculture, Livestock and Fisheries, only 56% of officers reported having access to motorised transport, with almost no support from the government (Chipman and Blum, 2016). The Tanzanian extension service should be equipped with sufficient extension workers who should all be equipped with a motor bike and budgets for gasoline to visit farmers more frequently. As a result, the majority of the Tanzanian livestock farmers do not have sufficient access to extension services. In addition, they should be trained in more intensive livestock farming systems (including farm level strategies to harvest and store feed) to increase the educational level and skills of farmers involved. In the end this knowledge will enable them to support farmers in a more efficient way of producing livestock.

In its Agriculture Sector Development Programme (ASDP), the government acknowledges the importance of extension services as a major instrument to increase the sector's productivity as a crucial link between research and experimental stations, expanding the knowledge base on the one hand, and the practical implementation at farmer level on the other hand. Extension, capacity building and training will not only contribute to better use of inputs, implying higher productivity, but will also have to focus on improving water and land use management in the context of the country's ecological fragility, the Programme argues. Tanzania's natural resources are limited and vulnerable to climate change; a reason why extension, training and education aiming towards promoting agricultural growth and development should also include contributions to the sector's knowledge and skills on how to enhance the sustainable use of resources. The government's ASDP 2016 document formulates policy goals and lists investment priorities which include actions enhancing sustainable agricultural development, yet also indicates that success depends on long-term investments of both public and private sources. In the ASDP2 – a 10-year road map for agricultural and rural development – for livestock, targeted beef and/or dairy priorities are to promote the further use of quality breeds adapted to key production systems including pastoralism and disease control, which requires strengthening disease detection capacities (veterinary laboratory diagnostic services) and access to vaccines (vaccine institute) (ibid, p. 61, 65, 78 and 99). Next to all public investments anticipated in the development plan – TZS 4,900 bn or $2.1 bn in the 10-year period - the government expects private investments to come in to build modern milk and meat processing units, cold storage facilities and other marketing services. Private investments are supported by credits, subsidies (targeted vouchers) and legal frameworks promoting entrepreneurial initiatives.

Sustainable intensification consists of a variety of practical and achievable activities. Many of these can be generated by farmers themselves. They consist of three parts:

1. *Environmentally sound intensification*: the utilisation and intensification of processes to create sustainable forms of crop and livestock production (e.g. intercropping).

2. *Genetic intensification*: the concentration of beneficial genes within crop varieties and livestock breeds, through existing methods and new plant breeding technologies (e.g. developing drought-tolerant maize).
3. *Socio-economic intensification*: the process of developing innovative and sustainable institutions on the farm, in the community and across regions and nations as a whole (e.g. better access to reliable markets, knowledge, grain-banks, etc.).

Sustainable intensification in this manner is achievable for Tanzanian smallholder farmers, and builds on many of the traditional practices in the region such as "micro-dosing" by which smallholder farmers use the cap of a drinks bottle to measure small amounts of fertilisers which boosts yields significantly while keeping costs down for farmers and reducing the risk of fertiliser runoff into waterways. Alternatively, they can combine mixed field and tree crops such as nitrogen-fixing varieties (examples mentioned in Achterbosch et al., 2014). Livestock farmers in Tanzania can use these practices to increase the volume and quality of fodder crops on their own plots. For instance, mixed dairy farms (see section 4.4) could integrate herbaceous forage legumes into their grass fodder cultivation practices (e.g. Mwangi and Wambugu, 2003 for an example in Kenya). A farmers marketing cooperative is a proven institution to empower farmers’ market position purchasing inputs and/or selling outputs. In particular, as noted in section 5.2.2 already, forming women owned groups or cooperatives in the poultry and dairy sector can empower gender-based sector development.

7 Conclusions

This study evaluates the socio-economic and environmental impacts of value chain activities related to three livestock sectors in Tanzania using the TEEB framework. The specific livestock production systems studied are:

- The pastoral cattle system (Maasai);
- The backyard poultry system; and
- The smallholder dairy system.

First, we evaluated the current value chains of each of the three livestock production systems. Next, we considered improved livestock systems by assuming technical improvements that lead to a more efficient livestock production system, without changing the structure of the primary production for the pastoral and the backyard poultry system. For the smallholder dairy system, the value chain beyond the farm gate needs some structural improvements (e.g. cold storage, collection, transportation and market structures). Finally, we considered a number of policy options that may enable these improved livestock systems. Below we present the key outcomes based on the improved scenarios for the economic dimensions and externalities for each livestock production system.

7.1 Pastoral cattle system

The financial and produced capital assessment of a pastoral cattle system shows that the economic contribution to household income is high and, although there are negative externalities, ecosystem services provided by pastoral grassland management are higher than the value of the meat produced (see Table 7.1). Carbon storage is the main benefit, although contribution to tourism and land degradation prevention also are important positive externalities. However, this is only true if pastoralism is maintained at the same intensity (number of ruminants per area). As always, it needs to be noted that carbon storage is a global benefit and the value of this benefit locally may be quite small.

Table 7.1: Some basic outcomes of an improved agricultural policy compared to the baseline for pastoral cattle systems

Pastoral cattle	Unit	Baseline	Improved
Environmental externalities (greenhouse gas emissions)	$ per kg meat	7.9	5.3
Ecosystem services - Contribution to tourism	$ per kg meat	0.35	n/a [3]
Ecosystem services - Carbon storage (land)	$ per kg meat	4.00	n/a [3]
Ecosystem services - Land degradation prevention	$ per kg meat	0.52	n/a [3]
Household income generation (financial + in kind[1] - costs)	$ per kg meat	1.38	1.21
Household income generation (financial + in kind[2] - costs)	$ per household	1,140	1,465

[1] Including sold and consumed meat, milk and skins for a herd of 300 cattle, 60 goats and 50 sheep.
[2] Conversion of results per herd to household-level has a level of uncertainty.
[3] Not available. The ecosystem services assessment focused on the baseline system.

The economic assessment of an alternative system with higher input use shows that an increase in year-round feed availability and improved basic bio-veterinary indicators, such as lower mortality rates, can increase the beef output of pastoral households, primarily due to an increased offtake rate, allowing pastoral households to sell more cattle while their herd remains the same size.

The environmental assessment shows about a 30% reduction in the emissions intensity in the improved case compared to the baseline scenario (see Table 7.1). This overall impact is distributed over a larger amount of meat produced (i.e. emissions intensity). In addition, in the present situation per kg of pastoral beef, there is about $4.90 of value created in ecosystem services, equivalent to 170% of its retail price. The main problem is to overcome the short-term benefits (from converting to an agricultural system) versus the long-term benefits (including ecosystem services in a pastoral system), and local benefits (such as income) versus global (such as carbon storage). Currently, these ecosystem services are not being paid for. Changing this would help to increase pastoral income and preserve natural capital. Additional policies are needed to restrict the total number of cattle to prevent overgrazing which could happen as a result of conversion from grassland to farmland.

From the human capital assessment, the pastoral system is providing positive effects on education and skills and human health. From a social capital assessment, the sector is mainly showing positive impacts on food security due to increased supply of beef, and is likely to require advanced social cooperation due to a decrease in mortality of the herd.

7.2 Backyard poultry system

The economic significance of backyard poultry systems is not reflected in absolute income, but rather in the ability for women to generate cash revenues and nutrition at very low input costs. The household income increases slightly when improving feed quality and fencing measures. This alternative scenario results in an increase in produced eggs that can be consumed by the households. Additionally, two more birds can be sold per year and generate added income. The amount of feed (in kg dry mass) required by animals in the different groups is roughly the same, because the different rations in the baseline and the improvement scenario have similar energy contents.

The environmental assessment shows a 10% reduction in the GHG emissions intensity in the improved case compared to the baseline, both for egg and meat produced in the system (see Table 7.2). Moreover, backyard poultry systems can improve human capital in the form of household food security and protein intake, and from a social capital assessment, the sector is showing a positive impact on community food security and the empowerment of women.

Table 7.2: Some basic outcomes of an improved agricultural policy compared to the baseline for backyard poultry

Backyard poultry	Unit	Baseline	Improved
Environmental externalities	$ per kg meat	1.6	1.4
Household income generation (financial + in kind - costs)[1]	$ per kg meat	2.48	2.49
Household income generation (financial + in kind - costs)[1]	$ Per household	140	140

[1] Only income generated from backyard poultry, including income in kind by consumption of own produce

7.3 Smallholder dairy system

The economic assessment of the traditional smallholder dairy system shows that the costs are very low. This traditional system was compared to a specialized improved system, which has higher inputs of feed and water and uses artificial insemination. Compared to the traditional system, the amount of milk produced per lactating dairy cow is much higher, and income generated is higher as well, provided the increased output can be marketed and sold at current prices (see Table 7.3).

The environmental assessment shows that the combined effect of better herd structure, animal health and feeding, results in an almost 90% reduction in the GHG emissions produced per kg of milk in the improved case compared to the baseline. This is reflected by the ten-fold increase in milk production (see Table 7.3).

The human assessment provides positive effects on educations and skills, human health and working conditions, and from a social capital assessment, the sector is mainly showing positive impacts on food security.

Table 7.3: Some basic outcomes of an improved agricultural policy compared to the baseline for smallholder arable dairy

Smallholder arable dairy	**Unit**	**Baseline**	**Improved**
Environmental externalities on product level	$ per kg milk	3.1	0.4
Environmental externalities on herd level	t CO_2 eq per herd	80	57
Household income generation (financial + in kind - costs)[1]	$ per kg milk	0.40	0.31
Household income generation (financial + in kind - costs)[1]	$ per household	705	3,990

[1] Only income and in-kind consumption of milk for dairy farming. Does not include the income from meat and the arable part of the farm, which are roughly estimated for the baseline scenario at $440 (meat) and $875 (crops), and $660 (meat) and $875 (crops) for the improved scenario.

7.4 Policy options

We suggest two key policy options that will enable the studied livestock sectors to be more efficient:

- Improve farmers' access to various inputs including feed and veterinary care to increase productivity of the food supply chain by investing in physical infrastructures such as veterinary and analytical laboratories, and storage facilities, and by promoting the empowerment of farmers e.g. via the establishment of marketing cooperatives; and
- Training of livestock farmers through improved extension services that need public investment to expand in number and quality of staff, and in operational scope, to raise awareness of the importance of the utilization of improved inputs.

In fact, these suggested policy options are very much in line with current government strategies to stimulate investments in productivity enhancing inputs, including improved knowledge and extension on how to use the inputs more efficiently. As stated in its 2016 ASDP, the government acknowledges the importance of extension services as a major instrument to increase the sector's productivity as a crucial link between research and experimental stations, expanding the knowledge base on the one hand and the practical implementation at farmer level on the other hand. This report underlines the importance of the combination of improved knowledge and skills, with investments in storage, machinery, equipment and facilities such as laboratories for quality control and veterinary services, and establishing cooperatives to empower farmers' market positions. It is this combination of software, hardware and orgware that will enhance sustainable livestock production in Tanzania, while the vulnerable balance between economy and ecology is also taken into consideration. The results of this report show that with mainly improved farm management and some small additional investments improving the sector's business environment, efficiency and household income gains can be achieved without expanding herds and compromising natural and social capital.

It is therefore important to be aware of the possibility that with the suggested policy measures and investments, and the anticipated responses in the sector to these interventions, livestock farming (pastoral cattle, poultry and smallholder dairy) will be expanding, given the net results of this analysis in a way that social and/or environmental goals are negatively affected. Policy measurements need to be developed that slow down farmers' overenthusiastic expansion strategies. To keep the balance between sector development and the natural resource capacity in Tanzania, the impacts of environmentally sustainable intensification strategies need to be monitored and analysed continuously. Given the general scarcity of data on the economics of farming and performances in the supply chain, the lack of recent and reliable information on natural and social capital, a government programme aiming towards enhancing agricultural development should also include significant investments in collecting the relevant data for analysing policy and investment impacts on the agricultural sector and the ecosystem.

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Annex 1: Data tables for livestock scenarios

Table A1.1: Data showing baseline and improved case for Tanzanian beef in a Maasai pastoralist system

Data	Unit	Baseline	Improved scenario
Production and herd data			
Beef cows (adult female)	heads	111	119
Number of animals in the herd[1]	heads	300	300
Number of animals leaving the farm alive	heads	48	72
Adult female weight	kg live weight/head	320	Same as baseline
Adult male weight	kg live weight/head	416	Same as baseline
Birth weight	kg live weight/calf	25	Same as baseline
Death rate female calves	%	21	**15**
Death rate male calves	%	21	**15**
Death rate adult females	%	7	**5**
Age at first calving	year	4	**3**
Slaughter weight female	kg	200	Same as baseline
Slaughter weight male	kg	260	Same as baseline
Fertility rate[1]	%	75	**80**
Replacement rate female[2]	%	10	Same as baseline
Bull to cow ratio	ratio	0.1	Same as baseline
Labour	Hours/day	1.2	Same as baseline
Feeding[3]			
Fresh grass	% ration	90	95
Crop residues	% ration	10	2
Meal oilseeds*	% ration	-	2
Grain by-products*	% ration	-	1
Feed nutritive value		*Calculated*	
Gross energy	MJ/kg DM	17.51	17.47
Net DM yield	kg/ha	4773	4871
Digestibility	%	57.35	58.94
Nitrogen content	g/kg DM	14.64	16.38
Total land use	m^2/kg DM	2.17	2.11

[1]Herd consisting of adult females, replacement females, adult males, replacement males, beef females and beef males.

[2]Fertility rate: % probability a pregnancy will result in birth of a calf

[3]Replacement rate female: % adult females replaced due to diseases or fertility problems

[4]Source of feed is on-farm, those marked with * are off-farm

A1.2: Data showing baseline and improved case for Tanzanian backyard chicken

Data	Unit	Baseline	Improved scenario
Production and herd data			
Chickens (adult female)	heads	2.4	1.5
Number of animals in the herd[1]	heads	29	29
Number of animals leaving the farm alive	heads	27	27
Adult female weight / Adult female weight fattening	kg live weight/head	1.35 / 1.35	Same as baseline
Adult male weight / Adult male weight fattening	kg live weight/head	1.92 / 1.85	Same as baseline
Birth weight	kg live weight	0.025	Same as baseline
Hatchability[1]	%	80	Same as baseline
Death rate pullets	%	50	**30**
Death rate adult females	%	20	**10**
Egg productivity	number of eggs/year	50	**70**
Clutches	number/year	3	**4**
Eggs per clutch	number/clutch	13	Same as baseline
Age at first parturition	days	168	Same as baseline
Egg weight	kg/egg	0.041	Same as baseline
Age at slaughter laying hens/fattening females	days	926/250	Same as baseline
Lay time	year/adult life	3	Same as baseline
Rooster: Hen ratio	ratio	0.19	Same as baseline
Feeding[2]			
Swill	% ration	39	**33**
Pulses*	% ration	2	**3**
Cassava*	% ration	8	Same as baseline
Wheat	% ration	1	**2**
Maize	% ration	11	**13**
Millet	% ration	3	Same as baseline
Rice	% ration	3	Same as baseline
Sorghum	% ration	3	Same as baseline
Soybean meal*	% ration	2	**4**
Meal oilseeds*	% ration	11	Same as baseline
Meal cottonseed*	% ration	6	Same as baseline
Grain by-products*	% ration	11	Same as baseline
Feed nutritive value		*Calculated*	
Gross energy	MJ/kg DM	18.45	18.45
Net DM yield	kg/ha	715	828
Digestibility	MJ/kg DM	12.1	12.2
Nitrogen content	g/kg DM	32.97	33
Total land use	m^2/kg DM	2.21	2.37

[1]Herd consisting of reproduction hens, reproduction replacement hens, reproduction roosters, fattening young females, fattening adult females, fattening males.

[2]Hatchability: % probability chicks will be produced from eggs

A1.3: Data showing baseline and improved scenario for Tanzanian dairy

Data	Unit	Baseline	Improved scenario
Production and herd data			
Dairy cows	heads	5	Same as baseline
Number of animals in the herd[1]	heads	15	8
Number of animals leaving the farm alive	heads	2	3
Adult female weight	kg live weight/head	320	Same as baseline
Adult male weight	kg live weight/head	450	Same as baseline
Birth weight	kg live weight/calf	20	Same as baseline
Death rate female calves	%	20	**15**
Death rate male calves	%	20	**15**
Death rate adult females	%	7	**5**
Age at first calving	year	4	**3**
Slaughter weight female	kg	310	Same as baseline
Slaughter weight male	kg	430	Same as baseline
Fertility rate[2]	%	75	**80**
Replacement rate female[3]	%	10	Same as baseline
Bull to cow ratio	ratio	0.69	**0.1**
Labour (adult males)	hours/day/animal	1.2	Same as baseline
Milk yield	kg raw milk/cow/year	240	**2,400**
Milk fat content	%	4.4	Same as baseline
Milk protein content	%	3.5	Same as baseline
Feeding[4]			
Grazed grass	% ration	24	0
Fresh cut grass	% ration	0	48
Crop residues	% ration	70	46
Maize*	% ration	2	Same as baseline
Meal oilseeds*	% ration	3	Same as baseline
Grain by-products*	% ration	1	Same as baseline
Feed nutritive value		*Calculated*	
Gross energy	MJ/kg DM	18.41	18.01
Net DM yield	kg/ha	2,545	3,809
Digestibility	%	47.92	53.73
Nitrogen content	g/kg DM	8.98	12.92
Total land use	m^2/kg DM	4.01	2.89

[1]Herd consisting of adult females, replacement females, adult males, replacement males (excluding number of meat females and meat males)

[2]Fertility rate: % probability a pregnancy will result in birth of a calf

[3]Replacement rate female: % adult females replaced due to diseases or fertility problems

[4]Source of feed is on- and off-farm, those marked with * are off-farm

Annex 2: Results tables for livestock scenarios

Table A2.1: Price for reference pastoralist value chain

Sold by	Sold to	Unit	Price per animal	Location and transport
Pastoralist	Market trader	US$/animal	220	Monduli and Longido districts
Market trader	Butcher	US$/animal	259	To Meserani and Weruweru market
Butcher	Consumer	US$/animal	313	From slaughter area to butchery

Table A2.2: Price, costs and profit for reference pastoralist value chain

	Unit	Producer	Market Trader	Butcher	Consumer
Buy price	US$/animal	0	220	259	313
Costs	US$/animal	113	14	15	-
Sell price	US$/animal	220	259	313	-
Price mark-up	US$/animal	220	39	54	-
Income (after costs)	US$/animal	107	26	38	-

Table A2:3: Household overview for reference pastoralist value chain

	Unit	Baseline	Improved
Income from livestock per FTE (financial + in-kind)	US$/FTE	1,220	1,570
Financial income from livestock sales per FTE	US$/FTE	745	1,095
In-kind income from consumed livestock per FTE	US$/FTE	475	475
Pastoralist FTE value	FTE/household	5.6	5.6
Financial income from livestock sales per household (before costs)	US$/year	8,465	13,290
Financial income per household (after costs)	US$/year	4,180	6,125
In-kind income from livestock per household	US$/year	2,660	2,660
Total costs per household per year	US$/household	4,280	7,165
Cost of hired labour for herding per household	US$/household	3.20	3.20
Cost of dipping/spraying per head cattle	US$/animal	2.90	2.90
Cost of drugs/Medications per head cattle	US$/animal	6.20	6.20
Cost of deworming per head cattle	US$/animal	2.50	2.50
Cost of other variable costs per head cattle	US$/animal	2.60	2.60
Total cattle per household	animals	300	300
Total cattle animals offtake per year per household	animals	50	70
Cattle milk output per year per household	kg	1,125	1,125

Table A2:4: Price for reference poultry value chain

Sold by	Unit	Sold to	Price per animal	Location
Producer	US$/animal	Middle man	3.30	Farmgate (village)
Middleman	US$/animal	Market trader	4.20	Area outside of market
Market trader	US$/animal	Consumer	5.10	Regional centre market

Table A2:5: Price, costs and profit for reference poultry value chain

Price, costs and profit for reference poultry value chain					
	Unit	**Producer**	**Middleman**	**Market Trader**	**Consumer**
Buy price	US$/animal	-	3.33	4.16	5.09
Costs	US$/animal	0	unknown*	unknown*	-
Sell price	US$/animal	3.33	4.16	5.09	-
Price mark-up	US$/animal	3.33	0.84	0.93	-
Income (after costs)	US$/animal	3.33	unknown	unknown	-

*There are likely to have been costs, these are not quantified in this assessment. Examples of costs for the middleman and market trader (poultry), and the trader (smallholder dairy) are transport and labour costs.

Table A2.6: Household overview for reference poultry value chain

	Unit	**Baseline**	**Improved**
Financial income from sales per household (before costs)	US$/year	85	85
Income per household per year (financial + in-kind, before costs)	US$/year	140	140
Flock size per household	Chickens	30	30
Total hens consumed per year per household	Hens/year	10	10
Total cocks consumed per year per household	Cocks/year	2.10	2.10
Total chickens sold per year per household	Chickens/year	27	27
Eggs consumed per year per household	Eggs	50	70
Total Chicken consumption In-kind income per year per household	US$/year	45	45
Total chicken sales income per year per household	US$/year	85	85
Total Egg consumption In-kind income per year per household	US$/year	9.30	15

Table A2.7: Price for reference smallholder dairy system

Sold by	**Unit**	**Sold to**	**Price per kg milk**	**Location**
Producer	US$/kg	Trader	0.42	Farm gate
Trader	US$/kg	Consumer	0.54	Local village

Table A2.8: Price, costs and profit for reference smallholder dairy system

	Unit	**Producer**	**Trader**	**Consumer**
Buy price	US$/kg	-	0.42	0.54
Costs	US$/kg	0.07	unknown*	-
Sell price	US$/kg	0.42	0.54	-
Price mark-up	US$/kg	0.42	0.12	-
Income (after costs)	US$/kg	0.35	unknown	-

*There are likely to have been costs, these are not quantified in this assessment. Examples of costs for the middleman and market trader (poultry), and the trader (smallholder dairy) are transport and labour costs.

Table A2.9: Household overview for reference smallholder dairy system

	Unit	Baseline	Improved
Income from livestock (financial + in-kind - total costs)	US$	705	3,990
Financial Income per year (before costs)	US$	505	5,060
In-kind income per year	US$	290	290
Number of cows per household	# animals	5	5
Milk Output per household per year (kg)	kg	1,765	12,890
Milk Consumed per household per year (kg)	kg	530	530
Milk Sold per cow per year	kg	245	2,470
Milk Consumed per cow per year	kg	105	105
Costs - Feed/fodder per herd per year	US$	75	940
Costs - Water per herd per year	US$	1.90	145
Costs - Artificial Insemination per herd per year	US$	0	30
Costs - Other per herd per year	US$	10	240
Costs - Total herd production costs (excl. Labour)	US$	90	1,360
Total costs per cow	US$	20	270
% Milk offtake sold	%	70%	96%
% Milk offtake consumed	%	30%	4%
Cows and bulls sold for meat	# animals	2	3
Price per animal sold	US$	220	220

Table A2.10: Total greenhouse gas emissions of Tanzanian beef case (kg CO_2eq/animal/year unless specified)

	Adult female	Replacement female	Adult male	Replacement male	Beef male	Beef female
Methane, CH_4						
Baseline	1,541	1,188	2172	1,448	785	991
Improved case	1,488	1,224	2056	1,447	808	1,000
Nitrous oxide, N_2O						
Baseline	306	218	440	259	133	163
Improved case	336	252	472	287	151	180
Feed emissions, CO_2						
Total land use (m^2/animal/year) – baseline	4,418	3,406	6229	4,152	2,252	2,842
Total land use (m^2/animal/year) – improved case	4,216	3,467	5826	4,099	2,290	2,833
Total emissions from feed intake – baseline	1,157	892	1631	1087	590	744
Total emissions from feed intake – improved case	1,088	894	1503	1,057	591	731
FEED INTAKE (kg DM/animal/day)						
Baseline	5.59	4.31	7.88	5.25	2.85	3.59
Improved case	5.47	4.50	7.56	5.32	2.97	3.68
Number of animals						
Baseline	111.0	53.4	11.1	13.0	42.3	69.1
Improved case	119.0	39.8	11.9	12.9	49.2	67.0
Emissions intensity (kgCO_2eq/kg product)						
Meat						
Baseline	60.4					
Improved case	40.4					

Table A2.11: Total greenhouse gas emissions of Tanzanian backyard chicken case (kg CO_2eq/animal/year unless specified)

	Reproduction hens	Reproduction replacement hens	Reproduction roosters	Reproduction replacement roosters	Fattening young female	Fattening adult female	Fattening males
Methane, CH_4							
Baseline	0.7	0.4	0.8	0.6	1.6	3.4	0.6
Improved case	0.7	0.4	0.8	0.6	1.6	3.4	0.6
Nitrous oxide, N_2O							
Baseline	5.0	2.9	6.3	3.9	2.9	4.0	3.8
Improved case	5.0	2.9	6.3	3.9	2.9	4.0	3.8
Feed emissions, CO_2							
Total land use (m^2/animal/year) – baseline	69.3	44.4	84.1	59.5	44.4	56.2	58.4
Total land use (m^2/animal/year) – improved case	75.9	47.4	89.7	63.4	47.4	59.9	62.3
Total emissions from feed intake – baseline	15.5	9.9	18.8	13.3	9.9	12.5	13.0
Total emissions from feed intake – improved case	16.1	10.0	19.0	13.4	10.0	12.7	13.2
FEED INTAKE (kg DM/animal/day)							
Baseline	0.086	0.055	0.104	0.074	0.055	0.070	0.072
Improved case	0.088	0.055	0.104	0.073	0.055	0.069	0.072
Number of animals							
A2.11 Continued							
	Reproduction hens	Reproduction	Reproduction roosters	Reproduction	Fattening young female	Fattening adult female	Fattening males

		replacement hens		replacement roosters			
Baseline	2.40	0.55	0.46	0.10	9.78	3.10	12.49
Improved case	1.50	0.28	0.29	0.05	10.70	4.19	12.09
Emissions intensity							
Egg ($kgCO_2eq$/kg egg)							
Baseline	8.1						
Improved case	7.2						
Meat ($kgCO_2eq$/kg carcass weight)							
Baseline	12.2						
Improved case	11						

Table A2.12: Total greenhouse gas emissions of Tanzanian dairy case (kg CO_2eq/animal/year unless specified)

	Adult female	Replacement female	Adult male	Replacement male	Beef male	Beef female
Methane, CH_4						
Baseline	2,041	1,869	3,368	2,377	1,567	2,012
Improved	2,279	1,516	2,632	1,896	1,340	1,721
Nitrous oxide, N_2O						
Baseline	207	184	371	225	150	184
Improved	243	227	445	271	196	241
Feed emissions, CO_2						
Total land use (m^2/animal/year) – baseline	9,624	8,810	15,877	11,207	7,385	9,485
Total land use (m^2/animal/year) – improved	8,256	5,494	9,535	6,870	4,854	6,235
Total emissions from feed intake – baseline	1,621	1,484	2,675	1,888	1,244	1,598
Total emissions from feed intake – improved	1,867	1,242	2,156	1,553	1,097	1,410
FEED INTAKE (kg DM/animal/day)						
Baseline	6.58	6.02	10.85	7.66	5.05	6.48
Improved	7.83	5.21	9.04	6.51	4.60	5.91
Number of animals						
Baseline	5.0	2.4	3.5	4.0	3.0	1.5
Improved case	5.0	1.7	0.5	0.5	3.3	4.4
Emissions intensity (kgCO_2eq/kg product)						
Milk						
Baseline	24					
Improved case	3					
Meat						
Baseline	78					
Improved case	22					

Annex 3: Ecosystem services of pastoralism methodology

This annex describes the methodology used to quantify the ecosystem services of pastoralism. The methodology builds upon and expands the natural capital valuation model of the Maasai steppe used in Baltussen et al (2017, from here referred to as: the previous study) and presented in detail in True Price (2016).

The assessment looks at pastoralism as an economic activity related livestock keeping in rangelands. It produces food but it also contributes to the functioning of the natural ecosystem where it occurs. The fact that rangelands provide ecosystem services (ES), which would be lost if pastoralism would not contribute to landscape management, is the positive externality of pastoralism that this study aims to assess.

Goal and scope

The goal of the assessment is to quantify the ES-related benefits of pastoralist food production in the Maasai steppe per unit of food produced.

The assessment starts from results at a landscape-level perspective of ES, in the previous study (Baltussen et al. 2017) and uses them to make an assessment at the product-level. The unit of the previous study was the whole region of the Maasai steppe, with farms, pastoralist rangeland and national parks. The unit of the assessment here is one dollar of food produced in the region by pastoralism. The baseline for the assessment is one dollar of food produced in the same region through sedentary farming, which includes livestock and crop farming and is the most realistic alternative[23].

The assessment focuses on three separate ES.

1. Contribution to tourism
2. Land degradation prevention
3. Carbon storage

Other ES can be identified in the region and were quantified in the previous study, but they are not included here. They include the supply by pastoralist rangeland of construction material, firewood, animal skins and hides, honey and gum, medicinal herbs, wild foods and drinking water. These were excluded here because they are not directly related to pastoralism as a livestock keeping activity or because their size was found to be relatively small.

Input data: the Maasai steppe natural capital valuation model

The assessment builds upon the natural capital valuation model of the Maasai steppe used in Baltussen et al. (2017). This model is made of several components including a land cover change model, an ES value transfer model, an attribution model and future scenarios. It is explained in detail in True Price (2016).

[23] Results per dollar are ultimately converted to results per kg of meat using local meat prices of TZS 6,000, or 2.93 $/kg meat (Meshack, 2015).

In the study, the natural capital stock value of land in the region was quantified as the net present value of final ecosystem services.

$$\textbf{\textit{Natural capital stock value}} = \sum_{t=0}^{n} \frac{Annual\ flow\ of\ ecosystem\ services_t}{(1-discount\ rate)^t}$$

This was done for various types of land use (grassland used by pastoralists and wildlife, farmland used by smallholders and national parks) and aggregated using land cover change scenarios developed based on a literature review. The results showed that if the existing trend of shifting from pastoralism to sedentary farming can be slowed down, this will conserve up to 1.3 billion $ of natural capital stock, since farming in the region leads to land degradation.
The model introduced some innovations:

1) **Exclusive focus on final ES**, as opposed to intermediate ones.

This choice helps to avoid double counting and reduces uncertainty. It avoids double counting because intermediate ES usually underlie the provision of final ES, creating problems in the computation of total value of an ecosystem. It reduces uncertainty, as it allows to use replacement cost or market prices, which traditionally have a lower uncertainty range than other valuation methods, such as contingent valuation.

2) **Attribution of ecosystem value between land and human inputs**.

This choice allows to compare ES that are provided fully by natural capital (such as wild food) with those that require human and produced capital as well (such as crops). The value of the annual flow of ES was defined as the share of total ecosystems-based revenues (there called *ecosystem benefits*) that can be attributed to land (encompassing local soils, climate, ecosystems and biodiversity), rather than human inputs (including labour, agricultural inputs, infrastructure, etc.).

*Annual flow of ecosystem services = Annual revenues from ecosystems * Attribution to land*

Revenues from ecosystems are defined as the total annual value of final goods and services that people derive from the ecosystems at market prices or replacement costs, even if this requires labour, (agricultural) inputs or produced capital.
Attribution to land is calculated as the ratio between the land rent and the sum of all inputs, including the land rent, labour and any other cost incurred by people to derive those benefits. When, like for rangeland, no land market or labour market exists, a shadow value of rent and labour is used, representing the rent value of comparable land or labour for local stakeholders.

Attribution to land = Land rent / (Land rent + Value of labour + Other costs)

In the table below the input data from the previous model that was used for the assessment in this study are presented.

Table A.3.1: Results of the 2016 Maasai case study

Input data	Unit	Rangeland (excl. National Parks)	National Parks	Farmland
Ecosystem revenues per ha (before attribution)	$/ha/yr	10.25	38.24	144.96
Attribution to land	%	95%	72%	27%
ES value per ha (after attribution)	$/ha/yr	9.73	27.37	38.59
Natural capital stock value per ha -Middle of the way scenario	$/ha	482	1,645	515
Natural capital stock value per ha - High farming scenario	$/ha	390	1,167	422
Natural capital stock value per ha - High pastoralism scenario	$/ha	508	2,170	561

Ecosystem services considered in the assessment include livestock production for rangelands, tourism for national parks and livestock and crops for farmland. Natural capital stock values per hectare represent the average present value for 20 years at a 2.5% discount rate, based on three scenarios developed in the previous study (True Price 2016). The three scenarios represent different rates of land use change from rangeland to farming and also take into account how these are expected to affect the annual value of ES per hectare. This study used the middle of the way scenario. Note that monetary values in the previous case study included an adjustment for Purchase Power Parity, since they were compared to results for other countries, while here the adjustment is removed. This reduces monetary values of about 50%, based on the ratio between US$ and International $ for Tanzania.

The rest of this annex introduces the additional modelling done for this study.

Approach

The assessment focuses on three ES, contribution to tourism, land degradation prevention and carbon storage. These are quantified for one unit of food produced by pastoralist livestock systems in the Maasai steppe, relative to food production by farming in the same region.
Contribution to tourism is considered a side-flow of economic benefits. The remaining two, carbon storage and land degradation prevention, are considered prevented losses of natural capital stock.

1. **Contribution to tourism**

The tourism value of national parks in the region comes from investment in tourism infrastructure and labour, but also from the existence of wildlife corridors and wet season grazing areas that are outside national parks and under pastoralist management. These grazing areas are frequented by pastoralists as well as wildlife and as such increase the habitat of elephants, wildebeests, giraffes and other animals.

To quantify contribution to tourism value we attribute to pastoralism part of the annual flow of tourism-related ES of national parks.

The flow of tourism ES of national parks in the region was defined in (True Price 2016) as the share of the total tourism revenue that is attributed to land, as opposed to labour and other human inputs. The annual flow of tourism ES of national parks was estimated to be 8.7 M$/yr, out of a total revenue of 12.1 M$/yr.

*Annual flow of tourism ecosystem services of national park = Annual tourism revenue of national parks * Attribution to land of national parks*

That assessment looked at national parks in isolation from pastoralist rangeland. However, it is also possible to look at the two together, as from an ecological point of view they are one whole. Animals spend part of the year in the parks and part in pastoralist rangeland, which is maintained by pastoralism.

Following this perspective, the annual flow of tourism ES of national parks is further attributed between national parks and pastoralism.

*Total pastoralism contribution to tourism value = Annual flow of tourism ecosystem services / total rangeland and national park inputs * pastoralist inputs*

With this step, 19% of the annual tourism value, or 1.6 M$/year is attributed to pastoralism. This is then divided by the total pastoralist food production of the region, 14M$/year, resulting in a contribution of pastoralism to tourism value per unit of food produced of 0.12 $ of tourism revenue/$ of food produced.

2. **Land degradation prevention**

Areas converted to agricultural land in the Maasai steppe degrade over time in productivity terms. In fact, grassland converted to farmland in this region has been shown to become abandoned after only 20 years of farming, by which time it has become unfit for agricultural purposes (Msoffe, 2010). The value of land degradation prevention is a positive externality of pastoralism.

To quantify land degradation prevention, food production by pastoralist livestock is compared to food production under a settled farming system in the same region. To determine the value of preventing land degradation of pastoralist grassland management, we estimate avoided depreciation of the natural capital stock value of land over total food production.

The loss of natural capital stock value per unit of food produced under a settled farming system in a period of 20 years is calculated. Pastoralist food production is considered to be roughly sustainable over time, since it is a traditional livestock keeping method that has been used in the region for generations. This is translated in no natural capital stock loss for pastoralist livestock systems. The avoidance of the loss of natural capital stock from farming is therefore seen as a positive externality of pastoralist food production, since if in the region pastoralist food systems would disappear, their place would be taken by settled farming food systems. Because a product perspective is taken, rather than a landscape perspective, the comparison is between one unit of food produced in the region with either of the two systems, rather than between the whole region under pastoralism management with the same area under sedentary farming. In fact, only 35% of the grasslands in the region could be converted to farmland (FAO 2009).

The total natural capital stock loss due to farming-caused land degradation is calculated as the difference between initial and final natural capital (NC) value, where initial is the value of a recently converted plot (515 $/ha) and final is the value of degraded land. This is assumed to be 0, as degraded land has been said to have no value for grazing, no value for other grassland products and also no value as a wildlife corridor, as this is likely to be encroached by other farms.

Land depreciation farmland ($ / $ output) = [NC value 1 ha farmland ($/ha) – NC value 1 ha degraded land ($/ha)] / Total output in period before degradation ($ output/ha)

Considering an annual food output of 145 $/ha/yr, the resulting depreciation value per unit of food produced is 0.18 $ natural capital lost/$ food produced. Since we compare meat from pastoralist livestock systems with meat from sedentary farming, this is equal to positive externalities of pastoralist meat production in terms of landscape management, measured in $ avoided land degradation/$ of food produced.

3. Carbon stocks

Potential carbon losses when fertile areas in the Maasai steppe are converted to sedentary farming are very large. As discussed in Baltussen et al. (2017) carbon is removed from agricultural land through crops and crop residues. Additionally, ploughing the land increases soil micro-organisms respiration and decreases soil carbon stocks. By managing grasslands to graze their livestock and by preventing land to be converted to agriculture, the pastoralist system allows for maintenance of carbon stocks.

The value of pastoralist landscape management for carbon stock maintenance is quantified following a similar approach to land degradation prevention. The main difference is that instead of the NC value of land we take the carbon storage value of land, quantified as carbon stocks multiplied by the social cost of carbon.

*Carbon storage value of soil = C stock (tC/ha) * Social cost of carbon ($/tC)*

Carbon storage value is compared for the two situations (rangeland just converted to farmland and degraded land) and the difference is divided by the total food output in the 20 years from conversion to farmland and abandonment of the land (see land degradation prevention section).

Total soil carbon depreciation of farming($/ha) = (initial - final C storage value) / total output in period before degradation

Upper, medium and lower values are provided for carbon stocks in soil, since these are subject to high uncertainty. In Baltussen et al. (2017), carbon storage was found to be the largest ecosystem service of the Maasai steppe, which led to the choice to expand the literature review in this study. The high estimate are of 87.7 t/ha for non-degraded grassland and 30.5 t/ha for degraded grassland, taken from the same sources used in Baltussen et al. (2017), a study specified for an area in South Africa with similar characteristics to the Maasai steppe (Petz et al., 2014). The medium estimate combines two studies done in Tanzania that found carbon contents of the top 30 cm of soil of 48 t/ha for grassland (Kempen et al., 2018) and 18.4 t/ha for degraded land (Osei, 2015, estimated as the sum of carbon stocks of the first 20 cm plus half of the 20-40cm layer). The lower bound estimate of 33 t/ha for grassland and 18 t/ha for farmland is based on a study of grassland carbon stocks conducted in Kenya (FAO, 2004). The results are shown in the table below.

Table A.3.2: Carbon stocks

		High range	**Mid-range**	**Low range**
C stock loss	t/ha	57.2	29.6	15.0
C stock value loss	$/ha	7,648	3,957	2,006
C stock loss (depreciation) farmland food	$/$ output	2.64	1.36	0.69