Animal Production Systems

Msc Thesis

Carbon footprint (LCA) of milk production considering multifunctionality in dairy systems:

A study on smallholder dairy production in Kaptumo, Kenya

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Abstract

Life Cycle Assessment (LCA) is an acknowledged environmental impact assessment tool to calculate greenhouse gas (GHG) emissions of dairy production. There is a variety in dairy production systems which are characterized by multifunctionality, i.e. cattle provide several products and services besides the production of milk and meat. The present study investigated options to account for multifunctionality within the LCA method. A methodological pathway to account for multiple products and services was developed. Such are included in the functional unit, using two allocation techniques, i.e. economic allocation and an allocation based on farmers` motivations. To investigate constraints and opportunities of the LCA methodology, field research was done in Kaptumo, Kenya from September 2012 to January 2013. Functions of dairy cattle and motivations behind cattle keeping were studied together with characteristics of cattle management. In the 20 dairy farms under this study the functions milk, meat, manure used as fertilizer, cattle as insurance, cattle as a mean of financing and strong socio-cultural values associated with cattle such as cultural identity, social status and cultural practices as dowry were identified. Total GHG emissions resulted in a mean of 6.795 kg CO_2-equivalents (1.243-21.842) per farm and year. Carbon Footprints (CF) of milk production were on average 2.1, 1.7 and 1.1 kg CO_2-equivalents per kg of milk applying no allocation, economic allocation to functions (milk, meat, manure as fertiliser, insurance and financing) and allocation based on farmers` motivations, respectively. Within the LCA methodology it is possible to account for multifunctionality, but there are limitations due to the abstract and intangible socio-cultural characteristic of some of the cattle functions. Within LCA research, ignorance regarding systems as the discussed smallholder, mixed systems often leads to a distorted view on results, as the common methodological frame of LCA and common mitigation options do not fit the reality of those systems. For future LCA research on dairy systems characterised by multifunctionality it is recommended to pay more attention to the multifunctional aspects of a production system, because CF results and consequently conclusions change depending on the functions included in LCA. When aiming at mitigation options that have a chance of adoption, GHG emissions alone are not an argument for intervention, but mitigation strategies must be discussed within the development context and in face of economic opportunities and constraints of farmers.

Content

List of abbreviations

ABS:	African Breeders Services
ALCA:	Attributional Life Cycle Analysis
APS:	Animal Production System
ASF:	Animal Sourced Food
CF:	Carbon Footprint
CH_4:	Methane
CLCA:	Consequential Life Cycle Analysis
CO_2:	Carbon Dioxide
DAP:	Diammonium Phosphate
DM:	Dry Matter
EADD:	East Africa Dairy Development Project
ECM:	Energy Corrected Milk
FAO:	Food and Agriculture Organization of the United Nations
FPCM:	Fat and Protein Corrected Milk
FU:	Functional Unit
GHG:	Greenhouse Gas
GIZ:	German Agency for International Cooperation
ICRAF:	World Agroforestry Centre
IFAD:	International Fund for Agricultural Development
IGAD:	Intergovernmental Authority on Development
ILRI:	International Livestock Research Institute
ISO:	International Organization for Standardization
KNBS:	Kenya National Bureau of Statistics
LCA:	Life Cycle Assessment
MICCA:	Mitigation of Climate Change in Agriculture Programme
N_2O:	Nitrous Oxide

Units

Acre:	Acre (1 acre = 0,4 ha)
ksh:	Kenyan Shilling (Value December 2012: 1 € = ksh 113,4)

1. Introduction

A number of studies have been conducted in the past years on the carbon footprint of milk production in various locations and with different scopes, using Life Cycle Assessment (LCA). The vast majority of those studies investigated systems under European and North American conditions (e.g. Casey & Holden, 2005, Capper et al., 2009, Thomassen et al., 2008b). The global study "Greenhouse gas emissions from the dairy sector" (FAO, 2010) researched dairy systems worldwide and revealed that extensive systems with rather low milk yields show higher greenhouse gas emissions per kg of product and therefore a higher carbon footprint than more intensive systems with higher milk yields.

Dairy cattle are kept for multiple reasons. In dairy oriented production systems (i.e. in the western world) the production of milk is the most important one. But in many cases also other reasons occur. Functions of cattle can be a buffer role in case of emergencies as a source of food or income when cash is needed, a symbol of social status and as insurance (i.e. in developing countries). Furthermore, cattle manure can be of high value for usage in arable agriculture and as combustible and cattle can be a source of energy as draught animals or a means of transport. For some people keeping cattle is an important part of culture and life.

In the analysis and comparison of different dairy systems, the carbon footprint is usually calculated per kg of product. As the reasons for keeping cattle and the outputs of dairy systems vary in different cultural and climatic settings, a comparison solely on the base of kg of product does not reflect the complexity of the dairy production appropriately. The results of mono-dimensional analyses tend to lead to conclusions that miss relevant parts of understanding. As the vast majority of studies on greenhouse gas emissions from dairy production analyzed systems in European and American conditions, little is known about the impacts of smallholder dairy systems in the tropics. Furthermore, cattle as livestock in general play a crucial role especially for poor people. Livestock is a mean to secure livelihoods and an important part of life for many people in developing countries. They are a source of food and income and a mean of security in difficult times. Some studies have acknowledged this importance and looked at the reasons why farmers keep cattle. However, the role of livestock as a livelihood tool has not been considered in environmental impact assessments of livestock production systems. This background on LCA studies of milk production combined with the fact that cattle play multiple roles in complex farming systems led to the idea of this Master thesis research. It aims at developing a path to account for multiple functions of dairy cattle and to study the impact on the carbon footprint of the system. The thesis also explores options and limitations of LCA in dairy systems characterized by multifunctionality and aims at contributing to the discussion of Carbon Footprinting of milk production considering socio-cultural aspects. The developed methodology is elaborated and implemented in a case study of smallholder Kenyan milk production in Kaptumo, Rift Valley. In Kenya, dairying is an integrated part of many smallholder mixed farming systems. Besides the fact that milk production levels increased in the past, still other functions also play a role for many farming households, such as insurance and financing values of cattle (Bebe et al., 2002; Moll et al., 2007) which makes Kenya an interesting location for the case study.

2. Research objectives and questions

The objective of this thesis is to research the use of the LCA methodology on dairy production systems that are characterized by multifunctionality. There are three sub-questions:

1. How can multiple functions be accounted for in LCA?

2. How is smallholder dairy production characterized in the case of Kaptumo, Kenya?

3. What is the carbon footprint of milk production in the study location with and without considering multiple functions?

Answering these questions facilitate the discussion of the overall question "Can we compare carbon footprints of dairy production systems with different degrees of specialization?"

3. Background (Literature review)

3.1 Carbon footprint of milk production

In recent years the livestock sector received increasingly attention regarding its environmental impacts. The publication "Livestock`s Long Shadow" (Steinfeld et al., 2006) pointed out that livestock is a user of natural resources and source for environmental pollution. Especially the figure of 18% as the share of livestock`s contribution to total global anthropogenic greenhouse gas emissions received a lot of attention in times of climate change being a prominent topic.

3.1.1 LCA studies on dairy production

In part as a result of "Livestock´s Long Shadow", a number of LCA studies have been conducted in the past years on the environmental impacts of milk production, differing in scope, location and system. Some studies researched environmental impacts of average milk production systems in a specific country (e.g. Casey & Holden, 2005 (Ireland), Vergé et al., 2007 (Canada)) or compared production in different times in history (Capper et al., 2009 (USA, 1944-2007)). Other studies assessed environmental impacts of dairy production in specific regions (e.g. Cederberg & Flysjö, 2004 (south western Sweden), Hospido et al., 2003 (Galicia, Spain) or for a specific production system (Høgaas Eide, 2002 (industrialized milk production)). Other focus areas of some studies lie in the comparison of different dairy farming systems, e.g. grass-based versus confined (Arsenault et al., 2009 (Nova Scotia, Canada), O`Brien et al., 2012 (Ireland)) or comparing organic with conventional production systems (e.g. de Boer, 2003 (Netherlands), Cederberg & Mattson, 2000 (Sweden), Grönroos et al., 2006 (Finland, only energy use), Haas et al., 2001 (Germany), Thomassen et al., 2008b (Netherlands)). Of all those studies, mostly full LCA were performed, which means assessing the impact categories eutrophication, acidification, land use, energy use and global warming potential.

In general, studies often differ regarding their focus area (farm, regional, national, global), their systems under considerations (average dairy systems, conventional versus organic, grass-based versus confined), their scope (different system borders), differences in the functional unit (FU) and the way co-products are handled. Direct comparisons of different LCA studies are difficult due to such differences in scope, methodological choices and assumptions. That was also remarked by Yan et al. (2011) who reviewed 13 LCA studies of European milk production.

There are almost no studies available on the environmental performance of dairy systems in developing countries, especially of smallholder dairying. Bartl et al. (2011) even state in their article that no LCA on tropical regions had been made. They compared typical Peruvian dairy systems in the Andean highlands and coast. A high land occupation and high methane emissions/kg ECM were found in the highland system whereas emissions per ha or per animal were smaller. According to the authors subsistence systems cannot be described in a suitable way with the common allocation methods and they suggest accounting for also non-monetary values in systems, e.g. cattle as saving.

In a study on environmental impacts of up-scaling smallholder dairying, Modupeore (2011) compared smallholder dairy systems (free-grazing, semi-grazing, zero-grazing) with relatively large scale and large scale dairy farms. The FU was kg FPCM and per animal with allocating impacts to milk only and to milk and other benefits, using economic allocation. The results per animal indicate a small contribution of keeping cattle on smallholder farms.

Carbon footprints of dairy production systems globally

Research on environmental impacts of milk production on a global scale shows different results of systems depending on productivity level and management. In the global study on dairy systems (FAO, 2010) average global emissions from milk production, processing and transport were estimated as 2.4 CO_2-equivalents per kg of FPCM at farm gate (±26 percent). The average regional emissions per kg of FPCM at farm gate ranged from 1.3 to 7.5 kg CO_2-equivalents per kg of FPCM (±26 percent) with developing regions as e.g. Sub Saharan Africa on the high end and industrialized regions as Europe on the low end of the range. Emissions from cradle-to-farm gate contributed between 78-83% to total emissions in industrialized countries and 90-99% in developing regions.

3.1.2 Higher milk yields = Smaller Carbon Footprint?

Following the report by FAO (2010), Gerber et al. (2011) studied the relationship between productivity of dairy production and greenhouse gas emissions. With increasing yields greenhouse gas emissions on a cow basis increased but decreased per kg of output (FPCM) with a significant relationship between productivity and greenhouse gas emissions per kg of milk. As illustrated in figure 1, the main reductions in GHG emissions per kg of FPCM take place until increases to about 2.000 kg per cow and year and then the reduction slows down, stabilizing at about 6.000 kg FPCM per cow and year.

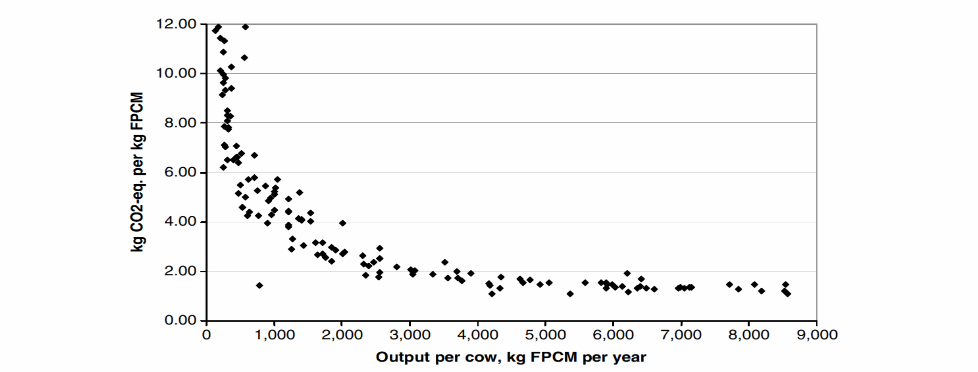


Figure 1 Relationship of total greenhouse gas emissions and output per cow (Gerber et al., 2011)

Weidema et al (2008) analyzed environmental improvement potentials of milk and meat products for the EU-27. They modeled with data from different cattle production systems in Europe an increased milk yield from 5.900 kg to 8.500 kg/cow and per year and its` effects. Methane emissions from dairy farms were reduced by 24%. A the same time feed requirements are increased and beef output from the dairy decreased (30% less due to less calves born and less slaughtered cows), implying more emissions from feed production and more meat out of pure beef systems to have the same beef output. Considering those changes, methane emissions changed only by 4%, plus more CO_2 emissions which in the end make overall changes negligible. Due to that plus negative effects which outweighed the positive ones (e.g. energy requirements in feed production and welfare implications regarding dairy cows and veterinary costs), the authors did not consider further the option of intensification of dairying.

Analyzing milk and meat production in Sweden for the years 1990 and 2005 in which milk yields increased from 6.100 to 8.200 kg per cow and year. Cederberg et al. (2009) found clear positive effects of intensification in dairy production and reducing the overall GWP from the whole cattle sector even though a significant increase in milk yields, a reduction of dairy cow herds by more than 30% and an increase by more than double of the suckler cow herds. Possible explanations for this different outcome compared to the results of Weidema et al. (2008) are the development of roughage production with lower mineral fertilizer inputs in grass production with an increase of roughages and pastures with very limited to no fertilizer inputs in beef production over the time period under study (effects of governmental subsidies and increased demand for organic products).

3.2. LCA methodology

Life Cycle Assessment historically developed out of the waste debate and energy crisis in the early 1970s with the first LCA being a study of Coca Cola in the late 1960s. LCA as known under this term and with its first standards named by the International Organization for Standardization goes back to 1997 (ISO 14040). Today it is an acknowledged tool which is not only used in industry, but also in other fields as agriculture. (Baumann and Tillman, 2004) Thomassen and de Boer (2005) found LCA a useful tool to assess global warming potential of dairy production systems.

3.2.1 Guidelines and structure of LCA

LCA can be used to assess the environmental impacts of a product under consideration of the related production processes and the impacts of those various processes connected to the product along the whole production chain. Relevant guidelines by the International Standard Organization (ISO) are

- ✓ ISO 14040:2006 – Environmental management – LCA principles and framework
- ✓ ISO 14044:2006 – Environmental management – LCA requirements and guidelines.

LCA is an environmental impact assessment tool, a "compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle" (ISO 14044:2006, 3.2). The life cycle perspective allows for a comprehensive way of assessing, i.e. the possibility of taking the whole production chain into account. LCA has a product-focus, which means that a certain product is in the heart of such an analysis.

LCA as a tool "can assist in the identification of opportunities for improving the environmental performance of products, in informing decision-makers, selection of environmental performance indicators and marketing" (ISO 14044:2006, Introduction). LCA is one tool among several available methods which results can be used "as a part of a much more comprehensive decision process". "It does not address the economic or social aspects of a product but the life cycle approach and method may be applied to these other aspects" (ISO 14044:2006, Introduction).

The issue of products is a central one in this study on considering multifunctionality why multiple functions are here understood as multiple products of a production system. In the LCA guidelines, product is defined as "any goods or services" with the additional note of "a product can be categorized as follows: services, software, hardware, processed materials. Services have tangible and intangible elements. Provision of a service can involve, for example, the following: an activity by a costumer-supplied tangible product, an activity performed on a customer-supplied intangible product, the delivery of an intangible product, the creation of ambience for the customer" (ISO 14044:2006, 3.9). Co-product is defined as "any of two or more products coming from the same unit process or product system" (ISO 14044:2006, 3.10).

Other aspects in LCA which are of special interest in this thesis are the issues of functional unit (FU), allocation and system boundary. The FU is defined as the "quantified performance of a product system for use as a reference unit" and shall be clearly defined and measurable. Comparisons between systems shall be made on the basis of the same function(s), quantified by the same FU in the form of their reference flows. If additional functions of any of the systems are not taken into account in the comparison of FUs, then these omissions shall be explained and documented. As an alternative, systems associated with the delivery of this function may be added to the boundary of the other system to make the systems more comparable" (ISO 14044:2006, 3.20 and 4.2.3.2). Allocation is "partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO 14044:2006, 3.17). The system boundary of the LCA is defined as "set of criteria specifying which unit processes are part of a product system. It determines which unit processes shall be included within the LCA. The deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study. Any decisions to omit life cycle stages, processes, inputs or outputs shall be clearly stated, and the reasons and implications for their omission shall be explained" (ISO 14044:2006, 3.32 and 4.2.3.3.1).

LCA is organized in four steps as illustrated in figure 2, the goal and scope definition, inventory analysis, impact assessment and interpretation. Here, a general description is given, as the methodology, as it is applied in this thesis research, is explained in chapter 4.

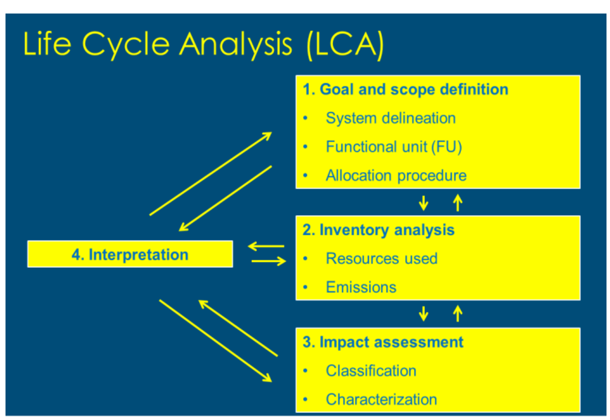


Figure 2 The four steps in LCA

3.2.1.1 Step 1: Goal and scope definition

The first step of the LCA defines the frame of the whole analysis. The system borders are drawn, which set the frame of what is included in the analysis and what is excluded. The functional unit (FU) is defined, which expresses resource use and environmental impacts. The impact categories as well as the method of handling multiple products are defined. In step 1 the allocation technique is explained. In production systems that have more than one output, environmental impacts need to be distributed to those (see earlier in chapter 3.2.1 and chapter 3.2.2).

3.2.1.2 Step 2: Inventory analysis

Step 2 of the LCA implies a data inventory of all input data needed for the analysis as LCA is a data demanding tool. Furthermore, all resources that are used in the production process as well as all emissions are quantified. On-farm and off-farm emissions are separated.

3.2.1.3 Step 3: Impact assessment

Total resource use and emissions are calculated and expressed in a pre-defined unit. In case of the computation of greenhouse gas emissions, such unit can be kg CO_2-equivalents per kg of milk.

3.2.1.4 Step 4: Interpretation

During the last step of the LCA the results of the impact assessment for the different environmental indicators are interpreted and hot spots of emissions are identified. CF results and mitigation options are discussed.

3.2.2 The issue of co-product handling in LCA

The guidelines of LCA provide rules on how to handle co-products, but which method is applicable in which case still misses a common understanding (Flysjö et al., 2011). According the ISO guidelines allocation should be avoided as by dividing the process into sub-processes or by expanding the system (step 1). If that is not possible, then allocation should be based on physical relationships (step 2). If this also is not possible, then one can allocate according to relationships other than the physical (step 3; ISO 14044:2006, 4.3.4).

Cederberg and Stadig (2003) compared different methods to deal with co-products in LCA. Co-products were milk, meat and surplus calves. Different allocation techniques (no allocation, economic allocation and cause-effect allocation regarding feed intake) as well as system expansion as an alternative to allocation was performed and compared, looking at milk and beef production. System expansion as consideration of alternative ways of production meant in this case that the surplus calves and the meat of culled dairy cows came from the beef production system. The LCA results were strongly influenced by the choice of method of dealing with co-products. Changes in the dairy imply changes in the beef system and the authors conclude that when studying production systems that are interlinked to each other like in this case, system expansion should be done to get an understanding on the environmental consequences of changes, here in the dairy. LCA results are highly impacted by the choice of the allocation method and that mono-functional allocation does not provide sufficient information on the question of how to change milk and beef production to decrease the effects on the environment. Both systems need to be studied in an integrated manner together and system expansion is the method of choice when assessing environmental consequences when future milk production systems are changed.

There are two main approaches to LCA – attributional and consequential. Attributional LCA (ALCA) is on resource flows and environmental impacts of a specific system producing a FU (e.g. under a status-quo situation). Consequential LCA (CLCA) is on resource use and pollution within a system and including changes in the system and in the demand and output of the FU. It enables to assess consequences of a changed FU and can be used to take into account this change. Thomassen et al. (2008a) summarize the main characteristic of ALCA and CLCA.

Flysjö et al. (2011) studied how co-product handling affects the carbon footprint (CF) of milk, looking at the case of milk production in Sweden (mainly indoor) and New Zealand (outdoor pasture grazing). They researched the importance of accounting for by-products and differences in results related to the method using six scenarios (two scenarios for system expansion, physical/causality allocation, economic allocation, protein allocation and mass allocation). The CF results were very different depending on the chosen method. Allocation resulted in significantly higher CF results than system expansion. Between allocation choices, results differed more than 10% as allocation factors ranged 85-98%. Between the two assumptions in system expansion of replacing meat with beef or with beef and pork, in the first case the CF of milk is lower due to the higher emissions of beef compared to pork production. The authors see LCA and CF as a good environmental impact assessment tool but raise awareness on the consequences of methodological choices on results of such studies. They also raise the issue of the interconnectedness of milk and meat production and the fact that intensification in terms of higher milk yields per cow also result in less meat per kg of milk. The importance of a system analysis approach including all animal sectors and integrated study of the interlinked systems is pointed out when researching ways to fulfill an increasing demand of animal protein.

3.3 Dairy cattle and livelihoods

Livestock`s role as a livelihood tool and as a provider of multiple functions especially for poor smallholder farmers has been underlined in a number of studies. Part of the literature talks about livestock and others about cattle specifically why in this chapter both terminologies are being used. Benefits due to livestock are generally described as tangible and intangible or marketed and non-marketed products. Livestock can be a component of complex agricultural systems and people´s livelihoods and their use is in multiple ways, or as Wilson et al. (2005) phrase it,

> "Livestock are not raised simply for their own sake but to fulfill interacting and often conflicting human nutritional, economic and environmental needs. They contribute to human welfare and people's livelihoods in many ways".

Different authors use various ways of describing and categorizing livestock functions, e.g. Wilson et al. (2005) describe four main ways how livestock serves people, as concerning poverty alleviation, food security, environmental benefits and gender equity. They categorize livestock outputs as immediate (e.g. milk, meat), intermediate (e.g. draught power, manure as fertilizer) and interdeterminate (e.g. reduction and spread of risk from cropping). In a review on multifunctionality of livestock in developing communities, Moyo and Swanepoel (2010) use the categories of food and nutrition, social functions, risk buffer, contribution to crop production, income generation/wealth accumulation, its` economic role and its` role for the environment. A third example of categorizing livestock`s contribution to human wellbeing is to consider the roles it plays for capital – being financial, social and natural capital (IFAD, 2004).

3.3.1 Animal based products: A source of protein in human nutrition

Milk is a nutritious source of protein, calcium, potassium, phosphorous and other trace elements, vitamin C, vitamin B12 and some other B complex vitamins, vitamin D and of carotene (a precursor of vitamin A). All these elements have different nutritious values, e.g. protein and calcium are positive for growth and bone formation. Meat is acknowledged as a source of high quality protein (e.g. Wilson et al., 2005).

For a healthy development and maintenance of the human body a good nutrition is essential. Animal proteins have the potential to be a complementing part due to their richness in macro- and micro-nutrients (Ndlovu, 2010). In a review, Bwibo and Neumann (2003) describe diets in Kenya as mainly plant-based with cereals having the largest shares. Animal products are consumed to a very limited extend, even if people own livestock. Nutrient deficiencies can be found especially in poorer households. The authors state that Kenyan children don`t take enough energy, fat and micronutrients which may lead to poor child development. In a study with Kenyan school children, Neumann et al. (2003) found positive associations between intake of animal source foods (ASF) and growth, cognitive development and physical activity. Even little animal origin foods have the potential to significantly improve children diets in developing countries (IFAD, 2004). Animal origin foods can thus be a supplement in human diets, with in practice milk usually being more regularly consumed than meat (Pica-Ciamarra et al., 2011).

However, keeping livestock does not necessarily mean a higher consumption of ASF. Leroy and Frongillo (2007) reviewed studies on the impacts of promoting animal production on nutritional status and other nutrition-related outcomes. Of the reviewed studies that included effects on nutritional status, all showed positive effects. But there was no clear proof whether this is due to a higher intake of own livestock products or due to indirect effects through a higher income. Thus, extra income through livestock may be used to buy food (IFAD, 2004).

Many livestock-dependent poor people in the IGAD region "are net buyers of food items and tend to sell livestock and animal foods to buy cheaper sources of calories, typically staple grains" (Pica-Ciamarra et al., 2011, p.16).

3.3.2 Livestock as a source of income

The sale of livestock and livestock products are sources of income for many households. In their review on livestock and livelihoods in the IGAD region, Pica-Ciamarra et al. (2011) write that this is the case in pastoral systems as well as in other farming systems while in the latter livestock is one activity and source of income among several. There is also a difference between households depending on their economic situation, i.e. poorer household participate less in markets than better-off ones. Thus, livestock can be a mean of economic security through its´ role as a source of income. Livestock counteracts vulnerability in direct ways (e.g. animal products) and indirect ways (e.g. credit opportunities; Vandamme et al., 2010).

3.3.3 Livestock as "insurance" and "bank on hooves"

In parts of the world with limited financial ability, livestock can act as an important asset of a farming household. In case of cash need, an animal can be sold in order to meet the expenses. Due to those roles, the terminologies "insurance" and "bank on hooves" are used here.

Many rural areas are characterized by a lack or even absence of insurance schemes (Pica-Ciamarra et al., 2011). The benefit of cattle as an insurance in such areas lies in the ability to sell animals to meet unexpected expenditures, such as medical bills (Bebe et al., 2002). Thus, in many developing places, livestock work as insurance policies (Pell al., 2010). Case studies illustrate the role of livestock as a mean of insurance, e.g. in Burundi (Vandamme et al., 2010) or in Kenya (Bebe et al., 2002).

Livestock is an asset, especially in places where other credit options are lacking. It is a form of “capital accumulation, providing a cash buffer in times of need” (Wilson et al., 2005). In situations when expenses need to be met, livestock can be very useful as through animal sales cash can be liquidated within a short time. Besides the use of livestock as a bank by itself, cattle also increase the access to credit, e.g. as in a case study in Burundi where households with cattle had significantly higher access to such (Vandamme et al., 2010). Livestock is thus the primary form of saving for many households, enabling getting cash through animal sales quickly (IFAD, 2004). The review on the IGAD region showed that “livestock is used for saving and insurance” (Pica-Ciamarra et al., 2011). Previous research has tried to grasp the benefits of livestock as an asset (e.g. see Moll, 2005 and the review in chapter 3.4).

3.3.4 Dairy cattle as an integral part of mixed farming systems: Inherent benefits

In mixed farming systems keeping livestock is one farming activity among several and thus a mean of diversification. In diversification, risks are spread among several farming activities instead of just one, e.g. if a crop harvest is bad one year, the household can still rely on livestock outputs.

Crop growth requires nutrients and after a while of growing crops the soil fertility can decrease if no measures of fertilization are taking place. Nutrient cycling is a keyword in sustainable cropping systems. In mixed crop-livestock systems animals can be a valuable component of a nutrient cycle of a farming system with positive impacts on soil fertility and structure (e.g. Wilson et al., 2005). Thus, a benefit of keeping livestock can be improved crop growth due to fertilization with manure. Also a review in the IGAD region suggests that crop yields are significantly increased by the use of livestock manure. However, the authors of the review also state that the use and utilization by households of manure is very limited (review by Pica-Ciamarra et al., 2011). Manure can also be utilized in other ways than fertilizer, e.g. as energy source or construction material component.

3.3.5 Dairy cattle as a part of culture and social life

Livestock can be part of complex social relations and cattle can play important roles in social functions. Sometimes livestock is used for the social security in communities, e.g. among Boran people in East Africa in which wealthier tribe members shall give livestock to poorer ones which is yearly decided by elder groups (IFAD, 2004). Livestock loans and gifts "contribute to bonding, bridging and linking in social capital relationships and livestock is one means by which family and household social capital may be measured" (IFAD, 2004). Livestock´s role in social relations and as social capital is different depending on the socio-economic settings and not static but changing as it depends on different circumstances. There may be a negative correlation between livestock as social capital and (an increased) productive-orientation and commercialization of livestock (IFAD, 2004).

Livestock keeping is embedded in certain property structures as well as organisation of work within a community and also on household level. Criteria can be ethnic identity or financial situation, e.g. Zaibet et al. (2011) writes that pastoral groups often have more cattle than the other ethnic groups and that in some places cattle are mostly kept by richer people who use them as saving and insurance while poorer people keep more small ruminants.

Livestock can impact gender balance, i.e. through arrangements on property holding, workloads, decision making and who gets the outputs of livestock. Larger livestock is often owned by men. Small stock and backyard chicken are often earned by women (Waters-Bayer and Letty, 2010). In many cases a large part of the work related to livestock is done by women and with an increased commercialization of livestock, "women can lose strategic roles and changing gender roles" (IFAD, 2004). Livestock products are not treated and received by all household members equally but dealt with depending on the social role of the household member, e.g. milk and its revenues of Fulani households are usually handled by the women whereas men deal with the sale of animals (IFAD, 2004).

Livestock can be a component of social arrangements. Examples are sharing and borrowing arrangements between households, e.g. Aklilu et al. (2008) describes how poultry keeping and social networks are connected in the case of village poultry keeping in Tigray, Ethiopia. Sharing arrangements are based on social networks while others are more commercially, e.g. in Bolivia there is ´Al-Partido`, in which poor livestock owners use commercially based livestock share-rearing arrangements. In West Africa spreading herds among relatives of herders is a measure to distribute risks (IFAD, 2004).

Other examples of the use of livestock in a social context are the use of cattle for dowry, the use as gifts, using them in events or sharing to give such to friends or neighbours in times of emergency (Pica-Ciamarra et al., 2011; IFAD, 2004). Gifts and loans are more a sort of "social capital arrangement than commercially oriented" (IFAD, 2004). Another social function is social status, i.e. cattle are said to increase the social status of their owners (Moyo and Swanepoel, 2010). Livestock as a part of social networks in the IGAD region is also mentioned in the review of Pica-Ciamarra et al. (2011)

3.4 Grasping intangible livestock products and services

In LCA, environmental effects as GHG emissions are calculated for a certain product. One or several products of a production system are expressed in a common unit which reflects certain product characteristics (see chapter 3.2). As economic allocation is a common technique in LCA of livestock production, it is also in this thesis applied. Economic allocation requires economic values of products why in this chapter methods of economic quantification of tangible and intangible livestock products are reviewed. There has been limited work within LCA research on including and quantifying multiple functions of livestock before. Ripoll-Bosch et al. (2013) valued other services to society than meat (for example benefits regarding biodiversity and landscape conservation) and related those to agri-environmental subsidies of the EU and farm economic values. In general, research tried to grasp, i.e. quantify intangible livestock products and services already in the past, although not from an LCA perspective. Some argue that quantifying intangible functions provides policy-makers with a perspective that may be more close to that of smallholder farmers, who value not only the marketed products (Moll, 2005; Moll et al., 2007). Bosman et al. (1997) measured benefits of goat keeping and argued that in earlier research other roles than biological production have been acknowledged, but its` implications on productivity had been largely ignored. Bebe et al. (2002) included some non-marketed functions in their analysis of smallholder dairy systems in Kenya. And Behnke and Muthami (2011) studied the contribution of livestock to the Kenyan economy, including milk, meat, finance and insurance functions. As the traditional methods of accounting underestimate the contribution of livelihoods, the authors aimed at getting better estimates.

3.4.1 Milk

Behnke and Muthami (2011) looked at all milk off take for human consumption. As there was no official data on average national producer prices in 2009 available, the authors considered local information of some places and distinguished between informal and formal prices. Formal prices were based on the Kenya National Bureau of Statistics (KNBS) figures for

2009 and informal prices were calculated as a multiple of 1.275 of the formal price, which is a mean value of reviewed studies. To apply a producer price to all milk produced including the self-consumed parts can be a point for debate as well, as Behnke (1985) points out the idea of replacement costs, i.e. which would imply that the milk consumed at home could also be valued according to the milk retail price, which the household would spend when buying milk in a shop. Scoones (1992) valued milk based on the replacement costs of buying milk in local stores.

3.4.2 Manure

Earlier research economically valued manure in different ways. In places where there is a market for manure, the market value can be used for estimating the total value of manure, e.g. Scoones (1992) valued such of cattle in Southern Zimbabwe at $26 per animal and year in sandy soil and for younger animals a proportion of that. On clay there was less value for manure as it had no market value and thus it was treated at half of the economic value of that on sandy soil.

In situations without market values for manure, one option is to economically value manure based on its` nutrient contents, and to relate such to fertilizer values and prices. However, this way may underestimate the role of manure in mixed farming systems (Udo et al., 1992). In crop production, yields and the effects of manure can be studied in order to get to an estimate of the value of manure (e.g. Newcombe 1989 cited in Udo et al., 1992). In another case considering Bangladesh fish, Dolberg (1981 cited in Udo et al., 1992) accounted for the extra fish produced due to fertilization with manure and urea. Alary et al. (2011) estimated the manure value by relating it to the price of manure, considering urea content and the purchasing market price of urea fertilizer.

3.4.3 Financing

Instead of borrowing money animals can be a means of finance. A proportion that reflects this benefit is a premium on top of the sale price. That proportion can be estimated in relation to alternatives as e.g. keeping a saving account or getting credit. Livestock for finance, i.e. selling animals when required and not at an optimal moment from a production point of view has several advantages, as e.g. loss of value due to inflation, having cash for which can be asked by others and costs for borrowing are all avoided. An estimated proportion related to the alternatives in borrowing or other means of getting money can be applied to the sale price. (Moll, 2005; Moll et al., 2007) In their comparative study on dairy systems in Zambia, Sri Lanka and Kenya, Moll et al. (2007) applied 0.10 (unattractive alternatives in financing), 0.06

(presence of financial institutions, but independence of transaction costs and inflation if using animals) and 0.06 (high interest rates and moderate, annual inflation) for the benefit of dairy cattle as finance, respectively. Bosman et al. (1997) collected information on finance and as there was no formal or informal finance for direct comparisons they estimated the benefit from financing being equal to the inflation over a 3 months period which resulted in 0.06. The benefit from financing then was multiplied by the outflow value. Ayalew (2000, cited by Moll et al., 2007) applied a proportion of 0.10 based on commercial interest rates for credits in Ethiopia.

In the study on smallholder dairying in the Kenyan highlands, Bebe et al. (2002) explain the estimate of cattle for financing and applied an interest on loans of 12% to the herd value of one year. Those 12% are related to the interest of cooperative savings and credit societies. Behnke and Muthami (2011) calculated the financing benefit of Kenyan livestock according to Bosman et al. (1997) as considering the alternative and cost to get the amount comparable to liquidating the herd, i.e. applying an interest one has to pay to get a loan equal to the value of the livestock offtake. Such interest rates of cooperatives and informal money lenders ranged from 20-34% per annum. The authors applied an interest of 25% on the offtake value, which is the value of the animals that were sold or slaughtered resulting in ksh 16.797 billion on top of the ksh 67.147 billion of direct offtake value. However, the authors also note that almost 50% of lending in rural Kenya is handled privately, e.g. through friends and neighbours which imply a lower interest rate of 6.3% per annum (KNBS, 2006 cited in Behnke and Muthami, 2011).

3.4.4 Insurance

Moll (2005) understands the insurance function of livestock as the opportunity to sell animals when needed and thus, having animals is equal to having insurance. The absence to pay a premium is the intangible benefit. This is also important in places where alternatives are available, because even then animals remain assets that can easily be exchanged to cash. He applied an insurance premium to the average herd value over a year to obtain the insurance benefit. In case of lack of alternatives, he suggested to make a guess, i.e. 0.05 for stable situations without major weather risks and 0.20 for situations with severe risks. In line with that idea, Moll et al. (2007) applied proportions of 0.10 (unfavorable conditions), 0.05 (insurances can be accessed by smallholder but still livestock is an option of insurance) and 0.06 (farmers engage in different enterprises which spreads risks) for the benefit of dairy cattle as insurance in their comparative study on dairy systems in Zambia, Sri Lanka and Kenya, respectively. In a study on dwarf goats in Southern Nigeria, Bosman et al. (1997) used a proportion of 10% as by Ibe (1993 cited in Bosman et al., 1997) as a benefit factor for insurance as there were no studies on informal insurance available. This factor was applied to the average value of the flock over the year. The insurance benefit of goats in the Ethiopian highlands was set at 0.083 of the mean value of the stock for goats (Ayalew, 2000 cited in Moll et al., 2007). In a study on smallholder dairying in the Kenyan highlands the authors describe the example of a medical insurance policy for which one needs to pay an annual fee of ksh 12.000 in order to cover a benefit of ksh 200.000. This implies a 6% annual premium which when multiplied by the average herd value over one year gives an estimate of the insurance benefit through cattle (Bebe et al., 2002).

In their analysis of livestock`s contribution to the Kenyan economy, Behnke and Muthami (2011) argue in line with Bosman et al. (1997) and understand the insurance benefit of livestock as the saved annual cost that is involved in paying insurance coverage with the same value of their herd. Data on average producer prices of selling livestock and the actual values of the remaining herds were lacking, i.e. the authors assumed a livestock capital value of 75% of the mean sale value. The authors considered in their calculations the National Hospital Insurance Fund which on a voluntary basis implies costs of ksh 1.920 per year for a family, providing health coverage of ksh 396.000 per year, implying a premium to coverage ratio of 0.48%. Applied to the capital value of the national herd, this means an insurance benefit of Kenyan livestock in 2009 of ksh 2.013 billion.

3.4.4 Status

Earlier studies suggested to understand the benefit of livestock as a provider of status to their owners as related to the access to markets that provide other means to display wealth, e.g. durable consumer goods. To estimate the proportion of the benefit of status, Moll et al. (2007) argue that it should be smaller than the one for insurance, e.g. 0 in cases where cattle has no tradition to 0.10 in cases where cattle is the major indicator of status. In their comparative study on dairy systems in Zambia, Sri Lanka and Kenya, Moll et al. (2007) applied 0.03 (cattle is an expression for status), 0 (cattle has no cultural value) and 0.02 (cattle is a display for status, but farmers have more options than in the Zambia case), for the benefit of dairy cattle in providing status to their owners, respectively.

3.5 Summarizing remarks on the literature review

Thinking about the results of the global study on dairy production, which showed higher GHG emissions for dairy production systems with lower milk yields, compared to more intensive systems with higher productivity levels led to the idea of this Master thesis research. Some studies about CF of dairy production were presented above. Those studies are characterized by differences in scope, the system under study and location. Little is known about CF of dairy systems in Southern countries and in smallholder systems as the majority of studies are focusing on Northern locations as Europe and North America. As LCA is being applied to milk production systems characterized by a wide range of degrees of specializations, a very central question appears: Is it actually acceptable the way it is done or are we "comparing apples with pears"?

Some of the reviewed studies show what impacts methodological choices in LCA have on CF results. Some studies point out the interconnectedness of the dairy and beef sectors and that it makes sense to study those systems in an integrated manner. Taking one step further, I argue that this is the case not only for milk and meat but also for all other products (including services) cattle provide in a farming system.

As LCA has a product focus, multiple functions are understood as multiple products (including services) in this thesis. Farmers keep cows because they have an interest in certain products or services. If the main interest is to get milk from that cow, then milk is the most important product in that production system and milk is also the main reason to keep the cow. If the cow provides milk and a mean of financial security, then there are two reasons why a farmer keeps the cow. In that sense I argue that all outputs of a system, be it a tangible (e.g. milk) or intangible one (e.g. financial security) need to be considered when doing environmental impact assessment, because those other products or services than milk and meat can be (even the primary) reasons why cattle are kept in the first place. The intangible nature of many functions does not mean that they do not have a value. As the literature review revealed they do have value and are reasons why people keep those animals. Within the LCA methodology, entry points for a consideration of multifunctionality are in step 1, with the functional unit and allocation being key issues. Multiple outputs can be accounted for in the FU if expressed in quantitative terms and by valuing them in economic terms. Different ways of allocating emissions provide insights on results depending on methodological choices.

The degree of specialization is related to the purposes of dairy cattle, i.e. in highly specialized systems milk production is the most important function, whereas in many smallholder systems multiple functions play a role. Earlier in the literature review a thought about the need to study interlinked systems as dairy and beef in an integrated way was described. Taking that thought serious, I hypothesize it to be applicable to production systems that are even more interlinked, e.g. smallholder mixed systems, which has implications on how we study these systems.

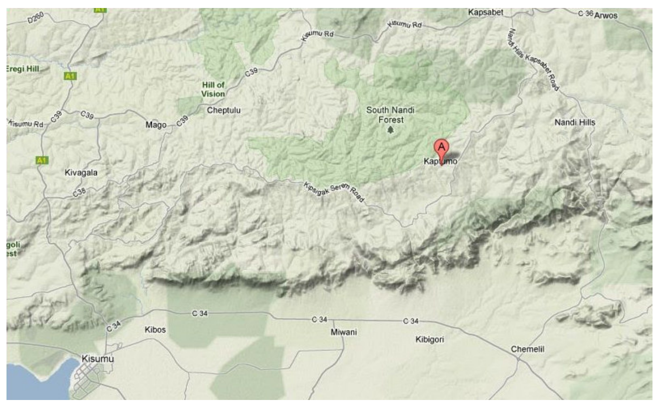
4. Materials and methods

This chapter is organized in three parts. At first the data collection in Kaptumo is described, followed by a description of the methodology on accounting for multiple functions in LCA. At last, the LCA method as applied in this study is explained.

4.1 Data collection in Kaptumo, Kenya

The case study is in and around Kaptumo village, Rift Valley Province, Kenya. It is an area in which the East African Dairy Development Project (EADD) has been working since 2009 and the Mitigation of Climate Change in Agriculture (MICCA) programme of FAO since 2011. MICCA is collaborating with EADD and doing a pilot study in Kaptumo division. The entry point to this location was through MICCA.

Kaptumo village is in Nandi South District, Nandi County, Rift Valley Province, Kenya (see maps 1 and 2). Kaptumo Division lies in altitudes from 1.800 – 2.100 m above sea level and rainfalls range from 1,500 – 2,100 mm/year.



Maps 1 and 2 The case study location (GraphicMaps, 2012; GoogleMaps, 2012)

4.1.1 The Mitigation of Climate Change in Agriculture Programme (MICCA) and East Africa Dairy Development Project (EADD)

The MICCA Project of the Food and Agriculture Organization of the United Nations (FAO) aims at facilitating developing countries in contributing to the mitigation of climate change in agriculture and moving towards low carbon emission agriculture. It runs pilot projects integrating climate-smart farming practices into on-going development projects. The project site in Kenya is related to the East Africa Dairy Development Project (EADD) funded by the Bill and Melinda Gates Foundation. EADD is led by Heifer International in partnership with the International Livestock Research Institute (ILRI), TechnoServe (nonprofit organization), the World Agroforestry Centre (ICRAF) and the African Breeders Services (ABS) Total Cattle Management (distributor for American Breeders Service). It is running in three countries Kenya, Rwanda and Uganda and aims to help one million people in the region through more profitable milk production and marketing. MICCA does capacity building regarding climate-smart practices along the value chain. One part of the project is the assessment of greenhouse gas emissions through researching and monitoring changes in greenhouse gas emissions, ecosystem processes and productivity throughout the project implementation.

In the field I interacted with the local EADD staff of the country office in Eldoret, with the responsible staff of ICRAF in Nairobi and mostly with the local MICCA staff in Kaptumo. This setup enabled me to connect with the dairy hub from day one onwards which was helpful in making contacts. A local staff of the hub accompanied me the first few weeks in the field until I found my way around myself. I visited farmers of several farmers groups organized by the local MICCA staff. This was a beneficial structural setup for me in terms of data collection, as I was embedded in a bigger project frame, people already knew about.

4.1.2 Data collection methods, approach and sample size

During data collection several methods of interview techniques were applied, using a step-wise approach as described below.

4.1.2.1 Informal interviews (First interviews to explore the domain)

At first 10 farmers were visited to get an idea of the situation of dairying, which roles cattle play in the study location and what motivations farmers have behind cattle keeping. It enabled to get a first understanding about the local conditions and to set the scene for the following more in-depth interviews. The choice of method was qualitative ethnographic interview technique, as described by Schlehe (2008), which enables recording of daily experiences and local knowledge, trying to develop an understanding of cultural meanings and practices. Such an interview tries to open the access to the emic perspective of people. The open interview gives the opportunity to experience things for which the interviewer would not have asked because they are beyond the own horizon. The qualitative ethnographic interview technique is characterized by an open, exploratory nature and a process of intercultural interaction and communication. It provides space for more openness towards people´s views than it is the case with e.g. pre-structured interviews (where the interviewer already has more clear answers in mind). The method has a character of a conversation, but at the same time is not an equitable dialogue as the interviewer aims at finding out something about the other, being dairy cattle purposes in this case. The outcomes of these 10 conversations were inputs for the interview guide that was used for the main set of interviews later. The functions of cattle were evaluated and prepared as a list for a ranking exercise in the following interviews.

4.1.2.2 On-farm assessments

Following the first set of informal interviews, farmers of four farmer groups, with who the local MICCA field staff has been collaborating, were visited. In total 20 farms are included. Farmers were interviewed using a semi-structured interview technique as described by Schlehe (2008). An interview guide was prepared including the collection of qualitative and quantitative information, based on data needs for this research and under consideration of the data of the first informal, unstructured interviews. The guide was always handled in a flexible way, i.e. depending on the individual interview situation the order of questions could change. The interview guide was tested and changed several times to increase its` practicability. Finally, the guide consisted of four different parts, namely

a) Household and socio-economic situation;

b) Dairy cattle and their functions;

c) Farming;

d) Details on cattle.

Part a) captured household characteristics of the respondent (e.g. age) and the household (e.g. household composition, children in school), household activities (e.g. farming activities) and income sources among others. This part aimed at getting an idea of the general structure of the household.

Part b) aimed at the dairy cattle functions relevant for the respondent. Within part b), two cognitive methods were included, i.e. free listing and ranking as described by Antweiler (2008). He explains cognition ethnology as something that is about the implicit knowledge of people and how such cultural knowledge is learned, stored, how it shapes practice and can be changed and transferred to others. Generally, cognition is processes and contents of thinking and knowledge why also often the synonym of “cultural knowledge” is used. The general aim is to understand the order of the perceived reality. A more specific aim behind that is to use cognition to explain specific behaviour. Cultural-specific ways of thinking are central here. Cognitive methods turned out to be suitable in this case as one question of the research is the meaning of cattle to the farmers. Insights into cultural knowledge, the cognitive dimension and evaluative-emotive dimension to a topic can be gained, enabling to get some understanding of the farmers` views and perspectives on their cattle. In detail, free listing was applied in part b) of the interview, basically asking “Why do you keep cattle?” Later, to gain an understanding on the importance of cattle functions to the farmers, ranking was used. A list of five functions as an outcome of the first informal interviews was used for the exercise. Farmers were asked to rank the functions accordingly their importance to him/her why they keep cattle, using the numbers of 1 (most important) to 5 (least important).

Usually an interview started with parts a) and b) while sitting either in the house or outside the house. This part was recorded using a recording device, as part of the information was qualitative and writing everything down at the moment of the interview turned out to be disturbing the conversational character of the interview. Those parts were usually followed by a walk together around the farm, looking at the cattle and answering the more technical questions on farming and dairy management practices of part c) and d). This walking around and being with the cattle turned out to be more comfortable for everybody involved in the interview as doing the interview while only sitting at the table for a prolonged time turned out to be too tiring for some respondents.

4.1.2.3 Other data collection

A local bank in Kaptumo was visited in order to gather information about interest rates which could be used to compute the economic values of cattle for financing. Local cattle markets were visited to gain understanding on trade practices and interactions with a local butcher and a local cattle trader helped to gain knowledge on meat cuts, meat uses and cattle prices, which then could be applied to compute the economic value of the herds and the economic value of cattle for meat. To investigate the economic value of cattle as an insurance, information on insurances was collected by literature review and web information of the National Health Insurance Fund of Kenya. The concentrate composition was from a local provider in Eldoret.

4.2 Computation of milk production, feeds and manure

The accuracy of data collected in the field is sometimes not as high as a researcher wishes it to be. Sometimes it just lies in the nature of field research. But sometimes a change in data collection method can bring data quality improvements. Based on interview data, milk uses, feeds and manure were calculated.

t appeared to be a major challenge to get data on these three aspects, as there is usually no recording on farms. To estimate the amount of milk produced at a farm during one year, a calendar was drawn for the interview and farmers estimated milk consumption at home and milk sales of each month. Those estimates were used to compute the total milk yield per farm over the time frame of one year.

Feed inputs other than grazing were computed based on feeding calendars, which were used to make estimates on feeds given to cattle in each month of the time frame of one year. Those feed inputs were later translated into total kg DM per year. The conversion units are attached in the annex.

Manure production was calculated by multiplying the live weights of the average herd of one year by 0.08% as based on Lekasi et al. (2001) a ruminant produces 0.08% of its liveweight as faecal DM per day.

Manure used as fertiliser was computed based on the farmers` estimates of manure use on each crop during the year. Those estimates were translated into kg of DM manure used for each crop and the total manure use and manure was assumed to have a moisture content of 50%. Conversion factors for units in the estimation are attached in the annex.

4.3 Quantification of dairy cattle functions

For the economic allocation of GHG emissions, the economic values of milk, meat, manure as fertiliser, cattle as insurance and cattle for financing are computed. The reason is that all those five functions played a role in Kaptumo. A very important other function are the socio-cultural roles cattle play for their owners, but those were economically not quantifiable in this research.

4.3.1 Milk

The economic value of milk is calculated in line with Behnke and Muthami (2011), based on the producer prices. The total production of milk of a farm is multiplied by ksh 27.6/kg milk, which was the mean monthly producer price as paid by Kapcheno Dairies in 2012. This local hub, an installment by the EADD, was the main buyer of milk for the farmers.

$$MILK = \text{milk output} \times \text{milk price}$$

with

MILK = total economic value of milk of one year

milk output = kg of milk produced on a farm per year

Milk price = Average producer price of milk as paid by the local EADD hub Kapcheno Dairies

4.3.2 Meat

In the few cases where cattle were slaughtered, the economic value of meat was calculated as a function of the animal category and the price a local butcher would pay for the animal:

$$MEAT = head \times meatprice$$

with

MEAT = total economic value of the meat utilized from cattle during one year

head = number of cattle used for meat, corrected by cattle category

meatprice = producer price for the animal as paid by a local butcher

4.3.3 Manure

A fraction of the manure is used for fertilizing and a very small part is used for smearing houses and floors. The latter fraction is ignored, as it is applied only in very limited amounts and very seldom. The manure used for fertilizing is valued economically similar to Alary et al. (2011), i.e. the idea of replacement with synthetic fertilizer. It is a function of the amount of manure used for fertilizing, the nitrogen and phosphorous contents and the equivalent values for synthetic fertilizer. The amounts of manure applied to crops were assessed during the interviews. The amount of N in cattle manure are taken from Lekasi et al. (2001; 1.4% N). On the replacement side of synthetic fertilizer, it is referred to “DAP” as the most common fertilizer farmers used. N contents of DAP are 18% and DAP prices are based on local price at the farm shop. The manure used for fertilizing is also corrected for nutrient losses, i.e. it is assumed that 50% of N and P are lost during storage (Moore and Garroth 1993 cited in Samdup et al. 2013). The value of manure is calculated as:

$$MANURE = fertiliser\ price \times N_{manure}$$

with

MANURE = the total economic value of manure used as fertilizer in one year

fertilizer price = ksh/kg N in DAP

N_{manure} = amount of N utilized in manure

4.3.4 Financing

The benefit of financing is calculated in line with Behnke and Muthami (2011), Moll (2005) and Moll et al. (2007). Considering the alternative way of borrowing money at a bank, the benefit of financing is a function of the interest rate for the amount of the price of the animal and the sale price:

$$FINANCE = headpr\_f \times bf$$

with

FINANCE = the value of cattle as finance over one year

headpr_f = the price of the animal sold due to reasons of finance

bf = interest rate.

An interest rate of 19% is applied which is the rate at Equity Bank, the bank most used around Kaptumo.

4.3.5 Insurance

In line with Bosman et al. (1997), Bebe et al. (2002), Behnke and Muthami (2011) and Moll (2005), the benefit of cattle as insurance is understood as the absence to pay a premium in the case of an insurance:

$$INSUR = stockvalue \times bi$$

with

INSUR = the economic value of the cattle stock as an insurance for the household

stockvalue = the economic value of the cattle stock (the average stock during one year multiplied by the price of cattle, corrected for type of cattle)

bi = insurance premium (cost that cattle owners would need to pay to purchase insurance coverage equal to the capital value of their herd)

An insurance premium of 6% is applied as in Bebe et al. (2002).

4.4 Carbon footprinting of milk production

LCA consists of four steps which are described below. The LCA in this study follows an attributional approach studying greenhouse gas emissions in the status-quo situation under current production and market conditions. Greenhouse gas emissions occur at several stages on the dairy farm and the main greenhouse gases in agriculture are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). CO_2 occurs mainly through the burning of fossil energy, such as e.g. by the use of tractors for fodder production, buildings and equipment. CH_4 is a by-product of bacterial fermentation in the rumen under anaerobe conditions in feed and manure. N_2O emissions mainly occur in denitrification processes in manure and soils.

4.4.1 Step 1: Goal and scope definition

The goal of this LCA study is to calculate the carbon footprint of milk of smallholder mixed dairy production systems in Kaptumo, Kenya. The product system under study is smallholder, mixed dairy farming system in Kaptumo, Kenya. Functions of the product system regarding dairying are the production of milk, live animals, meat, manure, insurance, finance and socio-cultural functions. The functional unit is kg of milk. The system boundary of this LCA is characterized by a cradle-to-farm gate approach. Processes are separated into on-farm and off-farm processes. This distinction is essential for an integral assessment of greenhouse gas emissions related to the dairy production and useful as it enables to identify where emissions occur. Excluded are changes in carbon stocks and carbon losses due to deforestation.

On-farm processes and emissions

The on-farm processes considered in this LCA are the husbandry and management of the dairy cattle and the production of feed. Included on-farm emissions origin from

- Husbandry management of dairy cattle, i.e. grazing and housing
- Manure management, i.e. manure storage, usage and application
- Feed production, i.e. use of inputs as synthetic fertilizer
- Energy use, i.e. electricity (for milking, water), diesel, gas, oil (for cropping).

Off-farm processes and emissions

GHG emissions are distinguished between on-farm and off-farm emissions. On-farm emissions include

- CH_4 emissions from enteric fermentation
- CH_4 from manure management
- N_2O from manure management, i.e.
    - Direct N_2O emissions from manure management
    - Indirect N_2O emissions due to volatilization of N from manure management
    - Indirect N_2O emissions due to leaching from manure management

Off-farm processes include those that are related to the dairy activity off-farm, which is mainly through the provision of external inputs as feed. GHG emissions accounted for in this study are Off-farm emissions include emissions due to the production of molasses, emissions due to grinding of maize for feed and emissions related to dairy meal. Emissions due to molasses and grinding were computed using the EcoInvent database. Greenhouse gas emissions due to dairy meal were based on a feed composition of a local feed company in Eldoret.

Emissions are calculated based on chapter 10 and 11 of the IPCC guidelines (2007). Table1 summarizes equations used for the computation of GHG emissions. There are no emissions related to energy use during husbandry or cropping as all work on the farm was done manually.

Table 1 GHG emission calculations and equations (IPCC, 2007)

GHG emission calculation	Calculation based on
Methane emissions from enteric fermentation	Equation 10.21
Methane emissions from manure management	Equation 10.22
Nitrous oxide emissions from manure management	Direct: Equation 10.25 Indirect: Equations 10.27 and 10.29
Nitrous oxide emissions from managed soils	Direct: Equation 11.1 Indirect: Equations 11.9 and 11.10

Allocation

GHG emissions are divided to the product milk and other products of cattle using different allocation techniques, i.e. no allocation, economic allocation and "alternative" allocation based on farmers' motivations.

Within the economic allocation, which falls under rule 3 of the ISO guidelines (14044:2006), the following allocation scenarios are applied:

- Relative economic allocation to the products milk and meat
- Relative economic allocation to the products milk, meat, manure, insurance function and financing.

Within the "alternative" allocation based on farmers' motivations behind cattle keeping emissions are allocated to the five main domains of cattle keeping which were identified during the field stay. Those domains are milk for home consumption, milk for sale, `animal sales when cash is needed`, dowry and wealth. This allocation technique follows the argumentation that the reasons to keep cattle are related to products and services cattle provide their owners with and which can be independent of an economic rational. Positive aspects of this allocation technique are first, that it provides an opportunity to include socio-cultural values of cattle which were not included in the economic allocation. Second, to the fact that the products are based on categories farmers defined themselves reflect the production system's outputs more from an endemic perspective. In a ranking exercise farmers ranked those five categories or functions according to their importance why they keep cattle. Those ranks are associated with weighing factors, i.e. all functions are first equally treated and

20% of emissions are attributed to them. Based on the ordinal numbers of the rank (total = 15) the allocation of emissions shift depending on the rank of a function (table 2).

Table 2 Distribution of GHG emissions related to the rank of a function

Rank	% of emissions allocated
1	33
2	27
3	20
4	13
5	7

4.4.2 Step 2: Life cycle inventory analysis (LCI)

The input data and sources are listed in the annex and summarized below.

Animals and husbandry system

In the LCA model, animals were divided in the categories dairy cows, non-producing dairy cows, heifers and young stock. There were no adult males on the farms. Based on herd data at the time of farm visits and one prior to that, an average herd was computed for each farm. Due to stock changes and difficulties in obtaining exact ages of animals, young stock was summarized in one category. All cattle are kept in paddocks for grazing or part-time tethered (the latter is the case mainly for young stock).

Manure management

Manure production and manure used as fertilizer were calculated based on herd data and farmers` estimates. Manure used on crops was translated in DM manure, assuming a 50% DM content. It was assumed that all of the utilized manure used for fertilizing is stored in dry lot.

Dairy system products

Dairy cattle products are categorized in two ways related to the two methods of allocation as described earlier. For the economic allocation, system products are milk, meat, manure for fertilizing, insurance function and financing. For the "alternative" allocation based on farmers` motivations those are milk for home consumption, milk for sale, animal sales when cash is needed, dowry and wealth.

Feed basket and feed production

The feed basket consists of grazing, fodder crops produced on farms, crop-residues produced on farms and bought feeds. Feed inputs other than grazing are calculated based on farmers` estimates (see chapter 4.2). Feeds other than grazing were Napier grass, bean straw, maize stalks, Boma Rhodes, sweet potatoe residues, sugarcane cuttings, sorghum stalks, maize meal, molasses and dairy meal.

4.4.3 Step 3: Life cycle impact assessment

For the purpose of this study the focus is on the impact category climate change. The most important greenhouse gases related to dairy production are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). GHG emissions are expressed in CO_2-equivalents. For conversion in this common unit, the three gases are multiplied by the global warming potentials of CO_2=1, CH_4=25 and N_2O=298 (IPCC, 2007).

4.4.4 Step 4: Life cycle interpretation

In step 4 of the LCA, the CF results are discussed and hotspots of emissions are identified. The interpretation also includes a critical reflection of the own LCA. A sensitivity analysis was performed for an average farm to test the sensitivity of different input data.

5. Results

5.1 Description of the case study farms

The case study involves 20 dairy farms in three villages in near distance to Kaptumo village which were visited between September 2012 and February 2013. These farms are similar in terms of their main farming activities which are tea production and dairying, among other farming activities involving growing some other crops and keeping some small livestock.

5.1.1 Household and socio-economic characteristics

The main household and farming characteristics are summarized in table 3. The mean age of the respondents was 49.9 years (31 to 75) and 75% was male (n=20). The household was composed of on average 4.7 members (2 to 9; n=18). Of the on average 4.8 children (1 to 11; n=20) three were going to school (0 to 7; n=19). All households belong to the Kalenjin tribe, with 80% to the Nandi, a sub-tribe of Kalenjin. The two most important income sources are tea production and dairy. 90% of the households have no insurances, which will be picked up later in this report when discussing the role of cattle as insurance.

5.1.2 Farming practices

The farm size is on average 6.12 acres (1.5 to 18; n=20), mostly own land. Of those on a mean of 2.8 acres are used for cattle (0.2 to 12; n=20), including pasture and fodder crops.

On their mixed farms, farmers grow various crops. The purpose of crops depends on the crop, i.e. tea is for sale and thus, a source of income. Maize, beans, bananas and potatoes are used mostly for home consumption and some farmers sell a part of them. Vegetables are dominantly for home consumption. On 18 farms other livestock than cattle are kept, i.e. sheep, goats, chicken or donkeys.

5.1.3 Dairy cattle herds and management practices

Calculated over the time frame of one year and including stock changes farmers kept on average 2.9 cows (1 to 8), 1.1 heifers (0 to 4) and 1.3 other young stock (0 to 8) and no bulls or oxen. The majority of cattle are either a cross of Friesian or Ayrshire with local breeds.

In half of the cases, the man and head of the household is the owner of the cattle. In four cases, the man and wife together own the animals. In two cases ownership was animal-specific, i.e. some heads belong to the man and some to the wife or to the man and the son.

Cattle are kept on paddocks during the day and paddocking near the homestead during the night. Some are tethered, most often calves. Regular health management practices include tick control (in most cases weekly) and deworming in a three months rhythm.

Farmers have been keeping cattle themselves for years and most of them even since more than at least two decades. About a third of farmers got their cattle in the years between 1960 and 1980 and 42% between 1980 and 2000. As keeping cattle in the Kalenjin culture had a high importance also in the past (probably even higher), growing up with the family keeping cattle was normal, i.e. farmers have life-long experiences with them.

Figure 3 shows how tasks are distributed among the household. Feeding is done by several family members, i.e. the household head, wife and children in most cases. Milking is clearly a task of the wife. Moving means when cattle need to be brought from one place to another, e.g. from the paddock to the river to drink and it is done by different family members in about 36% of the fourteen cases where moving plays a role. Tick control measures, which are in most cases spraying, are not typically a woman`s task. The one case where a woman does the tick control is a case of a household without male members.

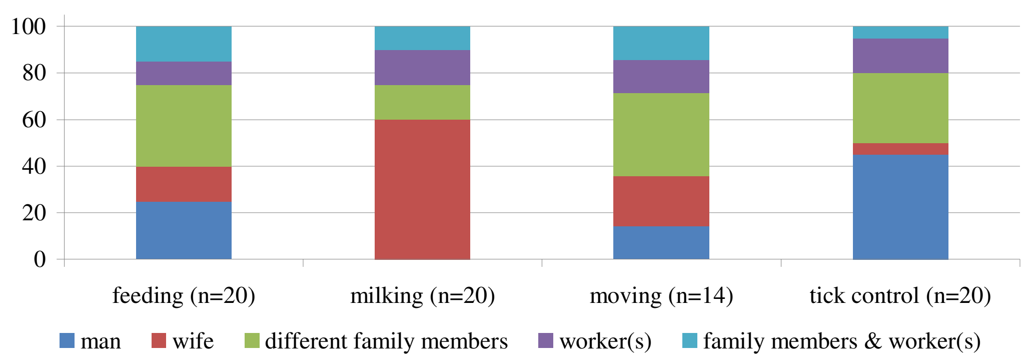


Figure 3 Tasks around the dairy cattle: Who does what?

5.1.4 Manure production and management

Over the year, on average 5 tons of DM manure were produced on a farm. 90% of the farmers used manure as a fertilizer on their land, on average 30% of the produced manure. Manure was collected and stored for differing periods of time, e.g. 2 to 3 months in bags or open heaps before it was applied dry on crops. The exact amounts of manure collected and storage durations were not known and in cases manure is collected and applied directly. Most farmers apply manure to Napier grass, bananas and vegetables, although higher amounts to the first two than to vegetables. Other crops on which manure is used include maize, beans, Boma Rhodes, passion fruits, sorghum, leucaena, millet and calliandra (for details see the annex).

Table 3 Summary of farm characteristics

Topic	Mean value	Range	Number of farms
Household characteristics			
Age of respondents	49,9 years	31 to 75	20
Sex of respondents	75% male		20
HH composition	4,7 members	2 to 9	18
Children per household	4,8 children	1 to 11	20
Farm size	6,12 acres	1.5 to 18	20
Land used for cattle	2,8 acres	0.2 to 12	20
Cropping characteristics	(in acres)		
Tea	2,42	0,3 to 7	17
Maize	0,7	0,1 to 3	20
Beans	0,5	0,1 to 1,5	18
Bananas	0,2	0,05 to 0,5	18
Potatoes	0,14	0,1 to 0,2	6
Vegetables	0,11	0,02 to 0,2	18
Other crops	0,59	0,1 to 1,5	12
Cattle herd size	(in no of animals)		
Cows	2,9	1 to 8	20
Heifers	1,1	0 to 4	20
Other young stock	1,3	0 to 8	20
Other livestock	(in no of animals)		
Sheep	3,4	2 to 8	5
Goats	1,5	1 to 2	2
Chicken	14,9	3 to 40	17
Donkeys	1	1 to 1	4
Feed inputs	(in kg DM per year)		
Napier grass	4414	0 to 43800	20
Banana stalks	59	0 to 537	20
Bean straw	422	0 to 3450	20
Maize stalks	2186	0 to 6000	20
Boma Rhodes	182	0 to 2281	20
Sweet potato plant	3	0 to 40	20
Sugarcane cuttings	2	0 to 32	20

Topic	Mean value	Range	Number of farms
Sorghum stalks	12	0 to 126	20
Maize meal	69	0 to 786	20
Molasses	14	0 to 236	20
Dairy meal	806	0 to 4789	20
Milk outputs	(in l/year)		
Home consumption	1404	600 to 5793	20
Sold	1921	0 to 7300	20
Total	3325	960 to 8354	20

5.2 Farmers` motives in keeping dairy cattle

In this sub-chapter the outcomes of the qualitative interview parts are elaborated. Citations of farmers are there to illustrate the endemic perspective. For all farmers milk for home consumption and milk for sale play a role. 95% of the farmers talked about the role of cattle as a security for them or had sold cattle due to its role as a mean of security. Dairy cattle as a ´bank on hooves` is the case for 85% of the farmers. The insurance function was mentioned directly by three farmers. For 90% of the farmers cattle play social cultural roles. The motives of a farmer behind cattle keeping are multiple and intertwined, thus like puzzle pieces that only when they are all together the whole picture is complete,

"The most important is milk for home use, and as a symbol of wealth. In our culture it is important to keep cattle for giving dowry, if in case of ceremonies let`s say my daughter is getting married sometimes we slaughter to welcome visitors. If you go round you will get everyone has got a cow this is because of our culture. If you don`t have a cow you will not be comfortable. So you must have a cow even if it is one." (4)

5.2.1 Milk for home consumption and for sale

All farmers are using the milk for home consumption. First, milk is used at home and additionally some is sold. The whole family usually gets some milk. There is a difference between own produced milk and bought milk, for example

"Have a cow, so that you don´t rely on buying milk from the outsiders. That´s the point. Make sure that you have one." (23)

There`s something more to milk consumption than simply doing it, i.e. a cultural connection as this farmer replied to the question of buying milk, *"When a Nandi doesn´t have milk for consumption I think it is not good…Sometimes you can walk around and you don´t get milk and maybe you still go, we´ll think it is not good in our culture. So better keep a cow … you can get some milk to consume and even sell a little." (20)*

Milk is an important component of tea drinking, which is very typical in the area. People drink tea especially in the morning hours but also at other times during the day. The tea is a mixture of water, tea leaves, milk and sugar.

"The most important thing cows help us in different ways, first we get milk and we don`t know to stay without a cow because in the morning we are supposed to drink tea before we go to any job and that we use milk to prepare." (3)

Milk is usually used by the whole family. Some farmers emphasized the importance for the children. Diets are mostly plant-based why the supplementation with milk can be very valuable for health and development, as mentioned in the literature review earlier.

"Get money in the morning, but in the evening you use, because you don´t leave children without drinking. They must take with something to make them healthy." (23)

The milk is used for home consumption and sale. From the morning milk, 2 liters were consumed at home and 7 liters were sold. All evening milk was used for home consumption. Milk at home is usually consumed fresh. At times, Murzik, a sour milk traditionally prepared in a calabash is prepared and drunk. Murzik is also offered to visitors.

5.2.2 Cattle as a security

Cattle act as a security. In the interview, farmers were asked on motivations of cattle keeping. Later the cattle sales of the past year were reviewed which indicate the role of livestock as a "bank on hooves" and "insurance". Some farmers explained the importance of their cattle for them for their household security in the interview,

"Like the sales, sometimes when you have an emergency and you own a cow or anything, so it`s like a security you own it. So when you need that cash you don`t need to borrow, you just sell, that`s only when it`s time for emergency. Purposely you just keep the cows but when emergency arises you already have a security like a calf." (2)

Many farmers didn`t mention the role of their cattle as a security directly, but during the discussion on their cattle sales this role became more clear. The reasons for cattle sales show that in the majority of cases such are not production-driven decisions, which include low productivity or health issues. The reasons to sell cattle are diverse and depending on the current situation, *"She said cattle serve a purpose because you sell for money, that´s one of the reasons. For school fees. Maybe pay for medical bills. At times when you get a piece of land you can sell and buy." (26)*

65% of the farmers had sold cattle in the past 12 months. Eight farmers had sold one animal and five farmers had sold 2-5 heads.

Of those sold cattle most of them were cows or heifers. The farmers who did not sell cattle in the past 12 months were asked what common reasons for sales are for them.

5.2.2.1 School fees

To be able to send the children to school, parents have to pay school fees. When the time of paying fees comes, cash is needed. Thus, to get cash within a short period of time, cattle can be sold.

"School fees, sometimes we sell for school fees. So for a child when you need money and you have not received for tea, you can sell one, so money. Anytime you need you can call somebody and sell. Cash money – you call somebody who comes with cash and you pay the school fees. Recently one in second year now was telling me we need about 5000 for registration – so we didn´t have that money so we go to sell a cow. So those are for emergency, milk first priority, and then money can use it for school fees, so we´re having no problem with school. That´s why all of them almost are finishing school." (27)

"(School fees) totaling 42.527 (ksh). So this is what comes in now. You have to sell and then you buy another one. Than the child stays at home. Pay fees and the child goes to school. And then you struggle for." (23)

5.2.2.2 Making investments

To be able to invest in the farm or other issues, money is needed. To get that cash for investments is a reason to sell cattle, be it to buy a piece of land or to invest in the construction of a new building, as the case for one farmer,

"The reason is this building was built recently. So to make these seats inside. So I sell (a cow)." (1)

5.2.2.3 Access to loans

Having cattle can increase the chance to get loans as one farmer explained,

"…you find that a cow can be used as security also when we want to borrow loans you can use as security, the bankers can come and observe the cow and take the photo and when you go to bank they give you the cash and the cow remain as security. They can take the photo and we can estimate the value of the cow. Then now let's say the value of the cow is 30.000 shillings and you wanted to borrow 50.000 you have now to give out two cows as guarantee of the loan they can give you 50.000, they say that if this man fails to pay back then they will take the cows." (14)

For the farmers who sold cattle in the past 12 months, in 16% of all cases it was due to production-oriented driven decisions, i.e. old age of cow, low milk production or animal health issues. The farmers who didn`t sell cattle but explained their usual reasons for selling, mentioned in 7% of the motivations of selling poor milk production. Also the production-oriented issue of overgrazing seems not to play a major role when it comes to cattle sales. Most farmers already have adapted their herds to their land size,

"…for example when they calf I always sell the young calves. And that can be source of income because I cannot increase from two because the land size is small so I have to maintain two." (14)

5.2.3 Socio-cultural values and functions of cattle

When asked about whether cattle mean something culturally to the farmers, 90% told about cultural issues. Often it is a combination of several aspects that make up for a socio-cultural value. Of those 18 farmers who talked about cultural issues related to their cattle, all of them explained dowry. Dowry is a very important practice in Nandi culture.

39% of the farmers made indications that cattle are a part of their own identity, followed by 33% who described cattle as a source of wealth and a sign of prestige. Two farmers explained the role of cattle in cleansing processes and one specifically mentioned the importance of milk consumption in Nandi culture.

5.2.3.1 Dowry

Dowry in Nandi culture means that the parents of the future groom and bride get together and negotiate about the cattle that are given by the groom`s parents to the bride`s parents. It is a form of appreciating for the girl and it is a sort of bonding of the two families,

"It is a kind of bargaining, it is not an issue you buy cash, it is a kind of strong bonding of relationship between the two parents and it is a kind of appreciation you give a price." (18)

Dowry was a lived experience for all of them – be it the own marriage when the parents had arranged cattle for dowry or be it in the case of the own children, i.e. giving out cattle for a son`s future bride or receiving cattle for the daughter. Be it married children or for children that are now young and who will be married in the future. It is quite a number of animals that sum up if the family has several children, as it is usually the case,

"The girls that I have given out I have received cows from them and the boys who have brought other peoples daughters I have gave out the cows. I have four boys who are married and I have given out twenty cows, five each." (4)

Nowadays, some people are using cash instead of cattle. Several farmers explained me this new practice, but none of them has applied it in their case yet, all used and use cattle. In the past Nandi used to marry with Nandi. Nowadays more inter-cultural marriages are taking place. In times of changes nowadays it can have practical reasons to use cash instead of cows,

"They´re turned to that one now (money instead of cattle*) because … maybe you want to marry from Central, so how will you take the cows from here to central? From here to Nyanza? Because they have inter-marriage, so what you´ll if you are going for a lady from Nyanza you go there, you talk with them, you agree, you may agree 200.000; 100.000; 150, so what you do you give them in form of cash…This time, for the last 5 years we have come to this idea of giving them cash so that we don´t waste time arranging for all this.* (But still negotiate in terms of cattle?) *Yes, and that one we call dowry. Even if you pay in terms of cash." (23)*

One farmer explained that cattle don`t play a cultural role for him. He wanted to give money as he doesn`t really believe in it, but his family put pressure on him, saying that it would be more expensive in terms of money. So he went and bought two heifers, a cow and a calf (worth ksh 63.000) and gave cattle to the future wife`s family. In a discussion with another farmer on whether using cash will be more expensive, he explained his view on the issue, which showed that the terminology of `expensive` caused a misunderstanding here, but which then opened a new perspective on the whole issue,

"No. it won´t be expensive, because if the lady is learned; if earning money, if employed, the amount is so high, because they know you go and will benefit from the lady. You go and continue … even if you give out now them 200 (thousand) for maybe 5 to 10 years you´ll have recovered the ones you gave the parents of the lady. So you don´t term it as expensive because the lady is marketable." (23)

An explanation of another farmer on the issue of whether using cattle or cash for dowry indicated a challenge that can arise regarding the sustainability of using cash,

"It is necessary anyway to have cattle because you can also negotiate and give them cash, that what they do currently. They prefer using cows. You find that most families here, for example now the mother and the father when they given cash they don`t plan for it wisely, that's why they prefer cows so that they can go and keep and they can use it for their own use in the family and also the children from that family can get something out of it." (14)

5.2.3.2 Cattle as a part of the own identity

Cattle are a part of the own identity and a part of life. One farmer (22) explained that in Kalenjin someone without a cow is cast and even if poor, one must have at least one cow. Illustrating his personal importance of having cattle he compared it with having children, which are very important to have in the community – ´If you don`t have, why you don`t have?` Another farmer explained his connection with his cattle in a different way,

"And this culture; in the culture we are having those animals. We feel comfortable when they are still there – they´re comfortable, the way you can see them they´re also comfortable they´re sleeping there and happy – culture." (27)

It seems to be essential to have at least one cow to be regarded as part of the community,

"You find that according to our culture mainly a man without a cow is regarded as nobody." (14)

Or, phrased in an even more extreme way, one farmer replied to the question if he did not have cattle,

"You are seen as outcast." (18)

The own cultural identity, belonging to a community and the interpretation of cattle as a sign of wealth lie close to each other,

"We Nandis, or me as a Nandi it is our culture to have cattle in your home, because it serves a lot; As you have cattle it means that you are rich; that is our main aim. When you have cows you turn yourself as a rich man, because without cows, as far as Nandi is concerned, you are nowhere. You don´t deserve to be a Nandi when you don´t have a cow. So it is very important." (23)

5.2.3.3 Cattle as a sign of wealth and prestige

Having cattle shows that the farmer is doing right and he is regarded as ´someone`, *"When you don´t have it will not work now. You are somebody very less. It is a sign of viewing that you are hard working. You have your farm." (1)*

"You are seen as respectful person when you have cattle in the society." (8)

5.2.3.4 Other cultural related uses of cattle

That drinking milk is also an issue of culture was described earlier. Milk and murzik are also special drinks offered to visitors. The area around Kaptumo is famous for its good runners,

"When you see our runners, when they are coming from competition usually we give them murzik, that´s a sign of honour. Tradition. The mother does the work." (1, son)

Milk can be used for blessings, where the milk fat is used for the skin at a ceremony, as a blessing or also after a disaster for anointing the effected ones,

"So the same way Nandis prefer that one as something very important. Even the grandfathers or grandmothers who are very old they use to call the grandsons or granddaughters and anointing them; anointing them you put them oil on their faces and their skin, as a blessing." (24)

Cattle can be used to compensate for a crime,

"If I kill somebody by mistake we compensate the family by considering a certain amount of animals and pay the family of the deceased that curse will have been cleansed." (8)

Cattle may also be used to borrow each other in times of need. One farmer explained the option to borrow cattle to each other within the family in times of dowry,

"A relative of mine like my brother for example can come to borrow to assist him during this shorter period then they will come and recover later…for example for me I can even go up to my uncle`s place and borrow a cow and he can give then I can give as dowry and then later when I settle I can purchase and return that why you must remember this one in your mind. (You have it in your back of your mind when you have cows that you might assist somebody or you might use it for yourself in the future?) *Yes, for example if my elder sister can come here and tell me the son is going for a somebody`s daughter somewhere and we have nothing, can you assist us with one cow, that`s where you can talk with your family and surrender one cow and when they settle they can return." (14)*

5.2.4 Uses of cattle manure

Within the interview part on cattle functions, nine farmers mentioned the use of cattle manure. The most common use of manure is as a fertilizer on the own farm. Manure used for smearing was also explained by a few farmers, as it is an older practice in houses made of local materials. Smearing means that a mixture of soil, water and cattle manure is applied to walls and floors regularly.

"In some other homes, take for example now when you have not plastered the walls or the floor, because sometimes you have cemented walls, cemented floor, but some of the homes have not, so they use the cow dung to mix with the soil and you smear the walls and the floors. He is still doing." (24)

In new houses built with cement, this old practice is not necessary any more. Smearing in practice was done only by few farmers. More detailed information about manure uses by farmers is in the chapter on manure management. Although only nine farmers mentioned the benefits of manure, 18 farmers did utilize such for fertilizing.

5.2.5 Meat

In the open interview on functions, meat was mentioned only by two farmers. When farmers were asked about whether they had slaughtered cattle in the past 12 months, only two had done so. In one case it was due to a broken leg of the animal and in the other cases it was due to visitors. All other farmers that had not slaughtered in the past 12 months were asked about what reasons there would be for them to slaughter cattle for the meat. Those were special occasions, be it a ceremony (e.g. wedding, funeral), a family meeting or welcoming of visitors. Two mentioned that they wouldn´t slaughter the own animals but would buy so. Making use of the skin was specifically mentioned by three farmers. After slaughtering, skin may be used for sitting and sleeping on it or to sell it.

5.2.6 Ranking of cattle functions based on farmers` motivations

Farmers were asked to rank cattle functions according to how important those are to them as reasons why they keep cattle. The list consisted of five categories, namely ´milk for home consumption`, ´milk for sale`, ´cattle sales when cash is needed`, ´dowry` and ´wealth`.

Of the 20 farmers, 80% did the ranking exercise, the other four farmers could not or refused to do it. This shows that even if the ranking exercise didn't work at all for four farmers, it was not a matter of no relevance of the topics to them, but rather the nature of the exercise. Of the 16 farmers who did the ranking, nine did it in a complete manner, i.e. ranked all five functions. That means a total reply quote of 45% who did the exercise completely. The other seven farmers ranked only 2 – 4 functions. The analysis of the whole interviews showed that for those 6 farmers who did not rank all five functions, four of them mentioned more topics being relevant to them than the number of functions they ranked during the exercise. These reply quotes of the ranking exercise are picked up later again in the discussion part of the thesis.

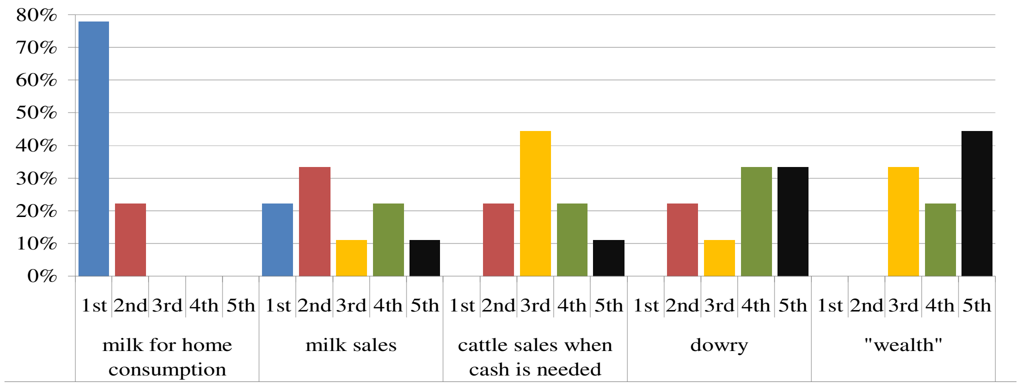


Figure 4 Ranking of dairy cattle functions (n=9)

Figure 4 shows the results of the ranking exercise, considering only the completed exercises of the nine farmers. Rank 1 as most important reason to keep dairy cattle was milk for home consumption and milk sale, i.e. milk for home consumption is by far the most often ranked number one (78%). Milk for sale (33%) was ranked second, followed by milk for home consumption, cattle sales when cash is needed, and dowry (all 22%, respectively). Rank 3 was given to cattle sales when cash is needed (44%), wealth (33%), dowry (11%) and milk sales (11%). Rank 4 and rank 5 were distributed to milk sales (22% and 11%), cattle sales when cash is needed (22% and 11%), dowry (33% and 33%) and wealth (22% and 44%). Thus, milk can be found mostly in the higher ranks 1 and 2, dowry in the mid-range and dowry and wealth was mostly ranked in the lower ranks. Given the complementing information collected during the interviews and countless conversations with the farmers during several visits on each farm, the explanatory power of these results in figure 4 is very limited. Functions are complementing each other and in this case, "counting the parts (accounting for single functions) make up more than just the sum of them". One farmer who did not finish the ranking exercise said,

"…It is difficult. They (the five functions in the list) *are all important. They all come together." (1)*

There might have been different understandings of the term ´wealth`, i.e. the meaning was explained to farmers as keeping cattle as a sign of wealth. However, it was understood in different ways, indicating that for example one thought of it as that it is an accumulation of wealth to have cattle. And one explained that all functions together those mean wealth.

5.3 Farmers` development plans

All farmers intend to increase their milk production in the future. Regarding the whole farms, the farmers were asked about the future plans for their farms. Doing more on dairying was an intention mentioned by 17 farmers. Doing more on tea production was mentioned 10 times, followed by doing more on other crops than tea (5 times) and others (6 times). Others include staying diverse; increasing the number of workers; do more on feeds and dairy; have tea, cattle and a bit of garden for home consumption; continue with passion fruits and buying land.

5.4 Economic quantification of cattle uses

For the economic allocation of GHG emissions within the LCA, the benefits of cattle of milk, meat, manure, insurance and financing were quantified. The share of each of the total economic value is shown in figure 5.

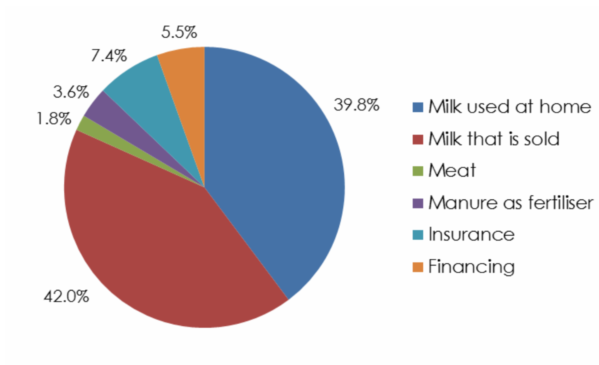


Figure 5 Shares of the total economic value of dairy cattle, including milk, meat, manure as fertilizer, insurance and financing

Milk constitutes for the largest share of the economic value on all farms with a mean value of ksh 91.765 or 82% with a range of 59 to 95% of the total value of cattle. Within the milk, on average almost half of the value of it is attributed to milk consumed at home (10 to 82%). Meat played a role for only two farmers. Both cases were due to special occasions, i.e. welcoming visitors, and in one case it was due to a broken leg of a cow. The economic value of manure is on average 4% of the total value or ksh 3.201. Some farms used no manure for fertilizing whereas the farm with the highest manure use comes to an economic value of ksh 14.082 per year equal 13% of the total value. The value of cattle as insurance constitutes ksh 1.800 to ksh 21.120 or on average 7% of the total value on all farms. The benefit of cattle for financing is accounted for 50% of the farms as they sold cattle in the past year due to reasons of finance and with the highest value of ksh 18.240 and an average share of the total economic value of 5%. The results for each farm are in the annex.

5.5 GHG emissions of dairy production and CF of milk

Total GHG emissions per farm were on average 6.795 kg CO_2-equivalents (1.243-21.842, see table 4).

Table 4 Greenhouse gas emissions of the 20 dairy farms (in kg CO_2-equivalents)

	Enteric fermentation (CO_2)	Manure (CH_4)	Manure (N_2O)	Feeds-related (CO_2, CH_4, N_2O)	Total
Mean	5.461	107	4	1.224	6.795
Min.	1.020	20	0	72	1.234
Max.	14.810	289	15	6.739	21.842

The largest share of emissions is due to methane of enteric fermentation with on average 83% of the emissions. That emission hot spot is followed by greenhouse gases produced in feed production with on average 15% of the emissions. Of those feed emissions, 72% occurred off-farm and dairy meal was the most important source of emissions. This is due to the fact that there are no other emission hot spots as for example from mechanical field work and respective fossil energy use. Furthermore, the CF of dairy meal was computed as 1.36 kg CO_2-equivalents/kg dairy meal and those emissions are much influenced by the rice bran, which is associated with methane emissions in rice production.

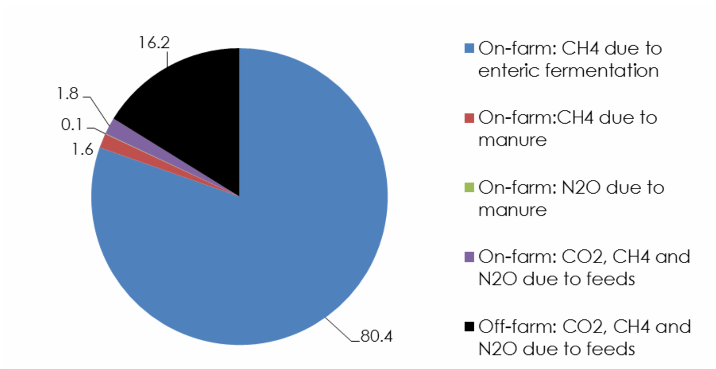


Figure 6 Greenhouse gas emission spots at the 20 dairy farms (in %)

5.5.1 CF of milk production with economic allocation to milk and meat

The CF of milk production without allocation is on average 2.1 CO_2-equivalents/kg milk, ranging from 0.9 to 4.9. Meat played on only two farms a role. On those two farms, the CF of milk changes from 3.9 to 2.6 and from 1.6 to 1.4 kg CO_2-equivalents/kg milk considering milk only or milk and meat, respectively.

5.5.2 CF of milk production with allocation to multiple functions

The CF of milk production with economic allocation to milk, meat, manure as fertilizer, insurance and financing is on average 1.7 kg CO_2-equivalents/kg milk and ranging from 0.8 to 3.3.

5.5.3 CF of milk production with allocation based on farmers` motivations

Applying the allocation based on farmers´ motivations, the mean CF result is 1.1 kg CO_2-equivalents/kg milk, ranging from 0.5 to 1.7 kg CO_2-equivalents/kg milk. Between 40 and 60% of emissions are allocated to milk in this scenario due to the fact that farmers ranked milk for home use and milk for sale as the most important reasons why they keep dairy cattle.

5.5.4 Comparison of CF of milk production using different allocation techniques

CF results of milk production differ depending on the allocation technique applied (see summary of results in table 5). Emissions are highest when no allocation is performed, followed by allocation to milk and meat. The latter was only the case for two farms. The emissions further reduce from no allocation to economic allocation regarding five functions by on average 0.5 kg CO_2-equivalents/kg milk (0 – 1.6). When applying allocation based on farmers` motivations, the CF reduces to a mean of 1.1 CO_2-equivalents/kg milk.

Table 5 CF of milk depending on allocation (in CO_2 -equivalents/kg milk)

Allocation technique	Mean	Range
No allocation	2.1	0.9 - 4.9
Economic allocation to milk and meat (two farms)	3.9 →2.6 1.6 →1.4	-
Economic allocation to milk, meat, manure as fertiliser, insurance and financing	1.7	0.8 - 3.3
Allocation based on farmers' motivations	1.1	0.5 - 1.7

5.5.5 Sensitivity analysis

A sensitivity analysis was performed for an average farm regarding the amount of total GHG emissions to test the effects of certain input values on GHG emissions. Results are presented in Table 6. The largest effect on emissions is associated with a change in the methane conversion factor, i.e. implying an alteration of 8% of GHG emissions. A 10% increase of manure stored in dry lot and 10% increases of DAP of manure as fertilizers do not noticeably change the results of GHG emissions. This may be due to limited impact on overall emissions on the dairy farm and due to the fact that inputs are currently rather low meaning that a 10% change does not imply a noticeable change.

Table 6 Sensitivity analysis: Effects of changes of the amounts of applied dairy meal, DAP, manure, manure management or methane conversion factor (Values are indicating the percentage of change of GHG emissions due to the respective alteration)

Baseline: Farm 26 (CF=2.5)	
+/- 10% manure in dry lot	0.0
+/- 10% Ym	8.5
+/- 10% DAP	0.0
+/- 10% Manure	0.0

6. Discussion

The following discussion is written in a loop just as this research is, i.e. beginning at the starting point (method), moving along the learning path (field research) to then get back to the question started with.

6.1 LCA methodology and multifunctionality

The review on the LCA methodology with special attention to the aspect of how it handles multiple outputs of a system showed that products are understood as goods or services. The understanding of cattle functions as products in this thesis is thus in line with the understanding of products in LCA. Here, products are seen as goods and services of a tangible or intangible nature, just as stated in the LCA guidelines where services have tangible and intangible elements (14044:2006, 3.9). The literature review about multifunctionality demonstrated the various ways livestock serve their owners. It is argued that you can call those goods, services or outputs of a systems as products or in LCA terms, co-products, which are one or more products coming from the same production system (14044:2006, 3.10). In the case of this Kaptumo case study, six main products were identified, i.e. milk, meat, manure as fertilizer, insurance, financing and socio-cultural values. The latter involve both social (e.g. cattle as a part of their owners` identity, cattle providing acceptance and social status for their owners in a community) and cultural factors (e.g. the use of cattle for dowry). These six products are production system-specific features. In other systems, different products may be of importance, e.g. draft power. In LCA, a co-product is defined as "any of two or more products coming from the same unit process or product system" (ISO 14044:2006, 3.10) and it is debatable what in a system like those under study are the main and what are co-products, thus e.g. there are many main products or as the presentation of the endemic views of farmers revealed, the multiple products all come together and the value of cattle needs to be understood as a cluster of all those together.

Depending on the socio-cultural context, the economic and natural environment, such products can be of very high or low importance for farmers as reasons why they keep their livestock. For example in dairy systems in countries such as Germany or The Netherlands, clearly the production of milk is the most important output of the system and thus the most important reason for farmers to keep dairy cattle. In the Kaptumo case it appears to be more complex. The intangible nature of some products challenge a sound assessment. So, in this study several methods of social and natural science were used, i.e. interview techniques, ethnographic method and structured questionnaires to collect information about why people keep their cattle, how they use them and what they mean to them.

Within the LCA guidelines, the FU is defined as the "quantified performance of a product system for use as a reference unit" and "shall be clearly defined and measurable". Soft parameters like cattle as part of cultural identity are definable, but not commonly measurable. To allocate emissions, three different techniques were applied which are discussed in chapter 6.4.

6.2 Inclusion of multiple functions in LCA using different allocation techniques

6.2.1 An attempt to grasp multifunctionality: Economic quantification

Economic allocation and thus, economic quantification of products was applied, because it provides an opportunity to include functions into LCA and because economic allocation is an established procedure in LCA on dairying.

6.2.1.1 Milk

To compute the economic value of milk, the average producer price of ksh 27.5 as paid by the local cooler Kapcheno Dairies was applied to the milk output of a farm. Most farmers sold a part or even all their milk to Kapcheno Dairies. Other buyers were local hawkers or workers of the tea plantations. Milk constituted the largest share of the total economic value of cattle for all farmers with on average 82%. About half of this value is associated with the amounts of milk consumed at home. Thus, the inclusion of home consumption is very essential as it makes up for almost half the amount of milk produced. Behnke (1985) argues that milk consumed at home should have the value of milk as bought in the shop (the idea of replacement). This would imply a higher value of milk as prices in the shop are above producer prices. One could also argue that when people have less or no own milk then they would in general consume less milk and not replace all of it through buying. Thus, the application of the producer price was applied here.

Generally, the personal observations and interviews with farmers revealed that milk is an essential food in Kaptumo for multiple reasons. First, it provides protein in the diets which are very much plant-based. Especially the value for children is acknowledged and providing children with some milk has positive impacts on health and child development (e.g. Neumann et al., 2003). Furthermore, milk is important in a cultural way for Nandi people. It is important for people to have own milk at home and milk at home is not the same as milk you buy in a shop. In special occasions, for example when there are visitors, those are given milk or murzik as an appreciation.

It is obvious that the applied method of economically quantifying the value of milk only reflects a part of the real value of it. The value is simplifying the real value of milk and nutritional and socio-cultural values attached to milk and positive impacts on people`s health are not accounted for in an economic value like this.

6.2.1.2 Meat

Using their cattle as a source for meat was the case for only two farmers. Two times young animals had been slaughtered due to a special occasion and to welcome visitors, and one cow was slaughtered due to a broken leg. To quantify the economic value of meat, the respective price as a local butcher would pay for was applied. One could argue to follow the replacement idea as for milk by Behnke (1985), i.e. to consider the costs a farmer had to cover when buying the meat in the shop. As in the case of milk, this replacement idea leaves the question if people would actually buy the same amount of meat then. This approach also complicates an economic quantification further as in that case all other parts than meat (e.g. hides, organs) need to be quantified due to the fact that in Kaptumo all parts are utilized and have an economic value.

The three cases of slaughtering show that cattle are very valuable and too valuable to be consumed as a source of meat as such. The interview outcomes underline this finding, as all farmers argued that slaughtering is done only in special events as for example a ceremony like a wedding or to welcome visitors. Another aspect is the socio-cultural importance in slaughtering cattle in special events. Slaughtering an animal is considered as something very special. In the applied method of economic quantification those special and much intangible characteristics are not accounted for and are as in the case of the milk challenging to grasp.

6.2.1.3 Manure

In the case of Kaptumo manure is used for fertilizer and for smearing houses and floors. The latter is left out in this thesis, because only a few farmers used manure for smearing and if so, it was only a small amount of manure that is usually mixed with soil and water. The utilization of manure for fertilizing was limited and on average 30% of the available manure on farms. Most manure was left on the paddocks. To calculate the economic value of manure as fertilizer, the replacement idea was applied, i.e. what the equivalent amount of nitrogen would cost. The fertilizer values are calculated as a function of N contents and the equivalent values of synthetic fertilizers. However, manure has positive impacts on soil structure and water holding capacity of soils and can be a part of a sustainable nutrient cycle of a mixed farm. To account for those positive effects is challenging and due to the complexity not done. Another option would have been to look at yield gaps, i.e. what crop yields are like with and without manure. The advantages of the latter method do not outweigh the additional work it requires and the benefits to the chosen method here. Besides the nutritive values of manure and the additional positive effects of manure on soil structure and soil organic matter there is also the benefit of nutrient cycling on farms.

6.2.1.4 Insurance and financing

For the value of cattle as insurance a value of 6% of the economic value of the herd was applied, which is in line with previous works (Bebe et al., 2002; Moll et al., 2007). The economic value of cattle as insurance was thus ksh 1.800-8.021 or on average 7% of the total economic value of cattle and larger herds mean a higher insurance value. Now there is the National Hospital Insurance Fund which is available to Kenyan citizens and in line with the costs and benefits of that insurance, Behnke and Muthami (2011) applied an insurance value of 0.48%. Applying this percentage would have resulted in a lower insurance value of cattle. However, this option of health insurance did not seem very present in the field research location. The benefit of insurance does not only cover health issues, but all kinds of cases where an insurance is beneficial, e.g. in case of crop damages due to extreme weather effects.

6.2.1.5 Socio-cultural functions

There are several socio-cultural aspects related to cattle keeping, i.e. cattle are a part of the cultural identity, they are used for cultural purposes (dowry) and they are a symbol of wealth. No previous studies could be identified which had quantified all those functions in economic terms, e.g. Scoones (1992) commented that cattle and goats as part of ceremonial activities "cannot be assessed in terms of a quantitative comparison, but should not be ignored". The fact that such a function is not straight forward complicates the issue even more. To give an example, cattle for dowry plays a role for most farmers and also all farmers have been or will be involved in dowry. But this does not necessarily mean that they keep their cattle for that reason. This reminds of a study on cattle in Madura, Indonesia where Widi et al. (2013) found that although cattle races were very popular for people, the farmers did not primarily keep their cattle for races. But the races kept the sale prices of cattle at a high level. Furthermore there are not just the direct contribution of livestock to wellbeing of their owners, but various indirect effects and interactions with other activities.

Moll (2005) quantified the value of cattle as prestige, but this approach gives only a partial picture and the method of quantification is debatable. There are two issues here open for discussion why there is no quantification for socio-cultural functions. First, it is not possible to find economic values to apply to those functions. For example, how can one estimate the economic value of cattle as a part of cultural identity? Possibly the theory of replacement, e.g. with durable consumer goods could give indications, but only to a limited extend. Secondly, it appears that at this point there is a border, as an edge of a cliff of our way of thinking and putting things in boxes that make sense in our line of how we look at the world. And here also comes in that there are limitations in our Western civilization dominated perspective in looking at livestock production systems only with our lense. In context of the different perceptions towards cattle compared to a cultural background of for example Germany, to give economic values does not reflect its values. It appears as with the LCA and kind of thinking and thus with a cultural bias, we assume that there is a kind of an universal reality. Already in 1985, Behnke discussed this issue, although in a different setting than LCA. His approach confronted research in agriculture and its problem of "cross-cultural objectivity". He calls for "working backwards", first to understand production systems and then out of that to come up with expressions that reflect its nature. To some extend this approach was applied in this case study with trying to understand the endemic perspectives of farmers. Combined with an extended field research duration the attempt was made to understand the production system from a perspective that is more close to the one of the farmers and embedded in the social and economic environment.

6.2.2 Valuation of cattle functions based on farmers` motivations

The method of allocating GHG emissions based on farmers` motivations opens the door to another perspective of cattle functions. First of all, it is based on the functions farmers expressed themselves as the ones being most present to them. Thus, the categories slightly change to those in the economic quantification. They were defined by the farmers as milk for home use, milk for sale, animal sales when cash is needed, dowry and wealth. Animal sales when cash is needed reflect what under the economic quantification is the insurance and financing benefits of cattle. The five categories here were identified during the first set of informal interviews and manure did not appear in this identification of functions. This could be explained by either that those farmers of the informal interviews did not use manure or that the use of manure is not a primary function that is not consciously present. The latter could in part be explained by the cultural background of Nandi people as herders. Second, this method provides an opportunity to value functions in an alternative way and not based on economic terms, which enables the inclusion of socio-cultural aspects that were excluded in the economic allocation technique. On the other hand there are also issues for debate, i.e. the success rate of the ranking exercise of nine of twenty farmers being able to do the exercise in a complete manner shows that there is a limitation regarding the fitting of such an exercise to farmers` perception that they have towards their cattle. Furthermore, different ranks imply an equidistant difference regarding the importance of the functions which might not be always the case. Concluding, the method of allocation based on farmers` motivations provides a new perspective on the value of dairy cattle functions and the respective CF of milk. At the same time the method needs to be understood with its opportunities and limitations.

6.3 Moving from the desk ´into the field`: Doing LCA on the ground

LCA and GHG emissions lie outside the reality of most farmers which makes explaining the issue strange. This whole topic does not play a role in everyday life. LCA and GHG emission lie outside the realities of farmers as they face other problems and questions.

Due to the data demanding character of the LCA tool and the intention to understand the systems beyond their bio-physical characteristics, on-farm data collection was covering many different topics from social aspects of functions and meanings of cattle to the more production-oriented topics of management. LCA is a data demanding tool and in this study numerous data related to the management of dairy cattle needed to be collected to compute the CF of milk. Data collection comprised qualitative and quantitative information and took quite some time in the field and several visits of each farmer. The structural setup through MICCA and EADD was very useful in two ways. First, because it made it easier to access farmers as to be embedded in an existing frame of on-going activities and second, because it enables giving feedback to farmers even after the time of field research.

Data collection as such was an experience of itself. First, data collection is never done as such, but always embedded in a bigger social frame and act, because a researcher is a person, who meets other persons. Secondly, the data collection as such faced several challenges which lie in the nature of field research. Respondents did not always know the answers to some questions, due to the fact that some questions were not valid in their perspective, i.e. the nature of the question was outside their reality. This was the case for example for the ranking exercise. In other cases questions remained open because there was little to no data recording on the farms. Three examples are discussed in the following sections, being milk yields, feed baskets and manure uses.

Example 1: Estimating milk yields

Collecting information about yearly milk yields for each cow was a challenge due to the fact that there was limited to no milk recording on the farms. The use of milk for home consumption and sale appeared to be a more comprehensive question and thus led to the idea to use calendars of the past year on hand which supported in the process of estimates by farmers on their milk uses, i.e. how much milk the household had been consuming and how much milk been selling in those months. This perspective, i.e. the handling of the milk on a daily basis, is something that seemed more logical and close to reality than the abstract idea of calculating a cow milk yield over one year. Another advantage of this approach is that the herd changes are automatically accounted for as milk uses depend on the number of lactating cows. After this field research experience the question appears how other surveys handle this issue, i.e. asking farmers about a yearly milk yield of a cow can be a very difficult and abstract or maybe even impossible question.

Example 2: Manure uses

Manure was used by 90% of the farmers, but only in limited amounts. Manure used as fertilizer is another question that many farmers reacted with laughing to. Usually people do not measure or quantify the amounts of manure they apply to their crops. In extended interviews information for each crop and amounts farmers usually used were collected, e.g. in buckets, bags or wheel barrels. These estimates were later translated into kg of DM manure. The amount of manure stored was impossible to quantify due to varying practices of direct application or storing in bags or open heaps for different time frames. Thus, an estimate of amount of stored manure was necessary and based on own observations in the field and farmers estimates.

Example 3: Feed basket

Feed inputs appeared to be another challenge to obtain good quality data due to the fact that farmers usually do not measure and do not record what they feed. The direct question about feedstuffs and amounts fed appeared to be an invalid question and too abstract. Facilitating a better understanding of feed amounts, feeds were weighted during feeding hours. Feeding calendars, i.e. a drawn calendar of the past year supported getting estimates in a step-wise approach. First, utilized feeds were listed for each month. Then average amounts expressed in local units (e.g. bags, buckets) were estimated by the farmers. The information was later translated into kg DM feeds. This approach is more labour-intense for the researcher than if the information was collected simply through an interview as such, but it gives a better picture on what actually happened. Using feeding calendars as here offers an opportunity to tackle the question of feed baskets and the challenge of filling or improving otherwise missing or unreliable information.

Regarding those examples of milk yields, manure uses and feed baskets, the ultimate solution would be actual measurements. But measurements require time and labour and if both of them are limited, then the applied methods as described here at least offer opportunities to collect the data.

6.3.1 Farm systems, cultural background and dairy cattle management

Dairy farming is to be understood as one activity among several on the mixed and diverse farms as the results on household compositions and farming activities reveal. Responsibilities and tasks are shared by the man and wife of a household. All farmers were Kalenjin and 80% belonged to the local Nandi community, a sub-group of the Kalenjin. Kalenjin are originally cattle keepers and herders. Men used to herd cattle on common grazing lands while women and children stay at a homestead. Cattle keeping used to be the main activity besides growing some millet, sorghum and other local crops. Cattle used to be the main asset and an object and part of Nandi culture.

Originally the area around Kaptumo was covered by forests, which were destroyed during the last century. German and British colonial settlers introduced tea, maize and also brought high potential yielding dairy animals with them. During the colonial times, tea growing was only for white people as also the keeping of improved dairy breeds was not allowed for locals. To give an example, a story by one of the interviewees was that one time a dairy bull of a white farmer had jumped the fence and bred a local cow of a local farmer. When the local cow calved a crossbred animal, the white farmer accused the Kenyan and went to court to achieve a punishment for the local farmer. It was only due to a number of witnesses that the local farmer was proven to be not guilty. After independence in 1964, white settlers gradually moved away. Today one of the main reminders of colonial times are the tea plantations e.g. the vast tea monocultures owned by tea estate companies which dominate the landscape close to the study location area. Another colonial reminder is the prevalence of Friesian and Ayrshire cross-bred animals. Originally local breeds known as Nandi cattle were kept in the area, roaming in and along the forests and on common grazing pastures. The dairy animals of white settlers were interesting for many local farmers due to their higher milk yields compared to the local cows. When the white settlers were moving away, local people bought the dairy animals and/or crossed with their local cows. That is the reason why nowadays almost only crossbred animals of Friesian and Ayrshire can be found. People commonly talk about those two breed names when they characterize their animals. However, these are not pure-bred but crossed animals which in part have some local breed origins as well.

Due to the growing population, the original landscape of forests and common grazing lands were transformed into less forests and the domination of private properties. Around the study location most land is owned by smallholder farmers who have mixed farms, i.e. tea growing, dairying and cropping of subsistence and crops for sale. In view of history, it is worth noticing that lifestyle and production systems changed drastically in only a relatively short period of time. The population is continuing to grow which will cause challenges in the future as land sizes are becoming smaller. It appears as there is a transition of farmers between tradition and modernity. The idea of marketing milk and e.g. by the installment of the local buyer of Kapcheno Dairies through the EADD pushed towards a more business oriented way of thinking, i.e. dairy as a business.

6.4 GHG emissions of dairy production and CF results

6.4.1 Total emissions and emission sources

The majority of total farm emissions of on average 6.795 kg per year CO_2-equivalents occurred on-farm (87%). The amount of total emissions is explained by the capital-extensive nature of the farming system as there is no mechanization, little use of concentrates and synthetic fertilizers and thus, no burning of fossil fuels associated which are associated with high emission intensities.

Between emission sources, the largest share of emissions of on average 83% were associated with methane emissions from enteric fermentation. Those high shares are related to the nature of ruminant digestion and influenced by the quality of the feed. Feed digestibility was estimated at 65% and a lower feed digestibility is associated with higher methane emissions due to enteric fermentation. The other important aspect influencing total methane emissions from enteric fermentation is the number of cattle. Due to difficulties in obtaining exact ages of calves, a further sub-categorisation of young stock into suckling calves and older ones was not possible. It could be that emissions related to young stock due to enteric fermentation are thus overestimated as emissions differ between age groups, i.e. younger calves produce methane not at all or in very limited amounts. Generally, the number of bio-physical unproductive animals has a strong effect on the CF results as the total emissions are later divided by the kg of milk produced. Here comes in the aspect of "not productive", i.e. as elaborated earlier from a production point of view it is inefficient to keep animals that do not produce milk. At the same time those animals are kept because they serve as a security and have a high socio-cultural value. These aspects explain why “unproductive” animals are kept and why thus emissions due to enteric fermentation make up for such a large share of the total GHG emissions.

Emissions due to feed production with on average 15% of the emissions was the second most important emission source after enteric fermentation. Within emissions due to feed production, on average 90% of the emissions were due to the use of dairy meal. This is due to the fact that there are no other emission hot spots as for example from mechanical field work and respective fossil energy use. Furthermore, the CF of dairy meal was calculated as 1.36 kg CO_2-equivalents/kg dairy meal and those emissions are much influenced by the rice bran, which is associated with methane emissions in rice production (Phong et al., 2011).

During on-farm feed production manure and DAP fertilizers were applied, which are associated with nitrous oxide emissions in crop production. Due to the limited amounts of these inputs, direct and indirect N_2O emissions in feed production are low. For fodder crops as Napier grass and Boma Rhodes, all emissions are allocated to the feed, as 100% of the plant is used for feeding. In cases of crop residues, the fraction of biomass used as feed is less, e.g. 0.2 for banana residues and 0.9 for maize residues fed to cattle.

Regarding on-farm emissions due to feed production it appeared that in cases the amounts fed to cattle were higher than the amounts the farms could have produced on their land sizes. This could be due to different reasons, i.e. amounts of feeds were overestimated, or land sizes for each crop were underestimated or the yields for each crops were underestimated or a mixture of all three. The sensitivity of amounts of feeds actually showed to be low why this discrepancy was left as it is. Within the feed GHG calculations, the values for FCR (the annual amount of N in crop residues, and from forage/pasture renewal, returned to soils annually), were in cases negative. This can be explained by the nature of the calculations as the amounts and N contents of above and below-ground biomass are calculated on IPCC data (IPCC, 2007). The respective data inputs are average values why the actual above-ground crop residue removed in form of feed can be at times higher than the calculated amounts available. Due to a low sensitivity of the FCR on CF results, in cases where negative balances occurred, those were put at zero.

Methane and nitrous oxide emissions in manure management accounted for on average about 1% of the total emissions. This can be explained by the limited amount of manure that is handled and stored on farms. Furthermore, all manure was stored in dry lot, which is a manure management system associated with low emission factors compared to liquid or slurry systems.

6.4.2 CF of milk using different allocation techniques

The CF of milk production was on average 2.1, 2.0, 1.7 and 1.1 kg CO_2-equivalents/kg milk using no allocation, using economic allocation to milk and meat, applying economic allocation to milk, meat, manure, insurance and financing and the alternative allocation based on farmers` motivations behind cattle keeping. The difference of the CF of milk between no allocation and allocation to milk and meat is small due to the limited use of cattle for meat and thus, on most farms no economic value of cattle for meat. The inclusion of milk, meat, manure, insurance and financing using economic allocation reduces the CF of milk as on average 82% of emissions are allocated to milk in that case. In the last allocation method on average 54% of the emissions are allocated to milk which reduces the CF of milk further. If in line with the allocation technique based on farmers' motivations emissions were allocated equally to the five domains defined by the farmers (means 20% of GHG emissions to each function), the CF of milk would be even lower than on average 1.1 kg CO_2-equivalents/kg milk. The results show that the products included and the allocation method have strong impacts on the CF of milk.

Up to date there has been very limited research on LCA considering multiple functions of livestock. In a study on the CF of lamb meat, Ripoll-Bosch et al. (2013) compared three contrasting meat-sheep farming systems characterized by different degrees of intensification. The CF of a kg of lamb meat was highest in the pasture-based system. When accounting for multifunctionality which meant the inclusion of other services to society than meat as biodiversity and landscape conservation, the CF results of lamb meat changed and the pasture-based system showed the lowest CF of the three sheep farming systems.

There are few studies that can be used for comparisons of results as there has been limited research of CF on smallholder dairy systems. In an LCA study on dairy systems in Ethiopia, Woldegebried (2013) came to CF results of 2.3 to 8.5 kg CO_2-equivalents/kg milk for intensive and rural systems when applying no allocation. When economically allocating considering multifunctionality (including milk, animal, manure, insurance, financing and social status) the CF of the rural system changed to 1.5 kg CO_2-equivalents/kg milk. In a desk study on smallholder dairy systems in Kenya, Modupeore (2011) calculated a CF of 2.57 and 1.67 kg CO_2-equivalents/kg milk for free grazing systems using economic allocation to milk and meat and economic allocation including more functions, respectively. The results of this study applying economic allocation to multiple functions are comparable with those two studies of Ethiopian and Kenyan cases, although here the CF is not as extremely changing when applying no allocation as in Woldegebried (2013).

Compared to specialized and high producing dairy systems as in OECD countries, the results of the CF of this study using alternative allocation based on farmers` motivations are in the range of results of 0.84 to 1.3 kg CO_2-equivalents/kg milk (de Vries and de Boer, 2010). Thus, from an emission intensity point of view related to kg CO_2-equivalents per kg of milk, the systems in the Kaptumo case are not performing worse than high producing, specialized farms. This result is contradicting previous study results which did not consider multifunctionality in dairy systems, e.g. the CF of milk in this study using economic allocation and considering the five functions mentioned above are below the CF results of the global study on GHG emissions of dairy systems, which were 2.4 and 7.5 kg CO_2-equivalents/kg milk for the global average and for Sub Saharan Africa, respectively (FAO, 2010).

Due to such changes in emissions per kg of milk, a direct comparison of specialized systems with multifunctional dairy systems is thus not correct when ignoring other products than milk and meat as those other system outputs as manure, insurance and financing also play an important role on smallholder farms as in Kaptumo. Accounting for multifunctionality using economic allocation still reflects only a partial picture due to socio-cultural values that cannot be accounted for in economic terms. Therefore the alternative of relating the GHG emissions to the products based on farmers` motivations behind cattle keeping provides a new angle on the whole issue. Here, the products are defined more from a farmer`s point of view and that is much different to that of a dairy farmer e.g. in Germany. In the latter, the production of milk is the most important reason to keep dairy animals and the motivation behind dairy production is more strongly dominated by economics compared to a farmer in Kaptumo. Due to the different nature of those systems they cannot be analyzed in the same way, i.e. applying the production units of LCA of specialized farms does not work for smallholder, mixed systems, because too many significant products are then left out. This is also started in the LCA guidelines as “the deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study” (ISO 14044:2006, 3.32 and 4.2.3.3.1). Thus, this study of one multifunctional dairy production system leads to the conclusion that if one compares production systems with different degrees of specialization it is not correct, because the systems functions differ. It is possible to allocate emissions accordingly to correct for such system differences, but if there are functions involved which are not quantifiable then there lacks a common reference unit.

6.5 Mitigation and improvement options

To find the best mitigation options within mixed farming systems as in the Kaptumo case, it makes more sense to assess the whole farm as the most effective GHG mitigation options may lie outside the dairy component. In the Kaptumo case study one example of another area for mitigation options could be the cooking devices as women usually cook with wood. A stove ("rocket stove") has been introduced by the GIZ (German Agency for International Cooperation) which reduces firewood use and smoke. Most farmers around Kaptumo use the traditional wood stove for cooking and it needs a lot of firewood to cook. In the area is also the rocket stove, which reduces the amount of firewood needed as well as the smoke related to burning. Besides the positive effect regarding less smoke and CO_2 emissions, such a stove has positive impacts on health due to less smoke, on work load and costs for farmers to get fire wood and less pressure on the anyway decreasing forest areasAnother example is fertilization in tea production. Farmers usually do not use manure or compost but only synthetic fertilizers on tea. The farmers fertilized their tea not with manure or compost, but exclusively with synthetic fertilisers. No farmer could really explain reasonable arguments for this practice, but it seemed to be more of a thing they were advised to do. Synthetic fertilizers are from a GHG emission point of view not good and also very costly for the farmers. One can wonder if such a kind of advice is not connected to a business strategy, i.e. sales of such fertilizers.

Within the dairy component, feeding and manure management provide two fields for opportunity to improve. Feeding has been challenging due to dry seasons, feed shortages at times and limited feed conservation on farms. Here the use of leguminous fodder shrubs are an opportunity with several advantages, i.e. N-contents are comparable to those in commercial dairy meals and plants have positive impacts on soil conservation and can be integrated in-between crops. More manure utilization and composting to recycle more nutrients on the farms is another option. A central issue is extension service, i.e. if farmers have the opportunity to receive training they are enabled to make different management decisions which are best for their individual situation. An assured market for milk with stable producer prices is maybe the most important issue. Farmers want to increase their milk production and income through dairying and a stable income increases the motivation to change management practices. LCA mitigation options thus need to be understood and designed in line with that.

6.6 Summarizing remarks

The critical review regarding the methods of economic quantification of dairy cattle functions shows that there are still many aspects left out in an economic value or that are debatable. There is a limit to the here applied methodology in economically quantifying functions. The issues of socio-cultural values cannot be economically expressed in a proper way. And when quantifying the other functions as explained above, also some aspects still get lost, e.g. the positive impacts of milk consumption to child health. In fact, big parts of the experience and understanding of cattle in a production system as in Kaptumo gets lost in the LCA frame and along the way of calculations. There are weaknesses and costs to it, but also opportunities, i.e. the fact that the issue is put on the table of discussion, because when leaving them out completely, a very small part of the production system is reflected. But when trying to include them major challenges are ahead. Including various functions changes the perspective of the research on the topic and the research object. It gets more complex. And in the attempt to get closer to reality, one realizes on the way that there is a limit. Are we facing two worlds here? LCA and the living experience as cattle as a livelihood are different worlds? The personal experience in the field showed that if only the classic production focus with the focus of attention on milk and meat production of the dairy farms had been considered, data collection would have been quicker and much simpler. But through extended time in the field and openness towards what there might be important regarding why people keep cattle, many more issues came clear. All those parts of social and cultural meanings of cattle as well as the importance as insurance and finance would have been missing in a study considering milk and meat production only.

In some way this issue here in LCA seems to have been present before, i.e. the focus of livestock research and policy measures has been on production and productivity in the past, and as Bosman et al. (1997) puts it this focus is valid and useful but it is important to keep in mind that farmers have more goals as well as there are differences in understanding production and productivity between farmers and researchers. They argue that “the objectives in research and improvement programs should be set in relation to this comprehensive perspective on livestock keeping“. In the past “livestock development policies generally focused on marketed inputs and outputs of livestock systems and on services directly linked to these” (Behnke, 1985 cited in Moll et al., 2007). “Livestock keepers, however, usually take a wider viewpoint that takes into account their institutional environment, which is characterized by absent or ill-functioning markets for products, production factors, insurance and finance. As a result, they view the non-marketable by-products of their animals (e.g. manure), consume part of products themselves and appreciate the intangible benefits of livestock in insurance, financing and display of status. The additional value gained from non-marketed products and from the intangible benefits often means that small livestock producers are more competitive than policy-makers generally view them to be" (Moll et al., 2007). In their analysis of the contribution of Kenyan livestock to the economy, Behnke and Muthami (2011) confirm concerning Kenya the argument that livestock production is underrepresented in the GDP estimates.

The impression that the GHG debate repeats previous similar story (already in the past the focus was always on the marketable products of livestock, e.g. when designing policies) may in part be due to the way politics and research commonly think and work, i.e. much in metrics, measures and numbers. One could just leave it like that if there were not the implications on the overall conclusions of such a CF study. The CF of milk changes depending on accounting for other products or not. Thus, conclusions of such a study change.

According to the LCA guidelines, comparisons of systems should be done on the basis of the same functions. If additional functions are left out, it needs to be explained. Thinking about this LCA and previous LCA studies it opens the discussion whether it is correct to compare systems with such very different outputs and intensities as it is the case for example of a farm of this Kaptumo study and a typical dairy farm in Germany. Deletion of life cycle outputs is only permitted if it does not significantly change the overall conclusion of the study. When something is omitted, it needs to be explained why. In previous LCA studies other products than milk and meat have been left out and mostly it is argued with the difficulties of obtaining good quality data and how to grasp intangible livestock products. Researchers often back away from certain system outputs due to their complex and intangible nature, but it must be clear that conclusions of a study change, depending on which outputs are considered. Whether research has taken this issue serious enough is debatable.

Smallholder, mixed farms like those under study in Kaptumo are complex. Farmers are struggling to make a living for their families and to send all their children to school. One can wonder if LCA should be done on such kind of farms for several reasons. Due to their nature of having many farming activities interconnected on their farms, an LCA that looks only at one farming component covers only a limited part of the farm. The most effective mitigation options might actually not be in the component of the LCA focus, i.e. in this case very effective mitigation options may lie not in the dairying, but how people manage their tea or what kind of cooking stoves they use.

Another aspect of wonder about LCA on such farms is what LCA actually covers and what not. This study shows that there are weaknesses in the methodology, i.e. important aspects of a dairy production system as multiple functions of cattle to their owners are usually left out. If one tries to include them as done in this study and with the methodology of economic allocation still a lot of the value is not accounted for, especially when it comes to socio-cultural meaning and importance. Thus, LCA reflects only a very limited picture of a production system. It comes clear that LCA is an industry tool in its origin and as such cannot cover the complex faces of agricultural systems. Here comes in the discussion if agriculture is an industry. Characteristics of so called "modern" ways of farming of relying on feed imports from across the globe and a lot of fossil energy use due to high levels of mechanization are much different compared to the ones in Kaptumo. Here, the approach of allocating emissions related to farmers` motives behind cattle keeping provide a new perspective on emissions.

Another aspect of questioning the application of LCA to such systems is the point of data need and data accuracy. Even when doing a study in the field with the best intentions to get farm data that is as exact as possible, there are clear limitations. Due to the complex nature of smallholder mixed farms like in this case, most things are not as straight forward. And many things are not recorded (e.g. milk yields or feed inputs) and as a researcher one needs to come up with methods of getting rather good estimates than poor ones. The quality of some of those estimates is debatable, but are the best one can get in such a field research situation. The alternative are actual measurements on farms over a period of time, which are money and labour intensive. Also the data demanding nature of LCA as such is a challenge, because it requires intense interviewing and observation in order to come up with better data and that is energy demanding for both researcher and farmers.

Additionally to estimates one has to make about farm data, there are a number of uncertainties in the factors and data inputs given by the IPCC. An example are emission factors, i.e. how much applicable they are for cows in the tropics. The research that actually did measurements of greenhouse gases in the tropics goes to zero. So basically one is dealing with modeled values and extrapolations in many cases.

When interacting with farmers and trying to explain the issue of climate change and greenhouse gas emissions, it comes clear that those are not issues close to the reality of most farmers. The chance that farmers adapt management strategies that reduce GHG emissions is only realistic when farmers see a clear advantage for them. And that can be through better productivity and increased income. Those are also the issues the Western world should focus on when interacting with farmers, to look for options how to best assist them so that they can help themselves to improve their farming systems and to make a better living of it. Even if farmers receive a lot of extension service and training, it remains open if or what they change in their management. Thinking and perspective is strongly connected with culture and here traditionally that was one of herders. True development comes from within. What outsiders can do is offer knowledge or technologies, but what people in the end do with it is their decision. Regarding LCA, there is a certain arrogance to it when Western people come to do LCA on such smallholder farms and propose mitigation options, if those options are not connected to a better income or options to improve their livelihoods. The nature of often heard mitigation options like reduced herd sizes or improved feeding are outcomes of theoretical desktop research that are not likely to be adapted, because as such they do not fit the way of thinking of farmers and the way their systems work. Global scale studies are important, but exporting mitigation options of such studies to actual local field conditions is unrealistic, because farmers just will not apply it, unless there are incentives that show also benefits for their livelihoods. This might be true not only for the farmers of the Kaptumo case study, but also for European farmers.

There is no doubt that in agriculture, in livestock production and in dairying GHG emissions occur and that management practices that imply lower GHG emissions are favourable. But one should not forget the bigger picture, i.e. GHG emission development and sources and why our world faces a climate change today (see figure 7). Let alone a flight to Kenya and back account for 2.990 kg CO_2 (calculated with atmosfair.de). Decreasing emissions due to less flying and less meat consumption in the developed world are only two of many mitigation options in a lifestyle characterized by maximum resource use and causing environmental harm. Within the world of LCA and agriculture or dairy production in specific it seems as this bigger picture is at times lost when research is loosing itself in itself.

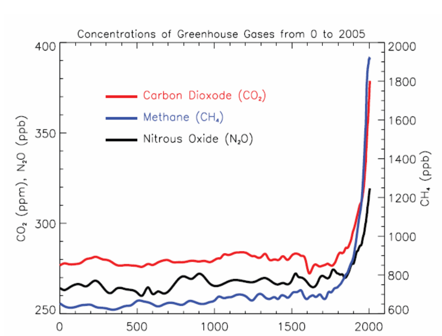


Figure 7 Atmospheric concentration of important, long living greenhouse gases during the past 2.000 years. For the rise in emissions starting around the year 1750 humans are responsible. (IPCC, 2007)

7. Conclusions

It is possible to account for multiple functions of dairy systems within the LCA methodology, but there are limitations to it. Economic allocation and economic quantification of cattle functions showed that this is one methodological option to include multiple products, but in economic valueing some important products are still left out and cannot be captured in economic terms, i.e. socio-cultural values related to cattle keeping.

When opening the perspective for smallholder mixed farming systems and what they actually are, the picture changes, i.e. the understanding of cattle keeping and farmers` motivations behind it shows another perspective on the systems. In this case there are strong socio-cultural values associated with cattle in times of transition from traditional understanding as herders to mixed farming on decreasing land sizes and increased interest in viewing dairying as a business. A new allocation method was applied to see what effects there are on the CF of milk if more of an endemic perspective is chosen. The CF changed from 2.1 to 1.7 to 1.1 CO_2-equivalents/kg milk applying no allocation, economic allocation to five functions and the allocation based on farmers` motivations, respectively. The process of applying such different perspective on the systems revealed that there is a limit in understanding systems as what they are when applying a common LCA frame. In part that could be explained by the nature of the LCA tool, which originates in industry.

Concerning the CF of milk, farmers perform well in comparison to results of other studies. However, to find the best improvement options, it makes more sense to assess the whole farm as the most effective GHG mitigation options may lie outside the dairy component. Within the dairy component, feeding and manure management provide two fields for opportunity to improve. A central issue is extension service, i.e. if farmers have the opportunity to receive training they are enabled to make different management decisions which are best for their individual situation. An assured market for milk with stable producer prices might be the most important issue. Farmers want to increase their milk production and income through dairying and a stable income increase the motivation to change management practices. GHG mitigation options must be discussed within the development context and in face of economic opportunities and constraints of farmers. Within LCA research there is the danger of applying ignorance towards systems as the ones of this study as the common methodological frame of LCA and common mitigation options do not fit to those systems.

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