Understanding dairy commercialization

Evolving market linkages, transition, and resilience of dairy farming in the East African highlands

Jan van der Lee

Propositions

1. The common typology of dairy farms in ‘(peri-)urban’ and ‘rural’ farms ignores proximity to local input and output markets.
(this thesis)

2. Building farm resilience needs to move beyond specific and known risks to multiple and unknown risks.
(this thesis)

3. Interdisciplinary studies should be evaluated on the value added by integration of concepts from different disciplines, rather than on the deepening of those concepts.

4. Any perceived tension between faith and science may be addressed by less pretention to absolute knowledge of truth on either side.

5. Development initiatives that do not adapt Western agricultural technology to local context are destined to fail.

6. Public funding diverts NGOs from their civil society roots.

7. Milk powder imports by subsidized Dutch enterprises negate Dutch development support to local dairy farmers.

8. Epic stories such as the ‘Lord of the Rings’ instruct us to look for a greater purpose, if good is to prevail in this world.

Propositions belonging to the thesis, entitled

Understanding dairy commercialization
Evolving market linkages, transition and resilience of dairy farming in the East African highlands

Jan van der Lee

Wageningen, November 13, 2020

Understanding dairy commercialization

Evolving market linkages, transition, and resilience of dairy farming in the East African highlands

Jan van der Lee

Thesis committee

Promotor

Prof. Dr Laurens W.A. Klerkx, personal professor, Knowledge, Technology and Innovation Group, Wageningen University & Research

Co-promotor

Dr Simon J. Oosting, associate professor, Animal Production Systems Group, Wageningen University & Research

Other members

Prof. Dr Miranda Meuwissen, Wageningen University & Research

Dr Seife Ayele, Institute for Development Studies, Brighton, United Kingdom

Dr Mirjam A.F. Ros-Tonen, University of Amsterdam

Dr Oliver V. Wasonga, University of Nairobi, Kenya

This research was conducted under the auspices of the graduate school Wageningen School of Social Sciences (WASS).

Understanding dairy commercialization

Evolving market linkages, transition, and resilience of

dairy farming in the East African highlands

Jan van der Lee

Thesis

submitted in fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. Dr A.P.J. Mol,
in the presence of the Thesis Committee
appointed by the Academic Board
to be defended in public
on November 13, 2020
at 4.00 p.m. in the Aula.

van der Lee, Jan

Understanding dairy commercialization
Evolving market linkages, transition, and resilience of dairy farming in the East African highlands

200 pages

PhD Thesis, Wageningen University, Wageningen, The Netherlands (2020)
With references, with summaries in English and Dutch

ISBN: 978-94-6395-512-6

DOI: https://doi.org/10.18174/529710

Contents

List of boxes

List of tables

List of figures

1. General introduction

1.1. Dairy development opportunities and challenges in East Africa

Getting out of the smallholder farming box

In August 2015, I visited Amos Githige and his wife Rahab, dairy farmers in Ciondo, a Kenyan village near Engineer, South Kinangop. I went there with a team from SNV's Kenya Market-led Dairy Program and with the late Dr James Maiteri, head of the extension section of Muki Dairy Cooperative Society. Amos and Rahab were farming in an area called the White Highlands, where after the first World War, white settlers practiced dairy farming. Around independence in 1963, Kenyan settlers here received 35 acres each. Cash crops such as pyrethrum used to be prominent, now potatoes are. Ayrshire cattle used to be the main dairy breed, now being mixed with Holstein as in so many places on this planet.

Since 2012, Amos is following his father into dairy farming, after working for a company for a decade and planting potatoes on rented land for two years. Out of the ten cattle he had in 2015, he was milking two, while two were dry. He was also milking his father's two cows. Next to vegetables such as cabbage he was growing fodder crops – kikuyu grass, oats, maize and vetch – which he fed to his cows along with dairy meal. He employed two casual labourers to get the work done. He constructed a zero-grazing unit, bought a grass cutter, and was renting land from others (mostly brothers and cousins), bringing his land to ten acres in total. Paddocking his grassland helped him to have sufficient grass, next to the maize silage he started making.

As a member of Muki dairy cooperative, he had access to artificial insemination, extension, credit, forage seed and dairy meal. From Muki and from private service providers, he received advice about zero-grazing, forage crop management, and paddocking. He was using cow record cards for his herd recording – he adopted this from Willens, a practical dairy training centre in Eldoret where he attended a training. Muki also assured him of a market – milk was collected at seven every morning and Muki paid him 35 Shilling a litre (US$ 0.35).

At the time of my visit he was milking around 40 litres a day and he thought he could reach 60 litres once his dry cows calved. His dream was to milk 300 litres a day from ten cows. To reach this target, he planned to improve his feeding, breeding, and husbandry practices. He was in good spirits that he could overcome his main challenges: access more capital; become less dependent on the unpredictable rainfall through zero-grazing and silaging; bring down the calving interval to below fifteen months; and deal with animal health threats – mainly East Coast Fever, worms and mastitis.

In April 2020 we talked to Amos again to see how his farm had developed. He had been well on his way to fulfilling his dreams, until last year's drop in milk prices (to as low as 19 Shillings). This *poor market made him decide to sell half of his cows and buy a lorry to start a transport business. He was now renting just five acres, of which two were dedicated to growing maize for silage. Out of seven cattle he was now milking four cows, doing 45 litres per day. He felt his productivity was recovering from last year's drop, when he was not able to feed the cows well due to the low prices.*

This story from Kenya illustrates several topics common to dairy development in East Africa and beyond. It shows the drive of a young entrepreneurial farmer couple to professionalize and commercialize their farm in response to market opportunities, but also their difficulties encountered in achieving this. Amos and Rahab's success lies in dealing with the scarcity of land that results from hereditary subdivision, which in many places hampers farm succession; in securing access to milk markets, inputs and services; and in their resilience in dealing with prevailing shocks, in this case fluctuations in the milk price, other times it may be natural disasters. After building up assets in their dairy herd for a number of years, they were able to use part of these to invest in a transport business: a new livelihood activity that at that moment appeared more rewarding than dairy farming. For this, they were willing to put on hold dreams of growing dairy production, allowing it time to recover while they monitor dairy market conditions. As such, they exemplify the growing number of entrepreneurial, commercializing smallholders.

In my research and advisory work in the East African highlands over the past decade, I have interacted with a wide range of dairy sector actors: public and private sector, farmers and farmers organizations, development agencies, research and education institutes, etc. While organizational objectives and strategies vary and do colour stakeholders' perspectives on development of the sector, much common ground on dairy development and its opportunities and challenges exists. This section attempts to describe that common ground and to clarify the societal issue behind this thesis.

Not unlike other developing and emerging economies, countries in the region face a growing urban population with a rising middle-class of consumers in search of more animal protein in their diet (Reardon *et al.*, 2015). Their diet options include fresh milk and dairy products such as cheese, yogurt, and ice-cream. The challenge of getting sufficient dairy products to the cities to meet this growing demand is real, both in terms of quantity and quality – milk spoils easily and needs proper chilling or processing when transported beyond the next village.

Dairy supply planners in public agencies, private companies, and farmer organizations face several choices when deciding how to meet this increasing demand for milk. As imports of dairy products are associated with several socio-economic trade-offs, many policy makers prefer to stimulate local production and sourcing (Sraïri *et al.*, 2013). This can mainly be achieved through two strategies: upgrading of existing smallholder farms or development of larger scale commercial farms. Commercial dairy farms are few in East Africa (with some exceptions, such as in Southwest Uganda), and new private investments in large-scale dairy farming are not very attractive, considering the high investment costs and operational risks against relatively low returns (Kebebe, 2019). Lower dependence on hired labour and external financing gives smallholder farms a comparative advantage over large-scale commercial farms (Salami *et al.*, 2010). Stimulating upgrading (see **Box 1.1** for definition of various processes related to commercialization) of smallholder dairy farms – in terms of market participation, farm size and farm practices – is thus a logical choice for policy makers in the region (MoALF, 2010; MoALF, 2013; Shapiro *et al.*, 2015). By upgrading infrastructure and dairy support services, they aim at dairy self-sufficiency at national level, at local economic livelihood development for farmers, and at employment generation in the dairy value chain (Jaffee *et al.*, 2011; Royer *et al.*, 2016; Sraïri *et al.*, 2013).

Transition to more intensive and market-oriented dairy is ongoing in many parts of the region (Brandt *et al.*, 2018; Didanna *et al.*, 2018; Makoni *et al.*, 2014). This trend offers opportunities that attract new, entrepreneurial farmers. These may be young people who overcome the many barriers for young entrants into dairy, or they may be older ones who turn to farming after making money in business or urban employment. Together with entrepreneurial farmers from existing farms, such as Amos and Rahab, they are filling the traditional gap between the many subsistence-oriented smallholders and the few larger scale commercial farms (Jayne *et al.*, 2014; Jayne *et al.*, 2016). Being entrepreneurial, they may shift focus to other on-farm or off-farm ventures though, when dairy farming becomes less profitable. However, growth of the sector seems to be stunted: the market share of processed dairy products continues to hover around 25% in Kenya and remains under 2% in Ethiopia; consumer prices are high and rising (1-1.80 US$ per litre of pasteurized milk); and farmgate prices are higher than in, for example, the European Union, yet fail to offer decent livelihoods to farmers (Makoni *et al.*, 2014).

Such a focus on the commercialization of smallholder dairy farming does have its own set of difficulties:

- After generations of dividing land between (many) children, many farms in the region have become too small to feed the farm household, limiting the next generation's choice of livelihood options to either stepping out of farming or stepping up to more market-oriented yet resource-intensive farming, for which the required capital or skill set may be out of reach (Dorward *et al.*, 2009; Waithaka *et al.*, 2006).
- Adoption of recommended market-oriented dairy practices and innovations may remain low, as the required investments – be they in physical or human resources – are considered too risky by many farmers (Falconnier *et al.*, 2018; Royer *et al.*, 2016). Increased use of inputs and services is more easily adopted by the relatively resource-rich

smallholders, which enlarges inequity within farming communities and raises questions of inclusivity (Falconnier *et al.*, 2018).

- Next to access to land, capital, and skills, access to input and output markets is a key factor limiting production increase. Collection of milk from smallholders and distribution of inputs and services to them is relatively expensive – poor infrastructure contributing to high transaction costs for small volumes – and faces real challenges of quality assurance (Kilelu *et al.*, 2019; Royer *et al.*, 2016). Availability and quality of animal feed can pose real challenges where farms are small, where land is needed for human food production, or where dry seasons are long. Yet, provision of a broad set of services is required and should meet key needs of different types of farms if productivity and market participation are to be increased (Poulton *et al.*, 2010). Not only the farming system, but a whole range of related yet separate systems needs to be upgraded, including dairy supply chains, provision of inputs and services such as extension, veterinary services, artificial insemination (AI), financial services, disease control and food safety systems, and knowledge systems for research, innovation, extension and education, etc. (van der Lee *et al.*, 2014).
- Where the responsibility for supply of inputs and services shifts from public to private actors, new support service configurations need to be developed (Poulton *et al.*, 2010). Chain integration usually is lacking. Farmers thus find it hard to capitalize on the opportunities that the growing demand for milk and dairy products offers (Makoni *et al.*, 2014).
- Development of dairy production in peri-urban areas addresses some of the above market access challenges, but often proves to be a temporary solution only. Dairy may be outcompeted by vegetable production, real estate development, or other intensive land uses, and peri-urban areas may appear too small to meet rising demand (Jayne *et al.*, 2014). Intensive dairy production with feed procured from other areas raises environmental issues of manure management and makes fodder an expensive external resource, hampering feasibility of dairy farming (Odhong *et al.*, 2015).

Summarizing, the societal issue this thesis intends to contribute to is the question how dairy farmers in the land-scarce East African highlands can be enabled to increase their market participation in a sustainable way. This question about supply of sufficient and safe milk and dairy products to rural and urban consumers primarily concerns issues of whether and how farmers can make a decent livelihood, and whether the investments and changes in their practices are achievable and do not expose them to unsurmountable risks. The question also touches on societal expectations regarding what is being produced and how, with profound concerns about social inclusivity and the impact of market dynamics and climate change, and with budding concerns about the environmental impact of dairy farming.

In the next section, I will show which scientific debates and underlying research questions are connected to this issue.

1.2. Research problem, objective and questions

1.2.1. Research problem

The above trends and challenges in dairy development concern the process of commercialization of dairy farming, i.e. increasing participation of farms in dairy input and output markets (Linderhof *et al.*, 2019). This concerns the evolving and gradually more complex relationship between farming and market systems, that results over time and space from decisions taken by farmers and other actors.

Important building blocks for understanding this commercialization process have been made by various strands of research:

The farming system research tradition mostly looks from the inside out, starting from the farm or farmer, primarily focusing on internal dynamics between farming activities and resources and to some extent on marketing activities. It pays attention to agroecological context, farm diversity, adoption of innovations and the role of the innovation system (Darnhofer *et al.*, 2012). The latter elements receive attention in literature studying the innovation system, defined by Hall *et al.* (2006) as 'a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge'.

The relationships of farming systems with markets, the innovation system, and other support systems is further receiving attention in the food system research[1] that is gaining traction over recent years (Ruben *et al.*, 2019). It attests to the panarchical relationships between the various sub-systems nested within the agrifood system, which influence the development path of farming and other sub-systems (Gunderson and Holling, 2002; Tittonell, 2014). This points at the important role of systems theory that offers heuristics for understanding dynamics of non-linear systems, including adaptive cycles and resilience of farming systems and other socio-ecological systems (Walker *et al.*, 2006).

From the market system side, a number of economic theories offer insights regarding the conditions under which market participation of farmers increases. The location theory from economic geography has a long tradition in studying connections between farming and end-markets, showing that proximity to urban markets influences production and marketing decisions of farmers, and ultimately influences the structure and function of farming systems (Reardon, 2015; Vandercasteelen *et al.*, 2018b). Commercialization literature underlines the

Box 1.1. *Commercialization, intensification, specialization and upgrading*

Commercialization of farming (or of particular farming activities) refers to the increasing participation of farms in input and output markets (Linderhof *et al.*, 2019). It is related to a number of other processes in the farming system:

- *Intensification* of farming, defined as increase of the output quantity and/or value per unit input, be it land, labour, or capital (Udo *et al.*, 2011). While commercialization and intensification often coincide, commercialization focuses on the market relationships and intensification focuses on the production side of farming (Pingali and Rosegrant, 1995).
- *Specialization* at farm level, *diversification* at sector level – commercialization can lead to specialization and less diversity of crops and livestock products at farm level, with simultaneous diversification of farms at farming system and sector level (Linderhof *et al.*, 2019), which in turn cascades into positive effects on the diversity in the food supply and better food security outcomes (Smeets-Kristkova *et al.*, 2019). Specialization of dairy may lead to loss or lower emphasis of other livestock or crop activities that were hitherto more commercial.
- *Upgrading* is defined as 'changes in the production process to increase productivity and added value and/or to improve product quality' (Giuliani *et al.*, 2005; Kilelu *et al.*, 2017); as a term from value chain literature (Ramirez *et al.*, 2017; Ruben *et al.*, 2017) in this thesis it is also applied to farming system, lower level market systems such as support services, and institutions such as quality assurance and regulations.

importance of spatial factors in the commercialization process, but also the need to better understand the underlying interaction mechanisms between farming and market, and how differences between farmers result in processes of in- and exclusion (Chamberlin and Jayne, 2013; Poulton *et al.*, 2010). Other relevant economic concepts with spatial, temporal and institutional aspects include value chains and (commodity) clusters, amongst others dealing with governance of input and service arrangements for specific client situations (Borisova *et al.*, 2015; Poulton and Lyne, 2009) and transaction cost theory, which helps explain comparative cost advantages of diverse farms (Ruben *et al.*, 2017).

While these theories offer important building blocks for understanding the commercialization process, they each offer only partial answers to the issue of how dairy farming commercializes in the land-scarce East African highlands. In order to be able to contribute insights on this issue that could be used for design of change trajectories and interventions (section 1.1), a number of knowledge gaps need to be addressed. These include:

- What is the role of spatial, temporal, and institutional factors in driving or hindering upgrading and transition of dairy farming systems in interaction with markets within different contexts? These include internal dynamics within each of the two systems, their interactions, as well as influences from the context (such as dynamics in support services, the innovation system, infrastructure, climate change, social safety nets etc.), including the question to what extent farm characteristics within the system affect responses of individual farms (Ruben *et al.*, 2019). The role of spatial factors appears important, as land shortage is an important limitation in the region and as dairy farming systems have important spatial components in both the production and marketing component (Duncan *et al.*, 2013).

- The effects of (pluralistic) input and service arrangements on the market quality (i.e. access to a local dairy market, access to local input markets, and conduciveness of service arrangements) and market participation of dairy farmers, in particular whether and how they cater to the needs of farmers at different levels of market participation and ultimately contribute to sustainable outcomes (Duncan *et al.*, 2013; Kilelu *et al.*, 2014; Poulton *et al.*, 2010).
- A number of questions around transition of farming systems – under what conditions they take place, whether leverage points for influencing them can be identified (Oosting *et al.*, 2014), what the role is of resilience of farm and livelihood vis-a-vis the drivers of commercialization, how resilience can be assessed, and whether low adoption of market participation strategies is indeed due to the notion that long-term effects on resilience are not or only marginally positive, as Udo *et al.* (2011) suggest.

1.2.2. Research objective

In view of the knowledge gaps identified in section 1.2.1, the objective of this thesis is to gain insight into factors affecting commercialization of dairy farming under land scarcity, through assessment of the dynamics of market participation, land use intensification, and resilience of dairy farming systems in relationship to the markets for inputs, services, and outputs in different contexts.

It is expected that increased understanding of commercialization will benefit the design of dairy development strategies referred to in section 1.1. Such strategies, pursuing objectives such as ‘connecting farmers to markets’, ‘increasing supply of milk to the cities’ or ‘making dairy climate smart’ – can be regarded as socio-economic drivers that intend to alter the change trajectory of farming systems toward outcomes desired by stakeholders such as policy makers, dairy industry, civil society, and farmers (Clay and Yurco, 2019; Jayne *et al.*, 2014).

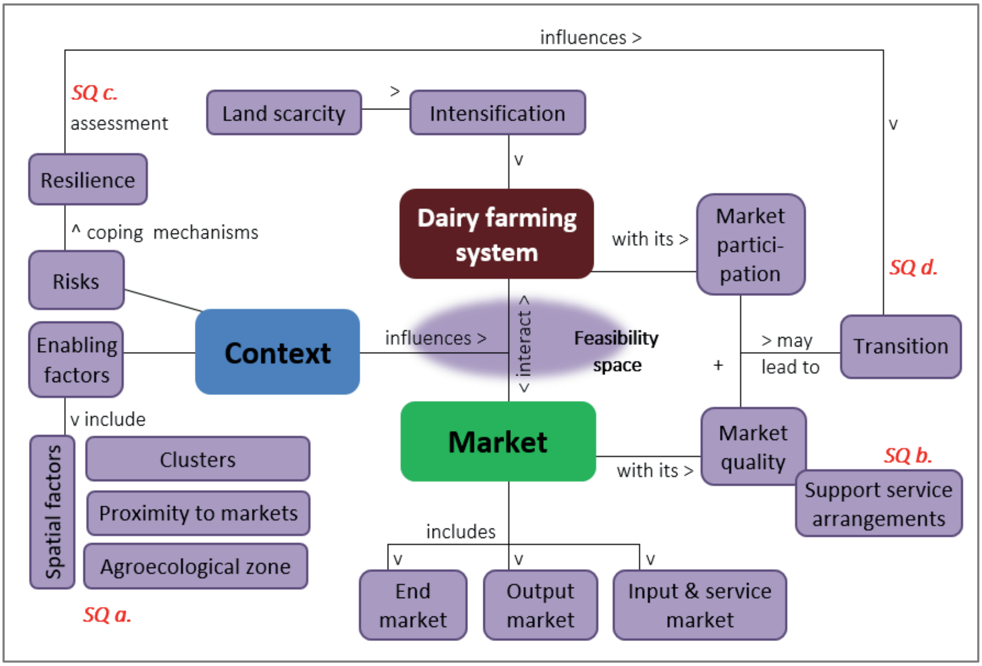


Figure 1.1. *Concept chart showing relationships between concepts used in this thesis, and focus areas of sub-research question (marked SQa–SQd in red)*

1.2.3. Research questions

To meet the above objective, the following main research question was formulated: In what ways do market quality and spatial factors affect commercialization of dairy farming systems under land scarcity in two countries in the East African highlands?

This main research question was further elaborated into four sub-questions:

a. What are effects of spatial factors on farmers' production and marketing strategies across different contexts?
b. What are the effects of service arrangements on farm resilience and market participation?
c. How has assessment of resilience in farming systems been conceptualized and operationalized and how does this inform further development of assessment approaches? – *though seemingly basic, this is a key bottleneck hampering application of the concept in dairy farming commercialization*
d. In what ways does commercialization affect transition and resilience of dairy farming systems?

Figure 1.1 positions these sub-questions in a chart that portrays the concepts and the relationships between them, as used in this thesis, to explore these questions. These concepts are further elaborated in the next section.

1.3. Analytical framework

The analytical framework has commercialization to consider as a major factor, but not as the only one. Indeed, it is necessary to look at how the dairy farming system interacts with its context and markets (**Figure 1.1**). From this, it can be seen that better **market quality** leads to better **market participation**, in conjunction with better input and service provision. Also key is how dairy clusters and proximity to markets contribute to a better enabling environment, and how resilience enables healthy transition.

The analytical framework in this section thus describes the concepts related to commercialization, market quality and service arrangements, resilience, and transition. Before elaborating the methodology used (section 1.4) and the structure of this thesis (section 1.5), this section briefly explores the concepts that make up the analytical framework. **Figure 1.1** shows the relationships between these concepts and positions the four sub-questions expounded above. **Figure 1.2** below gives a more spatial representation of these concepts and links them to the different chapters in this thesis.

1.3.1. Commercialization as outcome of interaction between farming systems, markets and context

Building on the work of Chamberlin and Jayne (2013) and Duncan *et al.* (2013) outlined above, I explore the effects of spatial factors on the dairy farming system commercialization process, as a function of the interaction between dairy farming system and market(s). The underlying mechanism of **commercialization** of dairy farming (defined in **Box 1.1**) is that increased use of purchased inputs and services improves farm productivity, leading to increased sales of produce and increased turnover (Udo *et al.*, 2011). Part of the returns are used for new investments that increase productivity. Net results for the livelihood of the farm household should be positive.

Figure 1.1 portrays that understanding the commercialization dynamics of a dairy farming system requires assessment of its interaction with its market(s) and context. I now discuss these main components:

- Termed as the 'food system context', the **context** in which farming and farm-market interaction take place extends to socio-economic and environmental drivers that affect farming and its interactions with markets (Andeweg, 2020). These drivers can be defined in terms of **enabling factors** – that facilitate the performance of dairy farming systems – and **risks** (disabling factors) that threaten its performance. One example is the combination of demographic growth with the institution of ongoing sub-division of the scarce production factor 'land' between multiple heirs, even to the extent that farm size may drop below viable levels (Waithaka *et al.*, 2006). This is an important driver of **land**

use intensification. Due to the link between dairy farming and land, **spatial factors** form an important sub-set of the enabling factors. They include **agroecological conditions**, **proximity to markets**, and **commodity clusters** that farms may be located in (Bosire *et al.*, 2019; Joffre *et al.*, 2019).

- Relevant markets for dairy farming include the **markets for inputs, services, and production factors** required to produce, as well as the markets for milk and dairy products to supply to. The (local) intermediating market connects farms to the consumer end-market it supplies to, be it located near the point of production (rural consumers) or farther away (urban consumers) (Oosting *et al.*, 2014). Provision arrangements for inputs and services on the input and output market side, in short **service arrangements,** have an important influence on market participation (section 1.3.2).
- **Dairy farming system** here refers to 'a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate' (Dixon *et al.*, 2001), and in which dairy production forms a significant part of farm livelihood activities (Darnhofer *et al.*, 2012; van de Steeg *et al.*, 2010). Giller (2013) notes that resource bases can vary significantly, that system boundaries can be blurry (particularly for livestock systems), and that farm typologies can be useful to distinguish patterns of farms, farming livelihoods, and production objectives. He further notes that 'farm(system)s exhibit varying degrees of interdependency and interact in use of common property resources. The diversity of farm enterprises requires that development strategies, interventions, and policies need to be tailored to their different needs and opportunities.'

  While dairy farming activities constitute the production step in the value chain that supplies dairy products to end-markets (Andeweg, 2020), farming systems are much more than merely a part of a value chain. They tend to be suppliers to value chains for multiple commodities and perform multiple functions that go beyond chain participation. This is particularly valid for subsistence-oriented mixed crop–livestock systems prevalent in East African dairy production (Thornton and Herrero, 2014). Other farming system functions include household food supply, landscape management, labour pool for off-farm activities, and supply of transportation services (Darnhofer *et al.*, 2012). Livelihood activities next to dairy may include food-, cash- and forage crops, other livestock, hunting and gathering, forestry, and backyard gardening. Non-agricultural on-farm and off-farm activities strictly speaking may not be considered part of the farming system. However, the proceeds of such activities can form an important contribution to farm household livelihood and its stability (Fraval *et al.*, 2018; Giller, 2013). Dairy farming systems are thus regarded as complex adaptive, socio-ecological systems with biophysical, technical, and socio-economic aspects, in panarchical interaction with markets and the larger agrifood system and its multiple nested sub-systems (Gallopín, 2006; ten Napel *et al.*, 2011; Tittonell, 2014; Walker *et al.*, 2006). See **Appendix 5.2** for background on key system dynamics terms used.

1.3.2. Market quality, service provision arrangements and market participation

Farmers show a lot of variation in the production and marketing strategies they use to respond to changes in market and context – note the diversity of farming styles described by van der Ploeg (2008). Still, participation in more sophisticated markets generally goes hand in hand with a set of commercialization-related developments. The interaction between farming system, market, and context offers farmers a certain **feasibility space** to operate in (Schiere *et al.*, 2012). Once adopted, strategies and practices can significantly change structure and functions of farming systems over time (Elzen *et al.*, 2017), through intensification and specialization of farming, formalization of contracts within the chain, and standardization of products (Kilelu *et al.*, 2017; Udo *et al.*, 2011). While opening up new market opportunities for farmers, these developments may also mean more external control over farmers' production and marketing strategies (Poulton *et al.*, 2010) and affect farmers resilience (next section).

The required external inputs & services can be provided through various types of input and output support service arrangements, each with their own strengths. They are important determinants of market quality, defined by Duncan *et al.* (2013) as the reliability and attractiveness of these service arrangements for both milk procurement and delivery of livestock inputs and services, extending beyond the physical infrastructure to the institutional service arrangements around milk procurement and input supply.

Recent service arrangements in Kenya and Ethiopia include (1) government-led service provision; (2) producer organization-led service provision models such as dairy business hubs; (3) supply chain-embedded service provision such as processer-led models; (4) independent private service providers such as agro-veterinary shops; and (5) horizontal service provision models such as lead farms (Kruse, 2012; Poulton *et al.*, 2010). They can be operated by public, private and civil society actors; as stand-alone service or in combination with other inputs & services; subsidized or fully paid for (Kilelu *et al.*, 2011; Kilelu *et al.*, 2014; Poulton *et al.*, 2010). Input and advisory service providers are important influencers of on-farm decision making on increased market participation (Oreszczyn *et al.*, 2010). As information and resource brokers, they can provide – or withhold – key incentives for increasing market participation (Kilelu *et al.*, 2014). Ideally, input and service providers 'walk alongside farmers on their adaptation journey', in a process in which farmers collect, integrate and apply information from multiple sources, and in which input & service providers act as advisors (Folke, 2006; Loeber *et al.*, 2007).

1.3.3. Conditions for systems transition and resilience

As a change process to more market-oriented farming, commercialization involves changes in farm production and marketing practices, that likely, but not necessarily, will lead to **system transition**[2], i.e. large shifts in shape and function of farming systems (Dorward *et al.*, 2009; Poole *et al.*, 2013; Poulton *et al.*, 2010; Termeer and Metze, 2019).

Commercialization significantly changes the set of farm assets and the relationship between production and market function. As this is expected to occur stepwise (Chantre and Cardona, 2013), farming systems may be characterized along a market participation trajectory, with a typology of ideotypes (Pingali and Rosegrant, 1995). Transitions or 'jumps' between ideotypes can be expected (Koning and van Ittersum, 2009; Oosting *et al.*, 2014), rather than ongoing gradual change, as system change requires significant investments in new resources – such as barns, equipment or another breed of animals – and practices – such as fodder production or changes in milk sales channel.

Such socio-technical transitions can also be viewed as the result of coping with perturbations caused by prevailing shocks and stresses. Here the concept of **resilience** comes in, defined early on as 'the capacity of a system to deal with external and internal disturbance' (Holling, 1973; Pimm, 1984). In the context of farming system transitions, more elaborate definitions may be used that distinguish between buffering and adaptive responses to less severe perturbations and transformative responses to more severe perturbations, such as 'the capacity of a system to absorb and adapt to external and internal perturbation, and reorganize along a trajectory while undergoing change, so as to still retain essentially the same function, structure, identity, and feedbacks' (Walker *et al.*, 2004). Resilience is an emergent property that results from the management decisions that farmers continuously make on a range of issues: asset management, nutrient management, market participation, risk management, and intergenerational dynamics (DFID, 1999; Kaufman, 2003; Meadows, 1999; Roling, 2009). Perturbations may stem from within the farming system (e.g. animal diseases or changing household needs), from the market (e.g. changing consumer demands), or from the context (e.g. changing policies or climate change) (Amankwah *et al.*, 2012; Dorward *et al.*, 2009). The same is true for the resources and capacities needed to cope with perturbations (Cabell and Oelofse, 2012). Assessment of the sustainability of commercialization therefore requires evaluation of the resilience implications of changes in farming practices, in which not only farmer learning plays a major role (Chantre and Cardona, 2013), but also the ability of advisors and other farm support system actors to understand the farming system's dynamics and support resilience at the farm level (Darnhofer, 2014; Nettle *et al.*, 2014). When the innovation system functions well and context conditions are right, this contributes to co-innovation in an experiential learning process, and to shaping of an optimal input and advisory service configuration that supports adaptive capacity of dairy farmers in commercialization trajectories to safeguard resilience (Kilelu, 2013; Klerkx and Jansen, 2010). Assessment of the resilience of a farming system and of the impact of interventions to promote its resilience is an area that is still under development, in particular regarding the factors that contribute to it and the methodologies that should be used (Meuwissen *et al.*, 2019).

1.4. Methodological design

1.4.1. Research design

Research approach

Figure 1.2 places the various studies conducted in a basic representation of the farming system and its relationships with market and context. Commercialization of dairy farming in the East African highlands is a process that happens over time, across a diverse area, at different system levels, involving a range of stakeholders. This requires a number of methodological choices in terms of focus on temporal, spatial, and social dynamics and in terms of system scale. I made the following methodological choices:

- To understand the farming system, I studied a sample of individual farms and their market linkages. By studying a representative sample of individual farms and their interactions with each other and with other actors in the system, a cross-sectional description of the farming system is achieved that allows extrapolation of findings.
- To capture the farming system dynamics, including variation in the degree of market participation, I studied the resources, livelihood activities, farming practices, and market linkages of individual farms (Darnhofer *et al.*, 2012). For the mixed crop–livestock farms in the study areas, this should go beyond dairy, as dairy is just one of multiple on-farm and off-farm livelihood activities (section 1.3.1), that together constitute the livelihood of the farm household and associated employees, be it as food or as income derived from produce sales to different value chains.
- In studying interactions between farming system and market, understanding of the dynamics in both systems is required. I thus studied dynamics in both farming and market systems; where limitations were needed, I focused on the farming system.
- By choosing study sites with similar agroecological conditions[3], the effects of these conditions were minimized.
- Studies described in Chapters 2 and 3 took place in contexts where travel time has significant impact on market participation, due to limitations in infrastructure development. This was more so the case in Ethiopian study sites, where infrastructure was less developed than in the Kenyan sites. It can be assumed that in contexts where

good infrastructure reduces travel times, the location theory used in this thesis becomes less relevant, with theories such as Porter's diamond (Porter, 2000) gaining importance.

- Where assumptions are made about contributions from other actors, such as service providers or milk processors, it is constructive to look from the service provider's perspective – this was done in Chapter 4 with the case study of service providers.
- Due to the lack of clarity on appropriate methodology for resilience assessment of farming systems research, systematic literature review was used for Chapter 5.

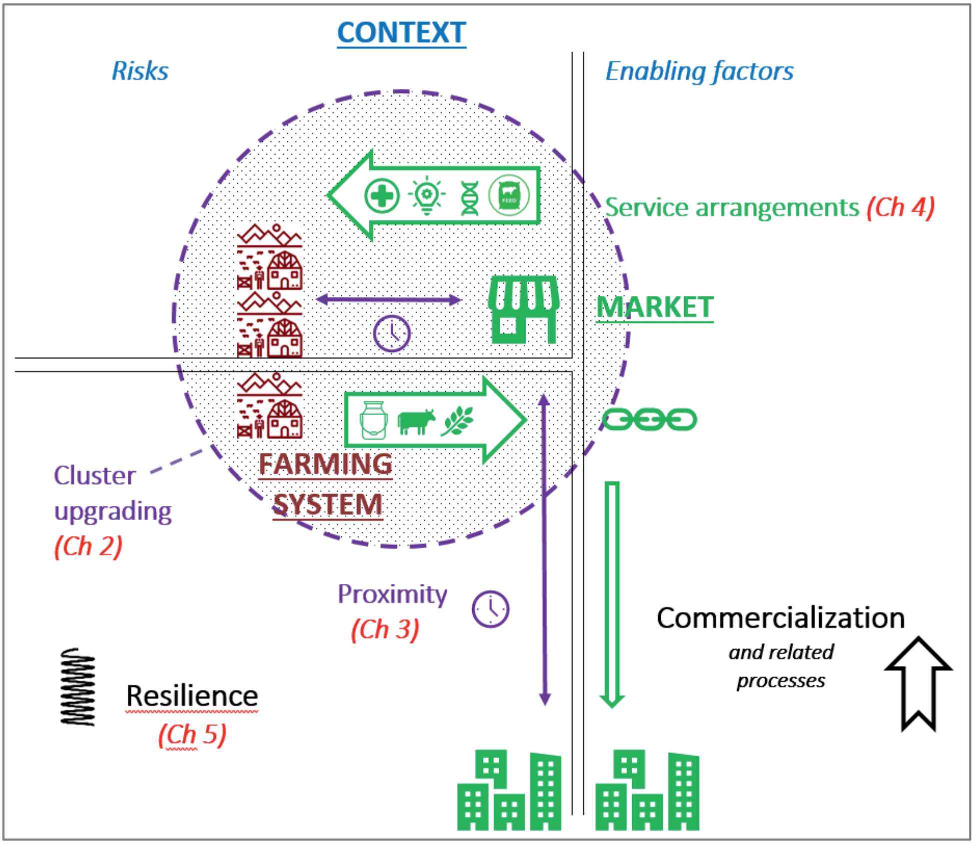


***Figure 1.2**.* *Visual overview for understanding commercialization dynamics of dairy farming systems as interaction between farming system, markets and context (study chapters in red next to relevant theme)*

As unit of analysis, Chapters 2 and 3 therefore take clustered mixed crop–livestock farms (representing farming systems) in selected study areas of Ethiopia and Kenya, which serve as representative countries for the East African highlands (see **Figure 2.2** in Chapter 2 for a map situating the study areas). These studies particularly look at the dairy production and marketing functions of these farms, and their linkages with the dairy-related input and output markets.

Livelihood activities other than dairy – other livestock production, food and cash crop production, and other on- and off-farm livelihood activities – are only studied as far as they are relevant to understand dairy production and marketing. Where necessary, the study takes the value chain or cluster as the 'one level up' system and livelihood activities as the 'one level down' system (Amankwah *et al.*, 2012; Kilelu *et al.*, 2011).

Sampling

In the two countries, study areas for Chapters 2 and 3 were selected in collaboration with partners of the ADIAS research project[4], based on milk production potential, commercialization level, and partner interests. In these five clusters, dairy farmers face the question of whether to transition from 'marketing of small surplus to local markets' to 'commercial supply to wholesale chains'. Within these clusters, transects of study villages (locations and sub-locations) were selected along proximity to market gradients. For Chapter 3, a double proximity gradient set-up of 3 locations * 3 sub-locations, with at least 10 surveyed farms per village ensured that in each country (n > 2*90), each location and each sub-location group had at least 30 surveyed farms, which was considered an adequate sample size for the majority of variables studied (see Chapter 3 for more detail). The number of surveyed farms in Ethiopia was slightly higher, to satisfy the minimum sample size criteria deemed adequate by the University of an MSc student involved in the study (i.e. n= 120). In Chapter 4, eight service providers enterprises (SPEs) were randomly selected from the fifteen SPEs initiated by the first phase of SNV's Kenya Market-led Dairy Program (2012-2016), after selecting four out of six counties, guaranteeing diversity. Search criteria for the literature review are elaborated in Chapter 5.

Data collection and analysis

A mixed method case study approach was used, zooming in on farming systems in selected areas and countries. Chapters 2–5 used data collected with various qualitative and quantitative methods, in varying combinations (**Table 1.1**). These included (1) a farm survey; (2) focus group interviews (FGIs) with farmer groups; (3) semi-structured interviews with other value chain actors and value chain enablers (primarily government staff at county and sub-county levels); and (4) systematic literature review.

1.4.1. Study area

While similar issues are common in dairy development around the world, this thesis zooms in on the East African highlands, a region stretching from Eritrea in the North to Tanzania in the South. From a continental perspective, East Africa ranks second after North Africa in terms of dairy production volumes, producing over 13 million tonnes in 2018, with annual growth rates exceeding 5% (IFCN, 2019). Traditionally little urbanized, the region now experiences high urbanization rates (Reardon *et al.*, 2014). For centuries, communities in the region have used their agroecological resources to produce dairy products. Cattle and milk have become important parts of culture, attracting high social value (Njuki *et al.*, 2016). Imports of dairy products into the region have been low. Annual dairy consumption ranges from 10 to 115 kg per capita across countries (KDB, 2020; Makoni *et al.*, 2014). The vast majority (99%) of an estimated nine million dairy farms in the region are smallholdings, which produce over 80% of all marketed milk; most are mixed crop–livestock farms (IFCN, 2019; Makoni *et al.*, 2014). This

Table 1.1. *Sampling, data collection, and analysis methods*

Chapter	Data collection method	Data analysis method	Study areas	Sampling strategy	Sample size
2 and 3	Farmer survey	Regression analysis in R	3 clusters with 18 sub-locations in 2 double gradients	Random sampling within selected sub-locations	215 farmers (122 in Ethiopia, 93 in Nyandarua, Kenya)
	Focus group interviews with farmers	Qualitative analysis of transcriptions in Atlas.ti	5 clusters with 10 locations, 30 sub-locations	By invitation (inter-viewed farmers in surveyed locations, open invitation in non-surveyed)	30 FGIs (9 in Ethiopia, 9 in Nyandarua, 12 in Nandi), 240 farmers
	Key informant interviews	Qualitative analysis of transcriptions in Atlas.ti	5 clusters + national	Snowballing	118 KIs along value chain (38 in Ethiopia, 80 in Kenya)
4	SPE interviews	Quantitative analysis in SPSS, qualitative analysis of transcripts in Excel	4 counties	Random sampling	8 SPEs, 2 representatives per SPE (total 15)
	FGIs with farmers	Quantitative analysis in SPSS, qualitative analysis of transcripts in Excel	4 counties	Purposive sampling	8 groups, 72 farmers
	Key informant interviews	Qualitative analysis of transcripts in Excel	4 counties	Purposive sampling	Representatives from 8 farmer organizations
5	Literature search	Quantitative analysis in Excel Qualitative analysis	Web of Science	Inclusion/exclusion criteria	1016 papers identified, 123 papers analyzed (106 empirical, 17 conceptual)

makes dairy smallholders important contributors to both food security and employment, at both local and national level. Milk offers daily nutrition and a regular cash income to the family, next to other functions that cattle have in the farming system (Udo *et al.*, 2011). East African farming systems are becoming more market-oriented due to increasing demand for dairy products from urban end-markets (Makoni *et al.*, 2014; Reardon *et al.*, 2015).

In the East African tropical highlands region, I selected Ethiopia and Kenya as case study countries – two countries with different socio-political contexts but with comparable agroecological conditions. In broad strokes, the Kenyan dairy sector has developed a significant formal market segment (Muyanga *et al.*, 2019). A near-collapse of the sector around 2000 resulted from the withdrawal of public support services – such as extension, artificial insemination, animal health care and milk collection – after which private service provision developed (Chamberlin and Jayne, 2013). Since then, the sector has recovered. Devolution of local economic development policy to the counties in 2010 has given a boost to dairy in many counties (Rademaker *et al.*, 2016). On the other side of the border, in Ethiopia, the formal market segment has remained tiny and support services have largely remained in the public domain, with the EPRDF government investing in a large public extension system (Berhanu and Poulton, 2014; Makoni *et al.*, 2014).

Ethiopian study sites were selected from two administrative zones – East Shoa and Arsi Zones. Kenyan study sites were selected from Nyandarua and Nandi Counties, with one case study focusing on youth group businesses providing fodder silaging services to dairy farmers covering Nyandarua, Baringo, Nyeri, and Meru Counties in Kenya. This selection offered opportunities to compare farming systems in more remote areas with those in areas that were (relatively) close to the major urban centres Addis Abeba (Ethiopia) and Nairobi (Kenya).

1.5. Structure of this thesis

This thesis is built up as follows (**Figure 1.3**), with each chapter addressing one or more of the research sub-questions, from different angles:

Chapter 1. Introduction – elaboration of research design (this chapter)

Chapter 2. Intensification and upgrading dynamics in emerging dairy clusters – explores the impact of how being located in a certain cluster affects commercialization, comparing dairy to other commodities (SQa). It describes how farming and service delivery systems (both pre- and post-production) interact under increasing intensification and commercialization (SQb). And it studies how interactions of the farming system with market and context determine upgrading pathways and outcomes (SQd).

Chapter 3. Effect of proximity to markets – studies how proximity to markets influences dairy farming, specifically unravelling spatial factors underlying variation in market participation of dairy farms (SQa). It studies variation across countries (SQb) in dynamics of dairy production and marketing strategies (SQc,d).

Chapter 4. Performance of emerging service enterprises – explores SQb, how SPEs, an emerging model of private service delivery agri-enterprises offering forage production and conservation services, perform technically – in supporting farms in transforming agrifood systems (SQc,d) – and in business terms – creating profitable enterprises themselves.

Chapter 5. Resilience assessment review – reviews how resilience assessment of resilience of farming systems (of different scales) has been viewed in literature (SQc). It distinguishes the contextual positions ('lenses') taken in journal papers describing resilience assessment and compares assessment approaches followed.

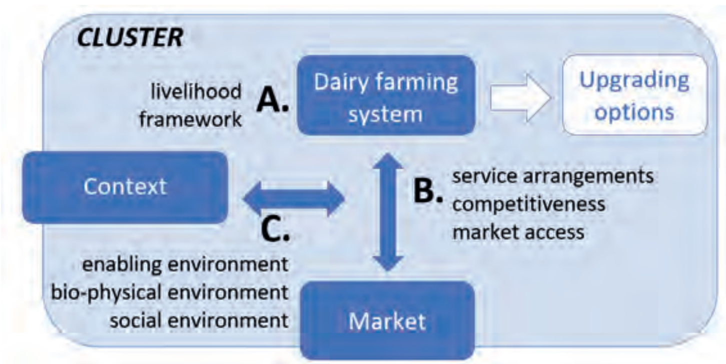
Chapter 6. General discussion – discussion of findings across SQa-SQd, theoretical contributions, reflections, further research, and impact.

Chapter	Research sub-question: SQa. Spatial aspects	SQb. Service arrangements	SQc. Resilience	SQd. Transition
1. Introduction	elaboration of research design			
2. Cluster upgrading	Being part of a cluster; access to production factors and inputs & services	Service arrangement types and farm typology		Upgrading of farms, markets, and context
3. Effects of proximity	Scarcity of production factors; effects of travel time to input, output, and end-markets	Inter-country variation	Variation in transition	Dairy production and marketing strategies
4. Service provider performance		Technical and entrepreneurial performance	Contribution to core needs of farmers	Reduction of seasonality
5. Resilience assessment			Concepts and methodology	
6. Discussion	synthesis of results			

***Figure 1.3**.* *Thesis structure outlining chapter contributions to research sub-questions*

2. Effects of clusters

Abstract: Based on farmer and value chain actor interviews, this comparative study of five emerging dairy clusters elaborates on how the upgrading of farming systems, value chains, and context shapes transformations from semi-subsistent to market-oriented dairy farming. The main results show unequal cluster upgrading along two intensification dimensions: dairy feeding system and cash cropping. Intensive dairy is competing with other high-value cash crop options that resource-endowed farmers specialize in, given conducive support service arrangements and context conditions. A large number of drivers and co-dependencies between technical, value chain, and institutional upgrading build up to system jumps. Transformation may take decades when market and context conditions remain sub-optimal. Clusters can be expected to move further along initial intensification pathways, unless actors consciously redirect course. The main theoretical implications for debate about cluster upgrading are that co-dependencies between farming system, market, and context factors determine upgrading outcomes; the implications for the debate about intensification pathways are that they need to consider differences in farmer resource endowments, path dependency, concurrency, and upgrading investments. Sustainability issues for consideration include enabling a larger proportion of resource-poor farmers to participate in markets; enabling private input and service arrangements; attention for food safety; and climate smartness.



Published as: *van der Lee, Jan, Laurens Klerkx, Bockline Bebe, Ashenafi Mengistu, and Simon Oosting. 2018. Intensification and Upgrading Dynamics in Emerging Dairy Clusters in the East African Highlands, Sustainability, 10: 4324, doi:10.3390/su10114324.*

2.1. Introduction

Upgrading of dairy farming and value chains has been promoted by policy makers and development practitioners as a promising pathway to deal with the sustainability challenges of mixed crop–livestock systems (Giuliani *et al.*, 2005; Kilelu *et al.*, 2017). These challenges include alleviation of rural poverty, supply of sufficient and safe food to growing urban populations, and making farming climate-smart (Oosting *et al.*, 2014). Of all livestock farming systems in the world, mixed crop–livestock systems produce the majority of livestock output and constitute the majority of livestock-keeping households, often smallholders (Herrero *et al.*, 2014; Oosting *et al.*, 2014). Therefore, prospects for these systems to become more market-oriented and sustainably intensify are matters of academic, political, and societal interest (Mockshell and Kamanda, 2018; Oosting *et al.*, 2014).

Studies on the commercialization of milk production repeatedly show the complexity of the transition from semi-subsistence to market-oriented dairy farming, which is often associated with intensification and specialization (Burke *et al.*, 2015; Didanna *et al.*, 2018; Novo *et al.*, 2013; Olwande *et al.*, 2015; Udo *et al.*, 2011). For this transition, many farm practices may need innovation in areas such as feeding, housing, and output marketing. These innovations contribute to upgrading, defined as changes in the production process to increase productivity and added value and to improve product quality (Giuliani *et al.*, 2005; Kilelu *et al.*, 2017). They require higher input levels, for which farmers need sufficient access to external resources, inputs, and services, both pre- and post-production (Oosting *et al.*, 2014; Udo *et al.*, 2011). In practice, upgrading occurs in so-called agribusiness clusters, i.e., geographic concentrations of producers and other actors engaged in the same subsector that facilitate the required linkages to input and output markets (Kilelu *et al.*, 2016). In clusters, the range and types of input–output connections for dairy farms and small and medium enterprises are increased, positively influencing knowledge creation and transfer between actors, enabling them to benefit from economies of scale (e.g., volumes of inputs and outputs) and scope (e.g., use of imported semen and sale of milk to new markets) (Brasier *et al.*, 2007; Dirven, 2001; Morosini, 2004; van Dijk and Sverrisson, 2003).

Many studies have focused on understanding the drivers and bottlenecks affecting upgrading of dairy farming systems and value chains. These drivers include breeds; farm size; access to capital, inputs, and services; demand for dairy products; collective action; infrastructure and policies (Burke *et al.*, 2015; Didanna *et al.*, 2018; Kebebe *et al.*, 2015; Novo *et al.*, 2013; Olwande *et al.*, 2015; Omiti *et al.*, 2009; Ruben *et al.*, 2017). Literature yields limited analysis, however, of how these upgrading processes facilitate dairy cluster emergence and transformation to more market-oriented dairy farming, as most studies focus on a particular type of upgrading, on partial processes, or on single cases. Moreover, various authors have indicated that looking at the socio-economic context aids comprehension of changes in agricultural practices and upgrading of farming systems (Dorward *et al.*, 2009; Duru and Therond, 2014; Vroegindewey and Hodbod, 2018). It is apparent that understanding the complex dynamics of dairy farming systems requires assessment of upgrading in three domains: farming system, market, and context (including biophysical, institutional, and social conditions) (Medina *et al.*, 2015; Poulton *et al.*, 2010). However, empirical analysis of these dynamics remains limited. A comprehensive analysis of multiple clusters in comparable transition trajectories is expected to offer insight into the upgrading dynamics, causes of variation, and interactions between the three domains.

The present study, therefore, explores how interactions of the farming system with market and context determine upgrading pathways and outcomes. In particular, it (1) describes the present status of regional clusters; (2) assesses upgrading pathways; and (3) analyzes how interactions affect pathways and outcomes of upgrading. It compares five emerging clusters in the Kenyan and Ethiopian tropical highlands that vary in upgrading status. In all these clusters, dairy farmers face the question of whether or not to transition from 'marketing of small surplus to local markets' to 'commercial supply to wholesale chains' (Oosting *et al.*, 2014).

By looking systemically at these interactions, this chapter contributes to the debates about upgrading in clusters, value chains, and farming systems; inclusion of smallholders in markets; system jumps; and pathways to sustainable intensification. The results can be used in devising future scenarios for system development and in co-design of interventions, as outlined by Martin *et al.* (2018). They inform strategic upgrading options for farmers and other value chain actors by pointing at the future shape of farm operations and the markets to supply to.

2.2. Methodology

2.2.1. Analytical framework – two subsystems in context

The analytical framework for this study considers that farming systems evolve because of the interaction with the market and context within a cluster (**Figure 2.1**). We take the dairy farming system within an emerging cluster as the main unit of analysis (A), from which we analyze linkages with and influences from the other two domains – market system (Campbell, 2014) (B) and context (C) – taking into account inter-farm variation within clusters. Upgrading, defined above, can occur in all three domains and in this study is respectively distinguished as technical, value chain, and institutional upgrading (Giuliani *et al.*, 2005; Kilelu *et al.*, 2017). Upgrading leads to system change (transition) and ultimately to alternative system state (transformation). The three forms of upgrading collectively can lead to commercial dairy farming and to the emergence of dairy clusters (Ramirez *et al.*, 2017). Transformation to a next development stage requires significant upfront investments in new practices, technologies, the innovation system,

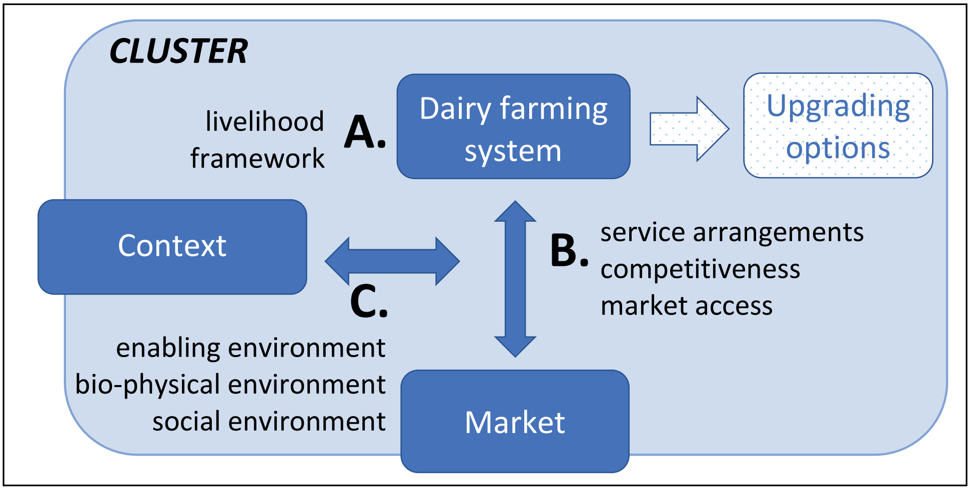


Figure 2.1. *Dairy farming system upgrading options as a result of interaction between farm, market, and context within a dairy cluster*

etc. (Oosting *et al.*, 2014; Schiere *et al.*, 2012).

We view the farming system and market system as two interacting, co-evolving systems within dairy clusters, each of which may experience 'system jumps' between development stages (Oosting *et al.*, 2014). Various system behaviours can be expected, as described by Schiere *et al.* (2012), depending on the specific farm, market, and context factors that influence farmers' livelihood strategy choices. These may include 'adaptive cycles', where change is episodic and periods of slow accumulation of capital (e.g., nutrients) are punctuated by release of capital and reorganization, for example by a forest fire or an epidemic; and 'lock-in', where systems get used to particular routines (Schiere *et al.*, 2012).

We build on two approaches for farming system analysis: (1) the farmers' perspective of Oosting *et al.* (2014), who in their LIVCAF model describe the transition from 'rural farmers supplying to rural consumers' to 'rural farmers supplying to urban consumers'; and (2) the market quality perspective of Duncan *et al.* (2013), who found that well-developed markets with good procurement and support service arrangements are key to sustainable dairy intensification, and that better market quality is associated with a higher proportion of improved cows that are better fed (sustainability here is used in the blended approach advocated by Mockshell and Kamanda (2018).

In all clusters, the primary driver for upgrading is the decline in livelihood due to diminishing farm size, mainly as a result of population growth (Veldwisch *et al.*, 2013). This requires intensification, i.e., the increased use of external inputs and services to increase outputs per unit of input (Udo *et al.*, 2011), in this case land use. We analyze upgrading dynamics by identifying and exploring changes in farming and marketing practices, as well as the secondary drivers that influence these; these act as accelerators of upgrading if present and as inhibitors if absent.

Analysis of upgrading dynamics thus includes three components:

A. Farming system factors – Technical upgrading of the farming system is explored based on the sustainable livelihoods framework (DFID, 1999). This considers how farmers combine the different types of livelihood *resources* they own or can get access to into livelihood *activities*, such as food and cash cropping, livestock-keeping, and off-farm activities, using a variety of *practices*, which often reinforce each other (Darnhofer *et al.*, 2012; Kebebe, 2015). Farmers optimize several objectives into a livelihood strategy (Bosman *et al.*, 1997). We thus assessed dynamics in the current mixed crop–dairy farming systems by looking at changes in the livestock and crops grown and at their functions in the farm, e.g., livestock for meat, milk, manure, draft power, social functions, household food, or sale; crops for food or sale (Udo *et al.*, 2011).

B. Farm–market interaction – Value chain upgrading changes the way a farm interacts with the market. Following the Windmill approach of Leonardo *et al.* (2015), we explored the influence of the various service arrangements that determine farmers' options for marketing their produce. We looked at farmers' access to markets, associated transaction costs, and fit of service arrangements with particular degrees of market integration (Brasier *et al.*, 2007; Ruben *et al.*, 2017). The service arrangements offer varying degrees and combinations of the horizontal (between farmers) and vertical (with input and output side chain actors) coordination that are necessary to effectively integrate smallholders into markets (Bijman *et al.*, 2012; Kilelu *et al.*, 2016). Market-integrated dairy requires a large variety of pre-production inputs and professional services, so this typology needs to cover service arrangements on both the input and output side.

C. Context influence on farm–market interaction – Lastly, several context factors significantly influence farm–market interaction and determine the need for *institutional upgrading*, i.e., the improvement of institutional voids that constrain value chain operations (Kilelu *et al.*, 2017; Medina *et al.*, 2015). We considered three types of factors: (1) factors in the biophysical environment, which include land use patterns, infrastructure (roads and utilities), climate and weather, animal and crop pests and diseases, risks of natural and human-induced disasters (such as droughts and wars), seasonality of production, and environmental impact of farming, including effects of agro-chemical use (Odhong *et al.*, 2015; Omiti *et al.*, 2009); (2) factors in the enabling context, i.e., the regulatory framework elements and their enforcement (such as agricultural policies, subsidies, access to finance, property rights, and quality standards) that determine whether the institutional context enables upgrading (Arias *et al.*, 2013; Kebebe *et al.*, 2015; Medina *et al.*, 2015; Veldwisch *et al.*, 2013; Zeleke and Awulachew, 2014); and (3) factors in the social environment, i.e., social identity and (dairy) farming history (Poole *et al.*, 2013).

2.2.2. Data collection and analysis

Case study sites were selected from the highlands of Ethiopia and Kenya, home to significant dairy production on a large number of smallholder mixed farms and a smaller number of medium- and large-scale dairy farms. The two countries differ in terms of socio-political context. The presence, reliability, and attractiveness of market service arrangements for pre- and post-production inputs and services vary between and within countries, leading to differences in market quality (Duncan *et al.*, 2013).

Sub-regional administrative units of roughly similar size were chosen as starting points for cluster selection: Ethiopian Zones and Kenyan Counties. Based on a scoping exercise and team knowledge, in each country two emerging clusters were selected that have good and comparable agroecological potential for dairying (located between 1750 and 3000 m above sea level) but differ in market quality (**Figure 2.2**). Milk production differs widely between clusters. For example, while Nyandarua and Nandi counties are roughly equivalent in terms of arable land, human population, and cattle herd size, the annual milk production in Nyandarua is nearly three times that of Nandi (KNBS, 2015a; KNBS, 2015b) (see **Appendix 2.1** for more detail). Due to two distinctly different milk-marketing situations within Nandi County, Nandi was divided into two clusters. To capture the within-cluster variety in market quality, six villages were selected per cluster, with the exception of East Shoa and Nyandarua clusters, where three and nine villages were selected respectively (see **Figure 2.2** for location of study sites). Villages vary in access to rural service centres and end-markets, with one-third each having good, medium, and poor access to a service centre, located at zero, one, and two hours' walk from a service centre respectively.

Interviews with farmer groups and with other value chain actors occurred between September 2016 and May 2017. Dairy farmer group interviews (FGIs) were held in all thirty villages, with group numbers ranging from five to eleven participants, averaging eight. In Arsi, East Shoa and Nyandarua clusters, all farmers who had been interviewed for the study in Chapter 3 were invited; in Nandi North and Nandi South, a new sample was invited to participate in FGIs. Farmers were purposively sampled to represent the range of dairy farm sizes in the village. The FGIs used a questionnaire with open questions for discussion and a number of participatory ranking exercises, focusing on both current situation and historic developments. The latter used either importance ranking or the ten seed technique (Jayakaran, 2002), which was modified to use twenty seeds in case answers exceeded five items. Farm classification categories offered by FGIs were harmonized, as categories such as 'small scale' and 'medium scale' are context-specific; some categories were combined. Questions about dairy experience, farm acreage, number of dairy cows and main crops grown were included in the FGIs in Nandi; for other clusters, these data were derived from previous dairy farmer interviews (Chapter 3).

For value chain actor interviews (VCAIs), dairy actors were selected by using information from earlier farmer interviews (Chapter 3) and by snowballing. A broad range of value chain actors was covered: private and public suppliers of pharmaceutics, agro-chemicals, semen, feeds, forage, and equipment; private and public providers of artificial insemination (AI), veterinary, extension, and financial services; milk and butter traders, transporters, and dairy processors; cooperative societies and farmer groups; and development agencies and

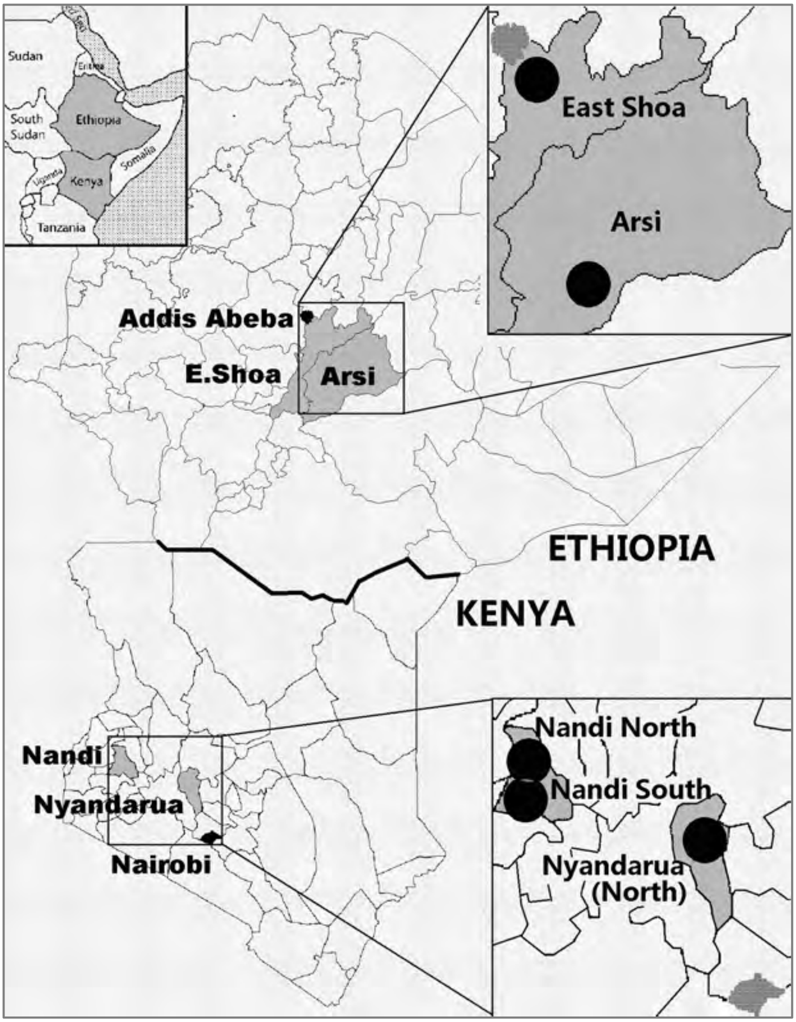


Figure 2.2. *Map of Ethiopia and Kenya with study clusters and study sites*

knowledge institutes (see **Appendix 2.1** for portrayal of dairy value chains in Ethiopia and Kenya). VCAIs numbered 118 in total (18 in East Shoa, 20 in Arsi, 43 in Nyandarua, 18 in Nandi North, 10 in Nandi South and 9 with multi-county actors in Kenya).

Secondary factors assessed in the FGIs and VCAIs – which act as drivers of upgrading and transition if present and as bottlenecks if absent – were derived from literature (Amankwah *et al.*, 2012; DFID, 1999; Duncan *et al.*, 2013; Francesconi, 2009; Gebremedhin and Jaleta, 2010; Kebebe *et al.*, 2015; Kilelu *et al.*, 2016; Omiti *et al.*, 2009):

- Farming system internal factors: changes in farmer livelihood strategies, practices, outcomes, and resources (also called capitals or assets) including natural (land acreage and soils, water, climate and weather, herd size and genetics, functions of and interaction between livestock and crops used); economic (capital); physical (farm structures, equipment); human (labour, knowledge and skills);
  and social resources (networks, groups)
- Market factors: dairy pre- and post-production service arrangements and service offer; farmer utilization and satisfaction; demand for dairy products (product, price, place); scarcity of inputs, services, and production factors; key marketing institutions, such as competition, role division in service supply, availability of market information, actor relationships, and milk quality assurance
- Context factors: collective action; dairy history and identity; consumer preferences; conducive infrastructure; access to production factors; regulatory space for private services; policy priority/instruments, public services, and subsidies; social inclusion and environmental impact.

Analysis – FGI and VCAI recordings were transcribed. Along with notes made during FGIs, they were analyzed in Atlas.ti using secondary factors as codes. Differences between clusters were rated by the first author based on data analysis. Results from FGI ranking exercises were translated into percentages and tabulated along with quantitative data; simple statistics were calculated.

2.3. Results

2.3.1. Cluster description

The five clusters selected are briefly described using the schematic positioning of their specialization and upgrading dynamics along two axes (**Figure 2.3**): feeding system and cash crop types. These axes denote the variation and recent upgrading in farming systems that, under pressure of land shortage, intensify in different ways along two directions (as observed in clusters studied): a feeding system transition from 'grazing with crop residue use' (low dairy intensity – L_d) to 'zero-grazing with planted forage' (high dairy intensity – H_d) and a cash crop transition from 'grains' (low cropping intensity – L_c) to 'horticulture and/or perennials' (high cropping intensity – H_c).

The clusters are thus characterized as (**Table 2.1**):

I. Dairy clusters – H_dH_c Nandi North and Nyandarua gradually specialize to dairy and become increasingly market-oriented; there is significant milk collection by cooperatives and processors; increasingly sophisticated types of service arrangements exist; other cash crops or livestock products are produced as a second activity; Nyandarua enjoys high demand for milk from processors and traders; 98% of the dairy farm herd is either crossbred or purebred exotic; potatoes come second after dairy; Nandi North has more non-dairy farmers and more medium- and large-scale farms; the choice of dairy over horticulture or perennials is still tentative.

II. Grain and fattening cluster – L_dL_c Arsi specializes in barley and wheat as cash crops, enabled by farm sizes that still allow such relatively extensive crops; for a long time, poor roads limited market access for dairy; just before roads improved around 2012, farmers adopted improved grain crop packages promoted by government and agribusiness; as a result, farmers focus on livestock activities, other than dairy, that utilize cash crop residues, but do not require daily marketing, i.e., beef, mutton, and heifer production; dairy development interventions have been occurring since the 1950s.

III. Perennial and horticultural crop cluster – L_dH_c Nandi South saw a diminishing role for dairy, as a move to high-value/ha activities occurred; farmers specialize in tea due to better support services; milk collection is almost only informal; cattle are being replaced by small livestock; semi-subsistence farming with extensive livestock and off-farm labour continues in areas unsuitable for tea and vegetable marketing.

IV. Mixed cluster – L_dH_c East Shoa, some farmers specialize in dairy (Type I), others in horticulture (Type III), while in more remote areas grains prevail (Type II). In the dairy herds of interviewed farmers, only 34% of animals are crossbred or purebred exotic; both subsectors benefit from fresh food demand in the nearby metropolis; competition for land occurs between the two and with export-oriented flower farming and urban development.

In all of the five clusters, intensification pressure is high. Over the past decades, farm sizes have shrunk due to customary intergenerational subdivision of land. In addition, the Ethiopian clusters reported land scarcity due to significant withdrawal of farm land for town and infrastructure development (past two decades) and due to allocation of land to state farms (L_dL_c Arsi cluster, 1980s) and flower farms (L_dH_c East Shoa cluster, 1990s–2000s).

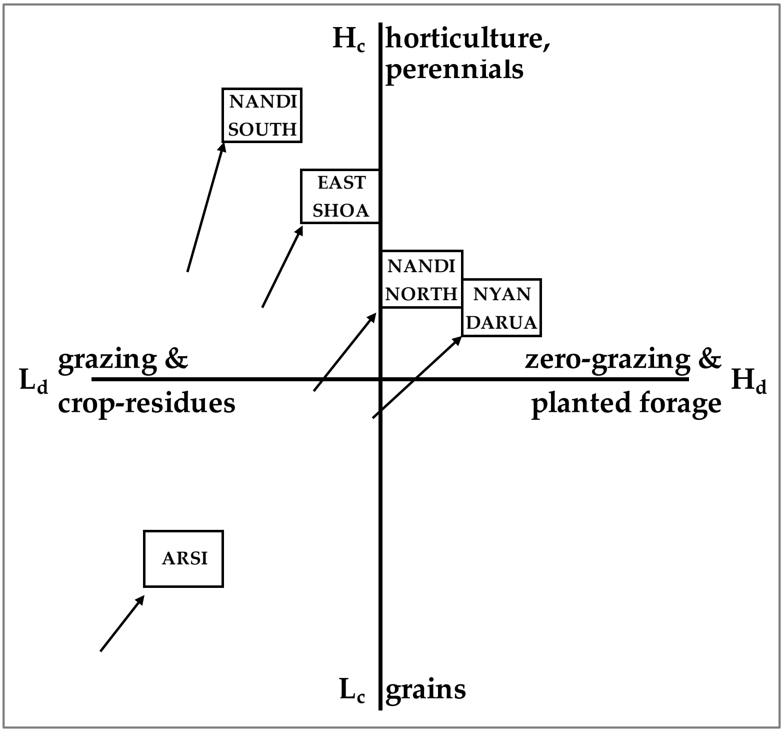


Figure 2.3. *Schematic positioning of specializing clusters along cash crop and feeding system intensity scales*

Table 2.1. *Key characteristics of dairy farming and marketing in five Ethiopian and Kenyan clusters*

Country:	Ethiopia		Kenya		
Cluster type:	L_dL_c	L_dH_c	L_dH_c	H_dH_c	H_dH_c
Characteristics Cluster name:	Arsi	East Shoa	Nandi S	Nandi N	Nyandarua
Average farm size (ha)	3.2	4.0	0.8	1.6	2.9
Proportion improved cattle	55%	34%	n.a.	95%	98%
Feeding system (*1*)	grazing + residues	grazing + residues	grazing + residues	residues + planted fodder	residues + planted fodder
Main cash crop(s) (*2*)	grains	various	tea	various	potatoes
Main marketing channel	traders	processors + coops	traders	coops	coops
Milk demand	low	medium	low	medium	high
Average est. milk sales (US$/year)	859	2,384			1,621
Input service offer	low	low–med.	low	med–high	high
Main service providers	public	public	private	private	private

(1) In all clusters, urban farms mostly practice zero-grazing.
(2) 'Various' indicates that no crop is dominant.

2.3.2. Analysis of upgrading in three domains

Figure 2.4 lists the main secondary factors that were identified in this study as influencing upgrading dynamics in the clusters. Upgrading in all three domains is most advanced in H_dH_c clusters, especially in Nyandarua, as **Table 2.2** shows. While a number of context conditions in L_dH_c Nandi South are good, specialization toward high-value cash crops is at the cost of upgrading in dairy. In L_dH_c East Shoa, competition with cash crops explains upgrading limitations for dairy. In L_dL_c Arsi, market constraints clearly affect dairy prospects. In the latter two clusters, less favourable context factors also dampen upgrading. Observed dynamics related to these factors are described in the next sections, following steps A–C from **Figure 2.1**. Factors with less apparent effect on upgrading dynamics were considered, but generally not described. A more detailed description of upgrading dynamics in each cluster is included as **Appendix 2.2**.

The examined clusters are under land-scarce conditions, which means that farm acreage and stocking rate (livestock units per hectare) are key indicators to observe when assessing intensification and upgrading status. A number of additional parameters – suggested by this study as potential indicators for upgrading in the three domains that score resource base, intensity of production, and market – are shown in **Figure 2.4**.

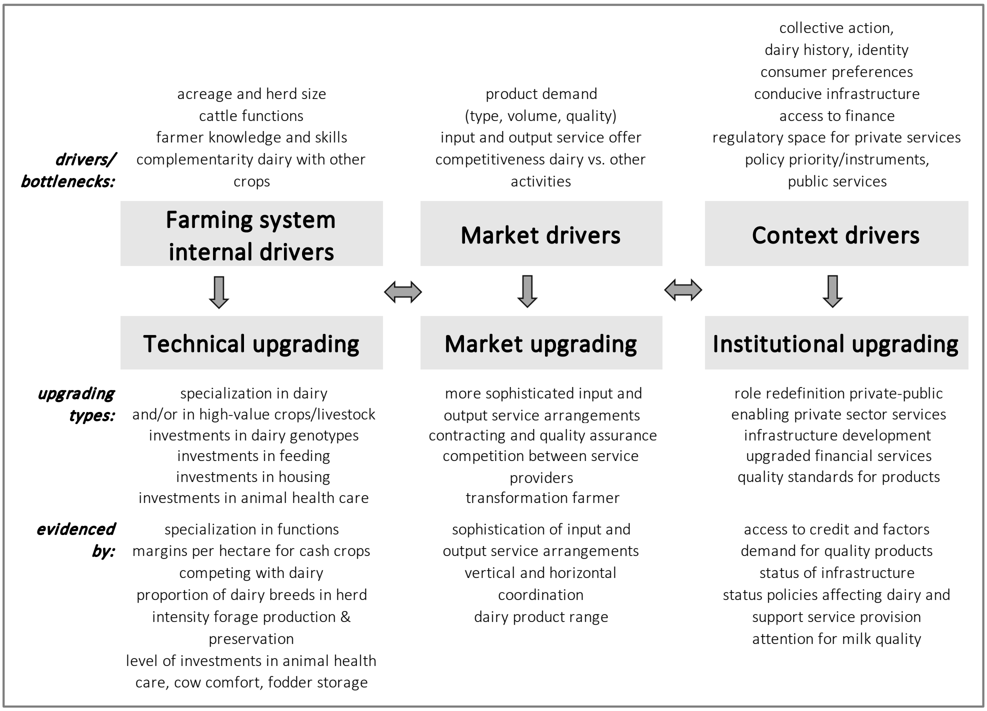


Figure 2.4. *Causal relationships between secondary drivers and upgrading types*

Table 2.2. *Technical, value chain and institutional upgrading in the five clusters*

Country:	Ethiopia		Kenya		
Cluster type:	L_dL_c	L_dH_c	L_dH_c	H_dH_c	H_dH_c
Cluster name:	Arsi	East Shoa	Nandi South	Nandi North	Nyandarua
Upgrading type					
Technical upgrading					
- specialization in 'dairy as business'	+	++	+	++	+++
- investments in dairy genotypes	++	++	+	++	+++
- investments in feeding	+	+	+	++	++
- investments in housing	+	+	+	++	+++
- investments in animal health care	+	++	+	++	+++
- specialization in high-value crops/livestock i.o. dairy	*++*	*++*	*+++*	*++*	*+*
Value chain upgrading					
- more sophisticated input and output service arrangements		+	+	++	+++
- contracting and quality assurance		++	+	+++	+++
- competition in service provision		++	+	++	+++
- transformation farmer organizations		+	+	++	+++
Institutional upgrading					
- role redefinition private–public			+	++	+++
- enabling private sector services	+	+	+	++	+++
- infrastructure development	+	++	++	++	+++
- upgraded financial services	+	+	++	+++	+++
- quality standards for products		+		++	++

N.B. Number of + denotes degree of upgrading: one + means some upgrading, additional + means more upgrading than in other clusters; no + means no upgrading identified.

Farming system factors (A)

This section describes technical upgrading dynamics identified in the farming systems domain. The data in **Table 2.3** offers insight into the ongoing changes in farming and the similarities and differences between clusters.

Specialization in dairy: smaller herds and less cattle functions – With farm size dropping to an average of three to four hectares, farmers in the Ethiopian FGIs reported that they specialize and reduce herd sizes, focusing on productivity rather than number of animals by crossbreeding with exotic dairy types: 'two improved cows compare to ten local cows, but they need intensive care.' Farmers did not consider classification based on cattle number or land acreage to be meaningful; rather, they classified dairy farms based on market orientation and management level (**Table 2.3**). This points to the ongoing transition in cattle functions in the farming system, from multipurpose (with local cattle for draft power, beef, manure, savings, social functions such as dowry, household consumption, and a small surplus for market) to more dairy-oriented, with fewer but specialized dairy cows. In Kenya, where average farm size is already well below three hectares and nearly all dairy cows have exotic blood, farmers specialize further to increase income per hectare. Breed choice is mainly between Friesian (higher producer) and Ayrshire (more disease-resistant and less heavy feeder). Entrepreneurial entrants, who have accumulated resources through employment or business, are investing in medium- to large-scale commercial farms and in advanced technology for feeding, housing, reproduction, etc., but often without commensurate investment in high quality farm labour.

Specialization in high-value crops/livestock/off-farm activities – Due to ongoing pressure on land, farmers reported that they choose livestock types and cash crops with shorter maturation time and higher margin per hectare, to offset rising land costs. Choice of crops/livestock types depends on how available options 'fit' within the farm, market, and context, including personal preferences and identity: especially in the Nandi clusters, farmers consider cattle-keeping an inalienable part of their identity. This brings important experience and skills, but also explains why farmers continue with dairy cattle even where the farm size barely allows for it (**Table 2.3**) and when competitive advantages of other livestock and crops as livelihood options outweigh those of dairy. Until some decades ago, sale of fresh milk and dairy products was subject to taboos (e.g., in L_dL_c Arsi cluster) that are only gradually losing their impact as milk undergoes commodity individuation (Pearson and Schmidt, 2017).

While dairy is being upgraded in H_dH_c Nyandarua, H_dH_c Nandi North and L_dH_c East Shoa clusters, it is being replaced by smaller species (such as goats, sheep, chickens, or rabbits) in L_dH_c Nandi South and by heifer production and/or fattening in L_dL_c Arsi and remote parts of Nandi and Nyandarua. Farmers increase roots/tubers/bananas and horticulture (in all clusters but Arsi) and perennials (tea, fruit trees and sugarcane, in Nandi), largely at the expense of grains. Due to more favourable market service arrangements for tea, since the 1980s 30–40% of farmers in L_dH_c Nandi South cluster have planted tea; this crowds out dairy, as tea plantations do not offer edible crop residues nor sufficient space for forage. In the Nandi clusters, mechanized land preparation is being replaced by manual work due to declining farm sizes and shift to perennials. In Ethiopia, draft animals are starting to be replaced by equipment such as broad bed makers and combine harvesters, due to scarcity of feed resources for draft animals. Nevertheless, the presence of draft animals explains why only one in three animals in the dairy herd is a dairy cow, compared to two in three in Kenya.

Farmers reported an increase of private business activities and casual labour in agriculture, construction, and transportation services. Around 40% of farmers indicated that they are engaged in off-farm activities, primarily in formal employment, private business, and trade. Households with jobs in the public or civil society sector are generally involved in private business as well, in which they invest their salaries.

Table 2.3. *Farm characteristics for the five clusters.*

	Clusters (*with sub-counties/districts where study sites are located)*	No. of villages (FGI part.)	Management level (% of dairy farms) *(1)* Low	Medium	High		Farm size (ha) (2)	Herd size	Milking cows as % of herd	% Improved cattle in herd *(2)*	Main crops (2), (3) (dominant crops in bold)	% hh w/ off-farm activities. *(2)*	Non-dairy farms (% of hh.)
	Breed Type		*Local*	*Local and improved*	*Improved*								
	Market focus		*Within village*	*Mixed*	*Outside village*								
L_dL_c	Arsi *(Limu-Bilbilo and Digalu-Tiyo)*	6 (42)	61		39		3.2	6.5	31	55	**Cereals**, pulses, vegetables	42	13
L_dH_c	East Shoa *(Ada'a)*	3 (21)	67		33		4.0	7.6	31	34	Cereals, pulses, oil seed, vegetables	35	40
Average for clusters Ethiopia			**64**		**36**		**3.4**	**6.9**	**31**	**45**		**40**	**27**
			Farm size (% of dairy farms) Very sm.	**Small**	**Medium**	**Large**							
	Farm Size (ha)		*<2.5*	*<2.5*	*2.5–8*	*>8*							
	No. of Dairy Cows		*1–2*	*3–5*	*6–20*	*>20*							
L_dH_c	Nandi South *(Aldai, Nandi South)*	6 (63)	78	16	6	0	0.8	2.2	66	n.a.	**Tea**, maize, RTB, veg., fruits	n.a.	19
H_dH_c	Nandi North *(Chesumei, Nandi North)*	6 (47)	76		20	4	1.6	3.3	64	n.a.	Maize, sugarcane, tea, vegetables, fruits	n.a.	25
H_dH_c	Nyandarua *(Ol Kalou, Kipipiri)*	9 (63)	92		8	0	2.9	4.3	65	98	**Potatoes**, cereals, pulses, vegetables	40	13
Average for clusters Kenya			**87**		**11**	**1**	**1.8**	**3.3**	**65**				**19**

(1) In the Ethiopian clusters, FGIs distinguished between 'low', 'medium' and 'high' management levels; numbers for the first two categories have been combined, as not all villages identified an intermediate management level.

(2) From dairy farmer interviews for East Shoa (n=37), Arsi (n=85), Nyandarua (n=91) [Chapter 3]; from focus group discussions for Nandi North and South; different methodologies may affect results; farm size in Nyandarua was 2.88 ha according to FGI, 3.59 ha according to dairy farmer interviews [Chapter 3].

(3) RTB = roots/tubers/bananas; here it includes Irish potatoes, sweet potatoes, arrowroot, cassava and bananas.

Table 2.4. *Support service arrangements and input and output service offer in five clusters*

	Output service arrangements with integrated input services (if any)							Input service arrangements (5)				
Service delivery model:	**Local market**	**Trader/ restaurant (1, 2)**	**Self-help group (3)**	**Coop-erative (4)**	**Proces-sor**	**Cooperative company (4)**	**Processor with services**	**Independ suppliers**		**Dept. of Livestock**		**Dev. agen-cies**
Arrangement type:	Spot market	Relational contract	Formal contract	Multilateral contract	Formal contract	Equity participation	Vertical integration	Formal contract		Public services		Various
Prevalence in:												
Ethiopia												
Arsi	++	++		+				+/-		++		+
East Shoa	+	+		+	++	+/-		+		++		+
Kenya												
Nandi South	+/-	++		+/-				+		+/-		+/-
Nandi North	+/-	+	+	++	+	++	+/-	++		+/-		+/-
Nyandarua	+/-	+	+	++	+	++	+	+++		+		+/-
Output services offered to farmers												
Collection from farm		+	+	+/-	+/-	+/-	+/-					
Chilling			+/-	+/-	+/-	+/-	+/-					
Transportation MCC to plant				+/-	+	+/-	+					
Quality testing at collection				+/-	+	+	+					
Input services offered to farmers								**Eth**	**Ken**	**Eth**	**Ken**	
Farm advice						+/-			+/-	+	+/-	+/-
Artificial insemination						+/-		+/-	+	+	+/-	
Veterinary services				+/-		+/-		+/-	+	+	+	
Feed, forage, and drugs				+/-		+		+	+	+/-		
Linking to input suppliers				+/-		+/-	+/-				+	+/-
Facilitate access to finance				+/-		+	+/-					+/-
Input advancing (on credit)				+/-		+	+/-					

\+ *commonly provided; number of + denotes relative dominance of service arrangement; +/- = provided by some actors only or to some farmers only.*

(1) *Direct supply to restaurants primarily by peri-urban farmer.*

(2) *In Ethiopia: butter traders; in Kenya: private milk collectors buying from farmers and selling to retailers, restaurants, consumers, and MCCs.*

(3) *In Ethiopia we encountered no farmer groups (less formal than cooperatives) supplying milk.*

(4) *Some cooperatives also process, which adds additional output services.*

(5) *In both countries, private companies, public agencies and NGOs/development projects play a role in provision of (subsidized) inputs and services. As these affect other service arrangements, we include them as separate categories.*

Changes in dairy practices – The specialization mentioned above plays out in a number of 'technology upgrades' in terms of farming practices. Only some farmers make these changes, and there are large differences between clusters. The highest proportions of farmers who make changes are in H_dH_c Nyandarua and Nandi North clusters and in dairy farms in or close to towns in all clusters:

- Investments in dairy genotypes using AI or improved bulls. This breed-replacement process is ongoing in Ethiopia and mostly completed in Kenya; except for in some remote, barely specialized villages, farmers in Kenya overwhelmingly keep purebred or crossbred Ayrshire, Friesian, Jersey, and Guernsey
- Investments in feeding practices follow a standard pattern over time: (1) grazing and crop residues are supplemented with industrial by-products and mixed rations; (2) grazing land is paddocked; (3) investments are made in production and preservation of planted forages such as oats, maize, and Napier and Rhodes grass to counter forage shortages
- Investments in animal housing in Ethiopia include new barns to house improved breeds; in Kenya, zero-grazing units and feed storage are used when intensifying further
- Investments in animal health care increase; due to the failure of communal cattle dips to control tick-borne diseases, in Kenya many farmers have moved to individual spraying and some vaccination for East Coast Fever; treatment by veterinary workers is increasing, as is self-administration of drugs purchased from agro-veterinary shops, especially de-wormers; in Ethiopia, farmers use government veterinary personnel, who often provide better private service on the side.

Farm–market interaction (B)

The data in **Tables 2.4** and **2.5** reflect upgrading dynamics stemming from the interaction between farming system and market, which become particularly clear when comparing clusters. As input service arrangements are important in more intensive dairy and become increasingly integrated with output service arrangements, **Table 2.4** includes both input and output service arrangements identified. This description follows the value chain upgrading categories of **Table 2.2**.

More sophisticated input and output service arrangements, tailored to farmer types – Dominant service arrangements range from local markets and traders in the limited market conditions of L_dL_c Arsi and Nandi South clusters to cooperative companies and processors, with increasingly integrated services in H_dH_c Nyandarua. In L_dH_c East Shoa cluster, processors and cooperatives are replacing the first two output service arrangements, as yet without significant upgrading in input service arrangements. In H_dH_c Nandi North and Nyandarua clusters, service arrangements of cooperative companies (i.e., upgraded cooperative societies) are being upgraded to integrated input and output service packages. Processors here, who source from farmer organizations and larger farms, are experimenting with integrated input and output service arrangements as well, more so in H_dH_c Nyandarua where competition for milk and service provision is fiercer.

Service arrangement use by farmers depends on their market integration and milk sales volumes. **Table 2.5** shows how different service delivery models cater to different farmer categories. Interviews revealed a strong relation between farmers' choice of service arrangements and farm household resource level, which in turn is related to off-farm activities. For resource-poor farmers, payment conditions are most important. They mainly sell to traders, as they need today's milk money for today's food, and they often lack the cash to acquire external inputs and services. Smallholders with more resources tend to sell to cooperatives and processors (sometimes through self-help groups), to benefit from larger two-weekly or monthly payments that can be used for inputs and investments. However, they usually sell at least some milk to traders to benefit from higher prices and to satisfy immediate cash needs. In Kenya, the resource-endowed smallholders selling to cooperatives can benefit from input and service advancing through widespread 'check-off' systems, in which costs for inputs and services advanced are deducted from the next milk payment. Medium-scale farms in both countries seem to use any of the output service arrangements and mainly consider price, buyer dependability and transaction costs.

Table 2.5. *Factors affecting choice of service arrangement by farmer category*

Service Arrangement:	**Local Market**	**Trader/ Restaur.**	**Self-help Group**	**Coop-erative**	**Pro-cessor**	**Cooper. company**	**Processor w/ Serv.**
Dominant Farm Size	*Small-holders - (peri-urban)*	*Resource-poor smallhold.*	*Resource-endowed smallhold.*	*Resource-endowed smallhold.*	*Larger farmers, organized smallhold.*	*Resource-endowed smallhold.*	*Larger farmers, organized smallhold.*
Factors affecting choice							
Payment period (days) (*1*)	direct	negotiable	<45	<45	<45	<45	<45
Farmgate price (US/kg) (*2*)							
- Ethiopia: milk	0.35–0.90	0.55–0.75	-	0.35–0.65	0.35–0.70	-	-
- Ethiopia: butter	3–12	7–13	-	-	-	-	-
- Kenya: milk	0.30–0.45	0.30–0.50	0.28–0.37	0.26–0.34	0.26–0.37	0.26–0.34	0.26–0.37
Milk buyer advances	-	cash	-	(inputs)	-	inputs	inputs
Proximity to services	< 1 hour	farmgate	------------------ *depending on location* ----------------------				

(1) With the exception of one processor in Kenya, whose terms are 90 days. (2) Using 2016 prices and exchange rates of ETB 20:USD 1 and KES 100:USD 1; includes dairy farmer interview data [Chapter 3].

(2) Interviews in both countries further indicated that increases in productivity and marketed milk volumes are necessary to be able to pay for the extra inputs and services. Farmers in Ethiopia mentioned a break-even point of 9 litre/cow/day.

Chain contracting arrangements and quality assurance – Low levels of trust in the chain form a strong inhibitor to upgrading, especially in Kenya. This is evidenced by significant 'side-selling' of milk: farmers and farmer organizations hedge marketing risks by selling to multiple clients. Processors do the same by contracting fixed volumes with suppliers. The result is a supply network rather than a supply chain, with associated high production and transaction costs. Marketing is volume- rather than quality-driven. Marketing relationships are complicated by the stark seasonality of production, with a slump in production during the dry season, and by the seasonality of consumption due to Orthodox Christian fasting seasons in Ethiopia.

Competition in service provision – In Ethiopian clusters, government agencies are the primary input and service providers. Although the main product in L_dH_c Nandi South, Kenya, is fresh milk rather than butter, the output service arrangements are unsophisticated, as in L_dL_c Arsi. Stronger competition leads to more sophisticated arrangements with higher degrees of horizontal and vertical coordination, as observed in H_dH_c Nyandarua cluster. Here, improved service levels were reported in milk contracting, milk collection, value chain financing, feed supply, drug supply, and AI services, but less so in curative health care and hay supply. Use of own bulls rather than AI services is diminishing, but still common in all clusters, pointing to issues with the quality of AI services (proportion of farmers using bulls is lowest in H_dH_c Nyandarua, at around 40%).

Transformation of farmer organizations – The poor track record of cooperatives in both countries in terms of governance, efficiency, and sustainability makes many farmers wary of investing heavily in them; many regard cooperatives primarily as channels for public and NGO subsidies. The more entrepreneurial smallholders in Kenya circumvent these issues by forming less formal 'self-help' groups that aggregate milk and supply directly to processors. Cooperative companies, generally initiated with support from development agencies such as Heifer and partners, add a variety of services to these inputs, including access to credit lines (**Table 2.4**). In Ethiopia, such systems are much less developed.

Context influence on farm-market interaction (C)

This section describes identified upgrading dynamics stemming from interaction with the context. Institutional upgrading (or the absence of it) may have a synergistic, antagonistic, or inconsequential influence on technical and value chain upgrading. The main context factors identified in interviews are presented in **Table 2.6** and are described here following the institutional upgrading categories of **Table 2.2**. A more elaborate description of policy dynamics is included in **Appendix 2.3**.

Impact of role division between private and public actors on service arrangements – Both countries have a turbulent history of public influence on agricultural service provision, contributing to large changes in Kenya and stagnation in Ethiopia. In Ethiopia, public actors play an overriding role in access to inputs, services, and land. In Kenya, 25 years of significant policy changes have affected dairy in diverse ways: very significant cuts in public services in the early 1990s resulted in a collapse of the dairy sector, evidenced by the bankruptcy of many cooperatives and the state processor KCC (1999); market liberalization policy only gradually resulted in private service delivery (Kijima *et al.*, 2009); and the enabling environment now varies from county to county (Recha, 2018).

In both countries, many interviewees complained about the inconsistency and inadequacy of public services for dairy. Minimization of dairy extension services in Kenya in the 1990s resulted in declining farmer skills and ultimately in declining yields. Public agencies have a (virtual) monopoly on vaccination for notifiable diseases in Kenya and on vaccination, AI, veterinary, and extension services in Ethiopia. The regulatory gaps for private AI, animal health services, and quality assurance of feed and the low policy priority for dairy compared to crops and meat received strong negative feedback. Relatively large positive impact was attributed to development projects.

In both countries, governments use subsidies to promote uptake of more market-oriented practices and to make services more accessible to farmers in remote locations and/or with fewer resources. In Kenya, interviewees mentioned many downsides to subsidized services. In Ethiopia, public monopolies on most inputs and services lead to an insensitivity toward demand, favouritism and lack of a level playing field for private providers. In both countries, subsidies seem to have created dependency on chemical fertilizers, leading to soil fertility issues.

Space for private sector service provision – The above indicates a number of bottlenecks for private service provision, even in Kenya where market liberalization is standing policy. In Ethiopia, regulatory space for private service providers primarily results in private agro-input shops (feed, drugs) and milk/butter trade; in Kenya, it results in agro-input shops and milk trade, as well as AI, veterinary, and advisory services. In both countries various business licenses are required, but monitoring of licenses is lax in Kenya.

Infrastructure development – Infrastructure, in terms of roads and utilities, was improving in all clusters. Market access for remote villages was more restricted by poor roads in Ethiopia than it was for remote villages in Kenya, as was least restricted in H_dH_c Nyandarua, where authorities have invested more in roads. While road upgrading in L_dL_c Arsi did improve access to markets, in L_dH_c East Shoa cluster it was mostly seen as taking away land from farming.

Financial services, factor access and information supply – In Ethiopia, poor access to finance is a significant bottleneck for upgrading of dairy farms and support services; farmers primarily rely on community savings and community credit institutions such as '*ekub*'. This is less of an issue in Kenya, where people who are connected to more formal value chains benefit from chain financing mechanisms, cooperative savings and credit institutions, and easier access to bank loans. Capping of interest rates at 14% per year for agricultural loans was applauded by Kenyan farmers. Access to labour is impeded by the image of dairy as involving much heavy and dirty labour. Access to information is increased by the presence of private advisory service providers next to public ones, and local language radio and TV programs about agriculture are highly appreciated by farmers.

Quality standards for products – In Kenya, demand for dairy products is strong and growing (annual consumption exceeds 110 L/capita (Makoni *et al.*, 2014)). Consumer preference for raw milk gives the informal market a strong advantage. Its market share remains over 70%, despite many decades of formal chain development efforts and presence of product standards (KDB, 2018; Makoni *et al.*, 2014). In Ethiopia, annual consumption is much lower, at around 20 L/capita, and the informal market trades over 98% of the volume (Makoni *et al.*, 2014); here, cooperatives and processors find it difficult to deal with seasonality of consumer demand resulting from long fasting seasons (on top of seasonality of production), although interviewees may have been using this as a metaphor for the difficult business climate.

Table 2.6. *Conduciveness of context factors in five study clusters*

Country:	Ethiopia		Kenya		
Cluster type:	L_dL_c	L_dH_c	L_dH_c	H_dH_c	H_dH_c
Context factors / Cluster name:	Arsi	East Shoa	Nandi S	Nandi N	Nyandarua
Biophysical					
Climate/weather	+++	++	++	++	+++
Absence of disease threat	+	+			++
Infrastructure	+	+	+	++	+++
Enabling environment					
Policies promoting dairy			+	++	+++
Policy space for private service	+	+	++++	++++	++++
Public disease prevention services	++	++	+	+	+
Research–extension–farmer linkages	++	++	+	+	+
Enforcement of service quality			+	++	+
Enforcement of milk quality			+	+	+
Access to finance			+	++	++
Chain upgrading facilitators	++	++	++	++	++
Social environment					
Dairy history and culture	+++	+++	+++	+++	+++
Dairy seen as business	+	+	++	+++	++++
Milk consumption	+	+	+++	+++	+++
Land availability	+	+			+
Labour availability	+++	++	++	++	++

N.B. The number of +'s indicate how conducive the situation is in comparison with other clusters.

2.4. Discussion

2.4.1. Present upgrading status of farming and clusters

This comparative assessment between clusters clearly draws out important differences in upgrading of farming systems that emanate from farm–market–context interactions. It reveals that all five clusters show clear evidence of technical, value chain and/or institutional upgrading of 'typical' semi-subsistence mixed crop–livestock systems to more market-oriented systems. The need for higher returns per hectare requires specialization and commercialization, in order to maintain or increase farm yields and household incomes. Technical, value chain and institutional upgrading are most pronounced in the H_dH_c clusters and least in the L_dL_c cluster, where the market system showed little to no upgrading (**Table 2.2**). Degrees of upgrading are clearly related to secondary drivers that act as accelerators and inhibitors.

The current status of each cluster is the result of diverging pathways along dairy feeding system and cash crop intensification dimensions. These lead to increased market orientation of farmer livelihood strategies, marketed volume, and use of pre- and post-production inputs and services (**Figure 2.3**), but for different commodities and to different degrees. More intensive dairy can thus be considered to be one of the high-value 'cash crop' options that farmers can specialize in when market and context conditions are right; so are other intensive livestock activities, such as commercial poultry. This makes the Windmill approach, postulated for crop commodities by Leonardo *et al.* (2015), to be applicable to livestock commodities as well. However, ample attention is needed for input service arrangements, which need to be especially elaborate for livestock ventures.

2.4.2. Cluster upgrading pathways toward the future

Cluster upgrading directions diverge as a result of different specialization choices. The different clusters react differently to the primary driver of land use intensification, which requires higher productivity and higher returns per hectare. Choice of either intensive dairy or horticultural and perennial cash crops will be at the expense of the other option (L_dH_c vs. H_dH_c). Most clusters can be expected to move further along the intensification pathway type started, unless actors consciously redirect course:

- H_dH_c – dairy clusters. Dairy is competitive against other commodities; service arrangements become increasingly sophisticated and competitive; private and/or cooperative actors play a strong role. Continued development of H_dH_c clusters toward dairy seems likely, provided upgrading in farming, market, and context progresses. Further specialization may lead to singular focus on dairy (H_dL_c). This expected further upgrading of the H_dH_c dairy clusters contradicts modelling outcomes of Herrero *et al.*

(2014), who only foresaw such upgrading for peri-urban dairy in Kenya, and may warrant review of their modelling assumptions.

- L_dL_c – grain and fattening cluster. Strong public policy directions and public–private collaboration made grains in L_dL_c Arsi cluster more competitive than dairy. Future development of L_dL_c clusters toward dairy depends on serious value chain and institutional upgrading, if dairy is to effectively compete with cash crops. For the time being, available farmer expertise and presence of improved dairy breeds in L_dL_c Arsi keep the door open for upgrading of dairy, but heifer production and commercial forage production for supply to other dairy clusters seem to be more attractive alternatives. These alternative opportunities are enhanced by (1) the competition for fodder between dairy and draft animals in Ethiopia; and (2) the low capacity of intensifying tropical dairy systems to produce sufficient replacement stock and fodder (Bebe, 2008), which results in high prices for dairy heifers and fodder.
- L_dH_c – perennial and horticultural crop cluster. Severe land scarcity affects these clusters, with specialization toward perennials, horticulture, and intensive livestock. Due to strong path dependency, further upgrading and specialization of L_dH_c clusters around perennials and horticulture are most likely, along with intensive non-dairy livestock-keeping in areas not suitable for perennials and horticulture. It will be interesting to watch whether farmers with a strong 'cattle identity' will give up dairy.

Prospects for the remaining L_dH_c East Shoa cluster are still uncertain. It could either move toward intensive dairy, toward horticulture or toward other high-value commodity options. Upgrading prospects for dairy depend on how relative competitiveness of each venture is affected by dynamics in its respective markets (e.g., conduciveness of service arrangements for each option) and context (e.g., spatial planning and enabling policies).

An interesting next step would be to quantify the degree of specialization and intensification of (dairy) farming in clusters, building on recent work in Europe and West Africa (Gonzalez-Mejia *et al.*, 2018; Roessler *et al.*, 2016).

2.4.3. Upgrading options at farm level

To explore upgrading options for dairy farmers in different clusters, we draw attention to *path dependency*, farmer *feasibility space* and *aspirations*. Path dependency (Schiere *et al.*, 2012) as system behaviour applies at cluster, value chain, and farm level: past investments in an established commodity favour its current competitiveness. A 'new' commodity still needs to build up its capitals and is competing against stakes in the established commodity. This path dependency becomes stronger the more intensive the competitive crop or livestock activity. When dairy is being compared against tea and against barley as an investment choice, investments in technical and value chain upgrading for dairy need to be higher to beat tea than to beat barley, as tea has a higher expected return per hectare. Waithaka *et al.* (2006) suggested that the intensification of farms in Nandi South could increase milk production on purchased feed, but the present study shows that in this L_dH_c cluster, the suite of service arrangements required for entrepreneurial dairy are lacking, whereas they are present for tea. While path dependency is expected to be stronger for H_dH_c and L_dH_c than for L_dL_c type clusters, it can influence upgrading pathways in any cluster. For example, the ongoing reliance on draft oxen rather than on machines in Ethiopia appears to be a significant barrier for transition to market-oriented dairy, as a large proportion of the fodder biomass is fed to oxen and (local) oxen dams, limiting fodder availability for dairy cows.

Differences in *farmer livelihood strategies* help explain the presence of multiple types of service arrangements coexisting within the same cluster (**Table 2.4**). These cater to different farmer groups: the supply conditions of the formal arrangements are suiting resource-endowed farmers with more intensive dairy farming but are unfavourable to resource-poor farmers (**Table 2.5**). To them the informal arrangements offer a flexible and convenient market outlet with a competitive milk price, at an input level they can afford (**Table 2.5**). For policy makers and development actors who aim to connect more smallholders to (formal) markets, an important consideration should be that farmer livelihood strategies are the result of *feasibility space* and *aspirations*, which do not necessarily go hand in hand.

Farmers' *feasibility space* expands along with their resource base, access to production factors, presence of service arrangements, and conducive context factors (Schiere *et al.*, 2012). Resource-endowed farmers can intensify crop or livestock activities; utilize upgraded service arrangements; and access land, labour, credit, and information. In contrast, due to limited feasibility space, resource-poor smallholders are likely to choose *autonomy* and *risk aversion*, reducing external input and service use and using informal service arrangements.

Farmer *aspirations* determine the livelihood strategy choices made within this feasibility space. The less sophisticated informal service arrangements better fit with the livelihood strategies of resource-poor smallholders, for whom dairy likely serves food security, savings, and consumption assets objectives rather than income generation (Dorward *et al.*, 2009). A growing feasibility space will not necessarily be used to produce more milk (or other produce) for the market, let alone to make the significant changes to farming practices that are required for intensive dairy farming (Udo *et al.*, 2011). The effect of farmer aspirations is also apparent in the presence of 'positive deviants', those who actually utilize their feasibility space for dairy development. They are recognized by peers as 'serious farmers' (Kenya) with 'good management' (Ethiopia). These households achieve higher productivity and income levels with intensive dairy farming, utilizing more inputs and services, and marketing through formal channels. They adopt suitable upgrading options, such as investments in zero-grazing units, planted forage, feed rationing, mechanization of milking and forage production, and stronger contracting with milk buyers, which may also involve quality control of milk, inputs, and services (Dorward *et al.*, 2009).

2.4.4. Sustainability of intensification pathways

We now address the question of whether the identified transition pathways do actually contribute to the sustainability challenges mentioned in the introduction.

Alleviation of rural poverty – Social inclusion of smallholders in agricultural markets is a policy priority in both countries. It is enacted through infrastructure development, support to cooperatives, and public facilitation of pre-production inputs and services. To contribute to poverty alleviation, these services need to reach the rural poor, i.e., smallholder dairy farmers, and need to support upgrading of dairy farming. While not intending to evaluate public dairy interventions, this case study yielded the following insights:

- Market access for resource-poor farmers can be positively impacted by policy support instruments and development interventions; these have their own dynamics, which often appear to be at odds with the space for private service provision. Long-term impact assessment is critical, as their effects are often slow and not very noticeable (Lie *et al.*, 2018).
- Cooperatives offer no panacea for upgrading. In less sophisticated markets, cooperatives with a basic service offer can stimulate market orientation. In intermediate market conditions, they serve as collection and aggregation centres that are highly valued. In more sophisticated markets, however, in order to stay competitive they have to move beyond being what Royer *et al.* (2016) call a 'claim group' and develop into more efficient service providers.
- As membership of cooperatives consists of resource-endowed smallholders with a relatively large feasibility space, supporting them through the cooperatives has a large potential to grow agricultural output (Mellor, 2014) but excludes resource-poor smallholders.
- The quality of public services generally is insufficient for dairy farming upgrading, which requires dependable pre-production inputs and services (Udo *et al.*, 2011). While in Ethiopia authorities unintentionally hamper dairy farming upgrading by monopolizing key support services, authorities in Kenya at times hinder private service delivery development by subsidizing inputs and services to farmers who have sufficient purchasing power.

The question thus remains: how can authorities effectively support market inclusion of the resource-poor, offering them options to *step up* or *step out*, rather than *hang in* (Dorward *et al.*, 2009)? This study illustrates the urgency of this issue by the observation that in areas such as L_dH_c Nandi South, the size of many farms is close to or already below the 0.4 ha that farmers consider the threshold for a viable livelihood, according to Waithaka *et al.* (2006).

Supply of sufficient and safe food – In terms of quantity and product range, the Kenyan dairy sector is meeting demand (KDB, 2018). Focus on quantity rather than quality leads, however, to increased concern about safety of milk and dairy products. These need to be addressed through upgrading of quality assurance practices in all three domains. In Ethiopia, the sector cannot meet demand in terms of either quantity or quality, as is evidenced by high prices and growing imports (Makoni *et al.*, 2014; Ruben *et al.*, 2017).

Upgrading should lead to higher marketed milk volumes, higher farmer incomes, and marketing of safe food. This confirms findings of Duncan *et al.* (2013) and Murage *et al.* (2018). 'Jumps' in production are achieved by specialization, which requires investments of different kinds, including management focus. Specific upgrading options are relevant within specific cluster conditions. For example, the hub concept described by Kilelu *et al.* (2016) may work best under smallholder conditions with competitive demand for services and competition for milk; moreover, context conditions for hub success include policy priority for smallholder dairy development, ample space for private service provision, and presence of a third-party innovation intermediary (Reardon, 2015).

Making farming climate-smart – Regarding environmental impact, interviewees in both countries showed concern for the imbalanced use of fertilizer, leading to acidification and leaching of soils, and for the injudicious use of agro-chemicals that can affect human health, water quality, and product quality. The results suggest that farmers do worry about increasingly erratic weather – indicating the need for climate adaptation – but did not connect climate change with their own practices. These results show that before dairy sector actors will take action, climate change mitigation does require carefully designed policy regulations that address both farmer and public interests, as was also illustrated by Paul *et al.* (2018).

We conclude that, in both countries, progress is centred around poverty alleviation objectives, which aligns well with current policy interests. Sustainable upgrading pathways require more attention for food safety and climate-smart criteria.

2.4.5. Upgrading dynamics as result of farm–market–context Interactions

This study builds on three approaches for analysis of a farming system and its interaction with the market: the *farmers' perspective* of Oosting *et al.* (2014), the *market quality* perspective of Duncan *et al.* (2013) and the *sales arrangement*/*Windmill* perspective of Leonardo *et al.* (2015). Our exploration of the co-evolution of farming systems and service arrangements offers new insights in three areas.

Firstly, this study sheds light on the reasons particular types of farmers participate in particular chains: upgrading of service arrangements within a dairy cluster offers technical upgrading opportunities and enlarges farmers' feasibility space, but each individual farmer needs to master the resources required and aspire to upgrade. As farm resource endowments differ, a gradual and incomplete shift of farmers to upgraded chain and farming practices is apparent. This study shows that not only urban farmers but also rural farmers participate in multiple chains as a risk-reduction strategy where service arrangements are insufficiently dependable. The traders' arrangement connects rural farmers in all clusters to both rural and urban consumers, while in the more dairy-oriented clusters, farmers sell to both traders and processors. This suggests that farmers can be part of both chains for a large part of the transformation trajectory from 'semi-subsistence with small surplus to local markets' to 'commercial supply to wholesale chains'. The transition described by Oosting *et al.* (2014) of 'rural farmers supplying to rural consumers' to 'rural farmers supplying to urban consumers' can apparently last for decades when market and context conditions are sub-optimal.

Secondly, this study sheds light on dynamics of co-evolution between farming system and service arrangements. It adds five insights to the findings by Duncan *et al.* (2013): (1) technical upgrading of housing and health care practices accompanies upgrading of breeding and feeding; (2) relations with off-farm activities appear to be complex: while income from off-farm business and employment is important to finance dairy investments and to supplement farm income, the proportion of households engaging in off-farm activities in this study did not change with market quality; further research is warranted into the patterns of such investment and its impact on dairy upgrading; (3) it shows the competition between farming activities in the specialization process: in clusters where dairy support services remain less conducive, farmers specialize into cash crops and short maturity livestock production activities at the expense of dairy; (4) it shows the propelling role of competition between service providers in the co-evolution between farming system and service arrangements; (5) it shows the correlation between farming system upgrading and the activity of innovation intermediaries; various authors (Kilelu *et al.*, 2016; Ramirez *et al.*, 2017) have shown the important roles of innovation intermediaries in upgrading. While this study identified activities and impact of intermediaries in the various service arrangements – dairy cooperatives, processing companies, public–private collaboration and development agencies – further description goes beyond the scope of this chapter.

Lastly, this study sheds light on system behaviours such as system jumps and adaptive cycles (Oosting *et al.*, 2014; Schiere *et al.*, 2012). We postulate that co-dependencies between farm, market, and context are key to understanding the adaptive cycle dynamics of system upgrading, including system jumps, stagnation, and collapse. Section 2.4.6 further elaborates on these system dynamics.

2.4.6. Positive and negative co-dependencies in relation to system jumps

The marked differences in upgrading status between clusters can be attributed to co-dependencies between technical, value chain, and institutional upgrading processes. Co-dependencies make upgrading in one domain dependent on that in another. An example of strong co-dependency is when farmers can only adopt a new forage crop with commensurate investments in skills, (imported) seed, and equipment, if service providers simultaneously invest in providing the inputs and services necessary to grow the crop and if policy makers ensure adequate advisory services, as well as regulations for importation and control of seed and equipment. We coin the concept of 'concurrency' to describe this mutual dependency in terms of timing of synergistic upgrading in different domains.

Upgrading in all three domains can be expected to occur when 'all lights are green', i.e., drivers in all three domains work as accelerators. *Positive feedback loops* (Schiere *et al.*, 2012) propel upgrading, potentially leading to significant transitions. For example, farmers who consistently supply to formal milk buyers can use their supply records to more easily get credit from financial institutions. This enables investments in higher production capacity, which further improves access to services. This bankability cycle may be initiated by infusion of capital from other income sources, such as employment and/or business, and is more apparent in Kenya than in Ethiopia, where banks rarely provide (scarce) credit to dairy farms due to dairy's low rate of capital turnover.

Concurrency and positive feedback loops will not occur, however, when one or more drivers 'throw a spanner in the works', consecutively inhibiting upgrading in the three domains. In such cases, co-dependencies cause *negative feedback loops* (Schiere *et al.*, 2012) that lead to stagnation and may be hard to break. For example, the uncertainty about price and payment conditions pushes farmers to lower external input levels, leading to lower production levels and higher seasonality of production. These in turn inhibit processors from offering good payment conditions. Where other livelihood opportunities have a significant competitive advantage, farmers can be expected to turn to those. In their absence, decreasing farm size will lead to stagnation and declining wealth. Where dairy is hard to combine with new livelihood activities, as in the case of tea, dairy may collapse and the farming system will transform to a system without dairy; total disappearance of dairy in the L_dH_c cluster has so far been prevented by the strong 'cattle identity' of the Nandi farmers.

Progressive upgrading may lead to *transformation* of the farming system and/or market system. Farmers in all clusters noticed the final stages of the transformation from grazing land to farmland for crops. The L_dL_c cluster only recently completed this transformation 'from grazing to grain', following public promotion of improved grain variety packages in the 2010s. In the meantime, the most upgraded H_dH_c cluster appears to be facing another transformation that will manifest in upgraded feeding strategies: 'from grazing with crop residues to zero-grazing with planted forage'. However, this is co-dependent on further value chain upgrading that will ensure supply certainty and improved access to and quality of inputs and services.

When a sizable number of upgrades needs to occur concurrently, a *system jump* can be expected when reaching a certain threshold – or tipping point – of pressure to transform between alternative system states (Tittonell, 2011). This study illustrates this for two scale levels: (1) semi-subsistence clusters transforming to more commercial intensive systems (dairy or horticulture) mentioned above; and (2) households shifting their milk supply from traders to wholesale chains. At both levels the jump requires concurrent synergistic upgrading and build-up of resources. In H_dH_c clusters in Kenya, a number of positive dynamics occur that may lead to such a system jump, once the current lock-in of farming and market systems can be overcome. That system lock-in is evident in chain fragmentation, high costs of production and transactions, and disregard for quality assurance of milk and inputs. We speculate that the pressure to upgrade gradually builds up and forces a number of concurrent technical, value chain, and institutional upgrades to suddenly take place. Time will tell whether lock-in will be overcome by a system jump through upgrading, or whether it will persist by protection of vested interests, perpetuating the current situation until a crisis causes system collapse.

2.5. Conclusions

This comparative case study of five emerging dairy clusters in the East African highlands aimed to explore how interaction of the farming system with market and context shape cluster emergence and transformation from semi-subsistent to market-oriented dairy farming. Key findings of this study add to debates about upgrading in clusters, value chains and farming systems; inclusion of smallholders in markets; system jumps; and sustainable intensification pathways. They include:

- Co-dependencies between technical, value chain, and institutional upgrading processes are key to understanding the adaptive cycle dynamics of farming- and market-system upgrading, including system jumps, stagnation, and collapse. We coin the concept of 'concurrency' to describe co-dependency in terms of timing of synergistic upgrading in different domains. When a sizable number of upgrades needs to occur concurrently, a system jump can be expected upon reaching a certain threshold of pressure to transform. The implications for studies of technical upgrading in farming systems are that synergies between internal (farming system) and external (market and context) factors determine upgrading outcomes.
- The upgrading status of dairy clusters results from diverging pathways along two dimensions: feeding system intensification and cash crop intensification. Intensive dairy is competing with other high-value cash crop options – intensive livestock activities,

horticulture, and perennials – that farmers specialize in depending on market and context conditions. Clusters can be expected to move further along the intensification pathway started, unless actors consciously influence direction through investments in upgrading conditions. The implications for the debate on cluster upgrading are that (1) transition emerges from synergistic technical, value chain, and institutional upgrading; and (2) evaluation of upgrading options needs to consider notions of path dependency, concurrency, and investments in upgrading conditions.

- Farmers' feasibility space for participation in transition expands along with their resource base, access to production factors, presence of service arrangements, and conduciveness of context factors. Resource endowment levels help explain why particular farmers participate in particular chains. Transition from 'semi-subsistent farmers supplying to local markets' to 'market-oriented farmers supplying to urban markets' may take decades when market and context conditions are sub-optimal. This adds to earlier work on inclusiveness of connecting resource-poor farmers to markets.
- The most upgraded H_dH_c cluster appears to be facing another transformation that will manifest in upgraded feeding strategies and further value chain upgrading, which will ensure supply certainty and improved access to and quality of inputs and services. Studies of such real-life system transformation cases will add to understanding of system jumps.

Further research may focus on quantification of the degree and thresholds of specialization and intensification of (dairy) farming in clusters and on the impact of different service arrangements and vertical coordination mechanisms on local economic development.

In both countries dairy development objectives are centred around poverty alleviation, which aligns well with current policy interests. We recommend that policy makers and cluster development planners carefully design sustainable intensification pathways for competitive commodities. Sustainability issues to be considered include: (1) enabling a larger proportion of resource-poor farmers to participate in markets; (2) at the same time, enabling private input and service provision models that can last; and (3) more attention for food safety and climate smartness of agricultural development.

Limitations to this study

The two x three villages sampling scheme used appears to sufficiently capture variation within clusters to assess upgrading dynamics and transitions. While the small number of one x three study villages in East Shoa cluster may insufficiently capture variation in the zone, the study area can be considered representative for the peri-urban half of the zone. The three x three scheme used in Nyandarua did not yield significantly more insight than the two x three scheme used elsewhere.

The sub-regional administrative units taken as starting points for cluster boundaries allow a researchable unit in which farm, market and context can show sufficient homogeneity and variation. However, clusters do not necessarily coincide with such units. Nandi County in Kenya shows such distinct differences that we can speak of two clusters, each appearing to be part of multi-county clusters with Eldoret and Kisumu as centres. Further research will benefit from clearer delineation of clusters. This will also improve sampling of study sites.

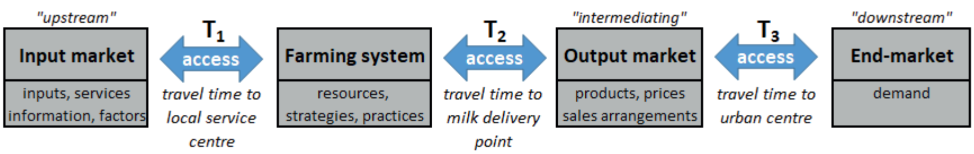
The retrospective interview tools, which explored timelines and past changes in farming practices, did provide considerable insight in developments since the 1980s. Nevertheless, overcoming the bias inherent in a snapshot approach when looking at time-based processes may only be possible through longitudinal or historic research.

While this study analyzed interaction between two systems – farming and market – the farming system was analyzed in more detail. Additional analysis of the market system may add valuable insight, as suggested by Reardon (2015), although it risks making the analysis too complex. Using a food systems approach may be useful.

Additional studies may explore the impact of different service arrangements and vertical coordination mechanisms on local economic development. Out-of-cluster service providers such as processors and input suppliers may play a key role in upgrading dynamics, but may also capture a significant part of the benefits of transition.

3. Effects of proximity to markets

Abstract: The effect of proximity to markets on dairy farming intensity and market participation traditionally has been viewed as a market quality effect stemming from distance to end-markets with resultant travel time. This study departs from this by distinguishing three travel time components: travel time to local service centre for inputs and services, to dairy delivery point, and to end-markets. Dairy farms in nine villages each in Ethiopia and Kenya were sampled and interviewed along a double proximity gradient. Effects on many production and marketing parameters were measured and compared using regression analysis, to test the hypothesis that intensity of dairy farming and degree of market participation increase with proximity to end-markets and with proximity to local service centres. Findings prove the hypothesis for proximity to local service centre, which causes better market quality for inputs and outputs, smaller farms with less available labour, use of more purchased feeds and services, higher stocking rates, higher yields and higher margins per hectare. Findings only partly prove the hypothesis for proximity to end-markets, mainly due to unexpected land scarcity in the most remote locations. Low productivity and low dairy farming intensity and market participation for remote farms in Ethiopia are attributed to limited and volatile market demand, a coarse milk-collection grid, and low quality of input and service markets, which are largely publicly organized. Implication of this study is that the common typology of dairy farms in '(peri-) urban' and 'rural' farms needs adjustment by outlining local market access and connectivity. 'Remote' rural farms need to be connected to milk collection infrastructure, input shops and services to even have the choice to increase participation in dairy- or other markets.



Published as: *van der Lee, Jan, Simon Oosting, Laurens Klerkx, Felix Opinya and Bockline O. Bebe, 2020. Effects of proximity to markets on dairy farming intensity and market participation in Kenya and Ethiopia. Agricultural Systems 184, 102891, doi: 10.1016/j.agsy.2020.102891*

3.1. Introduction

Intensification of livestock production with stronger market participation of smallholder farmers is generally promoted as an important pathway to secure food supply to growing urban markets in developing countries (Paul *et al.*, 2018; Reardon *et al.*, 2014). Where pressure on land increases, following population growth and urbanization, it is considered essential to focus on increasing output per unit of land (Akinlade *et al.*, 2016). Intensification of production per unit of land is associated with increased utilization of external inputs and services, with the aim of growth in marketable surplus (Barrett *et al.*, 2012; Duncan *et al.*, 2013). This trend toward commercialization of production usually leads to farm specialization and requires increasing market orientation, market participation and business skills (Akinlade *et al.*, 2016; Udo *et al.*, 2011).

Various authors indicate that in smallholder dairy farming systems, greater market participation is not only influenced by production level factors, but also by market access (Omiti *et al.*, 2009; Poulton *et al.*, 2010). Ever since von Thünen (1875)'s paper about the 'isolated state', proximity to urban end-markets for agricultural produce has received ample attention in attempts to understand market participation of remote farmers (Chamberlin and Jayne, 2013; Marino *et al.*, 2018; Oosting *et al.*, 2014). In many cases, however, von Thünen's proximity to end-market does not adequately explain intensification and market participation patterns observed, as recently shown by Migose *et al.* (2018); neither do analyses using travel costs or travel time to end-markets as proxy for market access transaction cost (Minten *et al.*, 2018). As Nanyeenya *et al.* (2009) stated, proximity to markets for inputs and services requires attention as well, especially where intensification of land use leads to increased use of inputs and services that need to be obtained from local service centres. This is particularly relevant for dairy farming, as it requires daily milk collection and a large variety of inputs and services, such as feed, artificial insemination, veterinary services and drugs, extension, and financial services.

Duncan *et al.* (2013) defined 'market quality' as the reliability and attractiveness of market arrangements, in which proximity to markets, infrastructure status, consumer demand and institutional arrangements around dairy product procurement and input and service delivery converge. Nanyeenya *et al.* (2009) and Omiti *et al.* (2009) have included proximity to local service markets in analysis of marketing patterns, but understanding of its influence on dairy farming system characteristics and performance as yet is inadequate.

This research aims to study how proximity to markets influences dairy farming systems in the East African highlands, specifically to unravel the factors underlying variation in market participation of dairy farmers. It thus is expected to reduce the gap in systematic research on the comparative analysis of (commercializing) dairy farming systems from a market quality perspective, as identified by Duncan *et al.* (2013), Nanyeenya *et al.* (2009) and Omiti *et al.* (2009).

It tests the following hypothesis: intensity of dairy farming and degree of market participation increase with proximity to end-markets and with proximity to local service centres, because of better quality of input and output markets and increasing scarcity of land and labour. The hypothesis is tested in Ethiopia and Kenya, two countries with similar agroecology, but with large differences in infrastructure, service delivery systems (centrally-led public vs. market-led private), and per capita dairy consumption, which in Kenya is over five times that in Ethiopia (Makoni *et al.*, 2014). In each country, a high-potential temperate highland dairy area was selected where mixed crop–livestock smallholder systems dominate.

The distinctive contribution of this chapter is in presenting a relationship between farm typology and access to in– and output market services across two institutional contexts, and in breaking up 'proximity to markets' into 'proximity to local input and service centre', 'proximity to delivery point for marketed dairy products', and 'proximity to end-market', all in terms of travel time. Knowledge of these relationships is essential for addressing variation in farming systems in policy making and in design of in– and output market systems that can adequately support (smallholder) dairy farms at different travel times from urban centres (i.e. access to end-markets) and at different travel times from main roads (i.e. access to local service centres).

3.2. Materials and methods

3.2.1. Key concepts

Along with agroecology, type and degree of market participation shapes farming systems to a large extent (Pingali and Rosegrant, 1995; van de Steeg *et al.*, 2010). Market participation is the result of farmer' production- and marketing strategies, which have been subject of many studies (Barrett, 2008; Barrett *et al.*, 2012; Dekker *et al.*, 2011; Duncan *et al.*, 2013; Gebremedhin and Jaleta, 2010; Schiere, 2001; Udo *et al.*, 2011). Various authors have shown how farmer' market participation is affected by market access or market quality (Akinlade *et al.*, 2016; Barrett *et al.*, 2012; Gebremedhin and Jaleta, 2010; Omiti *et al.*, 2006). In line with Duncan *et al.* (2013), we define market quality as access to relevant in- and output markets, associated with proximity, quality, price, and reliability of supply of inputs.

Market quality is particularly relevant for dairy. First, milk as fresh liquid product requires proximity to output markets, which explains peri-urban market-oriented dairy farming at close proximity to urban end-markets, even where agroecological conditions are less conducive. Second, milk production requires ample space for feed production. In remote areas, where this space may be available, marketing of milk to the urban centre may offer a challenge. Effective downstream linkages to end-markets are needed to escape an autarkic market situation

(Barrett, 2008). At the local level, year-round access to all-weather roads is needed for daily transport of milk to milk delivery points. Hence, travel time to delivery point is an important parameter for farmer' decisions to supply to particular dairy market channels (Muriuki and Thorpe, 2006; Voors and D'Haese, 2010). Farmers who are physically close to urban markets may be able to choose between channels (Migose *et al.*, 2018), while for farmers in remote areas, the opportunity for direct marketing is usually more limited. In very remote areas they often home-process and sell dairy products such as butter and cottage cheese (Gebremedhin *et al.*, 2014; Voors and D'Haese, 2010).

Effects of proximity to urban centres on farmer' production and marketing strategies have been described by various authors, including Nanyeenya *et al.* (2009), Duncan *et al.* (2013), Gebremedhin *et al.* (2014), Migose *et al.* (2018) and Minten *et al.* (2018). Remoteness and proximity are relative terms that are influenced by context factors: agroecology including altitude and aridity (Reardon *et al.*, 2014) and quality of infrastructure including roads, electricity and telecom connectivity (Hoddinott *et al.*, 2014; Kyeyamwa *et al.*, 2008; Mutambara *et al.*, 2013). Travel time can be decreased by road improvement, faster means of transport and collective action for bulking milk along roads, while milk cooling technology can decrease negative impacts of transport on milk quality (Gebremedhin *et al.*, 2014). For example, the introduction of ultra-high temperature (UHT) milk treatment in the 1990s illustrates how shifts in technology allow expansion of milk production at large distances from urban centres (Novo *et al.*, 2013). We therefore prefer 'travel time' rather than 'distance' as indicator for proximity to markets, as it better denotes transaction costs in terms of time and transportation (Vandercasteelen *et al.*, 2018a) (**Table 3.1** and **Appendix 3.1, Figure A**).

Intensifying dairy production requires increased market engagement both to access inputs and to reach larger output markets. Vice versa, supply of inputs and services depends on farmer demand (Jaleta *et al.*, 2013). Mutambara *et al.* (2013) indicated that remoteness results in reduction of both demand and supply of production inputs and services and proper coordination mechanisms are needed for effective and cost-efficient supply of inputs and services to farmers (Jaleta *et al.*, 2013; Poulton *et al.*, 2010). According to Voors and D'Haese (2010), remote farmers face high transaction costs to reach both input and output markets, including travel time, asset specificity and uncertainty surrounding the transaction. Due to the small volumes, 'last mile delivery' of inputs and services to the farm gate is the costliest part of the distribution chain, particularly in remote areas. Proximity reduces not only transport costs but also transaction costs of information gathering (Shiferaw *et al.*, 2006). It thus affects farmers' access to markets for inputs and services, which is associated with differences in external input use between hinterland and non-hinterland areas (Reardon *et al.*, 2014). Understanding of locality and particularity is important to understand the diversity in farmer decisions on market participation and dealing with associated risks (Poole *et al.*, 2013).

3.2.2. Analytical framework

This study uses a spatial analytical framework that looks at the dynamics of dairy farming systems in a region as being influenced by factors from the 'upstream' input market, 'intermediate' output market and 'downstream' end-market, and by internal dynamics of the farming system (**Appendix 3.1, Figure A**). It builds on Schiere (2001), Somda *et al.* (2005) and Reardon *et al.* (2015), who classified factors that influence market participation of dairy farmers, and on Gebremedhin *et al.* (2014), who suggested to characterize output market access with a proximity qualifier: farming 'near consumption centres', 'along the all-weather road', and 'remote'. To disentangle the influences of these factors on dairy farming, this study compares dairy farming along a double proximity gradient: i) from location near end-market to remote location, and ii) from sub-location with easy accessibility to local service centre – where farmers buy inputs and services and sell produce – to sub-location with remote accessibility (**Figure 3.1**). To deal with the complexity of this comparison, the main hypothesis is broken up into five sub-hypotheses, postulating that, with increasing proximity to end-market and with increasing proximity to local service centre:

a. quality of input markets (for inputs, technical and financial services) and output markets improves, evidenced by easier access to these markets, lower prices for inputs and services, and higher prices for marketed products, and
b. farmers face increasing scarcity of land and labour.

Because of a. and b.,

c. farmers increase dairy farming intensity, evidenced by increasing use of external inputs and services;
d. farmers increase dairy farming intensity, evidenced by increasing stocking rates, increasing milk yields, and product specialization, and
e. farmers increase dairy market participation, evidenced by increasing volumes of milk marketed and increasing margins.

To distinguish between proximity to local input market, local output market and end-market, we innovate on Gebremedhin *et al.* (2014) and Migose *et al.* (2018) by splitting up *travel time to markets* into *i) travel time to local service centre* where farmers obtain inputs and services *(T_1)*, *ii) travel time to local delivery point for marketed dairy products, be they fresh milk or home-processed (T_2)* where farmers sell milk or dairy products, and *iii) travel time from local service centre to urban end-market, i.e. milk processing plant or main end-user market for home-processed products (T_3)* (**Appendix 3.1, Figure A**).

Table 3.1 expounds key factors and relationships, listing the variables included in data collection and linking them to the main spatial factors relevant for the five sub-hypotheses. These spatial, farming system and market quality factors were selected from the wide range of factors described for different crops and livestock products by various authors (note 1, **Table 3.1**).

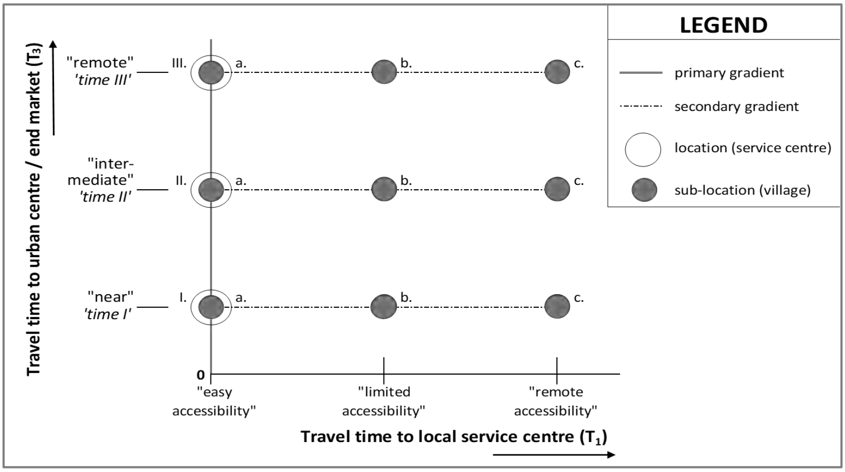


Figure 3.1. *Locations and sub-locations – primary and secondary gradients in spatial research setup used*

3.2.1. Research design, sampling and data collection

We conducted a field study to collect data for analysis of the effects of the spatial distribution of farms and infrastructure on dairy farming systems, quality of in– and output markets, and market participation of farmers.

In both Ethiopia and Kenya, we selected and surveyed a study area with good agroecological potential for dairy and with a dairy tradition, using maps and information from key informants on milk buyers and collection infrastructure. The *location effects* of proximity to urban end-market were distinguished from the *sub-location effects* of proximity to local markets for inputs and services and for outputs by using a double gradient, cross-sectional sampling scheme entailing 3*3 villages per study area, ranging from high to low proximity to markets (**Figure 3.1**). Thus, along the primary **location** gradient, *near*, *intermediate and remote* locations were selected, having short to long travel times to the end-market (T_3) and strong to weak service levels and market-pull, respectively (**Table 3.2**). Along the secondary **sub-location** gradient, sub-locations with *easy, limited and remote accessibility* (i.e. villages a.-c.) were selected at circa 0, ~1 and ~2 hours walk from 'the market' (a local service centre with input and service providers and output marketing opportunities). See **Appendix 3.1** for more detail on selection of locations and sub-locations. See **Figure 3.5** below for maps of the study areas.

In each of the eighteen villages, 10−14 dairy farmers were randomly selected from all dairy farmers in the village, using data provided by the local livestock department (Ethiopia) and the sub-location administrative office (Kenya). In selected households, the person responsible for dairy was interviewed. Thus, 93 farmers in Kenya and 122 farmers in Ethiopia were interviewed in May–November 2016. The questionnaires elaborated the variables displayed in **Table 3.1**.

Table 3.1. *Variables measured and relationship to relevant spatial factors and hypotheses*

Hypothesis		**Independent variables**
With increasing proximity to end-market and with increasing proximity to local service centre,		*T_1 = travel time to purchasing point for inputs and services; calculated as the average travel time to purchase point of twelve different inputs and veterinary and artificial insemination services; T_2 = travel times to dairy delivery point; T_3 = travel time to end-market; Country; Location; Sub-location.*
Sub-hypotheses	**Relevant spatial factors**	**Dependent variables (1)** ***(for computation details see Appendix 3.2)***
a. quality of input markets and output markets improves, evidenced by easier access to these markets, lower prices for inputs and services, and higher prices for marketed products.	density of dairy farm distribution; density of input and service providers; density and quality of milk collection grid and/or direct market outlets; road network (3, 4).	**Prices** of feeds, fodders, other inputs, and services (2). **Supply/ sales arrangements** **Prices of marketed products**
b. farmers face increasing scarcity of land and labour. *because of a and b,*	scarcity of production factors land, water, labour (number and skills) and capital.	**Labour:** household size and composition (adults and children); age and gender of dairy decision maker, off-farm occupation. **Land:** farm size, livestock land (divided on forage land, grazing land owned and rented), access to communal grazing land, crop land (divided in food and cash crops), and proportions between components. **Water:** water sources for use in dairy farming (5) **Capital:** use of credit services, as key source of additional capital, was used under sub-hypothesis c. as proxy for capital scarcity.
c. farmers increase dairy farming intensity, evidenced by increasing use of external inputs and services.	land (farm size, soil types); water sources; real estate; labour/household size.	**Feeds, fodders, other inputs, services** (2)**:** % farmers using, quantities used (per farm, cattle herd size unit (cattle TLU).
d. farmers increase dairy farming intensity, evidenced by increasing stocking rates, increasing milk yields, and product specialization.	altitude, aridity/rainfall, temperatures, soil types, biodiversity; animal disease prevalence; milk collection grid; sourcing relationships; access to infrastructure; demographic dynamics; impact of regulations at farm level; likelihood that areas that at one time are suitable for	**Herd size and composition:** total herd size in TLU, no. of equines (horses and donkeys), no. of small ruminants (sheep and goats), no of cattle, no. of dairy cattle. Dairy cattle types and numbers classified as no of milking cows, no of lactating cows, no of bulls, no of young stock, subdivided in local breeds, crossbreds, and exotic breeds. Proportions of types. **Intensity of land use:** cattle TLU as % total herd; stocking rate for all farm land and for livestock land (TLU/ha); feeding system used (intensive/zero-grazing; semi-intensive; grazing on own or rented land; tethering); practice changes over past

	dairy may lose out to other cash crops (like potatoes, coffee, tea, or sugarcane); livestock commodities (such as stock, beef or eggs) or off-farm income.	decade. **Production parameters:** % milking cows lactating; annual milk yield per cow, per farm, per ha of land; per ha of livestock land. **Dairy farming objectives:** rank of objectives (6) **Dairy history:** since when farm produces and markets dairy. **Product diversity:** % farmers selling non-dairy animal products (livestock, meat, eggs, honey, wool, manure); food crops and cash crops produced. **Changes in farming practices** over the past decade.
e. farmers increase dairy market participation, evidenced by increasing volumes of milk marketed and increasing margins.	road network, electricity and water grid; ICT network connectivity; transportation services; spatial effects of regulations relevant to dairy farmers and dairy chain actors (regarding inputs and services, dairy product marketing, labour, and land use).	**Dairy marketing:** % farmers using various marketing channels; % farmers selling various dairy products; product volumes marketed (per farm, hectare, cattle herd unit, milking cow, lactating cow); % of milk marketed; annual dairy sales income (per farm, hectare, dairy cow, lactating cow). **Other livestock products:** volume marketed, sales income per product. **External costs:** annual expenditures of feed, fodder, other inputs and services 2) per farm, per herd size unit (TLU), per cattle herd size unit, per milking cow, and per kg liquid milk equivalent (LME) marketed. **Margin after external feed costs (MAEFC):** per farm, hectare, milking cow, kg LME marketed**.**

(1) *Developed by authors based on (Akinlade et al., 2016; Bahta and Malope, 2014; Barrett et al., 2012; Gebremedhin and Jaleta, 2010; Hamilton-Peach and Townsley, 2004; Migose et al., 2018; Moll et al., 2007; Mugisha et al., 2014; Mutambara et al., 2013; Nanyeenya et al., 2009; Olwande et al., 2015; Omiti et al., 2009; Poole et al., 2013; Reardon et al., 2014; Somda et al., 2005; Udo et al., 2011; Vandercasteelen et al., 2018a; van de Steeg et al., 2010; van Melle et al., 2013; Voors and D'Haese, 2010).*

(2) *Based on farmer responses, these were categorized as:*
- *Purchased feeds: Dairy meal/mixed ration and by-products, the latter divided in mineral salt (commercial and local), oil seed cake, wheat bran, wheat short, brewery waste, poultry litter, other by-products*
- *Purchased fodders: hay & green forage, straw, stalks & stover*
- *Other inputs: forage seed, drugs & pesticides (incl. deworming, acaricides, self-treatment), dairy utensils, farm equipment*
- *Services: veterinary services, vaccination service, farm advice, AI service, bull service, credit and insurance. Information services: radio, tv, magazines and newspapers, internet, veterinary shop/agro-vetshop, veterinarian, extension worker, training centre, milk buyer/cooperative, other farmers, other.*

(3) *Road network – density and quality of roads, travel time to all-weather road, conditions throughout year.*

(4) *At remote farms, this may translate into the possibility to sell to processors in the dry season only, when milk supply is low, while in the glut season, processors can get plenty of milk closer to their plants.*

(5) *Categorized as: tap water, borehole/well, dam/water pan/water harvesting, and river.*

(6) *Rank of objectives: household food consumption; income; paying education fees, better living standards; build up household assets (house/land/savings/insurance); investment in other business/ farming enterprise; social value (status/interest/hobby/custodianship/self-employment); livestock used for draft power/manure.*

The three travel times (T_1, T_2, and T_3) were used as proxy indicators for proximity-remoteness. Based on Chamberlin and Jayne (2013), the estimated travel time by truck from local service centre to the nearest milk processing plant (T_3) served as proxy for the primary gradient. Collection points for milk delivery by farmers (T_2) and local service centres (T_1) served as proxy for the secondary gradient (**Table 3.1** and **Appendix 3.1, Figure A**).

Table 3.2. *Primary and secondary gradients / characteristics of locations and sub-locations*

Location	Type of town	Travel to next node	Sub-locations (villages)		
I	town, population 50-100k	by tarmac road (by highway)	a.	b.	c.
II	small town	by tarmac road	T_1 – travel time to local service centre		
III	small rural centre	by gravel road	0-20 min	45-60 min	90-120 min
Kenya (Nyandarua County)					
I	Ol Kalou, Ol Kalou subc.	35 km to Nyahururu (160 km to Nairobi)	Ol Kalou	Munyeki	Gachwe
II	Wanjohi, Kipipiri subc.	23 km to Ol Kalou	Wanjohi	Satima	Kiburuti
III	Geta, Kipipiri subcounty.	13 km to tarmac road in Wanjohi	Geta	Kianjogu	Kirima
Ethiopia (East Shoa and Arsi Zones)					
I	Bishoftu, Ada'a district	0 km to Bishoftu (60 km to Addis)	Bishoftu Kebele 09	Kaliti	Denkaka
II	Bekoji, Limu-Bilbilo district	175 km to Bishoftu	Bekoji town	Koma Welkite	Koma Angera
III	Digelu, Digelu-Tiyo district	14 km to tarmac road in Sagure	Digalu town	Digalu Bora	Kubsa Bora

3.2.2. Data analysis

Data were entered into Excel as input for R, using SI units and US$ (equated to ETB20 and to KES100; 2016 rates) to reconcile differences between local units being used in Ethiopia and Kenya. **Appendix 3.2** lists the variables computed based on questionnaire results. Adding sub-location and location to the analysis as nested random effects accounts for random differences due to a farmer being in a specific sub-location and location within a country. Missing values for T_1 and T_2 were imputed using R's Multivariate Imputation by Chained Equations method 'mice' package (version: 3.6.0) with the imputation method set to rf (random forest imputations), nnet.MaxNWts to 2500 and all other parameters set to default (van Buuren, 2007; van Buuren and Groothuis-Oudshoorn, 2011). The imputation was carried out using a subset of variables that define location and output market-linkages (village, longitude, latitude, milk buyer/channel, selling milk, selling butter) for each country-location-sub-location combination.

Regression analysis of the data was conducted using the following mixed–effects models for each dependent variable:

$$Y_{ijkl} = \mu + C_i + \beta_{1i}T1_{ij} + \beta_{2i}T2_{ij} + \beta_{3i}T3_{ij} + \beta_4 T1_{ij}\,x\,T2_{ij} + \beta_5 T1_{ij}\,x\,T3_{ij} + \beta_6 T2_{ij}\,x\,T3_{ij} + C\,x\,L_k + C\,x\,L\,x\,S_{kl} + \epsilon_{ijkl}$$

Code	Description
Y	dependent variable
i	refers to country with i=1 representing Ethiopia and i=2
j	Kenya
k	refers to the jth observation
l	k=I, II, III refer to location
	l=1,2,3 refer to sub-location
	Random effects
CxL	location within country factor
CxLxS	sub-location within location within country factor
ϵ_{ijkl}	error (residual) random effect
	Fixed effects
μ	intercept
C	country factor
T_1	travel time to input and service markets
T_2	travel time to dairy delivery point
T_3	travel time to end-market
$\beta_{1,2,3i}$	slope – the slopes of T_1, T_2 and T_3 depend upon levels of factor C (two-way interaction between C and variables T_1, T_2 and T_3)
T_1xT_2	interaction between T_1 and T_2
T_1xT_3	interaction between T_1 and T_3
T_2xT_3	interaction between T_2 and T_3.

Regression modelling was used in order to look for significant relationships and patterns within the complex system relationships between farming and marketing systems. Significant regressions do not necessarily indicate causality, but rather aid in testing the causal relationships in the hypotheses. Three-way interactions were deemed to be adding too much complexity as compared to their potential added explanatory value.

The model-building approach was an interactive forward selection process using Likelihood Ratio tests for model comparisons and a significance level of 0.05 as entry criterion ($p < 0.05$). The selection process started without any independent variable in the regression equation (null model). The procedure then updated the starting model with the addition of every single variable. The models were ordered based on their Log Likelihood, after which the best fitting model was evaluated for improvement in model fit by model comparisons via likelihood ratio tests with the R 'anova' function. Subsequently the significant variables included in the model were analyzed. If a variable lost significance, then it was removed. An independent Two-Sample t-test was performed to compare values of the independent variables T_1, T_2 and T_3 between the two countries and between locations and sub-locations within countries. A paired sample t-test was performed to compare the different time variables (T_1, T_2 and T_3) within the countries.

Where averages are given to compare values between countries, locations or sub-locations, the standard deviation is displayed between brackets, unless indicated otherwise.

The data set contained different data types, i.e. continuous data, count data, ordinal categorical data, and nominal data. All data analyses and model fitting were performed using R version 3.5.0 (Team, 2006). Linear mixed models were used to analyze all continuous variables using the 'lmer' function of the 'lme4' package (version: 1.1-21; Bates *et al.* (2014). For binary data, generalized linear mixed model (family binomial, logit link) were used, using the 'glmer' function of the 'lme4' package. Glmer was also used for count data (family Poisson). Cumulative link mixed model (clmm) analysis, a type of ordinal regression model (Agresti, 2003), was performed on ordered categorical variables. Clmm allows for regression methods similar to linear models while exploiting the ordered, categorical nature of the response variable (Christensen, 2019). For this the 'clmm' function of the 'ordinal' package (version: 2019.4-25; Christensen (2019) was used. For variables that were characterized by a high occurrence of zeros, two-step regression modelling was employed: the first models the probability of occurrence of an event (binomial), the second models the strictly positive size of the event conditional on its occurrence. For multi-level categorial variables a series of separate simple glmer (binomial distribution) analyses was performed. For this, a multi-level categorial variable was split into multiple 1/0 variables, each category of the variable having a value of 1 for its category and a 0 for all other categories.

3.3. Results

This section presents results following the five sub-hypotheses outlined above. Detailed regression analysis results for variables under each sub-hypothesis are added as **Tables a–e** in **Supplementary Material 3**[5], which displays coefficients and factors for significant effects for the relevant variables.

We first compare average travel times across locations and sub-locations to illustrate relationship between fixed and random effects. **Table 3.3** shows how T_1 (travel time to inputs and services) decreased in both countries for easily accessible sub-locations (as expected) and was higher for remote sub-locations in Ethiopia than for those in Kenya. For Kenyan farmers, T_2 (travel time to dairy delivery point), was much shorter than T_1. For Ethiopian farmers, however, T_2 was equal to or higher than T_1 (except in location II), and decreased for more easily accessible locations and sub-locations. T_3 (travel time to end-market) in Ethiopian location I was the lowest of all. T_3 for Ethiopian locations II and III was much higher than for any Kenyan location. T_3 for Kenyan locations I and II were equal due to relative proximity to alternative dairy plants (see also **Table 0 in Supplementary material 3** and **Appendix 3.3, Figure A-C**).

Table 3.3. *Mean values for travel times to markets per country, per location and per sub-location with standard deviations in parenthesis*

Travel time to market (in minutes)	Country	Location			Sub-location		
	Kenya	**I near**	**II interm.**	**III remote**	**a. easy**	**b. limited**	**c. remote**
T_1 – travel time to inputs and services	48.6^{Aa} *(± 34.3)*	55.6^{AaX} *(± 38.5)*	46.0^{AaX} *(± 39.0)*	44.6^{AaX} *(± 23.0)*	25.2^{Aax} *(± 21.0)*	43.0^{Aay} *(± 18.1)*	76.6^{Aaz} *(± 37.0)*
T_2 – travel time to dairy delivery point	6.7^{Ab} *(± 8.3)*	4.2^{AbX} *(± 6.2)*	6.7^{AbXY} *(± 10.0)*	9.1^{AbY} *(± 7.8)*	9.5^{Abx} *(± 7.9)*	2.7^{Aby} *(± 4.9)*	7.7^{Abx} *(± 10.0)*
T_3 – travel time to end-market	54.0^{Aa} *(± 12.8)*	45.0^{-a-} *(± 0)*	45.0^{-a-} *(± 0)*	72.0^{-c-} *(± 0)*	54.6^{Acx} *(± 13.1)*	54.0^{Acx} *(± 12.9)*	53.4^{Acx} *(± 12.7)*
	Ethiopia	**I**	**II**	**III**	**a.**	**b.**	**c.**
T_1 – travel time to inputs and services	70.4^{Ba} *(± 43.5)*	58.2^{AaX} *(± 38.0)*	82.6^{BaY} *(± 48.9)*	69.1^{AaXY} *(± 40.1)*	23.9^{Aax} *(± 23.8)*	73.7^{Bay} *(± 30.0)*	111.7^{Baz} *(± 18.1)*
T_2 – travel time to dairy delivery point	80.2^{Bb} *(± 53.1)*	57.9^{BaX} *(± 39.8)*	74.8^{BbX} *(± 50.3)*	104.8^{BbY} *(± 56.8)*	38.0^{Bax} *(± 49.4)*	85.7^{Bay} *(± 43.8)*	115.2^{Baz} *(± 34.2)*
T_3 – travel time to end-market	139.9^{Bc} *(± 92.7)*	12.0^{-b-} *(± 0)*	150.0^{-c-} *(± 0)*	240.0^{-c-} *(± 0)*	140.1^{Bbx} *(± 93.1)*	142.4^{Bbx} *(± 94.4)*	137.3^{Bax} *(± 92.9)*

N.B. Superscripts ABC indicate differences in travel times between countries (within columns); superscripts abc indicate differences between travel times within countries (columns); superscripts XYZ indicate differences in travel times between locations (rows); superscripts xyz indicate differences between sub-locations (rows); T3 has no variation within location within country, as values were estimated per location.

a. Quality of input and output markets

Prices for inputs and services – The survey identified twenty-four inputs and services, among which twelve feed stuffs, six other inputs and six services. The prices for these inputs and services showed very few effects of proximity to local service centre and to end-market (**Supplementary material 3, Table a**).

Prices of marketed products – In line with the sub-hypothesis, farmers fetched higher milk prices the closer they were to dairy delivery points (see also **Appendix 3.3, Figure H**). A clear country effect portrays the higher milk prices in Ethiopia: on average 0.57 ± 0.13 (SD) US$/litre vs. 0.31 ± 0.03 US$/litre in Kenya; in Ethiopia averages ranged from 0.50 US$/litre in the rainy season to 0.58 US$/litre in the dry season (i.e. +16%), in Kenya averages ranged from 0.28 US$/litre in the rainy to 0.33 US$/litre (i.e., +18 %) in the dry season. The prices of butter and cottage cheese, sold next to fresh milk in Ethiopia, showed no sub-location effects but were higher for locations closer to the end-market. Prices of eggs, livestock, meat, wool and honey showed no significant spatial effects. In only four Ethiopian sub-locations (= villages) farmers sold manure – with highest sales volumes in remote sub-locations c – so it is not surprising that manure prices only showed a random sub-location effect.

b. Scarcity of production factors

Labour – The scarcity of household labour available to farming was increasing with proximity to local service centre, evidenced by more engagement in off-farm labour (in both countries) and by fewer adults in the Ethiopian households in sub-locations a. (3.1 ± 1.3 adults) as compared to sub-locations c (4.5 ± 2.8 adults); in Kenya, households averaged 2.7 ± 1.2 adults across sub-locations (**Supplementary material 3, Table b**). In Ethiopia, decision making on dairy farming issues was much more a joint effort between husband and wife (74.6%) or wife only (22.1%) than in Kenya (22.5% husband and wife; 17.2% wife only). Farmers in Ethiopia at 43.3 years on average were 8 years younger than their counterparts in Kenya. In both countries age of dairy decision makers increased sharply with proximity to end-market.

Land – Farm size averaged 3.6 ± 5.0 hectare in Kenya, ranging from just the home plot (just house and barns) to 28.3 ha, and averaged 3.5 ± 3.6 ha in Ethiopia, ranging from just the home plot to 23.3 ha (**Figure 3.2**) displays averages and standard errors per location). Farm size showed both sub-location and location effects: it decreased with proximity to local service centre and it was smallest in remote locations III of both countries. Use of farm land for various purposes showed several location effects: rented grazing land in Ethiopia decreased with proximity to end-market while it was rare in Kenya. Access to communal grazing land (not displayed in **Figure 3.2**) has become uncommon, as was also observed by Minten *et al.* (2018), with only the villages in Ethiopian location I and one Kenyan village reporting access. In Kenya, woodlots and 'unaccounted for land use' were considerable in size (included in proportions for

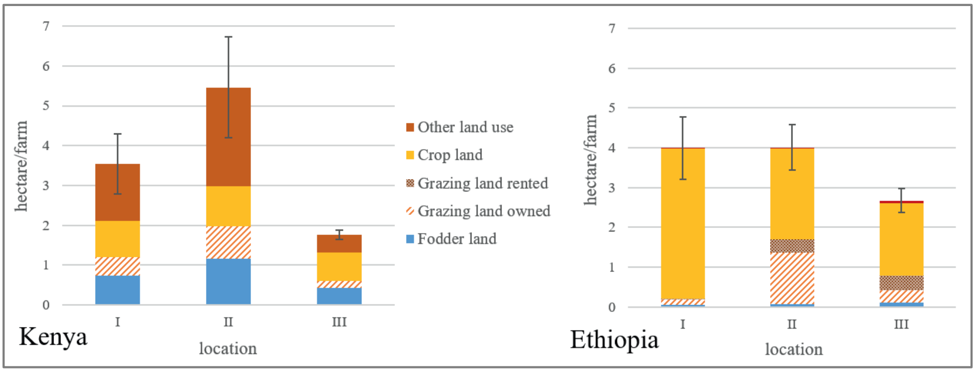


Figure 3.2. *Farm land use as averages per location in Kenya and Ethiopia, with standard errors and averages per location group, ranging from near (I) to remote (III),(n=215). N.B. No reported rented grazing land in Kenya*

'other land use'). Moreover, in sub-locations a. (with easy accessibility), the use of tap water for dairy husbandry has largely replaced the use of water from streams (Ethiopia) or use of boreholes, wells and harvested surface water (Kenya).

c. Dairy farming intensity as evidenced by use of purchased inputs and services

Inputs and services obtained from outside the farm included feeds and fodder, other inputs, services and information. In monetary terms, estimated expenditures on feeds (supplements and by-products), fodders (crop-residues and forages), and other inputs and services averaged respectively 72% (440 US$), 15% (90 US$) and 13% (80 US$) of reported costs per farm. Expenditures on artificial insemination (AI) (by farmers using it) increased with proximity to end-market; in Kenya it decreased with proximity to local service centre, while in Ethiopia it increased with the same as primarily farmers in sub-location Ia. reported expenditures. In Ethiopia, bull service and veterinary services were usually free of charge (only three farmers in sub-locations a reported payment for bull service).

Use of inputs

Feed purchases – The large majority of farmers purchased feeds (95% in Ethiopia and 99% in Kenya), with minor variation across locations and sub-locations. In Kenya, most farmers purchased ready-made dairy meal rather than by-products for on-farm feed preparation (80 vs. 48%), in Ethiopia the reverse was true (10 vs. 88%). The proportion of farmers purchasing dairy meal was highest for farmers far from the local service centre, while in Ethiopia, it was highest for those close to the local service centre. Annual farm expenditures on feeds and fodders showed a country effect only – being higher in Ethiopia (US$463) than in Kenya (US$407).

Fodder purchases – The proportion of farmers purchasing fodder increased with proximity to local service centre and dairy delivery point (**Supplementary material 3, Table c**). Farmers in Ethiopia primarily purchased straw, farmers in Kenya primarily purchased hay & green forage and stalks & stover. In both countries, farmers' spending on fodder increased with proximity to local service centre and to dairy delivery point, with a peak in Ethiopian villages a. (averaging US$ 316 and even US$ 664 in village Ia.). Fodder expenditures in Kenya (averaging US$33) decreased with proximity to end-market, while in Ethiopia these increased with proximity to the same (averaging US$134).

Other purchased inputs – In all sub-locations, 77-100% of farmers purchased drugs (medicines, vaccines and acaricides), except for village IIa. in Kenya (50%). The proportion decreased with proximity to local service centre in Kenya and for remote locations, as did expenditures on drugs.

Use of services

Proportion of farmers using services – The proportion of farmers using AI services increased steeply with proximity to local service centre in Ethiopia, but less so in Kenya. Complementarily, the use of bull services decreased with proximity to both end-market and local service centre, but was highest in location II rather than in location III. Use of vaccination services was widespread in Ethiopia (80%), increasing with proximity to end-market, and only 11% in Kenya, being reported in four remote sub-locations only (IIbc. and IIIbc.). Credit services were used by 44% of farmers in Kenya, vs. only by 17% of farmers in Ethiopia. Use of radio, TV, (agro-)vet shops, and milk buyers and cooperatives as information sources increased with proximity to local service centre in Ethiopia only. The use of extension workers and other farmers decreased along the same gradient in both countries. These were the most frequent info sources for remote farmers in Ethiopia.

d. Dairy farming intensity as evidenced by stocking rates and milk yields

The *stocking rate* increased with proximity to local service centre, even as livestock herds got smaller (**Supplementary material 3, Table d**. and **Appendix 3.3, Figure E**). At 15.2 ± 58.0 TLU/ha the average stocking rate in Ethiopia was over three times higher than that in Kenya (4.75 ± 8.8), but the median was comparable (3.2 vs. 2.6 TLU/ha).

Herd sizes and composition also varied with proximity to local service centre and to end-market (**Appendix 3.3, Figure D**). *Herd sizes for cattle, for equines and for all species together* (all in TLU) decreased with proximity to local service centre and increased with proximity to end-markets. The same pattern was observed for the *number of milking cows per farm.* The *proportion of milking cows in the cattle herd* averaged 35% ± 15 in Ethiopia and 55% ± 23 in Kenya, further showing a random sub-location effect only. The *proportion of local cows* (vs. cross-bred and exotic) was at least 70% in all Ethiopian sub-locations except IIb. (45%); it was negligible in Kenya.

Intensification of feeding system was noticed from the increase of zero grazing, semi-zero grazing and tethering at the expense of grazing (comparing subtotal of three practices compared with grazing; differences between three individual practices were not significant). Feeding system data were available for Kenya only. In Kenya, 23% of all farm land and 72% of livestock land was devoted to forage production (**Figure 3.2**). In contrast, these ratios were respectively only 2% and 19% for Ethiopia, where crop land and grazing were more dominant. In Kenya, these ratios decreased with proximity to local service centre and to end-markets.

Milk yields per hectare farm land increased with proximity to local service centre in both countries (**Appendix 3.3, Figure G).** Effects on other productivity parameters were less straightforward. *Milk yields per farm* increased in the same manner in Ethiopia, but decreased with proximity to local service centre in Kenya (**Figure 3.3**). *Milk yields per cow* increased with proximity to dairy delivery point and proximity to end-market in Ethiopia (in line with

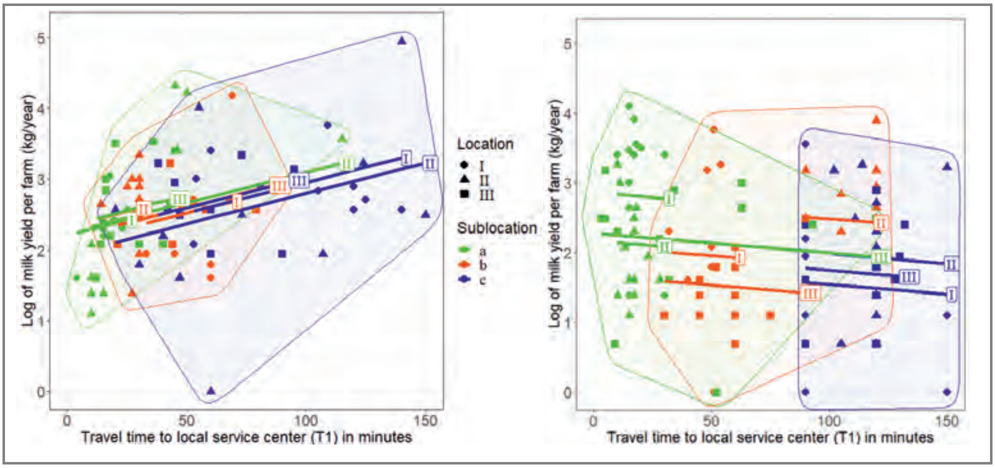


Figure 3.3. *Log of annual milk yield per farm vs. travel time to inputs and services for Kenyan and Ethiopian farmers in categories a–c of proximity to local service centre, with regression lines per village (n=215)*

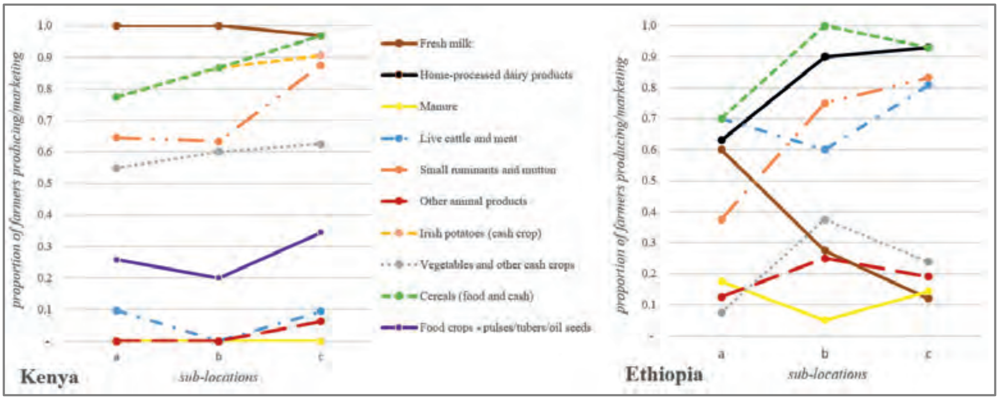


Figure 3.4. *Proportion of farmers producing various marketable products and food products, averages per sub-location group, ranging from easy accessibility (a) to remote accessibility (c); N.B. proportion is 1.0 when all farmers produce product*

Minten *et al.* (2018)), but showed the opposite effect for the first in Kenya. The parallel lines in **Figure 3.3** visualize the differences that occur between villages (i.e. random sub-location effects).

Produce choice and specialization – Depending on farm size and market access, farmers decide on the number and types of crops and the number and types of animal products they produce and market. Sub-location effects were most pronounced (**Figure 3.4** displays averages per sub-location group). Compared to Kenya, in Ethiopia product diversity was larger, with more variety in livestock products. The proportion of farmers selling milk increased with proximity to dairy delivery point, the proportion selling butter decreased with proximity, and the proportion selling cottage cheese was highest in sub-locations b. Where less farmers sold dairy products, more sold manure, live cattle, meat, and cereals. Farmers in Kenya focused on milk, with very limited sale of livestock. Location effects on produce choice were limited to the proportion of farmers marketing milk and manure in Ethiopia (increasing with proximity to end-market) and growing cereals (decreasing with proximity).

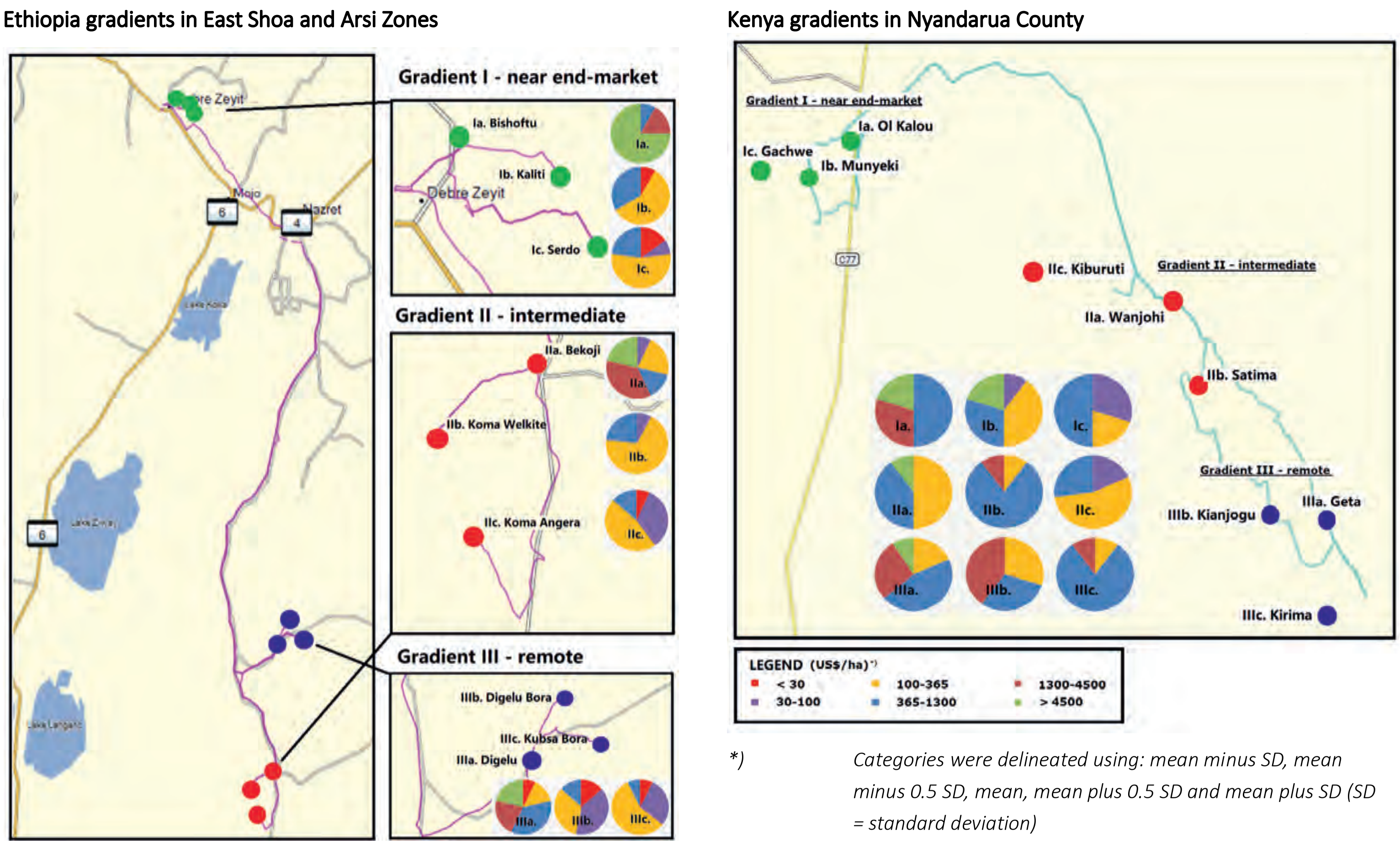
The proportion of farmers adopting new practices over the past decade points at farm intensification dynamics. Changes were most common in animal husbandry – 70% of farmers changed type and number of animals kept, 69% changed dairy feeding practices, 63% changed dairy breeding practices; 55% changed dairy animal health care, 33% changed dairy housing – and in cropping practices – 59% changed acreage farmed, 69% changed cropping practices. Farmers changing practices were more numerous in Kenya and proportions were more affected by proximity to end-markets than by proximity to local service centres.

e. Dairy output market participation

Products and channels – In Ethiopia, 33% of 122 respondents sold fresh milk, 76% sold butter, 59% sold fresh cottage cheese and only 2% sold yogurt (**Supplementary material 3, Table e**). The proportion of farmers selling milk increased with proximity to dairy delivery point, to a lesser extent decreased with proximity to local service centre, and increased with proximity to end-market. Contrary to milk, the proportion of dairy farmers selling butter and cheese decreased with proximity to dairy delivery point. All respondents in Kenya but one sold fresh milk, and it was the sole dairy product sold.

The proportion of farmers using formal milk sales channels decreased with proximity to local service centre and increased with proximity to dairy delivery points, but with different coefficients for the two countries and with exception of Ethiopian sub-locations c. The average proportion was much lower in Ethiopia (12%) than in Kenya (82%). In Kenya it decreased but in Ethiopia it increased with proximity to end-markets.

Sales volumes and incomes – As farmers in Ethiopia sold other dairy products next to fresh milk, we looked beyond sales of milk as individual dairy product to total dairy sales volumes (expressed in liquid milk equivalents (LME)) and incomes (expressed in US$, for computations see **Appendix 3.2**). Dairy sales volumes per farm averaged 2,611 ± 3,259 kg LME/year in Ethiopia and 5,245 ± 5,130 kg LME/year in Kenya; lowest sub-location volumes averaged 1371 kg LME/year in Ethiopian sub-location c. vs. 5132 kg LME/year in Kenyan sub-location b. When expressed per hectare, per milking cow, and per cattle herd unit, dairy volumes sold increased



*) Categories were delineated using: mean minus SD, mean minus 0.5 SD, mean, mean plus 0.5 SD and mean plus SD (SD = standard deviation)

Figure 3.5. *Maps of study areas with pie charts per sub-location (= village) showing proportion of farmers in categories for dairy sales income (US$/ha)*

with proximity to local service centre (**Figure 3.5** and **Appendix 3.3, Figure I**). The latter two showed interaction between T_2 and T_3 as well. Dairy sales income increased with proximity to local service centre when expressed per milking cow and per hectare. Differences were largest in Ethiopia, where most farmers in sub-locations a. achieved above average sales, while a minority did so in sub-locations b. and c.

Expenditures on external inputs and services and margins – While calculation of real margins per unit of milk, land or stock is beyond the scope of this study, we calculated *margin after external feed costs (MAEFC)* as a proxy for the cash flow result for dairy, available for household income. Costs categories estimated from farmer's responses included purchased feed, purchased fodder, and a third category 'other' that included expenditures on vaccination, veterinary, AI and bull service, and drugs, acaricides, dairy utensils and farm tools. As the quality of data in the third category was insufficient, we did not include them in margin calculations.

Farm *margins after external feed costs per farm* showed a random sub-location effect only, averaging USD 1074 ± 642, despite sub-location averages ranging from USD 220 ± 240 to USD 3034 ± 2376 in Ethiopia. *MAEFC per hectare* increased with proximity to local service centre (**Figure 3.5** and **Appendix 3.3, Figure J**).

3.4. Discussion and conclusions

This study disentangled various spatial effects on dairy farming intensity and market participation of dairy farming systems in Kenya and Ethiopia. To evaluate the hypothesis, we discuss effects of proximity to local service centre, to local dairy delivery/sales point, and to end-markets in section 3.4.1. We further discuss important context effects in section 3.4.2, and close with implications in section 3.4.3.

3.4.1. Validation of hypothesis and sub-hypotheses

Sub-hypotheses

Proximity to local service centre and dairy delivery point – The results, as expected, clearly showed that proximity to service centre and to dairy delivery point stimulates both dairy farming intensity and market participation, resulting from better market quality (for in- and outputs) and stronger scarcity of the production factors of land and labour (proving respectively sub-hypotheses a. and b., see **Table 3.1**). Farmers in more easily accessible sub-locations faced lower transaction costs in accessing inputs and services, as they had to spend less time accessing them and had access to information from more sources (Chamberlin and Jayne, 2013). Higher land scarcity near local service centres is likely related to the propensity of farmers to move closer to good roads (authors' observations).

Contrary to sub-hypothesis a, prices for inputs and services showed very few differences. However, price/quality ratios can be expected to be better in easily accessible places, as quality of inputs and of services tends to improve with proximity to local service centre as a result of easier infrastructural access and more skilled personnel; this was described in Chapter 3. Farmgate milk prices increased with proximity to milk delivery point, likely due to lower milk transportation costs and due to more choice between milk buyers for farmers with easy accessibility. It is in line with observations of Olwande *et al.* (2015) that higher farming intensity and market participation near local service centres go together with increasing land scarcity and smaller household sizes, but we postulate that higher market participation is more related to better market quality (Duncan *et al.*, 2013; Migose *et al.*, 2018) and competition for labour with off-farm employment opportunities – than with 'less mouths to feed' as was suggested by Olwande *et al.* (2015).

All three of the sub-hypotheses c.-e. were largely proven. Firstly, expenditures on feeds and fodders per animal increased with proximity to local service centres (Minten *et al.*, 2018), although the relatively low expenditures for other inputs and services did not (sub-hypothesis c.). Differences in use of information sources all pointed to strong proximity effects on their availability, with better access in easily accessible places in both countries, while farmers in remote locations and sub-locations depended more on information from local resource persons (i.e. agro-vet shops and other farmers in Kenya, extension workers and other farmers in Ethiopia). Secondly and in addition to higher external input and service use, the more intensive land use and stronger dairy focus for farmers near local service centres (Nanyeenya *et al.*, 2009) was evidenced by a range of parameters: higher stocking rates despite smaller herds, higher proportions of milking cows in the herd, higher proportions of exotic cows (Ethiopia only), higher milk yields per hectare, more investments in forage production, and fewer crop and livestock product types (sub-hypothesis d.). Thirdly, market participation indeed increased with proximity to local service centre, whether expressed in volumes marketed per hectare or per milking cow (sub-hypothesis e.). Marketing through informal channels increased with proximity, as farmers near service centres can choose the most beneficial from multiple marketing channels. While these farmers realized higher per hectare margins after purchased feed costs per hectare, the margins per farm did not show proximity effects. This means that results did not prove that farmers near local service centres, with smaller farms but more intensive production, earned significantly more (or less) from dairy than remote farmers. It may be that the data collection method used yielded insufficient quality of data to show such effects. Large heterogeneity in this parameter suggests differences in resource use efficiency between farms (Migose *et al.*, 2019).

Proximity to urban end-market – The results for the second gradient further showed effects on dairy farming intensity and market participation for a limited number of dependent variables only, largely in line with Migose *et al.* (2018). A major cause underlying non-significance of effects was the fact that in both countries, remote location III had smaller rather than larger farms, as these locations were hemmed in by mountain ranges and a national park that put physical and political limitations on land available for agricultural use – pointing to reasons why locations are remote (**Figure 3.2**); this effect was enlarged by three large farms among respondents in Kenyan intermediate location II. This unexpected remote land scarcity strongly influenced location effects (**Figure 3.2**), showing a parabolic-shape rather than a decrease with proximity, e.g. in the proportion of land used for livestock. Nevertheless, a number of trends expected in the hypothesis still did occur, although main differences appeared between locations I and II, rather than between I and III: butter prices (sub-hypothesis a.), purchase of hay & green forage (sub-hypothesis c.), herd size and number of equines for transportation (sub-hypothesis d.), and manure sales (sub-hypothesis e.) all increased with proximity to end-markets, while acreage for livestock did decrease (sub-hypothesis b.). Like Migose *et al.* (2018), we found that prices for inputs and services were little affected by proximity to end-market (sub-hypothesis a.), except for prices of AI services and of some feed stuffs that generally were used by a few farmers and were subject to local availability. Moreover, the very availability of services such as vaccination and credit showed random location effects (especially in Ethiopia), indicating that travel times to end-markets were not explaining variation. The strong location effect on age of dairy decision maker points to the fact that closer to the city, dairy seems comparatively less attractive for younger farmers, or less feasible due to high investment needs in land and stock that are needed to make dairy competitive vs. other activities.

Main hypothesis

This study proved that both intensity of dairy farming and market participation increase with proximity to local service centre (T_1) and to dairy delivery point (T_2). Farms with easy accessibility to local service centres face increasing scarcity of land and labour, but benefit from better market quality, and as a result increase stocking rates, use of external inputs and services, milk yields, and volumes marketed. By specializing into dairy and increasing market participation, they can obtain similar dairy incomes from smaller acreages. The effect of proximity to end-market is less straightforward, due to unexpected land scarcity in remote locations and random differences between locations in availability of inputs and services. Only a limited number of parameters show significant T_3 effects. We conclude that the results prove the main hypothesis regarding proximity to local service centre and to dairy delivery point, but not regarding proximity to end-market.

This study thus enriches earlier work on the relationship between market quality and dairy farming systems, such as by Nanyeenya *et al.* (2009), Duncan *et al.* (2013), Gebremedhin *et al.* (2014), Migose *et al.* (2018) and Minten *et al.* (2018) by showing the effect of local differences in market quality between farms with easy and with remote accessibility. It underlines the important role of secondary towns in increasing farmer' market participation, as discussed by Vandercasteelen *et al.* (2018a), suggesting this also applies to even smaller rural service centres.

Analysis included two types of measures for proximity to markets: (1) travel times to markets ($T_{1\text{-}3}$, as fixed effects); and (2) remoteness of village (as sub-location and location nested within country as random effects). Regarding the first type, the distinction between travel times proved very helpful in explaining (part of) the variation in dairy farming intensity and market participation between farms. Regarding the second set, sub-location is a measure for the influence of the particular village a farm is located in. Several parameters showed random sub-location affects, visualized by the parallel lines in graphs in **Figure 3.3** and **Appendix 3.3**). These may result from differences in natural resources (soil, altitude, rainfall etc.), but may also be sought in community attitudes, history in cattle husbandry and other social capital factors(Amankwah *et al.*, 2012). While positive deviance between farmers and the causes of this variation have been broadly described in literature (**Table 3.1**), the phenomenon of 'positive deviant villages' deserves further study. Nevertheless, the wide variation in T_1 and T_2 values within villages (**Table 3.3**) and the strong explanatory value of T_1 and T_2 suggests that they can be considered to be better proxies for proximity to local markets than is the nearness or remoteness of the villages they belong to.

This study also attests to the hypothesis of Gebremedhin *et al.* (2014) that farmers at different distances from main roads are likely to market different dairy products and require different types of support in farm development. Remote farmers in Ethiopia sell more home-process dairy products – adding value to small volumes of milk – cereals and other livestock products: manure, calves, dairy heifers and animals for slaughter. However, the 3*3-point comparison in this study adds nuance to Gebremedhin *et al.* (2014)'s comparison, showing that farmers in intermediate sub-locations b. may be in the sweet spot between increasing access to markets and decreasing availability of production factors land and labour.

The fact that the travel time and differences between Ethiopian locations I and II were much larger than between other locations (**Table 3.3**) and the equal travel times to end-market for Kenyan locations I and II illustrate the difficulties encountered in applying the spatial research set-up of **Figure 3.1** in real life. A neater set-up could be achieved by more clearly identifying end-market parameters for each potential location and selecting for equal travel times between locations. However, these gradient selection issues do not seem to have affected overall results.

As system dynamics are the result of a large number of causalities and feedback loops, the search is for patterns and their contributors rather than for single causal relationships. For this reason, apparent anomalies, such as decreasing expenditures on fodder with proximity to local service centres in Kenya, are not cause for concern but rather for further investigation.

3.4.2. Country effects

While farm size, mixed crop–livestock character of farming, and agroecological conditions were similar in both study areas in Ethiopia and Kenya, the effects of proximity to markets on dairy farming intensity and market participation showed important differences. In general, proximity effects on dependent variables were much stronger in Ethiopia, evidenced by the larger distance between Ethiopian sub-location lines in **Appendix 3.3, Figure D-J**, as compared to those for Kenya. For some variables, regression lines had opposite slopes, see for example **Figure 3.3**, meaning that different conditions in different countries lead (remote) farmers to different strategies. The clearest example is the fact that Ethiopian farmers with remote accessibility to input and output markets, home-process milk to sell small quantities of butter and cheese in the informal market, while Kenyan farmers with remote accessibility market fresh milk largely through formal channels. As a result, Ethiopian farmers in remote villages c. marketed only 27% of the annual dairy product volumes (in LME) marketed by their counterparts in remote Kenyan villages b. and c., while farmers in Ethiopian villages a. marketed 75% of the volumes marketed in Kenyan villages a.

We identified four factors that contribute to these differences in proximity effects between the study areas. Firstly, market demand in Kenya is much more robust – five times higher per capita dairy consumption translates in milk buyers competing for milk, resulting in a denser milk collection grid that reduces travel time to dairy delivery point, particularly for remote farmers (see also Van Campenhout *et al.* (2019). Secondly, better infrastructure–in terms of roads, electricity, piped water and telecommunications–reduces logistical transaction costs and improves availability of information (as was also pointed out by Chamberlin and Jayne (2013)). This enables Kenyan farmers in even the most remote villages to market fresh milk. Thirdly, Kenyan private-led service delivery models bring inputs and services closer to the farmers, while Ethiopian farmers are on the receiving end of scarce public services. Access to these public services is concentrated in the service centres and is not really client-oriented, resulting in strong proximity effects on transaction costs for purchase of inputs and services, sale of milk and acquiring information. These differences in service delivery models are resulting from different regulatory frameworks (Chapter 2). Fourthly, county-level policies in Kenya favour dairy sector development and boost public investments, while Ethiopian agricultural policies favour meat for export and commercial grain crops (Shapiro et al., 2015).

These conducive institutional and market conditions enable farmers in Kenya to increase dairy farming intensity and market participation. This translates to farming systems. Higher Kenyan yields and marketed volumes are fuelled by higher adoption of intensification practices, such as farm investments in forage production, dairy breed improvements, and purchases of ready-made feeds and other inputs and services. For remote farms, less intensive dairy farming with lower yields per hectare is a logical choice, as this is a better economic optimum when transaction costs are higher. In Ethiopia, remote farmers don't even have the choice to market fresh milk, being barred by infrastructural constraints. This study offers evidence that the Kenyan advantage is facilitated by a more conducive milk market, with collection of milk on or near the farm, and a more complete service offer as compared to Ethiopia, corroborating findings from literature (Nanyeenya *et al.*, 2009; Omiti *et al.*, 2009). Interviews showed however that farmers are still holding back investments due to perceived risks of market fluctuations and natural disasters.

Meanwhile in Ethiopia, farmers choose to market a larger diversity of products. They use their land primarily for crops rather than for grazing or forage production (**Figure 3.2**), feeding their cattle straw and other crop residues (as also observed by Duncan *et al.* (2013), Minten *et al.* (2018) and in Chapter 2). Farmers selling fresh milk are concentrated in the connected areas, closer to infrastructure and services, spending high amounts on feed and fodder. The four factors mentioned prevent remote Ethiopian farmers from utilizing their relative advantages in terms of more available land and labour (for sub-locations b-c.) and more conducive climate for dairy at higher altitudes (in locations II-III). In these locations (II and III), an autarkic market for milk and relatively low prices for butter result in low effective demand. This is a bleaker picture than Duncan *et al.* (2013) painted for neighbouring Tiyo district, where Asella town offers a larger market and better services, though that market too is autarkic. The relatively high proportion of crossbreds in Ethiopian locations II and III enables farmers to breed dairy heifers for areas with better dairy market quality, as hypothesized by Schiere (2001). We found no evidence though of the second opportunity he described, of calves being traded to these locations for dairy stock raising. Thus, especially the most remote farms are more subsistence-oriented – less sales but also less purchases of inputs and services – which explains the parabolic shape for butter sales between locations and between sub-locations (Minten *et al.*, 2018).

In summary, in Kenya, private service providers make use of the better infrastructure to compete for (remote) farmers as clients or milk suppliers. This better penetration of input supply and service provision into remote areas improves market quality by bringing agro-inputs and dairy delivery points closer to the farmer.

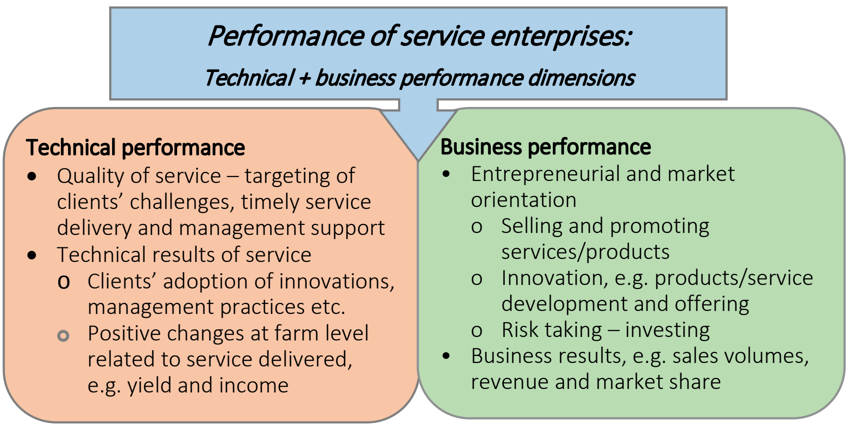
3.4.3. Implications for policy and development

What this study makes clear is that the common typology of dairy farms in '(peri-)urban' and 'rural' farms is inadequate, seeing the variability that proximity to input and service delivery centres creates between remote farms and connected farms in terms of market participation and intensification. This emphasizes the importance of infrastructure development to reduce travel times to markets, and service delivery models tailored to connected and remote farms, not least to improve access to information (Kilelu *et al.*, 2013; Omiti *et al.*, 2009). 'Remote' rural farms need to be connected to milk collection infrastructure, input shops and services to even have the choice to increase participation in dairy- or other markets.

Insights from this study can benefit the planning of in- and output marketing systems to adequately support (smallholder) dairy farms at different travel times from urban centres (i.e. access to end-markets) and at different travel times from main roads (i.e. access to input and service supply centres). Such indicators of market quality from the farmers' perspective may complement indicators for functioning of the entire market system, such as market efficiency. While the fine milk collection grid in Kenya effectively reduces travel time to dairy delivery point, positively affects milk production and marketing conditions for farms, and thus stimulates investments in dairy, travel time to local service centres for inputs and services is still rather long for many farms. For Ethiopian farms, service provision at much closer range and with much better price/quality ratios is required before they will invest in more market oriented and intensive dairy production. A more integrated service delivery system – that combines strengths of public agencies, private companies and producer organizations – will be necessary to achieve this. Nevertheless, for the foreseeable future farms far from all-weather roads will need to look for improvements in marketing of home-processed butter and cheese.

4. Effects of service arrangements

Abstract: This chapter addresses the gap in understanding performance of emerging private agricultural extension and advisory service (AEAS) models in developing country contexts, in relation to their dual objectives of supporting farmer-clients and becoming profitable agribusinesses themselves. It is a multiple case study of Service Providers Enterprises (SPEs), an emerging youth-led agribusiness model offering silage making and other services in the Kenyan dairy sector. Using mixed methods, data was collected through in-depth interviews and focus group discussions, from eight sampled SPEs, 72 farmers, and key informants across four counties. The results show SPEs' contribution to some changes in farmers' practices, including improvement in milk production, but with some limitations to optimal technical performance. SPEs' mixed business performance is linked to limited market demand, seasonality, and limited fit of some services offered, highlighting gaps in entrepreneurial and market orientation of such agribusinesses, compounded by a challenging operating environment. This evidence implies enhancing the contribution of such agri-enterprises – in offering employment opportunities especially for youth in transforming agrifood systems – requires sustained support in business incubation, market development, and strengthening the value proposition to farmer-clients. The dual perspective on performance expands theoretical perspectives for assessing AEAS, especially in relation to commercialization. The emphasis is on the mutuality of substantive demand and economic viability of these services, which is reliant on certain market growth maturity. This chapter is a first attempt to assess private AEAS models from both a technical perspective and regarding their viability as agri-enterprises.



Submitted to Journal of Agricultural Extension and Education as: *Kilelu, Catherine W., Jan van der Lee, Jessica Koge, and Laurens Klerkx, A Dual Perspective on Performance of Emerging Service Agri-enterprises: What value to farmers and as a business case?*

4.1. Introduction

Accelerated and sustainable agricultural development in sub-Saharan Africa (SSA), like other developing regions, is imperative as food systems transform, driven by population growth, increasing urbanization, and changing dietary patterns. The latter includes increased demand for more nutritious and safe food, i.e. meat, milk, fish, fruits and vegetables. This is coupled with pressures on land, water and other natural resources in agricultural systems that are increasingly confronted with effects of climate-change (Haggblade, 2011; McCullough *et al.*, 2012; Tschirley *et al.*, 2015). One characteristic of these transforming agrifood systems is that they are increasingly knowledge-intensive and technologically dynamic. This requires farmers who are part of this transformation to become more entrepreneurial and seek out the requisite technical and managerial support services to sustainably increase their production and remain competitive (Kilelu *et al.*, 2013; Tschirley *et al.*, 2015).

Several scholars note that entrepreneurial approaches need to be included as an integral part of the reforms to stimulate African sustainable agricultural development, in light of the transforming food systems (Haggblade, 2011; Ochieng, 2007). This is not only at the farm level, but also in recognition of additional opportunities in the sector for business and employment creation, including provision of technical and business support to farmers, i.e. agricultural extension and advisory services (AEAS). These services are uniquely positioned to grow into a broad range of agri-enterprises in the context of modernizing and transforming agrifood systems in the continent (Haggblade, 2011; Kabasa *et al.*, 2015; Lunguli and Namusonge, 2015).

Globally, the delivery of AEAS has evolved and continues to be a key instrument for enhancing livelihoods and supporting agricultural innovation, natural resource management, and rural development and (Faure *et al.*, 2012; Kabir *et al.*, 2020; Kilelu *et al.*, 2011; Labarthe and Laurent, 2013; Ragasa *et al.*, 2016). These services are integral to the agricultural innovation system. They seek to offer innovation support to farmers by enabling access to information on new technologies, inputs, effective and sustainable farming practices, and management options (Faure *et al.*, 2012; Kilelu *et al.*, 2013; Koutsouris and Zarokosta, 2020). The once dominant public-supported extension and input services have progressively been replaced or complemented by private AEAS. This means there is a diversity of actors – including public, private and civil-society organizations – that provide a range of services to farmers and are potentially more responsive to their needs. The structure and organization of AEAS delivery varies across countries and regions. While private sector-led, fee-based advisory service models have been operational longer in developed countries (Klerkx *et al.*, 2006; Labarthe and Laurent, 2013; Prager *et al.*, 2016), they are now emerging in SSA countries (Bebe *et al.*, 2016; Birner *et al.*, 2009; Chowa *et al.*, 2013; Kilelu *et al.*, 2011). The Kenyan dairy sector provides examples of private sector delivery models that have emerged triggered by increased farmer's demand for more external inputs and services as they seek to exploit expanding market opportunities (Bebe et al., 2016; Kilelu et al., 2013).

Studies argue that in many developing countries, demand-driven private advisory services have the potential to fill the gaps of limited government extension support and enhance the cost-effectiveness and quality of service delivery (Babu and Zhou, 2015; Kilelu *et al.*, 2011; Poulton *et al.*, 2010). Furthermore, Anderson and Feder (2003) contend that efficiency gains of AEAS can especially come from locally decentralized delivery systems with an incentive structure largely based on private provision. Engaging youth in providing such services is noted to offer opportunities for enlisting them in agriculture (Filmer and Fox, 2014; Franzel *et al.*, 2020). This ties in to what some scholars have projected as growth in demand for skills, related to on-farm (e.g. extension and advisory support; farm management) or post-farm (e.g. processing, logistics, food safety etc.) services, in what they refer to as 'food systems professions' (Kabasa *et al.*, 2015) in transforming agrifood sectors in Africa.

To understand the consequences of privatization of AEAS, some studies have looked into their performance from a technical dimension, i.e. the effects of these services on farm level outcomes. Coming mainly from developed countries, and a few from developing countries, these studies have shown mixed results regarding the effectiveness of these services in supporting production efficiency and sustainability coupled with enhancing decision making and managerial skills at farm level (Babu and Zhou, 2015; Bebe *et al.*, 2016; Clark, 2009; Dinar *et al.*, 2007; Klerkx *et al.*, 2006; Labarthe and Laurent, 2013). However, the performance of such service agribusinesses in terms of their business viability remains less understood. Thus the dual objectives of AEAS, in terms of their technical performance toward farmers and business performance in relation to their viability, have not been investigated and remain weakly conceptualized. This chapter seeks to fill this knowledge gap through an exploratory case study of the youth-led Service Providers Enterprise (SPE) model in the dairy value chain in Kenya. The main research question guiding the study is: 'how do emerging private service delivery agri-enterprises perform in providing support to farm enterprises and as a business in themselves?'

The next section reviews various literature to develop a conceptual framework for analysing the performance of emerging service agri-enterprises. We then introduce the case study. This is followed by a methodology section, then presentation of results and discussions. The final section concludes with implications and recommendations.

4.2. Literature review – understanding performance of emerging service agri-enterprises

In this section we expound on the analytical framework for an exploratory assessment of the dual dimensions of the performance of service agri-enterprises – technical and business performance. We emphasize that integrated approaches need to be applied in assessing the performance of emerging agri-service business models that provide extension and advisory support services.

4.2.1. Technical performance dimension of service agri-enterprises: impact on client

As agri-enterprises, private AEAS provide a broad range of innovation support aimed at enhancing farm-level technical and managerial practices to enable sustainable and profitable production and marketing, and ultimately contribute to livelihoods of farm households (Kilelu *et al.*, 2013; Koutsouris and Zarokosta, 2020). Such service agri-enterprises can be considered knowledge-intensive businesses (Hertog, 2000), through which the service provider and client enter into a relation, with the explicit goal to offer services to induce certain positive changes.

According to Prager *et al.* (2016), the technical performance of service agri-enterprises can be analyzed from a technical and a functional quality perspective. Technical quality refers to the actual changes induced by the services delivered (e.g. changes in farm skills and practices leading to increase in results, such as yields). Functional quality focuses more on the quality of service delivery (e.g. client-service provider interactions, client satisfaction, trust). A focus on functional quality is seen as necessary especially for 'intangible' farm advisory services, for which technical quality can sometimes be difficult to capture, as it requires more experimental methodologies in assessing these changes. The emphasis on quality of service remains of interest as this has a bearing on the outcome of such services in relation to the value they offer to their clients.

Assessment of these different technical dimensions of AEAS is emphasized again by Birner *et al.* (2009), who developed a multidimensional framework for analysing performance of pluralistic extension service systems. In this framework, the service provider is accountable at two levels. First, in terms of the quality of service provided, including content, targeting, timeliness, feedback, relevance, effectiveness, and efficiency. Second, in terms of the changes induced at farm level, including in decision-making capacity, adoption of innovations, and changes in practices (production, management, marketing etc.). Aspects of this framework have been applied to understand performance of public and pluralistic AEAS delivery systems in some developing countries (Kabir *et al.*, 2020; Ragasa *et al.*, 2016). Similarly, Labarthe (2005) states that technical performance has a number of dimensions. Those of particular relevance include the technical dimension that refers to the yield related to the service; the innovative dimension that relates to development of new products and tools to deliver the service; and the relational dimension that is concerned with personalization and intensity of services, including managerial support (e.g. farm information management and analysis and entrepreneurial support). However, it seems that aspects related to the role of advisory services in providing managerial and business support have received limited attention in literature (Hilkens *et al.*, 2018). Clark (2009) has demonstrated that the effectiveness of service agri-enterprises can be assessed by looking at their technical performance, i.e. how they support technical and management skills of farmers.

Thus, literature provides guidance on assessing technical performance of extension and advisory services by looking at how responsive the services are in reaching various farmer clients and in addressing their technical challenges and needs. Delivery of services and related inputs ideally integrates decision support and learning at farm level as part of building farmers' capacity to innovate and manage the enterprise. This ultimately contributes to impact level changes, such as enhanced productivity, income, and an optimized and sustainable farming enterprise, which in turn leads to strengthening of agrifood value chains.

4.2.2. Performance dimensions of service agri-enterprises as businesses

A business or enterprise is characterized as a bundle of internal and external resources that enable the venture to become competitive (Penrose 1959 in Lunguli and Namusonge, 2015). The viability of an enterprises is dependent on how well they are capable of stimulating demand and articulating value for customers and growing their market to generate income and profits. These capabilities relate to the concept of entrepreneurship, that has gained traction in literature in the agriculture sector and is defined as the identification, assessment and pursuit of business opportunities that occur along agricultural value chains (Lans *et al.*, 2013). Many studies on agricultural entrepreneurship tend to focus on the farm level, with a view of the farm as enterprise and the farmer as entrepreneur (Bebe *et al.*, 2016; Clark, 2009; Filmer and Fox, 2014; Meuwissen *et al.*, 2019; Seuneke *et al.*, 2013), but it equally applies to other actors and enterprises along the agrifood value chain.

Understanding how a business is performing is linked to how they develop and enhance their prospects, which is commonly assessed using financial and non-financial measures. The financial measures typically look at sales, net income, profitability, market share, and return on investment (Boso, Story, and Cadogan 2013). Various literature argues that successful business execution or performance can be explained by competencies, attitudes, and skills demonstrated by the entrepreneur. Together these have been characterized as entrepreneurial orientation. Entrepreneurial orientation is viewed as the proclivity of a business to explore opportunities in a market and grow the demand and income. The characteristics of entrepreneurial orientation are demonstrated in a business's innovativeness, risk-taking, pro-activeness and competitiveness as they seek out opportunities in a market (Boso *et al.*, 2013; Lindsay *et al.*, 2014; Verhees *et al.*, 2011). Further, Boso *et al.* (2013) note that complementary to entrepreneurial orientation there is market orientation, which is the implementation of marketing or the market-oriented operations of the business. This is characterized by how the business creates market opportunities through developing new services and products. Thus, the degree of entrepreneurial and market orientation is a reflection of a business's strategic positioning. This is widely recognized as impacting on its performance, although as Wiklund and Shepherd (2005) note, the relationship is more complex and usually is affected by the specific context.

These perspectives has been applied to understand performance of enterprises in developing and emerging economies (Boso *et al.*, 2013; Bruton *et al.*, 2013; Lindsay *et al.*, 2014). In these economies, entrepreneurship is increasingly noted as important for stimulating inclusive economic development and as a solution to poverty. Here, businesses operate in a context with weak demand and institutional uncertainty (Boso *et al.*, 2013; Lindsay *et al.*, 2014). This is clearly noted in the agricultural sector, where prospects for agribusiness, including service delivery, are growing. As such, entrepreneurial capabilities for growing a market – by stimulating substantive demand and articulating value for customers – are important for generating income and achieving profitability (Haggblade, 2011; Poulton *et al.*, 2010).

Following the exploration of literature above, **Figure 4.1** summarizes the analytical framework that is applied to examine the dual dimensions of technical and business performance of SPEs as agri-enterprises.

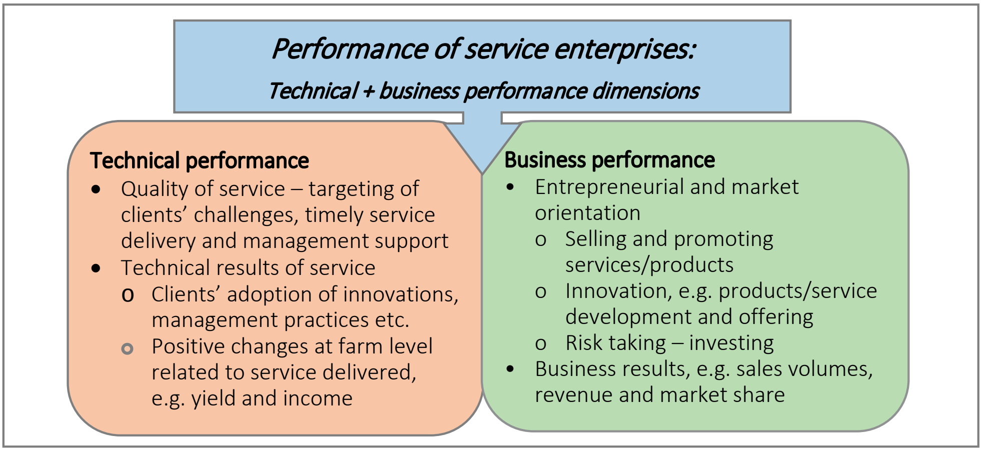


Figure 4.1. *Analytical framework to assess technical and business performance of service agri-enterprises (Source: authors' elaboration)*

4.3. Methodology

4.3.1. Case description: the SPE model

The Service Provider Enterprise (SPE) model is characterized as a group-centred enterprise of mainly post-school rural youth, defined as 18–35 years old, who offer agricultural advisory, support services, and inputs to farmers in their locality on a commercial basis. The SPEs are embedded within vibrant nodes of dairy value chains in target regions in Kenya where small and medium scale farmers are engaging in market-oriented production and are demanding various contracting and advisory support services. The main service entry point for the SPEs is contracted silage making services. The model was initiated in 2010 with the support of SNV's dairy program (SNV, 2013), starting with four SPEs located in Nyandarua, Nyeri and Embu counties. SNV's Kenya Market-led Dairy Program (KMDP, phases I and II, 2012–19), funded by the Embassy of the Kingdom of the Netherlands in Nairobi, scaled up the concept by establishing more SPEs in Meru, Baringo and Uasin Gishu counties. During establishment of the SPE groups, all recruited members went through a short practical training on silage making, forage establishment, basic dairy cow management and business skills. The SPEs were then linked to dairy farmers' cooperative societies (DFCSs) in their localities as the entry point for reaching potential farmer clients. SPE teams became the next-door solution for forage preservation, forage establishment, dairy management, as well as the supply of forage seeds and silage preservation materials.

Underpinning the SPE model are several conceptual building blocks, summarized as:

a. The model requires a vibrant sector in which to anchor service delivery. The assumption is that farmers in economically vibrant agricultural sectors will be willing to pay for services that support growth of their enterprises.
b. The service providers are equipped with practical skills that are tailored to needs in the sector and can generate demand.
c. The enterprise members may offer some services as a group, especially in silage making, which requires group work.
d. The service providers need to continually improve their competencies and develop new services that are offered competitively to their (would-be) clientele.

4.3.2. Case selection

This study used a multiple case study method (Yin, 2009). The study was conducted in four of the six counties where SPEs have been established, i.e. Meru, Nyeri, Nyandarua and Baringo. Eight out of fifteen operational SPEs that were formed between 2010 and 2015 were randomly selected: three SPEs from Meru County, two from Nyandarua County and one from Nyeri County. In Baringo, two out of five SPEs were purposively selected considering distances between them, in order to reduce travel time. Data was collected in June and July 2017. **Table 4.1** provides a summary of the selected SPEs and the DFCSs they were linked with.

4.3.1. Data collection and analysis

To illuminate the cases in detail and triangulate findings, data was collected using different methods. SPE representatives were interviewed using an open-ended questionnaire to collect information about their group members, service delivery, and business performance. Two SPE representatives were interviewed from each of the SPE groups, except for Unique SPE where only one representative was interviewed. Thedata collected had some gaps regarding enterprise results, as many SPEs did not have consistent business records.

Table 4.1. *Details of SPEs sampled and their linked dairy farmers' cooperative societies*

County	SPE	Related DFCS	County	SPE	Related DFCS
Baringo	**Bokimu**	Mumberes	Nyeri	**Unique**	Kiunyu
	IDM	Kiplombe Farmers	Meru	**DRIP**	Nkuene
Nyandarua	**Intertech**	Nyala		**Bidii**	Mbwinjeru Ariithi
	Ngorika	New Ngorika Milk Producers Ltd		**DASPE**	Naari

To collect farm level data, focus group discussions (FGDs) were held with farmers that were clients to the sampled SPEs. A total of 72 farmers participated in the FGDs. The FGDs were designed to collect a mix of quantitative individual farming data (e.g. feed preserved, milk produced and marketed) and qualitative information about farmers' views on the SPE's contribution to their on-farm changes. The level of detailed farm-level data was limited. Key informant interviews were conducted with representatives of DFCSs whose members were SPE clients to broaden perspectives on the contribution of SPEs to changes in dairy farms that access SPE services.

Descriptive analysis of the quantitative data was conducted using SPSS and the qualitative data was transcribed, coded and analyzed in Excel.

4.4. Results

4.4.1. Characteristics of sampled SPEs and their services

The eight SPEs offered services to members of the linked DFCSs. The majority (53%) of their 32 current members were characterized as youth. About 94% of the SPE members were male. On education levels, 3% of the members had acquired basic education only (primary level), while about 59% had attained up to secondary school education. About 38% had attended (some)

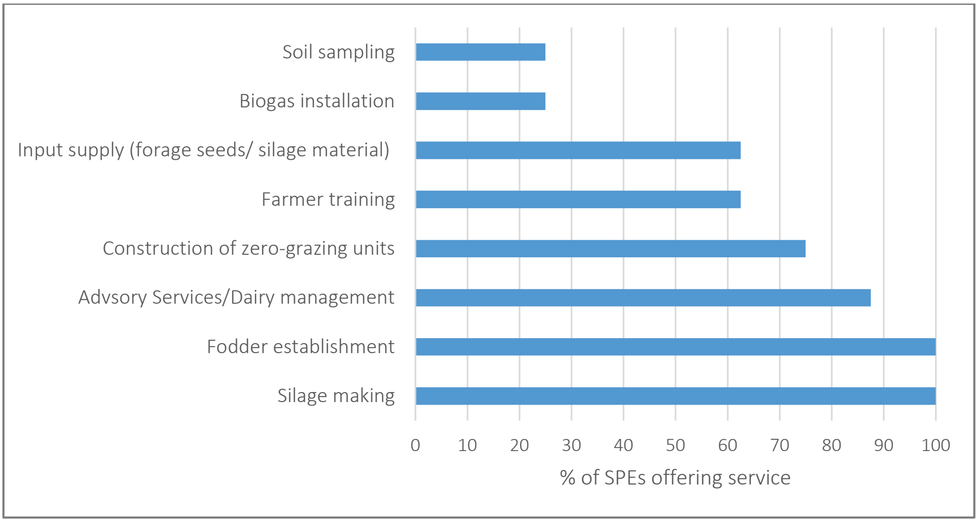


Figure 4.2. *Types of services offered by SPEs (n=8)*

additional post-secondary training. During the study, the SPEs had an average of four active members in each group, although at time of establishment the groups had recruited more members. About 43% of those recruited and trained remained active in the SPE groups.

The main service offered by SPEs was silage making. This was the initial value proposition, which targeted addressing fodder shortage as a key limitation in dairy farming in Kenya. The silage making services included harvesting, chopping, compacting, tubing, and (sometimes) provision of the materials required for ensiling. In addition, all SPEs have expanded their service packages to include complementary services to silage making, i.e. forage establishment, farmer (group) training, and input supply (e.g. forage seeds, silage making materials) (**Figure 4.2**). Most SPEs provided farm-level advice related to animal husbandry (e.g. calf rearing, breeding, record keeping). A few SPEs provided soil sampling, barn construction, and biogas installation as additional services. Farmers in the FGDs noted that silage making and forage establishment were the main services they sought from SPEs. On forage establishment, farmers interviewed wanted support with planting and advice on good forage management (e.g. fertilization, weeding and spraying). They sought advice from SPE members as government extension services were no longer available.

4.4.2. Technical performance of SPEs

Quality of service dimension

According to the FGDs, farmers noted that access to fodder and good feeding management were among their main challenges. SPEs enabled them to integrate silage in their farms and provided other support to improve fodder access and other improved feed management practices noted in **Figure 4.2** as solutions to these challenges. Many farmers had not made silage before, but with SPE support, silage making became a common practice in their localities, which shows that this service was well-targeted. The silage was made from maize, Napier grass, sorghum, or oats. Maize silage was most common, with an estimated 9,415 tonnes made in 2016 (about 83% of total silage made).

All farmers in the FDGs indicated that they have used silage making services at least once a year, with a few farmers using these services more than once a year. Use of SPE silage making services was most frequent among Mbwinjeru Ariithi DFCS clients, where the majority (75%) of clients used Bidii's service more than once. In Kiunyu DFCS, farmers said they had conserved silage in the past, but drought conditions had affected maize production for silage. Data from the eight SPEs indicated that in 2016, the groups collectively made about 11,269 tonnes of silage (**Figure 4.3**). Two out of three SPEs in Meru County made the highest volumes – over 3,000 tonnes – suggesting effective service delivery. Half of the SPEs produced only one-sixth of that amount, especially the two in Baringo County.

To integrate silage in their dairy enterprises, farmers indicated the need to make investments, such as purchasing equipment (including chaff cutters, choppers, polyethylene wrappers, and molasses), construction of bunkers, and allocation of farmland. Some farmers allocated part of their own land to grow forage, while others leased land for planting forage crops. The equipment (in some cases provided by SPEs), labour, and technical support were important elements of the service, as silage making is labour intensive and requires technical acumen to ensure quality.

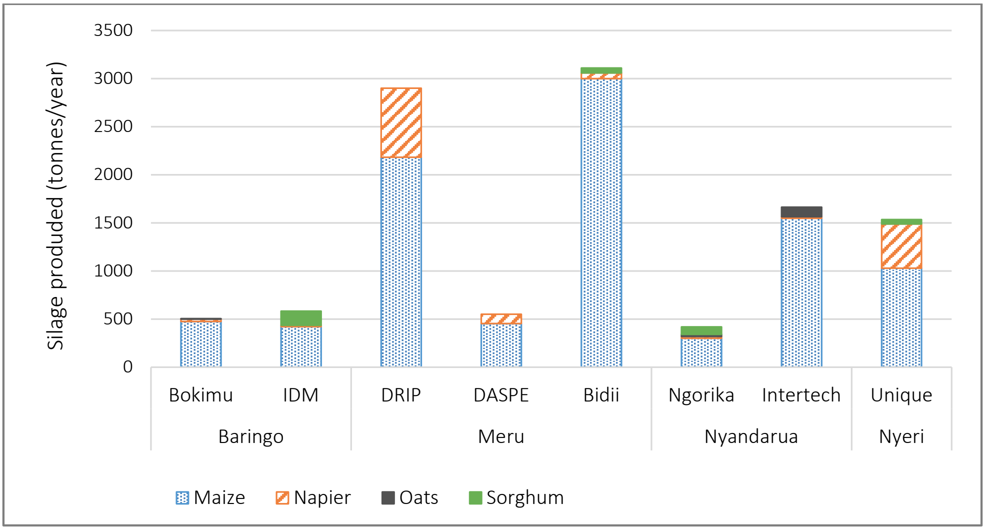


Figure 4.3. *Volumes of silage made by SPEs in four counties in 2016*

The average amount of silage made per farm varied widely, from 4 to 66 tonnes (one tonne feeds one cow for ca. 2 months). Farmers indicated that the silage made was insufficient to last the entire dry season. This indicates that SPEs did not offer comprehensive management support to clients, leading to clients understanding how much silage they would need for their cows in each season (feed planning) and to use this to guide silage making and other feed management strategies.

Improved farm-level results linked to SPEs

Increase in milk production was an important indicator of positive technical performance, as dairy farming was the primary source of income for most farmers involved in the study, with only a few indicating having off-farm income sources. In the FGDs, some farmers mentioned that milk production increased when they started to adopt silage through SPEs. The interviewed farmers in Meru, where SPEs made the most silage, indicated that their average production had gone up to about 9.5 litres/cow/day for those in Naari and Nkuene DFCS and to about 8 litres/cow/day for those in Mbwinjeru Ariithi DFCS. While there was no baseline data on productivity before SPE services, the milk yield in the high dairy producing regions in Kenya, such as Meru County, averages 5-8 litres/cow/day for wet and dry seasons combined. Therefore, farmers' own reporting suggests a productivity increase linked to uptake of silage and other good feeding practices introduced through the SPEs, but in absence of a baseline, a selection bias cannot be ruled out, where mainly capable farmers with higher than average milk yields engage SPEs. In addition to increased productivity, farmers mentioned other benefits resulting from integrating forage production and preservation in their farms. These were: stable production even during dry seasons, better animal health, lower production costs through reduced purchase of dairy meal, and increased fertility rates.

From the group discussions, it was estimated that farmers from Nkuene DFCS generated the highest gross revenue from milk at about KES 1,779 (1 USD ~ 100 KES) per day, while farmers in Mumberes DFCS had the lowest gross revenue of about KES 264 per day. Calculating gross margins would offer better understanding of the profit from the dairy enterprises in the farms involved. However, this would require detailed data on the cost of production, which was not collected in this study.

While these results suggest that enhanced use of silage and improved feeding management helped stabilize milk production across dry and rainy seasons, a more conclusive understanding of these effects requires more robust and longitudinal data collection, which was not available for this study.

Challenges affecting technical performance of SPEs

The SPEs faced several challenges that limit their operations and their ability to effectively provide services to their clients. The noted limitations facing the SPEs included lack of appropriate machinery and limitations in access to inputs, i.e. poor quality of ensiling material and quality and volumes of forage seed. During discussions, farmers noted some skill gaps in SPEs in relation to additional services they needed (e.g. artificial insemination and animal health care). Furthermore, some farmers indicated that during peak silage making season, there was a high demand for services but there were not enough SPEs available, affecting timely delivery of services.

4.4.3. Business performance of SPEs

This section analyzes the performance of SPEs as a business through understanding market- and entrepreneurial orientation as well as business results.

SPE entrepreneurial and market orientation

SPEs have adopted a hybrid business approach, offering services both as a group and as individual members. The group services are offered especially where there is need for higher labour input, such as forage planting, harvesting, and silage making. While SPEs started with silage making and forage establishment services, most expanded their service offer with new services and products (**Figure 4.2**). Expanding the service offer was said to be important, especially because silage making is seasonal. However, the SPE members noted that demand for some additional services remained relatively low (e.g. soil testing, barn construction, and biogas installation). Thus, it is key for SPEs to not only diversify services but also be able to create market demand for these services. The results show that Unique SPE was able to create demand for the largest number of services (**Figure 4.4**), while DRIP and IDM had the least services demanded.

As emerging entrepreneurs, SPEs promoted their services through various channels, such as dairy field days and agricultural fairs (exhibitions) organized by various actors at DFCS, county and national level. DFCS-facilitated forums were identified as a good marketing option. Word-of-mouth marketing by early adopters connected SPEs to new clients as well. Such referrals from clients and related social networks were the most common means of acquiring new clients.

To be effective in service delivery, some SPEs made various investments. The main investments highlighted were the purchase of efficient chaff cutters and chopping machinery by Unique, Intertech and Bidii SPEs. Financing of these investments came mainly from their own savings and some from bank loans. Bidii acquired more assignments for silage making in 2016 after it invested ca. USD 1,650 in efficient choppers. In this case, SNV provided financial

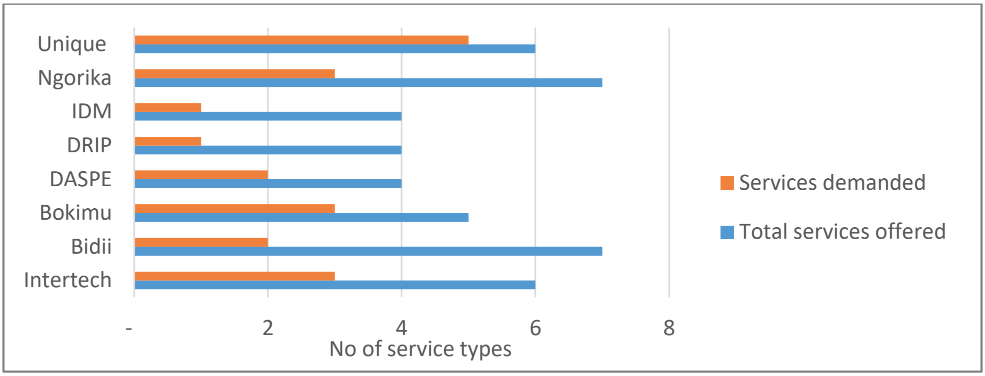


Figure 4.4. *Patterns in SPE service type delivery*

support through a cost-sharing arrangement to acquire their first chopper, with SNV matching a bank loan. However, we conclude that most SPEs showed low levels of investment in relevant technology in order to enhance their business.

SPE business results

As noted in the preceding section, the SPEs offer a diverse bundle of services to their farmer client base in the respective DFCSs. Based on SPE services and products uptake in 2016, the business results varied. However, a caveat to this analysis is that many SPEs did not keep proper financial transactions records, posing a challenge in robust analysis of business performance. This is why we used turnover as a proxy of income. The turnover came mainly from silage making, some advisory services, and sale of inputs. Silage making services made the highest contribution to earnings. The fees ranged from KES 250-1,000/tonne. In some cases, the price was set by the cooperative. For example, Naari DFCS set silage making fees at KES 2,000 per lot, irrespective of the amount of silage made, as they had invested in choppers that they rented out to the members. Another key revenue stream for some SPEs was the sale of inputs, mainly forage seeds. While SPEs conducted many training events, most of these were promotional activities to market services. This free training included silage making demonstrations. In some cases, the SPEs were brought in to conduct training through third parties such as dairy development projects (including SNV-KMDP). Rather than being paid commercially, the SPEs received a token honorarium to cover their transport costs and printing of training material.

The results show that Unique and Intertech had the highest monthly business turnover of USD 465 and USD 369 per member respectively; this included about USD 77 and USD 47 respectively from selling forage seeds and other inputs. On the other end, SPEs such as DRIP and IDM had an average monthly turnover of about USD 53 and USD 73 per member. This shows that there is a link between market demand for diverse services, and its effect on turnover and ultimately income. The SPEs that marketed most services, i.e. Unique and Intertech, also had chances of making the most income. The 14,227 active suppliers in the DFCSs that SPEs were serving can be regarded as their potential client base. At the time of the study, the SPEs had provided services to about 7% of this client base, an indication of low market penetration. SPEs observed that growing their customer base takes time. Together with the noted seasonality of the main service offered (silage making), this explains the limited incomes of the SPEs.

Challenges affecting business performance of SPEs

As a new model in dairy service provision, SPEs members indicated that they face several business challenges. For most SPEs interviewed, timely payment for their services was the main challenge, as they faced delays and defaulting from clients. This is because some of the farmers take an informal approach to the SPE business, viewing local youth as promoting community welfare rather than offering a commercial service. Costing of services was another issue. SPEs noted that they didn’t know how best to price their services to ensure that it was profitable but also reasonable for their clients. Other challenges were intertwined with the constraints of clients, including small land sizes for growing forage, low adoption of technologies and practices promoted, and drought and seasonality that affected demand for services. Dropout of SPE members after recruitment into the SPEs resulted in high attrition in the different groups, ranging from 20–85%. This affected some groups’ ability to offer services in a timely manner, especially during the peak silage making season.

4.5. Discussion

4.5.1. Reflections on technical and business performance of SPEs

This study on SPEs illustrated the growing opportunities for agri-service enterprises in Kenya. From the technical performance dimension, findings showed that SPE services contributed to enhancing forage preservation through silage making, although they faced challenges and limitations in adequately delivering services to their target clients. The findings suggested some closing of the feed- and milk seasonality gap and productivity improvement for part of the farmers receiving SPE services. Another study on the same model, Ndambi *et al.* (2020), showed similar results, where farmers using SPE services reported improved forage availability, reduced fluctuation in milk production across seasons, and increased milk yields and margins. However, it noted that higher impacts on productivity could be achieved by combining forage conservation with advice on feed ration formulation, support that SPEs did not offer.

Moreover, variations existed among SPE technical performance for different farms and regions, owing to factors such as agroecological differences and socio-economic status of the target clients. Other studies on private service delivery models in the Kenyan dairy sector point to similar mixed results, noting that while more farmers accessed services when new providers emerged, this did not necessarily translate into improved farm results (Bebe *et al.*, 2016; Kilelu *et al.*, 2013). These findings confirm Clark (2009)'s argument that AEAS' effectiveness should be geared toward addressing both technological and managerial gaps in farming. For example, SPEs would be more effective in their support if they integrated forage production and conservation services with decision support on feed planning and management.

From the business performance dimension, the results showed that most SPEs have not reached full potential. SPEs offer a range of services, but with limited uptake by a small portion of their potential client base. Thus, many SPEs were not able to stimulate a substantive market demand to offer consistent income or fulltime employment to their members. This suggests that most SPEs have limited entrepreneurial and market orientation, although it is as yet unclear what proportion of smallholder suppliers is willing to pay for private services. An important factor for the low market penetration noted was the seasonality of their main service of silage making, without complementary effective demand for other services. In addition to low demand, other business challenges reflect the difficult operational context of SPEs, including delayed or defaulted payments, poor access to capital to make necessary investments, and clients' attitude toward them as offering community services. As Boso *et al.* (2013) note, the need to enhance entrepreneurial and market orientation is especially important in developing economy contexts, which have underdeveloped markets and a largely informal institutional context, constituting a high-risk business climate.

4.5.2. Implications of the dual perspective in organization of privatized AEAS

The application of the dual perspective in assessing SPEs from a technical and business performance angle illuminates new insights in the debate on privatization of AEAS, particularly in developing countries. The limited market power of smallholders and dominance of informal market systems creates a challenging business environment for private extension and input service providers, with a lack of consistent and substantive demand for their services. This affects business results (turnover and profitability) and makes it challenging for private sector actors, especially small enterprises, to invest (Poulton *et al.*, 2010). For such emerging services it is important to understand how best to stimulate and sustain service demand and increase the share of paid-for services, which has been referred to as a commercialization gradient (Prager *et al.*, 2016). This raises questions regarding market development for such services in the context of predominant smallholder production systems and implies more effort is needed to simultaneously stimulate supply and demand sides of such emerging markets.

The difficulties encountered by the SPEs in stimulating demand are also indicative of limitations in the training and deployment of the model, which focused mainly on the technical aspects of service delivery and less on business aspects, such as the entrepreneurial and market orientation skills needed to grow the agri-enterprises. Effectively addressing these gaps requires the development of more comprehensive private AEAS, which may be beyond the SPE model, which was designed to deploy limited hands-on advisory support on improvement of feeding (mainly silage making) and dairy management. This limited technical focus of the model indicates some competence gaps, that imply the SPEs face resource constraints to continually invest in updating their capacities to offer more service value to their clients and also make it possible to grow the business (Labarthe and Laurent, 2013; Ragasa *et al.*, 2016). This is further compounded in a context where farmers are unable to clearly articulate demand and hold service providers accountable for technical quality of their services (Birner *et al.*, 2009; Labarthe, 2005; Poulton *et al.*, 2010). Thus, to capture the potential of the emerging private AEAS, such as SPEs, there is need to ensure that the service providers are oriented toward a 'best fit' (Birner *et al.*, 2009) of both technical performance toward clients and their own business performance. Both dimensions are important considerations when developing policies to promote private sector services that are technically robust, to ensure their accountability and responsiveness to clients but also factoring in entrepreneurial skills . These are needed for the dynamic and challenging operational context where these business are embedded (Boso *et al.*, 2013; Poulton *et al.*, 2010; Wiklund and Shepherd, 2005), especially in developing countries that may not have attained a certain market maturity. This links to debates on the need to look at 'advisory subsystems' (Klerkx *et al.*, 2017), as some sectors or groups of farmers may be viably served by private AEAS, while others may need continued public support. Furthermore, the effectiveness of a service provider can be enhanced when they are embedded within networks of plural actors providing complementary services that offer a suite of solutions for a broad range of issues to fit the demands of diverse farmer-clients (Birner *et al.*, 2009; Klerkx *et al.*, 2017).

Another interesting point relates to the fact that the majority of SPE members were youth and male. The SPEs emerged from a development program intervention that provided practical, vocational training to skill agri-service providers. Such interventions are noted to be important for enabling easy entry for youth into agribusiness, in line with the entrepreneurial shift that is strongly promoted as part of the agrifood sector transformation in Africa (Birner *et al.*, 2009; FAO *et al.*, 2014; Franzel *et al.*, 2020; Haggblade, 2011). The mixed performance of SPEs calls for reflection on whether and how efforts including policy interventions for enlisting youth in the agrifood sector offer viable employment and livelihood options and contribute to agrifood sector development (Filmer and Fox, 2014; Franzel *et al.*, 2020; Kabasa *et al.*, 2015; Sumberg and Hunt, 2019; Tschirley *et al.*, 2015). Results showed that some SPEs exhibited more entrepreneurial and market orientation than others, implying that promoting program-induced entrepreneurship models need to consider the aspirations and motivations of different youth, and recognize that not all youth are necessarily innovative and enterprising (Mgumia, 2017; Sumberg and Hunt, 2019). Such understanding can guide in the design and promotion of entrepreneurial models that can attract youth with aspirations and who see real opportunities in agri-enterprise and will stay involved beyond initial program support.

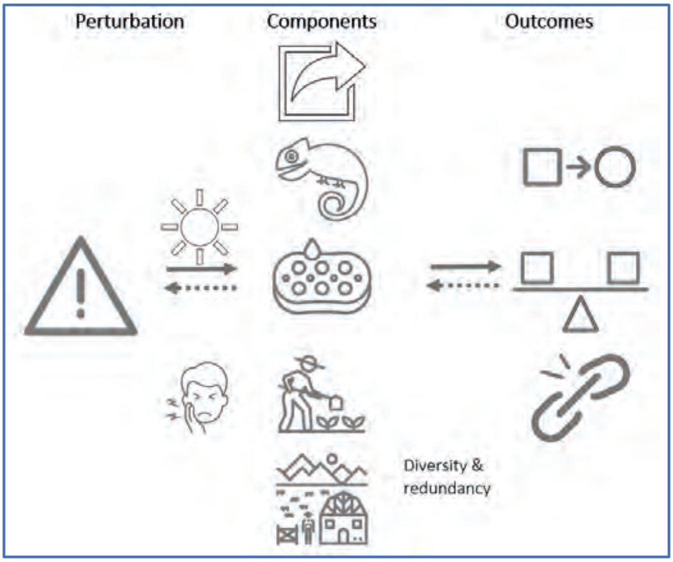
4.6. Conclusions

The study has provided insight into the technical and business performance of emerging agri-service enterprises in the context of transforming agri-value chains and food systems in SSA. The SPE model that emerged in the growing commercial dairy sector in Kenya demonstrates opportunities for service agri-enterprises, even when targeting smallholders. The bundle of services that SPEs offer has potential to provide innovation support to entrepreneurial farmers and contribute to sustainable growth of the sector. Nonetheless, the mixed results of SPEs indicate that while services are gaining some headway, the model is insufficiently robust. A number of technical and business challenges are affecting its performance – limitations in entrepreneurial and market orientation and skill levels of the group members, farmers' willingness to pay for services and in fit of services to client' needs, in a context of weak demand and limited business support. A strong value proposition for the SPE model can be demonstrated when these challenges are addressed. Beyond this single model, it is important to interrogate how to build pluralistic AEAS subsystems or configurations that are well fitted in such emerging markets, paying attention to the kind of 'push and pull' measures needed to strengthen their performance (Klerkx and Jansen, 2010).

By design, the SPE was intended as an inclusive business model that would attract youth (male and female) into service agribusiness opportunities, especially in recognition that their role in the sector has declined. The insights of the study show that providing rural youth with appropriate skills, as increasingly promoted through policy and development programs, is an important strategy to attract them to agribusiness and employment opportunities but requires more varied institutional support. The study also pointed to some assumptions about youth and agri-entrepreneurship and suggests the need for further research in understanding youths' aspirations, entrepreneurial characteristics, and the limitations they face in efforts to enlist them more meaningfully in agrifood sectors.

All in all, the study points to the need for public, private, and development sector interventions to rethink how to promote effective private AEAS delivery and how to support such small agri-enterprises in the sector. Sustained support should be embedded in policy decisions that consider more holistically the challenges of agricultural transformation, rural development, and the broader challenges of unemployment.

5. Assessing resilience



5.1. Introduction

Assessment of the resilience of farming systems has received increasing attention over the past decade (where farming system is defined as 'a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods, and constraints, and for which similar development strategies and interventions would be appropriate' (Dixon *et al.*, 2001)). After Holling (1973) applied the term resilience to ecological systems and Gunderson *et al.* (1995) applied it to socio-ecological systems such as agricultural systems, many authors stated that theory about resilience should be followed by methodologies for its assessment (Serfilippi and Ramnath, 2018). Agricultural systems at different scales – from farming activity, to farm, to farming system, to agrifood chain, to food system – are socio-ecological systems comprising both biotechnical and social factors, that are subject to disturbances by both external and internal stressors (Walker *et al.*, 2006). The concept of resilience describes how agricultural systems cope with different stressors, be they noise, shocks, cycles, or trends (Urruty *et al.*, 2016). Most users of the concept – be it academics or development actors who strive to strengthen resilience of vulnerable groups or systems – view it as a desirable characteristic that systems need to possess in order to deal with the turbulent environment they operate in, while a few authors point at the 'dark sides of resilience' – e.g., poor people can be very resilient, yet trapped in poverty (Berkhaut, 2008; Wedawatta *et al.*, 2010).

Assessment of the resilience of farming systems involves a process of identifying how resilience is created, maintained, or broken down (Quinlan *et al.*, 2016). While Walker *et al.* (2004)'s definition is widely accepted ('resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change, so as to still retain essentially the same function, structure, identity, and feedbacks'), it is resulting in a wide variation of assessment approaches that appear to use different conceptual positions. Over the past decade, multiple authors have published resilience assessment frameworks (see overviews in Meuwissen *et al.* (2019); Serfilippi and Ramnath (2018); Fang *et al.* (2018)) but theoretical underpinning and methodological choices diverge, in particular on (1) whether resilience is a capacity, a process, or an outcome of a process; (2) what the causal relationships are between resilience and other key concepts, such as adaptive capacity, vulnerability, stability, and various other attributes of resilience (Meuwissen *et al.*, 2019; Urruty *et al.*, 2016); and (3) whether it adds value to distinguish between multiple capacities such as absorptive, adaptive, and transformative capacities (Béné, 2013). Serfilippi and Ramnath (2018) also showed a similar variety in theoretical underpinning and methodological choices in frameworks used in the field of disaster risk reduction for household- and community-level livelihoods, a field that is somewhat related to that of farming systems. This lack of agreement on resilience and on its determinants contributes to the challenges faced in its assessment and of the impact of interventions designed to strengthen it (Bene *et al.*, 2014; Brown, 2014; Córdoba Vargas *et al.*, 2019; Meuwissen *et al.*, 2019), both in terms of methodological approaches and in terms of comparing findings and outcomes within and across systems. That is, depending on the conceptual stance and assessment methods chosen, decision makers may evaluate a particular farming system to be more or less resilient, with implications for the design of interventions to enhance its resilience. In short, this chapter contributes to filling the apparent ambiguity in theoretical underpinning of resilience assessment approaches.

Rather than adding another framework, we aim to identify from the existing literature the commonalities, differences, and gaps, as well as their implications, in resilience conceptualization and in its assessment approaches for farming systems. Specifically, we aim to (1) shed a more nuanced light on the theoretical stances that have been advanced in literature for assessing resilience of farming systems and (2) to identify advantages and disadvantages of different approaches used for assessment of farming system resilience. We therefore provide a systematic review of resilience assessment approaches, pointing out emerging patterns and methodological characteristics. This is expected to bring conceptual and operational clarity to the resilience assessment field.

The rest of the chapter is organized as follows: Section 5.2 presents the methodology for the literature review process and details the literature search results. Section 5.3 presents the review findings, section 5.4 the discussion, and section 5.5 the conclusions and implications of this chapter.

5.2. Materials and methods

This systematic literature review was based on the steps for good quality systematic reviews recommended by Petticrew and Roberts (2006). These are outlined below. See **Figure 5.1** for a flow diagram.

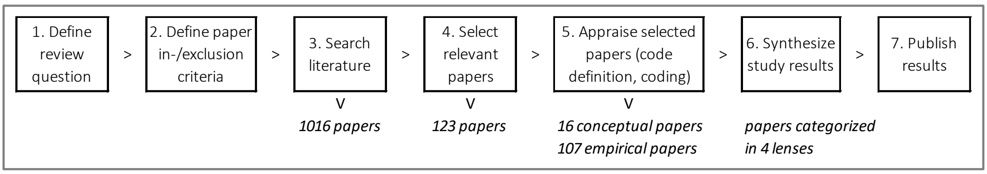


Figure 5.1. *Steps used in this review with resulting numbers of papers identified (authors elaboration based on Petticrew and Roberts (2006))*

5.2.1. Review question

This review addresses the following research question: How has assessment of resilience of farming systems been conceptualized and operationalized and what does this imply for further development of assessment approaches?

This question is broken down into the following sub-questions:

a. What theoretical and methodological features can be identified in the approaches used to assess resilience of farming systems?
b. What are the likely implications encountered when applying identified approaches?

5.2.2. Identification of study types that need to be selected in order to answer review question

In- and exclusion criteria were designed, as listed in section 5.2.4. A restrictive search string was developed that included the different levels of systems involved in farming – farming activity, farm, farming system, and farming as part of the supply- or value chain – as well as the different terms used for assessment of the resilience of such systems (measure or assess): TS: (((farm* AND resilience)) OR (chain AND resilience)) AND ((resilience AND measur*) OR (resilience AND assess*))), alternatively written as ((farm* OR chain) AND resilience AND (measur* OR assess*)).

5.2.3. Literature search for relevant studies

A search was run for peer-reviewed papers written in English language, published from 2010 onwards. The core collection of Web of Science database was chosen due to its nature of containing interdisciplinary studies and its large coverage of records (76 million). The first search in August 2018 yielded 798 papers, another search in early April 2019 yielded 176 papers. An additional 42 papers were added from Web of Science database alerts until the end of April 2019, bringing the total to 1,016 papers.

5.2.4. Selection of relevant studies

To select the relevant papers, three of the authors reviewed the 1,016 papers, in order to weed out the irrelevant papers. A sample of the papers was reviewed by multiple researchers, as were papers of which the relevancy was not entirely clear. Papers were considered irrelevant if any of the following exclusion criteria applied:

1. Paper did not focus on agrifood systems; e.g. focused on transport or automotive industry, network or cyber systems resilience, territorial resilience, or resilience of ecological systems; papers dealing with natural resource management activities other than 'farming’ (defined as at least one crop or livestock species being kept for production) were excluded as well;

2. Paper focussed on resilience of rural communities or of networks without specifically talking about any form of farming or agrifood system;
3. Paper did not focus on assessment of resilience; resilience or its assessment were mentioned just in passing, without playing a significant role;
4. Paper in language other than English.
5. Paper was published in a journal not meeting peer-review criteria described in www.ulrichsweb.com, a global series directory with detailed information on 300,000 periodicals; if information was not available on this website, we consulted the journal website to verify the information on peer-review; peer-reviewed conference proceedings were retained.

Having removed all irrelevant papers, we ended up with 123 papers for further analysis.

5.2.5. Appraisal of selected papers

In this step, the following approach was followed:

1. *Code selection and conceptual framework* – We identified patterns in the conceptualizations and assessment of resilience based on a cross-study of the 123 selected papers. The full coding frame is included in **Table 5.1**. Next to a number of factual characteristics, we used the following conceptual elements to define a coding frame fitting our research questions:
    - agrifood system and risks or perturbation being considered, following Carpenter *et al.* (2001)'s recommendation to ask the question 'resilience of what to what?'
    - determinants (or attributes) that can support a system in responding to risks, including:
        - adaptive capacity – the capacity to anticipate risks and design strategies not to be harmed by them and to keep moving toward aspirations
        - absorptive or buffering capacity – the various strategies by which individuals and/or households moderate or buffer the impacts of shocks on their livelihoods and basic needs
        - transformative capacity – the capacity to create a fundamentally new system when conditions make the existing system untenable (Béné *et al.*, 2012)
        - practices – agroecological and management activities for farming and marketing
        - resources (also called capitals) – tangible and intangible assets; including natural, economic, physical, human, and social resources (DFID, 1999)
    - system functions refers to the main objective of a system's existence including the 'resilience for what purpose?' following Meuwissen *et al.* (2019) recommendation
    - theoretical position of the authors (or the 'lens' with which they look at resilience), following Zawacki-Richter *et al.* (2020)

- dimensions of resilience – the aspects of a system that may be affected by risks, they can be environmental, economic, social, and technical (production) etc.

2. *Coding* – We then systematically coded selected papers; codes and sub-codes were summarized in Excel. Uncertain cases were discussed in the team.
3. *Reiterations of steps 1 and 2* – After assessing circa 25% of the papers, we refined the coding frame based on additional insights obtained; papers already assessed were assessed again, but by different team members, and the remainder of the papers was coded.

5.2.6. Synthesizing study results

Based on our first reading of papers included in the final sample, we distinguished four main lenses being used: the 'traditional' resilience theory lens (T), the 'vulnerability' lens (V), the 'capacities' lens (C), and the 'agroecology' lens (A). The code for 'lens' was selected as a grouping parameter for the concepts used in the papers and was used for further clustering and analysis. The papers in which the lens used was less explicit or unclear, were discussed between the three first authors until agreement on best suitable grouping was reached.

Frequency scores per lens group were calculated for the codes in **Table 5.1**. These were turned into histograms that illustrate the variation in codes between the lenses. Display was either by number of papers or by proportion of papers. Additionally, qualitative information from the papers was used to enrich and triangulate findings.

Among the 123 selected papers were 16 review and conceptual papers that did not describe any clear and implementable assessment approach. Among the remaining 107 empirical papers, seven papers could not be classified under one of the four lenses, leaving 100 papers grouped under the four lenses. All 123 papers were included in description of lenses, paper metrics and qualitative assessment in sections 5.3.1 and 5.3.2, but only the 100 were included in the quantitative analyses in sections 5.3.3–5.3.5. See **Annex 1** directly at the end of this Chapter for an overview of all papers assessed.

Table 5.1. *Codes and sub-codes used to characterize papers*

Codes	***Sub-codes***
System properties (resilience of what?) and risks (resilience to what?)	
Continent	Country(-ies) where study was conducted was in the following continent: Africa / Asia / Europe / Latin America / North America / Oceania (or: no country indicated).
System	System as described in paper.
System scale	Farming activity / farm / farm household or its livelihood / agroecosystem or farming system / supply- or value chain / larger system (food system etc.) / other. *Agroecosystem or farming systems, farm, and farm household or its livelihood farm household were later combined into 'farming system'; supply/value chain and larger system were later combined into 'larger system'.*
Main functions of system	E – ecosystem services; F – food production or food security; L – livelihood.
Risk categories / disturbances	Production disturbances / environmental, land & water disturbances / natural disasters and extreme weather events / climate change / food insecurity and poverty / global drivers and context changes / market & supply chain disturbances / policy changes / unspecified disturbances. *The first three categories were later combined in 'biophysical'.*
How is resilience viewed?	
'Lens' – theoretical position of looking at resilience	A – agroecology lens; C – capacities lens; T – traditional lens; V – vulnerability lens; O – other lenses.
What determinants of resilience are being described and assessed?	
Resilience determinants assessed	C – capacities; P – practices; R – resources; O – other components.
Capacity types assessed	B – absorptive; D – adaptive; T – transformative; O – other.
Dimensions of resilience assessed	E – environmental; M – economic; P – production; S – social, O – other.
How is resilience assessed?	
Data source	*Data were obtained from:* Farmers or farm households / Broader system stakeholders / Secondary data / Literature (conceptual).
Quantification score for assessment method	In the assessment methodology, parameters are mainly assessed using: 1. Perceptions/judgements of observer or interviewee – descriptive without evidence of scale or justification for judgement 2. Scoring of indicators without distinct categories (e.g. using 'high-medium-low') 3. Scoring using distinct categories (indicators have more quantitative scales) 4. Measured indicators without computation of indices 5. Measured indicators using a predetermined computation of index/indices 6. Measured indicators with weighted index/indices, and/or mathematical analysis.
Number and types of indicators used (stage 3)	Number of resilience indicators 'measured' (may be scored rather than measured; may be used as proxies of constructed indicators). Number of constructed indicators, i.e. computed from measured indicators. Number of calculated indices/determinants – computation from 'measured' and/or constructed indicators. Sum total of all indicators used.

5.3. Results

This section presents the findings on the characteristics described in section 5.2. They are grouped around the coding frame listed in **Table 5.1**: What is the theoretical stance taken by the paper? – 'lenses' or theoretical positions (section 5.3.1); followed by some basic characteristics of each lens group (section 5.3.2); resilience of what to what? – system properties and perturbations (section 5.3.3); what determinants of resilience are being described and assessed? – resilience components, capacity types, and dimensions of resilience assessed (section 5.3.4); how is resilience assessed? – quantification score and indicator use (section 5.3.5). Aspects of the conceptual and review papers not included in sections 5.3.3-5.3.5 are presented in section 5.3.6.

5.3.1. Resilience lenses

Four lenses were identified during analysis, i.e. the A-, C-, T-, and V-lens, and these were used for further clustering and analysis. We first describe these lenses, looking at three categories: the outcome definition these papers infer on resilience (stability, transformation, or reduced vulnerability, **Figure 5.2**), the prominent determinants of resilience (capacities, practices, and resources), and the risks or disturbance on the farming system.

Traditional lens (after this called T-lens) – This group of papers uses the approach developed over the past decades by authors such as Crawford Holling, Brian Walker, Carl Folke, and Stephen Carpenter. Key heuristics were summarized by Walker *et al.* (2006) as consisting of adaptive cycle, panarchy, resilience, adaptability, and transformability (**Appendix 5.1**). These authors, each quoted in circa 75% of the papers using this lens, repeatedly indicated the need to define approaches and metrics to assess resilience. Adaptive capacity and access to resources are regarded as components that help socio-ecological systems to retain their function (stability) in the face of risks that cause disturbances, also referred to as shocks, stresses, threats, or perturbations. Some attention is paid to transformation as possible outcome, with Tittonell [T14 – see **Annex 1** for details of reviewed papers] connecting regime shift (or hysteresis) to the three future options for smallholders that were described by Dorward *et al.* (2009) as 'hanging in', 'stepping up' or 'stepping out'.

Vulnerability lens (after this called V-lens) – This lens mainly looks at adaptive capacity from the viewpoint of the IPCC vulnerability framework, as described by IPCC (2014). Systems that are easily exposed and highly sensitive to shocks can be said to be vulnerable. [V03]. According to Béné *et al.* (2012), Adger (2006)'s definition of vulnerability comes closest to synthesising: 'Vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt'. Vulnerability is

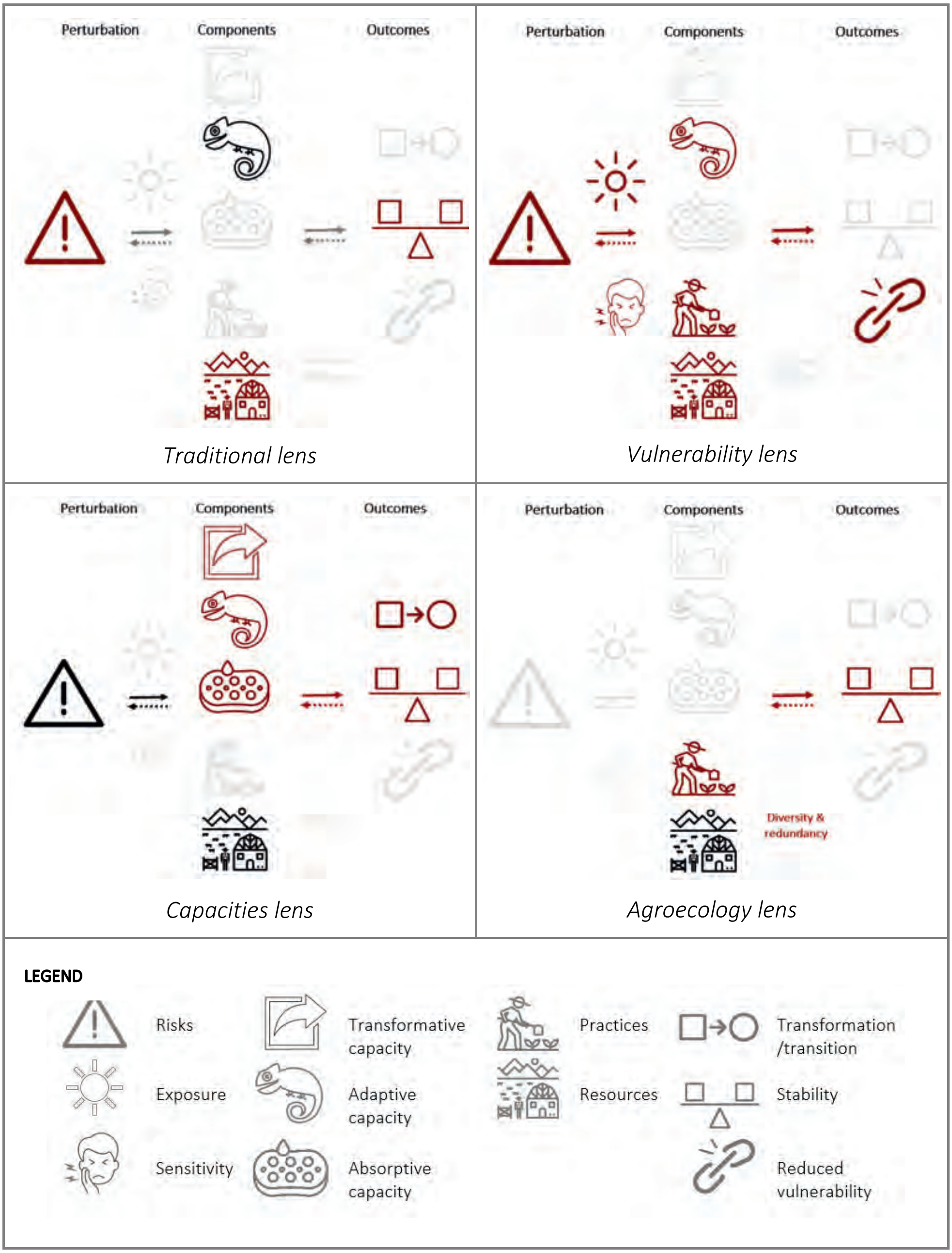


Figure 5.2. *Farming system resilience: perturbation, resilience determinants and resilience outcome concepts receiving attention in four resilience assessment lenses (authors' elaboration) N.B. Red-brown colouring denotes item receiving major emphasis in assessment methodology; black denotes intermediate emphasis; light grey denotes minor to no attention*

reduced by the system's adaptive capacity to deal with these shocks, for which resources and practice changes are important [V03]. Papers using this lens tend to focus on adaptive capacity, with the particular definition of IPCC (2014): 'the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences'.

Capacities lens (after this called C-lens) – Building on the T-lens and particularly on the work of Walker *et al.* (2004) and Osbahr *et al.* (2010), Béné *et al.* (2012) focus on two other capacities next to adaptive capacity: the absorptive or buffering capacity (i.e. the various (coping) strategies by which individuals and/or households moderate or buffer the impacts of shocks on their livelihoods and basic needs) and the transformative capacity (for which they use the definition 'the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable'). Most papers using this lens work with these three capacities, but a few use 'capacity for learning and adaptation' and 'capacity to self-organize (or 'reorganize')' instead of adaptive capacity and transformative capacity (i.e. C05, C10, C18, C19). The type of risks and the resources used in dealing with them do get some attention [e.g. C14].

Agroecology lens (after this called A-lens) – Falling under the definition of agroecology as integration of research, education, action, and change that brings sustainability to all parts of the food system: ecological, economic, and social (Gliessman, 2018), the papers in this group focus on diversity in agroecological practices and resources: diversity of crops/livestock [A01], or of biota and ecological functions [A03, A06]. Attention for resources as determinant of resilience mostly focuses on nutrient flows [A03, A05, A07]. Diversity is an important condition for redundancy, i.e. the extent to which elements are substitutable in the event of disruption or degradation (Norris *et al.*, 2008). Together, diversity and redundancy are conditions for ensuring adaptability (Darnhofer *et al.*, 2010) and [A08].

Other approaches – Nine out of 123 papers could not be classified in one of the four lens groups described above. Many of these used another lens or an approach that did not fit in the four lenses above. Among these were the Lifecycle Assessment for Climate Smart Agriculture approach [O01], the MESMIS agroecosystem sustainability evaluation framework [O02], profitability analysis [O04], the Household Livelihood Resilience Approach [O05], and resilience being used as indicator in sustainability assessment [O06]. Two papers in this category did not include sufficient information about their theoretical background to categorize them into any of the four lenses [O03 and R-O01]].

5.3.2. Paper metrics

Out of all 123 papers, 9 were classified as using the A-lens, 24 the C-lens, 39 the T-lens, and 43 the V-lens (**Annex 1**). Among these were fifteen empirical papers and five conceptual/review papers that portrayed elements of two lenses (e.g. A01; R-C04] – these were classified in the lens group that best fit their theoretical explanations. Numbers of papers published per year increased gradually from one in 2010 to a provisional peak of 42 in 2018 (2019 data are for the first 3.5 months only, search results (section 5.2.3) suggest a further acceleration in number of publications in 2019). While papers using the V- and T-lenses were published in significant numbers throughout the decade, the A-lens and C-lens started later (see **Figure 5.3** for numbers per lens).

Geographically, 30 papers were based on studies conducted in Africa, 25 in Europe, 19 in Asia, 17 in Oceania, 12 in Latin America, 7 in North America, and 14 did not indicate a study area. The largest number of papers using the A-lens focused on Latin America, the C-lens and the V-lens on Africa, and the T-lens on Europe (**Figure 5.4**).

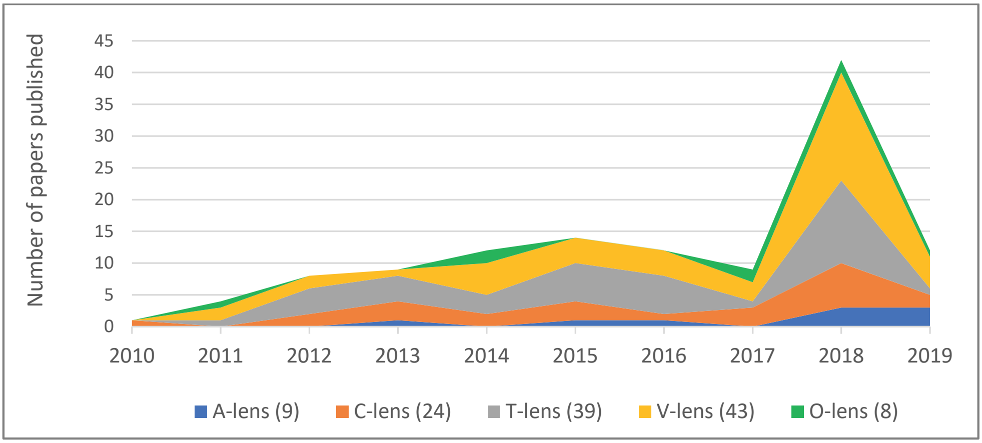


Figure 5.3. *Number of papers published per year (n= 123)*

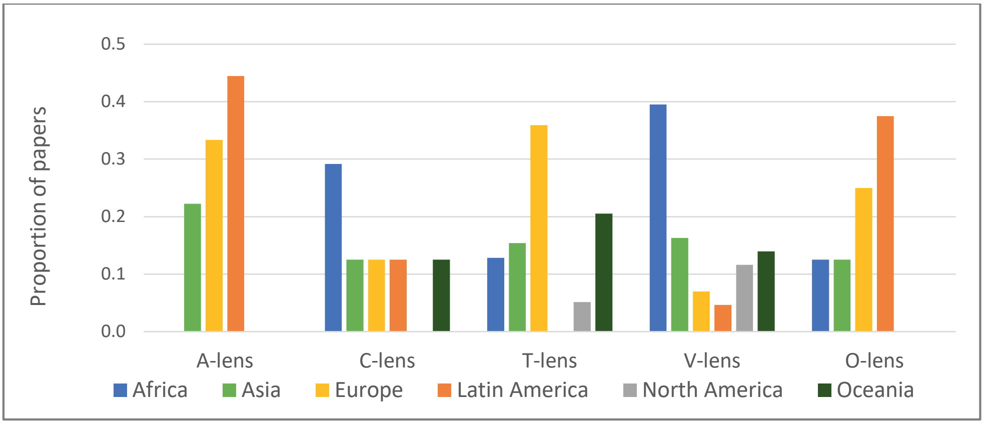


Figure 5.4. *Continents of cases studied (n=109)*

5.3.3. System types and kind of perturbations assessed

System types and functions

Now proceeding with the 100 papers in the four identified lenses, we first focused on the question 'resilience of what (system) to what (perturbation)'? **Figure 5.5** shows that all lens groups except the V-lens group mostly focused on farming system level (also including 'agroecosystem', 'farm' and 'household livelihood'). Those using a V-lens focused equally on production activity (crop or livestock) and on farming system level. Papers focusing on higher system levels (including 'value chain', 'food system', 'community livelihood', and papers assessing multiple system scales) mostly used the C-lens. In terms of system functionality, livelihood received most attention and environmental services (eco-system services) least attention in papers across the C-, T- and V-lens. In papers using the A-lens, most papers focused on food production (**Figure 5.6**).

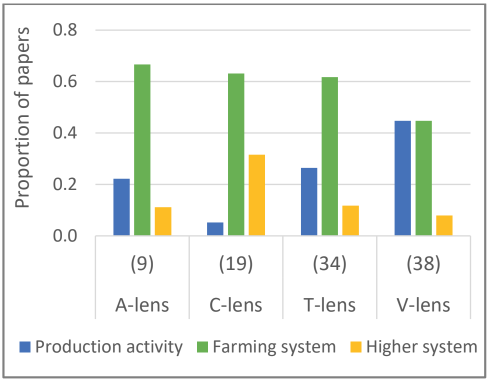


Figure 5.5. System scales assessed (n=100)

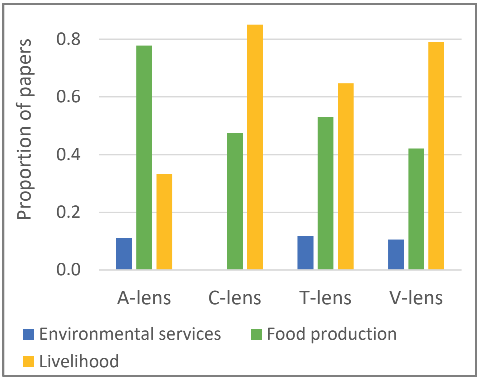


Figure 5.6. System functions assessed (n=100)

Risks and disturbances

Papers studied resilience to shocks potentially emanating from a wide variety of risks. Climate change and biophysical risks (either related to climate change or not, such as production disturbances, environmental issues, and extreme weather events) were the most common risks mentioned (**Figure 5.7**). Papers using the V-lens addressed these risk categories in all but one of the papers [i.e. V15]. Moreover, 87% of the papers in this group addressed 'climate change' and 58% of the papers in this group were focused on 'resilience to climate change' only. The other risk category receiving significant attention was that of market and supply chain disturbances, such as price fluctuations [e.g.C15]. Nearly half of the papers using the A-lens did not specify any risks to the system and on average addressed only 0.9 risk categories per paper, while 25% of papers using the C-lens did not specify any risks and on average addressed 1.1 risk categories per paper, compared to 1.3-1.4 for the T- and V-lenses. Sixty-three percent of the papers addressed a single risk category only; for the papers using A or V-lenses, this always concerned climate change (or the resulting weather extremes), while for the C and T-lenses this concerned a variety of risk categories. All lenses showing variation in the number of risks addressed, from 1 to 3 per paper, or even 4 risk categories per paper [A09, T09, V12, V30].

What we coin here as 'risks', actually is described in selected literature under a wide variety of similar or related terms: hazards, threats, disturbances, perturbations, shocks, stresses, or specific terms such as 'climate change'. Papers using the V-lens were most explicit about the underlying mechanism: Whether an external risk results in actual perturbation in the system depends on the system's exposure and sensitivity to the risk [e.g. V01]. As an example, chickens may be very sensitive to Newcastle's Disease, but exposure may be reduced by a barn with good biosecurity, while sensitivity may be reduced by vaccination.

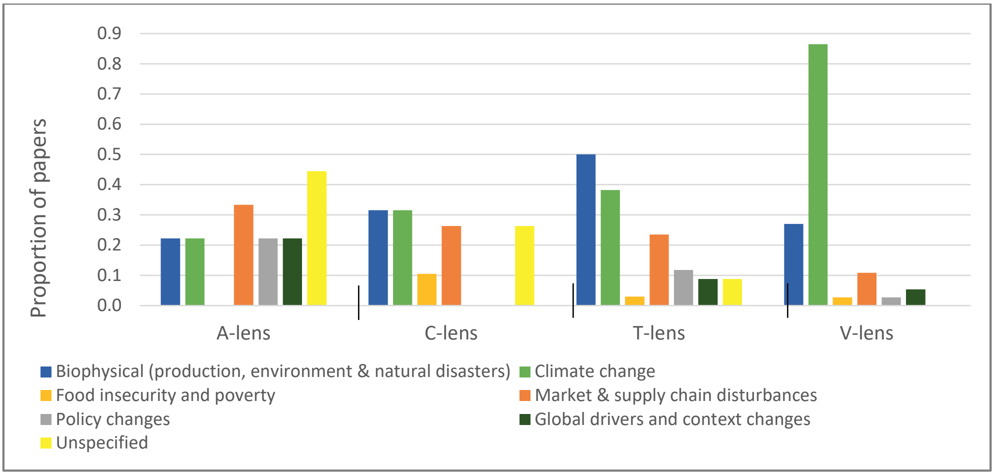


Figure 5.7. *Risk categories mentioned (n=100)*

5.3.4. Approaches to assess the determinants and outcomes of resilience

Different papers made different choices regarding the determinants of resilience they assess made in what determinants of resilience are being assessed, be they capacities, resources, or practices (both agricultural and social [V24]). Attention for capacities was particularly low in papers using the A-lens, which focused more on practices (**Figure 5.8**). Assessment of resources received attention in about two-thirds of papers in all groups. Next to these three common determinants, four papers in the T and V-lenses used other properties, be it attitudes and strategies toward risks [T28, V10] or performance of the system [T13, V12].

Adaptive capacity is well-grounded in resilience literature (**Appendix 5.1**). Attention for its assessment was, however, almost missing from papers using lens A. The distinction between multiple capacities was most prominent in papers using the C-lens (**Figure 5.9**). All papers using the C-lens used adaptive capacity, 95% used absorptive and 86% used transformative capacity.

This is not surprising, as the use of multiple capacities was a main selection criterion for this lens. What is more striking is the low use of these capacity types in papers using other lenses, in particular the V-lens [exceptions including V28].

A range of other terms was used to distinguish capacities (in 36 papers). These included 'coping capacity' [e.g. C04, V32] and 'capacity to learn' [e.g. V29] (in some cases 'to learn and adapt' [e.g. C18]). Sometimes these terms were used alongside 'adaptive capacity/adaptability' and 'transformative capacity/ transformational capacity/transformability', sometimes they were used as synonyms.

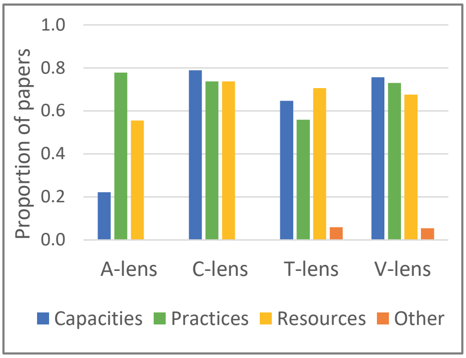


Figure 5.8. *Determinants of resilience assessed (n=98)*

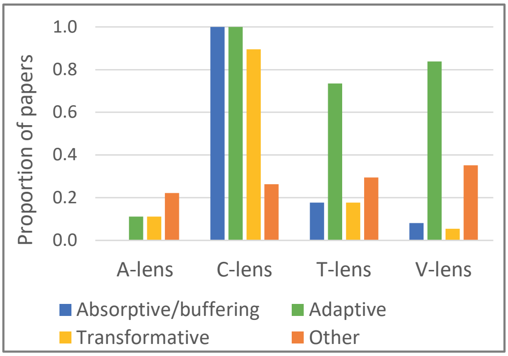


Figure 5.9. *Capacity types studied (n= 89)*

In terms of disciplinary pillars studied (economic, social, environmental, and technical/production dimensions of resilience), attention for social resilience aspects was highest in papers using the C-lens (95%) and lowest in papers using the A-lens (37%, e.g. A06) (**Figure 5.10**). The latter group of papers studied low numbers of dimensions overall (2.5 per paper vs. average of 3.2 per paper). The production dimension received most attention in papers using the C- or V-lens [e.g. V25]. Attention for the environmental dimension differed least between lenses.

5.3.5. Methodological features of assessment approaches

Looking at how resilience was assessed, papers used a wide variety of approaches, ranging from qualitative, opinion-orientated to more quantitative, index-orientated methods [as expounded by V16]. We distinguished these methods in two ways: (1) by looking at the degree to which the assessment applied quantification in data collection and analysis; and (2) by looking at the types and numbers of indicators used. The degree of quantification was scored as 1 (low) when the score depended on actor's judgement of system resilience, be it the perception of system actors such as farmers or the perception of the observer/researcher, without specification of indicators or scales. Higher scores (up to 6) were used for increasing quantification of indicators (from 'describing and scoring' to 'measuring'), increasing use of statistical and mathematical analysis, and increasing inclination to consolidate the information from multiple indicators into one or more compound indices. While **Figure 5.11** displays scores for degree of quantification, **Table 5.2** shows the number and types of indicators identified in the papers. These figures show that papers using the V-lens on average received high scores for degree of quantification, used a large number of indicators [highest was V09 with 126 measured indicators and sum total of 153 indicators] and most often used calculated indices. Papers using the T- and C-lenses tended to rely relatively more on perceptions and qualitative scoring; they also used fewer indicators than the V-lens; papers using the A-lens were in the middle when it came to degree of quantification.

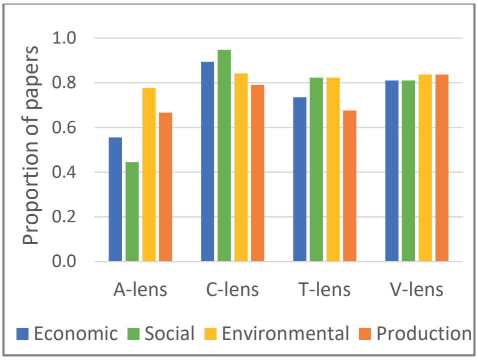


Figure 5.10. *Pillars covered by assessments (n=100)*

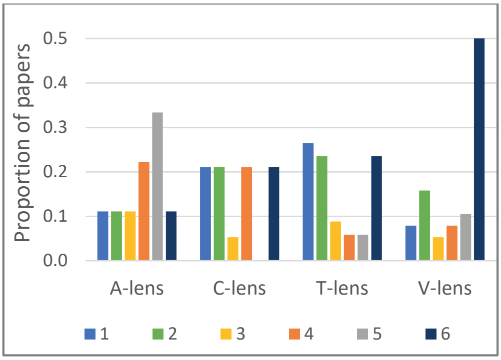


Figure 5.11. *Degree of quantification (6=highest, n= 96)*

Table 5.2. *Number and types of indicators and indices used*

	A-lens	C-lens	T-lens	V-lens	Sub-total
Total no of papers	**9**	**19**	**34**	**38**	**100**
Number of papers specifying number of indicators	9	17	31	36	93
Mean sum total of indicators	21.3	22.5	23.6	36.5	
SD	10.3	18.9	24.9	34.0	
Mean no. of measured resilience indicators	18.2	20.9	22.1	33.2	
SD	9.0	13.5	22.9	29.7	
Number of papers	9	15	30	33	87
Mean number of constructed indicators	4.5	6.0	5.3	6.6	
SD	2.4	5.6	3.8	4.9	
Number of papers	6	10	13	26	55
Mean number of calculated indices	1.0	4.5	1.0	3.3	
SD	-	0.7	-	2.2	
Number of papers	1	2	1	15	19

5.3.6. Prominent features in conceptual and review papers

Due to their diversity, the sixteen conceptual and review papers were difficult to compare. While nine papers elaborated conceptual issues from a theoretical angle [e.g. R-C05; R-T04], the others reviewed literature or did both [R-C01,02; R-O01; R-T03; R-V01,03,04]. The objectives of the papers differed widely. Some papers offered recommendations for research or application of the concept [R-O01; R-T01,05; R-V04]. Others proposed a resilience assessment framework or indicator framework [R-C01,04; R-T02,04; R-V01,05]. Yet others looked at building resilience [R-T01], reviewed resilience aspects of regional agrifood systems [R-V02,03], or looked at the advantages and limitations of using resilience in the development field [R-C02,03]. The C-, T- and V-lens groups each contains five conceptual and review papers, while one review paper used an ethics perspective that did not fit in any of the four lenses [R-O01]. Important topics addressed in the conceptual and review papers include general vs. specified resilience and assessment approaches, including alternatives to performance-based resilience assessment approaches. We will draw on some of these topics in the discussion section.

5.4. Discussion

5.4.1. Synthesis of results

This review shows that most papers using the C-, T- or V-lens have a clear **theoretical basis**, as described in section 5.3.1. Their respective foci offer strong opportunities for complementarity: the T-lens offers a strong conceptual grounding, summarized as five heuristics by Walker *et al.* (2006) (**Appendix 5.1**), that contributes to understanding the ongoing dynamics in farming systems. The V-lens pays valuable attention to risks, systems' exposure and sensitivity to risks. The C-lens distinguishes absorptive and transformative capacities from adaptive capacity, thereby clarifying that resilience is a multi-capacity system characteristic, This offers a system different response types when confronted with risks: when faced with shocks, systems may absorb the shock, adapt to it, or transform to another system state. Papers using the A-lens shed light on a number of aspects: that resilience may arise from observable practices, that system diversity is an important indicator, and that farming as part of the agroecosystem is a social-ecological system. However, papers using the A-lens are less explicit about their theoretical underpinning (it should be noted that not all papers studying agroecological farming use the A-lens, e.g. [R-V02] uses the V-lens, with references to system dynamics theory). This gap was also noticed by Tittonell (2020) in a recent paper, with which he attempts to fill this gap. **Conceptualized determinants** of resilience vary between lenses, as described in section 5.3.4. We identified some important differences, as listed in **Table 5.3**:

- The C-lens' distinction of absorptive capacity is little reflected in other lenses, despite its prominence in Walker *et al.* (2004)'s definition. However, it may be implicitly included in the V-lens' use of 'sensitivity to risks/stressors' – a question deserving further analysis is whether low sensitivity indeed is a result of high absorptive capacity.
- The relationship between absorptive capacity and robustness remains unclear. Robustness generally is regarded as a characteristic of technical rather than socio-ecological systems, which according to Urruty *et al.* (2016) has a different meaning from resilience. According to Cochrane [C03] and Jacobi *et al.* [C09], absorptive (or buffering)

Table 5.3. *Comparison of conceptualization and assessment approaches across four lenses*

Characteristics	A-lens	C-lens	T-lens	V-lens
Conceptualization				
- *coherence*		✓	✓	✓
- *coverage (holistic)*			✓	✓
Conceptualized elements				
- *perturbation*		~	✓	✓
- *absorption*		✓	✓	
- *adaptability*		✓	✓	✓
- *transformability*		✓	✓	
- *practices*	✓			✓
- *resources*	~	~	✓	✓
Outcomes defined as	Stability Diversity	Stability / adaptation / transformation	Stability	Reduced vulnerability
Application across multiple				
- *risks*	✓	✓	✓	~
- *system scales*	✓	✓	✓	✓
- *system functions*	✓	✓	✓	✓
- *pillars*	~	✓	✓	✓
Methodology				
- *degree of quantification*	Medium-high	Intermediate	Low-high	High
- *indicator use*		*See Table 5.2*		
Components included in assessment				
- *absorptive/buffering cap*		✓		
- *adaptive capacity*		✓	✓	✓
- *transformative capacity*		~		
- *practices*	✓	✓	~	✓
- *resources*	~	✓	✓	✓
Contribution to operationalization	Grounding in practices	Distinction of capacities	System dynamics	Application for climate change
Remaining question areas	Conceptual-ization	Coverage of components	Method-ological consistency	Conceptual consistency; other risks than climate change; what is being measured?

capacity contributes to robustness as well as to resilience. However, ten Napel *et al.* [R-T04] used robustness instead of absorptive capacity, a stance that was recently taken by Meuwissen *et al.* (2019).

- While Walker *et al.* (2004) distinguish transformability from resilience and while 'capacity to reorganize' in their definition appears to refer to adaptive rather than to transformative capacity, confusion on this issue abounds – i.e. is a system's ability to transform to a system with different function, structure, identity, and feedbacks, part of being resilient or not? The C-lens takes a firm stance here by distinguishing transformative capacity as one of three resilience capacities, but its operationalization receives little attention in most papers, with some notable exceptions in papers using other lenses than the C-lens [T21, V23]. As various papers by Béné *et al.* show, this distinction of capacities – that can be build or strengthened – do fit well with application in the development field [R-C02,03].

Comparison of the resilience concepts used in the various lenses raises questions about the relationships between them. **Figure 5.1** distinguishes between perturbations, determinants of resilience, and outcomes of resilience. The findings and discussion above show that many papers are unclear about these relationships and often equate resilience as system characteristic with its determinants and with its outcomes. This review suggests that the cause-effect relationships summarized in **Figure 5.1** are meaningful and offer a causality framework covering the theoretical underpinnings encountered. An issue that remains unresolved is what (type of) relationships do exist between the five resilience components displayed in **Figure 5.1**. In a recent paper, Meuwissen *et al.* (2019) suggest a distinction between the three 'resilience capacities' and 'resilience attributes', which according to them connect to capacities, system functions and challenges (i.e. perturbations). Attributes include practices and resources, which they relate to the five generic principles of resilience proposed by the Resilience Alliance (2010). This proposal needs additional consideration.

Resilience outcomes identified in this review include stability, transformation and reduced vulnerability. These outcome concepts are coloured by their origins. [R-V05] points out that originally, for example, vulnerability was used for people and social systems, and only later was extended to agricultural systems, much like resilience first being used for ecological systems before being applied to agricultural and other socio-ecological systems. According to Urruty *et al.* (2016), vulnerability focuses on the direct impacts of specific perturbations on a given feature of the system, while resilience is most relevant on a long-term basis in order to describe and understand farm recovery processes and transformations over periods of time marked by significant economic, environmental or sanitary crises, in other words, the resilience concept mostly focuses on the consequences of one to several perturbations, including unpredictable ones, on the overall trajectory of the system. Stability as outcome can be approached through most lenses. During this review we also got the strong impression that most resilience assessments using the V-lens would be equally valid if they would drop the term 'resilience' and just focus on vulnerability, for which a broad pallet of methodologies has been developed (see e.g. Barsley *et al.* (2013)).

Methodology used in papers – Papers showed a wide array of approaches, even within lens groups. We focused our analysis on the degree of quantification and the number and type of indicators used. The degree of quantification showed succinct variation between lenses. Papers using the V-lens are most likely to use an approach with quantification, identification of (proxy) indicators, evaluating their proxy value, index crafting and/or statistical analysis, followed by those using an A-lens. Papers using the C- or T-lens showed more duality between either using measured indicators and further mathematical analysis or using more opinion-based scoring. This appears to be related to the chosen conceptual stance on whether resilience can be measured by using (proxy) indicators [e.g. T13], or whether resilience is an emerging property that cannot directly be observed and of which only surrogates can be assessed [R-T05]. This is especially an area in which the difficulties of operationalization of resilience assessment come to the fore, with a multitude of assessment approaches as a result, that use indicators, opinions, surrogates, Likert scales, best proxies, indices etc. It must be noted that degree of quantification is not easy to determine, and that two papers from the same author(s) could score very differently [e.g. C14-C15, V22-V23]. This issue of measurability of resilience also raises the question of what papers are actually measuring when they say they measure resilience?

Contribution to operationalization – Approaches and lenses used in the reviewed papers in general seem to be rather neutral to system scales, system functions and domains. Higher attention for livelihood functions in the C- and V-lens groups may well be correlated to their propensity of being used in connection to humanitarian assistance and development initiatives, particularly in Africa. Relatively strong focus on farming system (including farm, household livelihood and agroecosystem) as compared to production activity or higher scale levels (value chains, food systems) could have at least two causes: (i) boundaries of these systems are more succinct; (ii) the search string selected papers on farm* and on chain*, but papers not dealing with farming were excluded.

The strong climate change focus and strong conceptualization of risk in papers using the V-lens results in the fact that other shocks or stresses than those related to climate change are rarely addressed. In situations where other shocks or stresses, such as market fluctuations or land scarcity, can be considered to be as much (or more) of a threat as climate change, assessment of multiple risk would make sense. In other words, the specified resilience to climate change in papers using the V-lens is so specific that its well-defined methodologies are not being extended to assessment of specified resilience against other risks.

5.4.2. Implications for research and practice

In terms of **applicability of approaches**, this review lead to the following observations:

- Looking at the coherence of theoretical underpinning, this review notices some shortcomings. A relatively low attention to risks, resources and practices accompanies strong attention for capacities in papers using the C-lens. The underlying system dynamics theory in papers using the T-lens generally does not offer clear ways to operationalize resilience assessment. Papers using the V-lens run the danger of equating 'resilience' with one particular resilience outcome ('reduced vulnerability') or with one particular resilience determinant ('adaptive capacity').
- Assessment of resilience against multiple risks or against the most important risk requires collaborative risk evaluation based on existing knowledge and the context under study [R-C05]. This implies one or more additional steps before resilience assessment is conducted (Urruty *et al.*, 2016). A few examples are reported in the reviewed papers [C09,10]. The example contained in **Appendix 5.2** indicates that exposure to identified risk categories differs between farmers and countries and that risks that rank high in exposure do not necessarily rank as most threatening. Reasons may include that a higher farmer commercialization level exposes farmers more to certain risks (such as market fluctuations) and that conduciveness of public services reduces the sensitivity to certain risks, such as risk of diseases.
- On top of multiple specified risks, assessment of general resilience against unexpected, unfamiliar and extreme shocks is an area that appears not well-developed, with next to [R-C05] only two papers in this review paying cursory attention to it [R-T03 and T34]. Considering the scarce resources for risk analysis and risk management of many smallholders globally, farmers' priority to reduce variation in system performance is understandable, even if that would result in low performance levels (Urruty *et al.*, 2016). Could development of assessment methodology for general resilience against unexpected and unspecified risks be considered a next frontier for resilience research?

This review suggests that some good progress has been made toward operationalizing resilience, but that there is strong need for convergence rather than further divergence. The different lenses do make valuable contributions, that should be combined in an assessment approach with, potentially, the following key elements:

1. Definition of system and system scale of interest. This is important to make resilience assessments feasible, but even more so as building the resilience of one system (scale), such as that of a value chain, may have negative repercussions for resilience of another, such as smallholder farming.
2. Identification of risk or risks to be considered. Assessment of resilience against one or more predefined risks can be justified, as long as this is made explicit. Evaluation of risks

to prioritize the most threatening one or ones is a second route to pursue. A third route deserving attention is that of general resilience against unknown and unspecified risks.

3. Selection of resilience outcomes that are of interest. As indicated above, reduction of vulnerability is a (justifiable) short-term objective. Stability of system performance (probably within a wider or narrower band-with) adds a longer-term perspective. System transformation due to prolonged stress, high risk probability or dissatisfaction with system performance is a third objective, that actually underlies many agricultural development interventions.
4. Justification of the resilience determinants to be considered – capacities, resources, practices or, preferably, a combination of these.
5. Other issues of scope, such as system functions and pillars (domains) to focus on.

5.5. Conclusions

The lack of agreement about resilience, links to other key concepts, and degree of specification lead to difference choices in assessment approaches. As stated, under different conceptual stances and assessment methods chosen, decision makers may evaluate a particular farming system to be more or less resilient, with implications for the design of interventions to then enhance its resilience.

This chapter has used a series of characteristics to code and assess 123 papers relating to resilience and its assessments, in order to clarify the apparent ambiguity in theoretical underpinning of resilience assessment approaches. The characteristics focused on how resilience is conceptualized, operationalized and assessed.

Whilst each particular approach to assessment has its own strengths and weaknesses, across all the studies there was insufficient attention to describing causal links between perturbations (risks), determinants of resilience, and outcomes of resilience. In addition, on top of multiple specified risks, assessment of general resilience against unexpected, unfamiliar and extreme shocks is an area that appears not well-developed, with only three papers in this review paying cursory attention to it.

This chapter proposes to further develop resilience assessment methodology by drawing from the different perspectives and identifies five key elements that need to be considered in assessing resilience. More attention needs to be directed to the collaborative identification and evaluation of relevant risks/stressors; methodology for assessing general resilience; and the operationalization of transformative capacity.

Annex 1. Characteristics of assessed papers

main lens	code	authors	article title	continent	system under study	system scale studied (1)	system functionality (2)	risk categories (3)	res.components assessed (4)	capacity types (5)	degree of quantification (6)	dimensions of resilience (7)
Selected relevant emperical papers (not being review or meta analysis papers)												
Agro-ecology	A01	Bahadur et al. 2016	Assessing links between crop diversity and food self-sufficiency in three agroecological regions of Nepal	Asia	production - crop/livestock	F	F	C	PR	0	5	MSP
	A02	Blesh, J, & Wittman, H 2015	"Brasilience:" Assessing Resilience in Land Reform Settlements in the Brazilian Cerrado	Latin Am	farming system	S	FL	EGM	PR	0	3	MPE
	A03	Dendoncker, 2018	How can integrated valuation of ecosystem services help understanding and steering agroecological transitions?	Europe	agro-ecosystem	S	F	U	PR	0	4	PE
	A04	Merot, 2019	Diversity of conversion strategies for organic vineyards	Europe	production - crop/livestock	F	L	U	P	0	5	MP
	A05	Stark, 2018	Crop-livestock integration determines the agroecological performance of mixed farming systems in Latino-Caribbean farms	Latin Am	farming system	S	F	U	PR	0	6	PE
	A06	Valencia, 2019	Structuring Markets for Resilient Farming Systems	Latin Am	multiple scales	L	F	MP	PR	0	5	MSPE
	A07	Vanegas, 2018	Effect of ecological and conventional managements on soil enzymatic activities in coffee agroecosystems	Latin Am	agro-ecosystem	S	F	C	P	0	4	E
	A08	Veisi et al. 2013	A participatory assessment of agro-ecosystem sustainability in Abesard, Iran	Asia	agro-ecosystem	S	EL	U	C	0	2	MSE
	A09	James, 2019	Muck and Magic: A Resilience Lens on Organic Conversions as Transformation	Europe	farm	F	F	AMPG	C	DTO	1	SE
Capacities	C01	Ashkenazy, 2018	Operationalising resilience in farms and rural regions - Findings from fourteen case studies	Europe	???	S	FL	U	CPR	BDT	0	MSPE
	C02	Ciftcioglu 2017	Assessment of the resilience of socio-ecological production landscapes and seascapes: A case study from Lefke Region of North Cyprus	Europe	agro-ecosystem	S	FL	N	CPR	BDT	2	MSPE
	C03	Cochrane, 2018	Does diversification enhance community resilience? A critical perspective	Africa	livelihoods - community	F	FL	U	CPR	BDT	1	SPE
	C04	d'Errico & Di Giuseppe 2018	Resilience mobility in Uganda: A dynamic analysis	Africa	livelihood - household	F	F	F	CR	BDT	6	MS
	C05	Galappaththi et al. 2017	Can start-up motives influence social-ecological resilience in community-based entrepreneurship setting? Case of coastal shrimp farmers in Sri Lanka	Asia	enterprise and community	F	FL	ACM	CPR	BDT	2	MSPE
	C06	Gilioli et al. 2015	Assessment of social-ecological transitions in a peri-urban Ethiopian farming community	Africa	enterprise and community	F	FL	EF	CPR	BDTO	1	MSPE
	C07	Greig, 2019	Resilience and finances on Aotearoa New Zealand farms: Evidence from a random survey on the sources and uses of debt	Oceania	farm	F	L	M	CR	BDO	4	MS
	C08	Jacobi et al. 2013	Agroecosystem resilience and farmers' perceptions of climate change impacts on cocoa farms in Alto Beni, Bolivia	Latin Am	farming system	S	L	AN	P	BDT	4	SPE
	C09	Jacobi et al. 2015	Farm Resilience in Organic and Nonorganic Cocoa Farming Systems in Alto Beni, Bolivia	Latin Am	farming system	S	L	C	CPR	BDT	2	MSPE
	C10	Jacobi, 2018	Operationalizing food system resilience: An indicator-based assessment in agroindustrial, smallholder farming, and agroecological contexts in Bolivia and Kenya	Africa +LA	food system	L	FL	U	CPR	BDO	4	MSPE
	C11	Knickel, 2018	Between aspirations and reality: Making farming, food systems and rural areas more resilient, sustainable and equitable	Europe	multiple scales	L	F	U	P	BDT	1	MPE
	C12	Osbahr et al. 2010	Evaluating successful livelihood adaptation to climate variability and change in southern Africa	Africa	production - crop/livestock	F	L	C	CPR	BDT	1	MSPE
	C13	Panpakdee & Limnirankul 2017a	Indicators for assessing social-ecological resilience: A case study of organic rice production in northern Thailand	Asia	farming system	S	FL	U	CPR	BDT	4	MSPE
	C14	Shadbolt & Olubode-Awosola 2016	Resilience, Risk and Entrepreneurship	Oceania	farming system	S	L	M	CP	BDT	2	MSPE
	C15	Shadbolt et al. 2013	Resilience to 'Bounce without breaking' in New Zealand dairy farm businesses	Oceania	farming system	S	L	M	C	BDT	6	MS
	C16	Smith & Frankenberger 2018	Does Resilience Capacity Reduce the Negative Impact of Shocks on Household Food Security? Evidence from the 2014 Floods in Northern Bangladesh	Asia	farming system	S	L	N	CR	BDT	6	MSE
	C17	Souissi, 2018	Impact assessment of climate change on farming systems in the South Mediterranean area: a Tunisian case study	Africa	farming system	S	L	C	PR	BDT	6	MSPE
	C18	Speranza 2013	Buffer capacity: capturing a dimension of resilience to climate change in African smallholder agriculture	Africa	livelihood	F	L	C	CPR	BDTO	3	MSPE
	C19	Speranza et al. 2014	An indicator framework for assessing livelihood resilience in the context of social-ecological dynamics		livelihood	F	L	CEMN	0	BDTO	0	MSPE

main lens	code	authors	article title	continent	system under study	system scale studied (1)	system functionality (2)	risk categories (3)	res.components assessed (4)	capacity types (5)	degree of quantification (6)	dimensions of resilience (7)
Traditional	T01	Allen et al. 2018	Quantifying uncertainty and trade-offs in resilience assessments	N.America	agro-ecosystem	S	E	E	R	BD	2	SE
	T02	Borda-Rodriguez & Vicari 2014	Rural co-operative resilience: The case of Malawi	Africa	farming system	S	L	U	CR	D	1	MS
	T03	Borda-Rodriguez & Vicari 2015	Coffee Co-Operatives in Malawi: Building Resilience through Innovation	Africa	farming system	S	L	U	CR	D	1	MS
	T04	Brunner & Gret-Regamey 2016	Policy strategies to foster the resilience of mountain social-ecological systems under uncertain	Europe	soc.-ecological system	L	EL	GC	CR	O	6	MSE
	T05	Chavarria, 2018	Retaining forests within agricultural landscapes as a pathway to sustainable intensification: Evidence from Southern Ethiopia	Africa	agro-ecosystem	S	F	E	P	O	4	PE
	T06	Chavas & Di Falco 2015	Resilience, Weather and Dynamic Adjustments in Agroecosystems: The Case of Wheat Yield in	Europe	farming system	S	F	N	P	O	6	PE
	T07	de Jalon et al. 2014	Building resilience to water scarcity in southern Spain: a case study of rice farming in Doana protected wetlands	Europe	production - crop/livestock	F	F	CE	CPR	D	6	MSPE
	T08	de Roest, 2018	Specialisation and economies of scale or diversification and economies of scope? Assessing different agricultural development pathways	Europe	multiple scales	L	L	EM	CP	BDO	1	MSP
	T09	Diserens, 2018	Resilience Assessment of Swiss Farming Systems: Piloting the SHARP-Tool in Vaud	Europe	farming system	S	F	CFMN	CPR	BDT	3	MSPE
	T10	Douglass-Gallagher, 2019	Crop Growers' Adaptive Capacity to Climate Change: A Situated Study of Agriculture in Arizona's	N.America	production - crop/livestock	F	F	C	PR	D	1	MSPE
	T11	Dwiartama 2017	Resilience and transformation of the New Zealand kiwifruit industry in the face of Psa-V disease	Oceania	chain	L	F	A	CPR	T	1	MSP
	T12	Epstein, 2018	Recovery and adaptation after the 2015 Nepal earthquakes: a smallholder household perspective	Asia	farming system	S	FL	N	CPR	BDO	5	MSPEO
	T13	Fall et al. 2018	Exploring milk shipment data for their potential for disease monitoring and for assessing resilience in dairy farms	Europe	farm	F	FL	A	O	D	6	P
	T14	Hansson, 2018	Farmers' mental models of change and implications for farm renewal - A case of restoration of a wetland in Sweden	Europe	farm	F	L	P	R	O	1	SE
	T15	Herman et al. 2018	Placing resilience in context: Investigating the changing experiences of Finnish organic farmers	Europe	production - crop/livestock	F	FL	G	CPR	D	1	MSPE
	T16	Kalaugher, 2013	An integrated biophysical and socio-economic framework for analysis of climate change adaptation strategies: The case of a New Zealand dairy farming system	Oceania	production - crop/livestock	F	F	CM	CPR	DO	0	MSPE
	T17	Kansiime & Mastenbroek 2016	Enhancing resilience of farmer seed system to climate-induced stresses: Insights from a case study in West Nile region, Uganda	Africa	farming system	S	L	C	PR	O	3	MSPE
	T18	Li et al. 2016	Role of capitals and capabilities in ensuring economic resilience of land conservation efforts: A case study of the grain for green project in China's Loess Hills	Asia	production - crop/livestock	F	FL	P	CPR	T	6	MSPE
	T19	Maleksaeidi et al. 2016	Discovering and characterizing farm households' resilience under water scarcity	Asia	livelihood - household	F	FL	E	CPR	D	3	SPEO
	T20	Maleksaeidi et al. 2015	Farm households' resilience scale under water scarcity	Asia	livelihood - household	F	FL	CE	C	DO	6	SPE
	T21	Marshall et al. 2012	Transformational capacity and the influence of place and identity	Oceania	production - crop/livestock	F	E	C	C	DT	2	MSPE
	T22	Marshall et al. 2013	Climate change awareness is associated with enhanced adaptive capacity	Oceania	production - crop/livestock	F	FL	C	C	D	2	MSPE
	T23	McManus et al. 2012	Rural Community and Rural Resilience: What is important to farmers in keeping their country towns alive?	Oceania	enterprise and community	F	L	MG	CR	D	6	MSE
	T24	Meadows 2012	Can Birds Be Used as Tools To Inform Resilient Farming and Environmental Care in the Development of Biodiversity-Friendly Market Accreditation Systems? Perspectives of New Zealand Sheep and Beef Farmers	Oceania	agro-ecosystem	S	E	A	R	BO	2	SE
	T25	Nettle et al. 2012	Crisis as an opportunity for change?: A case study of applying resilience thinking to extension responses in dairy industry crisis	Oceania	farming system	S	FL	CMP	CR	D	1	MSPE
	T26	Nettle et al. 2015	Empowering farmers for increased resilience in uncertain times	Oceania	farming system	S	FL	CMP	CP	D	1	MSPE
	T27	Nguyen & James 2013	Measuring Household Resilience to Floods: a Case Study in the Vietnamese Mekong River Delta	Asia	farming system	S	L	N	CPR	O	2	MSPE
	T28	Phuong, 2018	Understanding smallholder farmers' capacity to respond to climate change in a coastal community in Central Vietnam	Asia	livelihood - household	F	L	C	CPRO	D	2	MSPE
	T29	Ragkos, 2018	Labor management strategies in facing the economic crisis. Evidence from Greek livestock farms	Europe	farm	F	L	M	P	D	2	M
	T30	Ranjan, 2013	Mathematical modeling of drought resilience in agriculture		production - crop/livestock	F	L	N	PR	D	6	ME
	T31	Rescia, 2018	Quantitative evaluation of the spatial resilience to the B. oleae pest in olive grove socio-ecological landscapes at different scales	Europe	agro-ecosystem	S	F	A	R	D	5	PE
	T32	Salvia & Quaranta 2015	Adaptive Cycle as a Tool to Select Resilient Patterns of Rural Development	Europe	production - crop/livestock	F	L	ACEM	CPR	BD	2	MSE
	T33	Sumane et al. 2018	Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture	Europe	farming system	S	F	A	CR	DT	1	MSE
	T34	Tittonell 2014	Livelihood strategies, resilience and transformability in African agroecosystems	Africa	livelihood - household	F	L	U	O	DTO	4	MSPE

main lens	code	authors	article title	continent	system under study	system scale studied (1)	system functionality (2)	risk categories (3)	res.components assessed (4)	capacity types (5)	degree of quantification (6)	dimensions of resilience (7)
Vulnerability	V01	Abdul-Razak & Kruse 2017	The adaptive capacity of smallholder farmers to climate change in the Northern Region of	Africa	farming system	S	L	C	CPR	D	6	MS
	V02	Alam et al. 2018	How do climate change and associated hazards impact on the resilience of riparian rural communities in Bangladesh? Policy implications for livelihood development	Asia	production - crop/livestock	F	L	CE	CPR	O	6	MSP
	V03	Alayon-Gamboa, 2011	Vulnerability of smallholder agriculture in Calakmul, Campeche, Mexico	Latin Am	production - crop/livestock	F	L	N	CP	BD	4	MSP
	V04	Alhassan, 2019	Gender dimension of vulnerability to climate change and variability: Empirical evidence of smallholder farming households in Ghana	Africa	livelihood - household	F	L	C	CPR	D	6	MSPE
	V05	Ambelu et al. 2017	Intervention pathways towards improving the resilience of pastoralists: A study from Borana communities, southern Ethiopia	Africa	farming system	S	L	N	CPR	D	6	MSPE
	V06	Appiah, 2018	Smallholder farmers' insight on climate change in rural Ghana	Africa	production - crop/livestock	F	L	C	P	O	2	SE
	V07	Arslan, 2018	Diversification Under Climate Variability as Part of a CSA Strategy in Rural Zambia	Africa	livelihood - household	F	L	C	PR	O	6	MSPE
	V08	Below et al. 2012	Can farmers' adaptation to climate change be explained by socio-economic household-level variables?	Africa	farming system	S	EL	C	CPR	D	6	MSPE
	V09	Berry et al. 2011	Farmer Health and Adaptive Capacity in the Face of Climate Change and Variability. Part 1: Health as a Contributor to Adaptive Capacity and as an Outcome from Pressures Coping with Climate Related Adversities	Oceania	production - crop/livestock	F	EL	C	CPR	D	6	MSE
	V10	Buelow, 2018	What You Sow Is What You Reap? (Dis-)Incentives for Adaptation Intentions in Farming	Europe	production - crop/livestock	F	F	C	CO	D	6	MSPEO
	V11	Chandra et al. 2017	A Study of Climate-Smart Farming Practices and Climate-resiliency Field Schools in Mindanao, the Philippines	Asia	farming system	S	FL	CN	P	D	2	MSPE
	V12	Chodur, 2018	Assessing food system vulnerabilities: a fault tree modeling approach	N.America	food system	L	F	GCEMN	O	O	1	MSP
	V13	Colting-Pulumbarit, 2018	Sustainable Livelihoods-Based Assessment of Adaptive Capacity to Climate Change: The Case of Organic and Conventional Vegetable Farmers in La Trinidad, Benguet, Philippines	Asia	production - crop/livestock	F	L	C	CPR	D	6	MSPE
	V14	de Nijs, 2014	Quantification of biophysical adaptation benefits from Climate-Smart Agriculture using a Bayesian Belief Network	Africa	production - crop/livestock	F	F	C	PR	D	6	MPE
	V15	Falkowski, 2015	Resilience of farmer-processor relationships to adverse shocks: the case of dairy sector in Poland	Europe	chain	L	F	M	C	O	6	MP
	V16	Fang, 2018	Effects of natural disasters on livelihood resilience of rural residents in Sichuan	Asia	livelihood - household	F	FL	N	CR	O	6	MSPE
	V17	Gardezi, 2019	Spatially Representing Vulnerability to Extreme Rain Events Using Midwestern Farmers' Objective and Perceived Attributes of Adaptive Capacity	N.America	production - crop/livestock	F	F	N	CPR	DO	6	MSPE
	V18	Gnonlonfoun, 2019	New indicators of vulnerability and resilience of agroforestry systems to climate change in West Africa	Africa	agro-ecosystem	S	L	C	PR	D	4	PE
	V19	Heckelman, 2018	Cultivating climate resilience: a participatory assessment of organic and conventional rice systems in the Philippines	Asia	production - crop/livestock	F	FL	C	CPR	BDO	5	MSPE
	V20	Lawrence, 2018	Vulnerability of dryland agricultural regimes to economic and climatic change	N.America	agro-ecosystem	S	FL	CM	P	D	6	MPE
	V21	Marshall & Stokes 2014	Identifying thresholds and barriers to adaptation through measuring climate sensitivity and capacity to change in an Australian primary industry	Oceania	agro-ecosystem	S	EL	C	C	DO	2	MSE
	V22	Marshall et al. 2014	Social vulnerability to climate change in primary producers: A typology approach	Oceania	production - crop/livestock	F	L	C	C	DO	2	MSE
	V23	Marshall et al. 2014	Transformational capacity in Australian peanut farmers for better climate adaptation	Oceania	production - crop/livestock	F	L	C	CR	DTO	6	MSPE
	V24	Meldrum, 2018	Climate change and crop diversity: farmers' perceptions and adaptation on the Bolivian Altiplano	Latin Am	farming system	S	L	ACEN	CPR	D	6	MSPE
	V25	Mkonda, 2018	Comparing Smallholder Farmers' Perception of Climate Change with Meteorological Data: Experience from Seven Agroecological Zones of Tanzania	Africa	farming system	S	FL	C	CPR	D	2	PE
	V26	Moore et al. 2016	Quantifying network resilience: comparison before and after a major perturbation shows strengths and limitations of network metrics	Africa	production - crop/livestock	F	F	C	R	DT	4	SPE
	V27	Mugambiwa, 2018	Adaptation measures to sustain indigenous practices and the use of indigenous knowledge systems to adapt to climate change in Mutoko rural district of Zimbabwe	Africa	farming system	S	L	C	CPR	D	1	SPE
	V28	Mutabazi et al. 2015	Influence of livelihood resources on adaptive strategies to enhance climatic resilience of farm households in Morogoro, Tanzania: an indicator-based analysis	Africa	livelihood - household	F	L	CN	CPR	BD	6	MSPE
	V29	Nguyen, 2018	How do local communities adapt to climate changes along heavily damaged coasts? A Stakeholder Delphi study in Ky Anh (Central Vietnam)	Asia	livelihoods - community	F	L	C	CPR	DO	6	MSPE
	V30	Perez et al. 2015	How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective	Africa	???	F	FL	CGMP	CPR	D	3	MSPE
	V31	Safi et al. W 2012	Rural Nevada and Climate Change: Vulnerability, Beliefs, and Risk Perception	N.America	production - crop/livestock	F	L	C	CR	DO	6	SE
	V32	Sieber et al. 2015	Integrated assessment of sustainable agricultural practices to enhance climate resilience in Morogoro, Tanzania	Africa	production - crop/livestock	F	F	CF	CP	DO	2	MSPE

	V33	Simane & Zaitchik 2014	The Sustainability of Community-Based Adaptation Projects in the Blue Nile Highlands of Ethiopia	Africa	production - crop/livestock	F	FL	C	CPR	DO	5	MSPE
	V34	Simane et al. 2016	Agroecosystem specific climate vulnerability analysis: application of the livelihood vulnerability index to a tropical highland region	Africa	livelihood	F	L	C	CPR	D	5	MSPE
	V35	Stock, 2019	Let the people speak: improving regional adaptation policy by combining adaptive capacity assessments with vulnerability perceptions of farmers in Gujarat, India	Asia	farm	F	L	CN	CPR	D	3	MSPE
	V36	Wassie, 2018	Evaluating smallholder farmers' preferences for climate smart agricultural practices in Tehuledere District, northeastern Ethiopia	Africa	production - crop/livestock	F	FL	C	C	D	1	P
	V37	Webb et al. 2013	Integrating biophysical and socio-economic evaluations to improve the efficacy of adaptation assessments for agriculture	Oceania	agro-ecosystem	S	F	C	P	D	6	MPE
	V38	Alston et al. 2018	Limits to adaptation: Reducing irrigation water in the Murray-Darling Basin dairy communities	Oceania	production - crop/livestock	F	EL	N	CR	DT	0	MSPE
Other	O01	Acosta-Alba, 2019	The LCA4CSA framework: Using life cycle assessment to strengthen environmental sustainability analysis of climate smart agriculture options at farm and crop system levels	Latin Am	production - crop/livestock	F	F	CE	P	O	6	PE
	O02	Astier et al. 2011	Sustainability indicators, alternative strategies and trade-offs in peasant agroecosystems: analysing 15 case studies from Latin America	Latin Am	farming system	S	F	M	PR	O	4	SP
	O03	Bardsley & Bardsley 2014	Organising for socio-ecological resilience: The roles of the mountain farmer cooperative Genossenschaft Gran Alpin in Graubünden, Switzerland	Europe	farming system	S	EL	AMP	P	O	2	MSPE
	O04	Hamerlinck, 2014	Country-specific analysis of competitiveness and resilience of organic and low input dairy farming across Europe	Europe	farming system	S	L	M	P	O	6	MP
	O05	Quandt 2018	Measuring livelihood resilience: The Household Livelihood Resilience Approach (HLRA)	Africa	livelihood - household	F	L	C	PR	D	5	MSPE
	O06	Valenti, 2018	Indicators of sustainability to assess aquaculture systems	Latin Am	farming system	S	F	AEGMP	PR	O	3	M
	O07	Panpakdee & Limnirankul 2017b	Developing Social-ecological Resilience Indicators of Organic Rice Production through Intergrating Resilience Theories with Social Sciences' Disciplines	Asia	production - crop/livestock	F	FL	A	CPR	D	4	MSPE
Review papers and meta studies (R-)												
Capacities	R-C01	Aboah, 2019	Operationalising resilience in tropical agricultural value chains		chain	L	F	M	PR	DTO	5	MSPE
	R-C02	Béné et al. 2014	Review Article: Resilience, Poverty and Development		n.a.	L	L	F	CR	BDT	0	O
	R-C03	Béné et al. 2015	Is resilience a useful concept in the context of food security and nutrition programmes? Some conceptual and practical considerations		production - crop/livestock	F	FL	U	CPR	BDT	0	MSPEO
	R-C04	Cabell & Oelofse 2012	An indicator framework for assessing agroecosystem resilience		agro-ecosystem	S	F	G	CPR	BDT	4	MSPE
	R-C05	Carpenter et al. 2012	General Resilience to Cope with Extreme Events		soc-ecological system	L	-	UAMN	CRO	BDT	0	MSE
Other	R-O01	Alroe, 2017	Performance versus Values in Sustainability Transformation of Food Systems		food system	L	FL	C	O	O	2	MSPE
Traditional	R-T01	Macfadyen et al. 2015	The role of food retailers in improving resilience in global food supply		food system	L	F	CGM	PR	B	1	MPE
	R-T02	Peterson et al. 2018	Ways forward for resilience research in agroecosystems		agro-ecosystem	S	F	CE	P	O	1	P
	R-T03	Quinlan et al. 2016	Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives.		variety of systems	O	-	-	O	O	0	MSPE
	R-T04	ten Napel et al. 2011	A conceptual approach to design livestock production systems for robustness to enhance	Europe	production - crop/livestock	F	F	U	O	BDT	0	MSPE
	R-T05	Darnhofer et al. 2016	The resilience of family farms: Towards a relational approach	Europe	production - crop/livestock	F	F	U	CPR	BD	1	MSPE
Vulnerability	R-V01	Bailey & Buck 2016	Managing for resilience: a landscape framework for food and livelihood security and ecosystem		production - crop/livestock	F	L	CE	CP	D	0	MSPE
	R-V02	Brzezina, 2016	Can Organic Farming Reduce Vulnerabilities and Enhance the Resilience of the European Food System? A Critical Assessment Using System Dynamics Structural Thinking Tools	Europe	food system	L	F	AEM	CPR	O	1	MSPE
	R-V03	Elias, 2018	Diverse landscapes, diverse risks: synthesis of the special issue on climate change and adaptive capacity in a hotter, drier Southwestern United States	N.America	region/coll.of agric. systems	L	F	C	CR	D	0	MPE
	R-V04	Hansen, 2019	Climate risk management and rural poverty reduction		farming system	S	L	C	PR	O	1	MSP
	R-V05	Vroegindewey, 2018	Resilience of Agricultural Value Chains in Developing Country Contexts: A Framework and Assessment Approach		chain	L	F	M	CRO	D	2	M

(1) *System scale studied: F=farming; S=farming/agro-ecosystem; L=larger system*
(2) *System functionality: F=food production; L=livelihood/income; E=ecosystem services*
(3) *Risk categories: A=production disturbances; C=climate change; E=environmental, land & water disturbances; F=food insecurity and poverty; G=global drivers and context changes; M=market & supply chain disturbances; N=natural disasters and extreme weath*
(4) *Components of resilience assessed (C=capacities; P=practices; R=resources; O=other*
(5) *Capacity types: B=absorptive/buffering; D=adaptive; T=transformative; O=other*
(6) *Degree of quantification: 1. Perceptions/judgements of observer or interviewee - descriptive without evidence of scale or justification for judgement ; 2. Scoring of indicators without distinct categories; 3.Scoring using distinct categories; 4. Measured indicators*
(7) *Dimensions of resilience: M=economic, S=social, E=environmental, P=production, O=other*

6. General discussion and conclusions

6.1. Introduction

The objective of this thesis, as stated in section 1.2, was to gain insights into factors affecting commercialization of dairy farming under land scarcity, through assessment of the dynamics of market participation, land use intensification, and resilience of dairy farming systems in relation to the markets for inputs, services, and outputs. I set out to realize this objective by formulating the following main research question: in what ways do market quality and spatial factors affect commercialization of dairy farming systems under land scarcity in two countries in the East African highlands? Four sub-questions covered four angles of this main research question:

First, I looked at the role of spatial factors in driving or hindering upgrading of dairy farming systems. These effects include internal dynamics within the farming and market systems, their interactions, and influences from the context, which include interactions with innovation systems, infrastructure, climate change, social safety nets, etc.

Second, I looked at the effects of input and service arrangements on the market quality and market participation of dairy farmers, in particular whether and how they cater to the needs of farmers at different levels of market participation and contribute to resilience and sustainable outcomes.

Third, I looked at how resilience is being assessed. Though it seems easy, assessment is a key bottleneck hampering application of concepts of resilience in dairy farming commercialization.

Fourth, I looked at questions around transition and resilience of farming systems: under what conditions transitions take place, whether leverage points for influencing them can be identified, what the role is of resilience of farm and livelihood vis-a-vis the drivers of commercialization, and whether low adoption of market participation strategies is indeed due to the notion that long-term effects on resilience are not or only marginally positive.

In the next section, I discuss the answer to the main research question and broader theoretical implications, using findings for the four sub-questions as starting points and building blocks. This is followed by reflections on the research design (section 6.3), and implications for policy and practice (section 6.4).

6.2. Discussion of research results

6.2.1. Spatial effects on commercialization

The first sub-question addressed effects of spatial factors on farmers' production and marketing strategies. I looked at two spatial factors that influence commercialization of dairy farming by affecting the feasibility space of farmers (Schiere *et al.*, 2012) for market participation: proximity to markets and being located in a dairy cluster. This thesis makes a number of contributions to the ongoing debate about the potential commercialization of smallholders (Poulton *et al.*, 2010), specifically addressing the relationship between proximity to markets, market quality and market participation; commercialization-related processes in clusters; and on commercialization pathways. I address these in the remainder of this section.

Proximity to markets, market quality and market participation

The results in Chapter 3 resoundingly show that proximity to local service centres and to dairy sales points affects market participation and intensification level. Farms with easy accessibility to local service centres face higher scarcity of land and labour than farmers with remote accessibility, but benefit from better input and output market quality and lower transaction costs. They use more external inputs and services, which then result in higher stocking rates (livestock units per hectare). Through this more intensive land use, they are able to market more produce and realize higher margins per hectare. Effects of proximity to end-market proved less straightforward, due to unexpected land scarcity in remote locations and due to random differences between locations in availability of inputs and services.

The results described in Chapters 2 and 3 confirm that market quality and fit with the farm household's livelihood objectives play an important role in decisions on market participation and production intensity. They affect the type of dairy products sold (in Ethiopia), the extent to which farmers and farmer organizations will invest in milk quality (primarily Kenya), and the volumes of dairy products they will market (both countries). These findings (1) add depth to the study by Duncan *et al.* (2013) on the influence of spatial factors on market quality; (2) illustrate the connections between cost of production factors, travel time to markets, and transaction costs and benefits; and (3) generate knowledge about how these cost aspects affect a farmer's decision to commercialize dairy or other crops, and in what products and volumes (Leonardo *et al.*, 2015; Tittonell, 2014). Based on these, it may be good to extend the definition by Duncan *et al.* (2013) of market quality to include consideration of cost of production factors.

The inverse effects of market quality and transaction costs explain the existence of a 'sweet spot' between the extremes of easy and remote accessibility to local markets, where dairy farming is most advantageous and leads to highest marketed volumes per farm. These dynamics are illustrated in **Figure 6.1**, developed as part of this thesis, which connects them to well-known economic theories of land rent (Schmitz, 2010) and transaction costs (Ruben *et al.*, 2017): on the one hand, land scarcity is more severe close to markets, as better market quality drives up land prices and hence land rent (Schmitz, 2010); on the other, transaction costs for inputs and services increase with travel time to local service centres as well as with travel time to dairy delivery points (output market). Labour and gross feed costs, the other important costs in dairy farming, follow similar patterns. While the purchase prices of inputs and services generally do not change with proximity (Chapter 3), labour costs show a similar trend as land rent; purchased feed costs increase with transaction costs; and costs of farm-produced fodders are linked to land rent.

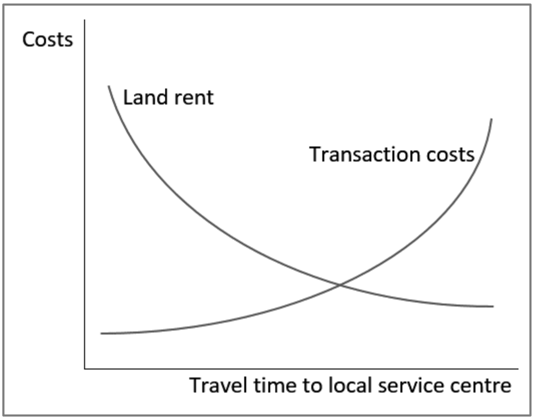


Figure 6.1. *Development of cost components with increasing travel time to local service centres*

Studies described in Chapters 2 and 3 took place in contexts where travel time has significant impact on market participation, due to limitations in infrastructure development. This was more so the case in Ethiopian study sites, where infrastructure was less developed than in the Kenyan sites. It can be assumed that in contexts where good infrastructure reduces travel times, the location theory used in this thesis becomes less relevant, and theories such as Porter's diamond (Porter, 2000) gain importance.

Clusters, commercialization-related processes and commercialization pathways

In Chapter 1, I defined commercialization of farming as the process of increasing participation in input and output markets, which usually occurs in conjunction with three other processes in the farming system: upgrading, specialization, and intensification (**Box 1.1**). The studies in Chapters 2–4 illustrate these processes in several ways.

Chapter 2 showed that differences between clusters in Ethiopia and Kenya can be characterized as outcomes of concurrent **upgrading** in the farming, market, and context domains. **Figure 2.4** in Chapter 2 illustrates that upgrading of dairy farming can be accelerated or inhibited by a wide range of drivers in all three domains, which Ramirez *et al.* (2017) label as 'cluster structure and governance'. Technical upgrading in dairy farms included investments in dairy genetics, feeding, housing, and health care. Market upgrading resulted in more sophisticated service arrangements, which affected supply contracting and quality assurance, competition between service providers, and transformation of farmer organizations. Institutional (i.e. context) upgrading became clear in role redefinition of private and public actors and enabling of private service provision, financial service upgrading, infrastructure development, licensing and product standard development.

Chapter 2 coined the concept of 'concurrency' to describe co-dependency in the timing of synergistic upgrading in the farming, market and context domains. Upgrading is unlikely to occur in just one of these domains in isolation. For example, upgrading to dairy breeds also needs a conducive market for milk, a properly performing AI service, an adequate breeding policy, innovation services that support this shift, etc. The concurrent upgrading of dairy service arrangements and institutions within a cluster make farm investments in dairy market participation and intensification more attractive. Without these concurrent upgrades relevant to dairy, farmers may choose to specialize into cash crops and short-maturity livestock production options with more conducive market quality and context conditions that show better feasibility.

Specialization in clusters toward high-value livelihood activities took place not only within livestock production but also within cash crop production. Examples of livestock production include specialization toward milk in Nyandarua (Kenya), toward heifer production in Arsi (Ethiopia), and toward intensive livestock production in Nandi South (Kenya). Examples of cash crops include specialization toward tea in Nandi South, toward potatoes in Nyandarua, and toward malt barley in Arsi. Differences in resource endowments (including farmers' skills, but also good soils, rainfall, etc.) and livelihood objectives (including farmers' preferences) do lead to differences between farms, between villages and between clusters. This means that specialization at farm level does not necessarily occur on all farms in the same way and at the same time, leading to 'dairy farms' vs. 'tea farms' in Nandi South, entire 'dairy villages' such as Koma Welkite in Arsi cluster vs. 'heifer breeding villages' such as Kirima in Nyandarua cluster, but also to well-performing vs. lower performing farms and villages. These differences in resource endowments at least partly underlie the occurrence of 'positive deviants' discussed in Chapters 2 and 3, as much as they may also be the result of it (see also Migose (2020)).

Intensification of land use occurred across all clusters, as shown in Chapter 2. It clearly depended on the relative land scarcity in each cluster and, within a cluster, along the gradient of proximity to the local service centre (Chapter 3). Land scarcity impacted use of external inputs, stocking rate, and milk yields per hectare. Land scarcity in both remote locations in

Chapter 3 was a surprise finding, although the impact of biophysical and political boundaries do explain this phenomenon.

Now looking again at **commercialization** in the different clusters, we notice that in certain clusters dairy was less commercialized than expected based on land scarcity. Apparently, farmers chose to commercialize those commodities with best market quality, in particular market demand and service arrangements. Changes in service arrangements for particular commodities influenced the commercialization-related processes in a cluster, as competitive advantages regarding market quality shifted from one commodity to another. A number of those shifts were aided by institutional upgrading (i.e. policy support) for particular commodities, such as barley in Arsi and dairy in Nyandarua. Depending on market demand, the conduciveness of service arrangements, and institutions for the various potential commodities, the farming system commercializes in a certain direction by specializing toward the 'best fit' commodity, upgrading farming and marketing, and intensifying land use.

Choices for farmers as well as expected commercialization pathways are summarized in the choice diagram displayed in **Figure 6.2**, developed as part of this thesis. Farming systems can be expected to move from the lower left (in East Africa: subsistence mixed crop–livestock and nomadic livestock systems) to the right with increasing land scarcity, and they move up with increasing quality of input and output markets. This diagram applies to individual farmers and to the cluster at large if the conditions for many farmers in the cluster are sufficiently similar. It thus clarifies differences in commercialization direction between clusters in Chapter 2.

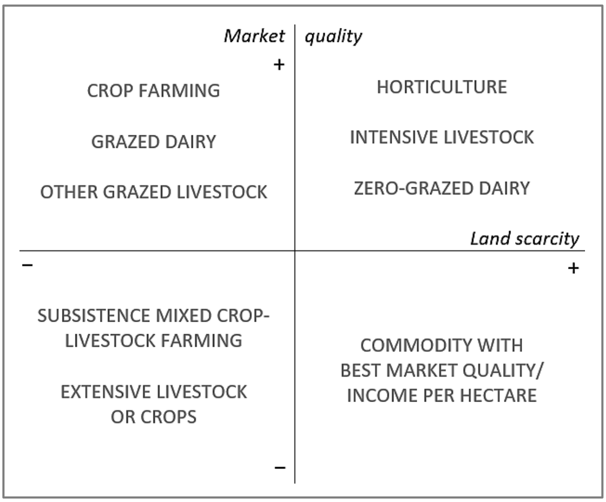


Figure 6.2. *Commercialization of farming as a function of land scarcity and market quality*

Theoretical implications for spatial effects on commercialization

This thesis shows that spatial effects influence commercialization of dairy farming through farmers' decisions to upgrade and invest in one or more commodities (Leonardo *et al.*, 2015). Dairy is in competition with other commodities for land, labour and capital. In land-scarce conditions, production potential is allotted to production activities generating most added value per unit of land. Through technical upgrading of farming, intensification of land use, increased market participation, and specializing toward commodities with conducive service arrangements, farmers in such land-scarce conditions are able to maintain their livelihoods. This occurs under several conditions: market and context conditions for the relevant commodity should co-evolve with the farming system, a process benefiting from clustering; remote farmers should also have access to service arrangements and local markets, as proximity to local markets has a strong effect on commercialization.

These findings add a spatial dimension to the three options of 'hanging in', 'stepping up', or 'stepping out' described by Dorward *et al.* (2009). The commercialization option ('stepping up') has the alternatives of 'hanging in' – remaining less market-oriented, with declining livelihoods as a result of land scarcity and low profitability – or 'stepping out' of farming into other business or employment. Tittonell (2014) illustrated this for five types of farmers in a Western Kenya farming system. He connects this to an analysis of systems jumps in farming systems, which I elaborate on in section 6.2.4.

This thesis shows the usefulness of the concept by Duncan *et al.* (2013) of market quality ('attractiveness and reliability of procurement channels and associated input supply arrangements') in studying commercialization dynamics of dairy farming. It underlines the need to further operationalize this definition in such a way that it (1) diversifies procurement channels into markets for inputs, outputs, and production factors; and (2) stresses the importance of conduciveness of service arrangements when defining 'attractiveness and reliability'. Such development of the market quality concept may assist in addressing the gap in comparative analysis of dairy systems that Duncan *et al.* identified, in particular regarding commercializing systems.

6.2.2. Effects of input and service provision arrangements

The second sub-question concerned the effects of input and support service arrangements on market participation and farm resilience. As Chapters 2 and 3 show, the conduciveness of dairy support services appears to be a key factor among the market and context factors that reinforce or modulate spatial effects and thus co-determine the feasibility space for dairy commercialization. The following examples illustrate this: (1) The superior support service package for tea in the 1990s in severely land-scarce Nandi South made farmers switch focus from dairy to tea and experiment with more intensive, short-maturity livestock ventures. Over the next decades, the lack of support services for intensive livestock keeping made farmers continue with dairy at a low input–output level, rather than shift to livestock activities better fitting their small farm sizes, likely motivated by its high social value and the other functions it serves in the system; (2) In contrast, market quality, and in particular strong dairy support services, in Nyandarua promoted dairy commercialization; (3) The confining effect of context factors was illustrated in the Ethiopian Arsi cluster, where government policy favoured cereals. This encouraged farmers to specialize into cereals and other livestock activities (heifers, mutton), rather than in dairy, despite a long history of dairy farming.

Plurality of service arrangements, resource endowment and commercialization

Pluralistic service arrangements aid the commercialization process by offering different types of farmers the service options that fit with their production and marketing strategies. **Table 2.4** described the input and output market options farmers may have, ranging from spot markets to integrated supply chains. As van der Ploeg (2010) showed, farmers' production and marketing strategies vary along with multiple factors, such as resource endowment, entrepreneurial outlook, and personality. Along with the spatial factors expounded in section 6.2.1, such factors influence farmers' fit with and preference for particular service arrangements (Leonardo *et al.*, 2015; Poulton *et al.*, 2010). Taking choice of milk marketing channel as an example, the number of potential market channels and milk buyers increases not only with proximity to local markets, but also with the resource level of farmers. To meet daily subsistence cash needs, resource-poor farmers need immediate payment for their milk. If they are close to the market, they can opt to sell for cash to traders or other clients, while farmers with more resources can also opt for channels that pay bi-weekly or monthly. In remote villages, where marketing through cooperative channels (Kenya) or to long shelf-life product markets (Ethiopia) are the only options, resource-poor farmers do not even have direct sales options.

Plurality of service arrangements can thus offer a wide variety of farmers the services they demand, as well as the opportunity to upgrade to a service arrangement that offers access to additional services, once they can afford to wait weeks for milk payments.

Chapters 2 and 4 showed that the variety of service arrangements encountered not only gives service providers competitive advantages for particular segments of farmers, but also helps farmers in balancing the power positions of intermediaries – including input suppliers, service providers, and milk buyers, be they private, public, or cooperative. Such power positions emanate from linking innovation support services to input supply, milk marketing or other services, but also from their local embeddedness and governance (Ramirez *et al.*, 2017). While intermediaries thus do influence farm upgrading, they also depend on farmers' readiness for innovation, which translates to demand for services and inputs. Conduciveness of service arrangements can thus also be measured by the number of options farmers have to obtain information on farming and marketing strategies, which are linked to a variety of services and intermediaries. Both Ramirez *et al.* (2017) and Royer *et al.* (2016) suggest that variety of ownership structures, motivations and networks helps in reaching different types of farmers, aiding inclusiveness of value chains. Hence, having access to pluralistic service arrangements as well as having the resources to utilize them seem to work together to lead to successful commercialization.

Performance of service providers affects farm upgrading, market participation, and resilience

The important roles of service providers as intermediaries in upgrading (Kilelu *et al.*, 2016; Ramirez *et al.*, 2017) is illustrated by the various service arrangements in Chapter 2. Competition between service providers plays a propelling role in co-evolution of farming system and pluralistic service arrangements. Competition for business leads individual service providers (such as AI technicians) in Kenya to bring services to the farm and tailor services to farmer demand. Competition for supplier loyalty and milk volumes leads milk buyers to innovate on service arrangements (such as cooperative dairy service hubs and processor's integrated service models described in Chapter 2, Kruse (2012) and Katothya *et al.* (2020)). In contrast, the Ethiopian State's virtual monopoly on provision of most inputs and services hampers such competition, with dire consequences for the client orientation, quality of service and innovativeness of service arrangements, and the upgrading of dairy farming (Jaleta *et al.*, 2013; van der Lee *et al.*, 2018).

With regards to the performance of service providers, Chapter 4 illustrates how limitations in their business performance affect the technical performance of service providers, that is, the quality and fit of their services and the effect of these services on client-farm performance. Extrapolation of these findings to other input and service providers and milk buyers suggests that the feasibility space of farmers for upgrading their dairy production is affected by the technical quality and fit of inputs and services offered. The limitations in performance of private service providers thus have three important ramifications for their ability to facilitate commercialization and build resilience of dairy farms. First, their limited entrepreneurial performance forces service enterprises to limit themselves to simple services that offer direct returns, rather than on the services most essential for upgrading of dairy farming practices (Katothya *et al.*, 2020). Second, limited quality of services reduces their relevance to farmers and farmers' willingness to pay for these services, which directly impacts viability of the service provider (Lans *et al.*, 2013). Third, limited technical quality means that these services have limited impact on farmers' resilience, that is, their ability to deal with shocks and stresses (Poulton *et al.*, 2010). Thus, both technical and entrepreneurial performance issues limit the ability of private service providers to create a real competitive advantage over public services with their famously low technical performance (refer to case studies in van der Lee *et al.* (2018) and Kilelu *et al.* (2020)).

These limitations point to the need for a conducive enabling environment for service providers if they are to offer quality services to farmers and flourish as enterprises. Offering regulatory space for private and civil society service providers (Ethiopia) and building the technical and entrepreneurial capacities of service providers (Kenya and Ethiopia) could thus promote plurality of services options and inclusiveness of dairy commercialization.

Theoretical implications for effects of service arrangements on commercialization

This thesis adds depth to the debate on co-evolution of innovation systems and bundling of input and services (Kilelu *et al.*, 2013), highlighting that service arrangements with different sophistication levels can complement each other and form a supportive factor in commercialization. It also shows how competition in a pluralistic network of service provision arrangements can contribute to 'best fit' (Birner *et al.*, 2009; Klerkx *et al.*, 2017). It extents the meaning of plurality in such systems beyond different types of service providers and services to types of farmers with different resource endowments and different levels of market quality as result of spatial factors. Linkages between market maturity and performance of service providers (Prager *et al.*, 2016) should be considered from a spatial perspective as well, as spatial factors affect market quality and farm commercialization levels. This will impact on market development and inclusivity of private service providers, as market pull will not only be affected by entrepreneurial orientation of farmer-clients, but also by their readiness to commercialize.

6.2.3. Assessing resilience

The third sub-question reviewed how assessment of resilience in farming systems has been conceptualized and operationalized and how this informs further development of assessment approaches. The literature review in Chapter 5 showed the large divergence in resilience assessment methodologies and the need for convergence in terms of theoretical perspective, outcome definitions, resilience determinants, and risk identification and evaluation. For reasons explained in section 6.3, this literature review could not be accompanied by empirical or theoretical work on development of assessment approaches, which would be needed to answer this question in more detail. Relevant applications of resilience and its assessment, particularly in supporting upgrading and transition in commercialization pathways, and adequately including risk, have been included in sections 6.2.2. and 6.2.4.

6.2.4. Transition and resilience as emerging outcomes

The fourth sub-question considered in what ways commercialization affects transition and resilience of dairy farming systems. This section connects theory around hysteresis of farming systems (Dorward *et al.*, 2009; Tittonell, 2014) with those on resilience determinants (Béné, 2013; Walker *et al.*, 2006). It offers a way to understand farmer attitudes toward commercialization. Transitions occur over space and over time (Schiere *et al.*, 2006). While Chapters 2 and 3 focused primarily on the spatial dimensions of commercialization and its related processes, inclusion of historic developments over the past decade(s) also yielded insights on temporal transition of farming systems and – on a smaller scale – farming and marketing practices. In terms of complex adaptive systems, it can be hypothesized that system dynamics and resilience theories offer tools to understand farmers' movement toward and away from their aspirations, such as the short-term goal of having sufficient food and income, the medium-term goal of resilience and managing risks, and the long-term goal of sustainable livelihoods for this and next generations. Chapter 2 defined a number of concepts that will be used in this section, including concurrency and co-evaluation of farming, market and context, farmers' aspirations and feasibility space, path dependency, and transformations (system jumps). Chapter 5 did the same for concepts around resilience, including importance of risk exposure and sensitivity, resilience determinants, and resilience outcomes.

Commercialization and resilience

Transitions of dairy farming systems, and particularly transformations[2] to a different system or regime (system jumps), occur when conditions make the existing system untenable (Béné *et al.*, 2012). Such transformations are likely to occur when sudden shifts in farm structure and/or market participation level occur, when many farmers adopt multiple production innovations and when farmers make large investments in new resource types (Oosting *et al.*, 2014; Tittonell, 2014). **Figure 6.3** summarizes some theoretical contributions from the studies of resilience and transition in this thesis. It combines Tittonell (2014)'s use of hysteresis theory to illustrate Dorward *et al.* (2009)'s distinction of livelihood strategies (i.e. 'hanging in', 'stepping up' or 'stepping out'), with Béné (2013)'s three capacities (i.e. absorptive, adaptive and transformative capacities).

The different regimes in **Figure 6.3** can be illustrated with examples from the study area. Imagine regime I as 'semi-subsistence, free range grazing-based, extensive, multi-functional cattle husbandry with limited off-take of milk'. Farmers in Ethiopia reported that from regime I, they transformed to regime II, 'restricted grazing with crop residue feeding, semi-market oriented dairy farming'. This transformation involved drastic reduction of herd size, change to dairy breeds, and marketing of fresh milk or significantly more butter, a first step in commercialization. Most farms in the study areas can be regarded to be in 'regime II'. In Kenya, a transformation from 'grazing with crop residue use' to 'zero-grazing with planted forage' seemed to be taking place in the Nyandarua and Nandi North study areas (regarded here as 'regime III'), as reported in Chapters 2 and 3. Farmers were adopting zero-grazing feeding

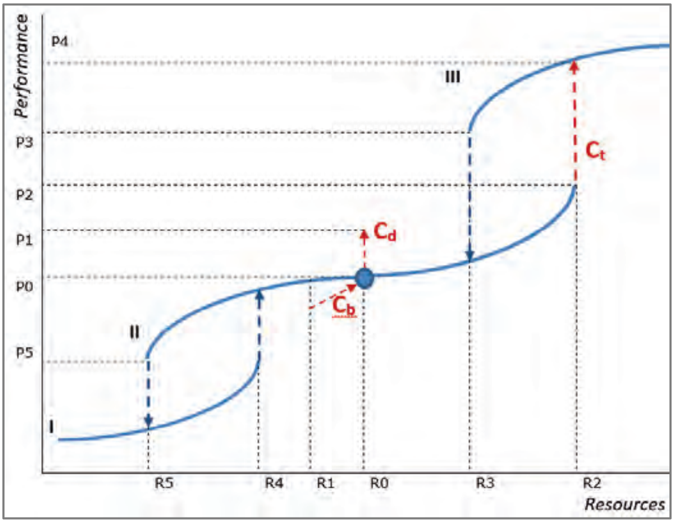


Figure 6.3. *Theoretical representation of farming system dynamics and resilience capacities as functions of resource endowments and system performance. Full lines indicate alternate three system regimes I–III, block arrows indicate shifts in livelihood strategies, red text and arrows indicate effects of resilience capacities C_b, C_d, and C_t (developed from Tittonell (2014) and Béné et al. (2013), further explanation in text)*

regimes and investing in forage production, preservation, and storage (Chapter 4) to overcome the dry season dip in production that limited their attractiveness as suppliers (as processors desire stable supply throughout the year).

To understand the interaction between commercialization and resilience aspirations, I explore some different scenarios of what could happen to a farm. When return on investment is positive (RoI>1), resources increase (move to the right). When performance approaches P2 at R2, a system jump of the (dairy) farm could take place to regime III (i.e. to a state with more market participation, labelled as 'stepping up' by Tittonell (2014)), that performs better at the same resource level due to higher RoI. If, however, performance drops and RoI becomes negative (<1), the farm's resources reduce (move to the left), which Tittonell labels as 'hanging in'. At R5, performance drop is such that continuation in regime II becomes untenable and a system drop to a less productive strategy at regime I is the only option to continue farming. Return to regime II is only possible once sufficient resources have been built up again. 'Stepping out' of farming is the more likely alternative (Tittonell, 2014).

Risk and resilience capacities

In terms of risks and the capacity to deal with shocks: Risks of shocks and stresses from inside or outside the system cause perturbations that may result in temporary loss of resources and/or performance of the system. These losses may be persistent if farm resilience is low. In

Figure 6.3, loss of resources due to shocks and stresses effectively makes a farm move to the left along the blue line (it may be evident that farm performance never is a stable outcome).

Different types of capacity can be distinguished, as has been done by Béné (2013). Absorptive capacity (Cb) enables the farm to recover from a loss of resources and/or performance due to a shock to the farm, such as loss of cattle due to an epidemic. When Cb is strong, a large loss of resources and/or performance can be overcome. Adaptive capacity (Cd) enables the system to make adaptations to its practices that make the farm less exposed or less sensitive to shocks and stresses. I have tentatively portrayed this as if it would result in higher performance (P1>P0), but the investment in adaptive measures might actually result in lower rather than higher performance. So far I have not found evidence of this in resilience literature. Transformative capacity (Ct) enables the farm to transition from regime II to regime III, that is, make a system jump.

Examples from this study

It is evident that such farming system transformations involve significant risks for the farmers involved. Will they be able to successfully 'step up', or are they better off 'hanging in' or 'stepping out'? I mention two examples to illustrate this.

The first is that of provision of dairy services in Ethiopia, where dairy commercialization is confined by the poor quality and reach of public services. Stakeholders in the dairy sector agree that without new regulations allowing private services such as AI and veterinary care, market quality for dairy input and service markets remains insufficient for farmers to risk commercialization. Instead, farmers resilience mechanisms that enlarge absorptive and adaptive capacity and are within their means in terms of resources and practices. These include risk avoiding low input–low output farming with many crop and livestock functions, maintaining large low-productive herds as buffer, using producer organizations as a buyer of last resort and as a gateway to subsidized inputs and services, and off-farm income-generating activities that reduce dependence on agriculture.

The second example is of farmers in Kenya being held back from making the jump to regime III due to limitations in the quality of both input and output markets, as well as by risks of adverse weather events (**Appendix 5.2**). These risks prevent them from dealing with seasonality of milk production (Chapters 2 and 4). Processors are interested in a stable and predictable supply of milk throughout the year that can meet any trends in demand. Seasonality of production limits ensured supply to the lowest marketed volumes in the dry season, resulting in price reductions of up to 25% in the high-productive main rainy season. These price fluctuations are rather unpredictable, as they depend on how various processors respond to expected rainfall and market demand (Dominic Menjo, 2017, personal communication). The ensuing uncertainty creates hesitation on the farmers' side to invest in forage conservation and other practices that would reduce effects of seasonality. Such uncertainty could be reduced through firmer supply contracts by processors with their suppliers (farmers and cooperatives). If such contracts are not forthcoming, a transition to dairy farming with more investments in forage conservation and related investments is unlikely.

This second case assumes that improving market quality would result in a tipping point by improving quality and reliability of inputs and services and of milk supply contracting, but also by improving the public roles in disease control and quality standard enforcement. This would require levelling of the playing field for milk buyers, as informal traders are now able to benefit from seasonal milk scarcities and side-selling of milk – in other words, it would require upgrading in both the market and context domains. Some firm indications for success, whether removal of the next bottleneck will just be a next step in system adaptation or whether it will result in a drastic system transformation beyond the tipping point ('system jump'), would certainly be in the interest of dairy supply planners investing in such transitions.

More theoretical implications on transition and resilience

Transitions can be slow and difficult to detect, as Tittonell (2014) indicated. They can take many years or even decades to complete. Upgrading of market and context conditions may be slow. Individual farms may differ in when they change their livelihood strategy under pressure of increasing land scarcity, even for system jumps. While these moves are fairly easy to identify in hindsight, it may be challenging to notice them in real time, let alone to predict when, or whether, they will take place in the future. The key is to look for indications of change and whether the tipping point is imminent. Identification of the key drivers of, or barriers to, change requires proper analysis of the dynamics between farming, market, and context. This should offer insight to the key cause–effect relationships blocking further commercialization.

Based on this research, it might be hypothesized that there are indicators that point to the next transition: if, apart from the drivers of change such as land scarcity and increased demand for milk, the confining factors in market and context can be identified and mediated, then farmers' feasibility space for change in practices may be estimated, progress of change in practices could be monitored, and transition may be supported.

One final question of interest is that of the nature of the relationships between farming and market systems and related context systems within the food system: Are they hierarchical or panarchical? Tittonell (2014) assumes they are hierarchical, with lack of upgrading in a higher-level system restricting upgrading in the lower-level system, for which he uses the metaphor of Matryoshka dolls. Such hierarchical confinement seems to be at odds with Walker *et al.* (2006)'s concept of panarchy (**Appendix 5.2**), as Tittonell points out. Farming and market systems, as well as supporting systems in the enabling environment, are not necessarily in hierarchical relationship, although they are clearly interdependent. This thesis therefore suggests that both options occur: the example of seasonality from Kenya suggests a more panarchical relationship, in which farms and markets are mutually dependent in their adaptive development cycle, while the example from Ethiopia suggests farming is confined in a hierarchical way by the regulatory context.

6.2.5. Main research question and objective

In this final part of section 6.2, I look at the extent to which the main research question has been answered and the objective of this thesis has been achieved. The main research question was: In what ways do market quality and spatial factors affect commercialization of dairy farming systems under land scarcity in two countries in the East African highlands? Drawing on the sections 6.2.1–6.2.4, the main answers to this question are that:

1. Spatial factors are critical drivers of commercialization of dairy farming. Proximity to local input and output markets and being located in a dairy cluster enhance commercialization.
2. Concurrent and co-dependent upgrading in farming, market, and context domains enhances market quality for dairy and/or other farming activities. Given conducive market demand, market quality, and institutions for the various potential commodities, farming system are likely to commercialize into a certain direction by specializing toward the 'best fit' commodity, upgrading farming and marketing, and intensifying land use.
3. Farmers' market quality and feasibility space are also enhanced by the plurality and performance of input and service provision. Plurality of service arrangements broadens the types of farmers served and the fit with their strategies, resources, and aspirations. Business and technical performance are vital for their contribution to farm performance and resilience.
4. Risks and risk perceptions around market quality play important roles in decisions of upgrading, especially around system jumps. Resilience assessment needs to move beyond specific and known risks to include multiple and unknown risks, in order for commercialization to be sustained over time.
5. Connecting theory around system jumps of farming systems and around resilience determinants offers a way to explain farmer attitudes toward commercialization.

The objective of this thesis – to gain insights into factors affecting commercialization of dairy farming under land scarcity, through assessment of the dynamics of market participation, land use intensification, and resilience of dairy farming systems in relationship to the markets for inputs, services, and outputs in different contexts – has been well achieved, considering the above findings and theoretical contributions. This gives a strong foundation to consider the implications for further research, policy, and practice. Before doing so, I present reflections on the research design and methodology.

6.3. Reflections on research design and methodology

6.3.1. Research design – quality

According to Yin (2009), quality of research design can be assessed using four criteria. **Construct validity** was achieved by basing interview guidelines on literature research (e.g. **Table 3.1**) and by using multiple information sources for data collection (**Table 1.1**). **Internal validity** was achieved by matching methods with research objectives. This has been achieved in terms of the spatial dimension of commercialization but was more of a challenge for the temporal dimension of this process. The research period did not allow repeated data collection. I have dealt with this challenge by including recall questions about past events and dynamics in interviews with all types of stakeholders (including timelines in focus group interviews) and through triangulation with statistical data and literature, but the limited historical comparison may be regarded as a weakness of these studies.

Selection of case study areas in the East African highlands offers questions about the **external validity** of extrapolation of results to other areas. External validity has been enlarged by (1) comparing case studies from different areas in two countries with very different institutional contexts (coined multiple-case embedded design by Yin (2009:46)); and (2) focusing on the system dynamics rather than on the quantitative outcome of these processes, which allows for analytical rather than statistical generalization. By way of example: results do not indicate at what land acreage farms need to shift to a more intensive mode of dairy production, but they do show the processes and reasons that cause such a shift under obviously land-scarce situations in various contexts. Finally, **reliability** of the research design was achieved by storing data in WUR databases, by properly documenting data collection and analysis, and by publishing research reports (Kilelu *et al.*, 2018).

6.3.2. Bias in design and implementation

Even though the quality of the research design compares well to Yin's four criteria, the design and implementation took into account potential sampling, stakeholder and researcher biases.

Sampling bias

Selection of case study areas, support service models, and respondents was influenced by the interests of local partners, whether they were from public agencies and private companies (e.g. in selection of study areas for Chapters 2 and 3) or development projects (e.g. in selecting project interventions and respondents in Chapter 4).

The main sources of sampling variation that this research considered include:

- *Farm sizes, farming systems, and access to resources and markets*[6] – the transect and random farm sampling approaches used showed that farm sizes were comparable across study sites, with similar averages across countries; Nyandarua and Nandi counties (Kenya) had a number of medium-sized farms, and Nandi had a considerable proportion of very small farms spread across the study areas; while in Ethiopia, very small farms were mainly found in or near towns. The dominant dairy farming systems in the study areas were mixed crop–livestock smallholder systems. Livelihood sources – apart from dairy – consisted mainly of other livestock, various food and cash crops, and off-farm income. Dominant cash crops were tea in Nandi, potatoes in Nyandarua, and cereals in Arsi. Roles of livestock in the farming system varied considerably between and within areas depending on dairy market participation levels.

- *Spatial factors* – location of farms in the landscape, that is, proximity to markets, location in commodity clusters, agroecological zones, and infrastructure; impact of agroecological context was expected to be negligible – all studies concerned temperate highland dairy areas with good potential for dairy production, located between 1,800 and 3,000 m.a.s.l.; infrastructure in terms of networks for transport and supply of electricity, water and ICT services differed widely within and between study areas.
- *Input and service provision arrangements* – these differ within and between study areas depending on market participation levels; they also differ between Ethiopia and Kenya due to the different socio-political context: in Ethiopia, the support service system is government-directed; in Kenya, it is pluriform with major space for the private sector and farmer organizations (see section 1.3.2); and they differ in terms of model initiator (government agencies, private companies, and producer organizations in Chapters 2 and 3; a development project in Chapter 4).

Stakeholder bias

Selection of case study areas and respondents is subject to the interests of local partners, be they from public agencies, private companies, or development projects. I have dealt with this in four ways: by defining selection criteria for study areas and interviewees as clearly as possible; by training research assistants on this subject; by spending significant time on the selection of study areas for Chapters 2 and 3 (using input from public administration, private sector, and university partners but deciding as a research team) and on selection of a project intervention cum service provision model for Chapter 4; and by using the same entry method into the selected communities in both countries for Chapter 3 (requesting assistance from local area administrators while clearly explaining sampling criteria).

Researcher and cultural bias

I have attempted to dilute the bias I bring with me as white European, academically trained, researcher cum dairy development expert by working closely together with Ethiopian and

Kenyan researchers of different seniority levels, from universities and consulting circles. In this interaction, listening, discussion and counterchecking of observations were important activities. Moreover, over the past decade I have been in frequent communication with partners from research institutes, NGOs, private companies, and government staff in the region, which has shaped my understanding of dairy, local culture, and context.

The three decades in development-related work since my graduation from Wageningen University have taught me how my own views have been coloured by societal and academic debates in this field. In that period, the focus in rural development has shifted from poverty alleviation, participation and empowerment, via food security and local economic development, to food system outcomes and private sector involvement. One memory of how this influenced my views is when in 2005, during my time in Myanmar, I first came across the application of the value chain approach in development work. During my study years, integrated chain management was somewhat regarded as 'morally off-limits' for tropical livestock students. Since then, I have come to appreciate the strong explanatory value of the concept, as well as the need to share value between actors along the chain.

These influences likely have coloured the way I look at the various actors and processes in dairy development – how I value inclusion, entrepreneurship, and collaboration, and examine critically the role of private and public sector actors, farmer organizations and civil society, and power issues. No doubt this experience affects my studies on commercialization, as reported in this thesis.

While involving local research assistants addressed both practical issues and my Western bias issues, it introduced issues of ethnicity and local language sensitivities. I have dealt with these issues by using teams of mixed ethnicity, of which at least one member was fluent in the mother tongue of respondents.

6.3.3. Research design – planned vs. actual

Significant modifications were made to the original plan. On the one hand, data collected for Chapters 2 and 3 turned out to be richer than expected, leading to more potential chapters than were required for this thesis. I chose to complete the thesis and leave the remaining data for later publication, rather than let studies on spatial effects dominate the thesis. On the other hand, several events in the study countries complicated matters significantly. Work in Kenya was affected by long-lasting university strikes. Field work in Ethiopia was affected by the 2016–2017 civil unrest. The ensuing political instability led the team to cancel the planned study of dairy-related policies in Ethiopia. The policy study carried out in Kenya was then excluded from this thesis to avoid a lopsided focus on Kenya. Nevertheless, policy and enabling environment aspects have significant bearing on the phenomena studied. I was able to partly correct for this gap as the various key informant and farmer focus group interviews did yield significant data on these aspects. Moreover, my experience in several dairy development projects in both countries provided additional insight.

Part of the modifications resulted from the way that this work was financed. The NWO ADIAS project that financed most of the research underlying this thesis required collaboration with private entities and local partners. While collaboration with private partners ensured linkages with practice, I also experienced that the research interest of these companies was more oriented toward short-term strategic interests. Coupled with high in-company staff turnover rates, this considerably affected study focus. While in both countries the private sector partners were interested in assessment of their integrated service arrangements, staff turnover and other priorities caused such delays that these assessments could not be included in this thesis. This was addressed by including Chapter 4, which was a joint study between the ADIAS and 3R Kenya project (a more in-depth comparison with an Ethiopian case would have allowed more rigorous comparison). The collaboration with local universities led to training of several research assistants and MSc students, but also to significant data quality issues that took much time to amend. In the case of resilience assessment of dairy farms, this has taken so much time that I was forced to exclude that study from this thesis.

The upside of all this is that the research set-up enabled me to intensify collaboration with other researchers – which is likely to result in additional publications – and to more deeply compare dairy clusters. The downside is that considerable changes had to be made to the shape of this thesis, that delays accrued, and that a significant amount of collected data is still unpublished. The net result is that this thesis focuses deeply on spatial aspects of the farm–market–context interaction, while the contribution of service arrangements and resilience of dairy farming are dealt with in a more focused manner. While service arrangements and resilience assessment aspects would have benefited from more empirical data, I believe that construct validity and internal validity for all studies is sufficient, but that external validity for Chapter 4 is limited.

6.3.4. Suggestions for further research

A broad thesis such as this offers a large number of opportunities for further research, as already indicated in the chapters. Let me just mention one idea to whet the appetite.

This thesis assumes that upgrading the institutional context and market quality for dairy in particular situations, concurrent with farm system upgrades, will result in a tipping point. Testing this assumption would be an interesting action research subject (or a topic for historic transition research). It may be linked to a dairy development project in a context where a transformation is imminent. Such a project should have the purpose of upgrading in farming, market, and context, for instance by focusing on quality and reliability of inputs and services, of milk supply contracting, of the public roles in disease control and quality standard enforcement, and of levelling the playing field for milk buyers where informal traders are able to benefit from seasonal milk scarcities and where side-selling of milk cannot be prevented. It may test whether removal of the next bottleneck results only in the next step in system adaptation or whether it results in a 'system jump'. This would certainly be in the interest of dairy supply planners who invest in such transitions, as would identification of specific indicators (general and tentative indicators are not so useful). It would also aim at understanding the dynamics around the tipping point, the conditions for it to happen, and the impact on different service arrangements and vertical coordination mechanisms.

Many of the implications for policy and practice, described in the next section, can also be considered as topics for further research, in order to further develop sound theories regarding commercialization and resilience.

6.4. Implications for policy and practice

What does this thesis offer dairy supply planners in public agencies, private companies, and farmer organizations as they are deciding how to meet the increasing demand for milk? How should they design strategies that enable dairy farmers in East Africa to increase market participation in a sustainable way? Let me answer this question in two parts: 'What makes conditions conducive for commercialization?' and 'What is necessary for sustainable transformation?'

Conducive conditions for commercialization

This thesis takes feasibility space as a key characteristic to indicate the conduciveness to commercialization of a farmer in a certain space and time. Feasibility space is influenced by market demand, market quality, farm characteristics, the institutional context, and by what is happening in terms of commercialization and related processes. Of course, robust market demand, in terms of volumes, product types, and product quality, is a sine qua non. The ways that dairy supply planners can influence market demand, for example through product offer and pricing, mostly fell outside the scope of this thesis, as it focused on farm–market interaction.

Farm–market interaction needs to be viewed with sufficient attention to the variation between farmers, in terms of their feasibility space for increasing market participation. Farms vary significantly in their spatial characteristics and resource endowments. Important spatial characteristics – apart from agroecological conditions – are proximity to local input and output markets and location in a dairy cluster. The all-too-common division of dairy farms as '(peri-)urban' and 'rural' is inadequate, seeing the variation in market participation and intensification between remote and connected farms that is created by proximity to local service centres. This emphasizes the importance of plurality of service arrangements to cater to multiple types of farms. Such plurality can create momentum in demand and supply for inputs and services. 'Remote' rural farms need to be connected to milk collection infrastructure, input shops, and services to even have the choice to increase participation in dairy or other markets.

Enhancing the quality of the input and outputs markets, so that they become more attractive for farmers to participate in, can be achieved by investments in two levels. The first is by bringing input and service supply closer to the farmers; refining the milk collection grid; establishing agro-input shops at the edge of the all-weather road network; delivering extension and advisory services close to or on the farm; and improving rural road and utility networks to reduce transaction costs and permit all-weather access to villages, as well as improving access to information.

The second is by investing in support services to agri-service enterprises that emerge in the context of transforming agri-value chains, even when targeting smallholders. This requires co-evolution of market and institutional arrangements, in order to improve the technical and business performance of input and service providers and to improve the fit of their service bundle with farmer demand – in short, to improve their value proposition. In many cases this means tying advice to inputs or to milk supply contracts. On the market side, this includes better contracting and investment in supply chain loyalty, coordination of services, and improving access to financial services. On the institutional side this includes improvement of regulations and licensing for service providers, so they can become competitive, and public support for the creation of input supply and milk collection networks to overcome the deadlock between low demand and low supply.

This study showed how spatial effects play a role at both farm and cluster level. Most of the above interventions are most obvious at farm and service provider level. However, many of these interventions can be applied to the cluster level as well. Identifying areas that have high production and marketing potential for dairy (or for another commodity) and promoting market quality in such selected dairy clusters makes a lot of sense. **Figure 6.1** presents the challenge of identifying locations with reasonable transaction costs and production factor costs, where the likelihood of viable dairy production is largest.

Sustainability of transformation

In both countries studied, dairy development objectives are centred around poverty alleviation, which aligns well with current policy interests. I recommend that policy makers and cluster development planners carefully design sustainable intensification pathways for competitive commodities. Sustainability outcomes to be pursued include: (1) enabling a larger proportion of smallholder farmers to participate in markets and increase food security; (2) enabling viable and pluralistic service arrangements that serve a broad range of farmers and generate employment along the chain; and, increasingly, (3) ensuring food safety and climate smartness of dairy development. Clearly this requires a much larger scope than just improving farmer access to markets. A systemic approach to dairy as part of the agrifood system has been referred to in the Introduction (Andeweg, 2020).

The main contribution this thesis makes is to show (1) the importance of resilience in dairy farming and how insufficient regard for it as a precondition that allows farmers to invest in market participation will dramatically increase the chances of failure and result in low returns on investment; and (2) the impact of spatial effects on commercialization pathways of individual farmers. This leads to the following implications.

First, the risks of commercialization need to be properly analysed and evaluated. It may have come as a surprise to some people in the dairy sector that it was not poor genetics, but feed shortage due to land scarcity, lack of disease control, and market fluctuations that were found to be the top risks. Risks that are not mitigated collectively are likely to diminish the effects of public and private investments in supply enhancement. Numerous risk mitigation interventions do exist but need to be intentionally and properly matched to bottlenecks in commercialization. These risk mitigation strategies will need to strengthen the coping strategies of farms, particularly by enlarging their absorptive, adaptive, and transformative capacities as well as their resources and practices.

Second, the impact of spatial effects on commercialization pathways of individual farmers means that inclusive development has a spatial component. A proper mix of interventions is required to include remote farmers, in addition to the usual attention to resource-endowment of farmers.

Some practical examples to deal with these two issues have been alluded to in earlier sections: better contracting and payment conditions in the supply chain will encourage farmers to invest in reduced seasonality of production; ensuring all-weather farm access to markets enables use of external inputs and services as well as fresh milk marketing; space for private service provision can improve market quality for farmers; offering business support services to emerging agri-service providers enables them to improve the quality of their services; policies that take into account the differences in agroecological and market potential between and within clusters will increase policy inclusivity, and land tenure reforms could address issues around scarcity of land.

Dairy commercialization will thus need to consider spatial effects (proximity to local input and output markets and being located in a cluster); concurrent upgrading in farm, market, and contextual domains; plurality and performance of input and service providers; risks and risk perceptions; and resilience so that commercialization can be sustained over time.

References

Adger WN. (2006) Vulnerability. *Global Environmental Change* 16: 268-281.

Agresti A. (2003) *Categorical Data Analysis*: Wiley.

Akinlade RJ, Balogun OL and Obisesan AA. (2016) Commercialization of Urban Vegetable Farming. *International Journal of Vegetable Science* 22: 24-34.

Amankwah K, Klerkx L, Oosting SJ, et al. (2012) Diagnosing constraints to market participation of small ruminant producers in northern Ghana: An innovation systems analysis. *NJAS - Wageningen Journal of Life Sciences* 60-63: 37-47.

Anderson JR and Feder G. (2003) *Rural Extension Services,* World Bank, Washington D. C.: For full text: http://econ.worldbank.org/view.php?type=5&id=24374.

Andeweg K. (2020) Dairy for nutrition, employment and sustainability. An action agenda for the Dutch contribution to dairy development in Africa and Asia. Position paper. Netherlands Food Partnership.

Arias P, Halam D, Krivonos E, et al. (2013) *Smallholder integration in changing food markets,* Rome: FAO.

Babu SC and Zhou Y. (2015) Private Sector Extension – Synthesis of the Case Studies. In: Zhou Y and Babu SC (eds) *Knowledge Driven Development.* San Diego: Academic Press, 253-267.

Bahta S and Malope P. (2014) Measurement of competitiveness in smallholder livestock systems and emerging policy advocacy: An application to Botswana. *Food Policy* 49: 408-417.

Barrett CB. (2008) Smallholder market participation: Concepts and evidence from Eastern and Southern Africa. *Food Policy* 33: 299-317.

Barrett CB, Bachke ME, Bellemare MF, et al. (2012) Smallholder participation in contract farming: comparative evidence from five countries. *World Development* 40: 715-730.

Barsley W, De Young C and Brugère C. (2013) Vulnerability assessment methodologies: an annotated bibliography for climate change and the fisheries and aquaculture sector. *FAO Fisheries and Aquaculture Circular*: I.

Bates D, Maechler M, Bolker B, et al. (2014) Linear mixed-effects models using Eigen and S4. *R package version* 1.

Bebe BO. (2008) Assessing potential for producing dairy replacements under increasing intensification of smallholder dairy systems in the Kenya highlands. *Livestock Research for Rural Development* 20.

Bebe O, B., Gowland MJ and Nicholas O. (2016) Changes in agri-business outcomes among the dairy beneficiaries of contracted extension service delivery model in Kenya. *Journal of Agricultural Extension* 20: 53-65.

Béné C. (2013) Towards a quantifiable measure of resilience. *IDS Working Papers* 2013: 1-27.

Bene C, Newsham A, Davies M, et al. (2014) Review Article: Resilience, Poverty and Development. *Journal of International Development* 26: 598-623.

Béné C, Wood RG, Newsham A, et al. (2012) Resilience: new utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. *IDS Working Papers* 2012: 1-61.

Berhanu K and Poulton C. (2014) The political economy of agricultural extension policy in Ethiopia: economic growth and political control. *Development Policy Review* 32: s199-s216.

Berkhaut F. (2008) Order in socio-technical systems: the dark side of resilience. *Re-framing resilience: a symposium report. STEPS Working Paper.*

Bijman J, Muradian R and Cechin A. (2012) Agricultural cooperatives and value chain coordination. In: Helmsing A and Vellema S (eds) *Value Chains, Social Inclusion and Economic Development: Contrasting Theories and Realities.* Routledge, 82-101.

Birner R, Davis K, Pender J, et al. (2009) From Best Practice to Best Fit: A Framework for Designing and Analyzing Pluralistic Agricultural Advisory Services Worldwide. *The Journal of Agricultural Education and Extension* 15: 341-355.

Borisova O, Abramova L, Zageeva L, et al. (2015) Role of agricultural clusters in provision of food security. *European research studies* 18: 287.

Bosire CK, Rao J, Muchenje V, et al. (2019) Adaptation opportunities for smallholder dairy farmers facing resource scarcity: Integrated livestock, water and land management. *Agriculture, Ecosystems & Environment* 284: 106592.

Bosman H, Moll H and Udo H. (1997) Measuring and interpreting the benefits of goat keeping in tropical farm systems. *Agricultural Systems* 53: 349-372.

Boso N, Story VM and Cadogan JW. (2013) Entrepreneurial orientation, market orientation, network ties, and performance: Study of entrepreneurial firms in a developing economy. *Journal of Business Venturing* 28: 708-727.

Brandt P, Hamunyela E, Herold M, et al. (2018) Sustainable intensification of dairy production can reduce forest disturbance in Kenyan montane forests. *Agriculture, ecosystems & environment* 265: 307-319.

Brasier KJ, Goetz S, Smith LA, et al. (2007) Small farm clusters and pathways to rural community sustainability. *Community Development* 38: 8-22.

Brown K. (2014) Global environmental change I: A social turn for resilience? *Progress in human geography* 38: 107-117.

Bruton GD, Ketchen DJ and Ireland RD. (2013) Entrepreneurship as a solution to poverty. *Journal of Business Venturing* 28: 683-689.

Burke WJ, Myers RJ and Jayne TS. (2015) A triple-hurdle model of production and market participation in Kenya's dairy market. *American Journal of Agricultural Economics* 97: 1227-1246.

Cabell JF and Oelofse M. (2012) An indicator framework for assessing agroecosystem resilience. *Ecology and Society* 17.

Campbell R. (2014) A Framework for Inclusive Market Systems Development. In: USAID (ed) *LEO brief*.

Carpenter S, Walker B, Anderies JM, et al. (2001) From Metaphor to Measurement: Resilience of What to What? *Ecosystems* 4: 765-781.

Chamberlin J and Jayne T. (2013) Unpacking the meaning of ‘market access’: evidence from rural Kenya. *World Development* 41: 245-264.

Chantre E and Cardona A. (2013) Trajectories of French Field Crop Farmers Moving Toward Sustainable Farming Practices: Change, Learning, and Links with the Advisory Services. *Agroecology and Sustainable Food Systems* 38: 573-602.

Chowa C, Garforth C and Cardey S. (2013) Farmer experience of pluralistic agricultural extension, Malawi. *The Journal of Agricultural Education and Extension* 19: 1-20.

Christensen RHB. (2019) ordinal - regression models for ordinal data. R package version 2019.4-25. Available at: http://www.cran.r-project.org/package=ordinal/.

Clark J. (2009) Entrepreneurship and diversification on English farms: Identifying business enterprise characteristics and change processes. *Entrepreneurship & Regional Development* 21: 213-236.

Clay N and Yurco K. (2019) Political ecology of milk: Contested futures of a lively food. *Geography Compass* n/a.

Córdoba Vargas CA, Hortúa Romero S and León Sicard T. (2019) Key points of resilience to climate change: a necessary debate from agroecological systems. *Climate and Development*: 1-11.

CSA. (2017) Agricultural sample survey 2016/17 [2009 E.C.], Volume II: Livestock and livestock characteristics (private peasant holdings) *Statistical bulletin 585.* Addis Abeba: Central Statistics Agency, Federal Democratic Republic of Ethiopia.

Darnhofer I. (2014) Resilience and why it matters for farm management. *European Review of Agricultural Economics* 41: 461-484.

Darnhofer I, Fairweather J and Moller H. (2010) Assessing a farm's sustainability: insights from resilience thinking. *International Journal of Agricultural Sustainability* 8: 186-198.

Darnhofer I, Gibbon D and Dedieu BE. (2012) *Farming Systems Research into the 21st Century: The New Dynamic*: Springer.

Dekker S, De Boer I, Vermeij I, et al. (2011) Ecological and economic evaluation of Dutch egg production systems. *Livestock Science* 139: 109-121.

DFID. (1999) Sustainable Livelihoods Guidance Sheets. Department for International Development.

Didanna HL, Wossen AM, Worako TK, et al. (2018) Factors influencing intensification of dairy production systems in Ethiopia. *Outlook on Agriculture*: 0030727018770463.

Dinar A, Karagiannis G and Tzouvelekas V. (2007) Evaluating the impact of agricultural extension on farms' performance in Crete: a nonneutral stochastic frontier approach. *Agricultural Economics* 36: 135-146.

Dirven M. (2001) Dairy clusters in Latin America in the context of globalization. *The International Food and Agribusiness Management Review* 2: 301-313.

Dixon J, Gulliver A and Gibbon D. (2001) Farming Systems and Poverty - Improving farmers' livelihoods in a changing world. In: Hall M (ed). Rome and Washington D.C.: FAO and World Bank.

Dorward A, Anderson S, Bernal YN, et al. (2009) Hanging in, stepping up and stepping out: livelihood aspirations and strategies of the poor. *Development in Practice* 19: 240-247.

Duncan A, Teufel N, Mekonnen K, et al. (2013) Dairy intensification in developing countries: effects of market quality on farm-level feeding and breeding practices. *Animal* 7: 2054-2062.

Duru M and Therond O. (2014) Livestock system sustainability and resilience in intensive production zones: which form of ecological modernization? *Regional Environmental Change*: 1-15.

Elzen B, Augustyn AM, Barbier M, et al. (2017) AgroEcological Transitions - Changes and Breakthroughs in the Making. Wageningen University & Research.

Falconnier GN, Descheemaeker K, Traore B, et al. (2018) Agricultural intensification and policy interventions: Exploring plausible futures for smallholder farmers in Southern Mali. *Land Use Policy* 70: 623-634.

Fang YP, Zhu FBA, Qiu XP, et al. (2018) Effects of natural disasters on livelihood resilience of rural residents in Sichuan. *Habitat International* 76: 19-28.

FAO, CTA and IFAD. (2014) Youth and agriculture : key challenges and concrete solutions. FAO.

Faure G, Desjeux Y and Gasselin P. (2012) New Challenges in Agricultural Advisory Services from a Research Perspective: A Literature Review, Synthesis and Research Agenda. *The Journal of Agricultural Education and Extension* 18: 461-492.

Filmer D and Fox L. (2014) *Youth employment in Sub-Saharan Africa,* Washington, D.C: The World Bank.

Folke C. (2006) Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change* 16: 253-267.

Francesconi GN. (2009) Cooperation for competition: linking Ethiopian farmers to markets. *Wageningen University, Development Economics.* Wageningen: Wageningen Academic Pub.

Franzel S, Lowicki-Zucca J, Miiro R, et al. (2020) Demand-driven extension and advisory services – catalysing opportunities for youth in agriculture. *Rural 21: International Journal for Rural Development* 54: 23-25.

Fraval S, Hammond J, Lannerstad M, et al. (2018) Livelihoods and food security in an urban linked, high potential region of Tanzania: Changes over a three year period. *Agricultural Systems* 160: 87-95.

Gallopín GC. (2006) Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change* 16: 293-303.

Gebremedhin B and Jaleta M. (2010) Commercialization of Smallholders: Is Market Participation Enough? *Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference.* Cape Town, South Africa, September 19-23, 2010.

Gebremedhin B, Tegegne A, Hoekstra D, et al. (2014) Developing the butter value chain in Ethiopia. In: Institute ILR (ed) *LIVES Working Paper I.* Nairobi, Kenya.

Giller KE. (2013) Can we define the term 'farming systems'? A question of scale. SAGE Publications Sage UK: London, England.

Giuliani E, Pietrobelli C and Rabellotti R. (2005) Upgrading in global value chains: lessons from Latin American clusters. *World Development* 33: 549-573.

Gliessman S. (2018) Defining agroecology. *Agroecology and Sustainable Food Systems* 42: 599-600.

Gonzalez-Mejia A, Styles D, Wilson P, et al. (2018) Metrics and methods for characterizing dairy farm intensification using farm survey data. *PloS one* 13: 18.

Gunderson LH, Holling C and Light SS. (1995) *Barriers and bridges to the renewal of regional ecosystems*: Columbia University Press.

Gunderson LH and Holling CS. (2002) *Panarchy: understanding transformations in human and natural systems,* Washington, USA: Island Press.

Haggblade S. (2011) Modernizing African agribusiness: reflections for the future. *Journal of Agribusiness in Developing and Emerging Economies* 1: 10-30.

Hall A, Janssen WG, Pehu E, et al. (2006) Enhancing agricultural innovation: how to go beyond the strengthening of research systems. The World Bank.

Hamilton-Peach J and Townsley P. (2004) An IFAD Sustainable Livelihoods Framework. In: IFAD (ed). Rome: Retrieved from http://ifad.org/sla/framework/index.htm.

Herrero M, Thornton PK, Bernués A, et al. (2014) Exploring future changes in smallholder farming systems by linking socio-economic scenarios with regional and household models. *Global Environmental Change* 24: 165-182.

Hertog PD. (2000) Knowledge Intensive Business Services as Co-producers of Innovation. *International Journal of Innovation Management* 04: 491-528.

Hilkens A, Reid JI, Klerkx L, et al. (2018) Money talk: How relations between farmers and advisors around financial management are shaped. *Journal of Rural Studies* 63: 83-95.

Hoddinott JF, Headey DD and Dereje M. (2014) Cows, missing milk markets and nutrition in rural Ethiopia. *ESSP Working Paper 63.* Addis Abeba: IFPRI.

Holling CS. (1973) Resilience and stability of ecological systems. *Annual review of ecology and systematics* 4: 1-23.

IFCN. (2019) Dairy Report 2019 - For a better understanding of milk production worldwide. Kiel: International Farm Comparison Network.

IPCC. (2014) Climate Change 2014. Impacts, Adaptation, and Vulnerability; Part A: Global and Sectoral Aspects. Cambridge, United Kingdom and New York, NY. USA: Cambridge University Press.

Jaffee S, Henson S and Diaz Rios L. (2011) Making the Grade: Smallholder Farmers, Emerging Standards, and Development Assistance Programs in Africa-A Research Program Synthesis.

Jaleta M, Gebremedhin B, Tegegne A, et al. (2013) Evolution of input supply and service hubs in dairy development at Ada'a milk shed in Ethiopia. *Development in Practice* 23: 249-263.

Jayakaran R. (2002) *The ten seed technique*: World Vision, People's Republic of China.

Jayne TS, Chamberlin J and Headey DD. (2014) Land pressures, the evolution of farming systems, and development strategies in Africa: A synthesis. *Food Policy* 48: 1-17.

Jayne TS, Chamberlin J, Traub L, et al. (2016) Africa's changing farm size distribution patterns: the rise of medium-scale farms. *Agricultural Economics* 47: 197-214.

Joffre OM, Poortvliet PM and Klerkx L. (2019) To cluster or not to cluster farmers? Influences on network interactions, risk perceptions, and adoption of aquaculture practices. *Agricultural Systems* 173: 151-160.

Kabasa JD, Kirsten J and Minde I. (2015) Implications of changing agri-food system structure for agricultural education and training in Sub-Saharan Africa. *Journal of Agribusiness in Developing and Emerging Economies* 5: 190-199.

Kabir KH, Knierim A and Chowdhury A. (2020) Assessment of a pluralistic advisory system: the case of Madhupur Sal Forest in Bangladesh. *The Journal of Agricultural Education and Extension*: 1-24.

Katothya GM, Kilelu CW, Sikumba G, et al. (2020) Emerging private extension and advisory services models in the Kenyan agrifood sector: selected case studies. Wageningen: Wageningen Livestock Research.

Kaufman S. (2003) Breaking the Galilean spell. *Edge*

KDB. (2018) *www.kdb.co.ke Website Kenya Dairy Board.* .

KDB. (2020) The Kenyan Dairy Board. http://kdb.go.ke/. Last visited June 10, 2020.

Kebebe E. (2019) Bridging technology adoption gaps in livestock sector in Ethiopia: A innovation system perspective. *Technology in Society* 57: 30-37.

Kebebe EG. (2015) Understanding factors affecting technology adoption in smallholder livestock production systems in Ethiopia: The role of farm resources and the enabling environment. *Animal Production Systems group.* Wageningen: Wageningen University.

Kebebe EG, Duncan AJ, Klerkx L, et al. (2015) Understanding socio-economic and policy constraints to dairy development in Ethiopia: A coupled functional-structural innovation systems analysis. *Agricultural Systems* 141: 69-78.

Kijima Y, Yamano T and Baltenweck I. (2009) Emerging markets in the post-liberalisation period: evidence from the raw milk market in rural Kenya. *Journal of African economies*: ejp014.

Kilelu C, Klerkx L, Omore A, et al. (2017) Value Chain Upgrading and the Inclusion of Smallholders in Markets: Reflections on Contributions of Multi-Stakeholder Processes in Dairy Development in Tanzania. *The European Journal of Development Research*: 1-20.

Kilelu C, Ndambi O, van der Lee J, et al. (2019) Making milk quality assurance work on an unlevel playing field- Lessons from the Happy Cow pilot: 3R Kenya Project Practice Brief 013.

Kilelu CW. (2013) Unravelling the role of innovation intermediaries in smallholder agricultural development: case studies from Kenya. *WASS.* Wageningen University.

Kilelu CW, Katothya GM and van der Lee J. (2020) Emerging private extension and advisory service models in Kenya's transforming agri-food sector. In: Wageningen Livestock Research WUR (ed) *3R Kenya Project Practice Brief 017.* Wageningen.

Kilelu CW, Klerkx L and Leeuwis C. (2013) Unravelling the role of innovation platforms in supporting co-evolution of innovation: Contributions and tensions in a smallholder dairy development programme. *Agricultural Systems* 118: 65-77.

Kilelu CW, Klerkx L and Leeuwis C. (2014) How Dynamics of Learning are Linked to Innovation Support Services: Insights from a Smallholder Commercialization Project in Kenya. *The Journal of Agricultural Education and Extension* 20: 213-232.

Kilelu CW, Klerkx L and Leeuwis C. (2016) Supporting smallholder commercialisation by enhancing integrated coordination in agrifood value chains: experiences with dairy hubs in Kenya. *Experimental Agriculture* 00: 1-19.

Kilelu CW, Klerkx L, Leeuwis C, et al. (2011) Beyond knowledge brokering: an exploratory study on innovation intermediaries in an evolving smallholder agricultural system in Kenya. *Knowledge Management for Development Journal* 7: 84-108.

Kilelu CW, Koge J, Kabuga C, et al. (2018) Performance of emerging dairy services agri-enterprises: a case study of youth-led service provider enterprises (SPE). Wageningen Livestock Research.

Klerkx L, De Grip K and Leeuwis C. (2006) Hands off but Strings Attached: The Contradictions of Policy-induced Demand-driven Agricultural Extension. *Agriculture and Human Values* 23: 189-204.

Klerkx L and Jansen J. (2010) Building knowledge systems for sustainable agriculture: supporting private advisors to adequately address sustainable farm management in regular service contacts. *International Journal of Agricultural Sustainability* 8: 148-163.

Klerkx L, Petter Stræte E, Kvam G-T, et al. (2017) Achieving best-fit configurations through advisory subsystems in AKIS: case studies of advisory service provisioning for diverse types of farmers in Norway. *The Journal of Agricultural Education and Extension* 23: 213-229.

KNBS. (2015a) *Nandi County statistical abstract,* Nairobi: Republic of Kenya, Kenya National Bureau of Statistics.

KNBS. (2015b) *Nyandarua County statistical abstract,* Nairobi: Republic of Kenya, Kenya National Bureau of Statistics.

Koning N and van Ittersum MK. (2009) Will the world have enough to eat? *Current Opinion in Environmental Sustainability* 1: 77-82.

Koutsouris A and Zarokosta E. (2020) Supporting bottom-up innovative initiatives throughout the spiral of innovations: Lessons from rural Greece. *Journal of Rural Studies* 73: 176-185.

Kruse G. (2012) The Chilling Hub Model and Social Capital in Dairy Value Chain Development. Heifer International Kenya.

Kyeyamwa H, Verbeke W, Speelman S, et al. (2008) Structure and dynamics of livestock marketing in rural Uganda: constraints and prospects for research and development. *Journal of International Food & Agribusiness Marketing* 20: 59-89.

Labarthe P. (2005) Performance of services: a framework to assess farm extension services. *11th seminar of the EAAE (European Association of Agricultural Economists):'The Future of Rural Europe in the Global Agri-Food System'*.

Labarthe P and Laurent C. (2013) Privatization of agricultural extension services in the EU: Towards a lack of adequate knowledge for small-scale farms? *Food Policy* 38: 240-252.

Lans T, Seuneke P and Klerkx L. (2013) Agricultural entrepreneurship. *Encyclopedia of creativity, invention, innovation and entrepreneurship.* Springer, 44-49.

Leonardo WJ, Bijman J and Slingerland M. (2015) The Windmill Approach: Combining transaction cost economics and farming systems theory to analyse farmer participation in value chains. *Outlook on AGRICULTURE* 44: 207-214.

Lie H, Rich KM, van der Hoek R, et al. (2018) An empirical evaluation of policy options for inclusive dairy value chain development in Nicaragua: A system dynamics approach. *Agricultural Systems* 164: 193-222.

Linderhof V, Janssen V and Achterbosch T. (2019) Does agricultural commercialization affect food security: The case of crop-producing households in the regions of post-reform Vietnam? *Sustainability* 11: 1263.

Lindsay V, Ashill N, Roxas B, et al. (2014) Entrepreneurial orientation and performance of microenterprises in an emerging economy. *Journal of Strategic Marketing* 22: 631-656.

Loeber AMC, Van Mierlo BC, Grin J, et al. (2007) The practical value of theory: Conceptualising learning in the pursuit of a sustainable development. *Social Learning towards a Sustainable World.* Wageningen: Wageningen Academic Publishers, 83-98.

Lunguli G and Namusonge G. (2015) Entrepreneurial Factors Influencing Performance of Youth Run Agro-Based Enterprises in Ngoliba Ward, Kiambu County, Kenya. *The Strategic Journal of Business and Change Management* 2: 1458-1482.

Makoni N, Mwai R, Redda T, et al. (2014) White Gold : Opportunities for Dairy Sector Development Collaboration in East Africa. Wageningen: Centre for Development Innovation, Wageningen UR, 205.

Marino D, Mastronardi L, Giannelli A, et al. (2018) Territorialisation dynamics for Italian farms adhering to Alternative Food Networks. *Bulletin of Geography-Socio-Economic Series* 40: 113-131.

Martin G, Allain S, Bergez J-E, et al. (2018) How to Address the Sustainability Transition of Farming Systems? A Conceptual Framework to Organize Research. *Sustainability* 10: 1-20.

McCullough EB, Pingali P and Stamoulis K. (2012) Small Farms and the Transformation of Food Systems: An Overview. In: McCullough EB, Pingali P and Stamoulis K (eds) *The Transformation of Agri-Food Systems : Globalization, Supply Chains and Smallholder Farmers.* Hoboken: Taylor and Francis.

Meadows DH. (1999) Leverage points: Places to intervene in a system. Hartland: The Sustainability Institute.

Medina G, Almeida C, Novaes E, et al. (2015) Development conditions for family farming: lessons from Brazil. *World Development* 74: 386-396.

Mellor JW. (2014) High rural population density Africa – What are the growth requirements and who participates? *Food Policy* 48: 66-75.

Meuwissen MP, Feindt PH, Spiegel A, et al. (2019) A framework to assess the resilience of farming systems. *Agricultural Systems* 176: 102656.

Mgumia HJ. (2017) Programme-Induced Entrepreneurship and Young People's Aspirations. *IDS* 48: 155-170.

Migose S, de Boer I, Bebe B, et al. (2019) A positive deviant approach to understanding key factors of smallholder dairy development in Kenya. *WIAS Science Day 2019: Trade-Offs in Science.* Wageningen University & Research, 23-23.

Migose SA. (2020) Addressing variation in smallholder farming systems to improve dairy development in Kenya. Wageningen University.

Migose SA, Bebe BO, de Boer IJM, et al. (2018) Influence of distance to urban markets on smallholder dairy farming systems in Kenya. *Tropical animal health and production*: 1417–1426.

Minten B, Habte Y, Tamru S, et al. (2018) Transforming agri-food systems in Ethiopia: Evidence from the dairy sector. E-Book: Intl Food Policy Res Inst.

MoALF. (2010) Kenya National Dairy Master Plan - Volume II, Action Plan and Implementation Strategy. Republic of Kenya.

MoALF. (2013) Sessional paper No. 5 of 2013 on the national dairy development policy - Towards a Competitive and Sustainable Dairy Industry for Economic Growth in the 21st Century and Beyond. Republic of Kenya, Ministry of Agriculture, Livestock and Fisheries, State Department of Livestock.

Mockshell J and Kamanda J. (2018) Beyond the agroecological and sustainable agricultural intensification debate: Is blended sustainability the way forward? *International Journal of Agricultural Sustainability* 16: 127-149.

Moll HA, Staal SJ and Ibrahim M. (2007) Smallholder dairy production and markets: A comparison of production systems in Zambia, Kenya and Sri Lanka. *Agricultural Systems* 94: 593-603.

Morosini P. (2004) Industrial clusters, knowledge integration and performance. *World Development* 32: 305-326.

Mugisha A, Kayiizi V, Owiny D, et al. (2014) Breeding services and the factors influencing their use on smallholder dairy farms in central Uganda. *Veterinary Medicine International* 2014.

Murage P, Ngigi M, Bebe B, et al. (2018) Technical efficiency of smallholder dairy farms across dairy business models and associated determinants in the Kenya highlands. . *submitted to Journal of Rural Studies*.

Muriuki H and Thorpe W. (2006) Smallholder dairy production and marketing in eastern and southern Africa: Regional synthesis. *The South-South Workshop on Smallholder Dairy Production and Marketing. ILRI*.

Mutambara J, Dube I, Matangi E, et al. (2013) Factors influencing the demand of the service of community based animal health care in Zimbabwe. *Preventive Veterinary Medicine* 112: 174-182.

Muyanga M, Tschirley D, Reardon T, et al. (2019) Synthesis Report III. Rural and Agrifood Systems in Transforming Economies in Africa and Asia *Feed the Future - Innovation lab for food security policy.*

Nanyeenya W, Staal S, Mugisha J, et al. (2009) Determinants Of Dairy Intensification In Uganda-An Integrated Analysis Of Farm Resources, Location And Gis-Derived Factors. *African Journal of Livestock Extension* 5: 14-20.

Ndambi A, Sinoya K, Sakwa B, et al. (2020) Impact of fodder management on dairy farm performance in Kenya. *3R Kenya research report 014/Wageningen Livestock Research Report 1250.*

Nettle R, Ayre M, Beilin R, et al. (2014) Empowering farmers for increased resilience in uncertain times. *Proceedings of the 5th Australasian Dairy Science Symposium.* 41.

Njuki JM, Wyatt A, Baltenweck I, et al. (2016) An Exploratory study of Dairying Intensification, Women's Decision Making, and Time Use and Implications for Child Nutrition in Kenya. *The European Journal of Development Research* 28: 722-740.

Norris FH, Stevens SP, Pfefferbaum B, et al. (2008) Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American journal of community psychology* 41: 127-150.

Novo AM, Slingerland M, Jansen K, et al. (2013) Feasibility and competitiveness of intensive smallholder dairy farming in Brazil in comparison with soya and sugarcane: Case study of the Balde Cheio Programme. *Agricultural Systems* 121: 63-72.

Ochieng CMO. (2007) Revitalising African agriculture through innovative business models and organisational arrangements: promising developments in the traditional crops sector. *The Journal of Modern African Studies* 45: 143-169.

Odhong C, Wahome R, Vaarst M, et al. (2015) Dairy cattle management, health and welfare in smallholder farms: An organic farming perspective. *Journal of Organics* 2.

Olwande J, Smale M, Mathenge MK, et al. (2015) Agricultural marketing by smallholders in Kenya: A comparison of maize, kale and dairy. *Food Policy* 52: 22-32.

Omiti J, McCullough E, Otieno D, et al. (2006) Participatory Prioritization of issues in smallholder agricultural commercialization in Kenya. *KIPPRA Discussion Paper No. 64.* Nairobi: Kenya Institute for Public Policy Research and Analysis.

Omiti J, Otieno D, Nyanamba T, et al. (2009) Factors influencing the intensity of market participation by smallholder farmers: A case study of rural and peri-urban areas of Kenya. *African Journal of Agricultural and Resource Economics* 3: 57-82.

Oosting SJ, Udo HMJ and Viets TC. (2014) Development of livestock production in the tropics: farm and farmers' perspectives. *Animal* 8: 1238-1248.

Oreszczyn S, Lane A and Carr S. (2010) The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations. *Journal of Rural Studies* 26: 404–417.

Osbahr H, Twyman C, Adger W, et al. (2010) Evaluating successful livelihood adaptation to climate variability and change in southern Africa. *Ecology and Society* 15.

Paul BK, Frelat R, Birnholz C, et al. (2018) Agricultural intensification scenarios, household food availability and greenhouse gas emissions in Rwanda: Ex-ante impacts and trade-offs. *Agricultural Systems* 163: 16-26.

Pearson O and Schmidt M. (2017) Commodity individuation of milk in the Somali Region, Ethiopia. *Area*: n/a-n/a.

Petticrew M and Roberts H. (2006) *Systematic reviews in the social sciences: A practical guide*: John Wiley & Sons.

Pimm SL. (1984) The complexity and stability of ecosystems. *Nature* 307: 321-326.

Pingali PL and Rosegrant MW. (1995) Agricultural commercialization and diversification: processes and policies. *Food Policy* 20: 171-185.

Poole ND, Chitundu M and Msoni R. (2013) Commercialisation: A meta-approach for agricultural development among smallholder farmers in Africa? *Food Policy* 41: 155-165.

Porter ME. (2000) Location, competition, and economic development: Local clusters in a global economy. *Economic development quarterly* 14: 15-34.

Poulton C, Dorward A and Kydd J. (2010) The Future of Small Farms: New Directions for Services, Institutions, and Intermediation. *World Development* 38: 1413-1428.

Poulton C and Lyne MC. (2009) Coordination for market development. *Institutional economics perspectives on African agricultural development*: 135-184.

Prager K, Labarthe P, Caggiano M, et al. (2016) How does commercialisation impact on the provision of farm advisory services? Evidence from Belgium, Italy, Ireland and the UK. *Land Use Policy* 52: 329-344.

Quinlan AE, Berbes-Blazquez M, Haider LJ, et al. (2016) Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives. *Journal of Applied Ecology* 53: 677-687.

Rademaker CJ, Bebe BO, van der Lee J, et al. (2016) Sustainable growth of the Kenyan dairy sector: a quick scan of robustness, reliability and resilience. Wageningen University & Research, Wageningen Livestock Research.

Ragasa C, Ulimwengu J, Randriamamonjy J, et al. (2016) Factors Affecting Performance of Agricultural Extension: Evidence from Democratic Republic of Congo. *The Journal of Agricultural Education and Extension* 22: 113-143.

Ramirez M, Clarke I and Klerkx L. (2017) Analysing intermediary organisations and their influence on upgrading in emerging agricultural clusters. *Environment and Planning A*: 0308518X17741316.

Reardon T. (2015) The hidden middle: the quiet revolution in the midstream of agrifood value chains in developing countries. *Oxford Review of Economic Policy* 31: 45-63.

Reardon T, Boughton D, Tschirley D, et al. (2015) Urbanization, Diet Change, and Transformation of the Downstream and Midstream of the Agrifood System: Effects on the Poor in Africa and Asia. *Faith & Economics* 66: 43–63.

Reardon T, Tschirley D, Haggblade S, et al. (2014) Five Inter-Linked Transformations in the African Agrifood Economy: Food Security Implications. *AU meeting 2013.* funded by the BMGF Meridian Institute ed. Addis Abeba: Global Food Security York Academy of Sciences.

Recha CW. (2018) Local and regional variations in conditions for agriculture and food security in Kenya. *AgriFoSe2030 Report 7.*

Resilience Alliance. (2010) Assessing resilience in social-ecological systems: workbook for practitioners (revised version 2.0). 22: 2011.

Roessler R, Mpouam SE, Muchemwa T, et al. (2016) Emerging Development Pathways of Urban Livestock Production in Rapidly Growing West Africa Cities. *Sustainability* 8: 1199.

Roling N. (2009) Conceptual and methodological developments in innovation. In: Sanginga PC, Waters-Bayer A, Kaaria S, et al. (eds) *Innovation Africa: enriching farmers'livelihoods.* London: Eathscan, 9-34.

Royer A, Bijman J and Bitzer V. (2016) Linking smallholder farmers to high quality food chains: Appraising institutional arrangements. *Quality and innovation in food chains: Lessons and insights from Africa.* Wageningen Academic Publishers, 359-381.

Ruben R, Dekeba Bekele A and Megersa Lenjiso B. (2017) Quality upgrading in ethiopian dairy value chains: dovetailing upstream and downstream perspectives. *Review of Social Economy*: 1-22.

Ruben R, Verhagen J and Plaisier C. (2019) The Challenge of Food Systems Research: What Difference Does It Make? *Sustainability* 11: 171.

Salami A, Kamara AB and Brixiova Z. (2010) *Smallholder agriculture in East Africa: trends, constraints and opportunities*: African Development Bank Tunis, Tunisia.

Schiere H. (2001) Livestock production in urban conditions, problems and opportunities; concepts and methodologies. *10th International Conference of the Association of Institutions for Tropical Veterinary Medicine "Livestock, Community and the Environment".* Copenhagen, Denmark, 20-23 August 2001.

Schiere H, Baumhardt RL, Van Keulen H, et al. (2006) Mixed crop-livestock systems in semiarid regions. *AGRONOMY* 23: 227.

Schiere JB, Darnhofer I and Duru M. (2012) Dynamics in farming systems: of changes and choices. In: Darnhofer I, Gibbon D and Dedieu BE (eds) *Farming Systems Research into the 21st Century: The New Dynamic.* Springer, 337-363.

Schmitz A. (2010) *Agricultural policy, agribusiness, and rent-seeking behavior*: University of Toronto Press.

Serfilippi E and Ramnath G. (2018) Resilience measurement and conceptual frameworks: a review of the literature. *Annals of Public and Cooperative Economics* 89: 645-664.

Seuneke P, Lans T and Wiskerke JS. (2013) Moving beyond entrepreneurial skills: Key factors driving entrepreneurial learning in multifunctional agriculture. *Journal of Rural Studies* 32: 208-219.

Shapiro B, Gebru G, Desta S, et al. (2015) Ethiopia livestock master plan. ILRI Project Report.

Shiferaw B, Obare G and Muricho G. (2006) Rural Institutions and Producer Organizations in Imperfect Markets: Experiences from Producer Marketing Groups in Semi-Arid Eastern Kenya. Socioeconomics and Policy Working Paper Series no. 23.

Smeets-Kristkova Z, Achterbosch T and Kuiper M. (2019) Healthy Diets and Reduced Land Pressure: Towards a Double Gain for Future Food Systems in Nigeria. *Sustainability* 11: 835.

SNV. (2013) Evaluation of the SNV Core Subsidy Funded Dairy Program Kenya-Evaluation Report. Evaluation done by Social Impact Consulting

Somda J, Tollens E and Kamuanga M. (2005) Transaction costs and the marketable surplus of milk in smallholder farming systems of The Gambia. *Outlook on Agriculture* 34: 189-195.

Sraïri MT, Benyoucef MT and Kraiem K. (2013) The dairy chains in North Africa (Algeria, Morocco and Tunisia): from self sufficiency options to food dependency? *SpringerPlus* 2: 1-13.

Sumberg J and Hunt S. (2019) Are African rural youth innovative? Claims, evidence and implications. *Journal of Rural Studies* 69: 130-136.

Team R. (2006) A language and environment for statistical computing. *Computing* 1.

ten Napel J, van der Veen AA, Oosting SJ, et al. (2011) A conceptual approach to design livestock production systems for robustness to enhance sustainability. *Livestock Science* 139: 150-160.

Termeer C and Metze T. (2019) More than peanuts: Transformation towards a circular economy through a small-wins governance framework. *Journal of Cleaner Production* 240: 118272.

Thornton PK and Herrero M. (2014) Climate change adaptation in mixed crop–livestock systems in developing countries. *Global Food Security* 3: 99-107.

Tittonell P. (2011) Farm typologies and resilience: The diversity of livelihood strategies seen as alternative system states. *5 th World Congress on Conservation Agriculture.*

Tittonell P. (2014) Livelihood strategies, resilience and transformability in African agroecosystems. *Agricultural Systems* 126: 3-14.

Tittonell P. (2020) Assessing resilience and adaptability in agroecological transitions. *Agricultural Systems* 184: 102862.

Tschirley DL, Snyder J, Dolislager M, et al. (2015) Africa's unfolding diet transformation: implications for agrifood system employment. *Journal of Agribusiness in Developing and Emerging Economies* 5: 102-136.

Udo HMJ, Aklilu HA, Phong LT, et al. (2011) Impact of intensification of different types of livestock production in smallholder crop-livestock systems. *Livestock Science* 139: 22-29.

Urruty N, Tailliez-Lefebvre D and Huyghe C. (2016) Stability, robustness, vulnerability and resilience of agricultural systems. A review. *Agronomy for sustainable development* 36: 15.

van Buuren S. (2007) Multiple imputation of discrete and continuous data by fully conditional specification. *Statistical Methods in Medical Research* 16: 219-242.

van Buuren S and Groothuis-Oudshoorn K. (2011) mice: Multivariate imputation by chained equations in R. *Journal of Statistical Software* 45: 1-67.

Van Campenhout B, Minten B and Swinnen J. (2019) Domestic versus export-led agricultural transformation: Evidence from Uganda's dairy value chain. LICOS-Centre for Institutions and Economic Performance, KU Leuven.

van de Steeg JA, Verburg PH, Baltenweck I, et al. (2010) Characterization of the spatial distribution of farming systems in the Kenyan Highlands. *Applied Geography* 30: 239-253.

van der Lee J, Dirbaba D, Minuye S, et al. (2018) The Dairy Feed Advancing Model-a Value Chain Innovation in the Ethiopian Dairy Sector. In: Research WU (ed) *ADIAS Research Brief 001.* Wageningen.

van der Lee J, Zijlstra J, Wouters AP, et al. (2014) Milking to Potential : Strategic Framework for Dairy Sector Development in Emerging Economies. Discussion paper. Wageningen: Wageningen University & Research centre, 30.

van der Ploeg JD. (2008) *The new peasantries: Struggles for autonomy and sustainability in an era of empire and globalization,* London: Earthscan.

van der Ploeg JD. (2010) Farming styles research: The state of the art. *Key note lecture for the workshop on 'Historicising Farming Styles'.* Melk, Austria.

van Dijk MP and Sverrisson Á. (2003) Enterprise clusters in developing countries: mechanisms of transition and stagnation. *Entrepreneurship & Regional Development* 15: 183-206.

van Melle C, Arinloye D, Coulibaly O, et al. (2013) Contribution to mango value chain development in Benin - A producer perception survey. In: al. ERPe (ed) *Proc. 4th International Symposium on Tropical and Subtropical Fruits.* Acta Hort. 975, ISHS 2013, 607-614.

Vandercasteelen J, Beyene ST, Minten B, et al. (2018a) Big cities, small towns, and poor farmers: Evidence from Ethiopia. *World Development* 106: 393-406.

Vandercasteelen J, Beyene ST, Minten B, et al. (2018b) Cities and agricultural transformation in Africa: Evidence from Ethiopia. *World Development* 105: 383-399.

Veldwisch GJ, Beekman W and Bolding A. (2013) Smallholder irrigators, water rights and investments in agriculture: Three cases from rural Mozambique. *Water Alternatives* 6: 125.

Verhees FJHM, Kuipers A and Klopcic M. (2011) Entrepreneurial Proclivity and Farm Performance:The Cases of Dutch and Slovenian Farmers. *The International Journal of Entrepreneurship and Innovation* 12: 169-177.

von Thünen JH. (1875) *The Isolated state in relation to land use and national economy,* Berlin: Schmaucher Zarchlin.

Voors MJ and D'Haese M. (2010) Smallholder dairy sheep production and market channel development: An institutional perspective of rural Former Yugoslav Republic of Macedonia. *Journal of dairy science* 93: 3869-3879.

Vroegindewey R and Hodbod J. (2018) Resilience of Agricultural Value Chains in Developing Country Contexts: A Framework and Assessment Approach. *Sustainability* 10: 916.

Waithaka MM, Thornton PK, Herrero M, et al. (2006) Bio-economic evaluation of farmers' perceptions of viable farms in western Kenya. *Agricultural Systems* 90: 243-271.

Walker B, Gunderson L, Kinzig A, et al. (2006) A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society* 11: 13.

Walker B, Holling CS, Carpenter SR, et al. (2004) Resilience, adaptability and transformability in social--ecological systems. *Ecology and Society* 9: 5.

Wedawatta G, Ingirige B and Amaratunga D. (2010) BUILDING UP RESILIENCE OF CONSTRUCTION SECTOR SMES AND THEIR SUPPLY CHAINS TO EXTREME WEATHER EVENTS. *International Journal of Strategic Property Management* 14: 362-375.

Wiklund J and Shepherd D. (2005) Entrepreneurial orientation and small business performance: a configurational approach. *Journal of Business Venturing* 20: 71-91.

Yin R. (2009) *Case study research: design and methods*: Sage Publications, Inc.

Zawacki-Richter O, Kerres M, Bedenlier S, et al. (2020) Systematic Reviews in Educational Research: Methodology, Perspectives and Application.

Zeleke T and Awulachew SB. (2014) Policy Analysis of Water for Productive Use among Smallholder Irrigators in Ethiopia. *Evaluation report.* Boston / Addis Abeba: OXFAM America.

Appendices

Appendix 2.1. Basic data on study areas

Table A shows basic data on dairy production as compared to crop production and other livestock. **Figures A** and **B** give a schematic representation of dairy value chains in both countries.

Table A. *Basic agricultural sector data for the study areas*

	Kenya (2014 data)			Ethiopia (2014–15)	
	Nandi	**Nyandarua**		**Arsi**	**East Shoa**
Population	753,000	659,848		2,637,657	1,356,342
Arable land *(ha)*	193,020	201,100		818,132	526,211
Area cropped *(ha, excl. tea (1))*	104,916	81,929		631,736	473,124
Livestock *(heads)*					
Dairy cattle	251,455	314,810	*(2)*		
Zebu cattle	45,584	30,620	Cattle	2,454,324	1,116,744
Small ruminants	70,048	426,027	Small ruminants	2,356,854	932,064
Poultry	605,097	445,145	Poultry	2,188,076	1,439,821
Equines	n.a.	10,633	Equines	678,711	330,603
Rabbits	n.a.	44,670			
Pigs	145	879			
Milk production *(Million kg)*	84	226	Milk production *(2) (Million kg)*	136	44
Agricultural turnover *(Million KES)*					
Milk	2,537	7,216		n.a.	n.a.
Potatoes	400	7,800	Cereals	1,369	877
Maize	2,700	421	Pulses	134	152
Other grains	12	232	Oilseeds	23	0
Beans	1,900	48	Vegetables	12	19
Tea *)	n.a	--	Root crops	53	36
Other	276	1,769	Permanent crps	11	3

Sources Kenya: (KNBS, 2015a; KNBS, 2015b) *Source Ethiopia: www.csa.gov.et*
(1) Tea statistics are maintained at national level. *(2) Data for 2013–2014*

The dairy sector in both countries is undergoing significant change. In Kenya, positive changes occur in all three domains. At *institutional level*, attention is growing for sector competitiveness in relation to other members of the East African Community and for milk quality, partly fuelled by media attention for safety of milk for consumers. *Value chain upgrading* examples include initiatives where cooperative companies and processors improve supplier loyalty through chain integration, e.g. by improved contracting and embedded services; increased participation of multi-national dairy companies works as stimulus; and farmers circumvent failing cooperatives by forming self-help groups that sell bulk (aggregated) milk to processors. Meanwhile, a number of innovations occur in the informal market[a]: pasteurized milk is sold through bulk dispensers in retail outlets that offer processed milk at two-thirds the price of packed milk, and traders rent processing capacity to sell unpacked pasteurized milk to bulk dispensers. At farm level, *technical upgrading* is increasing, including adoption of planted forage, forage preservation, and zero-grazing. In 'dairy cluster' Nyandarua (and to some extent in Nandi North), farmers have been aware of these upgrading options since the 1980s, but so far only the 'serious farmers with capital' invest in them; wider adoption is limited by uncertain milk prices.

Table A shows that, with similar populations and arable land areas, Nyandarua milk production was nearly three times that of Nandi, of which an estimated one-third is processed. Of the 193,000 hectares of arable land in Nandi, much was under commercial tea plantations. The significantly higher milk productivity and dairy focus in Nyandarua over Nandi is enabled by larger farm sizes (**Table 2.3**), higher percentages of improved breeds, larger number of providers of pre- and post-production services, and advantages in the enabling environment. Dairy farms in Nyandarua and Nandi South are overwhelmingly smallholdings, even though average farm size in Nyandarua is more than triple that in Nandi South in terms of hectares and double in terms of dairy cows; Nandi North has more non-dairy farmers (25% of farms) and more medium- and large-scale farms (24% of dairy farms, mostly owned by the descendants of the original Nandi population, while smaller farms are owned by post-independence settlers). In Nyandarua, average farm size is larger, but VCAI showed similar differences between early arrivals (West of Ol Kalou) and post-independence settlers (East of Ol Kalou).

The situation in L_dL_c Arsi cluster shows that a much higher than average percentage of improved breeds (**Table 2.3**) does not compensate for the bottlenecks in dairy market access and the competitive edge of grain production due to an improved input and service package.

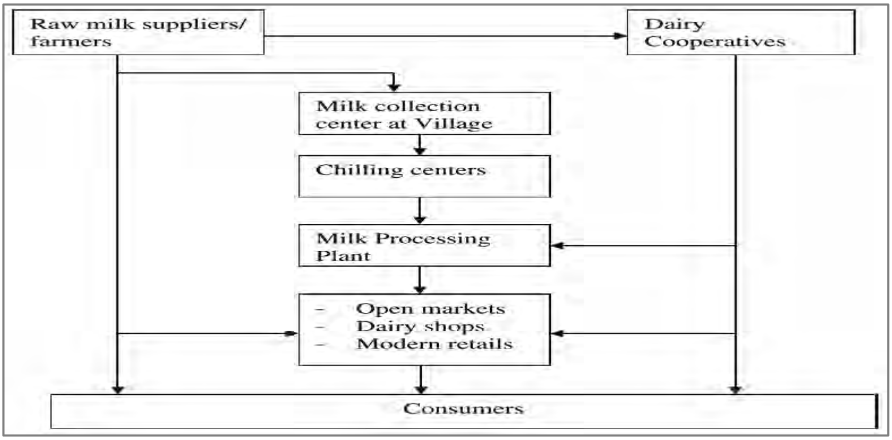


Figure A. *Dairy value chain structure in the greater Addis Ababa milkshed, Ethiopia. Source: (Ruben et al., 2017)*

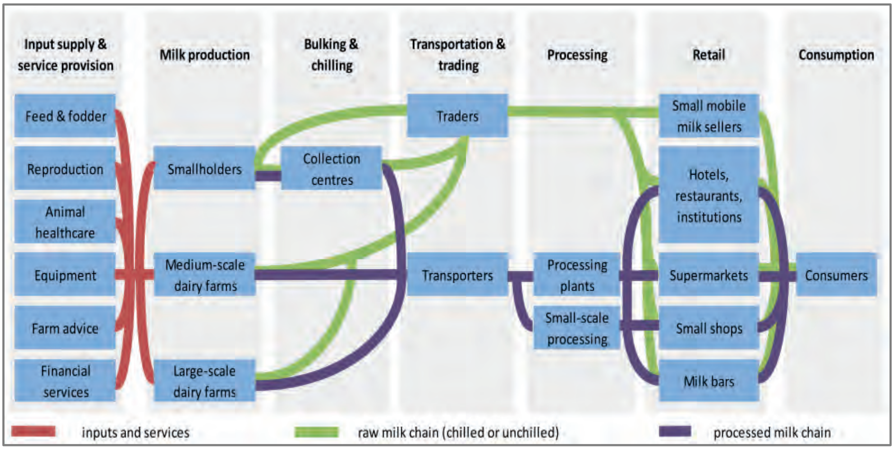


Figure B. *Overview of the dairy value chain in Kenya (Rademaker et al., 2016)*

Available online at http://www.mdpi.com/2071-1050/10/11/4324/s1

Notes:

[a] Bebe, Bockline Omedo, Ruth Njiru, Jan van der Lee, Catherine Kilelu, 2019. Assessing operational costs, consumer perceived risks and quality of milk from vending machine retail innovation in Kenyan urban markets (forthcoming)

Appendix 2.2. Cluster-wise description of upgrading dynamics

This section describes in more detail the dairy upgrading dynamics, summarized in **Table 2.2**, for the five clusters in Ethiopia and Kenya.

LdLc Arsi cluster, Ethiopia

Of the five clusters, Arsi is least progressed in *technical upgrading* of the 'typical' semi-subsistence mixed crop–livestock systems to more market-oriented systems (**Table 2.3** and **Figure 2.3**). In this area, which is particularly suited for dairy and has a long tradition of multi-functional cattle husbandry, transition from grazing land to cereal cropping was still evident very recently; farmers feel the pressure to change farming practices and reduce their number of cattle and sheep. Compared to the national average of 5.7%[a] dairy cows of improved breeds and 1.8% cattle of improved breeds (CSA, 2017), the proportion of improved breeds in the herd of interviewed dairy farmers is high (55%), primarily so in urban farms. This can be attributed to the crossbred bull and AI distribution of the breeding centre at Asella University, which has been active since the 1950s. This high proportion of crossbreds is despite the fact that due to poor road access, *value chain upgrading* to marketing outside the cluster never happened – farmers and cooperatives only market some butter to Southern Nations and Oromia regions in addition to local sales of milk and traditional dairy. Nevertheless, at 31% the proportion of milking cows in the herd is low, reflecting other uses including draft power and heifer breeding. Collection by a processor from Adama was quickly discontinued due to milk quality issues. The taboos on sale of fresh milk and dairy products are only gradually losing their impact as milk undergoes commodity individuation (Pearson and Schmidt, 2017). Because of these marketing constraints, dairy is primarily concentrated around the towns (i.e. consumer centres). Breeding heifers for sale and fattening calves and sheep are important livestock activities (see **Table 2.3**) and enable private feed sellers to have a presence. In terms of *institutional upgrading*, interviews showed that by the time main roads improved in the early 2010s, the public extension system's promotion of improved potato and grain variety packages, along with accompanying inputs and services, had already caused the balance to shift in favour of cash crops. Where roads and electricity are improved, more off-farm activities emerge. Various technologies have gradually gained popularity, starting with fertilizer (since the late 1980s), then agro-chemicals (since the late 1990s), then mechanization (since the late 2000s). The contracted equipment is owned by the urban elite, who invest in agriculture due to profitability of cash crops. Government-promoted dairy cooperatives primarily cater to local demand and are unable to offer significant additional services (**Table 2.4**). Hence, farmers largely depend on general public support services and their (subsidized) inputs but are unsatisfied with service quality. Some exceptional extension officers, additional veterinary and AI services provided by off-duty government staff, and one-off development projects have only a small effect on this situation.

L_dH_c East Shoa cluster, Ethiopia

Being located just south-east of the capital offers this cluster good access to end-markets, including for dairy, but also results in competition for space with infrastructure projects (e.g. express roads, railways); industry; and agribusiness, notably flower farms. Ongoing intensification leads to specialization, from food and cash crops to horticulture (40% non-dairy farms) and intensive livestock-keeping. This *technical upgrading* (**Table 2.3**) occurs especially in town. Dairy being maintained on larger rather than smaller farms could be an explanation for the larger farm size compared to those in the L_dL_c Arsi cluster, despite pressure on land. Adoption of technologies and innovations generally preceded that in L_dL_c Arsi cluster by about ten years, due to proximity to end-markets and information being available from livestock research and education institutes. For villages with good road connections, *value chain upgrading* over the past two decades, involving establishment of processing plants (including a cooperative plant), has made farmers less dependent on traders (**Table 2.4**). The large seasonal variation in milk prices and high feed prices discourage farmers, despite high average milk prices. Processors offer virtually no input services; these have to be obtained from the open market and from public providers. Due to the unreliability of government AI and veterinary services, farmers turn to private providers, who are mostly off-duty government staff. Feed suppliers abound, but so do poor quality feed and high prices. Little *institutional upgrading* is evident. Farmers complain about general lack of public support in terms of regulations for dairy and supply of industrial feeds and forage seeds. Access to finance for dairy is very limited and limits dairy expansion. Where possible, farmers rely on community groups, '*ekub'* and *'edir',* for mutual support on labour and capital. High prices of production factors and inputs and low availability of support services are seen as serious threats to the sustainability of dairy farming.

L_dH_c Nandi South cluster, Kenya

In Nandi South dairy, has clearly lost out to tea and horticulture. Dairy was strong until the early 1990s, even though farmers struggled with introducing exotic breeds due to tick-borne diseases such as East Coast Fever. After the collapse of the public dairy support services following the Structural Adjustment Plans of the World Bank and IMF in the early 1990s, most cooperatives collapsed, along with the state processor KCC (Kijima *et al.*, 2009). In effect, this resulted in *technical and market downgrading.* When the Cheptumo Tea Factory in the study area offered a good service support package, farmers shifted to tea: 30–40% of farmers have planted tea over the past four decades. The small farm sizes (<1 ha, **Table 2.3**) only allow for certain combinations of high-value crop and livestock production, i.e. tea, horticulture, and market-oriented livestock (**Table 2.3**). For cultural reasons, most farmers prefer to keep a few cows, even if they lack the space. The surplus milk is collected and marketed in Western Kenya by traders. The single small cooperative that was revived caters to local demand and sells to traders.

The transition to horticultural crops (vegetables and roots/tubers/bananas) and perennials (tea and fruit trees) is ongoing and applies to the large majority of farmers. Moreover, since the early 2010s nearly half of the farmers have reduced the size of their cow herds in favour of smaller livestock such as small ruminants, poultry, and rabbits. Tea plantations offer smallholders opportunities for casual labour. Around Kaptumo town more market-oriented, specialized dairy farmers, who take pride in breeding and good dairy management resulting in higher yields, plant forage and contract AI providers and veterinarians. Except for these 'serious' farmers with higher inputs and higher yields, the cluster shows low investments in forage production, breeding and health care, and productivity remains low. The low demand for services results in low market development efforts by input suppliers and service providers and low farmer satisfaction. In the remote parts of the cluster where little tea is grown, some farmers focus on fattening and some on breeding of heifers.

H_dH_c Nandi North cluster, Kenya

While issues of small farm sizes, disease threats, tea promotion, and the 1990s collapse of cooperatives apply to Nandi North as well, the dairy upgrading situation is markedly different from that in Nandi South. The main contributors to this appear to be the higher proportion of medium-scale and large farms, resulting in slightly larger farm sizes (average 1.56 vs. 0.83 ha, **Table 2.3**), and the presence of some stronger cooperatives. Larger farm sizes cause less pressure to replace maize with high-value, short maturation crops and livestock (about 60% of farmers as compared to 85% in Nandi South) and allow for multiple crop–dairy combinations: sugarcane or fruit trees next to tea. Individual farmer practices depend on their preferences and resources, especially labour and land. While around 20 out of 30 dairy cooperatives have collapsed since the late 1990s, the stronger dairy cooperative societies such as Tanykina, Lessos, and Kabyet are now able to effectively collect larger volumes of milk. *Value chain upgrading* is evidenced by their offer of pre- and post-production service packages. These include agro-veterinary input shops and loans. They thus attempt to offer a competitive alternative market to the traders mentioned above. Three processors collect milk. One of them has started to integrate input supply and service provision such as credit linkages in its supply chain. In the dry season, competition for milk is fierce and cooperatives often lose out to traders. Price fluctuations and inconsistent payment conditions in the chain have a negative effect, resulting in much market uncertainty for farmers. While traders ship milk to Western Kenya, the cooperatives sell to processors in Eldoret (Uashin Gishu County) and further afield. Cooperatives and the Kenya Dairy Farmers Federation are talking with Nandi County authorities about establishment of a dairy plant in the county, but viability is still uncertain. Although Nandi people are reportedly slow adopters of innovation, interviewees were positive about (resource-endowed) dairy farmers' adoption of new practices and approach to 'dairy as business', but also lamented the recent slump in milk prices as a threat to the sector. Interviewees were rather negative about *institutional upgrading* in terms of the county's policy support for dairy and its actual implementation, including vaccination, extension, and road maintenance. This was also reflected in farmers' information sources.

H_dH_c Nyandarua cluster, Kenya

This is clearly the most market-oriented dairy cluster of the five, in terms of volumes marketed, number of actors and input–output linkages, and competition between service providers. The high altitudes and cool weather favour dairy, potatoes, and cabbages over other crops – that is, if prices do not decline further. Spatial variation within the county stems from diversity in rainfall patterns, in farm sizes resulting from land allocation policies following independence, and in inherited household resources. Compared to Nandi County, farmers are more prone to looking at dairy as business; younger entrants in particular lead *technical upgrading*. Farmers invest in dairy or specialize in heifer breeding, bull fattening, or hay production. Yet a considerable proportion of farmers hesitate to invest in more intensive dairy production. The required investments in a zero-grazing unit (barn), forage storage, forage planting and preservation are seen as risky, due to high interest rates and uncertainties in the milk market (insufficient collection guarantees; fluctuating prices; and high retail price over farm-gate price ratios, up to a factor 3). *Value chain upgrading* is characterized by significant competition between around eight processors and a range of milk traders, some twenty dairy farmers' cooperative societies (of which the larger have become public companies), a large number of farmer self-help groups that supply directly to processors or traders, and pooling of milk between farmer groups to benefit from volume bonuses. Traders are starting to pasteurize milk to supply milk dispensers at supermarkets and milk bars. Processors and cooperative companies such as Ol Kalou Dairy compete through supply contracts (dependability), payment conditions, and integrated services (as they do in H_dH_c Nandi North). On the input side, competition is evidenced by elaborate distribution networks and training outreach of a number of animal drug, semen, and feed companies (around five companies each, compared to between one and three in Nandi County) and by around 200 AI technicians, giving farmers a choice between five and fifteen technicians and over five agro-input shops. There is less choice available for animal health care and hay. Unlike in Nandi clusters, Holstein-Friesian inseminations outnumber Ayrshires by three to two, denoting larger focus on production volume to meet market demand rather than on milk composition, feed economics, and disease resistance, in the absence of incentives for higher milk solids contents. Even though a large proportion of farmers were already using AI, the county government started a subsidized AI scheme in the pre-election year 'to increase farmer access to AI and to address high AI service prices'. Private and cooperative providers regard this as undue competition. *Institutional upgrading* is more evident in the increasing emphasis on qualifications of AI and animal health technicians by County government and the Kenya Veterinary Board, to address malpractice. Road and electricity construction are ongoing but remain an issue in remote areas.

Available online at http://www.mdpi.com/2071-1050/10/11/4324/s1

Notes

[a] *CSA (2017) data are inconclusive in this respect; they mention 674,765 exotic cows out of a total of 11,833,179 'milking cows' of which 7,155,114 are 'dairy cows' that are 'used for milk'.*

Appendix 2.3. Context conduciveness – the impact of dairy policy

Both countries have a turbulent history of public influence on agricultural service provision, contributing to large changes in Kenya and stagnation in Ethiopia.

In Ethiopia, public actors play an overriding role in access to inputs, services, capital, and land. Major past policy changes affecting dairy farming include collectivization of land and farmer organizations under the socialist regime (1974–1991). The incumbent Ethiopian People's Revolutionary Democratic Front regime has adopted agriculture-led industrialization as the principal development strategy, which equates to economic development that builds on upgrading of agriculture. Successive Agricultural Growth Programs are gradually giving more attention to dairy. If we take feedback in FGI and VCAI as practitioner opinions about the conduciveness of public support, the picture is bleak. The regulatory gaps for private AI, animal health services, and quality assurance of feed and the low policy priority for dairy compared to crops and meat received strong negative feedback. Positive impact was reported on the improved bull distribution program by the breeding farm at Asella University, which has been active since the 1950s and has resulted in relatively high proportions of exotic blood in the L_dL_c Arsi dairy herd. Some positive impact was reported from knowledge shared by colleges and research stations in Asella and Bishoftu. Relatively large positive impact was attributed to development projects, both multi-lateral and non-governmental.

In Kenya, the enabling environment has varied between counties since devolution of power in 2010 (Recha, 2018). Counties promote the commodities they are strong in, including dairy in Nyandarua and Nandi. This follows two decades of significant policy changes affecting dairy: very significant cuts in public services followed the Structural Adjustment Program of the IMF and World Bank (early 1990s, (Kijima *et al.*, 2009); the resulting collapse of the dairy sector was evidenced by the bankruptcy of many cooperatives and the state processor KCC (1999); and the market liberalization policy only gradually resulted in private service delivery, with private sector priority going to post-production services. Current government equipment and capacity-building support to dairy cooperatives was welcomed by farmers but was seen as being driven by political rather than sector interests. For example, an unused cooling tank at a cooperative society in Nyandarua was seen as 'a political cooler'. In Nandi, limited provision of equipment to cooperative societies regularly seemed to be used as an excuse for poor performance.

Many interviewees complained about lack of consistency and limited geographic coverage of public services for dairy. Public agencies have a (virtual) monopoly on vaccination for notifiable diseases in Kenya and on vaccination, AI, veterinary, and extension services in Ethiopia. For example, in Kenya, routine vaccinations for notifiable diseases are often replaced by ring vaccination upon outbreak, which may be late anyway due to staff capacity issues; inadequate preventative services for vaccination and tick-control result in high prevalence of diseases such as Foot and Mouth Disease, Lumpy Skin Disease and East Coast Fever. Public and community animal health services have not kept up with the transition to improved breeds, which have higher genetic production potential but lower resistance to diseases. Ayrshires are perceived to be more disease-tolerant than Holstein-Friesians but still need good preventative measures. Withdrawal of dairy extension services in the 1990s resulted in declining farmer skills and ultimately in declining yields. Small milk sales volumes allow for purchase of very few external services. Farmers in Nyandarua acknowledge that the county government recognizes problems in dairy support services, but they see it as choosing the wrong instruments to address them, such as public investment in processing plants and subsidized public AI services.

In both countries, governments use subsidies to promote uptake of more market-oriented practices and to make services more accessible to farmers in remote locations and with fewer resources. However, eligibility conditions and implementation flaws can have adverse effects. In Kenya, interviewees mentioned many downsides to the county government subsidizing inputs such as fertilizer distribution, cooling equipment, and the AI system. Though relatively well designed in terms of accountability and pricing, the latter is still vulnerable to political whim (i.e. risk of discontinuation). In Ethiopia, public monopolies on most inputs and services lead to insensitivity to demand, a focus on select clients and lack of a level playing field for private providers. In principle, public services should be open to all farmers who meet the criteria, but in practice, the focus may be on farmers who are easy to reach (geographically or socially). A supply- driven rather than demand-driven system results in competition with private providers for accessible clients, while the more remote farmers may not receive services from either type. The net result may be unfair competition for private providers as well as low coverage and low service quality levels for farmers. In both countries, subsidies seem to have also created dependency on chemical fertilizers, with manure becoming relatively expensive. The has led to soil fertility issues, such as leaching and acidification. The injudicious use of agro-chemicals is affecting human health, water quality, and product quality.

The clusters studied are not prone to natural disasters, but they are subject to marked seasonality of production and the occasional drought. Farmers do worry about more erratic weather, but they worry more about the threat of disease, to which exotic breeds and crossbreds are more susceptible.

In summary, dairy farming development in Kenya was punctuated by market liberalization policies connected to the Structural Adjustment Program in the early 1990s. Major cuts in public service supply initiated a collapse of the (processed milk) sector, which has taken a significant part of the past 25 years to recover. In contrast, the Ethiopian dairy sector saw no such disruption, but low consumer demand and lack of conducive policies have not led to a flourishing sector. Despite many development interventions supporting a formal sector, the market share of pasteurized and packaged products has not yet exceeded 2% (Makoni *et al.*, 2014).

Available online at http://www.mdpi.com/2071-1050/10/11/4324/s1

Appendix 3.1. Study area and site selection

In each country, a study area with good agroecological potential for dairy and a dairy tradition was selected (located between 1,750 and 3,000 m.a.s.l.). After scoping of collection and service infrastructure, a double gradient in terms of density of i) input supply services and ii) output marketing services was selected in each study area (see maps in **Figure 3.5**):

I. *Primary gradient* – Three locations (I-III) with dairy potential along a market quality gradient (at increasing travel time from urban market (T_3 in **Figure A**) and getting less connected). In East Shoa and Arsi zones, Ethiopia, locations were selected along the axis from the urban centre Addis Abeba to remote parts of Arsi Zone; in Nyandarua County, Kenya, locations were selected along the axis of secondary town Nyahururu to remote parts of Kipipiri sub-county. The resulting selection in either country can be characterized as:
   - location (I) being a town centre of 50-100,000 people that is (relatively) close to a major urban centre with strong market pull, where multiple milk collection centres are available – in Kenya, this was Ol Kalou town, in Ol Kalou sub-county, Nyandarua County, 35 km from Nyahururu town; in Ethiopia, this was Bishoftu town in Ada'a District, East Shoa Zone, Oromiya Region, 60 km from Addis Abeba city; both locations have good connections to urban markets by major tarmac roads;
   - location (II) being a small town service centre with moderate market pull, with input shops and one or few (preferably chilled) milk collection centres, accessible by tarmac road – in Kenya, this was Wanjohi, Kipipiri sub-county, Nyandarua County (23 km from Ol Kalou); in Ethiopia, this was Bek'oji in Limu-Bilbilo District, Arsi Zone, Oromiya Region (175 km from Bishoftu);
   - location (III) being a small rural centre that is considered remote by local standards, accessible by gravel road, offering some services – in Kenya, this was Geta, Kipipiri sub-county, Nyandarua county (13 km from Wanjohi); in Ethiopia this was Digelu in Digelu-Tiyo District, Arsi Zone, Oromiya Region (14 km from Sagure).

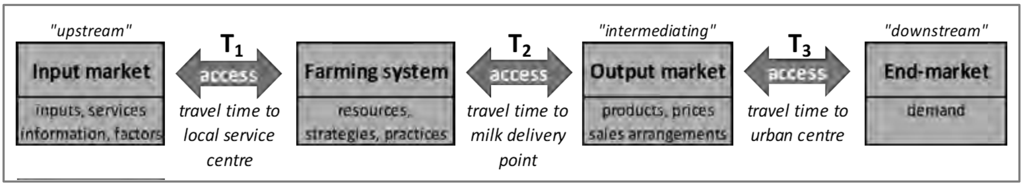


Figure A. *Analytical framework – spatial factors in market quality affecting farming intensity and market participation of dairy farmers. N.B. T_1 and T_2 denote sub-location effects, T_3 denotes location effects*

Areas with plantations, areas where agroecology favours cash crops over dairy (due to lower altitude and rainfall) and areas where no secondary gradient could be selected for geographical reasons were not selected, explaining the relatively large distance between Bishoftu and Bek'oji.

II. *Secondary gradient:* in each of the locations I-III in each country, a secondary gradient was established with three sub-locations each (a.-c.), differing in travel time T1 from 'the market' (a local service centre with input and service providers and output marketing opportunities) from all-weather roads[a]: (a) accessible – around local service centre, close to all-weather roads; (b) semi-accessible – 45-60 minutes' walk from local service centre, accessible by feeder roads; and (c) remote – 0.5-1 hour walk from feeder road, 1.5 -2 hours walk from local service centre, located along farm roads. This gradient is an elaboration of distinctions made by Gebremedhin *et al.* (2014).

Notes:

[a] Roads were classified as:

- *all-weather roads* that farmers can travel on with either private or public transport and that vehicles of input and service providers can travel on, year-round;
- *feeder roads* with minor surfacing that can be used part of the year, and
- *farm roads* that cannot be used by vehicles at all, irregularly or with much difficulty;

Milk collection trucks can traverse the first two types only.

Appendix 3.2. Computed variables

Table numbers 0 and a-e correspond to Table numbers 0 and a-e in ***Supplementary material 3.***

Table 0. *Independent variables – travel times*

VARIABLE DESCRIPTION	EQUATION
T1 – travel time to access inputs and services from this farm (minutes)	= (FodderSeed_TravTime + DairyMeal_TravTime + OilSeed_TravTime + WheatBran_TravTime + WheatShort_TravTime + MinSalt_TravTime + Vet_TravTime + Treatment_Deworming_TravTime + DipAcaracides_TravTime + Vaccination_TravTime + AI_TravTime) / (count of variables with values)
T2 – travel time to access market for dairy products (minutes)	= (TimeMilkC ollectionPoint+ TimeButterSellingPoint + TimeCheesSellingPoint + TimeYogurtSellingPoint)/(count of variables with values)
T3 – travel time to end-market from local service centre (in minutes)	Estimation based on interviews, survey data, and own observations

Table a. *Quality parameters of input and output markets – no computations*

Table b. *Scarcity of land, household water, labour and capital*

VARIABLE DESCRIPTION	EQUATION (KENYA)	EQUATION (ETHIOPIA)
Household with off-farm income (Yes/No)	'Yes' if farm household has off-farm occupation (Var16)	Idem
Total farm size (hectares) – *this variable was given a minimum value of 0.05 hectares*	= (AcrgeOwned+AcrgeLeased'=) TotalLandUsed_Acr*0.4046856	= ha_owned + ha_leased
Livestock land (hectares)	'= (forageLand + GrazelandOwn + Grazeland Rent'=) LivestockLandFarm_Acr * 0.046856	= forageland_ha + GrazelandOwn + GrazeLandRent
Forage land (hectares)	= (acrg_forage1+acrg_forage2+ acrg_forage3+acrg_forage4'=) forageLand_Acr*0.4046856	as is, no computation
Grazing land owned (hectares)	= GrazelandOwn (Acres) * 0.4046856	as is, no computation
Livestock land as proportion of all farm land (ha)	= (LivestockLandFarm_Ha/ TotalLandUsed_Ha)*100%	Idem
Forage land as proportion of all land	= forageLand_Acr / TotalLandUsed_Acr * 100%	= forageLand_Ha / TotalLandUsed_Ha * 100%
Forage land as proportion of livestock land	= forageLand_Acr / LivestockLandFarm_Acr * 100%	= forageland_Ha / LivestockLandFarm_Ha
Total land for food crops (hectares)	= (AcrgFoodCrop1 +AcrgeFoodCrop2'=) FoodCropLand_Acr * 0.4046856	no data for Ethiopia
Total land for cash crops (hectares)	= (AcrgCashCrop1 + AcrgCashCrop2 + AcrgCashCrop3 + AcrgCashCrop4'=) CashCropLand_Acr * 0.4046856	no data for Ethiopia

Total land for crop farming (hectares)	= (FoodCropLand + CashCropLand'=) Land_Crop_Acr * 0.4046856	as is, no computation
Other land use (hectares) – *this variable was given a minimum value of 0.01 hectares*	= (TotalLandUsed_Acr – FoodCropLand – CashCropLand – forageLand – LandOn-farm – GrazelandOwn – GrazelandRent'=) LanduseOther_Acr * 0.4046856	= LanduseOther_Ha

Table c. *Dairy farming intensity – use of external inputs and services*

VARIABLE DESCRIPTION	EQUATION (KENYA)	EQUATION (ETHIOPIA)
Farmer purchasing fodder (Yes/No)	'Yes' if farmer purchases hay, straw, stalks & stovers	Idem
Farmer purchasing feed (Yes/No)	'Yes' if farmer purchases feed	Idem
Farmer purchasing crop residues or byproducts (Yes/No)	'Yes' if farmer purchases crop residues or by-products	Idem
External feed use (kg/cattle TLU)	= (DMeal_KgQttyYR + MinSaltKgQttyYr + BojiLocSalt_KgQttyYr + OilSeedCake_KgQttyYr + WhBran_KgQttyYr + WhShort_KgQttyYr + ORMByPr_KgQttyYr BrewPoult_KgQttyYr) / TotalCattleTLU	Idem
External fodder use (kg/cattle TLU)	= (HayGrFodd_KgQttyYr + Straw_KgQttyYr + StlkStov_KgQttyYr)/TotalCattleTLU	Idem
Average cost per veterinary service (KES)	= Average of min and max (Var536–537)	Idem
Total costs for inputs and services per year (KES)	=Feed_CostYr+Fodder_CostYr+OthIS_CostYr	Idem
Fodder costs per year (hay, straw, stalks and fodder seed)	=HayGrFodd_CostYr+Straw_CostY r+StlkStov_CostYr+FodSeed_CostY r	Idem
Annual cost of purchased fodder	=HayGrFodd_CostYr+Straw_CostYr+StlkStov_C ostYr	Idem
Feed costs per year	=DMeal_CostYr+MinSalt_CostYr+BojiLocSalt_C ostYr+OilSeed_CostYr+WhBran_CostYr+WhSho rt_CostYr+ORMByPr_CostYr+BrewPoult_CostYr	Idem
Costs of other (non-feed/fodder) inputs and services per year	=Vet_CostYr+TreatDew_CostYr+DipAc_CostYr+ Vacc_TotCostYr+Bull_TotCostYr+AI_TotCostYr+ FTool_CostYr+DairyUt_CostYr	Idem
Annual cost for purchased feed per total farm TLU	=Feed_CostYr/Farm TLU	Idem
Annual cost for purchased fodder per total farm TLU	=Fodder_CostYr/Farm TLU	Idem
Annual cost of purchased fodder seed per total farm TLU	=FodSeed_CostYr/Farm TLU	Idem
Annual cost for drugs per total farm TLU	=TreatDew_CostYr/Farm TLU	Idem
Annual cost for veterinary services per total farm TLU	=Vet_TotAmntYr/Farm TLU	Idem
Annual cost for AI services per total farm TLU	=AI_TotCostYr/Farm TLU	Idem
Annual cost for farm tools per total farm TLU	=FTool_CostYr/Farm TLU	Idem
Costs for other inputs and services per cattle TLU	= Costs of non-feed/fodder inputs and services per year / Total Cattle TLU	Idem
External IS Costs/Cattle TLU	=TotalCostsIS_Yr/TotalCattleTLU	Idem
Annual cost for purchased feed per cattle TLU	=Feed_CostYr/TotalCattleTLU	Idem
Annual cost for purchased fodder per cattle TLU	=Fodder_CostYr/TotalCattleTLU	Idem
Annual cost of purchased fodder seed per farm TLU	=FodSeed_CostYr/TotalCattleTLU	Idem

Annual cost for drugs per cattle TLU	=TreatDew_CostYr/TotalCattleTLU	Idem
Annual cost for veterinary services per cattle TLU	=Vet_TotAmntYr/TotalCattleTLU	Idem
Annual cost for AI services per cattle TLU	=AI_TotCostYr/TotalCattleTLU	Idem
Annual cost for farm tools per cattle TLU	=FTool_CostYr/TotalCattleTLU	Idem
Annual cost for purchased feed per dairy cow	=Feed_CostYr/DairyCow_Tot	Idem
Annual cost for purchased fodder per dairy cow	=Fodder_CostYr/DairyCow_Tot	Idem
Annual cost of purchased fodder seed per dairy cow	=FodSeed_CostYr/DairyCow_Tot	Idem
Annual cost for drugs per dairy cow	=TreatDew_CostYr/DairyCow_Tot	Idem
Annual cost for veterinary services per dairy cow	=Vet_TotAmntYr/DairyCow_Tot	Idem
Annual cost for AI services per dairy cow	=AI_TotCostYr/DairyCow_Tot	Idem
Annual cost for farm tools per dairy cow	=FTool_CostYr/DairyCow_Tot	Idem
Number of Information Sources Used	Count of Information sources used by farmer	Idem

Table d. *Dairy farming intensity – dairy farming objectives and actual livestock production*

VARIABLE DESCRIPTION	EQUATION (KENYA)	EQUATION (ETHIOPIA)
Total herd size (TLU)	= Total cattle(TLU) + no of chickens*0.01 + no of donkeys*0.4 + no of horses*0.8 + no of sheep*0.1 + no of goat*0.1	Idem
No. of equines (horses, mules and donkeys)	= No of horses + no of donkeys	= No of horses + no of mules + no of donkeys
No. of small ruminants (sheep and goats)	= No of sheep + no of goats	Idem
Total cattle (TLU)	= LactCowLoc*0.7 + LactCowCross*1.3 + LactCowExot*1.7 + DryCowLoc*0.7 + DryCowCross*1.3 + DryCowExot*1.7 + HeiferLoc*0.5 + HeiferCross*1.1 + HeiferExot*1.2 + CalveLoc*0.2 + CalveCross*0.25 + CalveExot*0.3 + BullLoc*0.8 + BullCross*1.6 + BullExot*2 + OxenTot*1.1	Idem
Total number of cattle owned	= TotalCattleOwned	= LactCowTot + DryCowTot + HeiferTot + CalveTot + BullTot + OxenTot or : CattleLoc + CattleCross + CattleExot
Total number of local cattle	= MilkCowLocal + HeiferLoc + CalveLoc	= LactCowLoc + DryCowLoc + HeiferLoc + CalveLoc + BullLoc + OxenLoc
Total number of cross cattle	= MilkCowCross + HeiferCross + CalveCross	= LactCowCross + DryCowCross + HeiferCross + CalveCross + BullCross + OxenCross
Total number of exotic cattle	= MilkCowExot + HeiferExot + CalveExot	= LactCowExot + DryCowExot + HeiferExot + CalveExot + BullExot + OxenExot
Total all milking cows (KE) or dairy cows (ET)	= MilkCowNr (1..–8.)	= DairyCowLoc + DairyCowCross + DairyCowExot
Total local milking cows (KE) or dairy cows (ET)	= MilkCowNr (6. Sahiwal, 7. Boran, 8. Zebu)	= LactCowLoc + DryCowLoc
Total cross milking cows (KE) or dairy cows (ET)	= MilkCowNr(5. Crossbred) + DryCowCross + HeiferCross + CalveCross + BullCross + OxenCross	= LactCowCross + DryCowCross
Total exotic milking cows (KE) or dairy cows (ET)	= MilkCowNr (1. Friesian, 2. Ayrshire, 3.Guernsey, 4.Jersey	= LactCowExot + DryCowExot
Proportion dairy cattle of local breed in herd	= (DairyCattleLocal/ DairyCattleTotal) *100%	= (DairyCattleLocal/ CattleTotal) *100%

Proportion of milking cows in herd	= Milking CowTot/Total Cattle*100%	= DairyCowsTot / CattleTot * 100%
Proportion of milking cows that is local	= DairyCowLocal/DairyCowTot *100%	Idem
Proportion of milking cows that is crossbred	= DairyCowCross/DairyCowTot *100%	Idem
Proportion of milking cows that is exotic	= DairyCowExot/DairyCowTot *100%	Idem
Proportion of cows currently lactating	= LactCowTot/Total Cattle*100%	= LactCowTot / CowTotal %
Proportion of youngstock that is local	= (CalveLocal+HeiferLocal)/ (CalveTot + HeiferTot) *100%	Idem
Proportion of youngstock that is crossbred	= (CalveCross+HeiferCross)/ (CalveTot + HeiferTot) *100%	Idem
Proportion of youngstock that is exotic	= (CalveExot+HeiferExot)/ (CalveTot + HeiferTot) *100%	Idem
Cattle as proportion of total herd (TLU)	= TotalCattle(TLU)/Farm TLU*100%	Idem
Stocking rate for all farm land (TLU/ha)	= FarmTLU/TotalLandUsed_Ha	Idem
Stocking rate for livestock land (TLU/ha)	FarmTLU/LivestockLandFarm_Ha	Idem
Proportion of milking cows lactating	= PercLactCow/PercMilkCow *100%	Idem
Average milk production per cow per day	= MilkProdCowAver	= (MilkProdLocAver + MilkProdImpAver)/2
Minimum milk production per cow per day	= MilkProdCowMin	= (MilkProdLocMin + MilkProdImpMin)/2
Maximum milk production per cow per day	= MilkProdCowMax	= (MilkProdLocMax + MilkProdImpMax)/2
Average milk production per farm per day	= MilkProdFarmAver	Idem
Annual milk production per hectare of farm land	=MilkProdFarmAver/TotalLandUse_Ha	Idem
Annual milk production per hectare of livestock land	=MilkProdFarmAver/LivestockLandFarm_Ha	Idem
Rank dairy objective for build-up household assets – house, land, savings, insurance – or for other business	Combines ranks for (Var188) Assets and (Var189) Other business	Idem
Rank dairy objective for other purposes	Combines ranks for all dairy objectives except for Var 184–186) Food, Income and Education fees	Idem
Since when farms produce milk	= 01.01.2016 minus StartDairyFarm	Idem
Livestock production other than dairy (Yes/No)	'Yes' if doing beekeeping, chicken production, or fattening	Idem

Table e. *Output marketing and margins*

VARIABLE DESCRIPTION	EQUATION (KENYA)	EQUATION (ETHIOPIA)
Farmer using formal marketing channel (Yes/No)	'Yes' if (Var199) has 'Processor' or 'Cooperative/Union'	Idem
Proportion of milk marketed	= MlkBttrYog_TotSoldYr / (MilkProdFarmAver*365)*100%	Idem
Total volume of milk and milk products sold in kg milk equivalent/year (milk, butter and yogurt)	= MilkSoldKgYr + Butter_SoldKgYr*18 + Yog_SoldLitYr	Idem
Milk, butter or yogurt sold in kg milk equivalent per hectare	=MlkBttrYog_TotSoldKgYr/TotalLandUsed_Ha	Idem
Milk, butter or yogurt in kg milk equivalent sold per cattle TLU	=MlkBttrYog_TotSoldKgYr/TotalCattleTLU	Idem
Milk, butter or yogurt in kg milk equivalent sold per lactating cow	=MlkBttrYog_TotSoldKgYr/CattleTotal*PercLactCow	Idem
Milk, butter or yogurt in kg milk equivalent sold per milking cow	=MlkBttrYog_TotSoldKgYr/DairyCowTotal	Idem
Dairy income from all dairy products – milk, butter, cheese, yogurt	=Milk_IncmYr+Butter_IncmYr+Chees_IncmYr+Yog_IncmYr	Idem
Dairy income per hectare	=DairyInc/TotalLandUsed_Ha	Idem
Dairy income per lactating cow	=DairyInc/CattleTot*PercLactCow	Idem
Dairy income per milking cow	=DairyInc/DairyCowTot	Idem
Total costs for purchased inputs and services per kg milk equivalent marketed	=TotalCostsIS_Yr/MlkBttrYog_TotSoldKgYr	Idem
Feed costs per kg milk equivalent marketed	=Feed_CostYr/MlkBttrYog_TotSoldKgYr	Idem
Fodder costs per kg milk equivalent marketed	=Fodder_CostYr/MlkBttrYog_TotSoldKgYr	Idem
Costs of non-feed/fodder inputs and services per kg milk equivalent marketed	=Inputs_CostYr/MlkBttrYog_TotSoldKgYr	Idem
MAEFC (Margin after external feed cost)	= (Var644) DairyIncome – (Var652) Annual Feed Costs – (Var653) Annual Fodder Costs	Idem
MAEFC per hectare	=MAFC/(Var 24)TotalLandUsed_ha	Idem
MAEFC per dairy cow	=MAFC/(Var45)DairyCowTotal	Idem
MAEFC per kg milk equivalent marketed	=MAFC/(Var202)MilkButterYogurt_TotalSoldKg/Yr	Idem

Appendix 3.3. Additional graphs on key variables

All graphs show clusters for sub-location groups (i.e. a-b-c categories of proximity to local service centre), with three sub-locations Ix, IIx, IIIx per category per cluster. Each regression line represents one sub-location (i.e. one village).

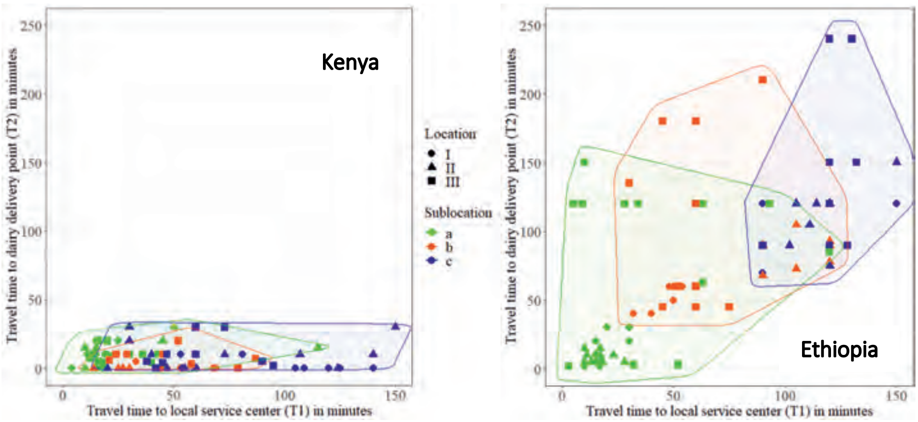


Figure A. *Travel time to dairy delivery point (T_2) vs. Travel time to local service centre (T_1), both in minutes*

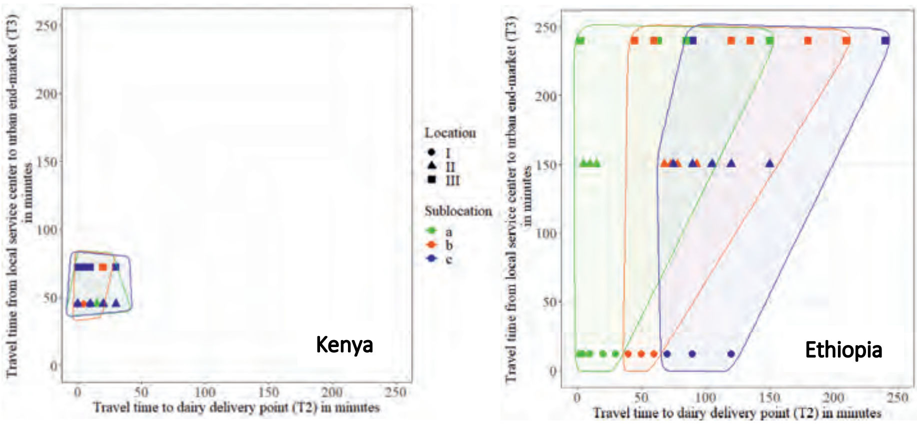


Figure B. *Travel time to dairy delivery point (T_2) vs. Travel time to end-market (T_3), both in minutes*

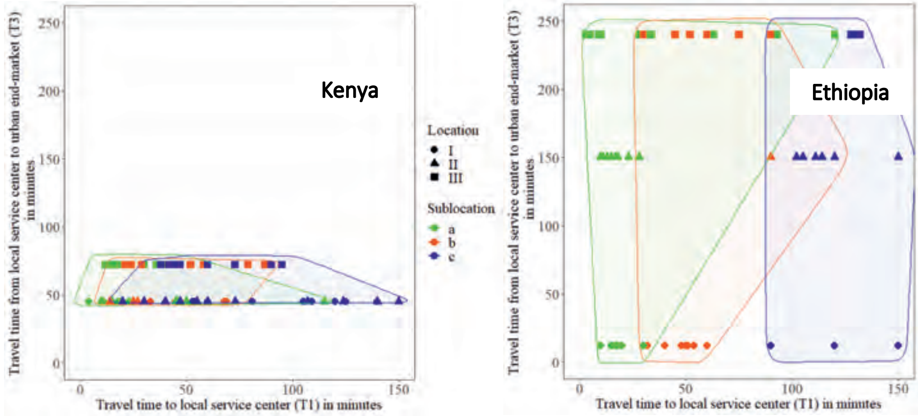


Figure C *T_3 vs. Travel time to local service centre (T_1), both in minutes*

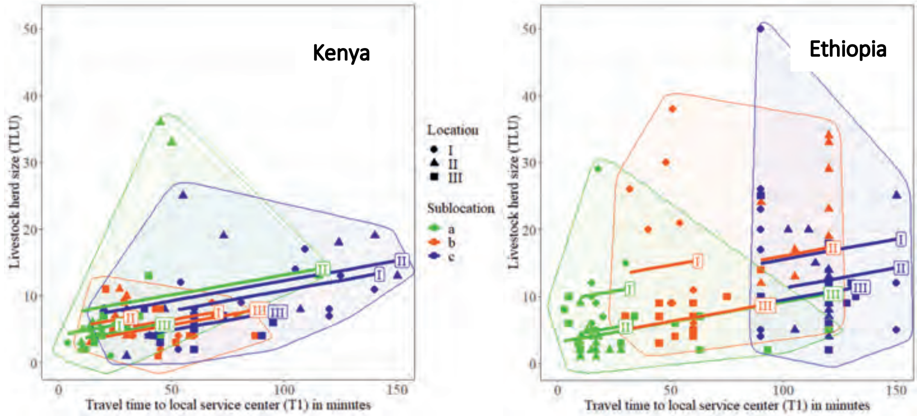


Figure D. *Livestock herd size (TLU) vs. Travel time to local service centre (T_1, in minutes)*

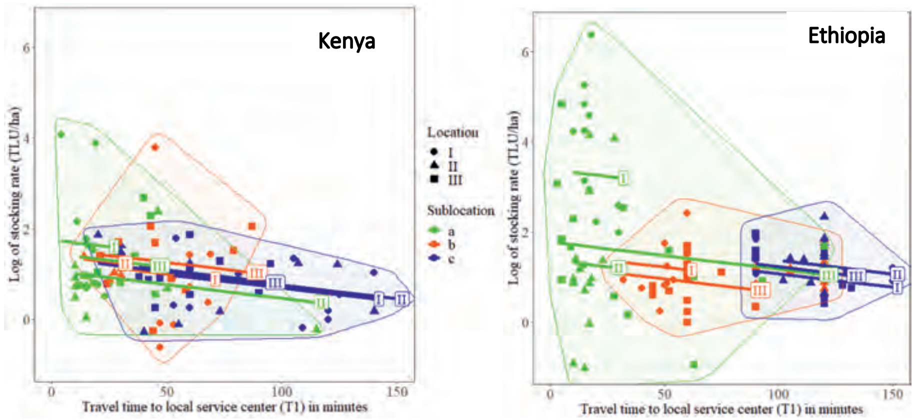


Figure E. *Log of stocking rate (log(TLU/ha)) vs. Travel time to local service centre (T_1, in minutes)*

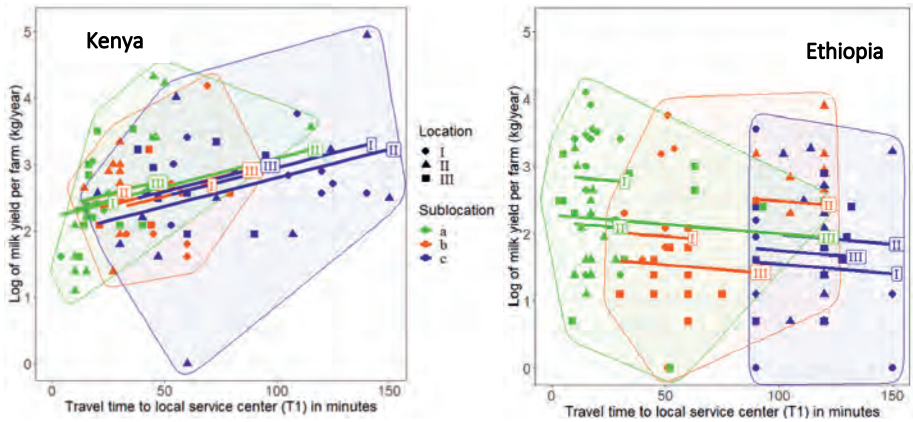


Figure F. *Log of milk yield per farm vs. Travel time to local service centre (T_1, in minutes) – displayed as* ***Figure 3.3*** *in text*

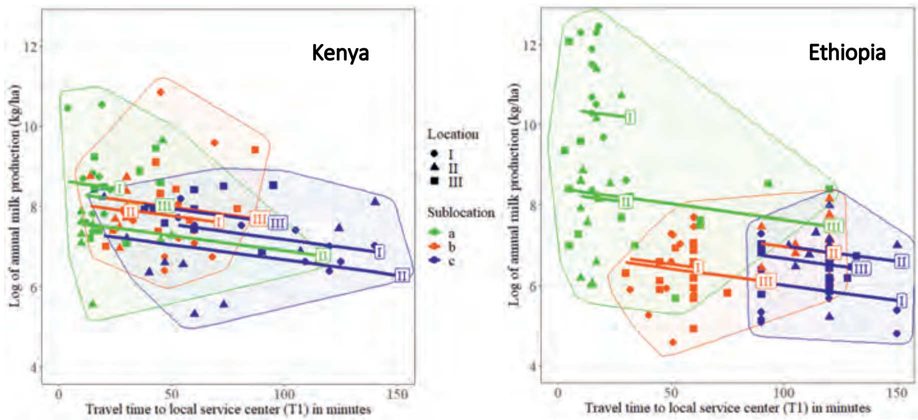


Figure G. *Annual milk production (kg/ha) vs. Travel time to local service centre (T_1, in minutes)*

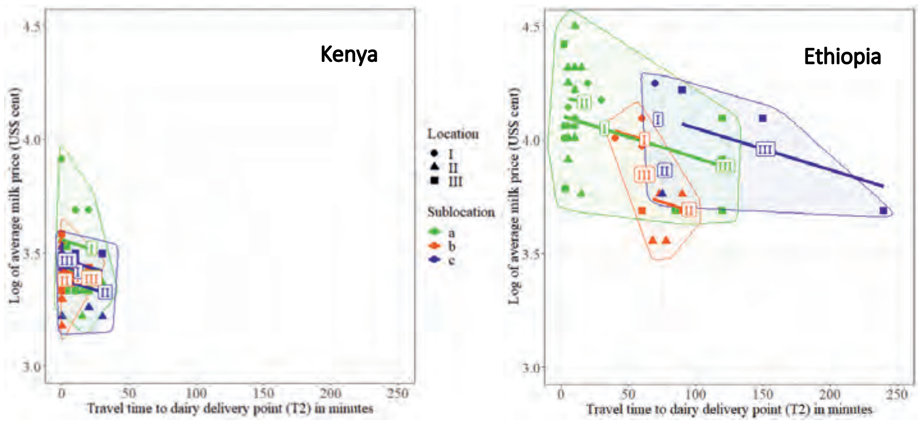


Figure H. *Average milk price (US$ cent) vs. Travel time to dairy delivery point (T_2) (minutes)*

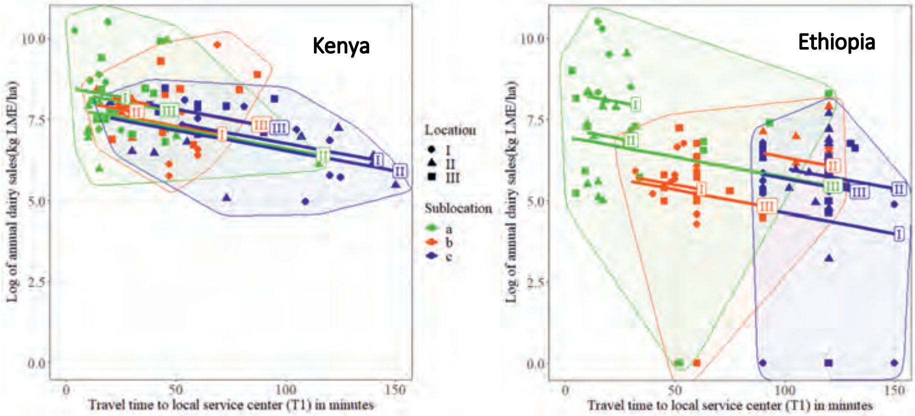


Figure I. *Log of annual dairy sales (log(kg LME/ha)) vs. Travel time to local service centre (T_1, in minutes)*

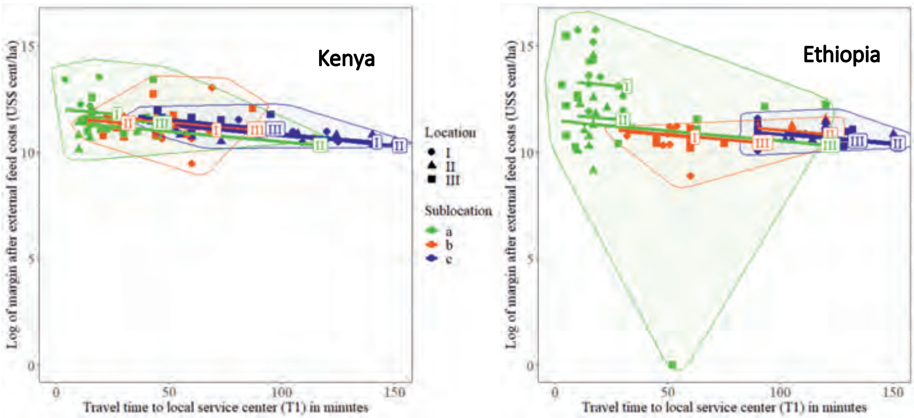


Figure J. *Log of margin after external feed costs (log(US$ cent/ha)) vs. Travel time to local service centre (T_1, in minutes)*

Appendix 5.1. Key heuristics as defined by Walker *et al.* (2006)

Patterns of abrupt change (Gunderson 2003) are described, in a handful of heuristics. The first two describe the dynamics of systems within and across scales, whereas the last three are the properties of socio-ecological systems that determine these dynamics. Each is described in the following sections, and together they provide the foundation for the subsequent propositions.

Adaptive cycle (Figure a.)

Over time, the structures and functions of systems change as a result of internal dynamics and external influences, resulting in four characteristic phases described by Holling (1986, 2001) for the dynamics of ecological systems. The first is a phase of growth (r), characterized by readily available resources, the accumulation of structure, and high resilience. As structure and connections among system components increase, more resources and energy are required to maintain them. The second phase is thus one in which net growth slows and the system becomes increasingly interconnected, less flexible, and more vulnerable to external disturbances. This is described as the conservation phase (K). These two phases, r to K, called the fore loop, correspond to ecological succession in ecosystems and constitute a development mode in organizations and societies. Disturbances lead to the next phase, a period of release of bound-up resources (W) in which the accumulated structure collapses, followed by a reorganization (a) phase, in which novelty can take hold, and leading eventually to another growth phase in a new cycle. These two phases are referred to as the back loop. The new r phase may be very similar to the previous r phase, or it may be quite different. Many systems appear to move through these four phases, described as the adaptive cycle, including ecosystems (e.g., Holling 1986), social systems (e.g., Westley 2002), institutional systems (e.g., Janssen 2002), and social-ecological systems (e.g., Gunderson *et al.* 1995, Holling *et al.* 2002).

Panarchy

Social-ecological systems have structures and functions that cover wide ranges of spatial and temporal scales. Most structures are not scale invariant, but rather occupy discrete domains in space or time. All of these structures are posited to change in the phases described in the previous paragraph at a given scale. Structures and processes are also linked across scales, based on the interactions between slow and broad structures and processes as well as those that are fast and small. These interactions can be characterized as either hierarchical confinement or panarchical relations. Hierarchical confinement is demonstrated when slow, broad features constrain and shape the small, fast ones (Allen and Starr 1982, O'Neill *et al.* 1986). Panarchical relations suggest that both top-down and bottom-up interactions occur (Gunderson and Holling 2002). The dynamics of a system at a particular scale of interest, i.e., the focal scale, cannot be understood without taking into account the dynamics and cross-scale influences of the processes from the scales above and below it. Examples include disturbance dynamics such as forest fires (Peterson 2002), forest pest outbreaks (Ludwig *et al.* 2002), or

Native American societies (Delcourt and Delcourt 2004). Recent work on resilience suggests that many of the observed shifts, crises, or nonlinearities observed in ecological systems are from processes and structures interacting across scales (Gunderson and Holling 2002, Walker and Meyers 2004).

Resilience

Resilience is the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity. It follows Holling's (1973) notion of resilience as the amount of disturbance a system can absorb without shifting into an alternate regime. Social-ecological systems exhibit thresholds that, when exceeded, result in changed system feedbacks that lead to changes in function and structure. The system is said to have undergone a regime shift (e. g., Scheffer *et al.* 2001, Carpenter 2003) that may be reversible, irreversible, or effectively irreversible, i.e., not reversible on time scales of interest to society. The more resilient a system, the larger the disturbance it can absorb without shifting into an alternate regime. In general, the state of a system at any one time can be defined by the values of the variables that constitute the system. For example, if a rangeland system is defined by the amounts of grass, shrubs, and livestock it contains, then the state space is the three-dimensional space of all possible combinations of the amounts of these three variables. The dynamics of the system are reflected as its movement through this space. In complex ecological and social-ecological systems, the term 'alternate states' is a misnomer. Configurations of states in which the system has the same controls on function, i.e., the same feedbacks, and essentially the same structure represent different states within the same system regime. Configurations in which the kinds or strengths of feedbacks differ and in which there are different internal controls on function represent alternate system regimes with thresholds between them. These alternate regimes can have significantly different implications for society and so, from a purely human point of view, may be considered desirable or undesirable. That desirability can be expressed in economic terms (Carpenter and Brock 2004); in ecological terms, i.e., the flow or production of ecosystem services (Walker and Meyers 2004); or in social terms (Scheffer *et al.* 2000, 2002). Some system regimes may be considered desirable by one segment of society and undesirable by another. In addition, some regimes that are considered undesirable can also be very resilient, e.g., harsh dictatorships and desertified regions of the Sahel.

Adaptability

Adaptability is the capacity of the actors in a system to manage resilience. Complex adaptive systems are generally characterized by self-organization without system-level intent or centralized control. Humans, however, are unique in having the capacity for foresight and deliberate action, and selforganization in complex social-ecological systems is therefore somewhat different from that in ecological or physical systems (Westley *et al.* 2002). On the one hand, it can be argued that, although the dynamics and direction of change in such systems are influenced by individuals and groups that have intent, the system as a whole does not, as in the case of a market. However, because human actions dominate social-ecological systems, the adaptability of such systems is mainly a function of the individuals and groups managing them. Their actions influence resilience, either intentionally or unintentionally (Berkes *et al.* 2003). Their capacity to manage resilience with intent determines whether they can successfully avoid crossing into an undesirable system regime or succeed in crossing into a desirable one.

Transformability

Transformability is the capacity to create a fundamentally new system when the existing system is untenable (Walker *et al.* 2004). Social-ecological systems can sometimes get trapped in very resilient but undesirable regimes in which adaptation is not an option. Escape from such regimes may require large external disruptions or internal reformations to bring about change (Holling and Gunderson 2002). The transformation of a social-ecological system can be in response to the recognition of the failure of past policies and actions, triggered by a resource crisis, or driven by shifts in social values (Gunderson *et al.* 1995). Although transformations generate novel system configurations, the pathways and mechanisms that drive transformations are not well understood and are one of the foci of the case comparisons in this volume.

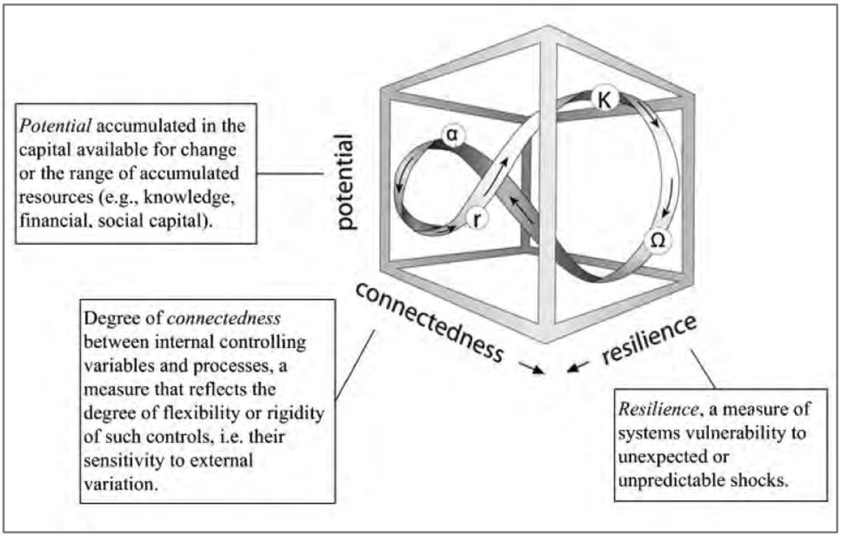


Figure a. *Adaptive cycle*
Source: Méndez P, Isendahl N, Amezaga J, et al. (2012) Facilitating transitional processes in rigid institutional regimes for water management and wetland conservation: experience from the Guadalquivir Estuary. Ecology and Society 17.

Appendix 5.2. Risks and stresses as perceived by farmers in study areas

An assessment of risks and resilience in Kenya and Ethiopia (as yet unpublished) offered insights in the threats to dairy farming as perceived by dairy farmers. Based on an inventory of risks made in the survey underlying Chapter 3, farmers were asked whether they perceived a range of issues to be a threat to their dairy farming, whether they saw any other risks, and whether they would identify the three most severe risks. Study areas consisted of East Shoa and Arsi Zones in Ethiopia and Nyandarua and Narok/Bomet Counties in Kenya. In each area, 60 small and medium scale dairy farmers were interviewed.

Figure A shows that seven risks were considered as a threat to dairy farming by more than 40% of the farmers, with three most felt risks being felt by the large majority of farmers.

Figure B show that 88% of Kenyan farmers mentioned price fluctuations as a top risk, against 44% of Ethiopian farmers, who are less commercialized (Chapter 3). In Ethiopia, the most mentioned top-three risk was diseases, parasites and pests (75% of farmers), indicating poor performance of animal health care services, closely followed by insufficient land to grow fodder).

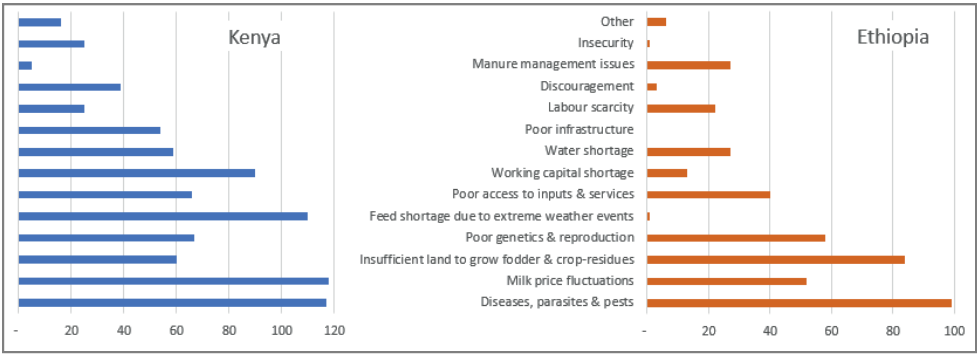


Figure A. *Number of farmers considering issues as a threat to their dairy farming (n=232, 120 in Kenya, 112 in Ethiopia)*

*) 'Other risks' include agrochemical side-effects, unfavourable policies, regulations & taxes, and relocation risk.

Figure B. *Risks ranked as top three as number of responses by dairy farmers in Kenya and Ethiopia ($n_{farmers}$= 232; $n_{responses}$= 659 (339 in Kenya, 320 in Ethiopia)*

Notes

[1] *As a concept recently gaining traction, food systems include all elements and activities related to the production, processing, distribution, preparation, and consumption of food, the market and institutional networks for their governance, and the socio-economic and environmental outcomes of these activities (Ruben et al., 2019). It regards food production and marketing and their dynamics in the context of consumer characteristics, business services, enabling environment and food environment, as well as drivers of change (Alroe et al., 2017; van Berkum et al. 2018; Worstell and Green, 2017). Socio-economic and environmental drivers of change in the food system include demographic drivers, such as urbanization and a rising middle class demanding more animal-source food (Andeweg et al., 2020). These drivers affect sub-systems, such as farming, marketing and supply to consumers, but also supporting systems such as agricultural research and extension.*

[2] *Transition and transformation both indicate a fundamental change in form and/or function of a system (Termeer and Metze, 2019). They are often used interchangeably, although transition is more often used to denote the process or period of changing from one state or condition to another, while transformation denotes a change in form, nature, or appearance and is associated with three characteristics of change: it is in-depth, system wide, and fast (Termeer and Metze, 2019). Reardon et al. (2014) (2014) mention five interlinked transformations of the agrifood system occurring in sub-Saharan Africa that are relevant for the dairy sector: (1) urbanization; (2) diet change; (3) agrifood system transformation; (4) rural factor market transformation; (5) intensification of farm technology (or agricultural transformation, i.e. intensification, diversification, and commercialization of farming (Minten et al. 2018) (Box 1.1).*

[3] *Agroecological conditions – The effects of variation in natural biophysical factors were minimized by choosing case studies from comparable agroecological zones (upper tropical midlands and lower tropical highlands (Jaetzold R, Schmidt H, Hornetz B, et al. (1983) Farm Management Handbook of Kenya Vol. II Part B: Ministry of Agriculture, Kenya, in Cooperation with the German Agricultural Team (GAT) of the German Agency for Technical Cooperation (GTZ)) and by omitting hot and dry areas that have little competitive advantage for dairy (Chapter 3). Still, agroecological factors likely do explain part of the variation encountered: altitude to some extent affects climatic suitability for dairy (Chapter 2); local differences in soil, rainfall and temperature conditions may have contributed to country, location and sub-location effects (Chapter 3); agroecological conditions may have affected demand for silage contracting services across Kenyan counties (Chapter 4). Nevertheless, upgrading the status of clusters appeared to be more related to differences in infrastructure, market and enabling environment than to the relatively small differences in agroecological conditions between and within study areas.*

[4] *ADIAS project – Assessing and supporting Dairy Input and advisory service Systems for resilient market-oriented smallholder dairy systems in the Ethiopian and Kenyan highlands. NOW-WOTRO GCP W08.260.2015.302*

[5] *Available at https://ars.els-cdn.com/content/image/1-s2.0-S0308521X20307526-mmc3.pdf.*

[6] *Diversity of farms is largely based on differences in their resource base and enterprise patterns (Giller, 2013). It leads to variation in how these farms respond to market opportunities and shape their livelihood strategies and farm practices. Farm typologies aid in understanding this variation (Muriuki and Thorpe, 2006; van de Steeg et al., 2010), but are describing the past and/or current status rather than exploring the future.*

Summary

How can dairy farmers in the land-scarce East African highlands increase their market participation in a sustainable way? Answering this question is important to ensure sufficient supply of safe milk and dairy products to rural and urban consumers. The question implies that farmers can make a decent livelihood, achieve investments and changes in their practices, and are not exposed to insurmountable risks. It also implies that other actors in the market chain do the same, and that a conducive enabling environment is present. The question further touches on societal expectations regarding what is being produced and how, with profound concerns about social inclusivity and the impact of market dynamics and climate change.

Chapter 1 further lays out the objective of this thesis, which is to gain insights into factors affecting commercialization of dairy farming under land scarcity, through assessment of the dynamics of market participation, land use intensification, and resilience of dairy farming systems in relation to the markets for inputs, services, and outputs. The main research question is: in what ways do market quality and spatial factors affect commercialization of dairy farming systems under land scarcity in two countries in the East African highlands? In looking at commercialization, the thesis distinguishes three related processes: land use intensification; upgrading of farming, market, and context; and specialization toward selected commodities. It considers the research question from different angles: the role of spatial factors in driving or hindering upgrading of dairy farming systems; the effects of input and service arrangements on the market quality and market participation of dairy farmers; and lastly, transition and resilience of farming systems. The study resulted in three empirical chapters and a systematic literature review.

Chapter 2 looks at the effect of being located in a dairy cluster on dairy farm commercialization. Based on farmer and value chain actor interviews, a comparative study of five emerging dairy clusters elaborates how the upgrading of farming systems, value chains, and context shapes transformations from semi-subsistent to market-oriented dairy farming. The main results show unequal cluster upgrading along two intensification dimensions: dairy feeding system and cash cropping. Intensive dairy competes with high-value cash crop options that resource-endowed farmers specialize in, given conducive support service arrangements and context conditions. A large number of drivers and co-dependencies between technical, value chain, and institutional upgrading build up to system jumps. Clusters can be expected to move further along initial intensification pathways, unless actors consciously redirect their efforts. The main theoretical implications are (1) for the debate about cluster upgrading, that co-dependencies between farming system, market, and context factors determine upgrading outcomes; and (2) for the debate about intensification pathways, that service providers need to consider differences in farmer resource endowments, path dependency, concurrency, and upgrading investments. Sustainability issues for consideration include enabling a larger proportion of resource-poor farmers to participate in markets, enabling private input and service arrangements, attention for food safety, and climate smartness.

Chapter 3 explores the effects of proximity to input and output markets on commercialization. These effects traditionally have been viewed as a market quality effect stemming from distance to end-markets with resultant travel time. This study departs from this by distinguishing three travel time components: travel times to local service centres for inputs and services, to dairy delivery points, and to end-markets. Dairy farms in nine villages each in Ethiopia and Kenya were sampled and interviewed along a double proximity gradient, to local and end markets. Effects on many production and marketing parameters were measured and compared, using regression analysis, to test the hypothesis that intensity of dairy farming and degree of market participation increase with proximity to end-markets and with proximity to local service centres. Findings prove the hypothesis that proximity to local service centres causes better market quality for inputs and outputs, smaller farms with less available labour, use of more purchased feeds and services, higher stocking rates, higher yields, and higher margins per hectare. Findings only partly prove the hypothesis about proximity to end-markets, mainly due to unexpected land scarcity in the most remote locations. An implication of this study is that the common typology of dairy farms as '(peri-)urban' and 'rural' needs adjustment by outlining local market access and connectivity. 'Remote' rural farms need to be connected to milk collection infrastructure, input shops and services to even have the choice to increase market participation.

Chapter 4 presents a case study from Kenya on one particular model of service agri-enterprises, evaluating both technical and business performance. It addresses the gap in understanding performance of emerging private agricultural extension and advisory service (AEAS) models in developing country contexts, in relation to their dual objectives of supporting farmer-clients and becoming profitable agribusinesses themselves. A multiple case study is presented of Service Providers Enterprises (SPEs), an emerging youth-led agribusiness model offering silage-making and other services in the Kenyan dairy sector. Using mixed methods, data was collected through in-depth interviews and focus group discussions, from SPEs, farmers, and key informants across four counties. The results show SPEs' contribution to some changes in farmers' practices, but with limitations to optimal technical performance. SPEs' mixed business performance is linked to limited market demand, seasonality, and limited fit with demand for some services offered, highlighting gaps in entrepreneurial and market orientation of such agribusinesses, which is compounded by a challenging operating environment. This evidence implies that enhancing the contribution of such agri-enterprises—which offer employment opportunities, especially for youth—to transforming agrifood systems requires sustained support in business incubation, market development, and strengthening of the value proposition to farmer-clients. The dual perspective on performance expands theoretical perspectives for assessing AEAS, especially in relation to commercialization. The emphasis is on the mutuality of substantive demand and economic viability of these services, which is reliant on certain market growth maturity. This study is a first attempt to assess private AEAS models from both a technical perspective and a business perspective regarding their viability as agri-enterprises.

Chapter 5 contains a review of how resilience is being assessed in recent literature. It aims to identify the commonalities, differences, and gaps, as well as their implications, in resilience conceptualization and in assessment approaches for farming systems. The lack of agreement on resilience, links to other key concepts, and degree of specification lead to different choices in assessment approaches. Under different conceptual stances and assessment methods chosen, decision makers may evaluate a particular farming system to be more or less resilient, with implications for the design of interventions to then enhance its resilience. This chapter uses a series of characteristics to code and assess 123 papers relating to resilience and its assessment, in order to clarify the apparent ambiguity in theoretical underpinning of resilience assessment approaches. The characteristics focus on how resilience is conceptualized, how it is assessed, and how it is operationalized. While each approach to assessment has its own strengths and weaknesses, across all the studies insufficient attention is given to describing causal links between perturbations (risks), determinants of resilience, and outcomes of resilience. The study proposes to further develop resilience assessment methodology by drawing from the different perspectives, and it identifies five key elements that should be included in such methodology development.

The discussion in Chapter 6 formulates conclusions and implications for theory, policy and practice. The main conclusions are:

- Spatial factors are critical drivers of commercialization of dairy farming, with proximity to local input and output markets and being located in a dairy cluster enhancing commercialization.
- Concurrent and co-dependent upgrading in farming, market, and context domains enhances market quality for dairy and/or other farming activities.
- Farmers' market quality and feasibility space are also enhanced by the plurality and performance of input and service provision.
- Risks and risk perceptions around market quality play important roles in decisions of upgrading, especially around system jumps; resilience assessment needs to move beyond specific and known risks to include multiple and unknown risks, in order for commercialization to be sustained over time.
- Connecting theory around system jumps of farming systems and around resilience determinants offers a way to explain farmer attitudes toward commercialization.

Dairy commercialization will thus need to consider spatial effects (proximity to local input and output markets and being located in a cluster); concurrent upgrading in farm, market, and contextual domains; plurality and performance of input and service providers; risks and risk perceptions; and resilience so that commercialization can be sustained over time.

Samenvatting

Hoe kunnen melkveehouders in de Oost-Afrikaanse hooglanden, waar land schaars is, hun marktdeelname op een duurzame manier vergroten? Deze vraag beantwoorden is van belang om toelevering te garanderen van veilige melk en zuivelproducten naar consumenten op het platteland en in de stad. De vraag impliceert dat boeren in staat zijn om in hun levensonderhoud te voorzien, investeringen te doen, en hun manier van werken te veranderen, zonder te worden blootgesteld aan onoverkomelijke risico's. Het impliceert ook dat andere ketenpartners hetzelfde doen en dat er een gunstige faciliterende omgeving is. De vraag raakt verder aan de maatschappelijke verwachtingen over wat en hoe er geproduceerd wordt, met grote zorgen over sociale inclusie en over de impact van marktdynamiek en klimaatverandering.

Hoofdstuk 1 beschrijft het doel van dit proefschrift, namelijk het verkrijgen van inzicht in factoren die de commercialisering van melkveehouderij onder landschaarste beïnvloeden, door de beoordeling van de dynamiek van marktdeelname, intensivering van landgebruik en veerkracht van melkveehouderijsystemen vis-à-vis markten voor toeleveranties, dienstverlening en productafzet. De hoofdonderzoeksvraag is: op welke manieren beïnvloeden marktkwaliteit en ruimtelijke factoren de commercialisering van melkveehouderijsystemen onder landschaarste in twee landen in de Oost-Afrikaanse hooglanden? Bij het kijken naar commercialisering, onderscheidt dit proefschrift drie gerelateerde processen: intensivering van landgebruik; opwaardering van landbouw, markt en omgeving; en specialisatie in de richting van bepaalde producten. Het belicht de onderzoeksvraag vanuit verschillende invalshoeken: de rol van ruimtelijke factoren bij het stimuleren of belemmeren van opwaardering van melkveehouderijsystemen; de effecten van toeleverantie- en dienstverleningsarrangementen op de marktkwaliteit en marktdeelname van melkveehouders; en de transformatie en veerkracht van landbouwsystemen. Het onderzoek resulteerde in drie empirische hoofdstukken en een systematisch literatuuronderzoek.

Hoofdstuk 2 behandelt de invloed van locatie in een melkveehouderijcluster op de commercialisering van melkveebedrijven. Op basis van interviews met boeren en ketenpartners, laat een vergelijkende studie van vijf opkomende melkveehouderijclusters zien hoe de opwaardering van landbouwsystemen, waardeketens en omgeving de transformatie van semi-zelfvoorzienende naar marktgerichte melkveehouderij vormgeeft. De belangrijkste resultaten laten een ongelijke opwaardering van de clusters zien langs twee intensiveringdimensies: voedersysteem en productie van handelsgewassen. Intensieve melkveehouderij concurreert met hoogwaardige opties voor handelsgewassen waarin boeren zich bij gunstige dienstverlenings- en omgevingsvoorwaarden specialiseren. Een groot aantal factoren, alsmede afhankelijkheden tussen technische, waardeketen- en institutionele opwaardering, leiden tot systeemsprongen. Clusters plegen zich verder te ontwikkelen langs ingeslagen intensiveringstrajecten, tenzij actoren dit bewust ombuigen. De belangrijkste theoretische implicaties van deze studie zijn (1) voor het debat over het opwaarderen van

clusters, dat afhankelijkheden tussen landbouwsysteem-, markt- en omgevingsfactoren bepalend zijn voor de uitkomsten van opwaardering; en (2) voor het debat over intensiveringstrajecten, dat dienstverleners rekening moeten houden met verschillen tussen boeren in toegang tot middelen, pad-afhankelijkheid, gelijktijdigheid van en investeringen in opwaardering. Relevante duurzaamheidsaspecten zijn onder meer het faciliteren van markdeelname voor een groter deel van de minder bemiddelde boeren, het mogelijk maken van particuliere toeleverantiemodellen, aandacht voor voedselveiligheid en klimaatslimheid.

Hoofdstuk 3 onderzoekt de effecten van de nabijheid van toeleverende- en afzetmarkten op commercialisering. Deze effecten worden traditioneel gezien als een effect van marktkwaliteit, die voortvloeit uit de afstand tot de afzetmarkt, met daaruit volgend reistijd tot de afzetmarkt. Deze studie wijkt hiervan af door drie reistijdcomponenten te onderscheiden: reistijden tot lokale servicecentra voor toeleverantie en dienstverlening, tot lokale melkafleverpunten en tot afzetmarkten. Melkveebedrijven in negen dorpen in Ethiopië en Kenia, langs een dubbele gradiënt voor nabijheid tot lokaal servicecentrum en tot afzetmarkten, zijn geselecteerd en geïnterviewd. Effecten op een groot aantal productie- en marketingparameters zijn gemeten en vergeleken met behulp van regressieanalyse, om de hypothese te testen dat de intensiteit van melkveehouderij en de mate van marktdeelname toenemen met nabijheid tot afzetmarkten en lokale servicecentra. Bevindingen bevestigen de hypothese dat nabijheid tot lokale servicecentra leidt tot een betere marktkwaliteit voor toeleveranties en productafzet, kleinere boerderijen met minder beschikbare arbeidskrachten, aankoop van meer voer en diensten, hogere veebezettingsgraden, hogere opbrengsten en hogere marges per hectare. Bevindingen bewijzen slechts gedeeltelijk de hypothese over de nabijheid tot afzetmarkten, voornamelijk als gevolg van onverwachte landschaarste op de meest afgelegen locaties. Een implicatie van deze studie is dat de gemeenschappelijke typologie van melkveebedrijven als '(rand-) stedelijk' en 'platteland' aanpassing behoeft, door lokale markttoegang en connectiviteit te typeren. Zonder aansluiting op infrastructuur voor het ophalen van melk, toeleveranciers en dienstverleners hebben 'afgelegen' boerderijen op het platteland zelfs niet de optie om hun marktdeelname te vergroten.

Hoofdstuk 4 presenteert een casestudie uit Kenia over één type dienstverlenende bedrijven, waarbij zowel technische als zakelijke prestaties worden geëvalueerd. De studie richt zich op de hiaten in het begrip van de prestaties van opkomende modellen voor particuliere landbouwvoorlichting- en adviesdiensten (AEAS) in de context van ontwikkelingslanden, vis-à-vis hun tweeledige doelstelling: het ondersteunen van boeren-klanten en winstgevendheid van de dienstverlener zelf. De meervoudige casestudie van Service Providers Enterprises (SPEs) evalueert een opkomend, door jongeren geleid landbouwbedrijfsmodel dat inkuil- en andere diensten aanbiedt binnen de Keniaanse melkveehouderijsector. Met gemengde methoden werden gegevens verzameld via diepte-interviews en focusgroep-interviews, met SPEs, boeren en sleutelinformanten uit vier counties. De resultaten tonen de bijdrage van SPEs aan een aantal veranderingen in de manier van werken van boeren, maar ook de suboptimale technische prestaties van SPEs. De gemengde bedrijfsprestaties van SPEs houden verband met een beperkte marktvraag, seizoensinvloeden en een beperkte aanpassing aan de vraag bij sommige aangeboden diensten, waardoor lacunes in de ondernemingszin en marktgerichtheid van dergelijke dienstverlenende bedrijven worden benadrukt, die worden verergerd door een lastige operationele omgeving. Dit resultaat impliceert dat vergroting van de bijdrage van dergelijke agrarische ondernemingen aan de transformatie van voedselsystemen, duurzame ondersteuning vereist bij het opstarten van bedrijven, bij marktontwikkeling en bij de versterking van de waardepropositie aan boeren-klanten. Het gebruikte tweeledige perspectief op prestaties verruimt het theoretische kader voor het beoordelen van AEAS, vooral in relatie tot commercialisering. De nadruk ligt op de wisselwerking tussen substantiële vraag en economische levensvatbaarheid van deze bedrijven. Dit vraagt een zekere volwassenheid van de markt. Deze studie is een eerste poging om private AEAS-modellen te beoordelen vanuit zowel een technisch als een zakelijk perspectief (wat betreft hun levensvatbaarheid als agrarische ondernemingen).

Hoofdstuk 5 bevat een overzicht van de methodes waarmee veerkracht van landbouwsystemen in recente literatuur beoordeeld wordt. Het bedoeld de overeenkomsten, verschillen en hiaten te identificeren tussen zulke benaderingen, alsmede de implicaties daarvan. Het gebrek aan overeenstemming over veerkracht als begrip, verbanden met andere sleutelbegrippen, en de mate van precisering leiden tot verschillende keuzes. Vanuit verschillende conceptuele standpunten en beoordelingsmethoden kunnen besluitvormers hierdoor een bepaald landbouwsysteem beoordelen als meer of minder veerkrachtig. Dit heeft gevolgen voor het ontwerp van interventies om die veerkracht te vergroten. Dit hoofdstuk gebruikt een reeks kenmerken om 123 artikelen over de beoordeling van veerkracht te coderen en te beoordelen, om de schijnbare ambiguïteit te verduidelijken in de theoretische onderbouwing van benaderingen voor de bepaling van veerkracht. De kenmerken richten zich op hoe veerkracht wordt gedefinieerd, hoe het wordt bepaald en hoe deze inschatting wordt uitgewerkt. Hoewel elke benadering zijn eigen sterke en zwakke punten heeft, wordt in alle onderzoeken onvoldoende aandacht besteed aan het beschrijven van causale verbanden tussen verstoringen (risico's), determinanten van veerkracht en de uitkomsten ervan. De studie stelt voor om de methodologie voor het bepalen van veerkracht verder te ontwikkelen door uit de verschillende perspectieven te putten. Er worden vijf sleutelelementen geïdentificeerd die in een dergelijke methodologie moeten worden opgenomen.

De discussie in hoofdstuk 6 formuleert conclusies en implicaties voor theorie, beleid en praktijk. De belangrijkste conclusies zijn:

- Ruimtelijke factoren vormen cruciale drijfveren voor de commercialisering van melkveehouderij, waarbij de nabijheid tot lokale toeleverantie- en afzetmarkten en de ligging in een melkveehouderijcluster commercialisering bevordert.
- Gelijktijdige en samenhangende opwaardering in landbouw-, markt- en omgevingsdomeinen verbetert de marktkwaliteit voor melkveehouderij en/of andere landbouwactiviteiten.

- De kwaliteit van de markt en de haalbaarheidsruimte van boeren worden ook verbeterd door de pluraliteit en prestaties van toeleveranciers en dienstverleners.
- Risico's en risicopercepties rond marktkwaliteit spelen een belangrijke rol bij beslissingen over opwaardering, vooral rond systeemsprongen; de beoordeling van de veerkracht moet verder gaan dan specifieke en bekende risico's, om meerdere en onbekende risico's te omvatten, zodat commercialisering door de tijd heen kan worden voortgezet.
- Het verbinden van theorie rond systeemsprongen van landbouwsystemen met theorie rond determinanten van veerkracht biedt een manier om de houding van boeren tegenover commercialisering te begrijpen.

Bij de commercialisering van melkproductie zal dus rekening moeten worden gehouden met ruimtelijke effecten (nabijheid van lokale toelever- en afzetmarkten en ligging in een melkveehouderijcluster); gelijktijdige opwaardering in landbouw, markt- en omgevingsdomeinen; pluraliteit en prestaties van toeleveranciers en dienstverleners; risico's en risicopercepties; en veerkracht, zodat commercialisering door de tijd heen kan worden voortgezet.

Acknowledgements

Life is a journey, not a destination (Lynn H. Hough, 1920)[1]

It is a pleasure to look back at this PhD, a part of my life's journey. As a lover of travel and travel histories, I am inspired by such stories as the epic journey of Frodo and friends, narrated by J.R.R. Tolkien in the Lord of the Rings[ii]. A journey that was measured in leagues or hours walk rather than in kilometres or miles. While a PhD is by no means such an epic crusade that alters the fate of an era, I still dare to draw on some similarities in order to thank the people who have been meaningful in my PhD adventure.

Every journey has a start. My Bag End was small-town Alphen aan den Rijn, a region of clay and peat where my parents, siblings and influencers educated me not only to be food-loving like a hobbit, but also to be a responsible and inquisitive traveller. After my boot camp in Wageningen—where on the Grintweg I actually lived next to a house called Rivendell (sic!)—my path led to far-away Eastern countries for work in rural development, into unheard-of cultures. I treasure the many lessons that the people of Laos and Myanmar taught me about humankind and about myself.

Towards the end of that leg of the journey, colleagues started suggesting that I should embark on the PhD path. When an application for a PhD vacancy in 2007 was turned down, I realized that it might be difficult to combine a PhD with raising three adolescent children and being employed in Myanmar. Putting plans on hold was not the end of the journey though. After joining Wageningen UR in 2008, after my wife Lénette completed her training as social worker, and after our kids started leaving the house, a PhD next to 'just' a job in Wageningen seemed timely and achievable! Still, I had as little clue what would befall me as did Frodo Baggins, when at the Falls of Rauros he decided to continue to Mordor alone.

Indeed, so many people have been part of this journey that it would easily create boredom if I would just list them. What Tolkien may have done is to describe their arrival as visitors to an important battle or festivity – and isn't a PhD defence a bit of both? So, in my mind's eye, I welcome them with full honour and flying banners, standing at the entrance to a great hall, accompanied by my family, relatives, and friends, who have been my staunchest supporters throughout these years. Lénette, the love of my life and my companion for over thirty years, a Master in the art of balancing encouragement and boundary setting, meaning more to me than Samwise Gamgee meant to Frodo Baggins; our children Annelies, Jan-Coen, and Josh with their partners, supportive in many ways no hobbits could imagine; the van der Lee and van den Brink clans and close friends, who showed ongoing interest, inspiration, and willingness to deal with my regular absence, be it in body or in mind.

But here the guests begin to enter, starting with the large contingents of co-workers who have been cheering me on to start and to persist with this journey. From the Far East I see Susan Stewart, Elisabeth Schüle, Khon Ja Labang, Dave McClintock, and other colleagues from World Concern Myanmar, the tight and inquisitive pre-PhD travel mob that put the ideas of this journey in my head. Then the rangers from the North, mostly residing in the Wageningen parts; those from Gondar who used to put up at the Hof van Wageningen and then moved to CampUs (some of them saw that as a move to Lothlorien, others as a move to Mordor–if only they knew) and those from Rohan, animal lovers and breeders of renown, who used to put up at the Red Deer Road in the Town of the Lilies; ranging far and wide across the globe, feeling as much at ease in farmers' homes as in kings' palaces, fighting for all that is just and fair, awaiting the return of the King, whether they know it or not. Usually travelling in ones or twos, see them now altogether: lead by the international livestock squad—Bram, Adriaan, Wim, Jelle, Jessica, Karin, Marion, Theun, Asaah, Arend-Jan, Adolfo, Alberto, Joep, Annabelle, Simone, Marlene, Caroline—as well as those who embarked on their own PhD journeys – Seerp, Cora, Gareth, and Nina. I owe them so much.

Behind them on their steeds I see the valiant Captains of Rohan and Gondar – Lord Sierk the Friesian to Spoelstra, Earl Kees van den Lokhorst, Lady Lucia van Lansbergen (later known as the Bald); Baron Roeland van den Veerkamp, Duchess Annie from the Ferry, Count Gert of Dunkirk, Sir Wouter Leendert van den Hijweege; Marchioness Marianne from the Hamlet; even people of foreign tongues – Sir James from the Woodhill in the land of Oz and Lady Karen from the British Isle of Buchanan. Just great how they have enabled and encouraged me over the past twelve years.

They are followed by the Teachers, the special counsellors, the Lords Laurens Klerkx and Simon Oosting, great supervisors, without whose guidance and direction I wouldn't be here today. They continued to challenge me to traverse the treacherous interdisciplinary wastelands between animal science, systems thinking, innovation science and economics, preventing me from getting bogged down, teaching me the difference between technical reports and scientific papers, and many other lessons. I fondly remember Lord Simon's remark "you don't need to write the bible on dairy development". But they are not the only co-authors, see how they are accompanied by professors, doctors and scientists – professor Bockline Omedo Bebe from Njoro, Ashenafi Mengistu from Bishoftu, Catherine Kilelu, Jos Bijman, Domenico Dentoni, Seyda Őzgan, Felix Akatch Opinya, Jessica Koge and Daniel Kangogo. And then, the others, they must be the Examiners, the illustrious committee I have to face later today. I am glad they came but must say I am a bit fidgety about meeting them!

Then, this procession of course has its fair share of squires. It was a pleasure to work with them, be they project assistants or students – Felix, Linette, Pauline, Ruth, Joan, Ida, Wilson,

Ann, Fred, Anne, Jessica, Cyrus, Liz, Lieke, Terefe, Gerko, Degu, Teshale, Temesgen, Aregaw, Feki, Alemayehu, Abera and Nicola. I wish them a golden future.

Next I see colleagues from the Lions Castle, who lighted up the long hours spent there over the past seven years on charting the territory, plotting my journey, leaving for my travels to the countries of Hararghe and Njoro and returning for support and to chronicle my journey reflections. It is fitting to see fellow students up front—Jean Porto Vilas Boas Souza, Julissa Galarza Villamar, Debashish Sen, Iman Nawireja, Margreet Mook, Vera Vernooij, Kelly Rijswijk and others—closely followed by professor Cees Leeuwis (does he resemble C.S. Lewis or not?!) and team. I should add to them the many people in- and outside WUR who supported my journey in so many ways: training courses; statistical analysis support by Ina Hulsegge, Jarl Kampen, Hilde Mooij, and Jan-Coen van der Lee; library services by Marc Loman, Corrie Snijder, and Ria Derkx; editing of thesis chapters by Ruth Davies and Annelies van der Lee; administrative support by Inge Ruisch, Vera Mentzel, Oscar Rootselaar, and the secretarial and finance teams; coaching by Hans Komen, Heleen van Houten, and Jan Brouwers; and moral support by Gert-Jan van Delft, Harke Pera, and the WUR prayer group.

Just as the elflords put the fellowship on their way, this PhD journey was facilitated by various projects that covered costs and structured collaboration. Thanks is due to the people involved in commissioning those projects and to the people and companies we partnered with—Dominic Menjo and Philip Pyeko, NKCC; Harry Schimmel, Geerten Wassink and Nega Getachew, Alema-Koudijs Feeds; Hailu Eshete, Family Milk; and Zeleke Kebede, Etete Milk Processing SC; and Ann Kingiri, ACTS.

My thoughts now wander to the many farmers, entrepreneurs, and employees whom we interviewed in the course of this project. It is unlikely to see them turn up here, but they too share in the glory. That certainly is true for the host of colleagues and partners I enjoyed and enjoy working with in Wageningen Research projects in Africa. Look, they send their representatives: Tinsae Birhanu for the Ethiopian DairyBISS team; Anton Jansen for the Kenyan KMDP team, Mahlet Yohannes for the Ethiopian EDGET and BRIDGE project teams; Rinus van Klinken for the NEADAP team; and Corne Rademaker, Gerald Mutinda Katothya, Felix Opola and many others for the 3R team.

Let me turn my mind to the journey again. Indeed, the gems in travelling are the conversations with people one meets on the road, even the unplanned encounters and maybe especially those. I fondly remember many, but can just mention a few of them: Abebe Tessama, Mike Griffiths, Henk Udo, Ken Giller, Maja Slingerland, Rogier Schulte, Roldan Muradian, Alemayehu Dekeba Bekele, Birhanu Megersa Lenjiso, Guillaume Duteurtre, Jos Lankveld, Yiheyis Maru, Sally Migose, Simon Nyokabi, Mercy Mwambi, Nathaniel Makoni, Tsehay Redda, Zelalem Yilma, Ika Darnhofer, Ann Notenbaert, Isabelle Baltenweck, James Rao, Jo Cadilhon, Berhanu Gebremedhin, Tesfaye Lemma, the late Azage Tegegne,... and fill in your own name if your memory is better than mine. My travels to the countries of Njoro and Hararghe also brought me into contact with colourful fellow travellers from the "Dutch" dairy league, a taste of home away from home, including Gerard & Catherine Oosterwijk, Annet Witteveen, Martin de Jong, Wytze Heida, Robert Baars, Marco Verschuur, Geert Westenbrink, Gerrit Noordam, and Melle Leenstra.

Finally, my mind's eye is drawn to the wizards, the Gandalfs, the mentors and friends who always were willing to offer guidance, ideas and council, even in the wee hours before submission deadlines. See them stride forward (do I see a wizard's wand there?) – the venerable Hans Schiere and Dave McClintock. We will meet again.

It is time to face the examiners. Indeed, I feel truly blessed by the fellowship of so many people who made this journey a pleasure, rather than the agony it was predicted to be. There must be some grant design behind all this! Our university prefers that we limit our acknowledgements to fellow human beings and refrain from addressing the supernatural. Indeed, even in the Lord of the Rings Tolkien never spoke about the Source of guidance, inspiration and persistence that was required for completing the grand quest described in his trilogy. Some things only are obvious to those who discern.

Surely, this PhD was some journey, but 'The Road goes ever on and on / Down from the door where it began / Now far ahead the Road has gone / And I must follow, if I can'[2].

[1] *1920 February 19, The Christian Advocate, [The Sunday School Lesson: Conducted by Lynn H. Hough: First Quarter – Lesson IX – February 29, 1920], Quote Page 266, Column 2. The Methodist Book Concern Publishers, New York*

[2] *J.R.R. Tolkien, 1954. The Lord of the Rings.*

About the author

Jan van der Lee was born on November 4, 1966 in Alphen aan den Rijn, the Netherlands. In 1991 he obtained his *ingenieur*'s degree in animal husbandry from Wageningen Agricultural University, with honours, for which he spent a six-month internship at the International Livestock Centre for Africa in Ethiopia and wrote theses on grassland science, extension science and tropical animal husbandry. In 1992 he moved to Laos with his family, where he coordinated ZOA Refugee Care's repatriation program till 1996, and managed WASH and community development projects for World Concern till 2001. After two years in the Netherlands, he moved with his family to Myanmar, where he worked as senior food security advisor and technical advisory unit coordinator in World Concern's rural development program and as representative of the inter-agency Food Security Working Group. Upon return to the Netherlands in 2008, he joined Wageningen UR's Centre for Development Innovation and Wageningen Livestock Research as senior advisor sustainable livestock systems. Since then he has been working for these two institutes on dairy projects in Southeast Asia and East Africa. In 2013, he started work on this thesis. In the latter part of 2015, he resigned from the Centre for Development Innovation to make space for a part-time PhD contract with the Knowledge, Technology and Innovation group of the Department of Social Sciences.

For an overview of publications see *https://research.wur.nl/en/persons/jan-van-der-lee/publications/*

Education certificate

Jan van der Lee

Wageningen School of Social Sciences (WASS)

Completed Training and Supervision Plan

Wageningen School of Social Sciences

Name of the learning activity	**Department/Institute**	**Year**	**ECTS***
A) Project related competences			
PhD Proposal writing	WASS	2013	4
Grant proposal writing ADIAS project, extending PhD proposal with research on policies and input models, and capacity building activities	NWO-WOTRO, 5 partners	2015	2
Ghana review workshop GCP-3	NWO-WOTRO, Grand Challenges program, Accra	2019	1
Basic PhD training course	CERES Research School for Resource Studies for Development, Utrecht	2013	10
Innovation for Sustainability: Bringing theory into practice	Transforum and Graduate School Production Ecology & Resource Conservation (PE&RC), Wageningen	2010	3
Systems Thinking in Practice in PhD Research - Appreciating and Effecting Transformations with Farming Systems Research	IFSA PhD course, Newport, UK	2016	4
Scientific Writing course	WUR - Wageningen in'to Languages	2017	1.8
'*Milking to potential - Strategic framework for dairy sector development in emerging economies*' (poster)	African Dairy Value Chain Seminar, CTA and ILRI, Nairobi, Kenya	2014	1
'*Driving innovations /Major transitions in agri-food systems'*	Development 2.0 or "Business as usual"? Summer school, University of Antwerp, Belgium	2015	1
'*Market quality gradients in smallholder dairy farming systems'*	12th European IFSA Symposium: Social and technological transformation of farming systems: Diverging and converging pathways, Newport, UK	2016	1
'*Sustainable Intensification Pathways for Dairy Farming in Kenya'* (poster)	Tropentag, Future agriculture: Social-ecological transitions and bio-cultural shifts, Bonn, Germany	2017	1
'*Resilience assessment tool for dairy & horti farming in the East African highlands'*	Tuesdays with resilience, Wageningen UR	2017	1

Name of the learning activity	Department/Institute	Year	ECTS*
B) General research related competences			
Qualitative data analysis for development research	CERES Research School for Resource Studies for Development, Utrecht	2013	1.5
Information Literacy PhD including EndNote Introduction	WUR library	2012	1.5
Qualitative Data Analysis with Atlas.ti: a hands-on practical	WASS	2014	1
KTI seminars	Wageningen University, KTI chair group	2016 - 2019	1
WASS PhD day PhD Workshop Carousel	WASS WGS	2014, 2014, 2019	1
Co-organization of 3R seminar on milk quality	3R Kenya project	2019	1
'Dairy the Motor for Healthy Growth'	Agri-ProFocus, NEADAP, Liquid, FBKP, WUR	2019	1
C) Career related competences/personal development			
Coaching trajectories on - working as management team - balancing PhD with job	 Groen & Partners Evenwicht Wageningen Livestock Research	2013 - 2019	2
Co-supervision of MSc thesis students *(Lieke Boekhorst; Henric Verjans; Gerko Wassink; Pauline Murage; Elizabeth Otunga; Terefe Taye Weldesilassie; Aregaw Abera Dodicho; Degu Tolera; Alemayehu Asrat; Teshale Endalamaw; Temesgen Assefa; Abera Jabessa)*	Wageningen Livestock Research projects with: - WUR – various groups - Egerton University, Kenya - Addis Abeba University, Ethiopia - Ambo University, Ethiopia	2011 - 2019	4
Total			**44.8**

**One credit according to ECTS is on average equivalent to 28 hours of study load*

Colophon

The research described in this thesis was financially supported by NWO-WOTRO (ADIAS project, grant W.08.260.301), the LNV KB22 Global Food & Nutrition Security program (Resilience of dairy farming in East Africa project), and the Embassy of the Kingdom of the Netherlands in Nairobi (3R Kenya project). Wageningen Livestock Research and Wageningen Centre for Development Innovation offered time for the author to work on this thesis.

Cover design by Rob Versluys

Printed by ProefschriftMaken


strategies
sub-locat
privat
categories
making
section
terms
output
factors
products
pathways
space
agricu
determinants
outcomes