Agricultural Systems 184 (2020) 102891

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Effects of proximity to markets on dairy farming intensity and market participation in Kenya and Ethiopia

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ARTICLE INFO

Keywords:
Food security
Commercialization
Sustainable intensification
Farming system design
Crop-livestock interaction
Input supply

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 center 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 centers. Findings prove the hypothesis for proximity to local service center, which causes better market quality for inputs and outputs, smaller farms with less available labor, 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.

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 towards 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 centers. This is particularly relevant for dairy farming, as it requires daily milk collection and a

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https://doi.org/10.1016/j.agsy.2020.102891
Received 3 April 2020; Received in revised form 5 June 2020; Accepted 14 June 2020

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 centers, because of better quality of input and output markets and increasing scarcity of land and labor. The hypothesis is tested in Ethiopia and Kenya, two countries with similar agro-ecology, 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 paper 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 center', '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 centers (i.e. access to end-markets) and at different travel times from main roads (i.e. access to local service centers).

2. Materials and methods

2.1. Key concepts

Along with agro-ecology, 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 agro-ecological 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 center 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 centers 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: agro-ecology 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 centers (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., 2018) (Table 1 and SM1 Fig.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).

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 (SM1 Fig.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 centers', '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 center—where farmers buy inputs and services and sell produce—to sub-location with remote accessibility (Fig. 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 center:

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 labor.

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 center* 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 center to urban end-market,* i.e. *milk processing plant or main end-user market for home-processed products (T_3)* (SM1 Fig.A).

Table 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 in Table 1).

Table 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 center,		*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 SM2)
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 labor	scarcity of production factors land, water, labor (number and skills) and capital	Labor: household size and composition (adults and children); age and gender of dairy decision maker, off-farm occupation.
because of a and b,		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, eviden-ced by increasing use of external inputs and services	land (farm size, soil types); water sources; real estate; labor/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 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	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 tethered land; tethering); practice changes over past 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.

(*continued on next page*)

Table 1 (*continued*)

Hypothesis		Independent variables
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, labor, 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; van de Steeg et al., 2010; van Melle et al., 2013; Vandercasteelen et al., 2018; 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 center, 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.

2.3. 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 agro-ecological 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 (Fig. 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 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 h walk from 'the market' (a local service center with input and service providers and output marketing opportunities). See Supplementary material 1 (SM1) for more detail on

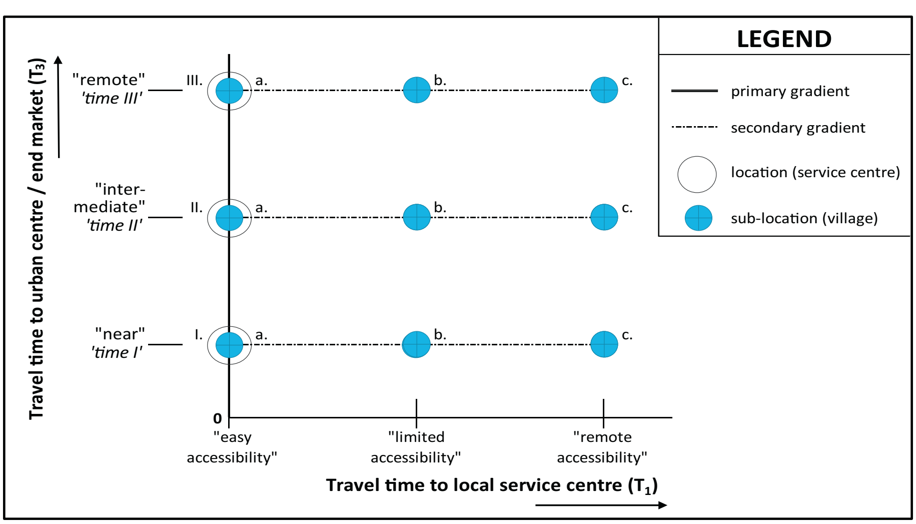

Fig. 1. Locations and sub-locations – Primary and secondary gradients in spatial research setup used.

selection of locations and sub-locations. See Fig. 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 sublocation administrative offices (Kenya). In selected households, the person responsible for dairy was interviewed. Thus, 93 farmers in Kenya and 122 farmers in Ethiopia were interviewed between May and November 2016. The questionnaires elaborated the variables displayed in Table 1.

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 center 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 centers (T_1) served as proxy for the secondary gradient (Table 1 and SM1 Fig.A).

2.4. 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. SM2 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 $i = 2$ Kenya
	refers to the jth observation
j	k = I, II, III refer to location
k	l = 1,2,3 refer to sublocation
l	
	Random effects
CxL	location within country factor
CxLxS	sub-location within location within country factor
	error (residual) random effect
ϵ_{ijkl}	
	Fixed effects
μ	intercept
C	country factor
T_1	travel time to input and service markets
	travel time to dairy delivery point
T_2	travel time to end market
T_3	slope - the slopes of T_1, T_2 and T_3 depend upon levels of factor C (two-
$\beta_{1,2,3i}$	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 ($p < .05$). 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 R, 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. 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 SM3, 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 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

Table 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 50-100 k	by tarmac road (by highway)	a.	b.	c.
II	small town	by tarmac road	T_1 - travel time to local service center		
III	small rural center	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

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 SM3 Table O and SM4 Fig.A-C).

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 center and to end-market (SM3 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 SM4 Fig.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

Labor – The scarcity of household labor available to farming was increasing with proximity to local service center, evidenced by more engagement in off-farm labor (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 (SM3 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 ha 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 (Fig. 2) displays averages and standard errors per location). Farm size showed both sub-location and location effects: it decreased with proximity to local service center 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 Fig. 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,

Table 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.

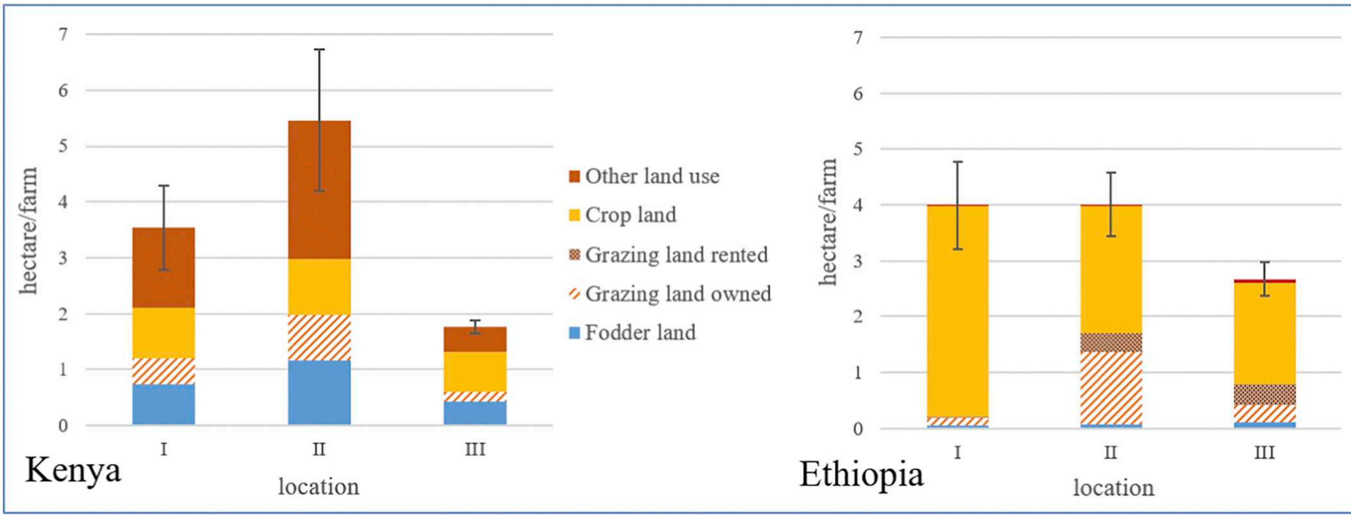

Fig. 2. Farm land use as averages per location in Kenya and Ethiopia, with standard errors and averages per location group, ranging from near (I) to remote (III), (n = 215). N.B. No reported rented grazing land in Kenya.

woodlots and "unaccounted for land use" were considerable in size (included in proportions for "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 center, 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 center, while in Ethiopia, it was highest for those close to the local service center. 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 center and dairy delivery point (SM3 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 center 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 center 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 center in Ethiopia, but less so in Kenya. Complementarily, the use of bull services decreased with proximity to both end-market and local service center, 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 center 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 center, even as livestock herds got smaller (SM3 Table d. and SM4 Fig.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 center and to end-market (SM4, Fig.D). *Herd sizes for cattle, for equines and for all species together* (all in TLU) decreased with proximity to local service center 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

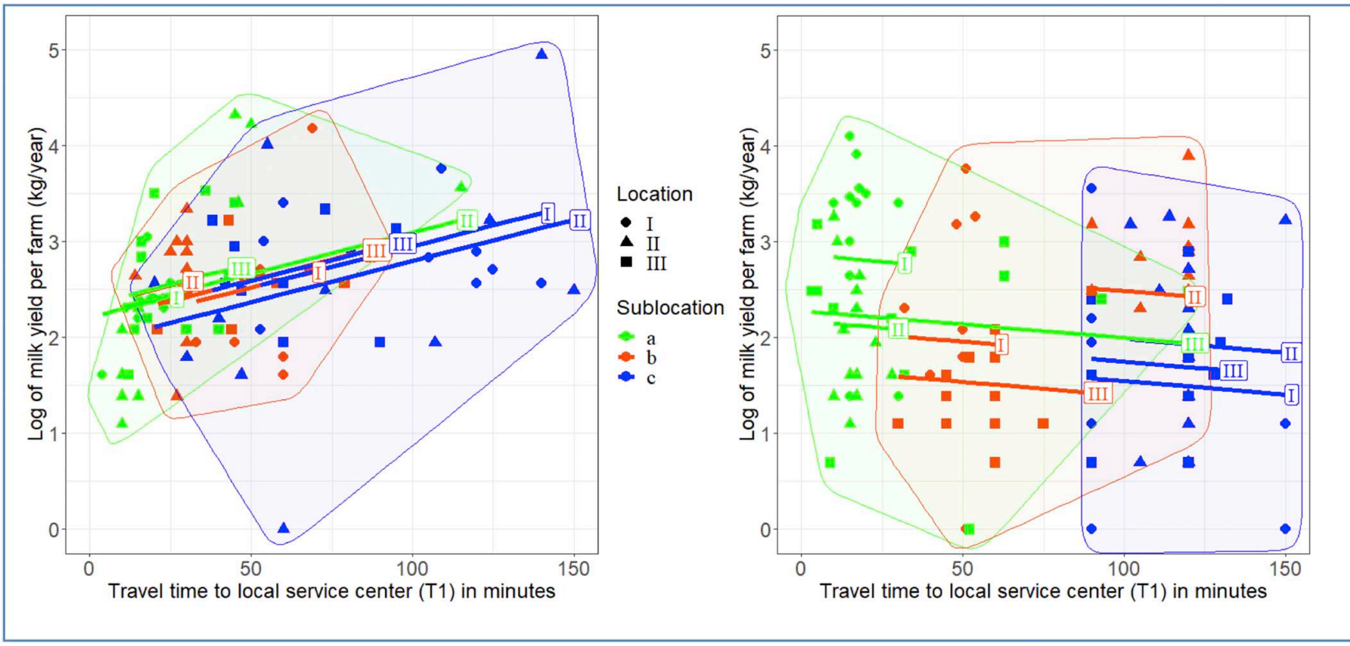

Fig. 3. Log of annual milk yield per farm vs. travel time to inputs and services for Kenyan and Ethiopian farmers in categories a - c of proximity to local service center, with regression lines per village ($n = 215$).

land and 72% of livestock land was devoted to forage production (Fig. 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 center and to end-markets.

Milk yields per hectare farm land increased with proximity to local service center in both countries (SM4 Fig.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 center in Kenya (Fig. 3). *Milk yields per cow* increased with proximity to dairy delivery point and proximity to end-market in Ethiopia (in line with Minten et al. (2018)), but showed the opposite effect for the first in Kenya. The parallel lines in Fig. 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 (Fig. 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

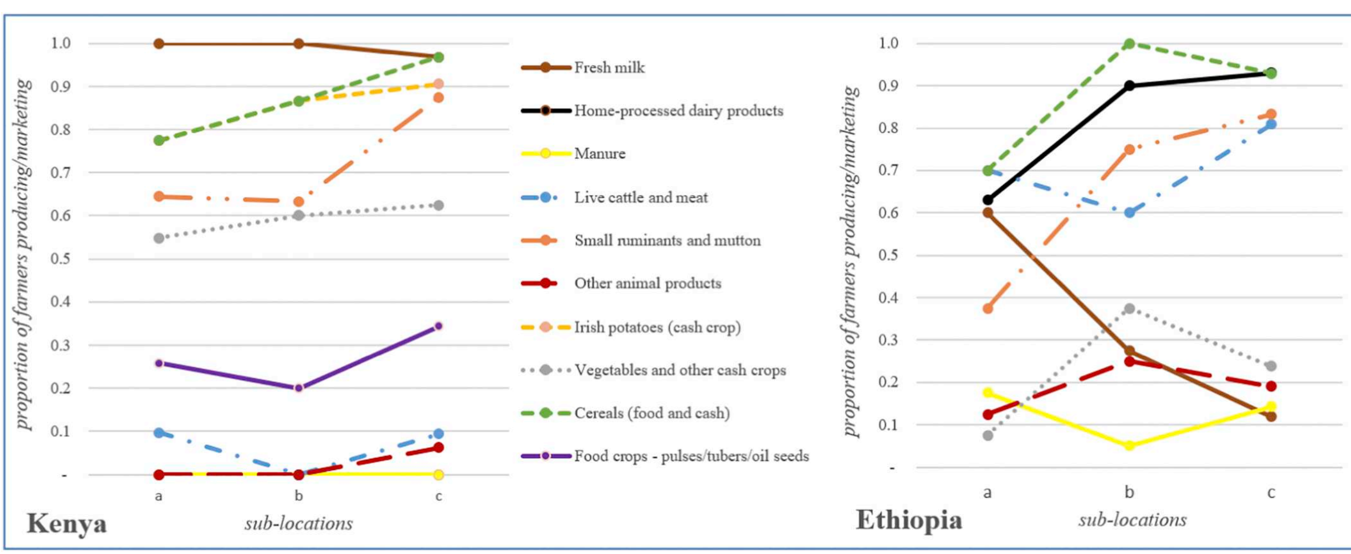

Fig. 4. Proportion of farmers producing various marketable products and food products, averages per sub-location group, ranging from easy accessibility (a) to remote accessibility (c). N.B. proportion is 1.0 when all farmers produce product.

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 centers.

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 (SM3 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 center, 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 center 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 SM2). Dairy sales volumes per farm averaged 2611 ± 3259 kg LME/year in Ethiopia and 5245 ± 5130 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 with proximity to local service center (Fig. 5 and SM4 Fig.I). The latter two showed interaction between T_2 and T_3 as well. Dairy sales income increased with proximity to local service center 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 center (Fig.5 and SM4 Fig.J)

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 center, to local dairy delivery/sales point, and to end-markets in section 4.1. We further discuss important context effects

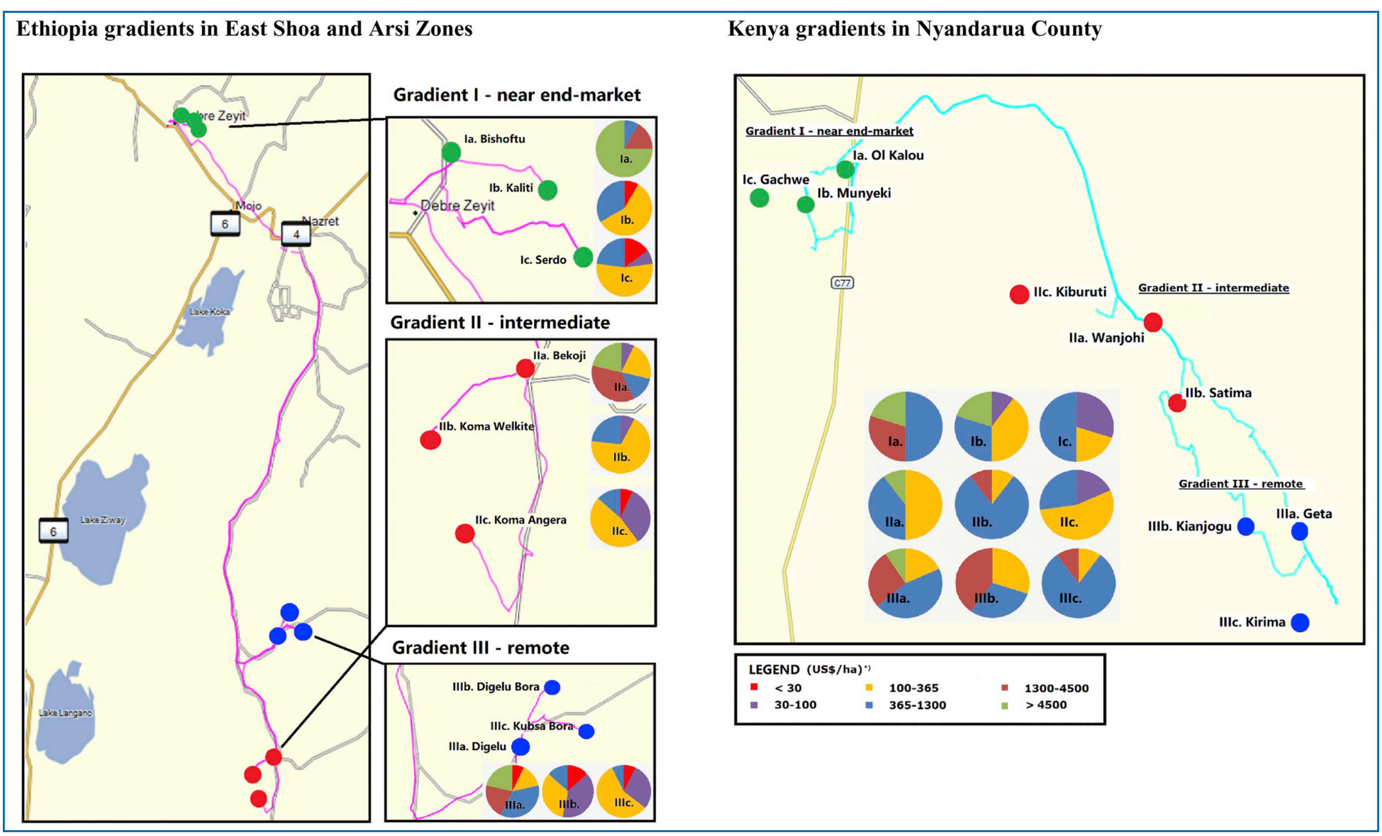

Fig. 5. Maps of study areas with pie charts per sub-location (= village) showing proportion of farmers in categories for dairy sales income (US$/ha).

in 4.2, and close with implications in 4.3.

4.1. Validation of hypothesis and sub-hypotheses

4.1.1. Sub-hypotheses

Proximity to local service center and dairy delivery point – The results, as expected, clearly showed that proximity to service center 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 labor (proving respectively sub-hypotheses a. and b., see Table 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 centers 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 center as a result of easier infrastructural access and more skilled personnel; this was described in van der Lee et al. (2018). 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 centers 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 labor 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 centers (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 centers (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 center, 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 centers 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 centers, 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 (Fig. 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 (Fig. 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.

4.1.2. Main hypothesis

This study proved that both intensity of dairy farming and market participation increase with proximity to local service center (T_1) and to dairy delivery point (T_2). Farms with easy accessibility to local service centers face increasing scarcity of land and labor, 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 center 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. (2018), suggesting this also applies to even smaller rural service centers.

Analysis included two types of measures for proximity to markets: i) Travel times to markets ($T_{1–3}$, as fixed effects); and ii) 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 Fig. 3 and SM4). 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 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) 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 labor.

The fact that the travel time and differences between Ethiopian locations I and II were much larger than between other locations (Table 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 Fig. 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.

4.2. Country effects

While farm size, mixed crop-livestock character of farming, and agro-ecological 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 SM4 Fig.D-J, as compared to those for Kenya. For some variables, regression lines had opposite slopes, see for example Fig. 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 centers 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 (van der Lee et al., 2018). Fourthly, county-level policies in Kenya favor dairy sector development and boost public investments, while Ethiopian agricultural policies favor meat for export and commercial grain crops (Shapiro et al., 2015; van der Lee et al., 2018).

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 fueled 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; van der Lee et al., 2018). 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 (Fig. 2), feeding their cattle straw and other crop residues (as also observed by Duncan et al. (2013), Minten et al. (2018)). 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 labor (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 neighboring 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.

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 centers 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 centers (i.e. access to end-markets) and at different travel times from main roads (i.e. access to input and service supply centers). 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 centers 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.

Acknowledgements

Authors express their appreciation to Dr. Ashenafi Mengistu of AAU-CVMA for coordination of data collection in Ethiopia; to field technicians and MSc students Feki Misbah, Alemayehu Asrat, Linnet Mwangi, Joan Kimutai, and Ruth Wangari Muriuki for data collection and entry; to farmers in Nyandarua Country, East Shoa Zone and Arsi Zone; to government officials and others who have helped us in the field; to Ina Hulsegge for statistical analysis and to Jan-Coen van der Lee and the team of BioMetris for advice on the same; and to friends and colleagues for feedback that helped us shape this study.

Author contributions

Conceptualization and methodology, J.v.d.L., L.K., S.O., B.O.B.; data collection, data curation, J.v.d.L., F.O.; formal analysis, writing–original draft preparation, and visualization, J.v.d.L.; writing–review and editing, L.K., S.O., B.O.B., F.O.; supervision, L.K., S.O.; funding acquisition and project administration, J.v.d.L., L.K.

Declaration of competing interest

None.

Funding

This work was funded by NWO–WOTRO, The Netherlands (project W.08.260.301).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2020.102891.

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