Dairy Technological Interventions, Cooperative Intermediation and Smallholder Livelihoods: Evidence from the East Africa Dairy Development Project in Nandi County, Kenya

Article history: *Revised format: 3rd July 2026, Available online: 12th November 2026*

Victor Kiptum Kering, PhD[1]

Abstract:

Purpose: *This study examines how dairy technological interventions delivered under the East Africa Dairy Development (EADD) project relate to the livelihoods of smallholder farmers, and how farmers' human capital and their dairy cooperatives condition these relationships.*

Material/methods: *A cross-sectional survey was conducted among smallholder farmers supplying three EADD-supported cooperatives (Kabiyet, Lelchego and Tanykina) in Nandi North Sub-County, Kenya. From a population of 5,640 farmers, 373 were sampled and 196 returned usable questionnaires. Group differences were examined with one-way ANOVA and correlation.*

Findings: *Farmers' perceptions of the interventions were positively associated with perceived household livelihoods ($r = 0.308$), daily milk output ($r = 0.295$) and monthly dairy income ($r = 0.346$). Dairying experience was the human-capital attribute most closely associated with output ($r = 0.449$) and income ($r = 0.456$), and older farmers produced more milk even though they operated less-intensive systems. Output, income and marketing channel differed sharply across cooperatives ($F = 27.58$, 18.45 and 16.28; $p < 0.001$), and selling through the cooperative was associated with higher output and income. Perceived livelihood benefits, however, were uniformly high and unrelated to output ($r = -0.072$) or income ($r = 0.033$), revealing a gap between perceived and objective outcomes.*

Conclusion: *Farmers' perceptions of the interventions were associated with livelihoods and dairy performance, while perceived livelihood benefits did not track milk output or income. The cross-sectional design, self-reported banded measures and bivariate analyses preclude causal inference; multivariate and longitudinal designs are needed to test the conditioning roles of experience and cooperative intermediation.*

Value: *By combining diffusion of innovations theory with the sustainable livelihood framework, the study shows that the returns to dairy technologies depend on farmers' experiential capital and on the institutional capital of their cooperatives, and that perceived and objective measures of project success can diverge. Extension should be differentiated by farmers' experience and production system, cooperative marketing and service delivery should be strengthened and standardized, and projects should monitor objective outcomes alongside farmer satisfaction.*

Keywords: *dairy technology, artificial insemination, dairy cooperatives, smallholder livelihoods, diffusion of innovations, sustainable livelihoods framework, Kenya*
Paper Type: *Research Article*
Recommended citation: Kering, V. K. (2026). Dairy technological interventions, cooperative intermediation and smallholder livelihoods: Evidence from the East Africa Dairy Development Project in Nandi County, Kenya. *Journal of Economics, Management Sciences and Procurement, 5*(1), 399–416.

[1] Department of Business Management, University of Eldoret, Eldoret City, Kenya. Corresponding author: kiriongi@gmail.com

1. Introduction

Global milk production continues to rise. The Food and Agriculture Organization estimated world output in 2023 at about 950 million tonnes, 1.3% above the previous year, with most of the growth in Asia, particularly India and China (FAO, 2023). Behind this aggregate lies a wide productivity gap. Average milk yield per lactation is about 2,200 kg globally, but commonly exceeds 9,000–10,000 kg in countries such as the USA and Israel, against 1,300–3,300 kg in India and Sub-Saharan Africa (Hegde, 2019). The gap reflects differences in genetic potential, reproductive technology and feeding and management systems, and it leaves many developing countries unable to meet rising domestic demand from local production (Hegde, 2019).

In the developing world, this demand is met largely by smallholders. Mixed crop–livestock systems dominate dairy production in Sub-Saharan Africa and South Asia (McDermott et al., 2010) and differ sharply from the intensive, specialized systems of North America and Western Europe (Cabrera et al., 2010; Nehring et al., 2011). They range from extensive, semi-subsistence systems to semi-intensive farms with one to five milking cows (Chagunda et al., 2016; Rota & Urbani, 2021). In Kenya, about 1.8 million households keep up to 6.7 million dairy cattle and supply most of the national milk output (Ouma et al., 2013).

For these households, dairying is a livelihood activity rather than only a production enterprise. Milk provides food and nutrition, a regular cash income and a buffer against shocks (Banda & Tanganyika, 2021; Herrero et al., 2013), within portfolios that combine crops, livestock and off-farm work to spread risk (Adato & Meinzen-Dick, 2002; Deshingkar et al., 2008). Yet many smallholder systems remain in a low-input, low-output equilibrium, constrained by inadequate feeding and housing, limited access to breeding services such as artificial insemination (AI), weak extension and veterinary support, and limited credit (VanLeeuwen et al., 2012; Wambugu et al., 2011). As landholdings fragment, extensive grazing becomes harder to sustain, but intensification that requires capital can exclude poorer farmers (Hegde, 2019; McDermott et al., 2010). The policy question is therefore not only whether technologies raise productivity, but whether they improve livelihoods across farmers with different endowments.

The literature suggests that technology alone rarely breaks this equilibrium. Improved breeds, feed and fodder innovations and zero-grazing are associated with higher technical efficiency on East African dairy farms (Gelan & Muriithi, 2012), and integrated interventions addressing animal health, nutrition and milk quality have improved management, productivity and livelihoods on Kenyan smallholder farms (VanLeeuwen et al., 2012). The returns to such technologies, however, depend on whether farmers can sell additional milk reliably and at low transaction cost: in the Kenya highlands, better market access and an effective milk marketing system encouraged the uptake of improved dairy technologies (Baltenweck et al., 2011; Staal et al., 2002). These findings explain the shift from isolated production interventions towards value-chain approaches that combine technology transfer with institutional support for marketing (Kilelu et al., 2017).

In Kenya, the gap between available technology and farm practice remains wide. Studies document knowledge gaps in genetics, disease control, nutrition and reproduction, limited access to extension and veterinary services (VanLeeuwen et al., 2012), and value-chain bottlenecks including seasonal production, inadequate feed, poor access to quality breeding services and unaffordable credit (Wambugu et al., 2011). Across Eastern and Southern Africa, smallholder dairy farms operate well below

their production frontiers (Adane et al., 2016; Gelan & Muriithi, 2012; Majiwa et al., 2012; Masunda & Chiweshe, 2015; Wubeneh & Ehui, 2006), and in Central Kenya the use of breeding services depends on their cost and accessibility, proximity to markets and expected conception success (Murage & Ilatsia, 2011). The binding constraint is thus less the existence of technologies than their transfer to, and effective use by, farmers (Nimbalkar et al., 2021).

The East Africa Dairy Development (EADD) project was designed to address these constraints. Funded by the Bill & Melinda Gates Foundation and led by Heifer International with the International Livestock Research Institute (ILRI), TechnoServe, the World Agroforestry Centre and African Breeders Service Total Cattle Management, it ran in two phases between 2008 and 2018 across Kenya, Uganda, Rwanda and Tanzania (TechnoServe, 2019.). Its model combined technological interventions, including genetic improvement, animal health services and farmer training, with farmer-owned dairy business associations organized around milk chilling plants. The chilling plants served as hubs for milk marketing and for inputs and services obtained through a check-off system, under which costs are deducted from monthly milk payments (TechnoServe, 2019.). EADD therefore offers a setting in which technology transfer and cooperative intermediation were deliberately combined.

Evaluations of such programmes have tended to report aggregate outcomes such as milk volumes and incomes (TechnoServe, 2019.), or to examine technology adoption and technical efficiency separately (Gelan & Muriithi, 2012; Murage & Ilatsia, 2011). Less is known about how the benefits of an integrated intervention are distributed among participating farmers: whether they accrue equally to farmers with different levels of experience and education, whether they differ across cooperatives operating under the same project, and whether farmers' perceptions of project benefits correspond to their objective outcomes. These questions matter because interventions that ignore heterogeneity among farmers and their organizations risk fragmented priorities and uneven results (Kilelu et al., 2017; Ouma et al., 2013).

This study therefore examines the relationship between EADD technological interventions and the livelihoods of smallholder dairy farmers in Nandi North Sub-County, Kenya, and the extent to which farmers' human capital and their cooperatives condition that relationship. Drawing on diffusion of innovations theory (Rogers, 2003) and the sustainable livelihoods framework (Scoones, 1998), it makes three contributions. First, it relates farmers' perceptions of technological interventions to both perceived livelihoods and objective dairy outcomes. Second, it shows that experiential capital, rather than formal education, is most closely associated with output and income. Third, it identifies a gap between perceived and objective outcomes across cooperatives, with implications for how integrated dairy projects are evaluated. The paper proceeds as follows: Section 2 develops the theoretical framework and hypotheses, Section 3 describes the methods, Section 4 presents the results, Section 5 discusses them, and Section 6 concludes.

2. Theoretical Framework and Hypotheses

2.1. Diffusion of Innovations Theory

Diffusion of innovations (DOI) theory explains how new ideas, practices and technologies spread through a social system. Rogers (2003) defines diffusion as the process by which an innovation is communicated through certain channels over time among the members of a social system, and identifies five attributes that shape its adoption: relative advantage, compatibility, complexity, trialability and observability. Technology, in this view, is the application of organized knowledge to practical

purposes and includes both hardware, such as improved breeds and semen, and the knowledge and techniques needed to use it (Rogers, 2003). Interpersonal channels, including peers, early adopters and opinion leaders, are particularly influential when farmers are deciding whether to adopt (Rogers, 2003), which helps to explain the growing role of farmer-to-farmer extension in Kenya (Kiptot & Franzel, 2014).

In dairying, the relevant innovations span the production cycle, from fodder cultivation to milk marketing (Nimbalkar et al., 2021). They include assisted reproductive technologies such as AI, sexed semen, oestrus synchronization and embryo transfer; feed and fodder innovations; animal health services; and the husbandry knowledge needed to use them (Murage & Ilatsia, 2011; Nimbalkar et al., 2021). On smallholder farms in India, AI, green fodder and concentrate feeds are the most common interventions (Malsawmdawngliana & Rahman, 2016). At the technological frontier, precision tools such as sensors for disease detection are spreading in commercial herds (Bianchi et al., 2022; Džermeikaitė et al., 2023), but their relevance to African smallholders depends on cost, infrastructure and skills (Tadele et al., 2025).

The attributes that DOI emphasizes are therefore not fixed properties of a technology; they vary with the farmer and the setting. The relative advantage of AI depends on access to the service and on conception success (Murage & Ilatsia, 2011), and its compatibility depends on the farmer's production system and existing practice. Adoption of agricultural innovations in developing countries is also constrained by farm size, risk, human capital, credit and access to information (Feder et al., 1985), and smallholders' limited capacity to finance initial investment restricts the uptake of improved dairy technologies (Misra et al., 2006). DOI has two further limitations for this study. It concentrates on the adoption decision rather than on the welfare outcomes that follow, and, as Rogers (2003) acknowledges, it is prone to a pro-innovation bias and to attributing non-adoption to the individual rather than to the conditions under which an innovation is offered.

2.2. The Sustainable Livelihoods Framework

The sustainable livelihoods framework addresses these limitations. It defines a livelihood as the capabilities, assets and activities required for a means of living, and analyses how households combine natural, financial, human and social capital into livelihood strategies, mediated by institutions and organizations, to achieve livelihood outcomes (Scoones, 1998). The framework has been used to assess the poverty impact of agricultural research (Adato & Meinzen-Dick, 2002) and to explain how asset endowments shape household livelihood strategies (Soltani et al., 2012; Xu et al., 2015). Its central insight for this study is that the same intervention can yield different outcomes for different households, depending on the assets they hold and the institutions through which they act.

Combining the two perspectives yields the framework that guides this study. DOI explains how technological interventions reach farmers and why they are valued differently; the sustainable livelihoods framework explains how those interventions are converted into livelihood outcomes. Two elements of the latter are central. Human capital, the knowledge, skills and experience that farmers bring to dairying, shapes the compatibility and complexity of a technology for a given farmer and therefore the returns to its use. Institutional structures, here the dairy cooperatives through which EADD delivered services and marketed milk, shape farmers' access both to technologies and to the markets that convert additional milk into income. This study refers to the knowledge accumulated through years of dairying as experiential capital,

and to a cooperative's capacity to deliver services and market access as institutional capital. The hypotheses below follow this logic: technological interventions are expected to be associated with performance and livelihoods (H_1), and human capital (H_2) and cooperative intermediation (H_3) are expected to be associated with how far farmers' benefit.

2.3. Hypothesis Development

2.3.1 Technological Interventions, Dairy Performance and Livelihoods

Breeding technologies are the cornerstone of dairy genetic improvement. AI gives smallholders access to superior genetics without the cost and disease risk of keeping bulls (Ogutu et al., 2014), and in Tanzania its adoption has been associated with growth in the population of improved cattle (Ogutu et al., 2014). The welfare gains can be large: in Uganda, ownership of improved dairy breeds more than doubled milk yields, and the gains passed to milk sales, household milk consumption, food expenditure and child nutrition (Kabunga et al., 2017). Use of breeding services is uneven, however. In Central Kenya it depended on the cost and accessibility of services, proximity to markets and expected conception success, while more complex technologies such as multiple ovulation and embryo transfer remained rare among smallholders (Murage & Ilatsia, 2011).

The returns to breeding technologies also depend on knowledge transfer. Extension programmes in the Ethiopian highlands raised smallholder farm productivity by about 6% (Elias et al., 2013), and in the western highlands of Cameroon a package combining AI, feed supplementation, farmer training and improved veterinary services reduced average monthly farm expenditure by 18% and turned losses per cow into gains (Bayemi et al., 2009). Efficient input supply and accessible extension are therefore prerequisites for market-oriented dairy development (Tegegne et al., 2013), and new dissemination tools such as interactive multimedia modules are being used to transfer good dairy practices to farmers (Mooventhan et al., 2017). Innovation and extension contact have likewise been linked to higher technical efficiency among Ethiopian smallholders (Asres et al., 2013).

The EADD interventions combined these elements: breeding programmes and financial support for breeding, access to improved breeds and dairy technologies, technical assistance, training and extension (Table 1). From a DOI perspective, farmers who perceive greater relative advantage in these interventions are more likely to use them intensively; from a livelihood's perspective, their use should raise output and income and, through them, household welfare. Hence:

H_1: *Farmers' perceptions of EADD technological interventions are positively associated with (a) household livelihood outcomes and (b) dairy performance, measured as daily milk output and monthly dairy income.*

2.3.2 Human Capital, Production Systems and Dairy Performance

Farmers differ in their capacity to benefit from the same technology. Human capital is among the main determinants of the adoption of agricultural innovations (Feder et al., 1985), and household-level analysis of improved dairy technology adoption in Kenya shows that household characteristics interact with location and market access in shaping uptake (Staal et al., 2002). Two forms of human capital are relevant here. Formal education can ease access to information and to off-farm income that finances intensification. Experience accumulated through years of dairying builds tacit knowledge of feeding, heat detection, calving and disease that can raise the returns to a given technology; modernization of livestock systems therefore needs to build on existing systems and local knowledge (Hegde, 2019), and smallholder mixed systems

depend heavily on such accumulated skills (McDermott et al., 2010). Age captures both experience and life-cycle differences in land, labour and herd size.

The choice of production system reflects the same endowments. Whether farmer grazes cattle extensively or keeps them under zero-grazing depends on land, capital and the opportunity cost of labour, on agro-ecology, and on whether dairying is a primary or supplementary enterprise (Banda & Tanganyika, 2021); more generally, household livelihood strategies follow asset endowments (Soltani et al., 2012; Xu et al., 2015). Because intensive systems and improved breeds are associated with higher technical efficiency (Gelan & Muriithi, 2012), differences in human capital should be reflected both in the systems farmers operate and in their performance. Hence:
H_2: *Farmers' human capital (age, education and dairying experience) is associated with their production system and with dairy performance.*

2.3.3 Cooperative Intermediation and Dairy Performance

Technology raises income only if the additional milk can be sold. Smallholders face high transaction costs in reaching markets, and collective action through producer organizations can reduce these costs, strengthen bargaining power and provide services (Markelova et al., 2009). In the Kenya highlands, improved milk marketing encouraged the adoption of dairy technologies (Baltenweck et al., 2011), and in Ethiopia's Selale area cooperative membership was associated with stronger technological change, measured by the share of crossbred cows and feed purchases, although cooperatives were weak in securing better milk prices (Chagwiza et al., 2016).

The evidence on cooperatives is nevertheless mixed. In East Africa, cooperative membership had a positive but statistically insignificant effect on technical efficiency (Gelan & Muriithi, 2012), and rural producer organizations do not necessarily reach the poorest households (Bernard & Spielman, 2009). These results suggest that what matters is less membership as such than the quality of intermediation a cooperative provides: reliable collection and chilling, prompt payment, and access to inputs and services on credit (Omore et al., 2004; Rademaker et al., 2016; TechnoServe, 2019.). Multi-stakeholder value-chain processes such as EADD aim precisely at strengthening these functions (Kilelu et al., 2017). Because the three cooperatives in this study operated under the same project, differences between them provide a test of whether institutional capital is associated with farm outcomes. Hence:
H_3: *Dairy performance (daily milk output and monthly dairy income) differs across cooperatives operating under the same project and is positively associated with selling milk through the cooperative.*

Finally, because evaluations of dairy projects often rely on farmers' own assessments, and interventions must be perceived as creating opportunities if they are to be sustained (Ouma et al., 2013), the study also examines, as an exploratory question, whether farmers' perceived livelihood benefits correspond to their objective dairy outcomes.

3. Methodology

3.1. Study Area and Research Design

The study was conducted in Nandi North Sub-County, Nandi County, among smallholder farmers supplying three dairy cooperatives supported by EADD: Kabiyet, Lelchego and Tanykina Dairies. A cross-sectional survey design was adopted, which suits the study's aim of describing farmers' perceptions and outcomes and examining associations among them at one point in time. Because the three cooperatives operated under the same project, the design allows outcomes to be compared across cooperatives while holding the project constant.

3.2. Population, Sample and Response

The target population comprised 5,640 smallholder dairy farmers registered with the three cooperatives. A sample of 373 farmers was determined with Yamane's (1967) formula at a 5% margin of error. Of the 373 questionnaires administered, 196 were returned complete and usable, a response rate of 52.5%. Respondents were members of Tanykina (40.8%), Lelchego (35.2%) and Kabiyet (24.0%) cooperatives. The study used a proportionate stratified random sampling by the cooperative unit, while the instrument was pretested in Lessos Farmers' Cooperative Society before being administered.

3.3. Measures

Data were collected with a structured questionnaire. Technological interventions were measured with eight items covering breeding programmes, financial support for breeding, access to improved breeds and dairy technologies, technical assistance, breeding training and extension services. Household livelihoods were measured with seven items covering dairying as a source of income, livelihood and employment, its contribution to nutrition and to the standard of living, and its place in the local economy (Table 1). All items were rated on five-point Likert scales anchored on (1 = strongly disagree, 5 = strongly agree), and composite scores were computed as the mean of the items in each scale. Farmer characteristics and dairy outcomes were measured as categorical variables: age (five bands from 21–29 to 60 years and above), education (six levels from primary to graduate), dairying experience (five bands from 1–5 to more than 20 years), production system (zero-grazing, semi-intensive or extensive), daily milk output (five bands from less than 10 kg to more than 40 kg), monthly dairy income (five bands from below KSh 10,000 to above KSh 40,000) and main milk marketing channel (cooperative or middlemen).

3.4. Data Analysis

Data were analysed with descriptive statistics, one-way analysis of variance (ANOVA) and Pearson's correlation. ANOVA was used to test differences in education, engagement in dairying, production system, milk output, income, marketing channel and perceptions across age groups, education levels and cooperatives, with post hoc comparisons identifying which groups differed. Pearsons's correlation was used to test associations among the study variables because most were measured on ordinal scales. Because cooperative affiliation is a nominal variable, differences between cooperatives were assessed with ANOVA rather than with correlation coefficients. H_1 was tested with the correlations between perceived interventions and the outcome variables, H_2 with the age and education comparisons and the correlations involving age and experience, and H_3 with the cooperative comparisons and the correlations involving the marketing channel.

4. Results

4.1. Profile of Respondents

Most respondents were male (67.9%). About 70% were younger than 50 years: 15.3% were aged 21–29, 31.6% were aged 30–39 and 23.5% were aged 40–49, while 23.0% were aged 50–59 and 6.6% were 60 or older. Secondary (39.8%) and primary (34.7%) education predominated, and smaller shares held certificates (9.7%), diplomas (8.2%), undergraduate degrees (4.0%) or graduate degrees (3.6%). Dairying experience was concentrated at 6–10 years (38.3%) and 1–5 years (27.0%), followed by 11–15 years (12.2%) and 16–20 years (6.1%), while 16.3% had more than 20 years' experience.

Just over half of the respondents (53.1%) relied on dairying alone, while 46.9% combined it with crop farming. Extensive grazing was the most common production

system (51.0%), followed by semi-intensive systems (37.2%) and zero-grazing (11.7%). Farm-level output was modest: 44.4% produced less than 10 kg of milk a day and 32.1% produced 11–20 kg, while 14.8% produced 21–30 kg and only 7.6% produced more than 30 kg. Monthly dairy income was correspondingly low: 47.4% earned below KSh 10,000, 34.7% earned KSh 10,001–20,000, 14.3% earned KSh 20,001–30,000, 1.5% earned KSh 30,001–40,000 and 2.0% earned more than KSh 40,000. Most respondents (81.4%) sold their milk mainly through their cooperative, and 18.4% sold mainly to middlemen. The sample therefore consists mainly of small, extensively managed but market-oriented farms whose output and income vary considerably.

4.2. Perceptions of Technological Interventions and Livelihoods

Table 1: Farmers' perceptions of EADD technological interventions and household livelihoods

Indicators of technological interventions	**Mean**	**SD**
The project introduced new breeding programs	4.2551	0.7346
The project assisted with the breeding program's financial support	4.3775	0.6327
The project enabled access to modern dairy breeds with higher productivity	4.3112	0.6325
The project enabled access to dairy improvement technologies	4.2704	0.6819
The project provided technical assistance to dairy farmers	4.3979	0.6678
The project assisted in the breeding programme training support	4.3878	0.6739
The project introduced animal extension services to farmers	4.3316	0.6922
The project assisted the cooperative access animal extension services	4.3214	0.6435
Indicators of Household livelihoods	**Mean**	**SD**
Dairy farming is the main economic activity in the community	3.9694	0.7226
Dairy farming provides a source of income to households	4.3469	0.5566
Dairy farming has provided a source of livelihood for households	4.3775	0.5549
The project has enabled farmers to exploit dairy farming	4.3316	0.5427
The project has contributed to a higher standard of living within the community	4.3520	0.5671
Dairy farming employs households in the community	4.3571	0.5774
Dairy farming has improved the nutritional requirements of households	4.3673	0.5798

Farmers rated the EADD interventions highly (Table 1). Mean scores ranged from 4.26 for the introduction of new breeding programmes to 4.40 for technical assistance, with similar ratings for breeding training (4.39), financial support for breeding (4.38) and extension services (4.33). Livelihood items were rated between 4.33 and 4.38, with one exception: the statement that dairying is the main economic activity in the community scored lower (3.97), consistent with the diversified livelihoods described above. Standard deviations were small (0.54–0.73), indicating broad agreement. Farmers therefore credit the project with improving breeding, access to technology and extension, and with contributing to income, nutrition, employment and living standards. Because the ratings are high and compressed, however, perceptions alone discriminate little between farmers, which is why the analyses that follow relate them to objective outcomes.

4.3. Differences by Age, Education and Cooperative

Table 2: One-way ANOVA of farmer characteristics, dairy outcomes and perceptions by age, education and cooperative

Variable	**F-test**	**p**	**Categorical differences**					
Age of the respondents			**1**	**2**	**3**	**4**	**5**	
Education # Age	4.198	0.000	2.05^{ab}	2.51^{b}	2.50^{b}	1.70^{ab}	1.30^{a}	
Dairying engagement intensity # Age	3.901	0.000	1.68^{b}	1.51^{ab}	1.60^{ab}	1.24^{a}	1.40^{ab}	
Dairy milk yield # Age	5.639	0.000	1.55^{a}	1.68^{a}	2.17^{ab}	2.49^{b}	2.50^{b}	
Monthly dairying income # Age	2.571	0.040	1.50^{a}	1.68^{a}	2.05^{a}	2.05^{a}	2.20^{a}	
Level of education			**1**	**2**	**3**	**4**	**5**	**6**
Dairying experience #Education level	6.997	0.000	3.33^{b}	2.07^{ab}	2.93^{ab}	2.21^{ab}	1.67^{ab}	1.33^{a}

Variable	F-test	p	Categorical differences					
Production system #Education level	2.881	0.016	2.54[b]	2.52[ab]	2.47[ab]	2.07[ab]	1.67[a]	2.00[ab]
Dairy cooperative society			**Kabiyet**		**Lelchego**		**Tanykina**	
Dairying experience #Dairy cooperative	3.121	0.047	2.15[a]		2.75[a]		2.82[a]	
Production system #Dairy cooperative	8.393	0.000	2.17[a]		2.36[ab]		2.63[b]	
Dairy Milk Output #Dairy cooperative	27.578	0.000	1.33[a]		1.91[a]		2.51[c]	
Monthly dairying income # cooperative	18.448	0.000	1.29[a]		2.14[b]		2.16[b]	
Milk sales #Dairy cooperative	16.282	0.000	1.77[b]		1.59[a]		1.99[c]	
Technological interventions	3.284	0.000	4.125[a]		4.681b		4.525[b]	
Households' livelihoods	2.141	0.000	4.335[a]		4.722[a]		4.223[a]	

[a, b, c,] *Means with the same letter superscript in a column are not significantly different (p<0.05)*

Note. Values are group means of category codes or scale scores. Age: 1 = 21–29, 2 = 30–39, 3 = 40–49, 4 = 50–59, 5 = 60 years and above. Education: 1 = primary, 2 = secondary, 3 = certificate, 4 = diploma, 5 = undergraduate, 6 = graduate. Daily milk output: 1 = less than 10 kg, 2 = 11–20 kg, 3 = 21–30 kg, 4 = 31–40 kg, 5 = more than 40 kg. Monthly dairy income: 1 = below KSh 10,000, 2 = KSh 10,001–20,000, 3 = KSh 20,001–30,000, 4 = KSh 30,001–40,000, 5 = above KSh 40,000. Production system: 1 = zero-grazing, 2 = semi-intensive, 3 = extensive. Milk sales: 1 = middlemen, 2 = cooperative. Technological interventions and household livelihoods are mean scores on five-point scales.

Age was associated with education, engagement and performance (Table 2). Farmers aged 30–39 and 40–49 had the highest education scores (2.51 and 2.50) and those aged 60 or above the lowest (1.30). Engagement in dairying also differed by age, with the clearest contrast between the youngest group (1.68) and farmers aged 50–59 (1.24). Daily milk output rose with age ($F = 5.639$, $p < 0.001$), from a mean of 1.55 among farmers aged 21–29, close to the lowest output band, to 2.49 and 2.50 among those aged 50–59 and 60 or above, midway between the 11–20 kg and 21–30 kg bands. Monthly income also differed by age ($F = 2.571$, $p = 0.040$), rising from 1.50 to 2.20, although post hoc tests did not separate individual age groups.

Education was associated with experience and production system. Dairying experience declined with education ($F = 6.997$, $p < 0.001$): farmers with primary education had the longest tenure (3.33, in the 11–15-year band), and those with graduate qualifications the shortest (1.33, between the 1–5-year and 6–10-year bands). Production systems also differed by education ($F = 2.881$, $p = 0.016$). Farmers with primary education operated the most extensive systems (2.54) and those with undergraduate degrees the most intensive (1.67).

The sharpest differences were between cooperatives. Daily milk output differed strongly ($F = 27.578$, $p < 0.001$): Tanykina members had the highest mean (2.51) and differed significantly from both Lelchego (1.91) and Kabiyet (1.33) members, who did not differ from each other. Monthly income also differed ($F = 18.448$, $p < 0.001$), but here Lelchego (2.14) and Tanykina (2.16) members earned similar incomes, both above Kabiyet (1.29). Marketing channels differed as well ($F = 16.282$, $p < 0.001$): almost all Tanykina members sold through their cooperative (1.99), compared with Kabiyet (1.77) and Lelchego (1.59) members. Tanykina members also operated the most extensive systems (2.63, against 2.17 for Kabiyet; $F = 8.393$, $p < 0.001$), and experience differed marginally across cooperatives ($F = 3.121$, $p = 0.047$) without significant pairwise differences.

Perceptions followed a different pattern. Kabiyet members rated the technological interventions lower (4.13) than Lelchego (4.68) and Tanykina (4.53) members, but perceived livelihood benefits were high in all three cooperatives (4.22–4.72), and post hoc comparisons did not distinguish between them. The cooperative whose members

produced the most milk did not report the greatest livelihood benefits, and the cooperative with the lowest output and income reported benefits similar to the others.

4.4. Hypothesis Tests

Table 3: Pearson correlations among the study variables

	1	2	3	4	5	6	7	8	9
Livelihoods	1.000								
Dairying technological interventions	0.308**	1.000							
Dairy cooperative	-0.218**	0.217**	1.000						
Farmer's age	-0.010	0.059	0.216**	1.000					
Dairy farming experience	0.067	0.099	0.166*	0.615**	1.000				
Dairy productions systems	0.304**	0.050	-0.271**	-0.170*	-0.134	1.000			
Daily Milk yield	-0.072	0.295**	0.595**	0.359**	0.449**	-0.010	1.000		
Monthly dairy income	0.033	0.346**	0.508**	0.291**	0.456**	0.071	0.863**	1.000	
Intermediation by the dairy cooperative	-0.043	0.055	0.330**	0.025	0.237**	0.105	0.280**	0.273**	1.000

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

H_1. Perceived technological interventions were positively associated with perceived livelihoods ($r = 0.308$, $p < 0.01$), daily milk output ($r = 0.295$, $p < 0.01$) and monthly dairy income ($r = 0.346$, $p < 0.01$). H_1 is therefore supported for both livelihood and performance outcomes. The associations are of moderate size, so perceptions of the interventions account for only part of the variation in outcomes. Output and income were themselves strongly correlated ($r = 0.863$, $p < 0.01$), as expected for farms that sell most of their milk.

H_2. Age was strongly associated with dairying experience ($r = 0.615$, $p < 0.01$), and both were associated with output (age $r = 0.359$; experience $r = 0.449$) and income (age $r = 0.291$; experience $r = 0.456$; all $p < 0.01$). Older farmers operated less intensive systems ($r = -0.170$, $p < 0.05$), and experience showed a similar but non-significant tendency ($r = -0.134$). Production system intensity was not associated with output ($r = -0.010$) or income ($r = 0.071$), but it was associated with perceived livelihoods ($r = 0.304$, $p < 0.01$). Together with the differences in education, experience and production system shown in Table 2, these results support H_2: human capital, and experience in particular, is associated with production system and with dairy performance. They also reveal a demographic paradox: older, more experienced farmers produced more milk and earned more, even though they operated less-intensive systems.

H_3. Selling milk through the cooperative was positively associated with output ($r = 0.280$), income ($r = 0.273$) and experience ($r = 0.237$; all $p < 0.01$), but not with perceived interventions ($r = 0.055$) or perceived livelihoods ($r = -0.043$). Combined with the large differences in output, income and marketing channel across cooperatives (Table 2), these results support H_3. The cooperative in which almost all members sold through the formal channel also recorded the highest output.

Exploratory question. Perceived livelihoods were not associated with daily milk output ($r = -0.072$) or monthly income ($r = 0.033$), nor with age ($r = -0.010$) or experience ($r = 0.067$). Farmers' assessments of livelihood improvement were therefore largely independent of the objective outcomes the project aimed to change, and were associated instead with their perceptions of the interventions and with the intensity of their production system. Table 4 summarizes the results.

Table 4: Summary of hypothesis tests

Hypothesis	Key evidence	Result
H_1: Perceived interventions are positively associated with (a) livelihoods and (b) dairy performance	Interventions–livelihoods r = 0.308; –output r = 0.295; –income r = 0.346 (all $p < 0.01$)	Supported
H_2: Human capital is associated with production system and dairy performance	Experience–output r = 0.449, –income r = 0.456; age–output r = 0.359; age–intensity r = −0.170; output and experience differ by age and education (Table 2)	Supported
H_3: Performance differs across cooperatives and is associated with cooperative marketing	Output F = 27.578, income F = 18.448, marketing channel F = 16.282 (all $p < 0.001$); channel–output r = 0.280, –income r = 0.273	Supported
Exploratory: Perceived livelihoods correspond to objective outcomes	Livelihoods–output r = −0.072, –income r = 0.033 (not significant)	Not supported

5. Discussion

The results show that the livelihood returns to dairy technologies are not determined by the technologies alone. They are associated with the farmer's experience and with the cooperative through which the farmer reaches services and markets, and farmers' perceptions of benefit do not necessarily track their objective outcomes. This section interprets each of these findings in turn.

5.1. Technological Interventions, Performance and Livelihoods

The positive associations between perceived interventions and both livelihoods and dairy performance are consistent with evidence that breeding, health and extension packages raise productivity and income on smallholder farms (Bayemi et al., 2009; Elias et al., 2013; Kabunga et al., 2017; VanLeeuwen et al., 2012). In DOI terms, farmers who perceive greater relative advantage in the interventions are those who report greater benefits (Rogers, 2003). Three qualifications apply. First, the associations are moderate: perceptions of the interventions leave much of the variation in output and income unexplained, which points to the conditioning factors discussed below. Second, the evidence is correlational. Farmers who already produced more may have had better access to the services and therefore rated them more favourably, so the direction of influence may run both ways. Third, the strong association between output and income indicates that production gains translate into income mainly through milk sales, which supports the use of performance indicators such as milk per cow per day as targets for intervention (Gelan & Muriithi, 2012; Ouma et al., 2013). As early users realize these gains, they can act as opinion leaders for neighbouring farmers, the mechanism through which DOI expects technologies to spread (Rogers, 2003).

5.2. Experiential Capital and the Demographic Paradox

The finding that older farmers produced more milk and earned more, despite operating less intensive systems, qualifies the assumption that intensification is the main route to higher output. Experience was more closely associated with output and income than age, which suggests that the tacit knowledge accumulated through years of dairying, in

feeding, heat detection, calving and disease recognition, raises the returns to a given technology (Hegde, 2019; McDermott et al., 2010). This interpretation is consistent with the DOI view that compatibility with existing practice shapes how innovations are used (Rogers, 2003): for experienced farmers, technologies such as AI may be absorbed into established extensive systems rather than requiring a change of system. Two alternative explanations should also be considered. Older farmers may own more land and larger herds, which would raise farm-level output without higher yields per cow, and the data do not include herd size or land area. Survivorship may also play a part, since farmers who remain in dairying for decades are likely to be those for whom it has been profitable. The absence of an association between system intensity and output or income contrasts with evidence that zero-grazing is associated with higher technical efficiency (Gelan & Muriithi, 2012); the difference may arise because efficiency measures output relative to inputs, whereas this study measured total farm output.

Education showed a different pattern. More educated farmers had entered dairying more recently and operated more intensive systems, whereas farmers with primary education had longer tenure and more extensive systems. This is consistent with evidence that livelihood strategies follow asset endowments (Soltani et al., 2012; Xu et al., 2015): educated farmers may use off-farm income to finance the housing, feed and labour that zero-grazing requires, while less educated farmers rely on land and accumulated skills. The choice of system also depends on agro-ecology and on whether dairying is a primary or supplementary activity (Banda & Tanganyika, 2021). That system intensity was associated with perceived livelihoods but not with objective outcomes suggests that farmers in more intensive systems perceive greater benefit from the project, possibly because they use more of its services, rather than that they earn more from dairying. Formal education and experience are thus distinct forms of human capital, and the second appears to matter more for performance.

5.3. Institutional Capital and Cooperative Intermediation

Differences between cooperatives were the largest in the study. Although all three cooperatives operated under EADD, their members' output and income differed markedly, and the cooperative with the most complete formal marketing recorded the highest output. Selling through the cooperative was associated with higher output, income and experience. These results support the view that the returns to technology depend on market access and on the transaction costs of selling milk (Baltenweck et al., 2011; Markelova et al., 2009; Staal et al., 2002), and that value-chain approaches which strengthen producer organizations are central to integrating smallholders into formal markets (Kilelu et al., 2017). They also help to reconcile the mixed evidence on cooperative membership (Chagwiza et al., 2016; Gelan & Muriithi, 2012). When all farmers belong to a cooperative, what differentiates their outcomes is the quality of intermediation the cooperative provides, including reliable collection, chilling, payment and access to inputs and services on credit (Omore et al., 2004; Rademaker et al., 2016; TechnoServe, 2019).

Several explanations for Tanykina's advantage are possible: better governance and leadership, more effective service delivery, better chilling infrastructure or stronger bargaining power with processors. Leadership has similarly been linked to growth in agricultural value chains in Nandi County's tea sector (Kemboi & Kering, 2024). The data do not allow these explanations to be distinguished, and the differences may also reflect agro-ecological conditions or the self-selection of different farmers into different cooperatives (Bernard & Spielman, 2009). The comparison between Lelchego and Tanykina adds a further nuance. Lelchego members earned similar incomes despite

lower output and greater reliance on middlemen, which suggests that prices and payment terms, and not only volumes, shape dairy income, and that cooperatives may be stronger in delivering technology than in securing better prices (Chagwiza et al., 2016).

5.4. The Perception–Performance Gap

The finding with the most direct consequences for project evaluation is that perceived livelihood benefits were high across all cooperatives but unrelated to output and income. Members of the cooperative with the lowest output and income reported livelihood benefits similar to those of members of the highest-performing cooperative, and perceived livelihoods were associated with perceived interventions and production system rather than with objective outcomes. Three explanations are plausible. First, farmers may value non-income dimensions of their livelihoods, such as household milk consumption, employment and security, which the livelihood scale captures and income does not (Herrero et al., 2013; Kabunga et al., 2017). Second, satisfaction may reflect the quality-of-service delivery and trust in cooperative management, which can differ from economic performance (Ouma et al., 2013). Third, the association between two perception measures collected in the same survey may be inflated by common-method variance (Podsakoff et al., 2003), and the high, compressed ratings limit the ability of the livelihood scale to discriminate between farmers. Whatever the explanation, the finding cautions against evaluating integrated dairy projects through farmer perceptions alone, and supports combining perception measures with objective indicators of output, income and nutrition.

6. Conclusion and Implications

6.1. Conclusion

This study examined how dairy technological interventions under the EADD project relate to the livelihoods of smallholder farmers in Nandi North Sub-County, Kenya. Farmers rated the interventions highly, and their perceptions were positively associated with livelihoods, milk output and dairy income. The returns to the interventions were not uniform, however. They were associated with farmers' experiential capital, with older and more experienced farmers producing more milk despite operating less intensive systems, and with the institutional capital of their cooperatives, which differed sharply in output, income and marketing even under the same project. Perceived livelihood benefits did not track these objective differences. The central conclusion is that technology is a necessary but not sufficient condition for improved dairy livelihoods: its effects depend on the knowledge farmers bring to it and on the cooperative institutions that connect it to markets, and project success should be judged by objective outcomes as well as by farmers' perceptions.

6.2. Theoretical Implications

The study contributes to theory in three ways. First, it extends DOI by showing that the relative advantage and compatibility of dairy technologies are not inherent properties of the technologies but depend on farmers' experiential capital and on the institutional capital of the organizations through which technologies and markets are reached. Second, it shows how DOI and the sustainable livelihoods framework can be combined: DOI explains how interventions reach farmers and why they are valued differently, while the livelihoods framework explains how human capital and institutions convert those interventions into outcomes (Scoones, 1998). Third, the perception–performance gap indicates that livelihood outcomes are multidimensional and that subjective and objective measures of the same outcome can diverge; models of technology and

livelihoods should therefore treat them as distinct outcomes rather than as interchangeable indicators.

6.3. Practical and Policy Implications

1. **Differentiate extension by experience and production system.** For experienced farmers in extensive systems, extension should integrate low-complexity, high-impact technologies, such as AI and targeted feed supplementation, into existing practice. For younger and more educated farmers, support should focus on semi-intensive and zero-grazing systems, financial management and more advanced reproductive technologies. Experienced farmers can also serve as farmer trainers for their less experienced peers (Kiptot & Franzel, 2014).
2. **Strengthen and standardize cooperative intermediation.** Project implementers and county governments should audit cooperative governance and service delivery, including milk collection, chilling, pricing, payment and AI services, and transfer practices from high-performing cooperatives to weaker ones.
3. **Monitor objective outcomes alongside perceptions.** Monitoring systems should track milk output per cow, dairy income and household nutrition in addition to farmer satisfaction, so that high satisfaction does not mask weak economic performance.
4. **Use demonstration farms to make technologies trialable and observable.** Community demonstration farms hosted by cooperatives can show technologies such as sexed semen, oestrus synchronization and improved fodder working under local conditions, reducing the perceived risk of adoption (Rogers, 2003).

6.4. Limitations and Future Research

The study has limitations that qualify its conclusions. First, the cross-sectional design and bivariate analyses identify associations but cannot establish causality or control for confounders such as herd size, land area, agro-ecology and off-farm income; the associations of age and cooperative affiliation with output may partly reflect these factors. Second, technological interventions and livelihoods were measured with self-reported perception scales in the same instrument, which exposes their association to common-method bias (Podsakoff et al., 2003), and output and income were recorded in broad self-reported bands, which limits precision. Third, cooperative affiliation is nominal and was not randomly assigned, so differences between cooperatives may reflect selection as well as institutional quality. Fourth, the response rate of 52.5% raises the possibility of non-response bias, and the study covers three cooperatives in one sub-county, which limits generalization to other agro-ecological zones.

Future research should use panel data over several lactation cycles and multivariate methods, such as regression with interaction terms or structural equation modelling, to test whether experience and cooperative intermediation moderate the relationship between technology and livelihoods. Measuring output per cow, herd size and milk prices would separate productivity from scale and price effects. Mixed-methods studies of cooperative governance could explain the perception–performance gap, and comparative studies across counties and countries in the EADD footprint would test the generality of the findings.

Declarations

Funding

This research received no external funding.

Acknowledgments
The author thanks the management of Kabiyet, Lelchego and Tanykina Dairies for administrative support during data collection.

Conflicts of Interest
The author declares no conflict of interest.

Data Availability Statement
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

References

Adane, Z., Shiferaw, K., & Gebremedhin, B. (2016). Sources of technical inefficiency of smallholder farmers in milk production in Ethiopia. LIVES Working Paper 3. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Adato, M., & Meinzen-Dick, R. S. (2002). Assessing the impact of agricultural research on poverty using the sustainable livelihoods framework (No. 581-2016-39396). IFPRI.

Asres, A., Sölkner, J., & Wurzinger, M. (2013). Innovation and technical efficiency in the smallholder dairy production system in Ethiopia. *Journal of Agricultural Science and Technology B*, *3*(3), 151-164.

Baltenweck, I., Yamano, T., & Staal, S. J. (2011). Dynamic changes in the uptake of dairy technologies in the Kenya highlands. In T. Yamano, K. Otsuka, & F. Place (Eds.), Emerging development of agriculture in East Africa (pp. 85–97). Springer. https://doi.org/10.1007/978-94-007-1201-0_6

Banda, L. J., & Tanganyika, J. (2021). Livestock provide more than food in smallholder production systems of developing countries. Animal Frontiers, 11(2), 7-14.

Bayemi, P. H., Webb, E. C., Ndambi, A., Ntam, F., & Chinda, V. (2009). Impact of management interventions on smallholder dairy farms of the western highlands of Cameroon. Tropical Animal Health and Production, 41(6), 907–912. https://doi.org/10.1007/s11250-008-9278-3

Bernard, T., & Spielman, D. J. (2009). Reaching the rural poor through rural producer organizations? A study of agricultural marketing cooperatives in Ethiopia. Food Policy, 34(1), 60–69.

Bianchi, M. C., Bava, L., Sandrucci, A., Tangorra, F. M., Tamburini, A., Gislon, G., & Zucali, M. (2022). Diffusion of precision livestock farming technologies in dairy cattle farms. Animal, 16(11), 100650.

Cabrera, V. E., Solis, D., & Del Corral, J. (2010). Determinants of technical efficiency among dairy farms in Wisconsin. Journal of Dairy Science, 93(1), 387-393.

Chagunda, M. G., Mwangwela, A., Mumba, C., Dos Anjos, F., Kawonga, B. S., Hopkins, R., & Chiwona-Kartun, L. (2016). Assessing and managing intensification in smallholder dairy systems for food and nutrition security in Sub-Saharan Africa. Regional Environmental Change, 16, 2257-2267.

Chagwiza, C., Muradian, R., & Ruben, R. (2016). Cooperative membership and dairy performance among smallholders in Ethiopia. Food Policy, 59, 165–173. https://doi.org/10.1016/j.foodpol.2016.01.008

Deshingkar, P., Farrington, J., Rao, L., Akter, S., Sharma, P., Freeman, H. A., & Reddy, J. (2008). Livestock and poverty reduction in India: findings from the ODI Livelihood Options Project. Discussion Paper No. 8 Targeting and Innovation, ILRI

Džermeikaitė, K., Bačėninaitė, D., & Antanaitis, R. (2023). Innovations in cattle farming: Application of innovative technologies and sensors in the diagnosis of diseases. Animals, 13(5), 780.

Elias, A., Nohmi, M., Yasunobu, K., & Ishida, A. (2013). Effect of agricultural extension program on smallholders' farm productivity: Evidence from three peasant associations in the highlands of Ethiopia. Journal of Agricultural Science, 5(8), 163-181.

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. Economic Development and Cultural Change, 33(2), 255–298.

Food and Agriculture Organization (FAO). (2023). Dairy Market Review – Emerging trends and outlook in 2023. Rome. Retrieved from http://www.fao.org/economic/est/est-commodities/dairy/milk-and-milk-products/en

Gelan, A., & Muriithi, B. W. (2012). Measuring and explaining technical efficiency of dairy farms: A case study of smallholder farms in East Africa. Agrekon, 51(2), 53-74.

Hegde, N. G. (2019). Livestock development for sustainable livelihood of small farmers. Available at SSRN 4345390.

Herrero, M., Grace, D., Njuki, J., Johnson, N., Enahoro, D., Silvestri, S., & Rufino, M. C. (2013). The roles of livestock in developing countries. Animal, 7(s1), 3-18.

International Livestock Research Institute. (n.d.). East Africa Dairy Development (EADD) project. Retrieved November 12, 2026, from https://www.ilri.org/research/projects/east-africa-dairy-development-eadd-project

Kabunga, N. S., Ghosh, S., & Webb, P. (2017). Does ownership of improved dairy cow breeds improve child nutrition? A pathway analysis for Uganda. PLoS ONE, 12(11), e0187816. https://doi.org/10.1371/journal.pone.0187816

Kemboi, J., & Kering, V. (2024). Strategic leadership and growth in agricultural value chains in tea estates in Nandi County, Kenya. East African Journal of Agriculture and Biotechnology, 7(2), 211-220.

Kilelu, C., Klerkx, L., Omore, A., Baltenweck, I., Leeuwis, C., & Githinji, J. (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, 29(5), 1102-1121.

Kiptot, E., & Franzel, S. (2014). Voluntarism as an investment in human, social and financial capital: evidence from a farmer-to-farmer extension program in Kenya. *Agriculture and Human Values*, *31*(2), 231-243.

Majiwa, E. B., Kavoi, M. M., & Murage, H. (2012). Smallholder dairying in Kenya: The assessment of the technical efficiency using the stochastic production frontier model. Journal of Agriculture, Science and Technology, 14(2), 3–16.

Malsawmdawngliana, R., & Rahman, S. (2016). Management practices followed by the dairy farmers of Mizoram, India. Journal of Livestock Science, 7, 220-225.

Markelova, H., Meinzen-Dick, R., Hellin, J., & Dohrn, S. (2009). Collective action for smallholder market access. Food Policy, 34(1), 1–7.

Masunda, S., & Chiweshe, A. R. (2015). A stochastic frontier analysis on farm level technical efficiency in Zimbabwe: A case of Marirangwe smallholder dairy farmers. Journal of Development and Agricultural Economics, 7(6), 237–242.

McDermott, J. J., Staal, S. J., Freeman, H. A., Herrero, M., & Van de Steeg, J. A. (2010). Sustaining intensification of smallholder livestock systems in the tropics. Livestock Science, 130(1-3), 95-109.

Misra, A. K., Subrahmanyam, K. V., Shivarudrappa, B., & Ramakrishna, Y. S. (2006). Experiences on participatory action research for enhancing productivity of dairy animals in rainfed agro-ecosystem of India. Indian Journal of Animal Sciences.

Mooventhan, P., Kadian, K. S., Senthilkumar, R., Kumaresan, A., Manimaran, A., & Karpagam, C. (2017). Dissemination of good dairy farming practices through interactive educational multimedia module-An innovative approach in farm technology transfer. The Indian Journal of Animal Sciences, 87(3), 396-400.

Murage, A. W., & Ilatsia, E. D. (2011). Factors that determine use of breeding services by smallholder dairy farmers in Central Kenya. *Tropical animal health and production*, *43*(1), 199-207.

Nehring, R. F., Sauer, J., Gillespie, J. M., & Hallahan, C. B. (2011). Intensive versus extensive dairy production systems: Dairy states in the eastern and midwestern US and key pasture countries in the EU: Determining the competitive edge. Journal of Agricultural and Applied Economics.

Nimbalkar, V., Verma, H. K., & Singh, J. (2021). Dairy farming innovations for productivity enhancement. In New Advances in the Dairy Industry. IntechOpen.

Ogutu, C., Kurwijila, L. R., & Omore, A. O. (2014). Review of successes and failures of dairy value chain development interventions in Tanzania. CGIAR Research Program.

Omore, A. O., Mulindo, J. C. O., Khan, M. I., Islam, S. F., Staal, S. J., Nurah, G., & Dugdill, B. T. (Eds.). (2004). Employment generation through small-scale dairy marketing and processing: Experiences from Kenya, Bangladesh and Ghana (No. 158). Food & Agriculture Org.

Ouma, R., Njoroge, L., Romney, D. L., Ochungo, P., Staal, S. J., & Baltenweck, I. (2013). Targeting dairy interventions in Kenya: A guide for development planners, researchers and extension workers. ILRI.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. Journal of Applied Psychology, 88(5), 879–903.

Rademaker, I. F., Koech, R. K., Jansen, A., & van der Lee, J. (2016). Smallholder dairy value chain interventions; The Kenya Market-led Dairy Programme (KMDP)– Status Report. Centre for Development Innovation.

Rogers, E. M. (2003). Diffusion of innovations (5th Ed.). Free Press.

Rota, A., & Urbani, I. (2021). IFAD Advantage Series: The small livestock advantage: A sustainable entry point for addressing SDGs in rural areas. International Fund for Agricultural Development (IFAD).

Scoones, I. (1998). Sustainable rural livelihoods: A framework for analysis (IDS Working Paper 72). Institute of Development Studies.

Soltani, A., Angelsen, A., Eid, T., Naieni, M. S., & Shamekhi, T. (2012). Poverty, sustainability, and household livelihood strategies in Zagros, Iran. Ecological Economics, 79, 60–70.

Staal, S. J., Baltenweck, I., Waithaka, M. M., de Wolff, T., & Njoroge, L. (2002). Location and uptake: Integrated household and farm level analysis of improved dairy technology adoption in smallholder dairy production systems in Kenya. Agricultural Economics, 27(3), 295-311.

Tadele, E., Worku, D., Yigzaw, D., Muluneh, T., & Melese, A. (2025). Precision of dairy farming: Navigating challenges and seizing opportunities for sustainable dairy production in Africa. Frontiers in Animal Science, 6, 1541838.

TechnoServe. (2019). East Africa Dairy Development. Retrieved November 12, 2026, from https://www.technoserve.org/our-work/projects/east-africa-dairy-development

Tegegne, A., Gebremedhin, B., Hoekstra, D., Belay, B., & Mekasha, Y. (2013). Smallholder dairy production and marketing systems in Ethiopia: IPMS experiences and opportunities for market-oriented development. ILRI.

VanLeeuwen, J. A., Mellish, T., Walton, C., Kaniaru, A., Gitau, R., Mellish, K., ... & Wichtel, J. (2012). Management, productivity and livelihood effects on Kenyan smallholder dairy farms from interventions addressing animal health and nutrition and milk quality. Tropical Animal Health and Production, 44(2), 231-238.

Wambugu, S., Kirimi, L., & Opiyo, J. (2011). Productivity trends and performance of dairy farming in Kenya (No. 680-2016-46762). KARI.

Wubeneh, N., & Ehui, S. K. (2006, August 12–18). Technical efficiency of smallholder dairy farmers in the central Ethiopian highlands [Paper presentation]. 2006 Annual Meeting of the International Association of Agricultural Economists, Queensland, Australia.

Xu, D., Zhang, J., Rasul, G., Liu, S., Xie, F., Cao, M., & Liu, E. (2015). Household livelihood strategies and dependence on agriculture in the mountainous settlements in the Three Gorges Reservoir Area, China. Sustainability, 7(5), 4850–4869.

Yamane, T. (1967). Statistics: An introductory analysis (2nd ed.). Harper and Row.