# Assessment of resilient capacities of typical and entrepreneurial dairy farms in Narok-Bomet and Nyandarua counties, Kenya

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## ABSTRACT

The dairy sector in Kenya is constrained by recurrent shocks spanning from climate change, which adversely intensifies production risks, to market risks coupled with poor infrastructural and technological advancement and institutional and financial risks. A move towards a robust, reliable, adaptive intensification and resilient dairy sector would ensure sustainability of the dairy farms in the face of these constant and intense shocks. This study examined the resilience capacities of 120 typical and entrepreneurial farms in Nyandarua County, with advanced dairy growth stage, and Narok County, with dairy growth at its inception phase. It is assumed that typical and entrepreneurial farms have different resilience capacities, with entrepreneurial farms perceived to be richly endowed and skilled, conferring higher resilience scores than typical dairy farms, which are also affected by environmental contexts. The resilience theory provides a platform for comprehending how farming systems react to risks and shocks through the three resilience frameworks, namely absorptive, adaptive, and transformative capacities. The study adopted a comparative cross-sectional design, aiming to explore differences in risk perception and coping strategies between typical and entrepreneurial dairy farmers. Both qualitative and quantitative data were collected using structured questionnaires and analyzed statistically. Using the stratified sampling method, cooperatives were identified, and a list of farmers selling to the cooperatives was categorized as typical if they sold up to 50 liters of milk with no increase over the last 5 years. Otherwise, they were entrepreneurial farmers if they consistently sold over 50 liters of milk with growth over the same period. Indicators for resilience were captured by use of indicators for absorptive, adaptive, and transformative resilience capacities. The indicators were first standardized and then weighted through Principle Component Analysis (PCA) using SPSS version 23 and finally fitted into a fractional regression model to generate the resilience indices. Absorptive and adaptive capacities were weak in both farm groups, with information systems, social networks, and human capital indicators being underutilized, whereas physical assets contributed significantly to these frameworks. Greater transformative capacity was demonstrated by entrepreneurial farms than in typical farms, with institutional and infrastructural indicators contributing significantly to the index. The overall resilience for both farm types was below 0.5, indicating an overall systemic vulnerability. Entrepreneurial farms had statistically higher resilience scores than typical farms. Enhancing resilience across the two farm types calls for strengthened human capital, social capital, extension services, and investment in infrastructure, which supports dairy farming.

**Keywords:** Capacities, Dairy Growth, Market Access, Resilience Indicators, Resilience, Social Networks

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## I. INTRODUCTION

Animal agriculture in a developing country such as Kenya is vulnerable to multiple shocks and they are more frequent and intense. There are climate-related shocks and others include natural disasters, food price volatility, financial crises, health crises and political unrests (Zseleczky &Yosef 2014). Vulnerability of animal agriculture to these shocks has been attributed to several underlying factors including low adaptive capacity, high rates of poverty, lack of safety nets, over-reliance on natural resources and imperfect knowledge of forecast prices and weather changes (Tofu et al., 2025; Bahta & Lombard 2023). In Kenya, the dairy farming experiences multiple shocks, varying from feed scarcity, market fluctuations, poor infrastructural development, limited access to veterinary services and artificial insemination, financial resources to poor technical and technological skills among others (Odero-Waitituh, 2017). Yet the ability to avert these risks is reported to be decreasing and threatening the sustainability of the dairy industry (Kassie et al., 2015). A move towards a robust, reliable, adaptive intensification and resilient dairy sector would ensure sustainability of the dairy farms in the face of constant and intense shocks (Rademaker et al., 2016; Perin & Enaharo, 2023).

The structural elements of resilience are absorptive, adaptive and transformative capacities (Bec et al., 2016). Three factors determine the employment of the three resilience capacities and the overall resilience of a system; the threshold of change that a system can tolerate, the capacity to self-organize and lastly the ability to build and increase learning, adapting, and where necessary transforming (Folke et al., 2010). As conceptualized by Bebe et al. (2017), farm resilience is influenced by risk perception, resource endowments and the ability to self-reorganize. Absorptive capacity, also known as buffer capacity, is comparable to persistence (Folke et al., 2010). It is commonly exhibited during small agitations and initial phases of coping with large shocks which involves use of available resources such as financial reserves, feed stocks, labour flexibility and social networks to respond to shocks such as market fluctuations, climatic events or disease outbreaks (Shadbolt et al., 2017). It is the ability of dairy farms to resist it effectively, that is, to absorb its impacts without consequences for its function, status, or state. When the absorptive capacity is exceeded, the individual will then exercise their adaptive resilience (Cutter et al., 2008). Adaptive capability is the ability of a system to adjust in the face of changing external drivers and internal processes, thereby allowing for development while staying within the current regime (Folke et al., 2010). It is the ability to either control the trajectory of the system (change precariousness), change the topology of the stability landscape (latitude and resistance), or change the processes in response to dynamics at other scales (Berkes & Ross 2016). This capacity involves "resourcefulness-the potential to identify challenges, develop priorities, and mobilize resources, to integrate experience and knowledge during crises, to plan for upcoming shock impacts". It is a factor of both experience and knowledge (Shokri 2022).

Adaptive capacity is influenced by economic and infrastructural development, education, technology, knowledge, institutions, equity and social capital (Kruse & Pütz, 2014). At the local level, this capacity is influenced by factors such as managerial ability; access to financial, technological and information resources; infrastructure; the institutional environment within which adaptations take place; political influence and kinship networks (Haider & Cleaver, 2023). When this capability is exceeded, transformative resilience is put in place. Transformative capacity refers to system-level changes that enable more lasting resilience and often challenge the status quo in a substantial way (O'Brien, 2012). It is the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable. It is a course to innovation, alternatives and possible futures. Determinants of transformability include incentives to change, cross-scale awareness, experimentation, reserves, and convertible assets and supported by inclusive governance, social learning, extension services and innovation to enable shift in practices, technology and institutional arrangement (Wolfram et al., 2019). Transformations may well be sparked by crisis (Coquil et al., 2014).

Measuring resilience is quite challenging due to its multi-scale, multi-dimensional and time specific nature. Quantifying resilience in farms present a major challenge in resilience literature due to its multidimensional and dynamic nature which varies across time, individual and production context (Taghipoor et al., 2023). Levine (2014) identified five approaches currently in use for measuring resilience which include: quantification based on functionality, quantification based on indicators and characteristics, quantification based on food access, quantification based on activities and quantification derived from theoretical resilience frameworks. The use of novate indicators is suggested for measuring resilience in farming systems. Use of indicators to measure farm resilience was also adopted by a study by Khan et al. (2014) emphasizing that resilience can be quantified through by assessing its three core capacities – absorptive, adaptive and transformative, using indicators.

Resilient dairy farms not only adapt to change in the environment, but also take advantage of opportunities created by the disturbance while maintaining productive capacity in the face of variability in production financial and market related factors (Meuwissen et al., 2019). There are clusters of factors that interact across temporal and spatial scales which influence resilience building in farms which include connectivity, spatial heterogeneity, and the capacity of systems to reorganize across different scales, which are crucial for sustaining ecosystem functions and adaptive governance (Cumming et al., 2017). Additionally, planning, communication, collaboration, and diversification each align with social capital theory which is encompassed within more recent interpretations of community resilience are key to building resilient farming systems (Bec et al., 2016). Further, a study by Perrin et al. (2020) noted that the key features of resilient dairy farming systems include farm diversity, autonomy, flexibility and strong farmer networks. Cafer et al. (2022) indicated that integration of social, economic and agro-ecological factors where farmers actively engage in learning, innovation and collaboration increase their capabilities to effectively respond to shocks and stresses and build resilient farming systems.

Robust infrastructure, strong farmer knowledge networks and adaptive decision making have been reported to enhance resilience capacities of farming systems enabling them to recover from shocks and stressors effectively (Urruty et al., 2016). In dairy farms, investment of herds which are disease resistant, with high fertility, longevity ensures stable production of milk under sub-optimal conditions thereby maintaining farm income (Bengtsson et al., 2022). Nettle et al. (2015) highlight that resilient farming systems are characterized by features such as flexibility in decision-making, strong farmer networks, continuous learning, and proactive risk management. Resilient farmers should also learn to live with uncertainties and disturbance (Mendoza et al., 2019; Sinclair et al., 2022). Careful disturbances within threshold limits make the system develop good reorganization responses and make it even stronger (Rudberg & Karpouzoglou 2022). It sets the motion of renewal and reorganization into motion and facilitates heterogeneity. This factor points out the need to building a memory of past events, abandoning the notion of stability, 'expecting the unexpected' and increasing the capability to learn from crisis (Darnhofer 2021). This makes farmers proactive and well equipped in case of any disturbance contributing to sustainability of these farms which is important in continuity as the system goes through changes because it can be tapped into to build more resilient systems (Grafton et al., 2019).

Resilient farmers nurture diversity in their farms. Diversifying activities and thus income sources, both on- and off-farm, is a widespread strategy by family farms to enhance their resilience (Cochrane & Cafer 2018). It is an important role in strengthening adaptive capacity, since it provides the seeds for new opportunities and thereby increases the options for coping with shocks and stresses (Noriega et al., 2017). An agro-ecosystem with a heterogeneous livelihood, pattern of land uses and crops more resilient. Heterogeneous landscapes enable dynamic relationships between populations. At the farm level, there are various 'variables' that contribute to diversity, such as: biodiversity (incl. diversity of crops grown), diversity of economic opportunities, diversity of resources, diversity of communication and partners, diversity in relationship types (Dardonville et al., 2020). Combining different types of knowledge and learning also built resilient systems (Ross et al., 2024). Traditions such as indigenous knowledge, institutions, seed, banks, and biophysical resources which should be well guarded and employed accordingly to enhance resilience (Šūmane et al., 2018). Combination of scientific information with traditional knowledge, and the ability to share insights, to bring together parties with different relative strengths in terms of knowledge and backgrounds and thus to create learning environments which are key to resilience building (Tiwari et al., 2023). This built upon social resources such as knowledge, skills, experience that can be mobilized through social relationships and membership in networks (Shittu et al., 2018). At the farm level, this can be found in the variety of information sources that farmers tap into and use to make decisions, in the variety of networks they are involved in, and their ability to build on past experiences and traditions (Duranovich et al., 2015).

The degree to which farmers, consumers, and other stakeholders can organize themselves as individuals, local and regional networks, and smaller institutions of governance can be more responsive and adaptable to changing conditions (Ortiz & Peris 2022). Linkages at high hierarchy and low hierarchy; good governance structures, layout should be overlapping to the grass roots whereby local institutions gather information faster and respond rapidly to changes whereas high level provide technical expertise and supporting during crises (Feye, 2018). At the community level, the ability to self-organize is strongly linked to social competencies. Ability to cooperate and build networks is key for future survival, as with increasing economic pressure, smaller farms can only survive if they cooperate with one another, pool their resources together and make a significant change. Existing agricultural framework and policies shape the farmers' decision and flexibility on how to respond to risks and shocks whereas rigid and misaligned regulations can constraint farmers' ability to adapt and undermine long term sustainability. They also ought to believe in their capacity to overcome stressful situation (Spiegel et al., 2020).

Self-efficacy relates to the ability of the community to maintain the local capacity for social and political organization, rather than relying on external intervention (Peng et al., 2020). Osumba et al. (2021) indicated that access to basic services such as roads, markets, extension, and credit significantly enhances the resilience capacities of smallholder farms by improving their ability to anticipate, absorb, and recover from shocks. Williams et al. (2020) added that unequal access to these services leads to disparities in resilience outcomes, with marginalized farmers often left more vulnerable despite the implementation of broader resilience strategies. Knickel et al. (2018) emphasized that access to basic services such as healthcare, education, infrastructure, and advisory support which enable farmer' ability to cope and adapt to shocks by improving their well-being, decision making capacity and contribution to wider support networks thereby contributing to more sustainable and equitable farming systems.

### 1.1 Statement of the Problem

Typical and entrepreneurial dairy farms pervasively confront multiple and recurrent risks but are likely to respond differently depending on their risk perception, resource endowments, and managerial skills. Compared to typical dairy farms, entrepreneurial dairy farms are proactive, richly endowed with resources, and higher risk-taking, but are these attributes a pathway to higher resilience capacity. Identifying the resilience capacities of typical and entrepreneurial dairy farms can inform effective interventions for increasing resilience capacity for a stable and sustainable dairy-based livelihood. These will ultimately inform the government to develop policies in the dairy sector that minimize the risks in the best way possible and to strengthen the resilience capacities of the community to ensure sustainable dairy farming.

### 1.2 Research Objectives

i. Identify the key indicators of the three resilience capacities in typical and entrepreneurial dairy farms
ii. Quantify resilience indices among the typical and entrepreneurial dairy farms.

## II. LITERATURE REVIEW

### 2.1 Theoretical Review

The resilience theory provides a platform for comprehending how farming systems react to risks and shocks through the three resilience framework namely absorptive, adaptive and transformative capacities. As conceptualized by Folke et al (2010), resilience is defined as the ability to absorb disturbances, self-organize, adapt or transform when necessary. Whereas absorptive capacity relates persistence buffering using resources, adaptive capacity is the ability to self-reorganize and learn to cope with scaled up challenges while transformative resilience offers an environment to shift to enhance long term viability.

As explained by Bec et al. (2016), thresholds of change, self-organization and continuous learning influence the resilience capacity. The social capital theory supports the theory of resilience by emphasizing the pivotal roles of networks, trust and cooperation in coping with shocks. Community resilience frameworks emphasize on the need for good governance structures, equity and participation at grass root levels as key to adaptive and transformative resilience (Norris et al., 2008). According to social-ecological systems theory by Cinner and Barnes (2019) institutions shape resilience capacities in dairy systems which plays a key role on adaptive governance and feedback mechanisms. In a nexus, these theories underlines the multi-dimensionality of resilience, which is also shaped by physical resources, socio-cultural factors and institutional resources.

### 2.2 Empirical Review

Empirical studies indicate that the high vulnerability of the smallholder dairy farming to shocks and stressors affect its productivity. The resilience scores of Ghanaian households was found to be below 0.5 indicating the high vulnerability to these shocks and stressors (Tambo & Wünscher, 2017). Livestock ownership and land were highlighted to be key buffers against climate and market risks (Asmamaw et al., 2019; Debie &Ayele, 2023). The weak social capital as reported by Egamberdiev (2024) have been reported to be among the limiting factors to resilience. Institutional support and information sharing have shown to enhance adaptive capacity as found out by Weldegebriel & Amphune (2017) in Ethiopia. Context specific mechanization as demonstrated by Mizik (2021) was found to improve the resilience capacity. The key drivers of transformative capacity were highlighted to be governance and market access by a study by Frankenberger et al. (2014).

In another study, Urruty et al. (2016) reported knowledge networks and robust infrastructures play pivotal role in improving recovery from shocks. Nettle et al. (2015) findings reported that proactive risk management, flexibility and farmer networks are key to resilient systems. Membership, trust and information exchange through social capital and farmer learning networks was reported to significantly strengthen farm resilience by improving adaptation and transformation capacities (Sinclair et al., 2022). In their study, Hassan and Akkermans (2022) showed that human, natural, social and financial capitals were significant determinants of dairy farmers' adaptive capacity in Ziway-Shashemene in Ethiopia with physical assets being strong predictors. Institutional and financial access were also reported by smallholder livestock farmers in South Africa to play pivotal role in resilience (Maltou & Bahta 2019). Overall, the empirical evidence emphasize that a balanced combination of physical assets, social capital and institutional supports are key requirements to building resilient dairy systems.

## III. METHODOLOGY

### 3.1 Study Areas

Nyandarua County is in the Central part of Kenya and represents areas with medium and high potential dairy production that have reached a stage of more developed dairying. It experiences temperatures in the ranges of 6°C to 9°C (43°F to 48°F) in July at minimum and 18°C to 25°C (64°F to 77°F) in December, maximum and an altitude between of 2,000-3,900 meters. The county has two rainy seasons, with the long rain season from March to May (1700 mm rain), and a short rainy season from October to December (700 mm rain).

Narok and Bomet Counties are located in the South-western part of Kenya and are representative for areas with dairy farms in the inception stage of dairy development, in areas with low production potential. Here, temperatures range from a minimum of 8$^{o}$C to a maximum of 28$^{o}$C. The counties experience two rainy seasons: the long rains from March to May and the short rains from October to December, with an average annual rainfall ranging from 1,000 to 1,400 mm and two dry seasons separating the two. A few respondents were sampled in Bomet County, close to the Narok-Bomet county border, with similar less-developed dairy cooperatives and market access. Typical dairy farmers are smallholders who have shown minimal growth in milk sales and limited adoption of external inputs over the past five years. In contrast, entrepreneurial smallholder dairy farmers are characterized by a gradual but consistent increase in both milk sales and the utilization of external inputs during the same period.

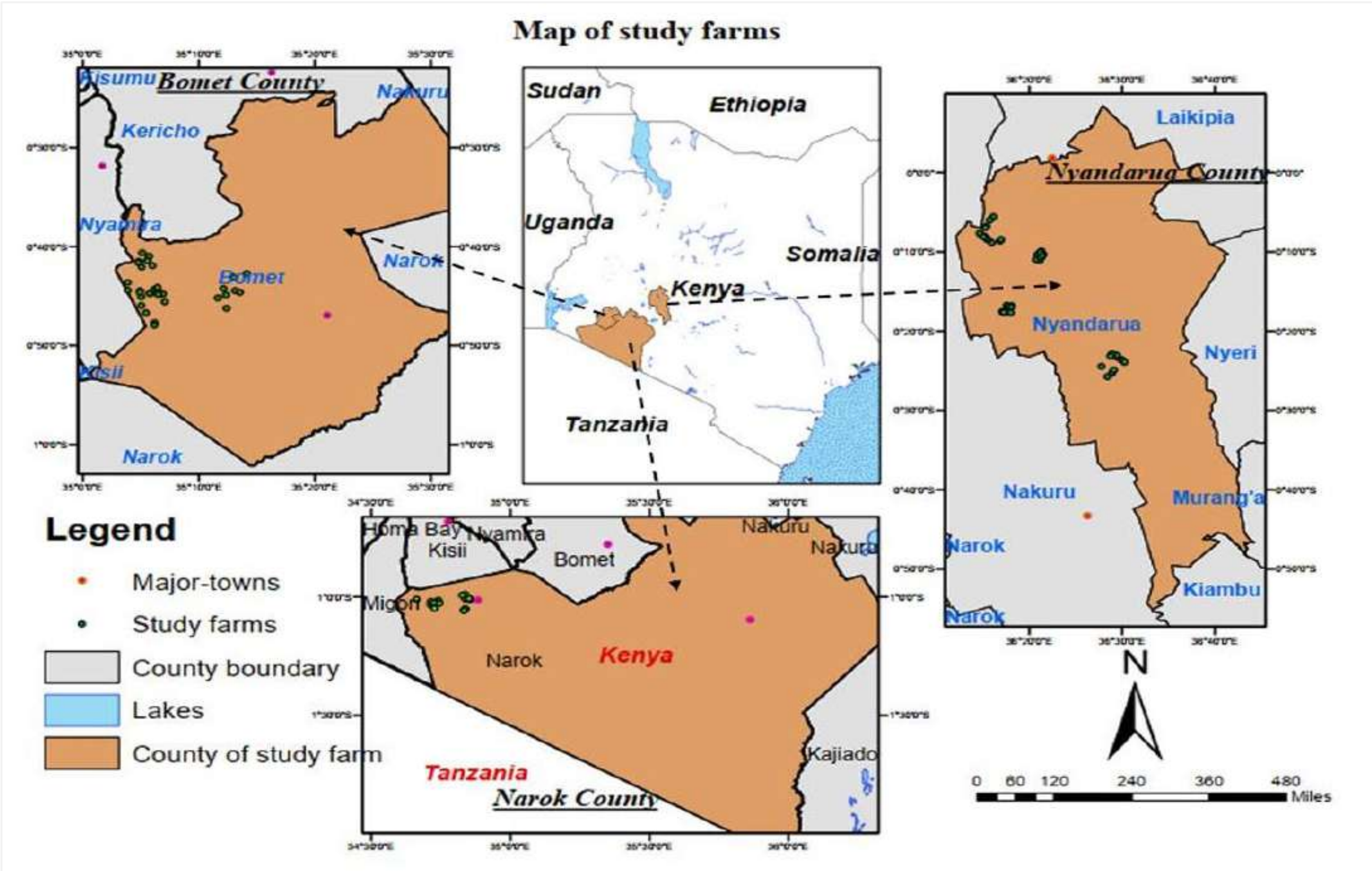


**Figure 1**
*Map of the study areas - Nyandarua and Narok*

### 3.2. Research Design

The study adopted a comparative cross-sectional design, aiming to explore differences in risk perception and coping strategies between typical and entrepreneurial dairy farmers. Both qualitative and quantitative data were collected using structured questionnaires and analyzed statistically. The research was grounded in identifying significant indicators in resilience capacities using descriptive statistics and Principal Component Analysis (PCA). This design enabled in-depth understanding of both farmer categories across different agro-ecological zones. The methodology was suitable for quantifying and comparing resilience indices under varied dairy development stages.

### 3.3 Targeted Population

The target population comprised smallholder dairy farmers in the two counties, particularly those affiliated with cooperatives, milk processors, or milk collection centers. Farmers were categorized as typical if they sold up to 50 liters of milk per day with no production increase over five years, and entrepreneurial if they sold more than 50 liters daily with consistent growth. The distinction ensured that participants represented contrasting production intensities and investment behaviors. The population included men and women, farming under diverse socio-economic and environmental conditions. These groups were ideal for understanding how varying risk exposures influence adaptive strategies.

### 3.4 Sampling and Sample size

Dairy farms at sampling were stratified by stage of dairy development (less and more). Lists of farmers were obtained from local dairy cooperatives and milk marketing channels in the target counties. Using Arsham's formula for determining sample size with a standard error of 0.04562 and 95% confidence interval, a sample of 120 farmers was selected: 60 from Nyandarua (27 typical, 33 entrepreneurial) and 60 from Narok-Bomet (29 typical, 31 entrepreneurial). This selection ensured fair representation across both dairy development stages and farmer categories. Final respondents were randomly selected from categorized lists, ensuring statistical validity and minimized selection bias. Use of indicators was to quantify resilience capacities of these farms as per the following indicator table:

**Table 1**
*Indicator Variables for Measuring the Resilience Capacities*

| Indicator Variable | Description | Measurable Unit |
|---|---|---|
| **Absorptive Capacity** | | |
| Risks, how severe in your dairy practice, satisfaction level in coping with them | Sensitivity, Preparedness | Percentage |
| Member to which groups? How relevant is each to your dairy farming, 5 years? | Membership to CBO's | Count and % relevance<br>Count |
| Number of social safety net programmes household participates in. | Social Safety nets | Count |
| Availability of insurance | Number of assets insured. | Amount |
| Access to cash savings | Amount | Amount |
| Access to remittances | Amount | Amount |
| Asset ownership | Amount | |
| **Adaptive Capacity** | | |
| Activities in farm contributing to your livelihood? | No. of income sources | Count |
| Activities outside the farm add to income. | Number | Count |
| Confidence in dealing with risks. | Percentage | Percentage |
| When did you start dairy farming? | No. of years in dairy | Number |
| Workers, how many casual/permanent, payment. | Expenditure | Ksh. |
| Their education level of the workers? | | |
| Any special training for the workers on dairy, explain | | |
| Did you buy any machine or equipment over the past 5 yrs? | Assets | Count |
| Land: own? Lease? Rent? | Total land owned | Acres |
| Land use; Building? Crop? Trees? Grass? Rest? | Land use | Acres |
| How many animals? Species? Breeds? Number | Tropical Livestock Units | TLU |
| Number of available climate change adaptation | | Count |
| strategies | Adult vs Minor | Ratio |
| Exposure to information | Information sources | Count |
| Improved practices | practices | Count |
| **Transformative Capacity** | | |
| Access to basic public services, | Distance to water source | Km |
| such as market, health services, | Distance to health facility | Km |
| primary school, road, credit and | Distance to market | Km |
| electricity, network coverage, | Binary | Binary |
| veterinary extension services | Distance | km |
| Police station | Distance | km |
| Communal; land, water, firewood, irrigation | No./amount accessible | specific km |

**Source:** *adopted from Asmamaw, (2019), Tambo, (2016)*

### 3.5 Data Analysis

The three resilience capacities absorptive, adaptive, and transformative was computed by use of indicator weights generated by PCA and fitted on a multiple linear regression model to get the resilience indices through the following steps.

*Step 1:* Normalization of the indicators: The aim of this step is to standardize the range of the continuous initial variables so that each one of them contributes equally to the analysis. More specifically, the reason why it is critical to perform standardization prior to PCA, is that PCA is quite sensitive regarding the variances of the initial variables. That is, if there are large differences between the ranges of initial variables, those variables with larger ranges dominate over those with small ranges, which would lead to biased results. The method used for normalization is that used in the Human Development Index. Where indicators were normalized for those directly proportional:

$$tnorm = \frac{tij - tmin}{tmax - tmin}$$

While for those indirectly proportional

$$tnorm = \frac{tmax - tij}{tmax - tmin}$$

*Step 2:* Assign weight to each indicator using Principal Component Analysis (PCA). Commonly used methods for assigning weights include arbitrary choice of equal weights, expert judgement, and statistical methods (Gbetibouo *et al.*, 2010).

*Step 3:* Compute the absorptive, adaptive, and transformative resilience capacities. The weights loadings obtained from PCA first principle components were fit into a fractional regression model to compute for absorptive, adaptive and transformative resilience scores so that the final score would have a maximum of one using the formula below:

$$ARC_j = \frac{\sum_j^k B_j X_{ij}}{\sum_{j=1}^k [B_j]}$$

Where $ARC_j$ = absorptive resilience capacity

$B_j$*= PCA rotated loading (can be negative) for a specific indicator

$X_{ij}$= Observed indicator value for farmer for a specific indicator

Numerator = sum of product of PCA loading and observed values for all independent variables

Denominator= absolute value of sum of PCA loadings

*Step 4*: Computing resilience index by fitting multiple linear regression model

$R_{ij} = (ABS_i + ADP_i + TNS_i)/3$

Where *R* is resilience; *i* is household; ABS is the absorptive capacity, ADP is the adaptive capacity and TNS transformative capacity.

## IV. FINDINGS & DISCUSSION

### 4.1 Indicator Weights for Absorptive Capacity

In typical farms in Nyandarua, PCA results for Principle Component 1 (PC1) had a KMO of .463 and explained a variance of 72% assigned weights of the factors as follows: TLU (.899), Land (.885) indicating access to livestock and land play pivotal role in absorbing and recovering from small agitations. Equipment (0.179), financial access (0.087), mutual groupings (0.061) and sensitivity to risks (0.045) contributed minimally to the absorptive capacity. Other groupings (-0.178) and social networks outside (-0.322) negatively contributed to the absorptive capacity in typical farms in Nyandarua. The findings suggested that physical assets were more influential on absorptive resilience capacities compared to institutional and social capital among typical farms in Nyandarua County. Typical farms in Narok PCA had KMO of .460 and explained a variance of 68% assigned weights of the components as follows: Land (.894), Equipment (.761), TLU (.681), On the other hand, institutional and financial access contributed negatively to the score indicating a gap in effective institutional support systems.

In entrepreneurial farms in Nyandarua, PCA results for PC1 had KMO of .511 and explained a variance of 75% assigned weights of the factors as follows; Land (.894), TLU (.887), Social Networks (.262), Risk sensitivity (.149), Equipment (.229) whereas mutual networks (-0.300) and financial access (-0.165) conferred negative weighting on the score. In entrepreneurial farms in Narok, PCA results with KMO of .373 and explained a variance of 75% assigned weights of the factors as follows: Land (.957), TLU (.804) while other variables had minimal or negative influence. These findings suggests entrepreneurial farms prefer independent model operations linked to physical assets with livestock and land being the primary buffers against risks.

**Table 2**

*Indicator Weights for Absorptive Resilience Capacity*

| **Typical - Nyandarua** | | **Typical Narok** | | **Entrepreneurial Nyandarua** | | **Entrepreneurial Narok** | |
|---|---|---|---|---|---|---|---|
| **Principle Component 1 Weights in PCA Rotated Varimax** | | | | | | | |
| Total Livestock Unit | 0.899 | Land | 0.894 | Land | 0.894 | Land | 0.957 |
| Land | 0.885 | Equipment | 0.761 | Total Livestock Unit | 0.887 | Total Livestock Unit | 0.804 |
| Social networks - Outside | -0.322 | Total Livestock Unit | 0.681 | Social networks – Outside | 0.262 | Grouping | -0.21 |
| Risk sensitivity | 0.045 | Social networks - Outside | -0.027 | Risk sensitivity | 0.149 | Risk sensitivity | 0.140 |
| Equipment | 0.179 | Mutual networks | -0.048 | Equipment | 0.229 | Financial access | -0.333 |
| Financial access | 0.087 | Risk sensitivity | 0.393 | Financial access | -0.165 | Mutual networks | -0.112 |
| Mutual networks | 0.061 | Financial access | -0.090 | Mutual networks | -0.300 | Social networks - Outside | 0.072 |
| Grouping | -0.178 | Grouping | 0.253 | Grouping | -0.071 | Equipment | -0.073 |

These findings are consistent with Karanja et al (2016) who reported livestock assets serve as buffers against climate risks emphasizing the role of TLU in resilience building. In other studies, Mizik (2021) highlighted the importance of mechanized equipment for farms in Narok in building resilience to climate-induced risks. The negative associations on social capital and financial access indicates a shift towards independence in Nyandarua county whereas in Narok county the lower role of finance and equipment in absorptive capacity is inclined to access constraints rather than disinterest owing to the distinct stages of commercialization and institutional integration in the two counties. Egamberdiev (2024) study agreed with the findings indicating that underutilized social capital constraint resilience building in food systems. These agreed with Cafer et al. (2022) and Boka and John (2017) findings which accentuates the key roles of social networks in reducing vulnerability and shortening recovery period in the face of shocks. Maru and Chemjor (2013) agreed that social capital is key to resilience building.

### 4.2 Indicators for Adaptive Capacity

In typical farms in Nyandarua, PCA results with KMO of .421 and explained a variance of 77% assigned weights whereas information sources (-0.786), social networks (-0.454) and dependency ratio (-0.315) contributed negatively to the score. This indicates that farmers rely more on internal resources and assets to adapt to risks rather than off farm resources or extension services. The knowledge exchange, financial and institutional support was under-utilized in the adaptive resilience framework. In typical farms in Narok, PCA results with KMO of .281 and explained a variance of 80% assigned weights of the factors as follows; Land (.916), Equipment (.848) and other on farm resources (0.454) carrying significant positive weights on adaptive capacity whereas social networks (-0.154) and information sources (-0.085) with negative loadings on the score. This shows the limiting factor of knowledge systems, human capital and social connections constraining adaptive resilience capacity across the typical farms.

In entrepreneurial farms in Nyandarua, PCA results with KMO of .417 and explained a variance of 71% assigned weights of the factors as follows; Land (.839), Education (.730), off-farm resources (.627) while negatively but weakly impacted by information sources (-0.170), skilled-unskilled labour ratio (-0.158) and social groupings (-0.098). This implied that adaptive capacity in these farms is inclined to both human capital and physical resources. In entrepreneurial farms in Narok, PCA results with KMO of .480 and explained a variance of 71% assigned weights of the factors as follows; information source (.795), Financial access (.795), Grouping (.702) and negatively but weakly impacted by land (-0.290), social networks (-0.127) and dependency ratio (-0.068). The findings in Narok portrays a network driven adaptive model pegged on collective action, access to market and information sharing.

These findings agree with Weldegebriel and Amphune (2017) whose findings highlighted the prominence of land in adaptive resilience where smaller landholdings reduce conservation efforts. Similarly, Asmamaw et al (2017) findings indicated the key role of information sharing in building the adaptive capacity. Additionally, Frankenberger et al (2015) findings stressed on the positive association between livelihood diversification and resilience while Marshall et al (2013) pointed out on the need for self-reorganize and learning (education) in response to change.

**Table 3**

*Indicator Weights for Adaptive Resilience Capacity*

| **Rotated Varimax Principle Components 1** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Typical Nyandarua** | | **Typical Narok** | | **Entrepreneurial Nyandarua** | | **Entrepreneurial Narok** | |
| Information Source | -0.786 | Land | 0.916 | Land | 0.836 | Information Source | 0.795 |
| On farm resources | 0.780 | Equipment | 0.848 | Education | 0.730 | Financial access | 0.795 |
| Off farm Resources | 0.054 | Experience | -0.028 | Off farm Resources | 0.627 | Grouping | 0.702 |
| Experience | 0.160 | On Farm resources | 0.454 | Dependency ratio | 0.055 | Confidence | 0.496 |
| Equipment | 0.382 | Mutual Networks | 0.048 | Experience | 0.093 | Dependency ratio | -0.068 |
| Mutual Networks | 0.192 | Social Networks | -0.154 | On farm resources | 0.204 | Off farm resources | 0.331 |
| Dependency ratio | -0.315 | Confidence | -0.096 | Skilled labour ratio | -0.158 | Water source | 0.261 |
| Social Networks | -0.454 | Education | 0.109 | Equipment | 0.224 | Education | 0.208 |
| Confidence | 0.025 | Water source | -0.073 | Water source | 0.457 | Skilled labour ratio | -0.050 |
| Water source | -0.113 | Financial access | 0.157 | Social Networks | 0.283 | Social Networks | -0.127 |
| Grouping | 0.160 | Grouping | 0.279 | Financial access | -0.044 | Mutual Networks | 0.193 |
| Skilled labour ratio | -0.178 | Off Farm Resources | -0.029 | Grouping | -0.098 | Land | -0.290 |
| Land | 0.478 | Dependency ratio | 0.103 | Information Sources | -0.170 | On farm Resources | 0.206 |
| Education | -0.123 | Skilled labour ratio | -0.050 | Confidence | -0.002 | Experience | 0.121 |
| Financial access | -0.043 | Information Sources | -0.085 | Mutual Networks | -0.070 | Equipment | 0.065 |

### 4.3 Indicators for Transformative Capacity

In typical farms in Nyandarua, PCA results with KMO of .476 and explained a variance of 68% assigned weights of the factors as follows; Market (.922), veterinary services (.884), security (.873), all-weather road (.675). This signify the importance of institutional infrastructure and functional market systems in fostering transformative resilience in more developed dairy ecosystem like Nyandarua that enables them to leverage market opportunities. In typical farms in Narok, PCA results with KMO of .527 and explained a variance of 60.88% assigned weights of the factors as follows; Access to all-weather road (.865), security (.772), veterinary services (.639) were strongest positive factors. The Narok dairy environs characterized by pastoral production systems and weaker access to basic services prioritized road infrastructure, access to veterinary services and public safety as key enablers to transformation. The negative contributions of market access (-0.16) and community land (-0.25) indicated poor integration and gaps in market connectivity and institutional systems in pastoral areas. The discrepancy in the indicator weights between the two counties stresses on role played by regional development levels in shaping the design and impact of resilience strategies.

In entrepreneurial farms in Nyandarua, PCA results with KMO of .375 and explained a variance of 69% assigned weight of the factors as follows; veterinary services .902, security (.884), market (.824), followed by access to all weather roads (0.498), electricity (0.488). Access to primary schools (-0.06) and forests (-0.11) had negligible negative influence indicating not all community asset contribute to farm transformative capacities. In entrepreneurial farms in Narok, PCA results with KMO of .618 and explained a variance of 70% assigned weight of the factors as follows; veterinary services (.902), Market (.868), security (.841) with moderate contributions from health facilities (0.460), roads (0.358). The findings indicated that the entrepreneurial farms in both Nyandarua and Narok have consistently higher transformative indicator weights.

Similarly, Frankenberger et al (2014) identified governance, infrastructure and access to basic services as the core to transformative resilience. Asmamaw et al. (2017) findings similarly suggested that households with better access to public services and local governance systems become more resilient supported the findings. Geographically isolated communities have been found to limit access to markets, inputs and diversification opportunities that negatively affect their resilience capacities (Burke and Jayne 2010, Tesso et al., 2012). A study by Khan et al. (2014) indicated that road networks affects both efficiency of emergency response and market access stifling resilience capacities. On the other hand, Frankenberger et al. (2015) argued that addressing structural risks and enhancing long-term social cohesion demands for high transformative capacity through infrastructure and human capital.

**Table 4**

*Indicator Weights for Transformative Resilience Capacity*

| **Rotated Varimax Principle Components 1** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Typical Nyandarua** | | **Typical Narok** | | **Entrepreneurial Nyandarua** | | **Entrepreneurial Narok** | |
| Market access | 0.922 | All weather road | 0.865 | Veterinary services | 0.902 | Veterinary services | 0.902 |
| Veterinary services | 0.884 | Security/police post | 0.772 | Security/police post | 0.884 | Market access | 0.868 |
| Security/police post | 0.873 | Veterinary services | 0.639 | Market access | 0.824 | Security/police post | 0.841 |
| All weather road | 0.675 | Market access | -0.16 | Primary school | -0.06 | Electricity | 0.075 |
| Primary school | -0.4 | Health | 0.154 | Health | 0.173 | All weather road | 0.358 |
| Health | 0.193 | Electricity | 0.447 | Electricity | 0.488 | Health | 0.46 |
| Water | -0.33 | Forest | -0.12 | Forest | -0.11 | Water | 0.027 |
| Electricity | 0.485 | Community land | -0.25 | All weather road | 0.498 | Primary school | 0.013 |
| Forest | -0.07 | Water | -0.06 | Water | -0.17 | Forest | -0.17 |
| Community land | 0.208 | Primary school | 0.457 | | | | |

### 4.4 Mean Absorptive, Adaptive, Transformative, and Overall Resilience Indices

The mean absorptive capacity of typical farms in Nyandarua was (.0246) whereas for typical farms in Narok was (0.2019). The mean absorptive resilience capacities of entrepreneurial farms in Nyandarua was (0.0487) whereas for entrepreneurial farms in Narok was (0.0587). The mean absorptive resilience capacities for both typical and entrepreneurial farms in both Narok and Nyandarua were all below 0.5 out of a maximum of one implying a dismal level across the farm types in both developed and less developed dairy growth environments.

Adaptive capacities in Nyandarua county for typical farms was 0.004 and entrepreneurial 0.273 whereas in Narok county, the mean adaptive index for typical farms was 0.216 and entrepreneurial farms was 0.347. These results support findings by Asmamaw et al. (2019), who also reported suboptimal adaptive resilience among farming households. This calls for the need to strengthen institutional, social, human capital and access to services to improve the adaptive resilience capacity.

Transformative capacity was consistently higher than both adaptive and absorptive capacity. In Nyandarua, the mean transformative capacity in typical farms was 0.3310 while in entrepreneurial farms was 0.4566. In Narok-Bomet county, mean transformative resilience capacity in typical farms was 0.4134 whereas in entrepreneurial farms was 0.2481. The sum of absorptive, adaptive and transformative capacities was used to generate the overall resilience score with the maximum index being 1 and an average of 0.5. Across the four farm types, the mean resilience score was below 0.5 indicating the resilience index being below average. The typical farms in Nyandarua had 0.1199 while entrepreneurial farms in had 0.2594 entrepreneurial farms. In Narok-Bomet, typical dairy farms had 0.2770 while entrepreneurial farms had 0.2180.

**Table 5**

*Mean Absorptive, Adaptive, Transformative, and Overall Resilience Indices*

| | N | Minimum | Maximum | Mean statistic | Mean std error | Std. Deviation | Variance |
|---|---|---|---|---|---|---|---|
| **Absorptive resilience indices** | | | | | | | |
| Absorptive capacity Nyandarua | 27 | -0.034 | 0.1077 | 0.0246 | 0.0063 | 0.0325 | 0.001 |
| Absorptive capacity Narok | 29 | 0.0532 | 0.548 | 0.2019 | 0.0199 | 0.1071 | 0.011 |
| Absorptive capacity Nyandarua | 33 | -0.0576 | 0.2164 | 0.0487 | 0.0109 | 0.0625 | 0.004 |
| Absorptive capacity Narok | 31 | -0.1525 | 0.6227 | 0.0587 | 0.0255 | 0.1419 | 0.02 |
| **Adaptive resilience indices** | | | | | | | |
| Adaptive Typical Nyandarua | 27 | -0.163 | 0.149 | 0.004 | 0.018 | 0.095 | 0.009 |
| Adaptive Typical Narok | 29 | 0.088 | 0.588 | 0.216 | 0.02 | 0.105 | 0.011 |
| Adaptive Entrepreneurial Nyandarua | 33 | 0.14 | 0.54 | 0.273 | 0.016 | 0.09 | 0.008 |
| Adaptive Entrepreneurial Narok | 31 | 0.14 | 0.617 | 0.347 | 0.023 | 0.128 | 0.016 |
| **Transformative resilience indices** | | | | | | | |
| Transformative typical Nyandarua | 27 | -0.0621 | 0.652 | 0.331 | 0.0428 | 0.2227 | 0.05 |
| Transformative typical Narok | 29 | 0.0622 | 0.7228 | 0.4134 | 0.0405 | 0.2181 | 0.048 |
| Transformative entrepreneurial Nyandarua | 33 | 0.039 | 0.8112 | 0.4566 | 0.043 | 0.2471 | 0.061 |
| Transformative entrepreneurial Narok | 31 | -0.0228 | 0.9275 | 0.2481 | 0.0438 | 0.2438 | 0.059 |
| **Overall resilience indices** | | | | | | | |
| Resilience typical Nyandarua | 27 | -0.0599 | 0.2738 | 0.1199 | 0.0181 | 0.0938 | 0.009 |
| Resilience typical Narok | 29 | 0.1528 | 0.5086 | 0.277 | 0.0139 | 0.0748 | 0.006 |
| Resilience Entrepreneurial Nyandarua | 33 | 0.0752 | 0.4172 | 0.2594 | 0.0156 | 0.0898 | 0.008 |
| Resilience Entrepreneurial Narok | 31 | 0.1044 | 0.3938 | 0.218 | 0.0141 | 0.0783 | 0.006 |

Mean comparison of absorptive capacities between typical and entrepreneurial farms in Nyandarua indicated unequal variances assumed through Levene test ($F=10.167$, $p=0.002$) whereas t-test (p value =0.076 and 0.061, is greater than 0.05) indicated no significant difference in absorptive capacity. In Narok-Bomet county, levene's test ($F = 0.252$, $p = 0.618$) indicated equal variance not assumed whereas t-test ($t = 4.387$ and 4.428, $p = .000$) revealed entrepreneurial farms had significantly higher absorptive capacity than typical farms.

Mean comparison of adaptive capacities in Nyandarua showed heterogeinity of variances ($F=0.327$, $P=0.569$) and a highly significant mean difference between entrepreneurial and typical farms ($p = 0.000$ which is less than 0.05) with entrepreneurial farmers portraying greater adaptive capacity. Similarly, the farms in Narok-Bomet county demonstrated unequal variances whereas t-test (p value =0.000) revealed entrepreneurial farms demonstrated significant higher adaptive capacity than typical farms.

Mean comparison of transformative capacities in Nyandarua confirmed homogeneity of variances through Levene's tests validating equal variances whereas the t-test indicated entrepreneurial farms had significantly higher transformative capacity than typical farms. In Narok-Bomet County, Levens's test ($F = 0.114$, $p = .737$) validated equal variances and the t-test ($t = 3.891$, $p < .001$) revealed entrepreneurial farms had significant higher transformative capacity than typical farms.

Mean comparison of the farms overall resilience capacity in Nyandarua confirmed equal variances ($F = 0.088$, $p = .767$) assumed while t-test ($p = .000$) revealed entrepreneurial farms demonstrated slightly higher resilience capacity than typical farms. Contrary to these, mean comparison of overall resilience score in Narok-Bomet county indicated homogeneity of variances ($F = 0.226$, $p = .636$) and significant difference of overall resilience capacity between typical and entrepreneurial farms ($p = .004$) from independent sample t-test,

**Table 6**

*Mean Comparison of Typical Versus Entrepreneurial Farms in Nyandarua and Narok-Bomet Counties*

| Mean Comparison Typical Versus Entrepreneurial | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Absorptive capacity** | | | | | | | | | | |
| | | **Levene's Test for Equality of Variances** | | **t-test for Equality of Means** | | | | | | |
| | | **F** | **Sig.** | **t** | **df** | **Sig. (2-tailed)** | **Mean Difference** | **Std. Error Difference** | **95% Confidence Interval of the Difference** | |
| | | | | | | | | | **Lower** | **Upper** |
| Nyandarua | Equal variances assumed | 10.167 | 0.002 | -1.808 | 58 | 0.076 | -0.0241 | 0.0133 | -0.0507 | 0.0026 |
| | Equal variances not assumed | | | -1.917 | 49.924 | 0.061 | -0.0241 | 0.0125 | -0.0493 | 0.0012 |
| Narok | Equal variances assumed | 0.252 | 0.618 | 4.387 | 58 | 0 | 0.1432 | 0.0326 | 0.0778 | 0.2085 |
| | Equal variances not assumed | | | 4.428 | 55.583 | 0 | 0.1432 | 0.0323 | 0.0784 | 0.2079 |
| **Adaptive Capacity** | | | | | | | | | | |
| | | | | | | | | | Lower | Upper |
| Nyandarua | Equal variances assumed | 0.327 | 0.569 | -11.198 | 58 | 0 | -0.269 | 0.024 | -0.3171 | -0.2209 |
| | Equal variances not assumed | | | -11.138 | 54.424 | 0 | -0.269 | 0.0242 | -0.3174 | -0.2206 |
| Narok | Equal variances assumed | 2.543 | 0.116 | -4.325 | 58 | 0 | -0.1317 | 0.0304 | -0.1926 | -0.0707 |
| | Equal variances not assumed | | | -4.353 | 57.075 | 0 | -0.1317 | 0.0302 | -0.1922 | -0.0711 |
| **Transformative capacity** | | | | | | | | | | |
| Nyandarua | Equal variances assumed | 0.709 | 0.403 | -2.159 | 58 | 0.035 | -0.1304 | 0.0604 | -0.2512 | -0.0095 |
| | Equal variances not assumed | | | -2.18 | 58.849 | 0.033 | -0.1304 | 0.0598 | -0.25 | -0.0107 |
| Narok | Equal variances assumed | 0.337 | 0.564 | 2.762 | 58 | 0.008 | 0.1653 | 0.0599 | 0.0455 | 0.2851 |
| | Equal variances not assumed | | | 2.772 | 57.891 | 0.007 | 0.1653 | 0.0596 | 0.0459 | 0.2847 |
| **Overall resilience capacity** | | | | | | | | | | |
| Nyandarua | Equal variances assumed | 0.088 | 0.767 | -5.87 | 58 | 0 | -0.1396 | 0.0238 | -0.1872 | -0.092 |
| | Equal variances not assumed | | | -5.844 | 54.646 | 0 | -0.1396 | 0.0239 | -0.1874 | -0.0917 |
| Narok | Equal variances assumed | 0.226 | 0.636 | 2.976 | 58 | 0.004 | 0.0589 | 0.0198 | 0.0193 | 0.0986 |
| | Equal variances not assumed | | | 2.981 | 57.973 | 0.004 | 0.0589 | 0.0198 | 0.0194 | 0.0985 |

The below average resilience index have been reported by studies by Tambo (2016) who reported a less than 0.5 score among both innovators and non-innovators emphasizing the high vulnerability among smallholder dairy farming systems in sub-Saharan Africa. In another study, Frankenberger et al. (2014) findings illustrated indicators for transformative capacities such as good governance, social protection systems and market access are key to building resilient communities. This was further emphasized by Asmamaw et al. (2017) whose studies reiterated the significance of access to basic public services and active participation in governance structure enhance absorptive, adaptive and transformative resilience capacities. Larger landholdings and livestock ownerships are associated with diversified livelihoods, which are key to stronger resilience outcomes (Debie & Ayele, 2023).

## V. CONCLUSION & RECOMMENDATIONS

### 5.1 Conclusion

Findings of the study established that resilience capacities among the smallholder farms regardless of their stages in the dairy growth and whether typical and entrepreneurial remain low although entrepreneurial farms had statistically higher resilience scores than typical farms. Transformative resilience capacity was relatively higher than both the absorptive and adaptive capacities. Land, livestock assets, on farm resources, equipment, market and veterinary services and road networks were consistently strong positive indicators for the three-resilience frameworks whereas financial access and social networks remained underutilized pointing at the systemic gaps in institutional integration, financial support and human capital development. Stronger transformative capacities were demonstrated among the entrepreneurial farms but they were constrained by weak adaptive and absorptive resilience. Multifaceted intervention aimed at strengthening both tangible assets and intangible social and institutional resources are therefore key to building stronger resilient households.

### 5.2 Recommendations

Building absorptive and adaptive capacities through strategic investment on social capital, financial access and strengthening cooperative networks are recommended as priorities to improve the resilience capacities of the dairy systems. Training and capacity strengthening aimed at enhancing technical and managerial skills would largely contribute to long-term resilience. Extended and inclusive integration of institutional support, credit and advisory frameworks will generate resilient and sustainable dairy producer systems.

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