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Foresight study on dairy farming systems in Central Kenya and north of Senegal

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Dairy farming activities play important roles in nutrition and health, livelihoods and employment, and culture, in Kenya and Senegal. Faced with various challenges such as climate change, increased populations, insecurity, and conflicts over (water, land, feed) resources, dairy production systems will have to undergo changes in the future that allow them to adapt. This study used a qualitative foresight approach that is mainly based on interviews with technical experts and key stakeholders, including dairy cattle herders, to identify the main evolution trends to be observed in dairy farming in Central Kenya and north of Senegal. It found that (semi)-intensification of production systems and increased settlement of herders who are nomad pastoralists are the prevailing trends. These trends are likely to persist into the future. For both countries, the key drivers of change and their potential environmental and socio-economic impacts were investigated. As dairy systems continue to confront challenges related to livestock feed and water availability, milk quality and safety, production costs, and market access, strategies are needed that can improve resilience of the systems while attaining the right balance between productivity and sustainability.

KEYWORDS

foresight study, dairy systems, Kenya, Senegal, resilience, climate change

1. Introduction

Dairy farming plays a crucial role in many countries in Africa, particularly among pastoralist and agro-pastoralist populations, generating a significant part of the incomes of many households (Diop et al., 2009). Milk is in addition a central component of many local diets, contributing strongly to food and nutritional security (Kibogy, 2019). Demand for dairy products, including milk, has been rising in Africa, reaching a growth rate of 4 % per year recently (ILRI, 2018; Kibogy, 2019). Rising income, population growth, urbanization and changing lifestyles are the main drivers of the increased milk consumption (Ochungo et al., 2016; ILRI, 2018). Kenya is currently one of the countries with the highest rates of *per capita* consumption of milk in sub-Saharan Africa (i.e., around 82 liters in 2019), including cow, sheep, goat, and camel milk, alongside Sudan, Mauritania, and Botswana (Kibogy, 2019; FAO, 2022). Milk consumption *per capita* is lower in Senegal (at around 12 litres in 2019) and has grown at a relatively modest rate of around 1 % annually over the last decade (FAO, 2022). However, milk is an important part of the diet, and its production an important income earner for many in parts of the country.

In Kenya, the annual *per capita* consumption of milk is expected to reach 200 litres by 2030 (Kibogy, 2019). Kenya is the leader in milk production among eastern African countries (ILRI, 2018; Africa-milk, 2019a). It is estimated that Kenya's livestock sector contributes to 12 percent of national gross domestic product (GDP) (Kimany, 2021) and the dairy sector is the largest agricultural sub-sector in terms of income and employment creation (Bebe et al., 2003; Africa-milk, 2019a). An estimated two million actors derive livelihoods from the dairy value chain in Kenya (Kibogy, 2019; Africa-milk, 2019a).

Agriculture makes a significant contribution to the economy of Senegal, with a share of agriculture in GDP at 17 percent in 2020 (The Global Economy, 2022). Milk production in the country is mainly provided by cattle (followed by goats and sheep), with approximately 3.7 million heads in 2020 (Ministère de l'agriculture, de l'agroalimentaire et de la forêt, 2014; FAOSTAT, 2022). National milk production has increased over the past decade, with the produced milk being consumed mainly within the household and sold on the markets (GRET/APESS, 2016; Africa-milk, 2019b). However, due to a largely unstructured local dairy value chain (Africa-milk, 2019b) as well as the large quantities of milk and milk products being imported annually, only ten tons of milk equivalent are processed yearly in the country's dairies, accounting for less than 10 % of the national milk production (Africa-milk, 2019b).

Faced with various challenges such as climate change and increased demand for milk and other livestock products, dairy systems in Kenya and Senegal are evolving (FAO and GDP, 2018). This raises many research questions which if answered could aid our understanding of how dairy systems are currently evolving and what changes to expect in the future. This study focused on four such questions: (i) how are dairy systems evolving in Kenya and in Senegal? (ii) what factors are driving dairy system evolution in both countries? (iii) what are the potential consequences of these changes, and (iv) how do the ongoing changes enable or limit the resilience of dairy systems in the face of current and emerging challenges (climate change, growing population, insecurity, and conflict)? In this study, these questions have been answered using a series of interviews of herders and dairy sector stakeholders. An inventory was done of their answers, including their interpretations of dairy systems in Kenya and Senegal, and analyzed to provide answers to the specific questions of this research. The specific objectives of the inventory and analysis of stakeholder perspectives carried out in the study were to identify, for dairy farming systems in the study countries, plausible scenarios of system evolution that represent the major tendencies in these countries. This was done without attempting to explore all possibilities of evolution of the dairy systems. This study further sought to identify, also through the interviews, the drivers and potential consequences of scenarios recognized by the dairy system stakeholders, and their implications for resilience of the dairy systems to current and future challenges. A literature review was conducted to initially characterize the dairy systems in Kenya and Senegal. This review provided the context for determining what stakeholders to engage with, where, and how. It also provided a knowledge base against which data emerging from the interviews could be compared.

The next section presents an overview of dairy farming systems in Kenya and Senegal compiled from the literature, followed by a description of the methods used to answer the research questions posed, after which the results of the foresight study are presented and their implications discussed. The discussion on implications allows to put the responses into perspectives while capturing the perspective of interviewees.

According to the literature, dairy farming systems in Kenya can be divided into three general categories: grazing systems, zero grazing systems, and semi-zero grazing systems (van der Lee et al., 2016; Kibogy, 2019) (see Table 1). These systems mainly differ based on their management practices, such as in the choice of cattle feeds, housing, grazing practices, and animal breeds.

Three dairy farming systems are also observed in Senegal: pastoral (also called sylvo-pastoral) systems, agro-pastoral systems, and intensive systems (see Table 2; Dieye et al., 2005; Magrin et al., 2011).

2. Methods

Three research questions, namely (i), (iii), and (iv), were answered using a foresight method called the futures wheel where technical experts and key stakeholders of the dairy systems in Kenya and Senegal were interviewed. Research question (ii) was answered using a combination of the same foresight method and literature review.

Expert and stakeholder knowledge was obtained from individuals representing a diversity of local actors from the dairy value chain in both countries (herders, dairy cooperatives members, consultants, university professors, public and private sector, etc). A foresight tool called the futures wheel was used to conduct interviews of the experts and stakeholders. Along with first-order impacts of a trend or a change (i.e., impacts being a direct consequence of the change), this qualitative foresight method analyses second order impacts (i.e., the consequence of the consequence), and beyond (Inayatullah, 2008) through a structured brainstorming (Glenn, 2009; Bengston, 2016). The futures wheel was invented in 1971 by Glenn (2009) and helps to organize, understand and clarify different future elements and their possible influences (Toivonen and Viitanen, 2016). Despite its simplicity, the futures wheel is seen as an effective method to investigate the future and allows to investigate several possible development paths for the future (Glenn, 2009). The futures wheel method was chosen as it is a method that seeks to outline an issue or a change, and outline its consequences within the context of the longer-term future (Inayatullah, 2008).

The futures wheel method was utilized with all experts and stakeholders interviewed, with little variations in its application to interviews of herders versus non-herders. After gathering information on the production and practices, the following two questions was posed to the herders regarding the future of dairy systems: (1) "What do you wish for you and your children in the future?" and (2) "How do you think dairy activities will change?." The future was here characterized as the coming 10 to 15 years and/or when children become old enough to be herders themselves. For non-herders, the equivalent question posed was « In your opinion, how will dairy activities change in the future, and what would be the consequences of this change?." After obtaining responses to understand how each expert foresees the evolution of dairy farming in their respective country, the futures wheel was then used to investigate perceptions about the consequences of the evolution of dairy farming. This component of the exploration mainly concerned the environment and the economy. Data were collected, aggregated, and analyzed with the use of an online tool (called Klaxoon) to organize the responses from the interviews into emergent scenarios.

The same methodology was applied in Kenya and in Senegal.

TABLE 1 Description of dairy farming systems in Kenya.

Grazing	Short summary	Cattle graze on pastures with or without feed supplementation and low to medium external input levels.
	Breed	Local – Zebu purebred (uncontrolled)[1] or crossbred (controlled)[2]
	Milk production	~2–5 L/cow/day
	Market access	Poor market access, mainly for self-consumption or milk sells directly to consumers
	Land availability	High
	Location	Uncontrolled[1] grazing: Pastoralist areas, Western and Eastern Region Controlled[2] grazing: Central Region, Rift Valley
Semi grazing	Short summary	Cattle are partly confined, mixing grazing during the day and confinement at night with feed supplementation.
	Breed	Exotic – Fressian crossbred or Ayshire crossbred
	Milk production	~6–10 L/cow/day
	Market access	Medium market access, milk sells to consumers or cooperatives
	Land availability	Medium
	Location	Central Rift, Western Region, Eastern Region, South Rift
Zero grazing	Short summary	Cattle are always stall-milked and stall-fed, using cut- and carry fodder as well as concentrates and supplements, with high external input levels and high level of management.
	Breed	Exotic – Fressian or Ayshire crossbred or purebred
	Milk production	~7–12 L/cow/day
	Market access	Market oriented, milk sells to traders or dairy cooperatives
	Land availability	Scarce
	Location	(Peri)-urban areas, Central Region, Central Rift, South Rift

Author's compilation using Bebe et al. (2003), Makoni et al. (2014), van der Lee et al. (2016), Odero-Waitituh (2017), and FAO (2018b).
[1]Uncontrolled grazing: cattle roam on communal lands in search of water and fodder, with unimproved pastures, limited supplementation, and low levels of use of external inputs.
[2]Controlled grazing: cattle graze on private lands, fenced, or divided in paddocks, with use of artificial insemination, possible supplementation, and medium level use of external inputs.

TABLE 2 Description of dairy farming systems in Senegal.

	Pastoral	Agro-pastoral	Intensive
Short summary	Cattle are mobile on long distances (nomad herders), extensive, mostly for self-consumption	Agriculture/livestock integration, mostly multifunctional objective (manure, draught power, production, self-consumption)	Stall-fed and stall-milked with a production objective
Feed	Grass, residues (dry season)	Grass, residues, crop concentrates	Grass (mainly fed as cut-and-carry), residues, crop concentrates, supplements
Breed	Local – Zebu Gobra	Crossbreed – Zebu Gobra, Djakoré, Ndama	Exotic – Montbéliarde, Jersiaise, Holstein, Gir
Milk production	~0.5–2 L/cow/day	~6 L/cow/day	/
Market access	Low	Medium	High
% of national livestock	32%	67%	1%
Location	Ferlo region and around the Senegal river	Other areas of the country	(Peri)-urban – Niayes zone, Dakar, Thiès

Dieye et al. (2005).

3. Results

The study focused on counties from the old Central and Rift Valley provinces of Kenya (specifically, Nyeri, Nyandarua, Murang'a, Nakuru, Bomet, and Kericho counties). In Senegal, the geographical focus of the study was an area in the north of Senegal spanning from the Senegal river to the Ferlo region (specifically, Saint-Louis, Louga, and Matam regions). These areas of Kenya and Senegal are important for dairy farming, having high numbers of dairy cattle (FAO, 2018b), and high milk production potential plus, high demand for milk and dairy products. Milk productivity per cow remains rather low in these regions placing pressure on the dairy production systems to undergo changes such as organization of markets and supply chains as well as re-structuring of production systems to reach their potential.

3.1. Present situation for the foresight study

In total, twenty-eight experts and stakeholders in Kenya and twenty-five in Senegal were interviewed (see Figure 1), with half of them being herders (twenty-six herders in total). Among these herders, twelve were herders in Kenya coming from Bomet or Nyandarua counties, all belonging to dairy cooperatives, and fourteen herders in Senegal coming from Richard Toll, Saint-Louis and Dahra areas with only four being affiliated to a dairy cooperative. Most herders – 50 percent in Kenya and 78 percent in Senegal – were aged 50 years old or above, as it is common in the study locations of both countries that the household head remains in charge of cattle until his sons inherit the cattle herd. Most of the interviewed herders in Kenya (seven) have adopted grazing systems, three practice semi-grazing, while two herders practice zero-grazing. Ten of the herders in Senegal are agro-pastoralists, three are pastoralists, and one practices intensive production (see Tables 3, 4). Herders interviewed in Kenya own between one and five cows, while the herders included in the study in Senegal possess between 3 and 15 lactating cows in herds of 15 up to 400 cattle. All herders combine dairy production with various other agricultural activities: small ruminant and poultry production mainly, but also fodder production, vegetable gardening, rice growing next to the Senegal river, and cereals, legumes, bananas and tea growing in Central Kenya.

Other experts were interviewed in addition to the herders (see Figure 1), namely, non-academic researchers (three in Kenya and five in Senegal) affiliated with international research organizations, and academic researchers (two in Kenya being also professors and one in Senegal) affiliated with different universities. These researchers had expertise in agricultural economics, smallholder herder systems, livestock feeds, livestock production systems, animal health, and animal breeding. Six technical and advisory consultants were also interviewed in Kenya that had expertise in dairy production, feeds, or milk quality. Interviewed dairy value chain actors included dairy managers and directors, and chairpersons of dairy cooperatives. Finally, experts were interviewed from other institutions in the public sector, the private sector and from herder associations.

Milk production among herders interviewed in Kenya varies between 5 to 13 L/cow/day, with an average of 7.8 L/cow/day, all with crossbreeds cattle (mainly Freisian and Ayrshire). Milk productivity does not seem to correlate with production systems as both the lowest and highest values of milk production were reported in grazing systems (see Table 3). On the other hand, milk production among interviewed herders in Senegal clearly varies among production systems and is associated with differences in cattle breeds (see Table 4). For the local breed in Senegal (Gobra Zebu), milk production varies between 1.5 to 6.5 L/cow/day, with an average of 2.5 L/cow/day. Herders in Senegal possessing crossbreeds (mix between Gobra Zebu and exotic breeds such as Montbeliarde, Holstein, Normande, or Guzerat Zebu) have milk productivity varying between 10 and 20 L/cow/day. The intensive farm, with exotic breeds (mainly Holstein), has a production of 15 L/cow/day. It is also noticeable that the youngest herders in Kenya, i.e., aged between 30 and 40 years old, have the highest milk productivity with 10 L/cow/day on average, compared to the oldest herders, i.e., aged over 60 years old, with the lowest milk productivity of 5 L/cow/day on average (see Table 3).

3.2. Evolution of dairy farming systems

This section answers the research question (i) how are dairy systems evolving in Kenya and in Senegal?

Based on the futures wheel method, three major scenarios were identified and discussed by experts and stakeholders in central regions of Kenya as the important trends that are either happening currently or have potential to dominate in the future (see Table 5). The first evolution scenario identified is the emergence of commercial and intensive zero-grazing systems in which farms own around ten lactating cows, and mainly purchase feeds externally. In that scenario, in the longer term (>15 years), it is envisioned that there will be fewer farms and fewer dairy herders than today, but these farms will have higher productivity and production. Smallholder operations (<5 cows) will slowly decrease in number, without disappearing completely and will serve mainly household own consumption needs. As some experts mentioned, the Rift Valley region still possesses larger

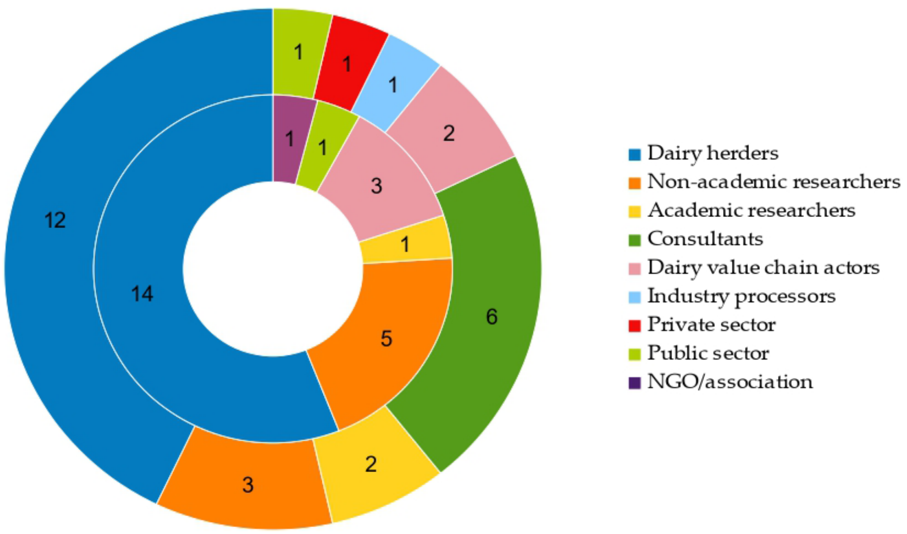

FIGURE 1
Number of interviewed experts and stakeholders in Kenya (outer circle) and Senegal (inner circle) according to their profession during the study (Authors).

TABLE 3 Characteristics of interviewed farmers in Kenya.

Dairy systems	Age group	Number of cows	Milk production (L/cow/day)
Grazing	30–40	2	8
	30–40	2	13
	30–40	5	8
	>60	1	5
	>60	1	5
	>60	2	/
	>60	4	/
Semi-grazing	40–50	3	6
	40–50	2	8
	30–40	4	11
Zero-grazing	50–60	3	8
	50–60	2	6

Authors compilation of information.

TABLE 4 Characteristics of interviewed farmers in Senegal.

Dairy systems	Age group	Total number of cattle (lactating cows)	Milk production (L/cow/day)	
			Local breeds	Crossbreeds/exotic
Agro-pastoralist	>60	400 (10)	2	–
	>60	50 (unknown)	1.5	–
	50–60	50 (10)	1.5	–
	50–60	30 (10)	1.5	–
	>60	20 (5)	1.5	–
	50–60	15 (3)	–	17
	>60	Unknown (6)	–	17
	50–60	Unknown (4)	–	12
	40–50	20 (6)	–	12
	50–60	150 (10)	4	–
Pastoralist	>60	50 (/)	1.5	–
	>60	40 (6)	1.5	–
	40–50	45 (13)	6.5	18
Intensive	<30	50 (15)	–	15 (exotic)

Authors compilation of information.

land size than Central Kenya, implying that the shift toward zero-grazing systems in this region will likely occur at a slower pace.

The second scenario identified in Kenya is the shift from extensive grazing to intensive zero-grazing small-scale dairy farms. In this scenario, most dairy farms will remain as small-scale family managed farms (<5 cows), without an increase in herd size. Most experts agreed that extensive grazing systems would still exist but at a smaller extent. Some argued that small-scale intensive zero-grazing systems are not economically sustainable, as the cultural attachment of people to dairy breeding activities would still be very present, leading to unproductive and non-sustainable activities, therefore mainly maintained for own-consumption purposes.

The third scenario in Kenya envisions the grouping of small-scale herders into cooperative farms with around 30 to 100 cows per cooperative, and herders as the shareholders. Cattle belonging to each herder are kept together on one piece of land and managed together by the cooperative. In this context, herders could then allocate time and land to fodder and food production on their own non-communal land. According to some experts, this scenario is likely not going to happen in areas with larger land sizes, as herders with higher access to land would continue processing milk on their own.

The first two scenarios are seen as most likely by interviewed experts and stakeholders.

In Senegal, using the same method, two evolution scenarios emerged from the discussions with experts and stakeholders (see Table 6). According to interviewed experts and stakeholders, the evolution scenarios will occur more slowly in Senegal than in Kenya in the medium-to-long term (>20 years). This slow pace is attributed to many challenges and uncertainties facing the sector in Senegal. The first identified scenario is the complete settlement of herders, with a

TABLE 5 Evolution scenarios for dairy farming systems in Central Kenya.

	Commercial and intensive scenario	Small-scale intensive scenario	Cooperative scenario
Farming systems	Zero-grazing	Zero-grazing	Zero-grazing
Number of farms (compared to nowadays)	Few	Unchanged	Few
Number of cows per farm	~10	~5	30–100
Feed origin	Off-farm	Off-farm/on-farm	Off-farm
Management	Commercially managed (trained manager)	Family managed	Commercially managed (highly trained manager)

Authors compilation of interview answers.

TABLE 6 Evolution scenarios for dairy farming systems in north of Senegal.

	Full settlement scenario	Partial settlement scenario
Farming system	Agro-pastoralism and intensive	Agro-pastoralism mainly
Number of cows per farm	<30	~5 lactating cows (within a big herd)
Breeds	Crossbreeds or exotic breeds	Crossbreeds
Feed origin	Mainly off-farm and use of crop's by-products	Mainly on-farm and use of residues and crop by-products
Number of farms (compared to nowadays)	Very few	Few
Presence of pastoralism	Reduced	Unchanged

Authors compilation of interview answers.

decrease in herd size (maximum 20–30 crossbreeds or exotic breeds), and the slow disappearance of pastoralism. Due to lack of water and forages during the dry season, pastoralism would evolve toward total settlement of cattle. Under this scenario, animal feeds would either be produced off-farm or will come from by-products of agriculture (sugar cane, rice, straw). This intensification scenario would make multi-objective farms shift to specialized production and would imply a decrease in the total number of farms and herders as these turn to other activities.

The second scenario in Senegal is a partial settlement of some herders that have access to markets and/or directly to consumers. These herders would have a small sedentary production herd (maximum 5 crossbreed lactating cows) situated close to collect centers or consumptions centers while with the rest of the herd (local breeds) will be kept under more extensive and nomadic conditions. The extensive components of the herds would still be able to take advantage of natural dry forages and exploit areas unsuitable for agriculture and would still produce cattle meat, which is important culturally in Senegal. In this second scenario, dairy systems in Senegal would still exist in their current forms, albeit with a higher proportion of agro-pastoralists and intensive farms as well as improved conditions for pastoralists practising semi-intensive systems.

In both scenarios identified in Senegal, integration of livestock with crop agriculture is needed to utilize residues and by-products for cattle feed. Agriculture could continue to be rain-fed or may shift toward irrigation when this is possible (e.g., at locations close to rivers, lakes, or other water sources).

3.3. Drivers of change

The results presented in this section were obtained during interviews with various experts and stakeholders, and from the literature search. The section answers the research question (ii) what factors are driving dairy system evolution in both countries?

3.3.1. Kenya

Central Kenya and the center of the Rift Valley are dominated by "improved" grazing and semi-grazing systems. Since the independence of the country in 1963, a gradual shift toward zero-grazing has largely been observed, especially in some counties of these regions (e.g., Kiambu county, at the periphery of Nairobi). At that period, the government encouraged farming and delivered ownership title and loaning facilities so local farmers could own their private piece of land, especially in Central Kenya and the Rift Valley. In other areas of the country, such as the southern Rift Valley, lands are still owned communally. These rural development policies aimed to improve rural livelihood, including income, education, health and nutrition, reduce inequality, and enhance growth of the rural sector (Kirori, 2003). However, the process of distributing land ownership titles may have led gradually to land division over time. Traditionally, when a farmer dies, his sons inherit the land by dividing it. Average land size has therefore decreased from average 5 acres in 2010–2015 to between 0.5 and 2.5 acres on average today (Kimuge, 2021) and from 2.6 to 5 cows per farm between 1996 and 2020 (IFCN, 2021). Furthermore, high costs and difficulties in acquiring new land provide an incentive in Kenya for individuals to aspire to own their own plot of land, no matter the size (Hlimi, 2013). In addition to land fragmentation, this tradition results in habitat fragmentation, deterioration of land quality, tenure insecurity and conflict, among others (Hlimi, 2013). Zero-grazing systems are therefore seen as a solution to continue dairy farming in the future, even with smaller pieces of land per unit.

One major factor driving the adoption of zero-grazing in Kenya has also been the National Dairy Development Project (NDDP), initiated in the 1980s under the Kenya Ministry of Agriculture, Livestock Development and Marketing. This project has been promoting establishment of intensive and stall-feeding units by farmers, in combination with adoption of the use of good quality fodder for feed (mainly Napier grass – *Pennisetum purpureum*) (Reynolds et al., 1996). Pilot farms with a zero-grazing model have also been established by international organizations and researchers, where farmers from Kenya, and from other African countries, are trained.

According to the interviewees, the gradual expansion of zero-grazing systems in regions where infrastructure is available is mainly driven by: better access to inputs (feed, artificial insemination, veterinary services), training, growing demand in urban areas, climate change, cultural change (young people are less willing to inherit farms), high cost of labor, and promise of high milk production, productivity, and income.

3.3.2. Senegal

Dairy systems in the north of Senegal are largely dominated by agro-pastoralists and pastoralists. Few intensive farms are also present, with exotic breeds imported mainly from Europe. Sedentary systems – agro-pastoralists and intensive farms – are mainly present close to urban areas and next to the Senegal river and water points. While sedentary systems are inclined toward milk production, traditional pastoralists are more oriented toward production for own-consumption and calf breeding (live animal sales). These systems are facing major challenges related to resource access during the dry season.

Experts and stakeholders in Senegal indicated that the government of Senegal developed irrigated rice agriculture along the Senegal river in the 1960s, which directly affected the traditional patterns of cattle movements. As natural fodder growing close to the river became unavailable, herders and their animals were pushed further south in search for forages. Following some recent difficult years with high cattle mortality and unavailability of forage due to droughts since 2011 (Reliefweb, 2018), evolution of the dairy production seems to be toward restricted animal movements as a climate change adaptation strategy. This is particularly true for herders close to the Senegal river, where feeding from agricultural residues and by-products (rice or sugar cane) is available perennially, and where the location of dairies and urban markets nearby provide ready access to markets (e.g., Laiterie du Berger in Richard Toll and mini-dairies).

In 2018, the Laiterie du Berger introduced "mini-farms" to their supplier herders. These mini-farms allow herders to keep a small number of productive cows (often crossbreeds) under sedentary conditions. According to dairy experts, other than milk production, mini-farms could allow the breeding of high value calves having higher economic value to the herder. This in turn can improve the genetic quality of the herd. Alongside a small, sedentary and productive herd, herders keep a mobile herd that could better utilize available dry forages due to their mobility.

Driven by these changes – closing of nomadic patterns along the river, droughts affecting the availability of natural forages and water, the opening of new markets in form of dairies – the evolution of dairy farming systems in Senegal seems toward (partial) sedentary lifestyle. According to experts, other drivers of change are: economic opportunities that are improving incomes and livelihoods, the growing demand for local milk and dairy products, access to training for herders, and increased school attendance of pastoralists' children (so that they are no longer readily available to care for the family cattle). In addition, increased scarcity of grazing lands, including due to the increase of agricultural and urban land use leads to more intense competition for land which is noted to sometimes lead to conflicts, with, for example, agribusiness establishments located around rivers or production basins cutting off traditional paths for nomadic livestock migration and preventing access to water points.

3.4. Potential consequences of the evolution of dairy systems

This section answers the research question (iii) what are the potential consequences of these changes?

3.4.1. Kenya

Direct and indirect environmental and socio-economical consequences were identified for the three potential scenarios of dairy farming evolution in Kenya (see Figure 2). They were identified by experts and stakeholders using the futures wheel method.

Multiple impacts were identified. The main positive environmental impacts identified by at least four experts for the three scenarios are: minimal dependence of feed production on climatic events due to the increased distribution of production to various regions of the countries, decrease in methane emissions per cow due to better feeding practices and better breeds, increased potential for biogas production, and reduced over-grazing and damage to biodiversity. Negative impacts that were identified include accumulation of waste (manure and feed waste) from increased production, higher nitrogen and phosphorus pollution, and decline in animal health due to increased confinement.

For socio-economic impacts, experts and stakeholders identified the possibility to have better nutrition and food security due to an increase in milk production, and a boost in the country's economy and in herder livelihoods due to increased net incomes. Some experts argued that a transition to zero-grazing is not economically sustainable as production costs (mostly feeds) will remain too high for dairy farming to become profitable, especially for small-scale herders. Without financial support, most herders would not be able to practise zero-grazing, resulting in less farm employment and decreased numbers of smallholders. To other experts, intensive and commercial farms are seen as attractive for employment even though they would only benefit a small number of people as the number of farms is likely to decrease.

3.4.2. Senegal

In Senegal, the futures wheel method identified direct and indirect environmental and socio-economical consequences of two potential scenarios of dairy farming evolution (see Figure 3).

Many of the potential impacts of evolution scenarios in north of Senegal that were identified by experts and stakeholders are like the ones reported from Kenya: livelihood improvements, high production costs, air and water pollution, reduction in over-grazing, increase of manure burden, disease spread, etc. The envisioned increase of milk production and productivity is also explained by use of more productive animal breeds and better cattle feeding explained, which in turn are traced to, in this case, agriculture/livestock integration. This is in contrast with the findings from Kenya, where the use of feeds purchased from external or off-farm sources was identified as the main reason for increased milk production and productivity.

Concerning herd size, at national and farm levels, farm sizes could either decrease due to better milk productivity per cow, or the

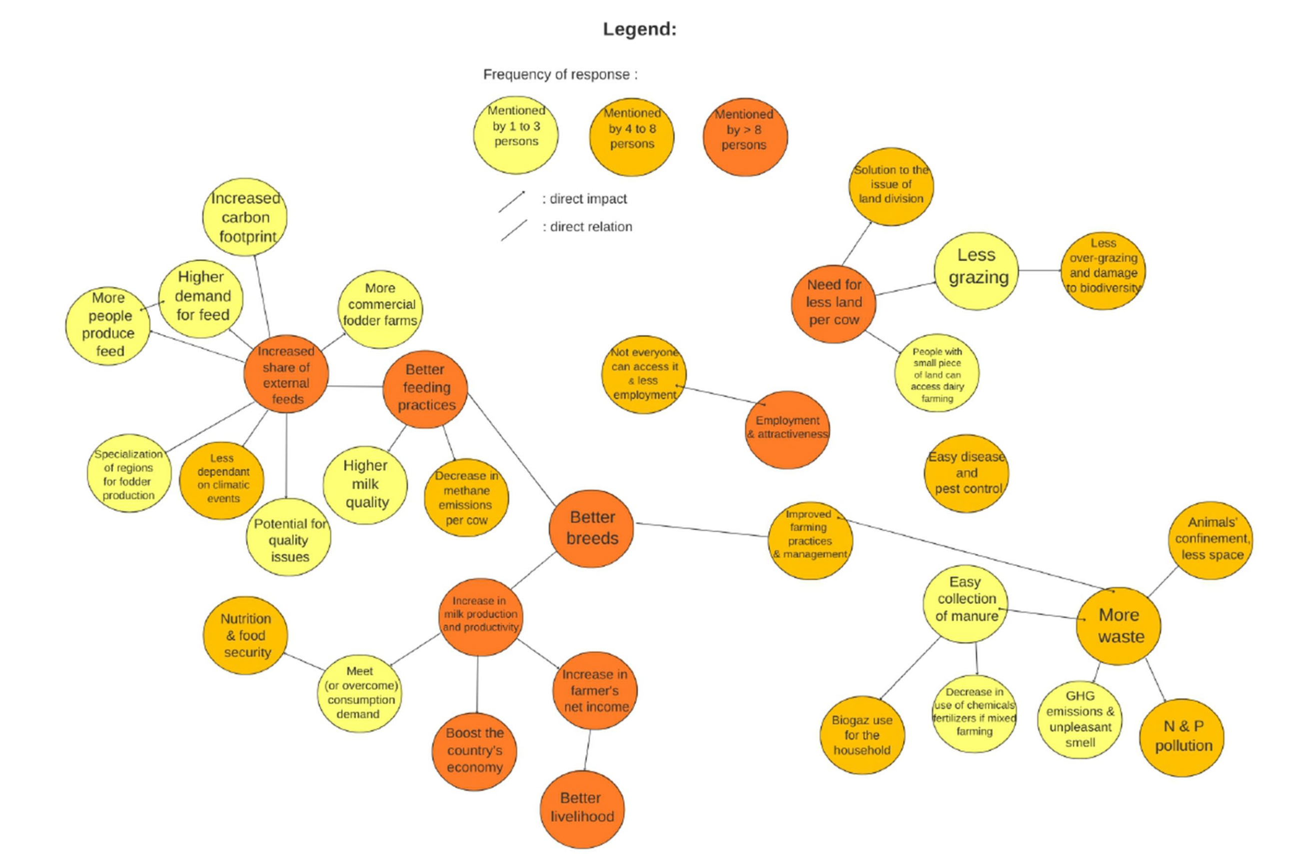

FIGURE 2
Map of the main potential direct and indirect impacts of the three evolution scenarios for dairy farming systems in Central Rift Valley according to the interviewed experts and stakeholders (Authors).

attractiveness of milk production and its income leads to an increase in herd size leading to an increased in environmental impacts and in meat availability.

3.5. Resilience of future dairy systems

This section answers the research question (iv) "how do the ongoing changes enable or limit the resilience of dairy systems in the face of current and emerging challenges (climate change, growing population, insecurity, and conflict)?," and derives from interviews of experts and stakeholders from the dairy value chain.

3.5.1. Resilience to climate change

Intensification or semi-intensification is seen by some experts and stakeholders as a solution for reducing the impacts of dairy farming on climate and the environment and as a mean for these systems to be less strongly impacted by climatic events (e.g., droughts, erratic rains, high temperatures). However, according to other experts as well as based on field observations, it seems that dairy systems will nevertheless have to face several challenges linked to climate change. These include:

1. Feed scarcity, particularly during the dry season, and decline in pasture quality (soil quality, diversity of fodder species);
2. Water shortages and/or difficulty to access water (high price, monopoly of water points by agribusinesses, conflicts over water);
3. Threats to animal well-being (heat stress, lack of movement) and animal health (high mortality rate, reproduction issues, spread of diseases);
4. Milk quality decline due to animal diseases, potential contamination from externally produced feed, unhygienic milking practices, and suboptimal milk storage and transportation.

To address these challenges, future dairy systems will need to adopt a range of climate change adaptation strategies. Results emerging from the futures wheel suggested that the main climate threat to intensive sedentary systems, in both Kenya and Senegal, is the difficulty in supplying cattle with quality feed. Therefore, when land is available in abundance, integration with agriculture to gain sufficiency in fodder production, and not depend on off-farm feed, is needed. On the contrary, when land is largely unavailable, herders must rely on externally produced feed that could be less impacted by adverse climatic events. In this context, various areas producing feeds commercially and unaffected by the adverse events could sustain affected areas. However, externally produced feed is more prone to market price fluctuation related to economic or political events, as well as raise potential feed

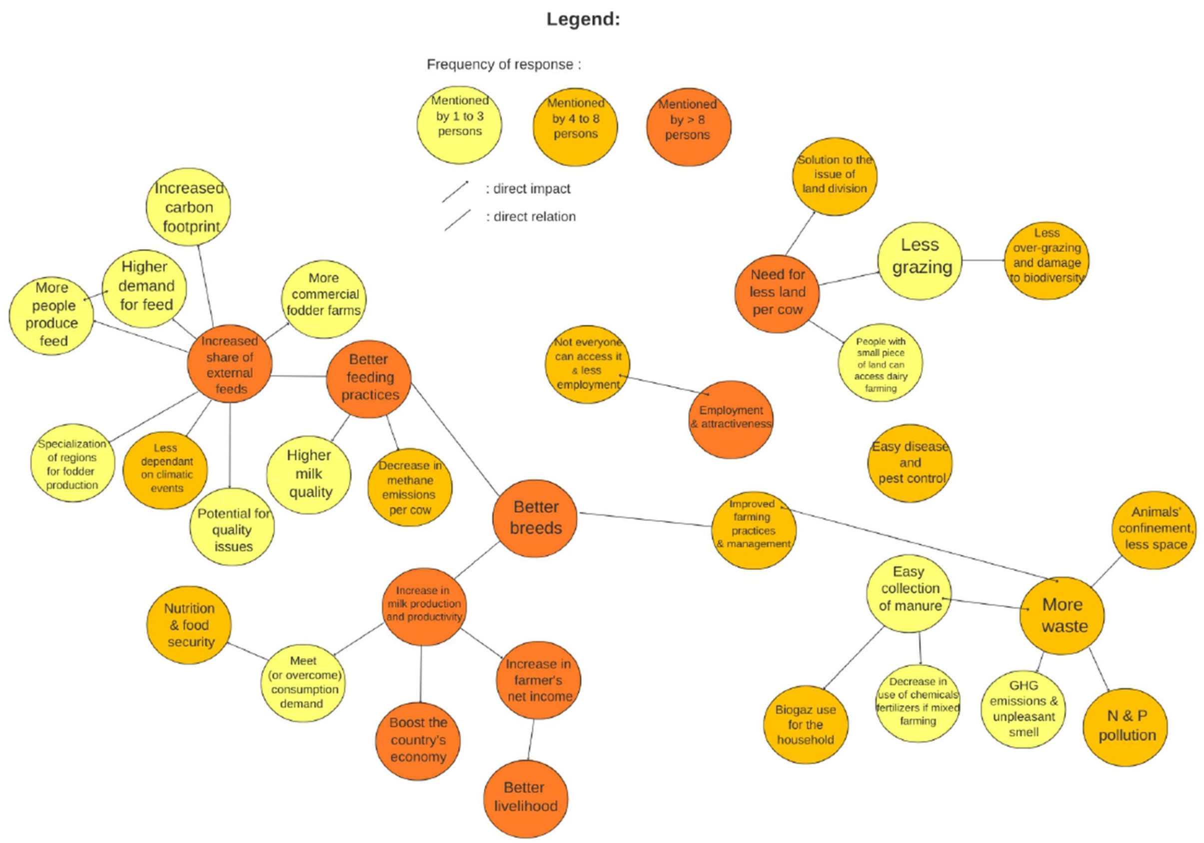

FIGURE 3
Map of the main potential direct and indirect impacts of the two evolution scenarios for dairy farming systems in northern Senegal according to the interviewed experts and stakeholders (Authors).

quality issues that require increased government regulations and/or the enforcing of standards. In either case of land availability, an additional strategy to limit climate impacts is to store fodder when they are available at a lower price (e.g., during the rainy season) which can then be provided to the herd during the dry season.

Finding a balance between productivity and environment protection and adaptation could be the key for sustainable milk production in the future. Practices identified by experts and stakeholders to maintain this balance include the use of locally adapted seeds (e.g., short cycle, highly digestible), and animal breeds (crossbreeds), biodiversity protection and reforestation, soil management and productivity, establishment of protected areas for natural fodder regeneration, integrated fodder production (circulation of nutrients through feed and manure, irrigation), and use of off-farm feeds (fodder conservation and productivity, new technology such as hydroponics).

The expert and stakeholder knowledge, particularly that emerging from the interviews of herders, suggested that the resilience of intensified dairy systems to climate change will also depend on the level of sensitization of herders. Further, focusing solely on strategies that address economic and productivity concerns, without considering sustainability and environmental issues, and the maintaining of equilibrium within production systems, should be avoided. To this end, providing information and training to herders and other dairy value chain actors, about how to manage emerging environmental challenges, will be key for resilience and adaptation. Such training could be implemented by NGOs, associations or cooperatives, while aligned with relevant government policies, but will need to take into account the culture and traditions of herders and others in the dairy systems.

Finally, according to some experts and stakeholders, settlement and intensification of herders might be an issue in the long-term since the herders could lose flexibility and adaptation capacities. In case of extreme climatic events, herders cannot adapt their feeding practices as they used to when they were more mobile. On the other hand, as settlement limits movements of animals in search of feed, it also limits unnecessary energy expenditure, allowing animals to allocate energy more effectively to milk production. However, intensification and settlement might not be the only viable options for the future. For herders who own reasonable tracts of land, (semi-)grazing systems could be a better solution as it address some issues that arise from to the confinement of animals such as poor hygiene of animal facilities, or non-autonomy regarding farmers' cattle feeding options.

To improve sustainability of dairy systems in the future, cooperation, diversity and adaptation of each dairy production system to local constraints and challenges, depending on land availability, agro-climatic context, and market access is the key.

3.5.2. Resilience under growing human population and higher food demand

The populations of Kenya and Senegal grew at the rates of 2.25 percent and 2.7 percent, respectively, in 2020 (The World Bank, 2022). Study interviewees thought that intensive and semi-intensive systems could increase milk production and productivity to supply the increasing demand for milk and dairy products in both countries. According to the expert and stakeholder interviews and observations from the field, dairy farming is facing three main challenges to meet the growing demand in milk and dairy products:

- High production costs (especially in relation to feeds, water management, and cattle reproduction);
- Market access as milk must be collected, transformed, and distributed to consumers – mainly in urban centers. There emerges a strong need for appropriate infrastructure, road networks, and re-organization of the dairy value chains;
- Territorial pressure with the increase of urban and agricultural lands.

From the futures wheel implementation, it emerged that direct sale of milk to consumers by herders or cooperatives could help Kenya better meet the increasing demand for local milk and allows herders to sell milk at a good price. When direct sale is not possible (e.g., when producers are located far from consumption centers), the organization of herders within cooperatives and/or (mini)dairies could help. Having higher numbers of dairies could increase the absorption capacity for locally produced milk and help fight against milk supply instability throughout the year. This can only be possible if the needed resources are available (especially feed – with an association with agriculture residues and by-products), and if producers have good access to markets. For the dairy value chain to be stronger and better organized (in terms of milk collection, transformation, and sales), there is a strong need for policy oriented toward supporting them. One question for the future is therefore to define the desired role, within the economy and territory, of dairy farming in the overall agricultural development of the country.

Milk production and stability throughout the year will likely help to decrease milk price volatility, according to experts, as there are strong differences in milk production quantities between dry and wet seasons. Based on the expert and stakeholder discussions, increase in milk production could also boost the national economy as well as farmers' livelihoods, and decrease imports of milk and other dairy production in the long term.

In Senegal, experts proposed the imposition of taxes on imported milk and dairy products to promote growth of the local dairy industry, at least in the short term. However, this will lead to increases in the prices of imported dairy products, and potentially to negative socio-economic impacts on vulnerable consumers in the short term. In the long-term, restrictions on imports could spur development of the local dairy sector, with potential to help (particularly dairy producer) households move out of poverty, like has been demonstrated previously in Bangladesh (FAO, 2009).

3.5.3. Resilience to insecurity and conflicts

Insecurity and conflicts over resources and land emerged as a common theme in the stakeholder interviews conducted in Senegal. According to experts and dairy system actors, the conflicts arise mainly due to confrontations between herders and farmers as cattle graze on agricultural lands. This phenomenon was less emphasized in the interviews in Kenya. Increased settlement of animals could improve the situation in Senegal as the movements of animals outside of a producer's own land decreases, creating fewer opportunities for conflicts with farmers. Keeping productive cattle enclosed close to the farms or homesteads could also prevent cattle theft even if cattle of high value (e.g., crossbreeds or exotic breeds) would be more prone to theft. However, settlement of herders could also create conflicts with farmers over land and water as herders would prefer to settle down on land with access to water points.

Animal movements may need to be more organized in the future to avoid conflicts with, as proposed by experts, movement calendars agreed within communities/regions, or the establishment of well managed and dedicated places for pastoralism (e.g., Ranch de Dolly in Senegal). Under such arrangements, cattle could in addition benefit from increased ease of veterinary and extension services to extend veterinary health coverage to the animals.

4. Discussion

4.1. A general trend for the evolution of dairy systems in Kenya and Senegal

Dairy sectors in Kenya and Senegal have a wide range of effect on society, contributing to livelihoods, food security and nutrition, while being a major consumer of natural resources, and present public health threats (FAO, 2018a). Dairy farming systems will likely undergo major changes. Potential evolution scenarios in Kenya and Senegal, identified in the result section, can be thought to represent global trends of change without being fully exploratory. Hence, not all possible evolution scenarios are explored in this study, but only those observed during field trips as well as elicited during the interviews of dairy system actors and stakeholders. Scenarios identified for both countries were found to be quite similar, as they are following a current trend.

Intensification seems to be the preferred and foreseen evolution scenario in both countries by the majority of interviewees. However, the pace of evolution will appear to be different in Kenya than in Senegal. Intensification of dairy production is already happening in some parts of Kenya, such as urban and peri-urban areas, due mainly to land unavailability. Further, as they observe increased productivity and higher incomes of other dairy producers, many dairy herders in the country express their desires to experience same. On the contrary, dairy systems are evolving more slowly in north Senegal than observed for Central Kenya, which is a commercially oriented region for dairy production. Many stakeholders expressed during interviews that the study region in north Senegal might not experience major changes within the next few coming decades. This could be due to the specific agro-climatic context of this part of Senegal inducing many challenges such as water and feed availability and could also reflect strong pastoralist culture and tradition.

4.2. Ideas for the main focus areas in dairy research and policy

One focus area to consider by dairy research and policy when intensifying production is the environmental impacts of such growth in production. Even if methane emission can decrease on a per cow basis, for example owing to improvements in the quantity and quality of the animals' diet (Kasyoka, 2020), there is a possibility of higher greenhouse gases (GHG) emissions in overall due to higher input levels and increased numbers of animals. Intensification of dairy production systems also opens new constraints and opportunities regarding manure management. If poorly managed, manure can lead to increased levels of water and air pollution. However, manure could also serve positive functions in the system, for example if used to produce biogas – a combination of methane and carbon monoxide generated during anaerobic digestion of manure (KENPRO, 2022) as witnessed during field visits. Many households in Africa face insufficient energy supply and rely on wood and other non-sustainable fuel sources for cooking, contributing to both increased GHG emissions and deforestation. Biogas could be a solution as an alternative source of energy to deal with issues of GHG emissions and manure disposal (KENPRO, 2022). Manure can also be collected and transformed to be used as organic fertilization in crop production.

Cattle diseases are a major public health issue. Extensive grazing systems have a higher prevalence rate for East Coast Fever and Brucellosis (FAO, 2018a), and many studies observed higher prevalence of nematode gut parasites and liver fluke in these systems (Arnott et al., 2015). In the meanwhile, other health and well-being issues tend to emerge within high confinement systems, such as lameness, mastitis, uterine diseases, and various infectious diseases (Arnott et al., 2015).

Another area to focus on would be market access and the dairy value chain organization. As milk production and productivity are expected to increase with intensification, according to stakeholder opinions, systems with higher capacities for milk to be collected, transformed, and distributed to consumers will be needed. Milk collection and transformation system and dairy systems evolution are mutually influencing each other transforming the dairy value chain to commercialize locally produced milk (Wane et al., 2017). As an example, the Laiterie du Berger in Senegal is a unique collect and milk commercialization firm linking market accessibility with key factors in dairy production systems evolution such as feed access, contracts with herders, and animal settlement (Wane et al., 2017). Market accessibility here solely concerns formal markets. Concerns also raised during some interviews about the evolution of informal markets and their effect on prices paid to herders. Specifically, milk prices paid to farmers could decrease when sold through formal markets, whereas milk price would not change for consumers. On the other hand, deliberate policy and related support to dairy value chain actors will need to be effected to minimize potential for loss of milk quality often associated with an increased role of informal markets in the supply of dairy products (Grace et al., 2020).

Whereas intensifying their use of inputs (such as feeds) could improve herders' livelihoods through higher productivity and production, and increased incomes, the experts and stakeholders interviewed highlighted challenges that herders face, including high production and investment costs. To enable herders in Kenya and Senegal to move to more intensified production, stakeholders identified the need for increased access to credit and other financing mechanisms, as well as access to relevant technical and management training. Interventions that seem to meet these criteria, and which are already being adopted in the study countries include the installation of biogas production units and solar panels, establishment of seed systems for forages and other feeds, creation of serviced mini-farms and use of improved genetics including crossbred cows for dairy production.

4.3. Evolution of Kenya and Senegal within their respective region

During the course of the interviews, stakeholders were also asked about the evolution trend in neighboring countries of Kenya and Senegal and their respective region. Regional trade – in feeds, milk, and live animals – seems to be similar between Kenya and its neighbors in East Africa, and between Senegal and neighboring countries in West Africa. The evolutionary paths of the dairy production systems in both countries may, however, differ.

Even if most countries in East Africa are moving toward zero-grazing, dairy farming systems in Kenya are somewhat different. Zero-grazing systems are currently more evolved in Kenya than in the other countries in the region, with Kenya being ahead in the area of technology adoption. Kenya is also the largest consumer of milk in East Africa with high levels of consumption per person. This high demand stimulates the national dairy sector but also attracts milk imports from neighboring countries. Compared to Kenya, for example, Ethiopia, Tanzania, Uganda, and Rwanda possess low levels of milk production and productivity. However, these countries are also slowly adopting zero-grazing. As they possess larger land size and good climatic conditions for grazing systems, the adoption of zero-grazing is at a slower pace than Kenya. Due to low production costs in Uganda and Tanzania, there is also a possibility that these two countries could become more competitive than Kenya in the future.

Senegal possesses many similarities with other Sahelian countries – especially concerning their agro-climatic and political contexts. However, differences arise in production systems. Even though there is a settlement tendency all over West Africa, Senegal possesses more intensive and semi-intensive systems than other countries in the regional, particularly in the Sahel, where pastoralism remains the dominant system. Moreover Senegal as a coastal country possesses a humid coast and therefore good climatic conditions for dairy farming and agriculture (e.g., Niayes region). Senegal also has high intensification and investment opportunities.

4.4. Potential future opportunities for women and youth

Previous studies have shown that most women in cattle-keeping communities have traditionally taken care of the family's cows, handled feeding and milking activities, and tended to sick animals (ILRI, 2021). Yet most women do not own the cattle, as men are often the owners and managers of the herd. Women in addition usually lack access to essential resources like land, labor, or finance (ILRI, 2021). According to stakeholders, intensification of the sector, if guided to support women, could enable women to be active in dairy farming and/or benefit from milk production increase, through participating in dairy cooperatives that could improve women's incomes and employment (Staal et al., 2020). Women interviewed in the study often noted that they are dependent on their husband for deriving the benefits from dairy farming activities. Against scenarios of increased intensification and settlement, most women indicated the wish to earn their own money to buy a house and to send their children to school while still taking care of the household. Investments in women-led farms could thus benefit their entire households, communities and nation (ILRI, 2022). It has also been found that increased participation of women in decision-making leads to better management of drought risks and decreases vulnerability to climate change (Grillos, 2018; ILRI, 2022).

According to the experts, youth are likely either turn to commercial dairy farms, shift to more productive crops (e.g., money crops such as avocados or horticulture in Kenya), or engage in other businesses. They will likely think commercial rather than traditional as they have less social attachment to tradition and animals than the elders, and will likely participate in training to obtain skills such as harvesting, making silage, etc. Farmer replacement rates might then slowly decline, making farming activities, including dairy, not a priority for younger generations. Many interviewees also thought that farmers' children will have to take over the farm and animals given limited alternatives in the form of employment and education.

4.5. Strength and weaknesses of the method

The contribution of this study lies mainly in the method used to interview a diverse group of dairy sector actors, experts and stakeholders, allowing participants to think about the future and of the links between the consequences and challenges associated with change (Bengston, 2016). However, it stands to reason that the output of the study is limited to the collective judgments of these experts and stakeholders (Bengston, 2016). There might also be potential biases concerning herders interviewed during the study, as in Kenya they were drawn from a pool participating in a dairy innovation platform close to urban and production centers. Hence, these herders are likely more familiarized with the evolution of dairy farming systems and have been targets already of sensitization and training on improved dairy production practices, making them more likely to include intensifying systems in their anticipation of the systems of the future.

The futures wheel remains, however, an appropriated method for this study and for answering the research questions. Indeed, interviews of experts and key stakeholders allow to identify diversified evolution of dairy systems and cover a multitude of potential consequences. The multitude of interviewees allow us to have various point of views about the research questions.

5. Conclusion

As the dairy sector will undergo changes in the future, and will face challenges such as population growth, climate change and insecurity and conflicts, there is a need for a holistic and integrated approach for future thinking, as well as training and sensitization that builds on the initial conceptualization. Changes in dairy production systems can also affect the autonomy of herders, having consequences on livestock and the society: loss of traditions and knowledge, loss of social links between communities, employment crisis, land use competition, biodiversity issues, etc.

The evolution of dairy systems in Kenya and Senegal seems to go toward intensification with potentially fewer but more productive farms. This evolution is driven by various factors such as land fragmentation in Kenya and government incentives, climate change, and new market opportunities in both countries. This evolution of dairy systems will potentially induce various environmental and socio-economic impacts that will affect the resilience of dairy farms to future challenges. In particular, this study highlights several challenges related to climate change: feed scarcity, water shortages, threats to animal well-being and health, and a decrease in milk quality. Both countries are also facing a growth in population. The challenges associated with the population growth are the difficulty to access markets for some herders, land pressure, and high costs of production. Finally, reduced grazing for cattle on agricultural lands through limited or planned movements of animals could increase the resilience of dairy systems to insecurity and conflicts.

Intensification of dairy cattle production could provide opportunities to women and youth. But these changes will also come with several challenges. For example, increases in productivity and income would potentially benefit only herders capable of accessing intensified systems as production and investment costs are high. Issue on herders' turn-over will also be a challenge as young people tend to abandon agriculture, preferring to migrate to cities to study or start other businesses. Even if GHG emissions per animal could be lower due to an improved diet, manure burden and total GHG emissions would increase, due to high input levels of production and input use. Expansion of agricultural and urban areas might also lead to conflict over land and resources.

Encouraging herders to produce more and better, while being sustainable for the future, is needed. This can be accomplished through climate-smart practices, the design and implementation of appropriate dairy and other policies, efficiency of production, and efficient coordination of contributing activities (e.g., animal breeding and agriculture). Finding a balance between dairy production systems and choosing the most appropriate system depending on the agro-climatic context, land availability, socio-economic context, production objectives as well as local constraints and current and future challenges seems essential to maintain balance and hence, resilience.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by ILRI IREC. The patients/participants provided their written informed consent to participate in this study.

Author contributions

LP and DE contributed to the conception, design of the work, discussing the results, and revising the manuscript. LP participated in the data collection and drafting the manuscript. DE contributed to the supervision of the work. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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