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EDITED BY
Tibebu Kassawmar,
Addis Ababa University, Ethiopia

REVIEWED BY
Befekadu Chemere,
Arsi University, Ethiopia
Omarsherif Mohammed Jemal,
Arsi University, Ethiopia
Belete Shenkute Gemeda,
Arsi University, Ethiopia

*CORRESPONDENCE
Alassan Assani Seidou
✉ alassanassani@gmail.com

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The effect of the silvopastoral system on milk production and reproductive performance of dairy cows and its contribution to adaptation to a changing climate in the drylands of Benin (West-Africa)

Alassan Assani Seidou[1]*, Oyéniran Thierry La Fronde Offoumon[1], Sorebou Hilaire Sanni Worogo[1], Isidore Houaga[2], Amoudawenou Koara Yarou[1], Maximilien Azalou[1], Foukpe Zhairath Adambi Boukari[1], Yaya Idrissou[1], Marcel Houinato[3] and Ibrahim Alkoiret Traoré[1]

[1]Laboratoire d'Ecologie, de Santé de Production Animales (LESPA), Faculté d'Agronomie (FA), Université de Parakou (UP), Parakou, Benin, [2]Centre for Tropical Livestock Genetics and Health (CTLGH), The Roslin Institute, University of Edinburgh, Midlothian, United Kingdom, [3]Laboratoire d'Ecologie Appliquée (LEA), Faculté des Sciences Agronomiques (FSA), Université d'Abomey-Calavi (UAC), Cotonou, Benin

Knowledge about dairy cows raised in small-scale agroforestry systems in dryland areas is of paramount importance to inform policy and decision making in the dairy production sector in the current context of climate change. The aim of this study was to evaluate the effect of integrated farming systems on daily milk yield and demographic traits of dairy cows in drylands. A study conducted on 447 dairy cows was carried out to compare their milk yield and demographic parameters under different small-scale agroforestry systems in drylands of Benin: traditional silvopasture (TSS); Improved silvopasture (ISS); Small Integrated Agrosilvopasture (SIAS) and Large Integrated Agrosilvopasture (LIAS). The type of cattle farms had a significant effect ($p < 0.05$) on daily milk yield and demographic traits. Dairy cattle from ISS farms had the highest daily milk yield regardless of the type of dairy cow breed. Demographic traits of herds were significantly ($p < 0.05$) influenced by the type of dairy cattle farms. The proportion of lactating cows was higher ($p < 0.05$) in herds of ISS (48.4%) followed by those in TSS and LIAS (36.1 and 25.0% respectively) while SIAS was the lowest in (14.4%). The pre-weaning mortality rate was higher ($p < 0.05$) in TSS and LIAS farms (18.3 and 17.6 % respectively) compared to SIAS and ISS farms (5.20 and 4.60 % respectively). The fertility rate was higher ($p < 0.05$) in ISS and SIAS farms (92.3 and 89.6% respectively) compared to TSS and LIAS farms (68.3 and 74.2% respectively). The weaning productivity was higher ($p < 0.05$) in ISS and SIAS (88.6 and 85.8 % respectively) than in TSS and LIAS farms (66.1 and 67.6 % respectively). This study showed that ISS farms are characterized by higher milk yield and demographic parameters. ISS systems can then be promoted in smallholder cattle farming to improve milk production and reproductive performance of dairy cows in drylands.

KEYWORDS

dairy cattle, integrated systems, climate change, fodder trees, milk yield

1. Introduction

In Sub-Saharan Africa, livestock farming plays important economic and social role for rural households. The livestock sector contribution to the agricultural Gross Domestic Product of African countries was estimated to be 40% and ranging from 30 to 80% depending on the country (Panel, 2020). However, despite its importance, livestock development faces enormous constraints. In fact, climate change (CC) has a serious impact on dairy cattle farming through the rise of drought and temperature (Idrissou et al., 2019). In general, CC has direct impacts on livestock by influencing animal performance and indirect impacts when it affects pastoral resources (Idrissou et al., 2019). The shortage of fodder in the dry season is of particular concern for pastoralists and agro-pastoralists. Direct effects of CC include temperature-related diseases and deaths, and animal morbidity during extreme weather events (Nardone et al., 2010). In fact, global warming in tropical environments causes secondary problems due to acclimatization: the reduction of food intake, respiratory rate and water consumption in the immediate term and a hormonal disturbance affecting the reactivity of target tissues to environmental stimuli (Lacetera, 2019; Magiri et al., 2020).

To address the adverse effects of CC in drylands of Benin, smallholder dairy farmers have developed feeding strategies integrating tree or shrub species to feed cattle during feed shortage. In fact, ligneous fodder represents an appreciable source of supplementary food used in ruminant feed in the dry season (Koura et al., 2021). In Benin, trees grow sometimes spontaneously in naturally or are planted and generally maintained. The woody fodder species encountered may be exotic or result from domestication and selection by local populations. Access to woody fodder is either by direct browsing of the leaves, twigs and fruits, or after cutting the branches (Houérou, 1980; Franzel et al., 2014). Woody fodder species also play an important role in production systems, particularly for their quality, their seasonal availability and the protection they offer to the herbaceous layer (Paul et al., 2020).

Livestock-tree integration practices have been the subject of several studies in sub-Saharan Africa (Sarr et al., 2013; Koura et al., 2015; Sèwadé et al., 2016). In fact, agroforestry parklands in this region of Africa are agricultural systems combining trees, crops and livestock. These agroforestry parks allow small farmers to reduce vulnerability to the risks of CC (Thorlakson and Neufeldt, 2012). Animals feed on crop residues, leaves, fruits and pods of trees; and contribute to the recycling of nutrients by the deposition of their droppings (Vandermeulen et al., 2018). In Nigeria, Amonum et al. (2009), identified three types of livestock-tree integration systems: Alley farming, Shelterbelts and Home gardens. In southern Benin, the integration of farm animals in oil palm tree plantations has also been identified by Koura et al. (2015) among smallholder farmers of taurine cattle breeds to ensure the cleaning of the plantations by grazing and to fertilize the soil. The presence of tress in dairy cows grazing/feeding systems also reduces the heat stress through provision of a favorable microclimate (Vieira et al., 2020; Skonieski et al., 2021). Thus, silvopastoralism and agrosilvopastoralism constitute an option for grazing-based cattle farming systems that promote soil-animal-fodder-tree interactions, improving the productivity of dairy cows and reducing heat stress (Broom et al., 2013; Zeppetello et al., 2022). Despite the importance of these systems, there is a lack of knowledge about dairy cows raised in agrosilvopostaoral and silvopastoral systems in drylands, thus emphasizing the importance of new studies aiming at elucidating the effect of these integrated farming systems on the productivity of dairy cows in drylands. Therefore, the aim of the study was to evaluate the effects of different small-scale agroforestry systems (agrosilvopastoral and silvopastoral) on daily milk yield and demographic parameters of dairy cows in drylands.

2. Materials and methods

2.1. Study area

The study was conducted on smallholder dairy cattle farms in two ecological regions of Benin (arid Sudanian and semi-arid Sudano-Guinean regions). The arid Sudanian region (7° 30-9° 30 N) is characterized by annual rainfall of 800 to 1,100 mm and a vegetation growing season of 145 days, while the semi-arid Sudano-Guinean region (9° 30-12° N) receives annual rainfall of 1,100–1,300 mm and a vegetation growing season of 200 days. The villages of Founougo, Goumori, Bagou and Sori were selected in the arid Sudanian region and the villages of Ouénou, Sirarou, Kika and Béterou in semi-arid Sudano-Guinean region for twelve-month farm monitoring (Figure 1). Dairy farmers of these regions are known for their practice of adaptation to CC based on the integration of animals with trees or shrubs. The herds of farmers who participated in this study were those who had at least two cows at the early lactation and who had participated in the previous study initiated by Assani et al. (2023). The previous study identified four types of smallholder dairy cattle farms namely traditional silvopasture (TSS); Improved Silvopasture (ISS); Small-scale Agrosilvopasture (SIAS) and Large Integrated Agrosilvopasture (LIAS). The characteristics of the four identified type of farmers in dryland areas of Benin are presented in Supplementary Table S1 (Assani et al., 2023). In TSS, farmers had an average of 26 Tropical Livestock Unit (TLU). They did not own land and they used trees and shrubs from the rangelands. They used native trees (*Khaya senegalensis, Afzelia Africana and Pterocarpus erinaceus*) as feed supplements for dairy cattle in natural rangelands during dry season (Figure 2). In ISS, farmers had a mean of 11 TLU per herd. They owned land (4.2 ha) and associated livestock, forage plants (*Panicum maximun C1, Pennisetum purperium and Brachiaria ruziziensis*) and trees/shrubs plantation (*Khaya senegalensis, Afzelia Africana, Pterocarpus erinaceus, Cajanus cajan, Gliricidia sepium, Acacia auriculiformis, Leucaena leucocephala, Stylosanthes guianensis Mucuna pruriens*) in pasturelands (Figure 3). Fodder trees are utilized throughout the year. The SIAS farmers adopted the integration of agriculture, ruminant livestock and trees. They owned a small area of land (3.0 ha) and low size of herd (6 TLU). SIAS farmers used native trees/shrubs fodder (*Cajanus cajan, Acacia auriculiformis, Leucaena leucocephala, Stylosanthes guianensis, Mucuna pruriens*) and crop residues (Maize stover, rice straw, sorghum straw and Cowpea haulms) as feed supplements for dairy cattle during dry season (Figure 4). In LIAS, farmers tilled large portions of land (9.3

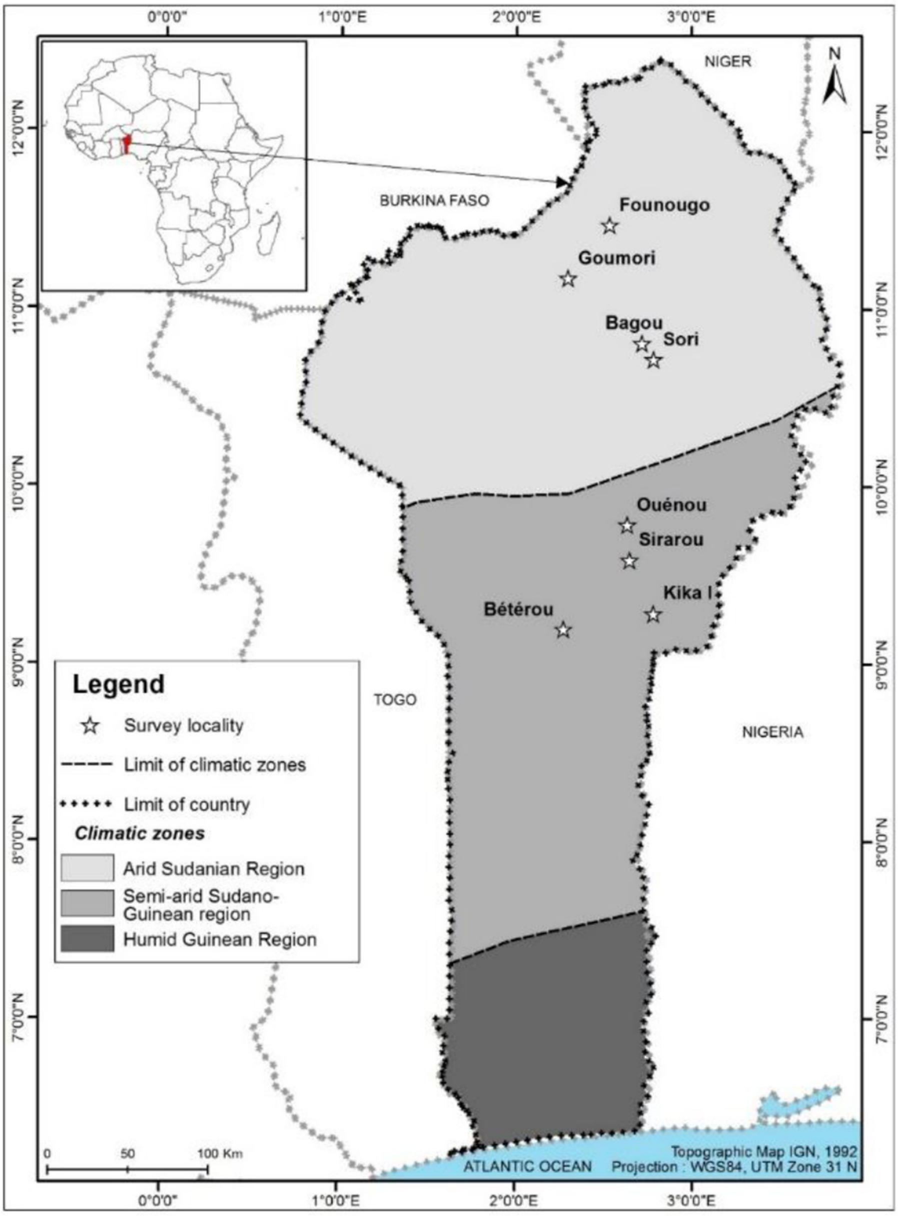

FIGURE 1
Map of Benin showing the locations investigated in dryland zones of Benin.

ha) and had a mean of 18 TLU. Leguminous fodder trees (*Khaya senegalensis, Afzelia Africana, Pterocarpus erinaceus, Cajanus cajan, Acacia auriculiformis, Leucaena leucocephala, Stylosanthes guianensis, Mucuna pruriens*) and crop residues (Maize stover, rice straw, sorghum straw and Cowpea haulms) are utilized to feed ruminants during the dry season (Figure 5).

2.2. Milk yield data collection

Monitoring of ten (10) farms per type of farming system identified in dryland areas of Benin i.e. 40 farms was carried out from March 2021 to January 2022. Daily milk yield data were collected from 113, 103, 102 and 129 cows respectively on the TSS, ISS, SIAS and LIAS farms, giving a total of 447 dairy cows. On each farm, dairy cows were selected according to breed (Borgou, Crossbreed, Gudali and White Fulani) and lactation rank (lactations 1, 2, 3, 4, 5 and more). Table 1 gives more details on the number of cows monitored during this study in each type of farming system according to breed and lactation number. The chosen cows were given an identification number or name to facilitate monitoring. All animals lost (mortality, sale, etc.) during monitoring were not counted in this number. Milk was collected once a week during 305 days of lactation. Hand milking is carried

FIGURE 2
Traditional silvopastoral system on rangelands in dryland areas of Benin.

FIGURE 3
Improved silvopastoral of Khaya senegalensis and forage plants in dryland areas of Benin.

FIGURE 4
Agrosivopastoral systems- integration of trees (*Khaya senegalensis*), crops (maize) and animals in dryland areas of Benin.

out twice a day twice a day, in the morning at 7 a.m. before leaving for pasture, and in the evening at 6 p.m. when return from pasture. Once the milk had been collected, the quantity was measured on a weighing balance and recorded on the data collection sheet. Daily milk yield is the sum of the morning and evening milk collections.

2.3. Demographic parameters data collection

The demographic parameters in TSS, ISS, SIAS and LIAS farming systems are studied on the basis of information collected on the movement of cattle on the farm during the year (initial cattle numbers, birth, purchase, mortality, sale, donation, exchange, slaughter and final cattle numbers), farm cattle composition (female calves, heifers, lactating cows, dry cows, male calves, subadult bulls and reproductive bulls), reproduction parameters (advanced gestation, abortion and calving) and viability-mortality parameters (stillbirths, age-specific mortality and live offspring at weaning). The 40 farms monitored for milk production were also used to collect one-year demographic data (from March 2021 to February 2022). Farm monitoring for demographic parameters data collection was done once a week. During each visit, all events concerning demographics parameters (number of cows present, number of cows in lactation, number of births, number of abortions, number of dead animals, number of animal entries and exits) were recorded using monitoring sheets. The animals were identified beforehand

FIGURE 5
Khaya senegalensis trees around fields for dairy cattle feed in dryland areas of Benin.

TABLE 1 Number of dairy cows monitored according to breed and lactation rank in each farming system identified in dryland areas of Benin.

	TSS	ISS	SIAS	LIAS	Total
Farm	10	10	10	10	40
Total cow	113	103	102	129	447
Cow breed					
Borgou	25	26	31	43	125
Crossbreed	21	23	17	31	92
Gudali	26	42	15	27	110
White Fulani	41	12	39	28	120
Lactation rank					
Lactation 1	23	26	25	40	114
Lactation 2	31	28	31	28	118
Lactation 3-4	35	34	24	33	126
Lactation 5 and more	24	15	22	28	89

TSS, Traditional silvopastoral systems; ISS, Improved silvopastoral systems; SIAS, Small Integrated agrosilvopastoral systems; LIAS, Large Integrated agrosilvopastoral systems.

taking into account the name of the animal or identification number, the breed and the date of birth. Demographic parameters were calculated using the formula proposed by Lhoste (2001):

Reproductive rates

Rate of abortions = Number of abortions ∗ 100/Number of cows

Calving rate = Number of calving ∗ 100/Number of cows

Fertility rate = Number of alive born calves ∗ 100/Number of cows

Mortality rates

Stillbirth rate = Number of stillborn calves ∗ 100/Number of calves born

Pre-weaning mortality rate = Number of pre-weaning dead calves ∗ 100/number of calves born alive

Global mortality rate = Number of dead animals ∗ 100/Average herd size

Numerical weaning productivity = number of alive weaned calves ∗ 100/Number of cows

Management rates

Offtake rate (OR) = Number of exploited animals ∗ 100/Average size of the cattle herd

Intake rate (IR) = Number of imported animals ∗ 100/Average size of the cattle herd

Net offtake rate = OR – IR.

2.4. Chemical analyses

To know more about the composition of the most fodder trees/shrubs, forage plants and crop residues used as feed supplements for dairy cattle in each farming system during dry season, the feed samples were collected to determine the chemical composition. Leaves samples were collected from several branches in the canopy. The samples (500 g) for each forage and crop residues were oven-dried at a temperature of 60°C for 72 h for dry matter, then ground and sieved. Analysis was carried out using the AOAC method (AOAC, 1990). The samples were analyzed in triplicate in accordance with approved methods (AOAC, 1990) to determine Dry matter (DM), ash, crude protein (CP) and ether extract (EE) (AOAC procedure 2001.12, 930.05, 978.04 and 920.39 for DM, ash, CP and EE, respectively). The fiber contents (NDF and ADF) were analyzed using the Velp Scientifica^{TM} FIWE 3 Fiber Analyzer according to Van Soest et al. (1991) methods. *In vitro* evaluation of DM digestibility was based on the two-step technique of Tilley and Terry (1963).

2.5. Data analysis

To assess the effects of different small-scale agroforestry systems (TSS, ISS, SIAS and LIAS) on daily milk yield, we used the General Linear Model (GLM) in R.4.2.1 software (R Core Team Development, 2022). The model used was:

$$Yijk = \mu + Si + Pj + Rk + Si{*}Pj + Si{*}Rk + Eijk$$

Where, Yijk = Response variable (Milk yield);

μ = overall mean;

Si = fixed effect of the silvopastoral system (4 classes; TS = 1, 2, 3, 4);

Pj = fixed effect of season (P = dry season, wet season; 2 classes) or fixed effect of lactation number of cows (P = L1, L2, L3-4, L ≥ 5; 4 classes);

TABLE 2 Chemical composition and nutritional value of tree/shrub leaves, forage plants and crop residues used to feed dairy cows in each farming system identified in the drylands of Benin.

Species	DM	Ash	CP	NDF	ADF	EE	DMd %
		% DM					
Khaya senegalensis	92.62^{a}	8.92^{c}	13.15^{c}	51.69^{d}	33.54^{cd}	2.55^{c}	59.10^{a}
Afzelia africana	94.10^{a}	6.58^{d}	16.14^{b}	68.45^{b}	65.32^{a}	3.24^{b}	52.40^{a}
Pterocarpus erinaceus	90.20^{a}	7.86^{cd}	14.86^{b}	54.70^{c}	37.25^{c}	4.62^{a}	48.62^{c}
Cajanus cajan	93.56^{a}	7.52^{cd}	23.80^{a}	49.21^{de}	31.40^{d}	4.75^{a}	56.12^{a}
Gliricidia sepium	89.20^{b}	10.01^{b}	18.21^{a}	39.46^{ef}	26.52^{e}	4.86^{a}	51.88^{b}
Acacia auriculiformis	90.21^{a}	7.62^{cd}	14.33^{c}	46.82^{de}	34.65^{d}	3.52^{b}	48.47^{c}
Leucaena leucocephala	92.10^{a}	6.82^{cd}	22.61^{a}	58.67^{c}	41.10^{b}	3.04^{b}	49.84^{c}
Panicum maximum C_1	91.10^{a}	5.84^{de}	8.89^{d}	68.20^{b}	38.42^{cd}	2.34^{c}	42.32^{d}
Pennisetum purperium	91.30^{a}	8.98^{c}	8.75^{d}	70.02^{a}	42.06^{b}	2.85^{c}	55.20^{a}
Brachiaria ruziziensis	89.20^{ab}	8.42^{c}	7.98^{d}	65.13^{b}	46.21^{b}	3.01^{b}	53.80^{a}
Stylosanthes guianensis	90.10^{a}	8.65^{c}	15.20^{b}	51.30^{d}	37.25^{cd}	2.65^{c}	57.45^{a}
Mucuna pruriens	92.82^{a}	6.58^{cd}	18.58^{a}	66.40^{b}	36.50^{c}	1.82^{cd}	52.64^{b}
Maize stover	93.10^{a}	7.20^{cd}	3.50^{e}	74.20^{a}	49.80^{ab}	1.10^{cd}	49.20^{b}
Rice straw	92.80^{a}	14.2^{a}	4.40^{e}	64.70^{b}	45.10^{ab}	1.20^{cd}	48.52^{c}
Sorghum straw	91.40^{a}	7.10^{cd}	2.80^{e}	74.60^{a}	43.30^{b}	0.80^{d}	43.51^{d}
Cowpea haulms	94.30^{a}	7.43^{cd}	11.60^{c}	47.85^{e}	32.46^{cd}	1.86^{cd}	63.20^{a}

[a,b,c,d,e,f]Within a column, values with different superscript letters are significantly different at $p \leq 0.05$.
DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; EE, ether extract; DMd, dry matter degradability.

Rk = fixed effect of cow breed (R = Borgou, Crossbreed, Gudali, White Fulani; 4 classes);

Si∗Pj = interaction of the silvopastoral system and the season;

Si∗Rk = interaction of the silvopastoral system and the cow breed;

Eijk = error.

Average milk yields for each type of farming system were compared using the least significant difference (LSD) test with *agricolae* package (de Mendiburu, 2021) to see if there was a significant difference at the 5% level.

To understand how different small-scale agroforestry systems impact the demographic parameters, we compared the following variables between farming system (TSS, ISS, SIAS and LIAS): reproductive rates (rate of abortions, calving rate and fertility rate), mortality rates (stillbirth rate, pre-weaning mortality rate, global mortality rate and numerical weaning productivity) and management rates (offtake rate, intake rate and net offtake rate). As the data for each of these variables were not normally distributed, the Kruskal-Wallis test was used for these analyses.

3. Results

3.1. Chemical composition and nutritional value of tree/shrub leaves, forage plants, and crop residues used as feed supplements for dairy cattle

Table 2 shows the chemical composition and nutritional value of tree/shrub leaves, forage plants and crop residues used as feed supplements for dairy cattle in dryland areas of Benin. The crude protein values of tree/shrub leaves, forage plants and crop residues range from 2.80% (Sorghum straw) to 23.80% (*C. cajan*). Crude protein values for tree/shrub leaves, forage legumes (*S. guianensis* and *M. pruriens*) and Cowpea haulms are above 10%. The lowest and highest NDF values were obtained in *G. sepium* (39.46%) and Sorghum straw (74.60%), respectively. Dry matter digestibility values ranged from 42.32 to 63.20%, respectively.

3.2. Milk yield

3.2.1. Milk yield of cows according to different cow breeds, seasons of the years and type of farm

The type of integrated cattle farming had a significant effect ($p < 0.01$) on milk yield (Tables 3, 4). Regardless of the cattle breed, cows from farms practicing ISS produced more daily milk (2.2, 4.1, 2.6, 2.4 kg/day/cow for Borgou, Gudali, White Fulani and crossbred cow, respectively) ($p < 0.05$), followed by cows from farms practicing LIAS (1.4, 3.1, 1.4, 1.6 kg/day/cow for Borgou, Gudali, White Fulani and crossbred cow, respectively) and finally SIAS (1.0, 1.8, 1.2, 1.1 kg/day/cow for Borgou, Gudali, White Fulani and crossbred cow, respectively) and TSS (0.9, 1.5, 1.1, 1.0 kg/day/cow for Borgou, Gudali, White Fulani and crossbred cow, respectively) whose milk yield was identical. Compared with other systems, ISS dairy cattle show better daily milk yields during the dry season (Table 4).

3.2.2. Milk yield of cows according to lactation rank and type of farm

Figure 6 compares the milk yield of cows according to lactation rank within each practice type of integration of the tree adopted by the farmer to cope with CC. Regardless of the integration of pasture in the trees for livestock feeding adopted by the farmer to cope with CC, the effect of number of lactations on milk production was significant ($p < 0.05$). The milk yield in young cows (Lactation 1 and 2) were low ($p < 0.05$). While it was higher ($p < 0.05$) in cows whose number of lactations was between 3 and 4, followed by those with 5 or more lactations.

TABLE 3 Effects of silvopastoral system, cow breed and seasons of the years on milk production (kg/day/cow).

Sources of variation	Daily milk yield	*p-value*
Silvopastoral system		*0.001*
Traditional silvopastoral systems (TSS)	1.0 ± 0.18^{d}	
Improved silvopastoral systems (ISS)	$2,8 \pm 0.63^{a}$	
SIAS = Small Integrated agrosilvopastoral systems (SIAS)	$1,2 \pm 0.26^{c}$	
Large Integrated agrosilvopastoral systems (LIAS)	$1,8 \pm 0.61^{b}$	
Cow breed		*0.001*
Borgou	1.1 ± 0.42^{c}	
Gudali	$2,6 \pm 0.95^{a}$	
White Fulani	$1,6 \pm 0.50^{b}$	
Crossbreed	$1,5 \pm 0.47^{b}$	
Season		*0.002*
Dry season	1.95 ± 0.92^{b}	
Wet season	$2,95 \pm 0.25^{a}$	

[a,b,c,d]Means with different superscript letters on the same column differ significantly ($p < 0.05$). *p*-value means the value of probability.

3.2.3. Milk yield per month of lactation according to type of farm

Regardless of breed, milk yield per month of lactation was significantly higher in the ISS cows than in the others (TSS, LIAS and SIAS) (Figure 7). The highest daily milk production was observed in the second month of lactation and the third month of lactation respectively in taurine and crossbred cows (Borgou and crossbreed) and zebu cows (Gudali and White Fulani). The lowest daily milk yield was obtained in the eleventh month regardless of the type of agroforestry systems practiced.

3.3. Demographic features

3.3.1. Herd structure

Herd structure of cattle according to type of farms integrated trees in cattle farming identified in drylands of Benin is presented in the Table 5. The type of farms statistically significant effect ($p < 0.05$) on the different cattle categories (Table 5). With regard to females, the proportion of lactating cows, total female and dry cows were higher ($p < 0.05$) in ISS herds compared with TSS, SIAS and LIAS. However, the proportion of heifers in SIAS herds was lower ($p < 0.05$) than in TSS, ISS and LIAS herds (Table 5). The proportions of female calves were similar in the four small-scale agroforestry systems.

When considering males, the type of agroforestry system had also a significant effect ($p < 0.05$) on male proportions. The reproductive bulls' proportions and total males in SIAS herds was higher ($p < 0.05$) than those of TSS, ISS and LIAS. The proportions of male calves were similar in the 4 types of agroforestry systems. The average herd size of TSS was 5, 2.6 and 1.8 times greater ($p < 0.05$) than that of SIAS, ISS and LIAS cattle herds, respectively.

3.3.2. Demographic parameters

Cattle herds in ISS and SIAS had the best ($p < 0.05$) demographic parameters (Table 6), characterized by high fertility, parturition and weaning productivity rates ($p < 0.05$) and low ($p < 0.05$) abortion and mortality rates (pre-weaning, stillbirth and overall mortality rates).

TABLE 4 Effects of interaction of silvopastoral system and cow breed or seasons of the years on milk production (kg/day/cow) across the type of farm.

	TSS	ISS	SIAS	LIAS	*p-value*
Silvopastoral system*breed					
Borgou	0.9 ± 0.18^{c}	2.2 ± 0.16^{a}	1.0 ± 0.15^{c}	1.4 ± 0.17^{b}	*0.02*
Gudali	1.5 ± 0.21^{d}	4.1 ± 0.22^{a}	1.8 ± 0.22^{c}	3.1 ± 0.24^{b}	*0.001*
White Fulani	1.1 ± 0.16^{c}	2.6 ± 0.24^{a}	1.2 ± 0.23^{c}	1.4 ± 0.18^{b}	*0.002*
Crossbreed	1.0 ± 0.20^{c}	2.4 ± 0.18^{a}	1.1 ± 0.26^{c}	1.6 ± 0.19^{b}	*0.02*
Silvopastoral system*season					
Dry season	0.9 ± 0.23^{d}	3.8 ± 0.23^{a}	1.2 ± 0.12^{c}	1.9 ± 0.21^{b}	*0.001*
Wet season	1.3 ± 0.16^{d}	5.2 ± 0.21^{a}	2.1 ± 0.16^{c}	3.2 ± 0.26^{b}	*0.001*

[a,b,c,d]Means with different superscript letters on the same row differ significantly ($p < 0.05$). TSS, Traditional silvopastoral systems; ISS, Improved silvopastoral systems; SIAS, Small Integrated agrosilvopastoral systems; LIAS, Large Integrated agrosilvopastoral systems. *p*-value means the value of probability.

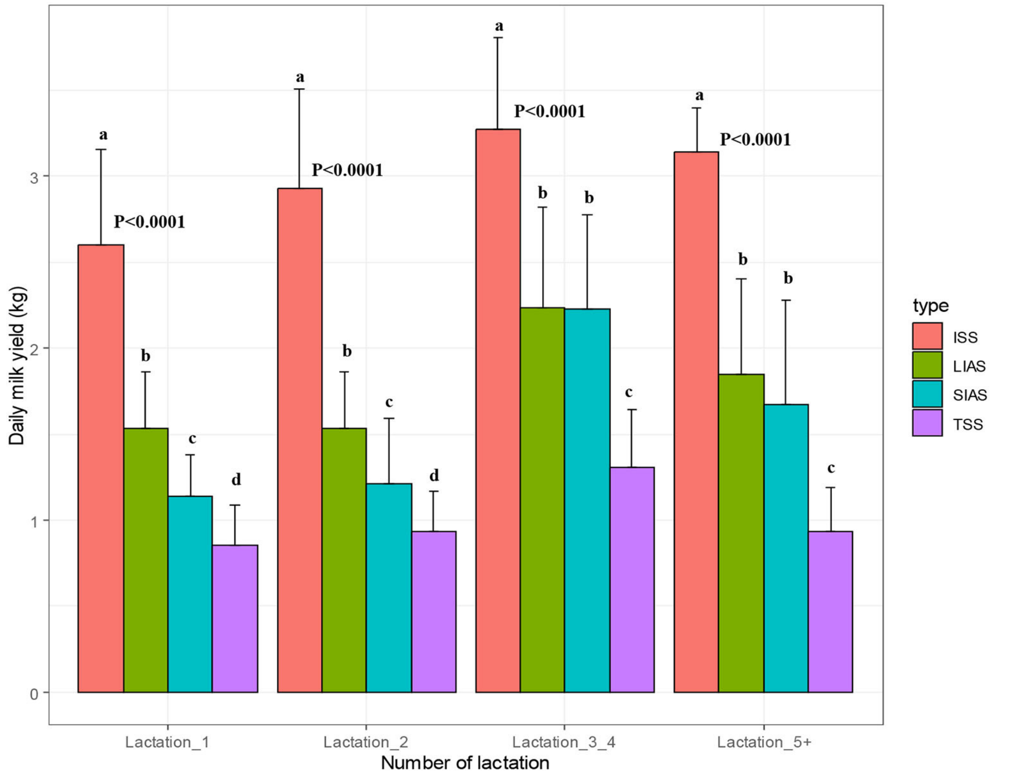

FIGURE 6
Milk production (kg/day/cow) of cattle cows according to lactation rank and type of farm. Barplots with different superscript letters differ significantly ($p < 0.05$). TSS, Traditional silvopastoral systems; ISS, Improved silvopastoral systems; SIAS, Small Integrated agrosilvopastoral systems; LIAS, Large Integrated agrosilvopastoral systems.

TABLE 5 Herd structure (%) by the type of farms with integration of trees in cattle farming identified in drylands of Benin.

Cattle categories	TSS	ISS	SIAS	LIAS	*p-value*
Female (%)					
Female calves	13.4[a]	10.2[a]	10.0[a]	11.2[a]	0.086
Heifers	11.2[a]	10.6[a]	7.20[b]	11.4[a]	0.001
Lactating cows	36.1[b]	48.4[a]	14.4[c]	25.0[b]	0.0001
Dry cows	10.1[b]	12.0[a]	6.20[c]	11.2[b]	0.01
Total Female	70.8[b]	81.2[a]	37.8[c]	58.8[b]	0.0019
Male (%)					
Male calves	8.20[a]	7.50[a]	9.70[a]	7.30[a]	0.110
Subadult bulls	9.60[b]	2.10[c]	18.3[a]	8.70[b]	0.0013
Reproductive bulls	11.4[c]	9.20[c]	34.2[a]	26.2[b]	0.0020
Total Male	29.2[c]	18.8[d]	62.2[a]	42.2[b]	0.0018
Herd size (heads)	68[a]	26[c]	13[d]	38[b]	0.001

[a,b,c,d]Frequences with different superscript letters on the same row differ significantly ($p < 0.05$). TSS, Traditional silvopastoral systems; ISS, Improved silvopastoral systems; SIAS, Small Integrated agrosilvopastoral systems; LIAS, Large Integrated agrosilvopastoral systems.

The offtake rate was higher ($p < 0.05$) in ISS herds. The intake rate in ISS and SIAS were higher ($p < 0.05$) than those of TSS and LIAS farms. The net offtake rate was positive in the TSS, ISS and LIAS herds and high ($p < 0.05$) than those of SIAS which was negative.

4. Discussion

4.1. Milk yield

The daily milk yield was higher in cows from farms adopting ISS compared to those practicing LIAS, SIAS and TSS. In fact, the animals from ISS farms benefit from a supplementation of woody fodder at any time of the year, which allows them to produce more milk. The effects of fodder trees or shrubs in improving milk production have been demonstrated in several studies (Mangesho et al., 2017; Salifou et al., 2017; Agani et al., 2022). Certain trees and shrubs are lactogenic in local dairy cows. In Benin, traditional cattle farmers use roots, leaves, bark, fruits and seeds to stimulate milk production in cows (Salifou et al., 2017). In northern Benin, certain woody fodder such as *Afzelia Africana, Khaya senegalensis and Pterocarpus erinaceus* are prized but *Afzelia africana* is the most sought after because it would increase milk production (Houehanou et al., 2008). This result corroborates those of Ibrahim et al. (2005) who reported that dairy cows fed on shrub forage produced an impressive daily milk yield without the use of supplemental concentrates. Furthermore, a study of Cohen-Zinder et al. (2016) on lactating cows revealed that milk production was improved by 2% if cows were fed on *Moringa oleifera* silage instead

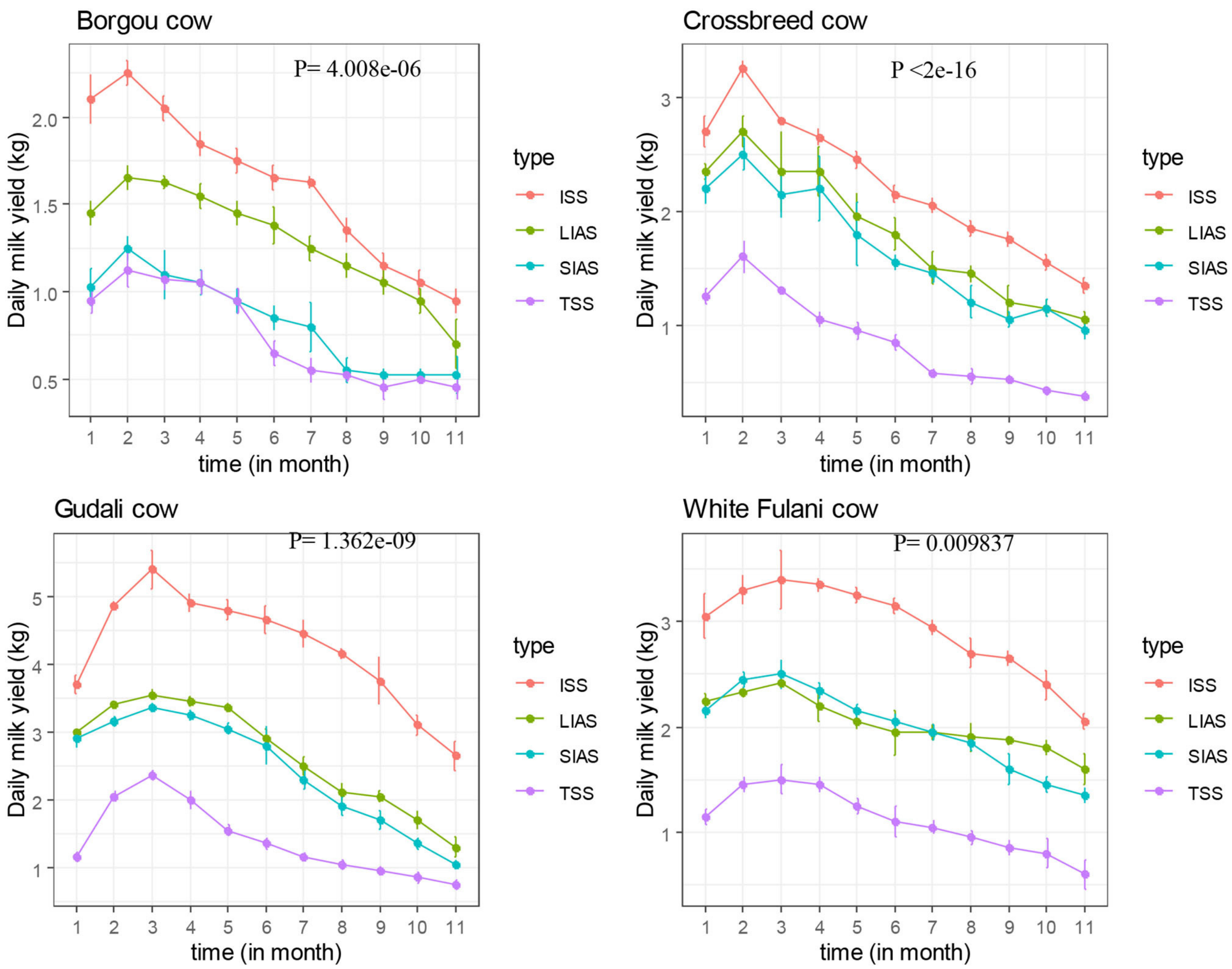

FIGURE 7
Evolution of milk production per month of lactation according to type of farm for each cattle breed in drylands of Benin. TSS, Traditional silvopastoral systems; ISS, Improved silvopastoral systems; SIAS, Small Integrated agrosilvopastoral systems; LIAS, Large Integrated agrosilvopastoral systems.

of wheat silage. Zhang et al. (2018) showed that the milk production of cows increased by 5% supplementing the diet with 6% *Moringa oleifera* in lactating multiparous Holstein dairy cows. *Leucaena leucocephala* supplementation also improved animal performance by increasing their proportion in cattle diet (Stifkens et al., 2022). Fodder trees are fodder resources for animals in dry periods. Their protein and vitamin content makes them the main fodder resource for livestock in the dry season to meet the maintenance and production needs of animals (Njidda and Ikhimioya, 2010; Mebirouk-Boudechiche et al., 2014; Sidi Imorou et al., 2016). In the Agrosilvopastoral territory of Nétéboulou in Senegal, the crude protein content of the leaves of *Pterocarpus erinaceus* can reach 15 to 20% of the dry matter (Mbaye et al., 2003). Trees and shrubs could then be used as alternative sources of protein for ruminants, which can lead to higher milk yield in native cows (Alam et al., 2009).

The highest daily milk yield obtained in the ISS, LIAS, SIAS farms compared to TSS cattle farm could also be due to the importance of woody fodder in the regulation of the body temperature of dairy cows. In fact, the presence of trees in the pastures can reduce heat stress, with positive effects on food consumption and milk production (de Abreu, 2002).

The amount of milk obtained from each local cattle bred based on tree integration practices in this study is greater than that obtained by Worogo et al. (2021) in traditional dairy cattle in northern Benin. This could be explained by the farming method practiced. In fact, the cattle farmers included in their study did not feed their cows with leaves from trees on their farm. Moreover, the quantity of milk produced by local cows in the TSS systems are similar to those reported by Kassa et al. (2016). This could be explained by the fact that the cows monitored by these authors practice extensive farming with seasonal exploitation of trees and shrubs on natural rangelands. Milk production increases gradually from the 1st to the 4th lactation where it reaches the peak and drops gradually from the 5th lactation. The development of mammary tissues during the reproductive life of the cow could explain this increase in milk according to the rank of birth (Rivière, 1991). From the 5th lactation, the milk production of dairy cows decreases, this

TABLE 6 Demographic parameters by the type of farms with integration of trees in cattle farming identified in drylands of Benin.

Parameters, %	TSS	ISS	SIAS	LIAS	*p-value*
Reproductive parameters:					
Rate of abortions	7.80[a]	1.80[b]	2.10[b]	6.20[a]	0.02
Calving rate	72.6[b]	94.2[a]	87.6[a]	77.6[b]	0.001
Fertility rate	68.3[b]	92.3[a]	89.6[a]	74.2[b]	0.001
Mortality parameters:					
Stillbirth rate	8.40[a]	2.10[b]	2.60[b]	6.10[a]	0.002
Pre-weaning mortality rate	18.3[a]	4.60[b]	5.20[b]	17.6[a]	0.001
Global mortality rate	5.80[a]	2.30[b]	2.40[b]	5.20[a]	0.004
Numerical weaning productivity	66.1[b]	88.6[a]	85.8[a]	67.6[b]	0.001
Management rates:					
Offtake rate	3.30[b]	8.80[a]	2.80[b]	3.80[b]	0.0001
Intake rate	1.20[b]	2.50[a]	3.60[a]	1.30[b]	0.01
Net offtake rate	2.10[b]	6.30[a]	−0.80[c]	2.50[b]	0.002

[a,b,c,d]Frequences with different superscript letters on the same row differ significantly ($p < 0.05$). TSS, Traditional silvopastoral systems; ISS, Improved silvopastoral systems; SIAS, Small Integrated agrosilvopastoral systems; LIAS, Large Integrated agrosilvopastoral systems.

could be due to the aging of the mammary tissues (Kassa et al., 2016). The parity number is therefore a physiological factor in the variation of milk production (Rivière, 1991). Several authors also reported the effect of parity number on cow milk production in Benin (Alkoiret et al., 2010; Assani et al., 2015; Worogo et al., 2021).

4.2. Herd structure

Monitoring the structure of a dairy herd provides important insights into herd profitability and farm dynamics (Muller, 2018). This study showed that herd structure varied with integrated production systems. The high proportion of lactating cows and dry cows in ISS herds is related to the main production objective of this farm (Assani et al., 2023). In fact, ISS farmers specialize in dairy production and direct their production toward the market or semi-dairies. This could be explained by the large number of dairy cows present on this type of farm. This herd structure, where the proportion of lactating cows is around 50%, confirms the specialization of herds in dairy production. Milk, in fact, represents an essential constituent of the food ration of human populations in Benin and provides a regular income to breeders of this type (Ogodja et al., 1991). Similar results were observed by Akpa et al. (2012) who showed that it is for milk production purpose that farmers raise a greater proportion of cows.

The largest proportions of adult males were found in the LIAS and SIAS types compared to the other types. This could be explained by the fact that the animals of these types are kept by agro-pastoralists and have a high number of draft oxen. Worogo et al. (2021) came up with similar observation where Borgou cattle were widely used for animal-drawn cultivation in northern Benin by agro-pastoralists. The composition of TSS cattle herds is on average 29.2% males and 70.8% females. This result is similar to those obtained in traditional cattle farms in Benin (Dehoux and Hounsou-Ve, 1993; Alkoiret et al., 2010; Assani et al., 2015; Worogo et al., 2021). According to these authors, the herds consist of one male for three females in traditional farms.

4.3. Demographic features

The superiority of the reproduction parameters of the ISS herds compared to the other types could be explained by the improvement of practices for the integration of livestock with the installation of fodder plots and the planting of fodder trees and shrubs adopted by farmers of this type. In fact, the presence of plantations of fodder trees and shrubs in livestock farms allows farmers to cope with feed shortages during the dry season, which improves cow productivity (abortion rate, parturition rate and fertility rate). Feeding influences all stages and components of reproduction in females (puberty, cyclicity and heat, mating, gestation, drying off, postpartum, and lactation) and males (puberty, libido, sperm and spermogram) (Meyer, 2009; Martins et al., 2021). In the Sahel, Diawara et al. (2017) observed a deterioration in reproductive performance in less mobile animals that do not receive enough feed supplements. ISS farms were more characterized by high fertility (92.3%), parturition (94%) and lowest abortion rate (1.8%). The results obtained in this type of dairy farming are similar to those obtained by Worogo et al. (2021) at the Okpara breeding farm. On the other hand, Dehoux and Hounsou-Ve (1993) obtained similar values of the fertility rate (65.4%) and the abortion rate (4%) in northern Benin within traditional beef herds corresponding to the performance of TSS.

The mortality parameters were also low in the ISS and SIAS type herds, this could be linked to the improvement of farming practices in this type. The study conducted at the Okpara breeding farm by Youssao et al. (2000) showed the reduction of mortality of the young animals to 2.5% by a program of regrouping of the births, a good feed and a good weaning. On the other hand, another study carried out in South Africa showed that most deaths are often caused by diseases (50%) and drought (34%) (Motiang and Webb, 2016). This is also the observation made in this study where the highest mortalities were obtained in the TSS and LIAS farms. This could be explained by the fact that there is a weak integration of the tree in this farming system, limited only to the exploitation of the trees natural range already very degraded in drylands of Benin which could cause a feeding imbalance and heat stress. In fact, heat stress increases respiration and mortality, reduces fertility, alters animal behavior and suppresses the immune and endocrine systems, thereby increasing the susceptibility of animals to certain diseases (Thornton et al., 2022). Furthermore, the mortality rate results obtained in this study are better than those found by others (Alkoiret et al., 2010; Assani et al., 2015; Worogo et al., 2021) in traditional cattle farming where the mortality rate youth ranged from 14 to 33%. These authors also confirmed that mortality rates are higher in traditional farming due to undernourishment and the absence or insufficiency of sanitary and medical prophylaxis. The main causes of mortality are almost the same for all farming systems in the study area and are of viral, bacterial, parasitic, feed or traumatic origin. Management rates vary depending on the type of farming systems. The superiority of the net offtake rate of the ISS herds would be linked to the low mortality rates recorded and to their objective of producing milk so that the several males are sold. Mortality being higher in the TSS and LIAS type, these herds have fewer animals to sell. The SIAS type consists of small herds, selling very few animals to achieve the goal of increasing numbers. They are also agro-pastoralists, they buy more young male cattle, which could explain the very high intake rate in this type. The numerical exploitation of cattle herds in drylands of Benin is consistent with that of traditional herds (Assani et al., 2015). According to these authors, the numerical exploitation rate of sedentary herds varied between 2 and 9%. Numerical exploitation also varies according to livestock categories: males are often sold very young in ISS farms, while females are kept for a long time for breeding in TSS and LIAS farms (Alkoiret et al., 2010). The low growth rates of herds in TSS and LIAS could be explained by the poor reproduction and mortality parameters associated with high numerical exploitation recorded in these herds. ISS-type herds that had the highest reproductive and exploitation parameters and the lowest mortality parameters had the highest numerical yield. In South Africa, some authors (Scholtz and Bester, 2010; Meissner et al., 2014) also reported that the high herd mortality of small-scale livestock keepers is the main cause of low productivity and low animal off-take rates.

4.4. Policy implications for sustainable animal production

Improved silvopastoral is adaptive to drought because foliage production from trees and shrubs is less affected by varying precipitation, temperature and other climatic variables thus enabling farmers to sustain livestock production even during extreme weather conditions (Papanastasis et al., 2008). The results show that dairy farming can be practiced in the drylands of Benin even during the dry season. The Benin government being aware of the great threat that climate change poses to the country's sustainable development, has drawn up National Action Programs for Adaptation to Climate Change (NAPA). Agrosilvopastoral and silvopastoral practices is one of the priority actions in this context, equally contributing to the adaptation and mitigation of climate change, as well as to food security. It is then necessary to:

- take into account agrosilvopastoral and silvopastoral systems and their potential in any development of national, sectoral and local policies on climate change;
- facilitate access to rural land for livestock smallholder farmers,
- promote tree plantations on small-scale pastoral farms in drylands;
- promote traditional and technical innovations adapted to each integrated animal production system identified;
- delineate animal corridors, including restoration of degraded rangeland with fodder trees;
- rehabilitate good management practices for silvopastoral resources, including capacity building for stakeholders (farmers, technicians, agricultural institutions, NGOs, etc.) and
- valorize indigenous knowledge of adaptation of livestock smallholder farmers to climate change.

5. Conclusions

The findings of this study showed that the silvopastoral system (ISS) increased milk production and improved demography parameters in dairy cattle. This type of feeding strategy can be promoted on dairy farms in the drylands of Benin. The adoption of this agroforestry technology is very linked to access to land, we recommend that policy-makers create the conditions necessary (facilitate access to rural land for livestock smallholder farmers, promote tree plantations on small-scale pastoral farms in drylands, training sessions on good practices of silvopastoral system, etc.) for the large-scale adoption of this agroforestry technology on cattle farms, in order to promote sustainable livestock production. Further studies are needed to assess the carbon footprint and sequestration capacity of each feeding strategy to select sustainable adaptation strategies to climate change in sub-Saharan Africa.

Data availability statement

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

Author contributions

AA, IH, and SS: conceptualization, methodology, validation, and investigation. AA, IH, SS, AK, and MA: writing—original draft preparation. AA, IH, SS, MA, MH, IA, OO, and YI: writing—review and editing. AA and IA: supervision, project administration, and funding acquisition. OO: supervision and funding acquisition. YI: supervision. All authors read and approved the final manuscript.

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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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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1236581/full#supplementary-material

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