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Milk quality and production under climate change uncertainty: case of the Algerian cattle breed

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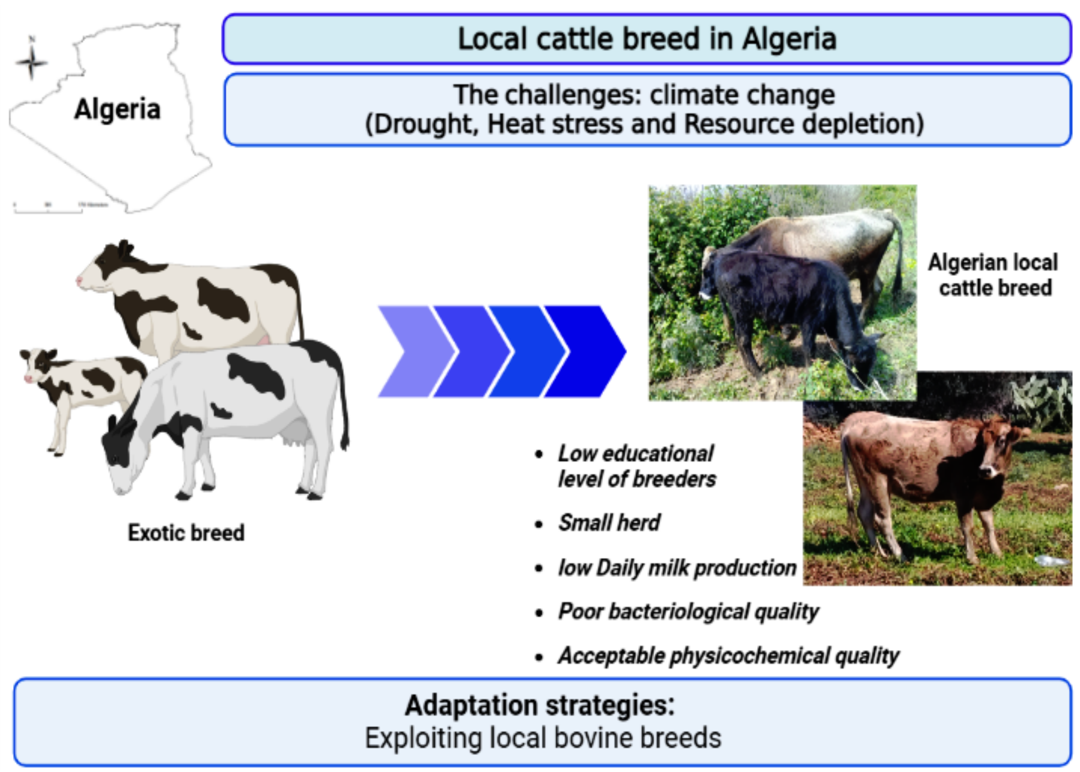
Abstract: Algerian indigenous cattle breeds are well adapted to the harsh local arid and semi-arid environments. This study aims to summarize livestock practices, milk quality, and discuss the potential of local cattle breeds to maintain production capacity in the face of global warming conditions. A total of 175 smallholder farmers who practice the breeding of the Algerian local cattle breed were interviewed using a formal questionnaire. Following that, 122 milk samples were collected for physicochemical and bacteriological analyses. Climate data variability in the study area was evaluated. Results reveal that between 1980 and 2018, the average annual temperature rose by 0.3 ± 0.001 °C per year. Predictions suggest that by 2081 to 2100, temperatures could increase by 1.18°C under SSP1-2.6, 2.33°C under SSP2-4.5, and 4.59°C under SSP5-8.5. In the same period from 1980 to 2018, annual precipitation decreased by -0.99 ± 0.24 mm per year. Projections indicate a further decline of 22.5 mm for SSP1-2.6, 44.4 mm for SSP2-4.5, and 95.2 mm for SSP5-8.5 from 1980-2000 to 2081-2100. These changes in temperature and precipitation coincided with an expansion of cropland, which increased by 90.3% from 1992 to 2005. Conversely, pasture areas decreased by 53.7% between 1993 and 2009. A socio-demographic survey revealed that breeders have a low educational level (39.4% are unlettered). They own a small herd (6.84 ± 8.66 cattle). Moreover, the average daily milk production was 4.13 ± 2.12 Liters/cow, with acceptable physicochemical quality but poor bacteriological quality. Considering the climate change vulnerability of the study area, we can conclude that the exploitation of local breeds seems to be the best adaptation strategy to climate change effects. Conservation programs for local breeds can enhance biodiversity and ecosystem balance. Concurrently, genetic improvement programs have the potential to boost productivity and profitability, making substantial contributions to social equity and local economies.

Keywords: *Sustainable livestock, Global warming, Local bovine breed, Milk quality, Milk yield*

Graphical abstract



Introduction

The most prominent cause of climate change is increased greenhouse gas emissions (GHGs) in the atmosphere, such as nitrous oxide (N2O), carbon dioxide (CO2), and methane (CH4), which cause irregularity, variability, and unpredictability in rainfall, floods, and drought periods (IPCC, 2021). More than 83% of the total agricultural emissions are due to livestock emissions. Enteric fermentation is considered the biggest contributor (about 5.5 MtCO2e) to livestock emissions, followed by manure left in pasture (4.5 MtCO2e) (Climate Watch, 2021).

Among the polluting sectors in Algeria, agriculture contributed 12.3 million tons of CO2 equivalent (MtCO2e) GHG emissions in 2012, which represented 5.63% of its total emissions excluding land-use change and forestry (219 MtCO2e) (Climate Watch, 2021; FAO, 1997). According to Prevention Web, Algeria is ranked 18 out of 184 of the most exposed countries to drought, and about 10% of its population (3,763,800 inhabitants) is exposed to droughts (WBG, 2022). Several studies predict a further future decrease in total annual rainfall by 15-30% (Christensen et al., 2007) and desert climate expansion at the expense of the temperate northern zone, which is explained both by increasing temperature and decreasing precipitation (Zeroual et al., 2020; Zeroual et al., 2019). Moreover, these negative effects will likely be "severe, pervasive, and irreversible" in the years to come (IPCC, 2014; IPCC, 2021; Mariotti et al., 2015; Sahnoune et al., 2013; Zeroual et al., 2016), which can negatively affect livestock production, crop yields, and threaten food and nutrition security (FAO, 2013).

In order to deal with these negative effects, it is urgently needed to transform agriculture, livestock farming, and food systems towards more sustainable production methods (Boudalia et al., 2023; Pretty, 2020). The reduction of carbon footprints and greenhouse gas fluxes, as well as the genetic conservation and preservation of local breeds that are well adapted to the local environment, are both strategies that can be profitable and safeguard natural resources for future generations (Bousbia et al., 2021; Brini, 2021; IPCC, 2014; Khelifa et al., 2021; Martin et al., 2020; Wainwright et al., 2019).

The Algerian Brown Atlas breed is well adapted to the harsh local arid and semi-arid environment. The animal is distinguished by tolerance to heat stress and disease resistance (Boushaba et al., 2019; Derradji et al., 2017; Djaout et al., 2017). They are subdivided into several subpopulations that are phenotypically differentiated by at least one different phenotypic and morphological character. Namely, coat color, head shape, and animal size: the Cheurfa ecotype, characterized by a light gray, almost whitish coat; the "Setifiénne" characterized by a uniform blackish coat; the "Guelmoise" ecotype, whose coat is dark gray, commonly; the "Fawn" (Chélifien" and "Tlemcenien"), whose coat color varies between brown and beige (Boudalia et al., 2020; Bousbia et al., 2010). Recently, we showed in a morphometric study that the Sétifien ecotype was larger than the other ecotypes for most morphometric traits (Bousbia et al., 2021). Therefore, the Algerian local cattle population has been estimated by the "Recensement National des Exploitations Agricoles et d'élevage RGA" (MADR, 2001) at nearly 896,287 subjects. Nevertheless, the breed has low milk production, which accounts for 1175 litters/cow/year (Mamine et al., 2011). To remedy this low yield, foreign breeds were imported (Holstein and Montbéliarde breeds), which has led to a profound change in the genetic structure of the dairy herd in Algeria, resulting in a drastic fall in the numbers of head dairy local cattle breed. Thus, the share of local breeds has been reduced from 82% of the total in 1986 to about 48% of the total in 2016 (Wilson, 2018).

The performance of imported breeds is lower in hot environments than in their native environments (Madani and Mouffok, 2008; Nigm et al., 2015). It is well established in the literature that when dairy cattle are under heat stress, there is an increase in water intake and a decrease in dry matter, protein, and fat content of milk, as well as milk yield (Gorniak et al., 2014). Moreover, contamination and pathogen proliferation increase under extreme heat and humidity (Montcho et al., 2021), resulting in economic losses for dairy farms (Bohmanova et al., 2007; Martín-Sosa et al., 2003). On the other hand, local breeds can perform well in adverse climatic conditions like high temperatures, drought, and feed and water scarcity (Sejian et al., 2015) because they are more robust and genetically better adapted to their environment (Lwin et al., 2018; Rodríguez-Bermúdez et al., 2019).

To our knowledge, the local bovine breed farming sector is not well studied in Algeria, and the potential effect of global warming on crops and/or livestock seems to be underestimated, because, since Algeria's independence in 1962, public authorities have focused on the development of the extractive industry (Boudalia et al., 2022), while agriculture (crops and livestock) remains dependent on imports. Therefore, the objectives of this study were to: a) summarize farming practices of local bovine farms in the northeast of the country; b) evaluate the physicochemical and microbiological properties of raw milk from the local bovine breed; and c) highlight the climate variability in the study area and discuss the potential of the local cattle breed to contribute to climate change mitigation and increasing resilience through adaptation.

Materials and Methods

Ethical statement

We conducted this study as part of the ARIMNet2-BOVISOL project (ARIMNet: Coordination of Agricultural Research in the Mediterranean, BOVISOL: Breeding and management practices of indigenous bovine breeds: Solutions towards a sustainable future, www.rias.gr/bovisol). The BOVISOL project (2018-2022) was a cooperation involving scientific teams from Greece, Tunisia, and Algeria and was formed around the hypothesis that the local bovine breeds must be preserved since they possess a valuable genetic pool and are a part of the landscape and biodiversity of rural areas (Boudalia et al., 2020). The local Data Protection Board (DPB) and the local ethics committee have approved experimental protocols. The study involved data collection from different farms, so the farmers were informed of the purpose of the project and have given their consent for their participation (completing the survey questionnaire and/or providing a sample of the milk) and the use of the collected and generated data for scientific publications.

Study area and environmental characterization

The present study was conducted in the northeast of Algeria (Figure 2) from June 2018 to August 2021. The region is characterized by a subhumid climate in the center and in the north and a semi-arid climate in the south. We used the WorldClim2 dataset for future climate data (Fick and Hijmans, 2017). These data are monthly values of minimum temperature, maximum temperature, and precipitation. Projected values averaged over 20 years (2021-2040, 241-2060, 2061-2080, 2081-2100) and provided for four Shared Socio-economic Pathways (SSPs): SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5. Since we were interested in the climatic changes that will take place at the end of the century, we used future projections for 2081-2100 based on three scenarios (SSP1-2.6, SSP2-4.5, and SSP5-8.5). The climate during winter is mild and rainy when it is hot and dry in summer (Figure 3A, B). To determine the historical (1980-2018) and projected future (2081-2100) climatic changes, the annual average temperature and annual precipitation from WorldClim2 were used (Fick and Hijmans, 2017). Moreover, the land use data of Venter et al. (2016), and particularly cropland and pasture data, were used to determine the temporal change in the area of these two land use types (cropland data are provided for 1992 and 2005, whereas pasture data are provided for 1993 and 2009). Croplands are coded as 0 (absence) or 7 (presence). Pastures are scored in four categories (None [0%] = 0, sparse [<12.5%] = 1, medium [>12.5%] = 2, dense [>50%] = 3). The pastures were categorized into “presence” and “absence” to estimate the historical change in percent covers in the study area.

Interviews and data collection

The study was conducted from June 2018 to August 2021. Detailed information was collected via a formal questionnaire developed for the BOVISOL project and used in Greece, Tunisia, and Algeria (Boudalia et al., 2020). It included open-ended and closed questions and covered the following topics: demographic information on the farmers, gender dimension, and details on the farms, breeds, animals’ performance, production systems, and market channels. Face-to-face interviews were conducted with one hundred seventy-five (175) farmers practicing the breeding of local bovine breeds, with 2 to 3 visits to each farm in the local dialect, where the content of the questionnaire was read and interpreted to all the farmers interviewed. The Algerian local cattle breed is known as the "Brown Atlas" breed, and it is further divided into several distinct subpopulations. These subpopulations include the Cheurfa ecotype, which is characterized by a light gray coat that is almost whitish in appearance. The "Setifiénne" subpopulation, on the other hand, is recognized by its uniform blackish coat. The "Guelmoise" ecotype typically has a dark gray coat. Lastly, the "Fawn" subpopulation, also referred to as "Chélifien" or "Tlemcenien," exhibits a coat that varies in color between brown and beige (Figure 1).

The collected data were coded, entered in a database, corrected, and validated by the research group. In this research article, we are presenting only preliminary results concerning farms and farmers’ data in Algeria.

Figure 1 - Brown Atlas cattle ecotypes. (A) ecotype Guelmois ; (B) ecotype Cheurfa (C) ; ecotype Sétifien ; (D), (E) and (F) ecotype Fawn (from (Bousbia et al., 2021))

Samples collection

One hundred twenty-two (122) out of the 175 participating farmers agreed to provide milk samples for analysis. A total volume of about 0.5-1 L of milk was collected from each farm in sterile glass bottles and placed immediately in cooler then transported to the laboratory for analysis. All bottles were previously autoclaved at a temperature of 121 °C under a pressure of one (1) bar for 15 minutes. The vials were filled from a container of mixed milk, respecting Good Laboratory Practices (GLP) and the rules of asepsis (disinfection of the hands). The milk collected in situ is a mixture of the milking of several females in lactation belonging to different lactation ranks and from different ecotypes. There was no conservative added to account for the real field conditions.

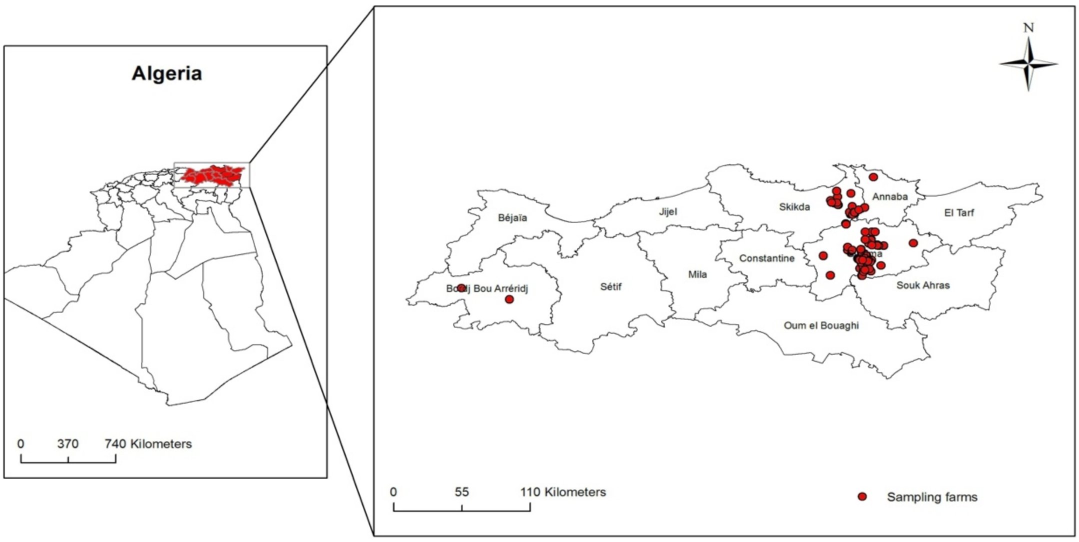


Figure 2 - Map showing the locations of the municipalities investigated. Map created using the Free and Open Source QGIS.

Physicochemical properties

For physicochemical analysis, pH was measured using a pH meter (Adwa, AD1000), and acidity (°D) was determined according to the method detailed in Tadjine et al. (2019). Freezing point (°C), conductivity (µS/cm), fat content (g/kg), protein content (g/kg), lactose content (g/kg), mineral content, and vitamins (g/kg) of milk were measured with a Lactoscan milk analyzer (Milkotronic Ltd., Nova Zagora, Bulgaria) according to the manufacturer's instructions.

Microbiological analysis

For bacteriological analysis, sample preparation and dilutions were performed according to the recommendations of the International Dairy Federation (IDF, 1991): The Total Mesophilic Aerobic Flora (TMAF) was enumerated using Plate Count Agar (PCA) and incubated at 30 °C for 72 hours. Total Coliforms and Fecal Coliforms were determined using Violet Red Lactose Bile agar (VRBL) incubated at 37 °C for total coliforms and 44 °C for fecal coliforms. Sulphite Reducing Clostridium was determined using the enrichment method in a liquid medium. The Staphylococci pathogens were counted using a selective medium (Chapman) and incubated at 37 °C for 24 to 48 hours. The formation of a black precipitate surrounded by a white halo indicates a positive culture of Staphylococci. For Salmonella, two mediums were used to enumerate the colonies: Selenite-Cystine for enrichment at 37 °C for 12 hours and SS medium (Salmonella-Shigella) for isolation at 37 °C for 24 hours. Salmonella appears as colorless, transparent colonies with or without a black center of small size (2 to 4 mm in diameter).

Data analysis

The physicochemical analysis results were expressed as means ± SD (standard deviation). All the colonies were counted as Colony Forming Units per mL of milk (CFU/mL) (IDF, 1991). Average slopes of the historical change of temperature and precipitation across farms were carried out using linear regressions. The data was processed using IBM SPSS Statistics package version 25 (IBM SPSS, 2017). The minimum threshold of significance retained is $p < 0.05$.

Results and Discussions

Climate variability

Across the selected study areas, the annual average temperature increased by 0.3 ± 0.001 °C yr-1 between 1980 and 2018 (Figure 3C). Between 1980-2000 and 2081-2100, future climate scenarios show that the annual average temperature will increase in the region by 1.18°C for SSP1-2.6, 2.33°C for SSP2-4.5 and 4.59°C for SSP5-8.5. Annual precipitation declined by -0.99 ± 0.24 mm yr-1 between 1980 and 2018 (Figure 3D) and is projected to decline by 22.5 mm for SSP1-2.6, 44.4 mm for SSP2-4.5, and 95.2 mm for SSP5-8.5 between 1980-2000 and 2081-2100. These data are in accordance with those of Zeroual et al. (2020); (2019) who have shown that predicted increased temperatures may further exacerbate droughts and water shortages, which will lead to an expansion of the desert climate zone at the expense of the temperate and steppe climate zones by the end of the twenty-first century (2045-2100).

Agriculture extension was accompanied by an increase in cropland and a decline in pasture areas. The cropland cover in our study area increased by 90.3% from 1992 to 2005 (Figure 3E, F). The pasture area declined by 53.7% from 1993 to 2009 (Figure 3G, H). This

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rapid change in land use has affected the distribution of high-quality foraging lands for livestock, including natural vegetation.

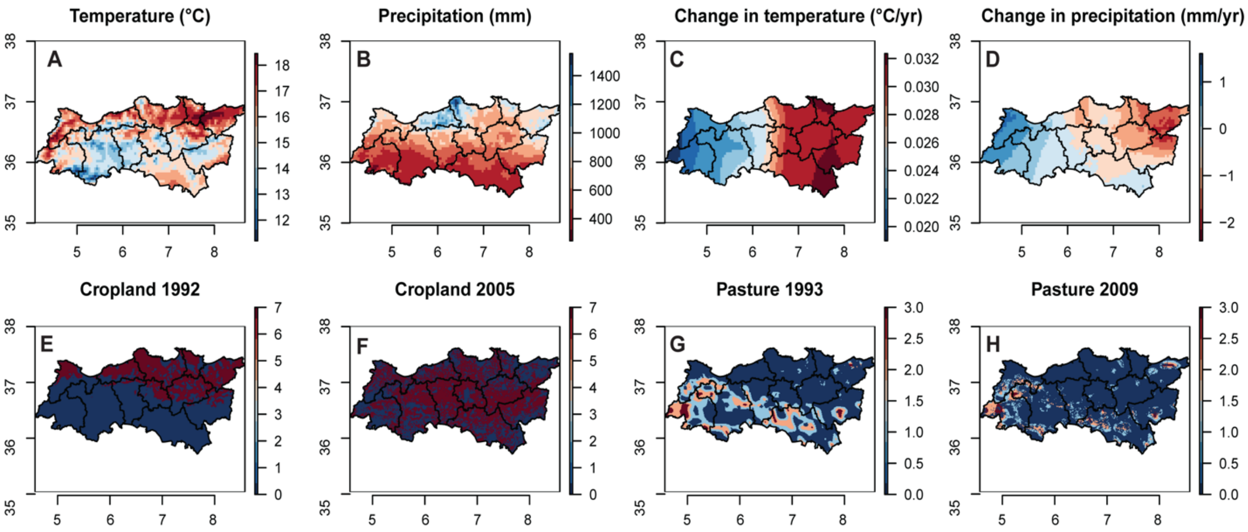

Figure 3 - Environmental characteristics of the study area. The plot shows annual average temperature (A), annual precipitation (B), change in annual average temperature during 1980-2018 (C), change in annual precipitation (D), cropland cover in 1992 (E), cropland cover in 2005 (F), pasture cover in 1992 (G), and pasture cover in 2009 (H). Cropland is coded as 0 (absent) or 7 (present). Pastures are scored in four categories (None [0%] = 0, sparse [<12.5%] = 1, medium [>12.5%] = 2, dense [>50%] = 3).

Socio-Demographic Characteristics

Tables 1 and 2 summarize farm and socio-economic data, respectively, collected from June 2018 to August 2021. The average number of cattle is 14.41 ± 14.65 per farm, with 6.84 ± 8.66 representing the local cattle breed, which includes several traditional ecotypes such as the Guelmois, Sétifien, Cheurfa, and Fawn and meets the standard of the local bovine breed (Bousbia et al., 2021). The level of education of breeders is often very low; 39.4% of breeders are unlettered, and 34.9% have a primary education level. Low literacy is a concept often observed in rural areas of Algeria, and it's partly explained by the farms location in remote areas without schools and cultural centers (Benidir et al., 2020; Mouhous et al., 2020).

All the interviewees were men; there were no women among the 175 respondents. This gender inequality represented by complete men dominance is in agreement with that already found by Laouadi et al. (2018) with smallholders' goat production systems in the area of Laghouat, located in southern Algeria (only one woman among 106 respondents), and Kadi et al. (2013) in the mountainous area of Kabylie in Algeria (86.2%). Although several studies show that global warming and climate change can amplify the effects of gender inequality in rural communities (Balehey et al., 2018), this question remains poorly documented in Algeria. This could be due to the traditional and cultural structure of society (customs) where men do not let women participate in interviews. Moreover, the majority of the surveyed farmers rely on family labor in their agricultural activities (65.1%). The man considered as head of the family; he relies on family members to accomplish the various tasks on the farm, where women and children play an important role in the functioning of farms.

In general, breeders with more than 20 years of experience are the most prominent, while new investors (≤ 5 years) represent only 0.57% of the total surveyed farmers. Moreover, the low percentage of breeders below 30 years old (1.7%) could indicate that young people are not interested in local cattle raising and are moving towards the practice of intensive production systems and/or other professions with better working conditions, fast and easy revenue, such as fattening cattle, poultry farming, and business. These results are in agreement with the reports of Laouadi et al. (2018) in Algeria and Yakubu et al. (2019) in Nigeria.

The daily average milk production was 4.13 ± 2.12 Liters/cow/day, very close to those reported for the Algerian local breed (Brown Atlas) with 1400 Liters/cow/year (≈ 4 Liters/cow/day) by Yakhlef (1989) in the same livestock management systems. However, they are lower compared to those recorded in the Kabylie region with 10.52 Liters/cow/day for crossbred cattle (indigenous × Holstein-Friesian of unknown percentage of genetic composition) (Mouhous et al., 2020), and higher than those recorded in the Central of Uganda (2.6 ± 0.19 Liters/cow/day) for indigenous cattle breeds (Nalubwama et al., 2016).

Concerning foreign imported Holstein and Montbéliarde, which are more adapted to cold climates, there is high variability of milk yield between semiarid and arid climates, with 1480 to 6703 Liters/cow/year (4.05 to 18.36 Liters/cow/day) in the mountainous region of northern Algeria (Bouzida et al., 2010) and 9.15 Liters/cow/day in the eastern region of Algeria (Yozmane et al., 2019). In Muscat (Oman), Alqaisi et al. (2020) reported a yield equivalent to 17.08 and 11.35 Liters/cow/day for Holstein and Jersey breeds, respectively.

According to previous studies, the milk yields of Holstein breeds in hot-climate regions were significantly lower than cold-climate regions. Rémond and Bonnefoy (1997) reported an average milk yield of 29 Liters/cow/day for multiparous Holstein in France, 28.3 Liters/cow/day reported in Southwest Quebec (Canada) for the same breed (Ouellet et al., 2019), 25.07 ± 5.61 Liters/cow/day for Holstein breeds in Oita prefecture (Japan) (Kino et al., 2019), and 24.36 ± 0.01 Liters/cow/day for Holstein breeds in Ukraine during the hot summer (Mylostyvyi et al., 2021).

In agreement with the reported data, 141 farms (80.58%) raise cattle for both meat and milk. This may be explained in part these breeds has low meat and milk yields, which force the farmers to improve their income by taking advantage of both the flocks' milk and meat yields. This diversification in farm activities has already been observed in South Africa, where Nguni cattle have multiple functions that include the provision of meat, milk, draught power, skins, dung, and cash through sales (Cletos et al., 2007). In Indonesia, Bali cattle are used to produce milk and high-quality leather (Sutarno and Setyawan, 2016). In Kenya, smallholder cattle farmers kept Sahiwal cattle for milk production, as a source of cash income (from sales of surplus milk and live animals), meat production, and breeding (Ilatsia et al., 2012). These examples show that, despite their low yields, cattle from native breeds are able to provide farmers with multiple income opportunities and thus represent an important component of agricultural diversification strategies.

The changes in climatic conditions negatively affect cattle milk yield, which, in turn, has adverse effects on farm income. For the period from 1950 to 1999, yields in the United States showed a decrease of 0.55 Liters/day/cow, which caused an economic loss of 670 US Dollars million per year. Predictive analysis shows a more important decrease of 1.35 Liters/day for the 2050s and 1.84 Liters/day for the 2080s, with economic losses as a whole of 1.7 billion US Dollars and 2.2 billion US Dollars per year in the 2050s and 2080s, respectively (Mauger et al., 2015). The same results were reported by other studies (Gisbert-Queral et al., 2021; Mylostyvyi et al., 2021; Ouellet et al., 2019).

Overall, considering the climate change vulnerability of our study area, it can have immediate effects on small farmers, leading to water stress, the degradation of pasture areas, reduced crop yields, livestock losses, and consequently, a decline in farmers' income. In this context, the exploitation of local breeds can be considered a viable adaptation strategy to mitigate the impacts of climate change.

Table 1 – Farms characteristics in the study area

Variable	Acronym	Modality	Surveyed farms	% farms
Numbre of total cattle (14.1 ± 14.65)	TC	TC (≤ 10)	95	54.28
		TC (11 to 20)	43	24.57
		TC (21 to 30)	23	13.13
		TC (> 31)	14	8.00
Number of local cattle* (6.84 ± 8.66)	LC	LC (≤ 5)	105	60.00
		LC (6 to 10)	38	21.71
		LC (11 to 15)	15	8.57
		LC (> 15)	17	9.72
Number of exotic (Imported) breed cattle (2.10 ± 4.60)	IC	IC (0)	136	77.71
		IC (2 to 6)	13	7.43
		IC (8 to 12)	13	7.43
		IC (> 13)	13	7.43
Number of ecotype Guelmois (2.51 ± 2.93)	EG	EG (0)	59	33.71
		EG (1 to 4)	79	45.15
		EG (5 to 9)	32	18.28
		EG (> 9)	5	2.86
Number of ecotype Cheurfa (0.60 ± 1.37)	EC	EC (0)	128	73.14
		EC (1 to 3)	40	22.86
		EC (4 to 6)	4	2.28
		EC (> 6)	3	1.72
Number of ecotype Fawn (1.88 ± 3.69)	EF	EF (0)	95	54.3
		EF (1 to 3)	51	29.14
		EF (4 to 6)	17	9.71
		EF (> 6)	12	6.85
Number of ecotype Sétifien (1.85 ± 2.88)	ES	ES (0)	76	43.42
		ES (1 to 3)	70	40.00
		ES (4 to 6)	19	10.86
		ES (> 6)	10	5.72
Crossbreed phenotype (local × local) (2.68 ± 4.78)	LL	LL (0)	93	53.14
		LL (1 to 3)	40	22.86
		LL (4 to 6)	21	12.00
		LL (> 6)	21	12.00
Crossbreed phenotype (local × exotic) (2.77 ± 3.98)	LE	LE (0)	77	44.00
		LE (1 to 3)	43	24.57
		LE (4 at 6)	30	17.15
		LE (> 6)	25	14.28
Number of ecotypes per farm (1.97± 1.26)	NEF	NEF (0)	24	13.72
		NEF (1)	42	24.00
		NEF (2)	51	29.14
		NEF (3)	31	17.72
		NEF (4)	27	15.42

*NOTES: The values in brackets correspond to the average calculated for all the farms surveyed with its standard deviation; * All genotypes combined. CT: Total Cattle; LC: Local Cattle; IC: Imported*

Cattle; EG: Ecotype Guelmois; EC: Ecotype Cheurfa; EF: Ecotype Fawn; ES: Ecotype Sétifien; LL: Local × Local; LE: Local × Exotic; NEF: Number of Ecotypes per Farm.

Table 2 - Socio-economic characteristics of cattle farmers in the study area

Variables		Results
Farmers		
Gender	Men	175
	Women	0
Age (years)	21-30	3 (1.71%)
	31-40	27 (15.42%)
	41-50	39 (22.28%)
	> 50	106 (60.57%)
Education level (%)	None	39.4.42
	Primary	34.85
	Medium	19.42
	High	6.28
Experience working on animal production (%)	< 5 years	0.57
	5 at 10 years	2.85
	10 at 20 years	29.75
	> 20 years	66.85
Number of family members		4.01 ± 2.26
Labor		
Family members working in farm (%)	0	61 (34.85%)
	1	66 (37.71%)
	2	29 (16.57%)
	3	13 (7.42%)
	> 4	6 (3.42%)
Economical aspects		
Milk production (Liters per Female per Day)		4.13 ± 2.12
Production products (%)	Milk	18 (10.28)
	Meat	16 (9.14)
	Mix Production products	141 (80.58)

Milk properties

Physicochemical properties of raw milk

Table 3 shows the physicochemical properties of raw milk collected from local bovine breeds in northeastern Algeria. In general, lactose, protein, and fat content correspond to the values of cow's milk standards [(45 to 51), (32 to 34), and (31 to 33) g/kg], respectively (Boudalia et al., 2016; Tamime, 2009). Matallah et al. (2017) showed similar results for raw cow milk from El Taref province with an average pH of 6.9 ± 0.37 vs. 6.5 ± 0.07, an acidity of 18.7 ± 3.32 vs. 18.9 ± 1.11°D, a density of 1031 ± 0.6 vs. 1030 ± 2.78, a protein content of 32.8 ± 4.32 g/l vs. 32.51 ± 8.87 g/l, but a lower fat content of 33.3 ± 3.93 g/l vs. 33.99 ±

14.47 g/l. Moreover, when comparing the results of this study with those conducted in four provinces (Guelma, Souk Ahras, Annaba, and El Taref) by Mahieddine et al. (2017), the results were within the range of acidity values [16.83-20.71°D], fat [32.01-60.00 g/l], lower for pH [6.97-7.23], but greater for density [1025-1027 kg/m3] and protein [28.7-31.23 g/l]. Furthermore, a study in the Kabylie region in the highlands of central-northern Algeria showed higher density (1032 ± 0.06 kg/m3), fat (61.6 ± 2.64 g/l) and protein (69.8 ± 5.61 g/l). This could be due to the higher plant species richness and abundance in mountain areas (Manganelli et al., 2001). In the same way, milk quality results were also close to ours obtained in a recent study on raw cow milk heat treatment effects in northeastern Algeria (Tadjine et al., 2019), and in the study on the raw milk of central Algerian farms from Tissemsilt province conducted by Elhadj et al. (2015).

From the literature, and especially for extensive livestock farming systems where grazing is the main source of feed, the nutritional composition of milk is highly related to changes in feed quality and availability, which themselves vary according to the climatic conditions (Rojas-Downing et al., 2018). Cattle grazing on poor-quality pastures during periods of drought would lead to a decrease in dry matter intake and therefore lower milk, protein, and casein yields (Pastorini et al., 2019).

Table 3 - Physicochemical characteristics of the analyzed samples (N = 122)

Parameters	Min-Max	Mean ± SD	CV (%)	Standard (JORA, 1998)
pH	5.68-7.76	6.95 ± 0.37	5.42	6.6 to 6.8
Density (mg/cm^3)	1.005-1.044	1.031 ± 0.006	0.58	1.028 to 1.033
Freezing point (°C)	-0.80 - -0.19	-0.56 ± 0.06	-11.54	-0.53 to -0.55
Conductivity (µS/cm)	4.20-8.03	5.03 ± 0.52	10.50	4 to 5.5
Titratable Acidity (°D)	10.33-31.33	18.78 ± 3.32	17.67	15 to 17
Fat content (g/kg)	10.83-86.70	33.99 ± 14.47	42.58	31 to 33
Protein content (g/kg)	11.10-51.03	32.51 ± 8.87	27.28	32 to 34
Lactose (g/kg)	40.10-66.03	49.49 ± 4.27	8.63	45 to 51
Minerals and Vitamins (g/kg)	5.23-8.79	7.25 ± 0.43	6.02	7 to 7.5
Dry Degreased Extract (g/kg)	22.63-108.93	87.55 ± 10.22	11.68	91

NOTES: N: Number of the analyzed samples; SD: Standard Deviation; CV: Coefficient of Variation; Max: maximum; Min: minimum.

Bacteriological qualities of raw milk

The descriptive characteristics of the enumerated flora reported in Table 4 show high variations between the different raw milk samples studied for the seven microbial groups analyzed. The concentration values of Total Mesophilic Aerobic Flora in raw milk varied between 1.49 and 1.81 × 107 CFU ml-1 with an average of 2.55 × 105 CFU ml-1. Moreover, the results show that 9% of the total analyzed samples exceed the standard of 105 CFU ml-1 required by JORA (1998), indicating a very poor quality of raw milk. These findings are consistent with those reported by Bousbia et al. (2018) and Bachtarzi et al. (2015) in the same traditional extensive livestock system, where high contamination was found with average values of 11.69 × 105 CFU ml-1 and 28.8 × 106 CFU ml-1, respectively. Total and fecal Coliform contamination was significant, with an average of 3.02 × 104 and 1.09 × 103 CFU ml-1, respectively. These values were extremely variable, with standard deviations exceeding the average for each flora. About 17.21% of all analyzed samples do not comply with national standards for fecal Coliforms (JORA, 1998), they are similar to the results obtained by (Bachtarzi et al., 2015) in the region of Constantine with an average of 3.67 × 105 CFU ml-1, but they are much lower than the results reported by Sraïri et al. (2005) in Morocco with an average of 2.0 × 106 CFU ml-1. The average enumerations were very variable from one farm to another; this can result from the lack of hygiene practices, which remain scarce (washing the udder before and after milking). The presence of Coliforms indicates poor hygienic and sanitary conditions during milking and subsequent manipulations (Yucel and Ulusoy, 2006).

The sulphite reducing Clostridium has been detected in 31 (25.40%) analyzed samples, with an average of 1.15 × 103 UFC ml-1. A contamination of 16.30 CFU ml-1 was reported by Bousbia et al. (2018) in the same region of Algeria. To our knowledge, few studies were conducted to estimate the frequencies of pathogenic bacteria in cattle raw milk collected from Algeria; Hamdi et al. (2007) found that among 153 samples of milk collected from farms in Algiers and Blida, 3.18% were contaminated. For all the analyzed samples, only 16 (13.11%) did not contain Staphylococcus aureus. The presence of a high content of S. aureus in raw cow milk samples could be explained by the presence of mastitis (Montcho et al., 2021), or poor hygienic conditions. In addition, the contamination spreads very quickly under favourable conditions like high temperatures and humidity, posing a risk to human health (Alghizzi and Shami, 2021).

Microbiological analysis has shown that one contaminated sample by Salmonella spp. The origin of this contamination might be related to the unhygienic husbandry practices of traditional extensive livestock system (Montcho et al., 2021). In our study, several breeders confirmed that they apply dung and urine on pasture to help fodder production during drought periods; the urea is used to increase the nutritive value of poor fodder, which is in agreement with the literature (Gunun et al., 2013). However, animal manure and urea might be sources of milk contamination, especially when hygienic conditions are absent (Montcho et al., 2021). Moreover, manure is considered an important source of GHGs emissions (25% of total livestock GHGs emissions), mainly methane and nitrous oxide, which can exacerbate global warming (Petersen et al., 2013; Tubiello et al., 2015). As a result, microbial contamination increases as environmental temperatures rise (Zweifel et al., 2005).

Table 4 - Descriptive characteristics of studied flora and milk standards (N = 122)

Flora (CFU ml^{-1})	Min-Max	Mean ± SD	CV (%)	Standard (CFU ml^{-1}) (JORA, 1998)
TMAF	1.81-1.49 × 10^7	2.55 × 10^5 ± 1.79 × 10^6	6.99 ×10^2	10^5
T. Col.	0-2.36 × 10^6	3.02 × 10^4 ± 2.16 × 10^5	7.14 ×10^2	10^3
F. Col.	0-1.81 × 10^4	1.09 × 10^3 ± 3.06 × 10^3	2.79 ×10^2	10^3
Sulphite reducing *Clostridium*	0-1.00 × 10^5	1.15 × 10^3 ± 9.28 × 10^3	8.03 ×10^2	50
Staphylococcus	0-8.00 × 10^6	2.12 × 10^5 ± 9.75 × 10^5	4.58 ×10^2	Absence /0.1 ml
Salmonella	0-2.6 × 10^5	2.13 × 10^3 ± 2.35 × 10^4	1.10 ×10^3	Absence
Yeasts and molds	0-1.6 × 10^3	1.11 × 10^2 ± 2.48 × 10^2	2.22 ×10^2	/

NOTES: TMAF: Total Mesophilic Aerobic Flora; T. Col.: total Coliforms; F. Col.: fecal Coliforms; N: Number of the analyzed samples; SD: Standard Deviation; CV: Coefficient of Variation; Max: maximum; Min: minimum.

Conclusion

This study confirmed that climate change is influencing temperature and precipitation levels, cropland, and pasture areas. Moreover, taking productive data into account, it could be concluded that the exploitation of the Algerian local breeds seems to be one of the best adaptation practices to climate change effects, as it can promote biodiversity and maintain a balanced ecosystem. Nevertheless, smallholder farmers have a low educational level. Moreover, low productivity and poor bacteriological quality of milk but acceptable physicochemical quality characterize small farms.

The implementation of selection and genetic improvement programs can increase the productivity and profitability of local cattle breeds. This can be beneficial for smallholder farmers and can provide them with a fair and stable income and good working conditions. Other strategies can also contribute to the fight against climate change effects, like women's empowerment promotion, policy issue development, and the improvement of suitable capacity-building programs for different stakeholders. These could contribute significantly to social equity and local economies.

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Disclosure statement

The authors have stated that they have no conflicts of interest to declare.

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